Carcass properties, chemical content and fatty acid composition of the *musculus longissimus* of different pig genotypes

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Abstract

The aim of this study was to examine carcass properties and variability in chemical content and fatty acid composition in the *musculus longissimus lumborum et thoracis (MLLT)* of different genotypes of pigs. Of 36 male castrated animals used in the trial, 24 were from two strains of Mangalitsa pigs (12 Swallow - bellied (SBM) and 12 White (WM)), while 12 were of the Swedish Landrace (SL) breed (the most abundant meat/fattening breed in Serbia). The warm and cold carcass weights at slaughter were significantly higher in the WM and SL compared with the SBM. Results showed differences in warm and cold carcass dressing percentage between the groups. The SBM had significant lower values than WM and SL pigs. The total fat content was higher in WM and SBM pigs than SL pigs. The SL pigs had a significant higher percentage of water in their *MLLT* than the SBM and WM pigs. The representative of pig meat breeds, SL, contained significantly less cholesterol in its *MLLT* compared with the SBM and WM (-15.23% and -15.84%). However, differences in the content of saturated and unsaturated fatty acids were more expressed and distinct. A higher percentage of saturated fatty acids (SFA) and polyunsaturated fatty acids (PUFA) were present in *MLTT* originating from SL pigs compared with the two Mangalitsa strains. The total monounsaturated fatty acids (MUFA) content was higher in SBM and WM than in SL pigs. The alpha linolenic acid concentration (C18:3 *n*-3) was significantly higher in SBM than in WM and SL pigs.

Keywords: Mangalitsa, carcass traits, meat quality, cholesterol, fatty acids, Swedish Landrace
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Introduction

The Mangalitsa is an indigenous swine breed and was the most typical breed in Serbia over 100 years ago. The breeders created a very robust and resistant race. The blond Mangalitsa proved to be the most popular, but also other colour variants, such as black, red and brownish-grey (wolf). The Swallow-bellied and the wild type (baris) were also found. However, in the middle of the last century, the population decreased and nearly disappeared because of the breed's excessive lard and lower reproductive performance than modern commercial breeds. In recent years, zoologists and livestock breeders worldwide have joined forces in the interests of saving indigenous breeds from extinction and introduced domestic livestock breeds. The best strategy for preventing the disappearance of such breeds is to strive to maintain genetic diversity, in which the indigenous breeds can prove useful.

The future of the Mangalitsa is dependent largely on whether products derived from it can be utilized effectively, and whether long-term market opportunities can be secured. The Mangalitsa pig is currently enjoying a renaissance, owing to endeavours aimed at restoring the presence of traditional breeds. Its meat is of outstanding quality; it has a high dry matter content, and its red colour corresponds to current

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requirements. The distinct palatable flavour is derived from the fat surrounding the muscle tissue (Csapó *et al.*, 2002).

Mangalitsa is a typical representative of the fatty pig breeds. That is, its average total mass consists of 65% - 70% fat tissue and 30% - 35% meat (Egerszegi *et al.*, 2003). Today, apart from the gene preservation aspect, rearing Mangalitsa pigs is commercialized by processing the high-quality meat into products that are attracting increasing interest in the food manufacturing market. The results of recent research (Szabó, 2001; Szabó, 2002) show that less than 40% of a Mangalitsa specimen consists of lean meat, which is reason enough for production of its high-quality and tasty products.

Mangalitsa meat belongs to the group of fat rich meat. Its fresh meat is darker, more succulent and softer than the meat from other pig breeds. Its odour is stronger. The tenderness of Mangalitsa pork is much higher than that obtained from any other commercial pig breed (Flegler, 1999).

Some findings were published recently in connection with the fatty acid composition and cholesterol content of the meat and backfat of the Mangalitsa pig. It was claimed that the fat is softer and easier to digest by human beings than that of modern pigs. Its softer, granular consistency is attributable to its different and also 'healthier' fatty acid composition. Another view is that the cholesterol content of the fat is substantially lower than that of the new, intensively fed genotypes of pigs (Csapó *et al.*, 2002).

The fatty acid composition of foodstuffs is of great importance to healthy human nutrition. Pork contains high quantities of saturated fatty acids (SFA) and cholesterol. An excessive intake of these components through meat consumption may lead to arteriosclerosis-related illnesses (Grys, 1995). Nutritionists recommend a reduction in total fat intake, particularly of SFA and *trans* fatty acids, which are associated with an increased risk of cardio-vascular diseases and some cancers (Burlingame *et al.*, 2009; Brouwer *et al.*, 2010; USDA & HHS, 2010; Mapiye *et al.*, 2011). Besides reducing fat intake, nutritionists urge consumers to increase their intake of polyunsaturated fatty acids (PUFA), particularly the *n*-3 PUFA, at the expense of *n*-6 PUFA (Simopoulos, 2004; Griffin, 2008; Harris *et al.*, 2009; Mapiye *et al.*, 2011). Therefore, PUFA/SFA and *n*-6/*n*-3 PUFA ratios have become important parameters in evaluating the nutritional value and healthiness of foods (Aldai *et al.*, 2005; Alfaia *et al.*, 2007; Riediger *et al.*, 2009; Mapiye *et al.*, 2011). Nevertheless, in recent years, red meat consumption has been discredited because of causal relations established between red meat consumption and coronary heart disease (CHD) and cancer (Forman, 1999).

