Arch. Anim. Breed., 59, 401–415, 2016
www.arch-anim-breed.net/59/401/2016/
doi:10.5194/aab-59-401-2016

Open Access
Archives Animal Breeding

Quality traits of *longissimus lumborum* muscle from White Mangalica, Duroc × White Mangalica and Large White pigs reared under intensive conditions and slaughtered at 150 kg live weight: a comparative study

Vladimir M. Tomović[1], Radoslav Šević[2], Marija Jokanović[1], Branislav Šojić[1], Snežana Škaljac[1], Tatjana Tasić[3], Predrag Ikonić[3], Mateja Lušnic Polak[4], Tomaž Polak[4], and Lea Demšar[4]

[1]University of Novi Sad, Faculty of Technology Novi Sad, Bulevar cara Lazara 1, 21000 Novi Sad, Serbia
[2]Group Univerexport Bačka ad, Joint-Stock Company, Meat Industry, Novosadski put 10, 21400 Bačka Palanka, Serbia
[3]University of Novi Sad, Institute for Food Technology, Bulevar cara Lazara 1, 21000 Novi Sad, Serbia
[4]University of Ljubljana, Biotechnical faculty, Jamnikarjeva 101, 1000 Ljubljana, Slovenia

Correspondence to: Vladimir M. Tomović (tomovic@uns.ac.rs)

Received: 10 May 2016 – Revised: 5 September 2016 – Accepted: 9 September 2016 – Published: 27 September 2016

Abstract. To compare quality traits of *longissimus lumborum* muscle of three genotypes, 20 White Mangalica (WM), 20 crossbred Duroc × White Mangalica (DWM) and 20 Large White (LW) pigs were allotted to the same indoor rearing and feeding conditions. Crossbred and LW pigs grew faster than WM pigs reaching 150 kg on average 168 and 288 days before WM, respectively. Meat from WM pigs had the highest intramuscular fat content and darkest and reddest colour; crosses were at an intermediate position, with significant differences among all genotypes. In addition, ultimate pH, water-holding capacity and iron content were significantly the highest in meat from WM pigs, compared to the other two genotypes. Crossing WM with Duroc had a significant effect on individual fatty acid content of meat. However, the sum of saturated, monounsaturated and polyunsaturated fatty acids remained unchanged. WM and DWM pigs had significantly more tender meat than LW pigs. Monounsaturated fatty acids (MUFAs) were most abundant, followed by saturated (SFAs) and polyunsaturated fatty acids (PUFAs) in meat from all animals. Meat from WM and DWM pigs had a significantly higher percentage of MUFAs and significantly lower percentage of SFAs than LW pigs.

1 Introduction

In Serbia only three native autochthonous pig breeds (Mangalica, Moravka and Resavka) exist, and are registered in the national genetic resources conservation programme. From these three breeds, the Mangalica pig is the most important both in population size and the economic importance. This breed emerged in Hungary as a result of crossing several Hungarian aboriginal pig breeds, which disappeared or were altered till the end of the nineteenth century, with Serbian Šumadinka pig. The earliest descriptions of Mangalica mentioned two types: the White and Black Mangalica. Later five colour types of this breed were portrayed: White (Blond), Black, Swallow-Belly and Brown (Baris), like wild boar, and the Red Mangalica. Nowadays only three types of Mangalica exist – White (Blond), Swallow Belly and Red. Similar as other autochthonous pig breeds, Mangalica have poor reproductive and growing performance and carcass composition (65–70 % of the carcass is lard) (Scherf, 2000; Egerszegi et al., 2003; Zsolnai et al., 2006; Tomović et al., 2014a; DAD-IS, 2016).

Traditionally, this pig breed was reared under extensive outdoor (free-range) management system with the utilization of pasture and woodland feed resources, such as grass, herbs, acorns, tubers, rhizomes, roots and bark. Some corn seed or other grain supplementation was provided in winter

Published by Copernicus Publications on behalf of the Leibniz Institute for Farm Animal Biology.

periods of low pasture and woodland feed availability. Mangalica pigs are slaughtered at high live weight (140–160 kg), which is considered as an optimum slaughtering weight in response to carcass traits and meat quality (Egerszegi et al., 2003; Tomović et al., 2014a; DAS-IS, 2016). Meat and lard from Mangalica pigs, as well as from other autochthonous pig breeds, show interesting quality (primarily in colour and fat content and composition) and have been transformed into unique highly priced dry-cured meats: hams, loins, shoulders, necks and dry fermented sausages ("kulen"). Most of these products still rely primarily on local, traditional manufacturing processes.

Although the link to free-range rearing increases the commercial value of products of autochthonous pigs, because of both effective characterization and consumer suggestion, various research in alter rearing (outdoors vs. indoors; extensive vs. intensive) and (cross-)breeding systems has been performed in order to determine the effective genetic potential of these breeds (Franci and Pugliese, 2007). Crossing with the Duroc pig breed is often done to improve the productivity of the autochthonous animals without greatly affecting their hardiness or reducing the level of intramuscular fat (Edwards, 2005; Pugliese and Sirtori, 2012), because Duroc is notable for having a high muscle lipid (marbling fat) content relative to subcutaneous fat compared with other breeds (Wood et al., 2008). This is particularly important for the processed products, such as dry-cured meats, where marbling is recognized as a criterion of quality (Lopez-Bote, 1998; Gandemer, 2002; Edwards, 2005).

The aim of this study was to compare *longissimus lumborum* quality of purebred White Mangalica, Duroc × White Mangalica and Large White pigs reared under intensive conditions and slaughtered at 150 kg live weight. Additionally, this research will compare their meat quality with other European autochthonous purebreds, their crosses and with modern pigs. Obtained data will increase knowledge regarding meat quality of purebred and crossed Mangalica intended for the production of high-quality dry-cured meats.

2 Materials and methods

A total of 60 pigs (females and castrated males) were sampled: 20 pigs from purebred White Mangalica (WM), 20 pigs from Duroc crossed with White Mangalica (DWM) (Duroc sires and White Mangalica dams), and 20 pigs from purebred Large White (LW). All animals were raised in modern farm and slaughtered in modern slaughterhouse in Serbia according to national legislations, which are mainly harmonized with EU legislation. All animals were reared, transported and slaughtered humanely. At the age of 5 ± 2 days, males were castrated. Castration was performed by a veterinarian under surgical anaesthesia with standard post-surgery treatment. All animals were reared under the same environmental and production regime. Pigs were fed the same commercial diets (Table 1) and were slaughtered at a target body weight of about 150 kg (Table 2). All pigs had ad libitum access to feed and water. Feed was withdrawn 12 h before slaughter, but water was freely available.

On the slaughter day, pigs were individually weighed and transported to a slaughterhouse located 1 km from the farm. The pigs were held in lairage for 2 h, with free access to water. All the animals were slaughtered and dressed in three different days (20 pigs on each day), using standard commercial procedures (Tomović et al., 2008). Carcass sides were conventionally chilled for 24 h in a chiller at 0–4 °C.

After chilling, *M. longissimus lumborum* (LL) was removed from the right side of each carcass, and visible fat and connective tissues were trimmed. All sensory, physical and chemical analyses were performed on LL muscles. Sensory and physical characteristics were measured on fresh or cooked pork. The samples for chemical analysis, taken after the homogenization of the fresh LL muscles, were vacuum packaged in polyethylene bags and stored at −40 °C until analyses (Tomović et al., 2014a).

pH was measured in the centre of LL muscles from right sides of all carcasses at 45 min ($pH_{45\,min}$) and 24 h ($pH_{24\,h}$) post-mortem (ISO 2917, 1999; Tomović et al., 2008).

Twelve (six female and six male) selected and trained (ISO 8586, 2012) panellists evaluated colour and marbling using sets of NPPC (2000) official colour (1 = white to pale pinkish grey to 6 = dark purplish red) and marbling (1 = devoid to 6 and 10 = abundant, corresponding to approximately 1–10 % intramuscular fat) standards. Chops for colour and marbling evaluation were taken perpendicularly to the long axis of LL muscle; the minimum thickness was 2.54 cm (Tomović et al., 2014a).

Instrumental colour parameters (eight replicates on the same chop taken perpendicularly to the long axis of LL muscle; minimum thickness: 2.54 cm) lightness (L^*), redness (a^*), yellowness (b^*), C^* (chroma – saturation index; $C^* = (a^{*2} + b^{*2})^{1/2}$), h (hue angle; $h = \text{arctangent}\,(b^*/a^*)$) and λ (dominant wavelength (nm)) were determined using a Konica Minolta Chroma Meter CR-400 on the cut surface after 60 min of blooming at 3 °C, using D-65 lighting, a 2° standard observer angle and an 8 mm aperture in the measuring head (CIE, 1976; Honikel, 1998; Tomović et al., 2008; AMSA, 2012; Tomović et al., 2014a).

Water-holding capacity (WHC) was determined as free water (exudative juice) using the filter paper press method (Grau and Hamm, 1953; Van Oeckel et al., 1999; Tomović et al., 2014a). For cooking loss determination, meat chops (thickness: 2.54 cm) were roasted in a temperature-controlled oven set to 163 °C, until an internal temperature of 71 °C, recorded by thermocouples, was reached (AMSA, 1995). The cooking loss is expressed as the percentage of the initial sample weight.

Samples of cooked meat, after cooking loss determination, were used for determination of tenderness (sensory and instrumentally) and juiciness (sensory). Tenderness was mea-

Table 1. Pig age and weight range, and ingredients and chemical composition of diets.

	Pre-starter I	Pre-starter II	Starter	Grower	Pre-finisher	Finisher I	Finisher II
Pig age and weight range							
All groups of pigs	from birth to weaning	first 7 days after weaning	to 15 kg	to 25 kg	to 60 kg	to 120 kg	from 120 kg
Ingredients (%)							
Corn	24	41	57	67	68	70	68
Soybean meal (44 % CP)	13	21	21	23	15	8	3
Soybean grits	7						
Soybean oil	3	2	2				
Sunflower meal (33 % CP)					5	6	6
Wheat meal				3	6	10	15
ActiProt (protein-rich feed)					3	3	5
Mixomel 38 (dairy feed)	17	12	7				
Fokkamix 80 (source of lactose)	22	10	4				
Fish meal	4	4	4	2			
Dextrose	5	5					
Premix (vitamin mineral mixture)*	5	5	5	5	3	3	3
Analysed chemical composition (%)							
Crude protein ($N \times 6.25$)	22.00	21.30	20.50	18.30	16.30	14.30	13.40
Crude fat	7.00	5.00	5.00	3.50	3.60	3.80	4.00
Cellulose	2.70	3.20	3.50	3.90	4.80	4.90	5.10
Lysine	1.60	1.50	1.40	1.15	0.85	0.70	0.58
Methionine	0.40	0.38	0.35	0.30	0.25	0.20	0.22
Threonine	0.90	0.85	0.75	0.67	0.55	0.50	0.44
Tryptophan	0.28	0.28	0.25	0.20	0.19	0.16	0.14
Lactose	21.50	10.50	5.00	0.00	0.00	0.00	0.00
ME (MJ kg^{-1})	15.00	14.50	14.40	13.75	13.55	13.10	13.10

CP: crude protein; * Pre-starter I and II: vitamin A, 350.000 IU; vitamin D_3, 40.000 IU; vitamin E, 1.500 mg; vitamin K_3, 70 mg; vitamin B_1, 80 mg; vitamin B_2, 150 mg; vitamin B_6, 100 mg; vitamin B_{12}, 0.8 mg; vitamin C, 1.000 mg; niacin, 800 mg; Calpan, 400 mg; biotin, 6 mg; folic acid, 30 mg; choline, 10.000 mg; Se, 4 mg; I, 25 mg; Fe, 2.000 mg; Cu, 600 mg; Zn, 3.000 mg; Mn, 1.000 mg; phytase, 3.000 mg; CRINA piglets, 6.000 mg; protease, 4.000 mg; amylase, 4.000 mg; RONOZYME WX, 3.000 mg; ROXAZYME G2G, 3.000 mg; RONOZYME VP, 3.000 mg; VEVOMIN Cu, 1.400 mg; VEVOMIN Fe, 2.000 mg; VEVOMIN Mn, 1.000 mg; VEVOMIN Zn, 2.000 mg; VevoVitall, 100.000 mg; organic Se source, 2.000 mg; antioxidant, 2.000 mg; lysin, 7.0 %; methionine, 5.5 %; Ca, 8.0 %; P, 4.5 %; Na, 3.0 %; probiotics, 1.000 mg; carrier, to 1.000 g.
Starter: vitamin A, 350.000 IU; vitamin D_3, 40.000 IU; vitamin E, 1.500 mg; vitamin K_3, 70 mg; vitamin B_1, 80 mg; vitamin B_2, 150 mg; vitamin B_6, 100 mg; vitamin B_{12}, 0.8 mg; vitamin C, 1.000 mg; niacin, 800 mg; Calpan, 400 mg; biotin, 6 mg; folic acid, 30 mg; choline, 10.000 mg; Se, 4 mg; I, 25 mg; Fe, 2.000 mg; Cu, 600 mg; Zn, 3.000 mg; Mn, 1.000 mg; phytase, 3.000 mg; CRINA piglets, 6.000 mg; protease, 4.000 mg; RONOZYME WX, 3.000 mg; ROXAZYME G2G, 3.000 mg; RONOZYME VP, 3.000 mg; VEVOMIN Cu, 1.400 mg; VEVOMIN Fe, 2.000 mg; VEVOMIN Mn, 1.000 mg; VEVOMIN Zn, 2.000 mg; VevoVitall, 100.000 mg; organic Se source, 2.000 mg; antioxidant, 2.000 mg; lysin, 6.5 %; methionine, 5.0 %; Ca, 12.0 %; P, 4.0 %; Na, 3.0 %; probiotics, 1.000 mg; carrier, to 1.000 g.
Grower: vitamin A, 350.000 IU; vitamin D_3, 40.000 IU; vitamin E, 1.500 mg; vitamin K_3, 70 mg; vitamin B_1, 60 mg; vitamin B_2, 150 mg; vitamin B_6, 90 mg; vitamin B_{12}, 0.6 mg; vitamin C, 1.000 mg; niacin, 600 mg; Calpan, 400 mg; biotin, 6 mg; folic acid, 30 mg; choline, 8.000 mg; Se, 4 mg; I, 20 mg; Fe, 3.000 mg; Cu, 1.000 mg; Zn, 3.000 mg; Mn, 1.000 mg; phytase, 3.000 mg; CRINA piglets, 6.000 mg; protease, 4.000 mg; RONOZYME WX, 3.000 mg; ROXAZYME G2G, 3.000 mg; RONOZYME VP, 3.000 mg; VEVOMIN Cu, 1.400 mg; VEVOMIN Fe, 2.000 mg; VEVOMIN Mn, 1.000 mg; VEVOMIN Zn, 2.000 mg; VevoVitall, 100.000 mg; organic Se source, 2.000 mg; antioxidant, 2.000 mg; lysin, 7.0 %; methionine, 3.0 %; Ca, 14.5 %; P, 4.0 %; Na, 3.0 %; probiotics, 1.000 mg; carrier, to 1.000 g.
Pre-finisher, finisher I and II: vitamin A, 300.000 IU; vitamin D_3, 60.000 IU; vitamin E, 2.000 mg; vitamin K_3, 80 mg; vitamin B_1, 66 mg; vitamin B_2, 160 mg; vitamin B_6, 70 mg; vitamin B_{12}, 0.6 mg; niacin, 800 mg; Calpan, 600 mg; biotin, 4 mg; folic acid, 20 mg; choline, 10.000 mg; Se, 15 mg; I, 50 mg; Fe, 4.000 mg; Cu, 1.100 mg; Zn, 4.200 mg; Mn, 3.000 mg; phytase, 5.000 mg; RONOZYME WX, 5.000 mg; ROXAZYME G2G, 5.000 mg; RONOZYME VP, 5.000 mg; VevoVitall, 150.000 mg; antioxidant, 3.333 mg; lysin, 4.0 %; methionine, 1.5 %; Ca, 22.0 %; P, 3.0 %; Na, 5.0 %; carrier, to 1.000 g.

sured as the Warner–Bratzler shear force (WBSF (N)) using texture analyzer (TA.HDplus, Stable Micro Systems, Godalming, UK). Shear force of each roasted chop was determined on minimum eight cylindrical cores (Ø 1.27 cm), taken parallel to the longitudinal orientation of the muscle fibres and sheared by V-shaped cutting blade (thickness: 3 mm) with a triangular aperture of 60° at a velocity of 1.5 mm s^{-1}. The same 12 panellists evaluated tenderness (1 = extremely tough to 8 = extremely tender) and juiciness (1 = extremely dry to 8 = extremely juicy) using AMSA (1995) standards.

Moisture (ISO 1442, 1997), protein (nitrogen × 6.25; ISO 937, 1978), total fat – intramuscular fat (IMF) (ISO 1443, 1973) and total ash (ISO 936, 1998) contents of muscle were determined according to methods recommended by the International Organization for Standardization.

Table 2. Age (days), average body weights (kg), and average daily gains (g) between birth and slaughter.