Hungarian researchers studied the fatty acid and cholesterol content of fatty tissues in Mangalitsa and Mangalitsa crosses with other breeds. They established that the unsaturated fatty acid content was greater than 60% in the Mangalitsa pig fat and reached almost the same percentage in the crosses (Csapó *et al.*, 1999; Csabó, 2001). Differences in cholesterol content detected in various breeds were insignificant (Csapó *et al.*, 1999). In addition, 68.7% of intramuscular fat in the *musculus longissimus dorsi* consists of unsaturated fatty acids, which represents a 6% increase in comparison with the German Landrace breed (Ender *et al.*, 2002).

The Swedish Landrace (SL) is one of the most common genotypes of pigs in Serbia and was thus selected for the current investigation.

The objective of this study was to investigate carcass traits and differences in chemical content and fatty acid composition, as well as cholesterol content in *musculus longissimus lumborum et thoracis* (*MLLT*) of different genotypes of pigs.

Material and Methods

Of 36 male castrated animals used in the trial, 24 (12 x 2) were Mangalitsa pigs (Swallow-bellied (SBM) and White (WM)), while 12 were of the SL breed. The experimental pigs were reared in late spring and early summer. Animals were kept in their natural habitat within the same area, on a small farm near the town of Bela Crkva, Labudovo okno (44° 50' 19.35" N; 21° 18' 10.82" E), Eastern Serbia. Pen space of approximately 10 m^2 was allocated to each animal. The pigs were fed twice a day in troughs with simultaneous access for all. When the experimental pigs reached between 20 kg and 25 kg in weight, all were housed in the same indoor area, with six pigs to a cage and 5 m^2 ground area per animal. The pens formed part of a group located inside a commercial pig grower's shed. This shed was enclosed with walls and had a roof. Manually opening and closing windows controlled airflow. The floor of the pen was made of concrete. One third of the pens had concrete slats above the faeces and urine drainage channel. Throughout the

investigation, the Mangalitsa and SL pigs were fed *ad libitum* diets of identical composition from self-feeders. The feed composition and analysed nutrients are presented in Table 1.

At the end of the trial, pigs were transported in the morning (between 8:00 and 9:00) to the nearby commercial abattoir of Banatski Karlovac (approximately 40 km) in groups of a maximum of 12 animals. They were all transported in a trailer by the same person. The time between arrival in the abattoir and the onset of slaughtering varied between 20 h and 22 h. This was performed by the same people over the slaughter days.

Table 1 Ingredient composition (% as-fed) and estimated analyses (g/kg) of the diet

Ingredients	Body weight (kg)	
	25 - 60	60 - 100
Maize	62.9	68.8
Wheat feed flour	15.0	15.0
Soy press cake	14.0	9.1
Sunflower press cake	5.0	4.0
Calcium carbonate	1.4	1.4
Monocalcium phosphate	0.6	0.7
Sodium chloride	0.40	0.45
Vitamin and micromineral premix	0.5	0.5
Lysine	0.07	0.09
Minazel plus (Min-a-Zel Plus)	0.10	-
Total	100	100
Estimated nutrient content		
Crude protein (N x 6.25)	15.00	13.00
Crude fat	3.48	3.62
Crude dietary fibre	4.21	3.87
Crude ash	5.01	4.88
ME content, MJ/kg	12.95	13.05

The animals were slaughtered at similar live weights (100 kg), but not similar ages, because slaughter and transport procedures could be standardized, but differences in carcass weight would have overruled other effects on carcass conformation or meat quality.

Before slaughtering, feed was withdrawn overnight. The animals were conventionally slaughtered according to standard commercial procedures after electrical stunning (250 V AC, ear to ear for 3-5 s) and sticking within 30 s. Thereafter the pigs were eviscerated and inspected by the appropriate government health official. This was performed by the same people. The body weight of the trial pigs was measured prior to and shortly after slaughter. Carcasses contained heads, trotters and kidney fat. Each carcass was weighed warm and then chilled (4 ºC for 24 h). At 45 minutes post mortem, the initial pH was taken (pH_{45}). After the 24 h chilling period the final pH (pH_{24}) was measured. The pH measurements were taken on the *MLLT*. The pH was measured with a penetrating glass electrode on a hand-held Testo 205 pH (± 0.02 pH; ± 0.4 ºC; Germany, 2007). The pH meter was rinsed with distilled water after every reading and re-calibrated after every fourth reading. During routine carcass splitting and cutting, samples of the *MLLT* were taken between the 13th and 14th thoracic vertebra and stored in a freezer for further analyses. Prior to laboratory analysis, all the samples were vacuum-packed and kept frozen at approximately -20 ºC.

The chemical composition of the *MLLTs* was measured, viz. protein, water, total fats, ash, fatty acids and cholesterol contents, using the methods as defined by the AOAC (1990). Cholesterol concentration was

determined by HPLC/PDA, on a HPLC Waters 2695 separation module, with a Waters 2996 photodiode array detector, as described by Maraschiello *et al*. (1996). Chromatographic separation was achieved with a Phenomenex Luna $C_{18(2)}$ column (150 mm x 3.0 mm, 5 µm) with adequate pre-column, isocratically, with mobile phase of isopropanol-acetonitrile 20% : 80% v/v. Injection volume was 10 µL. Cholesterol was determined by absorption at a wavelength of 210 nm. Analytical yield (recovery) for given quantities was between 66.3% and 74.8%. External calibration was used to calculate the cholesterol content. Empower Pro software was employed for system control and data gathering and processing.

In order to determine the concentration of fatty acids, total lipids were extracted by a rapid extraction method, using solvents on the Dionex ASE 200. A homogenized sample, mixed with diatomaceous earth, was extracted with a mixture of hexane and isopropanol (60 : 40 v/v) in a 33 mL extraction cell at 100 ºC and under nitrogen pressure of 10.3 MPa. The extract thus obtained was steamed in a nitrogen flow at 50 ºC until dry fat remains were obtained (Spirić *et al.*, 2010).

Fatty acids as methyl esters were detected by capillary gas chromatography with a flame ionization detector. A predetermined quantity of lipid extracts, obtained by the rapid extraction method, was dissolved in tert-butyl methyl ether. Fatty acids were converted to fatty acids methyl esters (FAME) with trimethylsulfonium hydroxide, according to the SRPS EN ISO 5509:2007 method. FAMEs were analysed with a GC-FID Shimadzu 2010 device (Kyoto, Japan) on a cyanopropyl-aryl column HP-88 (column length 100, internal diameter 0.25 mm, film thickness 0.20 µm). The injected volume was 1 µL. Temperatures of the injector and detector were 250 ºC and 280 ºC, respectively. Nitrogen was used as a carrier gas, 1.33 mL/min, with a split ratio of 1 : 50, while hydrogen and air were used as detector gases. The temperature of the column furnace was programmed to range between 120 ºC and 230 ºC. The total duration of analysis was 50.5 min. Methyl esters of acids were identified according to their retention times, which were compared with those of the mixture of methyl esters of fatty acids in the standard Supelco 37 Component FAME mix (Spirić *et al*., 2010).

The experimental data were statistically processed and analysed by the least squares method and by applying the GLM procedure of the SAS 9.1.3 program package (SAS Inst. Inc. 2002–2003). The breed was introduced into the model as an independent variable, while the mass of freshly slaughtered pig carcass sides was a dependent variable. When means were significantly different, Tukey's test was applied to compare the mean values of the genotypes. The data in the tables are presented as least squares means (LSM) and standard errors of the mean (SEM).

Results and Discussion

The results for the final live weight and carcass characteristics are presented in Table 2. When the trial ended, there were no significant differences (P >0.05) in live weight gain between the groups, as mean final live weights were similar in the three experimental groups, at about 100 kg. Significant differences were observed between the carcass weights of the experimental groups. The warm and cold carcass weights at slaughter were higher (P <0.01) in the WM and SL than the SBM group. However, final live weight had a significant (P <0.01) influence on the warm and cold carcass weight of pigs. In a similar study, Petrović *et al.* (2010) found significant differences in average masses of carcass sides (warm and cooled carcass sides) between breeds. The average mass of the cooled carcass sides of Moravka pigs was higher (84.2 kg) than SBM pigs (73.9 kg). In Table 2, the current results showed noticeable differences in warm and cold carcass dressing percentage between the groups. The SBM had significantly lower values than WM and SL (P <0.01). However, the final live weight had a significant influence (P <0.01) on carcass dressing percentage. Hoffman *et al.* (2003), in their study, presented the results of warm (77.5% - 77.7%) and cold (75.9% - 76.4%) dressing percentages of pig carcasses. Neither warm, nor cold dressing percentages differed significantly between the groups. In our study, a significant (P <0.01) difference in cooler shrink was observed between the pig genotypes. The SL pigs underwent less cooler shrink (1.80%) than the other two groups. Anupam *et al.* (2010) examined the slaughter performance of Ghungroo, a native swine breed, and found that they produced cooler shrink values ranging from 1.90% to 5.48%.

The average pH_{45} and pH_{24} values in *MLLT* were different (P <0.01) depending on pig genotype (Table 2). Initial muscle pH in SBM pigs had lower values than WM and SL (P <0.01). The final pH measurements showed that SBM pigs had lower (P <0.001) pH values compared with WM and SL pigs. In a similar study, Parunović *et al.* (2012a) concluded that the differences in the average pH values of *MLLT* were statistically significant between SL and WM (5.45 and 5.61; $P \leq 0.05$), and between SBM and WM (5.42 and

5.61; $P \leq 0.05$). Hoffman *et al.* (2003) concluded that muscle pH values (pH_{45} and pH_{24}) were not influenced by the two housing systems, free-range and conventional. Sather *et al.* (1997) found that initial muscle pH of free-range pigs tended to be lower than that of conventionally housed pigs. The results of Barton Gade & Blaabjerg (1989) and Enfält *et al.* (1997) showed that free-range pigs had lower final pH measurements than indoor housed pigs. Parunović *et al.* (2012b) reported that the initial muscle pH in the free-range Mangalitsa pigs had lower values than those of conventionally reared ones ($P < 0.01$). The final pH measurements showed that the free-range pigs had lower ($P < 0.001$) pH values than pigs reared indoors. These researchers reasoned that free-range pigs had higher levels of muscle glycogen than their pen-housed counterparts, which resulted in lower pH readings. Since our experimental pigs were kept in the same conditions, the initial and final muscle pH values clearly differed depending on the genotype of pigs.