	WM			DWM			LW		
	Age	ABW	ADG	Age	ABW	ADG	Age	ABW	ADG
Farrowing	0	1.6	–	0	1.7	–	0	1.5	–
	7	3.1	210.7	7	3.0	187.0	7	2.9	203.8
	14	4.6	212.4	14	4.3	186.0	14	4.8	239.3
	21	5.9	204.3	21	5.6	186.8	21	6.7	249.4
	28	7.2	198.8	28	6.6	176.7	26	7.9	246.0
	35	8.3	191.3	35	7.8	174.9			
	37	8.6	192.4	37	8.1	174.2			
Nursery	37	8.6	–	37	8.1	–	26	7.9	–
	42	9.8	244.6	42	9.1	133.2	31	8.4	96.4
	49	12.0	282.8	49	10.2	148.2	37	10.4	231.5
	56	14.6	315.1	56	12.4	201.0	42	11.0	196.6
	63	16.9	321.1	63	15.9	273.4	49	12.9	217.1
	70	19.6	333.3	70	19.5	323.3	56	15.4	250.6
	77	22.4	343.8	77	23.1	356.2	63	18.7	292.8
	84	25.3	354.5	84	27.4	409.2	70	22.4	330.6
							73	25.0	363.9
Grow-finish	84	25.3	–	84	27.4	–	73	25.0	–
	112	34.0	310.7	112	37.5	360.4	84	31.7	609.4
	140	47.8	401.7	140	50.7	410.6	112	53.7	735.4
	168	62.9	447.2	168	65.9	454.6	140	76.3	765.0
	196	75.8	450.9	196	87.1	530.4	168	99.2	779.3
	224	86.7	438.3	224	106.1	560.0	196	120.7	777.1
	252	94.8	413.1	252	120.1	550.3	224	140.2	762.1
	308	107.3	365.7	308	141.0	506.1	244	154.1	753.9
	364	119.8	337.5	364	154.1	451.4			
	420	133.7	322.6						
	476	142.3	298.2						
	532	150.7	279.7						

WM – White Mangalica. D – Duroc. LW – Large White. ABW – average body weight. ADG – average daily gain.

The fatty acid composition was determined by gas chromatography (C10:0 – decanoic (capric), C11:0 – undecanoic, C14:0 – tetradecanoic (myristic), C15:1*cis*-5 – *cis*-5-pentadecenoic, C16:0 – hexadecanoic (palmitic), C16:1*trans*-9 – *trans*-9-hexadecenoic acid, C16:1*cis*-9 – *cis*-9-hexadecenoic acid (palmitoleic), C17:0 – heptadecanoic (margaric), C17:1*trans*-10 – *trans*-10-heptadecenoic, C17:1*cis*-10 – *cis*-10-heptadecenoic, C18:0 – octadecanoic (stearic), C18:1*trans*-9 – *trans*-9-octadecenoic (elaidic), C18:1*cis*-9 – *cis*-9-octadecenoic (oleic), C18:2*cis*-9,12 – *cis*,*cis*-9,12-octadecadienoic (linoleic), C18:3*cis*-9,12,15 – all-*cis*-9,12,15-octadecatrienoic (α-linoleic), C20:0 – eicosanoic (arachidic), C20:1*cis*-11 – *cis*-11-eicosenoic (gondoic), C20:2*cis*-11,14 – *cis*,*cis*-11,14-eicosadienoic, C20:4*cis*-5,8,11,14 – all-*cis*-5,8,11,14-eicosatetraenoic (arachidonic), C22:0 – docosanoic (behenic), C22:5*cis*-7,10,13,16,19 – all-*cis*-7,10,13,16,19-docosapentaenoic, C24:1*cis*-9 – *cis*-9-tetracosenoic (nervonic)). The gas chromatographic conditions for the fatty acids methyl ester analysis were as described by Polak et al. (2008). The fatty acid methyl esters were expressed as percentage of total fatty acids; the ones that were on average less than 0.05 % were not shown (C12:0 – dodecanoic (lauric), C14:1*cis*-9 – *cis*-9-tetradecenoic (myristoleic), C15:0 – pentadecanoic, C18:3*cis*-6,9,12 – all-*cis*-6,9,12-octadecatrienoic (γ-linoleic), C20:1*cis*-5 – *cis*-5-eicosenoic, C20:5*cis*-5,8,11,14,17 – all-*cis*-5,8,11,14,17-eicosapentaenoic, C22:1*cis*-13 – *cis*-13-docosenoic (erucic), C22:6*cis*-4,7,10,13,16,19 – all-*cis*-4,7,10,13,16,19-docosahexaenoic, C24:0 – tetracosanoic (lignoceric)).

The total phosphorous (P) content was determined according to ISO method (ISO 13730, 1996). The contents of potassium (K), sodium (Na), magnesium (Mg), calcium (Ca), zinc (Zn), iron (Fe), copper (Cu) and manganese (Mn) were determined using inductively coupled plasma-optical emission spectrometry (ICP-OES) (iCAP 6000 Series, Thermo Scientific, Cambridge, UK), method 984.27 (AOAC, 2005), after microwave digestion (MWS-3^{+}, Berghof, Germany).

All data are presented as mean, standard error and range. Analyses of variance (Duncan's multiple range test) were used to test the hypothesis about differences between mean values. Pearson correlation coefficients among quality traits were also calculated, but not all values are shown. The software package STATISTICA 12 was used (StatSoft, 2015) for analysis.

3 Results and discussion

4 Growth performance

Although it was not the goal of this study, growth performances of the pigs are included. Genotype significantly affected average daily gain (ADG) during the whole rearing period (Table 2). As a consequence of the different growth rates, the three genotypes reached the target slaughter weight at very different ages. As expected, crosses with the Duroc showed higher growth rate than the Mangalica pigs, confirming other research that compared European autochthonous breeds with modern ones or their crosses (Serra et al., 1998; Labroue et al., 2000; Acciaioli et al., 2002; Alfonso et al., 2005; Renaudeau et al., 2005; Renaudeau and Mourot, 2007; Serrano et al., 2008; Sirtori et al., 2011; Maiorano et al., 2013; Robina et al., 2013; Franco et al., 2014). WM reached target slaughter weight (about 150 kg) on average 168 and 288 days later than DWM and LW, respectively. Also, DWM reached the same slaughter weight on average 120 days later than LW. Obviously it was difficult to obtain pigs of the same body weight at the same age. Despite the fact that age has a major influence on meat quality (Mayoral et al., 1999; Lawrie and Ledward, 2006; Wojtysiak and Połtowicz, 2014; Franco et al., 2016), pigs were slaughtered at different ages because it was necessary to reach a weight suitable for processing.

5 Physical and sensory traits

The physical and sensory traits of the LL muscles from WM, DWM and LW pigs are shown in Tables 3 and 4. There were no significant differences between LL muscles from different genotypes in pH value at 45 min post-mortem. Initial pH is a good indicator of the pale, soft and exudative (PSE) pork. All individual values of $pH_{45\,min}$ (especially for LW pigs) recorded in this study were above 6.0, which means the pork is not considered a PSE (Tomović et al., 2014b). Comparing initial pH of loin muscles from autochthonous and modern breeds and their crosses, authors (Serra et al., 1998; Labroue et al., 2000; Franci et al., 2005; Galián et al., 2007; Poto et al., 2007; Sirtori et al., 2011; Maiorano et al., 2013; Wojtysiak and Połtowicz, 2014) have reported contradictory or conflicting results. In the present study, 24 h post-mortem LL muscles from WM had the highest ($P = 0.002$) pH value when compared to the other two genotypes, while there were no significant differences between DWM and LW. Ultimate pH is a good indicator of the dry, firm and dark (DFD) pork. All individual values of $pH_{24\,h}$ recorded in this study were below 6.0, which means the pork is not considered a DFD (Tomović et al., 2014b). Average ultimate pH values, in all three genotypes, were in the range characteristic of pork (5.3–5.8, Honikel, 1999). Several authors (Serra et al., 1998; Labroue et al., 2000; Franci et al., 2005; Renaudeau et al., 2005; Renaudeau and Mourot, 2007; Wojtysiak and Połtowicz, 2014), in accordance with the present study, found ultimate pH values of loin muscles higher in autochthonous breeds than in their crosses and/or modern breeds, suggesting that autochthonous breeds could have slower rates of post-mortem pH decline. Galián et al. (2007), Poto et al. (2007), Sirtori et al. (2011) and Maiorano et al. (2013) did not find an effect of similar genotypes on ultimate pH of loin muscles. Conversely, Franco et al. (2014) found lower ultimate pH in loin muscles from Celta pigs than their crosses with Duroc and Landrace.

In the present study, all colour parameters (sensory and instrumental), except b^* value, showed significant differences between LL muscles from different genotypes (Tables 3 and 4). LL muscles from WM had the lowest L^* and h values and the highest sensory colour score, a^* and λ values; LL muscles from LW had the highest L^* and h values and the lowest sensory colour score, a^* and λ values, while crosses were at an intermediate position, with significant differences ($P < 0.05$–0.001). LL muscles from each genotype had individual L^* values lower than 53, the highest acceptable L^* value (pale colour: $L^* > 53$) for this muscle (Honikel, 1999). C^* values for LL muscles from WM and DWM were higher ($P < 0.001$) than from LW; however, there were no significant differences between WM and DWM. Thus, LL muscles from WM were numerically or significantly the darkest, the reddest and more intense in colour, followed by DWM and LW. Data of sensory analysis and instrumental measurements showed that the colour of LL muscles of WM can be considered "dark" (average sensory colour = 4.95; average L^* value = 40.31; Tomović et al., 2014b), giving the meat products a desirable dark red colour. According to Lindahl et al. (2001), most of the variation (86–90 %) in lightness (L^* value), redness (a^* value), yellowness (b^* value), chroma (saturation) and hue angle of pork of normal meat quality was explained by the pigment content, myoglobin forms and internal reflectance. Moreover, autochthonous breeds have a higher content of oxidative fibres in muscles than modern breeds, which causes higher myoglobin content (Rahelic and Puac, 1981; Serra et al., 1998; Wojtysiak and Połtowicz, 2014). In addition to genotype, darker and redder colour might also be explained by age and ultimate pH. With age the great increase in myoglobin (hem pigment) content is evident (Mayoral et al., 1999; Lawrie and Ledward, 2006; Zemva et al., 2015; Franco et al., 2016), while higher ultimate pH is associated with darker colour (Lawrie and Ledward, 2006). In this respect, significant negative cor-

Table 3. Physical traits of fresh and cooked *M. longissimus lumborum* from White Mangalica (WM), Duroc × White Mangalica (DWM), and Large White (LW) pigs.

Traits	WM	DWM	LW	P value
$pH_{45\,min}$	6.37 ± 0.03 6.03–6.53	6.26 ± 0.03 6.09–6.44	6.25 ± 0.03 6.01–6.52	0.117
$pH_{24\,h}$	$5.72 \pm 0.04^{a,d}$ 5.51–5.96	$5.53 \pm 0.02^{b,e}$ 5.44–5.70	$5.50 \pm 0.02^{b,e}$ 5.40–5.73	0.002
L^*	$40.31 \pm 0.64^{c,e,h}$ 37.26–45.23	$45.35 \pm 0.63^{b,d,g}$ 40.79–50.61	$47.98 \pm 0.40^{a,d,g}$ 45.37–50.69	< 0.001
a^*	$11.76 \pm 0.56^{a,d,g}$ 7.47–15.66	$10.12 \pm 0.32^{b,d,g}$ 7.56–12.21	$6.84 \pm 0.17^{c,e,h}$ 5.72–7.77	< 0.001
b^*	5.34 ± 0.33 2.94–7.93	6.24 ± 0.28 4.65–8.53	4.92 ± 0.16 3.75–6.15	0.055
C^*	$12.93 \pm 0.64^{a,d,g}$ 8.02–17.58	$11.92 \pm 0.40^{a,d,g}$ 8.92–14.16	$8.46 \pm 0.21^{b,e,h}$ 7.07–9.80	< 0.001
h	$24.13 \pm 0.47^{c,f,h}$ 20.93–26.56	$31.45 \pm 0.61^{b,e,h}$ 27.36–37.19	$35.70 \pm 0.69^{a,d,g}$ 31.19–40.27	< 0.001
λ (nm)	$607 \pm 0.6^{a,d,g}$ 604–613	$599 \pm 0.5^{b,e,h}$ 595–603	$595 \pm 0.5^{c,f,h}$ 593–599	< 0.001
WHC-M (cm^2)	$5.77 \pm 0.13^{a,d,g}$ 4.85–6.70	$4.94 \pm 0.09^{b,e,h}$ 4.40–5.60	$4.50 \pm 0.11^{b,e,h}$ 3.70–5.35	< 0.001
WHC-T (cm^2)	$9.78 \pm 0.11^{b,e,h}$ 9.20–10.75	$10.18 \pm 0.07^{b,e,h}$ 9.65–10.70	$11.34 \pm 0.12^{a,d,g}$ 10.35–12.00	< 0.001
WHC-RZ (cm^2)	$4.01 \pm 0.21^{c,f,i}$ 2.90–5.85	$5.25 \pm 0.14^{b,e,h}$ 4.35–6.05	$6.84 \pm 0.11^{a,d,g}$ 5.75–7.50	< 0.001
WHC-M / RZ	$1.56 \pm 0.10^{a,d,g}$ 0.86–2.31	$0.98 \pm 0.04^{b,e,h}$ 0.73–1.31	$0.67 \pm 0.02^{c,e,h}$ 0.50–0.82	< 0.001
WHC-M / T	$0.59 \pm 0.02^{a,d,g}$ 0.46–0.70	$0.49 \pm 0.01^{b,e,h}$ 0.42–0.56	$0.40 \pm 0.01^{c,f,h}$ 0.33–0.45	< 0.001
CL (%)	$18.49 \pm 0.40^{b,e,h}$ 15.74–20.81	$21.86 \pm 0.25^{a,d,g}$ 20.57–24.27	$22.28 \pm 0.40^{a,d,g}$ 19.95–25.44	< 0.001
WBSF (N)	$43.1 \pm 1.37^{b,e,h}$ 31.4–50.9	$44.9 \pm 1.53^{b,e,h}$ 39.3–57.3	$63.2 \pm 3.01^{a,d,g}$ 40.2–87.6	< 0.001

L^* – a measure of darkness/lightness (higher value indicates a lighter colour). a^* – a measure of redness (higher value indicates a redder colour). b^* – a measure of yellowness (higher value indicates a more yellow colour). h – hue angle (lower values indicates a redder colour). C^* – saturation index (higher values indicates greater saturation of red). WHC-M – surface of the pressed meat film. WHC-T – surface of the wet area on the filter paper. WHC-RZ = WHC-T – WHC-M. a bigger WHC-M / T ratio indicates a better WHC. CL – cooking loss. WBSF – Warner–Bratzler shear force. ^{a,b,c} Means with different letters in the same row indicate significant differences at $P < 0.05$. ^{d,e,f} Means with different letters in the same row indicate significant differences at $P < 0.01$. ^{g,h,i} Means with different letters in the same row indicate significant differences at $P < 0.001$.

relations ($P < 0.001$) were found between L^* value and age ($r = -0.79$) and between L^* value and $pH_{24\,h}$ ($r = -0.81$). Irrespective of age, body weight and/or rearing system, almost all literature (Serra et al., 1998; Labroue et al., 2000; Estévez et al., 2003; Alfonso et al., 2005; Franci et al., 2005; Galián et al., 2007; Poto et al., 2007; Renaudeau and Mourot, 2007; Serrano et al., 2008; Sirtori et al., 2011; Maiorano et al., 2013; Robina et al., 2013; Franco et al., 2014; Wojtysiak and Połtowicz, 2014) that compared autochthonous breeds with their crosses (with Duroc, Large White and Landrace) and/or modern breeds reported darker and/or redder loin muscles in autochthonous breeds or reported no difference; the opposite trend has not been determined. Comparable measurements with this study for L^* value of loin mus-

Table 4. Sensory traits of fresh and cooked *M. longissimus lumborum* from White Mangalica (WM), Duroc × White Mangalica (DWM), and Large White (LW) pigs.

Traits	WM	DWM	LW	P value
Colour	$4.95 \pm 0.18^{a,d,g}$ 3.50–6.00	$3.98 \pm 0.06^{b,e,h}$ 3.56–4.50	$3.19 \pm 0.08^{c,f,h}$ 2.63–3.63	< 0.001
Juiciness	$6.86 \pm 0.09^{a,d,g}$ 6.21–7.43	$6.29 \pm 0.09^{b,e,g}$ 5.64–7.07	$5.49 \pm 0.07^{c,f,h}$ 5.13–6.00	< 0.001
Tenderness	$6.69 \pm 0.12^{a,d,g}$ 5.79–7.43	$6.47 \pm 0.12^{a,d,g}$ 5.57–7.14	$5.09 \pm 0.11^{b,e,h}$ 4.38–6.00	< 0.001
Marbling	2.10 ± 0.12 1.25–3.00	2.01 ± 0.09 1.38–2.50	1.63 ± 0.10 1.00–2.50	0.075

[a,b,c] Means with different letters in the same row indicate significant differences at $P < 0.05$. [d,e,f] Means with different letters in the same row indicate significant differences at $P < 0.01$. [g,h] Means with different letters in the same row indicate significant differences at $P < 0.001$.

cles from autochthonous breeds were found by Fortina et al. (2005, 2009), Galián et al. (2007), Serrano et al. (2008), Rodríguez-Sánchez et al. (2010), Maiorano et al. (2013) and Robina et al. (2013); from autochthonous and modern breeds crosses were found by Poto et al. (2007), Serrano et al. (2008) and Robina et al. (2013); and from modern (Large White) breeds they were found by Labroue et al. (2000), Alfonso et al. (2005) and Wojtysiak and Połtowicz (2014) slaughtered at different ages and/or weights.