Table 2 Comparison of least squares means ± (SEM) for slaughter traits and levels of significance difference between pig genotypes

Trait	Swallow-bellied Mangalitsa SBM	White Mangalitsa WM	Swedish Landrace SL	Significance of the influence	
	(n = 12)	(n = 12)	(n = 12)	Genotype	LW
Live weight (kg)	100.7 ± 3.62	100.8 ± 3.62	96.2 ± 5.36	/	/
Warm carcass weight (kg)	76.2^{b} ± 0.56	78.5^{a} ± 0.56	79.1^{a} ± 0.59	**	***
Cold carcass weight (kg)	74.3^{b} ± 0.61	76.5^{a} ± 0.61	77.7^{a} ± 0.65	**	***
Warm carcass DP (%)	76.4^{b} ± 0.59	78.9^{a} ± 0.59	79.6^{a} ± 0.62	**	**
Cold carcass (%)	74.4^{b} ± 0.63	76.8^{a} ± 0.63	78.1^{a} ± 0.67	**	**
Cooler shrink (%)	2.52^{b} ± 0.18	2.63^{b} ± 0.18	1.80^{a} ± 0.19	**	NS
pH^{45} *MLLT*	5.96^{b} ± 0.06	6.06^{b} ± 0.06	6.41^{a} ± 0.09	**	NS
pH^{24} *MLLT*	5.58^{c} ± 0.05	5.77^{b} ± 0.05	6.00^{a} ± 0.07	***	NS

LW: live weight; *MLLT*: *musculus longissimus lumborum et thoracis*; n: number of samples; DP: dressing percentage; NS: not significant ($P \geq 0.05$).
*Statistical significance at the level of $P < 0.05$; **Statistical significance at the level of $P < 0.01$;
***Statistical significance at the level of $P < 0.001$.
[a-c] Means within a row with different superscripts differ ($P < 0.05$).

Comparisons of the means of the chemical composition of the *MLLT* derived from the various pig genotypes are presented in Table 3. Significant differences were found in chemical content of the *MLLT* between the groups. SL *MLLT* contained a higher ($P < 0.001$) percentage of water than the *MLLT* in the other two groups of pigs. The difference in water content between SBM and WM was not significant. However, final live weight had a significant influence on water content in *MLLT* ($P < 0.01$). The established value of water content in SL pigs (72.7%) was similar to the value of 71.9% found by Rahelic (1984), the 72.3% to 73.8% found by Estévez, *et al.* (2003) for Iberian pigs and Landrace pigs, but slightly below the average value of 75.5% obtained by Kim *et al.* (2008) for SL pigs. Holló *et al.* (2003) found water content ranged between 68.8% and 69.0% in Mangalitsa pigs of different body masses.

The differences in mean protein values between the groups were significant ($P < 0.01$) (Table 3). In our research, WM pigs had a lower protein content in *MLLT* compared with the results obtained by Holló *et al.* (2003) and Petrović *et al.* (2009). In the current study, the protein content of WM (19.5%) was lower than the 21.16% of SBM and 22.1% of SL, which were lower than those presented by Rahelic (1984). In the current study, the differences in protein content between SL (22.1%) and the two Mangalitsa strains (21.2% and 19.5%) were lower than those presented by Rahelić (1984). Values of protein content in the *MLTT* of pigs, according to data verified by other authors, vary from 21.2% to 24.1% (Rahelić, 1984; Holló *et al.*, 2003; Jacyno *et al.*, 2006; Kim *et al.*, 2008). Rearing pigs of the same genotype (Italian local breed) in an open system, instead of closed, while providing them with a diet based on commercial mixtures, increased their intramuscular and intermuscular fat and protein content (23.5% to 22.8%) (Pugliese *et al.*, 2005). The

protein content in *MLTT* of both Mangalitsa and SL pigs, as calculated in our research, was lower than that reported by Rey *et al.* (2004) and Pugliese *et al.* (2005).

Total fat content in the *MLLT* was higher in WM and SBM pigs than in SL pigs, and these differences were significant (P <0.001). However, final live weight had a significant (P <0.05) influence on total fat content in *MLLT*. Rahelić (1984), Holló *et al.* (2003) and Petrović *et al.* (2009) established that *MLLT* from Mangalitsa pigs contained between 4.91% and 9.04% of pure fat. Our research determined that total fat content in *MLLT* from Mangalitsa pigs was between 13.5% and 16.8%, which was higher than in previous studies.

The statistical difference in ash content between the groups was found to be significant (P <0.01). Ash content in *MLLT* of WM and SBM pigs was lower than in that of SL pigs. There was no difference in the ash content of *MLLT* derived from the two types of Mangalitsa pigs. Rahelić (1984) spotted a slight difference in ash content between Mangalitsa and Swedish Landrace (1.21% and 1.18%), while Holló *et al.* (2003) established no significant difference in average ash content in *MLLT* in three trial groups of Mangalitsa pigs.