In the present study, WHC, cooking loss and juiciness showed significant differences between LL muscles from different genotypes (Tables 3 and 4). Estimates of water-holding capacity obtained with the three methods were in agreement. As regards WHC, LL muscles from WM were higher ($P < 0.001$) than from DWM and LW in WHC-M value, while there were no significant differences between DWM and LW. In contrast, LL muscles from LW were higher ($P < 0.001$) than from WM and DWM in WHC-T value; however, there were no significant differences between WM and DWM. Further, LL muscles from WM had the lowest WHC-RZ value and the highest WHC-M / RZ and WHC-M / T values; LL muscles from LW had the highest WHC-RZ value and the lowest WHC-M / RZ and WHC-M / T values, while the WHC-RZ, WHC-M / RZ and WHC-M / T values of LL muscles from DWM were intermediate, with significant differences ($P < 0.05$–0.001). According to criteria for pork, all average WHC-M / T values indicated good WHC (a bigger WHC-M / T ratio indicates a better WHC) (WHC-M / T < 0.35 – exudative pork, WHC-M / T = 0.35–0.45 – non-exudative pork; WHC-M / T > 0.45 – dry pork; Hofmann et al., 1982; Tomović et al., 2014b). In addition, cooking loss of LL muscles from WM was lower ($P < 0.001$) than from DWM and LW, while there were no significant differences between DWM and LW. Finally, sensory scores for juiciness were the highest for LL muscles from WM, followed by DWM and LW, with significant differences ($P < 0.01$–0.001). Thus, LL muscles from WM had numerically or significantly the best WHC, cooking loss and juiciness, followed by DWM and LW. In addition to genotype, better WHC, cooking loss and juiciness might also be explained by age and ultimate pH. According to Mayoral et al. (1999) and Franco et al. (2016) water-holding capacity was better for older animals. Higher pH is associated with better water-holding capacity (Lawrie and Ledward, 2006). Similar as for colour, almost all literature (Mayoral et al., 1999; Labroue et al., 2000; Franci et al., 2005; Renaudeau et al., 2005; Renaudeau and Mourot, 2007; Sirtori et al., 2011; Franco et al., 2014; Wojtysiak and Połtowicz, 2014) which compared autochthonous breeds with their crosses and/or modern breeds reported better water-holding capacity of loin muscles in autochthonous breeds or reported no difference; the opposite trend has not been determined. It is difficult to compare water-holding capacity among trials due to different methods and/or result expression. Still, cooking loss of Mangalica meat was lower than recorded in other autochthonous breeds: Celta (Franco et al., 2014), Cinta Senese (Franci et al., 2005; Pugliese et al., 2005; Sirtori et al., 2011), Nero Siciliano (Pugliese et al., 2004), Creole (Renaudeau et al., 2005; Renaudeau and Mourot, 2007) and Puławska (Wojtysiak and Połtowicz, 2014) and higher than in Lampiño (Rodríguez-Sánchez et al., 2010). In agreement with previously discussed results for pH and colour, in this study significant correlation was also found between the following: juiciness and age ($r = 0.84$, $P < 0.001$), WHC-M / T and $pH_{24\,h}$ ($r = 0.73$, $P < 0.001$) and WHC-M / T and L^* value ($r = -0.84$, $P < 0.001$). Overall, these results imply better technological properties of Mangalica meat than Large White, with crosses at an intermediate position.

In this study, tenderness (sensory and instrumental – WBSF) showed significant differences between LL muscles from different genotypes (Tables 3 and 4). Estimates of tenderness obtained with the two methods were

Table 5. Proximate composition (g 100 g^{-1}) of fresh *M. longissimus lumborum* from White Mangalica (WM), Duroc × White Mangalica (DWM), and Large White (LW) pigs.

Traits	WM	DWM	LW	*P* value
Moisture	$70.72 \pm 0.24^{c,f,h}$ 69.40–72.50	$71.98 \pm 0.13^{b,e,h}$ 71.20–72.90	$74.08 \pm 0.16^{a,d,g}$ 72.70–74.90	< 0.001
Protein	21.83 ± 0.17 20.83–22.75	22.03 ± 0.11 21.68–23.25	21.82 ± 0.12 21.13–22.56	0.262
Total fat (IMF)	$5.86 \pm 0.37^{a,d,g}$ 3.11–8.16	$4.32 \pm 0.23^{b,e,g,h}$ 2.82–5.43	$2.56 \pm 0.18^{c,f,h}$ 1.57–3.83	< 0.001
Total ash	1.10 ± 0.01 1.06–1.17	1.11 ± 0.01 1.05–1.26	1.12 ± 0.01 1.04–1.19	0.566

IMF – intramuscular fat. ^{a,b,c} Means with different letters in the same row indicate significant differences at $P < 0.05$. ^{d,e,f} Means with different letters in the same row indicate significant differences at $P < 0.01$. ^{g,h} Means with different letters in the same row indicate significant differences at $P < 0.001$.

in agreement. LL muscles from WM and DWM had higher ($P < 0.001$) sensory scores for tenderness and lower ($P < 0.001$) WBSF values when compared to LW; however, there were no significant differences between WM and DWM. Thus, LL muscles from WM and DWM were significantly more tender than from LW. Collagen is an abundant connective tissue protein and is a contributing factor to variation in meat tenderness and texture. In general, collagen content in muscle remains similar as an animal ages, indicating that the changes in tenderness are related to the maturation of the collagen (McCormick, 1994; Mayoral et al., 1999; Weston et al., 2002; Lawrie and Ledward, 2006). Despite the fact that older animals often have less tender meat than younger animals our results were not unexpected. IMF tends to dilute the connective tissue of elements in muscle in which it is deposited, reducing the shear force during chewing of meat and making easier muscle fibre separation (Lawrie and Ledward, 2006). This may help explain that significantly older WM and DWM (and with significantly higher IMF content) had more tender LL muscles than LW. IMF content is discussed below. In this study, a significant correlation was found between tenderness and age (WBSF and age, $r = -0.62$, $P < 0.001$; tenderness sensory and age, $r = 0.74$, $P < 0.001$). Similar findings for loin muscles were reported by Franco et al. (2016) for Celta pigs, by Labroue et al. (2000) for French autochthonous breeds and Large White pigs and by Wojtysiak and Połtowicz (2014) for Puławska and Polish Large White pigs. According to Sirtori et al. (2011) and Franco et al. (2014) crossing of autochthonous breeds with Duroc had a positive effect on tenderness of loin muscles but not as a consequence of higher IMF content. When crossing the modern hybrids with the Iberian and Mangalica pigs the pork loins had improved textural properties; however, they had no difference in odour, appearance or flavour/taste when compared with the modern hybrids (Straadt et al., 2013). It is important to note that comparisons between literature data are difficult because of the differences in experimental methodologies.

6 Proximate composition

Among the components of the raw material, lipids play a key role in the final quality of dry-cured meats (Gandemer, 2002). For the manufacture of high-quality dry-cured meats (hams, shoulders, loins, etc.) a high level of fattening is required to provide correct ripening during maturation for the development of their sensory characteristics (Lopez-Bote, 1998; Gandemer, 2002). Likewise, sensory (tenderness, juiciness and flavour) acceptability of fresh pork may be improved by increasing IMF content, but this effect disappeared for IMF contents higher than 3.5 %, which are associated with a high risk of meat rejection due to visible fat (Fernandez et al., 1999). The proximate compositions of the LL muscles from WM, DWM and LW pigs are shown in Table 5. Moisture and total fat content (IMF) showed significant differences between LL muscles from different genotypes, while there were no significant differences for protein and total ash content. Moisture content was the lowest in LL muscles from WM, followed by DWM and LW, with significant differences ($P < 0.01$–0.001). In contrast, IMF content was the highest in LL muscles from WM, followed by DWM and LW, with significant differences ($P < 0.01$–0.001), confirming the inverse relationship of moisture, protein and ash levels with increasing percentages of fat (Keeton and Eddy, 2004). Correlation coefficients between IMF and moisture, protein and total ash content were $r = -0.93$, $P < 0.001$; $r = -0.44$, $P = 0.015$; and $r = -0.40$, $P = 0.030$, respectively. These differences in IMF content are caused by the high lipid synthesis capacity of the autochthonous pig breed (Lopez-Bote, 1998; Alfonso et al., 2005). In addition, marbling was also the highest (Table 4) for LL muscles from WM, followed by DWM and LW, but without significant differences: differences in IMF content were not visually detectable. Moreover, Galián et al. (2009) and Franco et al. (2016) reported that IMF content in loin muscles from Chato Murciano and Celta pigs increased during the growth period. In this study, a positive correlation between IMF and age ($r = 0.76$, $P < 0.001$) was found. Our results were in accordance with previous studies (Serra et al., 1998; Labroue et al., 2000; Estévez et al., 2003; Franci et al., 2005; Renaudeau et al., 2005; Renaudeau and Mourot, 2007; Serrano et al., 2008; Furman et al., 2010; Sirtori et al., 2011; Franco et al., 2014; Wojtysiak and Połtowicz, 2014) showing higher contents of IMF in loin muscles from autochthonous breeds than from their crosses and/or modern breeds. However, Poto et al. (2007), Salvatori et al. (2008) and Robina et al. (2013) did not find differences in IMF content between similar genotypes. Several authors (Franci et al., 2005; Serrano et al., 2008; Sirtori et al., 2011; Franco et al., 2014), in accordance with the present study, found a decrease in IMF in loin muscles when compared to autochthonous breeds with their crosses with modern pigs (Duroc, Large White and Landrace). On the other hand, Poto et al. (2007), Salvatori et al. (2008), Sirtori et al. (2011) and Robina et al. (2013) did not determine differences in IMF content in loin muscles when autochthonous breeds are crossed with modern ones (Duroc and Large White). For autochthonous breeds IMF content in loin muscles ranged from 2.4 % for Borghigiana pigs slaughtered at 181 kg (Fortina et al., 2009) and Celta pigs slaughtered at 140 kg (Franco et al., 2016) to 10.5 % for Chato Murciano slaughtered at 110 kg (Poto et al., 2007); for their crosses with modern pigs ranged from 1.60 % for Casertana × Large White slaughtered at 140 kg (Salvatori et al., 2008) to 11.17 % for Chato Murciano × Large White slaughtered at 110 kg (Poto et al., 2007); and for Large White slaughtered at higher weights over 0.9 % (Franci et al., 2005). Irrespective of age, body weight and/or rearing system, the mean IMF content found in this study was similar to that reported in previous studies for autochthonous breeds (Andrés et al., 2001; Cava et al., 2003; Muriel et al., 2004; Fortina et al., 2005; Rodríguez-Sánchez et al., 2010; Sirtori et al., 2011; Franco et al., 2014), for their crosses with modern breeds (Coutron-Gambotti et al., 1998; Andrés et al., 2001; Morcuende et al., 2007; Ramírez and Cava, 2007; Sirtori et al., 2011; Franco et al., 2014) and for modern breeds (Labroue et al., 2000; Renaudeau et al., 2005; Renaudeau and Mourot, 2007; Wojtysiak and Połtowicz, 2014). It is well known that sensory (tenderness, juiciness and flavour) and technological (ultimate pH, colour and WHC) traits of pork are closely related to the IMF content, which is in accordance with our results. In this study, increased IMF content was associated with significantly improved tenderness (WBSF: $r = -0.61$, $P < 0.001$; sensory: $r = 0.71$, $P < 0.001$), juiciness ($r = 0.78$, $P < 0.001$), ultimate pH ($r = 0.51$, $P = 0.004$), colour (sensory: $r = 0.56$, $P = 0.001$; L^* value: $r = -0.51$, $P = 0.004$) and WHC-M / T ($r = 0.60$, $P < 0.001$). Fat distribution and composition somehow regulate the water migration during processing of dry-cured meats (Lopez-Bote, 1998).

7 Fatty acid composition

The fatty acid compositions of the IMF of the LL muscles from WM, DWM and LW pigs are shown in Table 6. Content of all fatty acids, except C17:1*cis*-10 and C20:2*cis*-11,14, showed significant differences between LL muscles from different genotypes. Content of C10:0, C11:0, C16:0, C22:0 as well as total saturated fatty acids (SFAs) in LL muscles from WM and DWM was lower ($P < 0.05$–0.001) than from LW; however, there were no significant differences between WM and DWM. In addition, content of C14:0 was significantly ($P < 0.05$) higher in LL muscles from WM and LW than from DWM, while there were no significant differences between WM and LW. Content of C17:0 significantly ($P < 0.05$) differed between WM and DWM, but not between DWM and LW. Content of C18:0 and C20:0 was the lowest ($P < 0.05$–0.001) in LL muscles from WM, followed by DWM and LW, with significant ($P < 0.001$) differences between DWM and LW only for C18:0. Further, content of C15:1*cis*-5, C17:1*trans*-10 and C24:1*cis*-9 in LL muscles from WM and DWM was lower ($P < 0.05$–0.001) than from LW; however, there were no significant differences between WM and DWM. Content of C16:1*trans*-9, C16:1*cis*-9, C18:1*cis*-9, C20:1*cis*-11 as well as total monounsaturated fatty acids (MUFAs) in LL muscles from WM and DWM was higher ($P < 0.05$–0.001) than from LW; however, there were no significant differences between WM and DWM. Content of C18:1*trans*-9 was the highest in LL muscles from WM, followed by DWM and LW, with significant differences ($P < 0.01$–0.001). Finally, content of C18:2*cis*-9,12 as well as polyunsaturated fatty acids (PUFAs) was numerically or significantly ($P < 0.05$) higher in LL muscles from WM and LW than from DWM, while there were no significant differences between WM and LW. Content of C18:3*cis*-9,12,15 and C20:4*cis*-5,8,11,14 in LL muscles from WM and DWM was lower ($P < 0.05$–0.01) than from LW; however, there were no significant differences between WM and DWM. LL muscles from WM and LW had the lowest and the highest content of C22:5*cis*-7,10,13,16,19, respectively, with significant ($P < 0.05$) differences, while LL muscles from DWM had intermediate content without significant differences with WM or LW. Thus, crossing with Duroc had no significant effect on SFA and MUFA contents of LL muscles, while data for PUFAs are not consistent. In general, the most abundant fatty acid was the C18:1*cis*-9 (oleic acid) with percentages between 44.2 (LW) and 49.7 (DWM) of total methyl esters analysed. Palmitic (C16:0, 23.2–24.5 %), stearic (C18:0, 9.11–12.23 %), linoleic (C18:2*cis*-9,12, 5.68–7.34 %) and palmitoleic (C16:1*cis*-9, 3.60–4.48 %) fatty acids presented lower percentages. Results reported in the literature about effects of genotype and crossing on fatty acid composition of

Table 6. Fatty acid composition (%) of fresh *M. longissimus lumborum* from White Mangalica (WD), Duroc × White Mangalica (DWM), and Large White (LW) pigs.

Fatty acid of intramuscular fat	WM	DWM	LW	*P* value
C10:0	$0.079 \pm 0.002^{b,e}$ 0.069–0.090	$0.088 \pm 0.001^{b,d,e}$ 0.081–0.097	$0.099 \pm 0.004^{a,d}$ 0.060–0.122	0.002
C11:0	$0.071 \pm 0.001^{b,e,h}$ 0.064–0.086	$0.067 \pm 0.001^{b,e,h}$ 0.062–0.070	$0.085 \pm 0.002^{a,d,g}$ 0.067–0.097	< 0.001
C14:0	$1.37 \pm 0.03^{a,d,e}$ 1.27–1.68	$1.26 \pm 0.01^{b,e}$ 1.19–1.33	$1.45 \pm 0.03^{a,d}$ 1.21–1.70	0.003
C15:1*cis*-5	$0.83 \pm 0.07^{b,e}$ 0.54–1.54	$0.88 \pm 0.04^{b,d,e}$ 0.65–1.11	$1.23 \pm 0.08^{a,d}$ 0.74–1.82	0.008
C16:0	23.5 ± 0.23^{b} 22.5–26.3	23.2 ± 0.08^{b} 22.5–23.8	24.5 ± 0.30^{a} 22.8–27.6	0.018
C16:1*trans*-9	$0.29 \pm 0.01^{a,d,g}$ 0.19–0.33	$0.26 \pm 0.01^{a,d,g,h}$ 0.23–0.31	$0.22 \pm 0.003^{b,e,h}$ 0.19–0.24	< 0.001
C16:1*cis*-9	$4.48 \pm 0.07^{a,d,g}$ 4.02–5.12	$4.35 \pm 0.03^{a,d,g}$ 4.07–4.55	$3.60 \pm 0.07^{b,e,h}$ 3.24–4.17	< 0.001
C17:0	0.129 ± 0.010^{a} 0.062–0.175	0.079 ± 0.099^{b} 0.058–0.174	$0.106 \pm 0.007^{a,b}$ 0.072–0.156	0.027
C17:1*trans*-10	$0.36 \pm 0.03^{b,e}$ 0.25–0.73	$0.41 \pm 0.02^{b,e}$ 0.27–0.50	$0.61 \pm 0.03^{a,d}$ 0.42–0.84	0.001
C17:1*cis*-10	0.36 ± 0.01 0.31–0.50	0.31 ± 0.01 0.26–0.36	0.37 ± 0.02 0.27–0.49	0.165
C18:0	$9.11 \pm 0.10^{c,f,i}$ 8.39–9.77	$10.39 \pm 0.11^{b,e,h}$ 9.44–11.07	$12.23 \pm 0.18^{a,d,g}$ 11.13–13.99	< 0.001
C18:1*trans*-9	$0.28 \pm 0.01^{a,d,g}$ 0.22–0.36	$0.21 \pm 0.01^{b,e,h}$ 0.12–0.24	$0.16 \pm 0.01^{c,f,h}$ 0.09–0.24	< 0.001
C18:1*cis*-9	$49.3 \pm 0.4^{a,d,g}$ 45.9–51.9	$49.7 \pm 0.3^{a,d,g}$ 47.3–51.6	$44.2 \pm 0.5^{b,e,h}$ 40.1–48.2	< 0.001
C18:2*cis*-9,12	$6.81 \pm 0.20^{a,d,e}$ 6.09–8.77	$5.68 \pm 0.13^{b,e}$ 4.93–6.51	$7.34 \pm 0.29^{a,d}$ 5.44–9.27	0.002
C18:3*cis*-9,12,15	$0.098 \pm 0.009^{b,e}$ 0.047–0.159	$0.090 \pm 0.003^{b,e}$ 0.074–0.112	$0.147 \pm 0.010^{a,d}$ 0.093–0.232	0.003
C20:0	0.099 ± 0.005^{b} 0.055–0.127	0.129 ± 0.003^{a} 0.097–0.142	0.127 ± 0.007^{a} 0.099–0.183	0.012
C20:1*cis*-11	0.77 ± 0.03^{a} 0.41–0.93	0.73 ± 0.01^{a} 0.67–0.80	0.63 ± 0.02^{b} 0.38–0.72	0.013
C20:2*cis*-11,14	0.197 ± 0.010 0.095–0.247	0.167 ± 0.003 0.149–0.190	0.175 ± 0.009 0.082–0.227	0.181
C20:4*cis*-5,8,11,14	1.36 ± 0.11^{b} 0.93–2.48	1.48 ± 0.05^{b} 1.06–1.85	1.91 ± 0.09^{a} 1.36–2.47	0.012
C22:0	$0.108 \pm 0.012^{b,e}$ 0.048–0.213	$0.113 \pm 0.006^{b,e}$ 0.050–0.141	$0.175 \pm 0.009^{a,d}$ 0.125–0.265	0.001

Table 6. Continued.