Table 3 Comparison of least squares means ± (SEM) for the chemical composition of *musculus longissimus lumborum et thoracis* traits (%) and levels of significance difference

Trait	Swallow-bellied Mangalitsa SBM	White Mangalitsa WM	Swedish Landrace SL	Significance of the influence	
	(n = 12)	(n = 12)	(n = 12)	Genotype	LW
Water (%)	64.3^{b} ± 1.17	62.7^{b} ± 1.17	72.7^{a} ± 1.23	***	**
Protein (%)	21.1^{a} ± 0.60	19.5^{b} ± 0.60	22.1^{a} ± 0.64	**	NS
Fat (%)	13.5^{b} ± 1.71	16.8^{b} ± 1.72	4.23^{a} ± 1.82	***	*
Ash (%)	0.95^{b} ± 0.03	0.89^{b} ± 0.03	1.06^{a} ± 0.03	***	NS
Fat : protein ratio[1]	0.68^{b} ± 0.10	0.91^{b} ± 0.10	0.20^{a} ± 0.11	***	*

LW: live weight; n = number of samples; NS: not significant ($P \geq 0.05$).
*Statistical significance at the level of P <0.05; **Statistical significance at the level of P <0.01;
***Statistical significance at the level of P <0.001.
[1] Fat/protein ratio was calculated.
[a-c] Means within a row with different superscripts differ (P <0.05).

The calculated fat/protein ratio was significantly lower in *MLLT* of the SL pigs compared with both genotypes of Mangalitsa pigs, and these differences were significant (P <0.001). However, final live weight also had a significant (P <0.05) influence on fat/protein ratio in *MLLT*.

The fatty acid composition and cholesterol concentration of *MLLT* from the examined pigs are shown in Table 4. In general, palmitic acid (C16:0) was the most abundant SFA, with average percentages between 23.3 and 24.3, oleic acid (C18:1 *cis*-9) the most abundant monounsaturated fatty acids (MUFA) (between 38.6% and 47.3%), and linoleic acid (C18:2 *n*-6) the most abundant PUFA (between 4.06% and 8.76%) in the *MLLT* of the examined pigs. The SFA and PUFA concentrations were found in higher (P <0.001) percentages in *MLLT* of SL pigs (43.4% and 11.5%, respectively) than in the SBM and WM pigs. In contrast, MUFA and unsaturated fatty acid (USFA) were found in higher (P <0.001) percentages in the *MLLT* of SBM and WM than in SL pigs. Zăhan *et al.* (2010) showed Mangalitsa pigs contained high levels of palmitic and stearic (SFA), oleic (MUFA) and linoleic (PUFA) fatty acids. The amount of linoleic acid they found was double that found for the same pig breed by other researchers (Holló *et al.*, 2003). The results of research by Sans *et al.* (2004) on fresh meat quality in Gascon pigs that were reared within an open system connected to natural resources and fed acorns and limited quantities of concentrates showed more MUFA (58.3%), and less SFA (36.1%) and PUFA (5.61%) in *musculus longissimus dorsi*. Furthermore, some statistically significant differences in their fatty acid content were noted, depending on the type of muscle examined (*musculus longissimus dorsi* and *musculus biceps femoris*). Similar values for MUFA concentration (58.1%) in *musculus longissimus dorsi* (MLD) of Iberian pigs reared in an open system were established by Rey *et al.*

(2004). In our study, MUFA content in Mangalitsa animals (SBM and WM), especially in the WM breed (58.0% MUFA), confirmed the results of other authors. The Duroc breed is known for its high intramuscular fat content relative to backfat content compared with other breeds. In line with these considerations, the intramuscular SFA and MUFA proportions were higher and the PUFA proportions were lower for Duroc than for British Landrace pigs (De Smet *et al.*, 2004). Cameron *et al.* (2000) studied the genotype by nutrition interactions on fatty acid composition of intramuscular fat in Large White pigs. There were selection line effects on the fat content and on the fatty acid composition of triacylglycerols and phospholipids, but the diet effects were larger than the selection line effects, especially on the *n*-6/*n*-3 ratio. More importantly, there was no evidence of genotype-nutrition interactions.

Table 4 Comparison of least squares means ± (SEM) for fatty acid composition (%) and cholesterol concentration (mg/100 g) of *musculus longissimus lumborum et thoracis* traits and level of significance differences

Trait	Swallow-bellied Mangalitsa (SBM)	White Mangalitsa (WM)	Swedish Landrace (SL)	Significance of the influence	
	(n = 12)	(n = 12)	(n = 12)	Genotype	LW
C14:0	$1.22^{a} \pm 0.03$	$1.13^{a} \pm 0.03$	$1.13^{a} \pm 0.04$	NS	NS
C16:0	$24.3^{a} \pm 0.46$	$23.3^{a} \pm 0.46$	$24.3^{a} \pm 0.49$	NS	NS
C17:0	$0.24^{c} \pm 0.02$	$0.19^{b} \pm 0.02$	$0.12^{a} \pm 0.03$	**	NS
C18:0	$9.30^{b} \pm 0.32$	$9.01^{b} \pm 0.32$	$12.94^{a} \pm 0.34$	***	NS
C20:0	$0.14^{b} \pm 0.01$	$0.12^{b} \pm 0.01$	$0.20^{a} \pm 0.01$	***	NS
C16:1	$4.62^{b} \pm 0.19$	$4.21^{b} \pm 0.19$	$2.27^{a} \pm 0.20$	***	NS
C17:1	$0.24^{c} \pm 0.01$	$0.21^{b} \pm 0.01$	ND ^{a}	***	***
C18:1 *cis*-9	$44.2^{c} \pm 0.88$	$47.3^{b} \pm 0.88$	$38.6^{a} \pm 0.93$	***	NS
C18:1 *trans*-9	$0.56^{b} \pm 0.03$	$0.53^{b} \pm 0.03$	ND ^{a}	***	NS
C18:1 *cis*-11	$4.71^{b} \pm 0.16$	$5.03^{b} \pm 0.16$	$3.34^{a} \pm 0.17$	***	NS
C18:2 *n*-6	$5.43^{b} \pm 0.51$	$4.06^{b} \pm 0.51$	$8.76^{a} \pm 0.54$	***	NS
C18:3 *n*-3	$0.48^{a} \pm 0.04$	$0.18^{b} \pm 0.04$	$0.20^{a} \pm 0.05$	***	NS
C20:1 *n*-9	0.75 ± 0.02	0.71 ± 0.02	0.70 ± 0.02	NS	NS
C20:2 *n*-6	$0.34^{b} \pm 0.03$	$0.28^{b} \pm 0.03$	$0.45^{a} \pm 0.03$	***	NS
C20:3 *n*-3	ND ^{b}	ND ^{b}	$0.96^{a} \pm 0.17$	***	NS
C20:3 *n*-6	0.46 ± 0.04	0.46 ± 0.04	0.43 ± 0.05	NS	NS
C22:1 + C 20:4	$0.21^{b} \pm 0.19$	$0.22^{b} \pm 0.19$	$1.19^{a} \pm 0.20$	***	NS
C22:5 *n*-3	$0.09^{b} \pm 0.01$	$0.01^{a} \pm 0.01$	ND ^{a}	***	*
SFA	$35.3^{b} \pm 0.53$	$33.8^{b} \pm 0.53$	$43.4^{a} \pm 0.56$	***	NS
MUFA	$55.1^{b} \pm 1.04$	$58.0^{b} \pm 1.05$	$44.9^{a} \pm 1.11$	***	NS
PUFA	$7.01^{b} \pm 0.77$	$5.21^{b} \pm 0.77$	$11.47^{a} \pm 0.81$	***	NS
USFA	$62.1^{b} \pm 0.45$	$63.2^{b} \pm 0.45$	$56.3^{a} \pm 0.48$	***	NS
Total *n*-3 PUFA	$0.57^{b} \pm 0.05$	$0.19^{a} \pm 0.05$	$0.20^{a} \pm 0.05$	***	NS
Total *n*-6 PUFA	$6.23^{a} \pm 0.51$	$4.80^{a} \pm 0.51$	$9.63^{b} \pm 0.54$	***	NS
MUFA/PUFA	$8.32^{c} \pm 0.60$	$11.45^{b} \pm 0.60$	$4.51^{a} \pm 0.64$	***	NS
MUFA/SFA	$1.56^{c} \pm 0.04$	$1.72^{b} \pm 0.04$	$1.04^{a} \pm 0.04$	***	NS
PUFA/SFA	$0.20^{b} \pm 0.01$	$0.15^{b} \pm 0.01$	$0.33^{a} \pm 0.02$	***	NS
n-6/*n*-3 PUFA	$14.05^{b} \pm 2.99$	$34.01^{a} \pm 2.99$	$45.63^{a} \pm 3.17$	***	NS
Cholesterol	$62.3^{b} \pm 1.97$	$62.9^{b} \pm 1.97$	$47.1^{a} \pm 2.09$	***	NS

LW: live weight; n: number of samples; ND: not detected; NS: not significant ($P \geq 0.05$); *Statistical significance at the level of $P < 0.05$; **Statistical significance at the level of $P < 0.01$; ***Statistical significance at the level of $P < 0.001$.
SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids.
USFA: monounsaturated fatty acids + polyunsaturated fatty acids; content of SFA, MUFA, PUFA – calculated from all detected acids. $^{a\text{-}c}$ Means within a row with different superscripts differ ($P < 0.05$).

In the current study, Mangalitsa pigs showed higher levels of MUFA (P <0.001) in the *MLLT* than SL pigs. Ruiz *et al.* (1998) and Andrés *et al.* (2001) concluded that free-reared pigs fed on pasture and acorns showed higher levels of MUFA than those fed on concentrates. Nevertheless, in our study, oleic acid (C18:1 *cis*-9) levels in *MLLT* of Mangalitsa pigs were considerably higher than average levels of this fatty acid in the meat of SL pigs. These results are consistent with research from Hansen *et al.* (2006), demonstrating that organically reared pigs had a higher content of PUFA and a lower content of MUFA. Similarly, there were higher levels of C18:2 *n*-6 and PUFA *n*-6 in pigs fed organically than in pigs fed conventionally (Högberg *et al.*, 2003). In our research, the higher C18:2 *n*-6 concentration in SL pigs contributed to the higher total PUFA concentration in SL pigs (11.47 ± 0.81) compared with Mangalitsa pigs. This finding is consistent with the results of Nilzén *et al.* (2001). The higher level of this fatty acid in the SL pigs resulted in these animals having a higher overall amount of *n*-6 fatty acids compared with the WM and LW pigs.