Fatty acid of intramuscular fat	WM	DWM	LW	P value
C22:5*cis*-7,10,13,16,19	0.114 ± 0.009^{b} 0.066–0.197	$0.142 \pm 0.006^{a,b}$ 0.100–0.187	0.169 ± 0.013^{a} 0.078–0.240	0.029
C24:1*cis*-9	$0.16 \pm 0.01^{b,e,h}$ 0.12–0.27	$0.16 \pm 0.01^{b,e,h}$ 0.12–0.19	$0.34 \pm 0.02^{a,d,g}$ 0.24–0.44	< 0.001
∑SFAs	$34.5 \pm 0.3^{b,e,h}$ 32.8–38.2	$35.3 \pm 0.2^{b,e,h}$ 33.6–36.5	$38.8 \pm 0.5^{a,d,g}$ 35.6–43.8	< 0.001
∑MUFAs	$56.8 \pm 0.4^{a,d,g}$ 53.9–59.0	$57.0 \pm 0.3^{a,d,g}$ 54.9–58.6	$51.3 \pm 0.4^{b,e,h}$ 48.7–54.9	< 0.001
∑PUFAs	$8.58 \pm 0.31^{a,b,d,e}$ 7.47–11.75	$7.55 \pm 0.19^{b,e}$ 6.31–8.60	$9.74 \pm 0.40^{a,d}$ 7.16–12.26	0.006

SFAs – saturated fatty acids (C10:0, C11:0; C14:0, C16:0, C17:0; C18:0, C20:0, C22:0). MUFAs – monounsaturated fatty acids (C15:1*cis*-5, C16:1*trans*-9, C16:1*cis*-9, C17:1*trans*-10, C17:1*cis*-10, C18:1*trans*-9, C18:1*cis*-9, C20:1*cis*-11, C24:1*cis*-9). PUFAs – polyunsaturated fatty acids (C18:2*cis*-9,12, C18:3*cis*-9,12,15, C20:2*cis*-11,14, C20:4*cis*-5,8,11,14, C22:5*cis*-7,10,13,16,19). [a,b,c] Means with different letters in the same row indicate significant differences at $P < 0.05$. [d,e,f] Means with different letters in the same row indicate significant differences at $P < 0.01$. [g,h,i] Means with different letters in the same row indicate significant differences at $P < 0.001$.

Table 7. Mineral composition (mg 100 g^{-1}) of fresh *M. longissimus lumborum* from White Mangalica (WM), Duroc × White Mangalica (DWM), and Large White (LW) pigs.

Mineral	WM	DWM	LW	P value
K	$291 \pm 2^{b,e,h}$ 273–310	$298 \pm 8^{b,e,h}$ 256–343	$348 \pm 9^{a,d,g}$ 271–394	< 0.001
P	$218 \pm 1^{c,f,h}$ 209–223	$226 \pm 2^{b,e,g,h}$ 212–237	$233 \pm 1^{a,d,g}$ 226–239	< 0.001
Na	45.1 ± 0.5 43.1–50.7	42.2 ± 0.6 39.4–46.8	44.7 ± 1.2 38.7–58.3	0.167
Mg	19.3 ± 0.2 18.3–21.3	19.5 ± 0.2 18.4–20.5	19.4 ± 0.2 18.1–20.2	0.835
Ca	$7.92 \pm 0.27^{a,d,g}$ 6.07–9.60	$6.24 \pm 0.19^{b,e,h}$ 5.40–8.44	$6.22 \pm 0.09^{b,e,h}$ 5.56–6.89	< 0.001
Zn	$1.84 \pm 0.04^{a,d,g}$ 1.64–2.20	$1.64 \pm 0.04^{b,e,g}$ 1.32–1.78	$1.35 \pm 0.03^{c,f,h}$ 1.15–1.57	< 0.001
Fe	$0.94 \pm 0.05^{a,d,g}$ 0.70–1.42	$0.55 \pm 0.02^{b,e,h}$ 0.44–0.67	$0.46 \pm 0.04^{b,e,h}$ 0.36–0.95	< 0.001
Cu	$0.063 \pm 0.002^{a,d,g}$ 0.056–0.084	$0.050 \pm 0.002^{b,e,h}$ 0.037–0.062	$0.043 \pm 0.001^{c,e,h}$ 0.038–0.050	< 0.001
Mn	$0.0082 \pm 0.0003^{a,d,g}$ 0.0058–0.0098	$0.0059 \pm 0.0003^{b,e,h}$ 0.0041–0.0075	$0.0058 \pm 0.0002^{b,e,h}$ 0.0052–0.0081	< 0.001

[a,b,c] Means with different letters in the same row indicate significant differences at $P < 0.05$. [d,e,f] Means with different letters in the same row indicate significant differences at $P < 0.01$. [g,h] Means with different letters in the same row indicate significant differences at $P < 0.001$.

loin muscles are rather contradictory (Estévez et al., 2003; Alfonso et al., 2005; Renaudeau and Mourot, 2007; Salvatori et al., 2008; Furman et al., 2010; Parunović et al., 2012; Robina et al., 2013; Franco et al., 2014; Petrović, et al., 2014; Šević, 2014), because it is well known that fatty acid composition is mainly affected by rearing and feeding conditions (Cava et al., 1997; Coutron-Gambotti et al., 1998; Andrés et al., 2001; Tejeda et al., 2002). Our results agree with previous reports (Estévez et al., 2003; Renaudeau and Mourot, 2007; Parunović et al., 2012; Šević, 2014) showing that the content of MUFAs for loin muscles was higher in autochthonous breeds than in modern ones. Moreover, the increase in MUFAs for loin muscles with age is evident (Cava et al., 2003; Estévez et al., 2003; Zemva et al., 2015). A higher proportion of MUFAs in the IMF strongly influences the physical properties, leading to a soft and oily meat, which is highly appreciated by consumers. In this study, significant negative correlations ($P = 0.001$) were found between MUFA content and WBSF value ($r = -0.58$) and significant positive correlations ($P < 0.001$) were found between MUFA content and sensory scores for tenderness ($r = 0.73$) and juiciness ($r = 0.66$).

8 Mineral composition

The mineral compositions of the LL muscles from WM, DWM and LW pigs are shown in Table 7. Content of all minerals, except Na and Mg, showed significant differences between LL muscles from different genotypes. K content in LL muscles from WM and DWM was lower ($P < 0.001$) than from LW; however, there were no significant differences between WM and DWM. P content was the lowest in LL muscles from WM, followed by DWM and LW, with significant differences ($P < 0.01$–0.001). Further, Ca, Fe and Mn content in LL muscles from WM was higher ($P < 0.001$) than from DWM and LW, while there were no significant differences between DWM and LW. Finally, Zn and Cu content was the highest in LL muscles from WM, followed by DWM and LW, with significant differences ($P < 0.05$–0.001). Thus, according to results in this and other studies (Ventanas et al., 2006; Franco et al., 2014), crossing with Duroc leads to pork with significantly lower Fe content as well as Ca, Zn, Cu and Mn content. Results for Fe may explain previously described results for colour due to the close relationship between heme pigment content and CIE $L^*a^*b^*$ data (Lindahl et al., 2001). In this respect, significant negative correlations ($P = 0.002$) were found ($r = -0.59$) between Fe content and L^* value and significant positive correlations ($P = 0.001$) were found ($r = 0.57$) between Fe content and a^* value. Despite the fact that the major sources of variation in animal products are the proportion of lean to fat tissue (Greenfield and Southgate, 2003), LL muscles with the highest IMF content (WM pigs) had the highest Ca, Zn, Fe, Cu and Mn content, confirming that autochthonous breeds are an excellent source of highly bioavailable Fe (Estévez et al., 2003; Ventanas et al., 2006; Franco et al., 2014; Tomović et al., 2014a; Franco et al., 2016). In this study, positive correlations of Fe content with age and IMF content were found ($r = 0.78$, $P < 0.001$; $r = 0.54$, $P = 0.002$, respectively). On the other hand, IMF and neutral lipid content followed an inverse tendency to phospholipids (Cava et al., 2003; Estévez et al., 2003). Consequently, in this study, significant ($P < 0.001$) negative correlations were found ($r = -0.68$) between P and IMF content. Considering all investigated minerals, Fe and Cu content obtained in this study were noticeably lower than those obtained by Galián et al. (2007, 2009) and Poto et al. (2007) for Chato Murciano pigs and their crosses with Iberian and Large White pigs. Mineral contents determined in this study for LL muscles from LW pigs were in agreement with values reported for modern pigs (Greenfield et al., 2009).