Total MUFA to SFA ratios of the *MLLT* differed (P <0.001), with a higher MUFA/SFA ratio for the Mangalitsa pigs, compared with the SL pigs (Table 4). On the other hand, total PUFA to SFA ratios differed (P <0.001), with a higher PUFA/SFA ratio for the SL pigs, compared with that of the Mangalitsa pigs. The fatty acid composition of the intramuscular fat is influenced by several factors, of which diet in general seems to be one of the most important (Nürnberg *et al.*, 1998). Similarly, higher concentration of PUFA in organically produced pigs may not only be a result of the different feed, but may also be partially caused by a higher lean meat percentage (Hansen *et al.*, 2006).

Holló *et al.* (2003) determined MUFA values in *MLLT* from Mangalitsa pigs as ranging between 56.0% and 56.1%, PUFA values ranging between 6.51% and 8.24% and SFA values between 35.8% and 37.4%. Loins of Iberian pork were characterized by a high concentration of MUFA in intramuscular fat of the *MLLT*, especially where animals were reared in an open system and fed grasses and acorns (59.2%), while two other groups of animals, reared in a closed system, regardless of the diet provided, showed no difference in MUFA concentration (56.7% and 56.3%) (Daza *et al.*, 2007).

The SL pigs showed a higher PUFA concentration in their *MLLT* than the Mangalitsa pigs. These differences were produced mainly by their higher total *n*-6 PUFA content (P <0.001). However, SBM had a higher level of total *n*-3 PUFA (P <0.001) than SL and WM pigs. These led to lower (P <0.001) *n*-6/*n*-3 ratios in *MLLT* of SBM pigs. Therefore, the *n*-6/*n*-3 ratio was higher than dietary recommendations in all cases (British Nutrition Foundation, 1994). The housing system and diet of Mangalitsa pigs can significantly affect this ratio. For example, Parunović *et al.* (2012b) found that free-range Mangalitsa pigs showed a higher PUFA content in the *MLLT* than pigs reared indoors and fed conventionally. These differences were produced mainly by an almost four times higher total *n*-3 PUFA concentration in the *MLLT* of the free-range pigs (P <0.001), and also by slightly higher (P >0.05) levels of total *n*-6 PUFA. These led to lower (P <0.001) *n*-6/*n*-3 ratios in the *MLLT* of the pigs reared outdoors and fed on acorns and free pasture.

In our study, the C18:3 *n*-3 concentration was higher (P <0.001) in the *MLLT* of SBM than in that of WM and SL pigs. Other researchers found a higher total *n*-3 PUFA concentration in muscle phospholipids of animals fed a diet high in C18:3 *n*-3 (Ahn *et al.*, 1996; Specht-Overholt *et al.*, 1997), and increasing levels of C18:3 *n*-3, which were responsible mainly for a higher total *n*-3 PUFA. A diet with a higher C18:3 *n*-3 content led to increased amounts of certain fatty acids of the *n*-3 pathway, especially eicosapentaenoic acid (EPA) (C20:5 *n*-3) and C22:5 *n*-3, although not docosahexaenoic acid (DHA) (C22:6 *n*-3). In the study by Muriel *et al.* (2002), all individual *n*-3 PUFA, including EPA, DHA and C22:5 *n*-3, were significantly higher in animals reared outdoors and fed on acorns and pasture than in indoor-bred animals that were fed concentrates. The role of EPA and DHA in easing the symptoms of a number of diseases, including coronary heart disease, has been acknowledged (British Nutrition Foundation, 1994). An increasing EPA and DHA content and a decreasing *n*-6/*n*-3 ratio, together with high MUFA levels, indicate a potentially beneficial effect of feeding animals on pasture and support a 'healthy' image of 'organic' pork. In fact, nutritional studies have already related the inclusion of meat products from Iberian pigs reared outdoors in the diet of humans with improvement in plasmatic indicators of coronary and vascular disease (García *et al.*, 1998). Positive features of feeding pigs with grass are levels of the nutritionally important long chain *n*-3 PUFA are the increased i.e. EPA (20:5 *n*-3) and DHA (22:6 *n*-3) concentrations. Future research should focus on increasing, *n*-3 PUFA proportions in lean carcasses and the use of biodiverse pastures and conservation processes that retain the benefits of fresh leafy grass, and offer opportunities to achieve this. The varying fatty acid compositions of adipose tissue and muscle have profound effects on meat quality (Wood *et al.*, 2008).

As for the PUFA/SFA ratio, the *n*-6/*n*-3 ratio of the total lipid fraction may vary depending on the *n*-6/*n*-3 ratio of the phospholipid and triacylglycerol fractions, although the *n*-6/*n*-3 ratios are much more affected by feeding than by genetics, as shown for example for pork (Enser *et al.*, 2000) and for beef (Itoh *et al.*, 1999; Choi *et al.*, 2000) and as reviewed by Raes *et al.* (2004). The *n*-6/*n*-3 ratio plays an important role in reducing the risk of coronary heart disease (American Heart Association, 2008). However, the optimal balance between these two classes of fatty acid is still a matter of debate (Simopoulos, 2002). The *n*-6 PUFAs are involved in the synthesis of eicosanoids biologically active in very small quantities and with properties that are much more inflammatory than eicosanoids from the *n*-3 PUFAs (Simopoulos, 2002). Therefore, nutritional guidelines recommend that fat intake, especially SFA, should be reduced and the intake of *n*-6 fatty acids minimized relative to *n*-3 fatty acids (UK Department of Health, 1994).

Modern pig breeds are more prone to stress than the Mangalitsa and similar unimproved breeds. Honkavaara (1989) and Piedrafita *et al.* (2001) found only minor effects of the stress susceptibility genotype on the subcutaneous and intramuscular fatty acid profile of pigs. Hartmann *et al.* (1997), however, found a significantly higher PUFA/SFA ratio in muscle and adipose tissue for stress-susceptible pigs compared with normal pigs, but the authors also reported highly significant inverse relationships between the PUFA/SFA ratio and total lipid content in various tissues. Our research has shown that the ratio of PUFA/SFA was significantly higher in SL pigs than in both strains of Mangalitsa pigs.

Genotype significantly affected total SFA content in *MLLT* ($P < 0.001$), with SL producing higher levels than Mangalitsa pigs. The average value of SFA (43.4%) in SL pigs was higher than in WM and SBM pigs (Table 4). These differences were produced mainly by higher ($P < 0.001$) stearic acid (C18:0) and ($P < 0.001$) arachidic acid (C20:0) levels in their *MLLT*. Myristic acid (C14:0) and palmitic acid (C16:0) levels did not differ ($P > 0.05$) between the pig genotypes. The SBM and WM pigs had a higher ($P < 0.01$) C17:0 concentration than the SL pigs. However, stearic acid (C18:0) is considered a neutral fatty acid that has no effect on blood cholesterol (Mahan & Escott-Stump, 2000), compared with myristic acid (C14:0) and palmitic acid (C16:0), which have strong influences.

In our research, the type of genotype had a significant effect ($P < 0.001$) on cholesterol content in the *MLLT* of the pigs. Cholesterol content in *MLLT* was the lowest in SL pigs. The total cholesterol concentration in *MLLT* of SBM and WM pigs ranged from a minimum of 52.5 mg/100 g to a maximum of 76.9 mg/100 g, while the level of cholesterol concentration of SL pigs ranged from a minimum of 38.6 mg/100 g to a maximum of 55.1 mg/100 g. No statistically significant differences were established in the cholesterol content in SBM and WM. A number of previous studies reported lower levels of cholesterol in *MLLT* with 59 mg/100 g (Moss *et al.*, 1983) and 57 mg/100 g (Dorado *et al.*, 1999). Similarly, Bohac & Rhee (1988) reported cholesterol content of 55.9 mg/100 g, 53.1 mg/100 g, and 59.7 mg/100 g for *MLLT*. On the other hand, Tu *et al.* (1967) reported that the cholesterol contents were from 62 mg/100 g to 65 mg/100 g for pork *MLLT*. In a similar study, Parunović *et al.* (2012a) reported that the average cholesterol concentration in meat of WM was 63.3 mg, and varied from 52.0 to 76.9 mg/100 g. The average cholesterol content in 100 g *MLLT* of WM fattener pigs was 14.8 mg higher than in the meat of SL, and 1.15 mg higher than in the meat of SBM (Parunović *et al.*, 2012a). The average cholesterol content in SBM was 62.2 mg/100 g, which was 13.63% higher than in SL. No statistically significant differences in cholesterol content were found between the two Mangalitsa genotypes in that study. These values correspond well with our current data. Measurements taken by Csapó *et al.* (2002) indicate that the cholesterol concentration of Mangalitsa pig fat varied between 71 mg/100 g and 109 mg/100 g. The authors concluded that there is no truth in reports that indicate that the fat of the Mangalitsa pigs contains less cholesterol than that of the more generally produced types of fattening pig. Muchenje *et al.* (2009) and Mapiye *et al.* (2010) concluded that the cholesterol levels in beef were not affected by diet. The finding that diet had no substantial effects on meat cholesterol contradicts the results of García & Casal (1992), who observed that beef from steers finished on pasture had lower fat and cholesterol concentrations than that from concentrate-fed ones.

Conclusion

The results of our research led us to note differences between pig genotypes, especially between their carcass properties, chemical and cholesterol content and fatty acids composition in the *MLTT*. A significantly higher percentage of water in muscle tissues of SL, and a higher percentage of total fat in both Mangalitsa genotypes confirmed breed characteristics of these pigs and values obtained in research by other authors. The SL had significantly less cholesterol in its *MLTT* compared with SBM and WM. However, differences in the

content of saturated and unsaturated fatty acids were more expressed and distinct. A higher percentage of unsaturated fatty acids, which are purportedly less harmful to human health, were measured in WM and SBM breeds, whereas the percentage of saturated fatty acids was proven to be significantly higher in SL pigs.

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