9 Conclusions

In this paper quality of *longissimus lumborum* muscles from autochthonous purebred White Mangalica (WM), its crossbreed with Duroc (DWM) and purebred Large White pigs, which are intended for the production of dry-cured meats, was evaluated. Meat from WM pigs was significantly the darkest, the reddest, and had the best water-holding capacity and the highest content of IMF, followed by meat from DWM and LW pigs, with significant differences among the three genotypes. In addition, meat from WM pigs had a significantly higher ultimate pH and higher content of iron than meat from the other two genotypes. Further, meat from WM and DWM pigs was significantly more tender than meat from LW pigs. With regard to the fatty acid profile, monounsaturated fatty acids were predominant, followed by saturated and polyunsaturated fatty acid in meat from all pigs. Percentages of oleic and palmitoleic fatty acids were significantly higher in meat from WM and DWM than from LW pigs, while percentages of palmitic and stearic fatty acids showed the opposite trend, both without significant differences between WM and DWM pigs. Results for polyunsaturated fatty acids were not consistent.

The obtained results confirmed superior sensory, technological and nutritional quality of meat from autochthonous purebred Mangalica intended for processing. Nevertheless, meat from crosses (Duroc × Mangalica) also showed good quality traits, but more investigations are needed in order to provide additional information about quality of dry-cured meats.

The Supplement related to this article is available online at doi:10.5194/aab-2-401-2016-supplement.

Acknowledgements. This research was financially supported by the Ministry of Education, Science and Technological Development, Republic of Serbia, project TR31032. These results are also part of the project no. 114-451-809/2015, which is financially supported by the Provincial Secretariat for Science and Technological Development, Autonomous Province of Vojvodina, Republic of Serbia.

Edited by: S. Maak
Reviewed by: N. Karabasil and two anonymous referees

References

Acciaioli, A., Pugliese, C., Bozzi, R., Campodoni, G., Franci, O., and Gandini, G.: Productivity of Cinta Senese and Large White × Cinta Senese pigs reared outdoors and indoors, 1. Growth and somatic development, Ital. J. Anim. Sci., 1, 171–180, 2002.

Alfonso, L., Mourot, J., Insausti, K., Mendizabal, J. A., and Arana, A.: Comparative description of growth, fat deposition, carcass and meat quality characteristics of Basque and Large White pigs, Anim. Res., 54, 33–42, 2005.

AMSA (American Meat Science Association): Research guidelines for cookery, sensory evaluation and instrumental tenderness measurements of fresh meat, National Live Stock and Meat Board, Chicago, IL, USA, 1995.

AMSA (American Meat Science Association): Meat color measurement guidelines, American Meat Science Association, Campaign, IL, USA, 2012.

Andrés, A. I., Cava, R., Mayoral, A. I., Tejeda, J. F., Morcuende, D., and Ruiz, J.: Oxidative stability and fatty acid composition of pig muscles as affected by rearing system,crossbreeding and metabolic type of muscle fibreof pig muscles as affected by rearing system, crossbreeding and metabolic type of muscle fibre, Meat Sci., 59, 39–47, 2001.

AOAC International: Official Methods of Analysis of AOAC International (18th ed.), AOAC International, Gaithersburg, MD, USA, 2005.

Cava, R., Ruiz, J., López-Bote, C., Martín, L., García, C., Ventanas, J., and Antequera, T.: Influence of finishing diet on fatty acid profiles of intramuscular lipids, triglycerides and phospholipids in muscles of the Iberian pig, Meat Sci., 45, 263–270, 1997.

Cava, R., Estévez, M., Ruiz, J., and Morcuende, D.: Physicochemical characteristics of three muscles from free-range reared Iberian slaughter at 90 kg live weight, Meat Sci., 63, 533–541, 2003.

CIE: International Commission on Illumination, Colorimetry: Official Recommendation of the International Commission on Illumination, Publication CIE No. (E-1.31), Bureau Central de la CIE, Paris, France, 1976.

Coutron-Gambotti, C., Gandemer, G., and Casabianca, F.: Effects of substituting a concentrated diet for chestnuts on the lipid traits of muscle and adipose tissues in Corsican and Corsican × Large White pigs reared in a sylvo-pastoral system in Corsica, Meat Sci., 50, 163–174, 1998.

DAD-IS: Domestic animal diversity information system, available at: http://dad.fao.org/, last access: 14 April, 2016.

Edwards, S. A.: Product quality attributes associated with outdoor pig production, Livest. Prod. Sci., 94, 5–14, 2005.

Egerszegi, I., Rátky, J., Solti, L., and Brüssow, K.-P.: Mangalica – an indigenous swine breed from Hungary (Review), Arch. Tierzucht, 46, 245–256, 2003.

Estévez, M., Morcuende, D., and Cava López, R.: Physico-chemical characteristics of M. Longissimus dorsi from three lines of free-range reared Iberian pigs slaughtered at 90 kg live-weight and commercial pigs: a comparative study, Meat Sci., 64, 499–506, 2003.

Fernandez, X., Monin, G., Talmant, A., Mourot, J., and Lebret, B.: Infuence of intramuscular fat content on the quality of pig meat – 1. Composition of the lipid fraction and sensory characteristics of *m. longissimus lumborum*, Meat Sci., 53, 59–65, 1999.

Fortina, R., Barbera, S., Lussiana, C., Mimosi, A., Tassone, S., Rossi, A., and Zanardi, E.: Performances and meat quality of two Italian pig breeds fed diets for commercial hybrids, Meat Sci., 71, 713–718, 2005.

Fortina, R., Lussiana, C., Malfatto, V., Mimosi, A., and Tassone, S.: Productive performances of two Italian crossbred pigs fed high energy diet, Lucrări ştiinţifice Zootehnie şi Biotehnologii, 42, 359–367, 2009.

Franci, O. and Pugliese, C.: Italian autochthonous pigs: progress report and research perspectives, Ital. J. Anim. Sci., 6, 663–671, 2007.

Franci, O., Bozzi, R., Pugliese, C., Acciaioli, A., Campodoni, G., and Gandini, G.: Performance of Cinta Senese pigs and their crosses with Large White. 1 Muscle and subcutaneous fat characteristics, Meat Sci., 69, 545–550, 2005.

Franco, D., Vazquez, J. A., and Lorenzo, J. M.: Growth performance, carcass and meat quality of the Celta pig crossbred with Duroc and Landrance genotypes, Meat Sci., 96, 195–202, 2014.

Franco, D., Carballo, J., Bermñudez, R., and Lorenzo, J.M.: Effect of genotype and slaughter age on carcass traits and meat quality of the Celta pig breed in extensive system, Ann. Anim. Sci., 16, 259–273, 2016.

Furman, M., Malovrh, Š., Levart, A., and Kovač, M.: Fatty acid composition of meat and adipose tissue from Krškopolje pigs and commercial fatteners in Slovenia, Arch. Tierzucht, 53, 73–84, 2010.

Galián, M., Peinado, B., Martínez, C., Periago, M. J., Ros, G., and Poto, A.: Comparative study of the characteristics of the carcass and the meat of the Chato Murciano pig and its cross with Iberian pig, reared indoors, Anim. Sci. J., 78, 659–667, 2007.

Galián, M., Poto, A., and Peinado, B.: Carcass and meat quality traits of the Chato Murciano pig slaughtered at different weights, Livest. Sci., 124, 314–320, 2009.

Gandemer, G.: Lipids in muscles and adipose tissues, changes during processing and sensory properties of meat products, Meat Sci., 62, 309–321, 2002.

Grau, R. and Hamm, R.: Eine einfache Methode zur Bestimmung der Wasserbindung im Muskel, Naturwissenschaften, 40, 29–30, 1953.

Greenfield, H. and Southgate, D. A. T.: Food composition data: Production, management and use (2nd ed.), FAO, Rome, Italy, 2003.

Greenfield, H., Arcot, J., Barnes, J. A., Cunningham, J., Adorno, P., Stobaus, T., Tume, R. K., Beilken, S. L., and Muller, W. J.: Nutrient composition of Australian retail pork cuts 2005/2006, Food Chem., 117, 721–730, 2009.

Hofmann, K., Hamm, R., und Blüchel, E.: Neues über die Bestimmung der Wasserbindung des Fleisches mit Hilfe der Filterpapierpressmethode, Fleischwirtschaft, 62, 87–92, 1982.

Honikel, K. O.: Reference methods for the assessment of physical characteristics of meat, Meat Sci., 49, 447–457, 1998.

Honikel, K. O.: Biochemical and physico-chemical characteristics of meat quality, Tehnologija mesa, 40, 105–123, 1999.

ISO 13730: Meat and meat products, Determination of total phosphorus content – Spectrometric method, International Organisation for Standardisation, Geneva, Switzerland, 1996.

ISO 1442: Meat and meat products, Determination of moisture content (Reference method), International Organisation for Standardisation, Geneva, Switzerland, 1997.

ISO 1443: Meat and meat products, Determination of total fat content, International Organisation for Standardisation, Geneva, Switzerland, 1973.

ISO 2917: Meat and meat products, Measurement of pH (Reference method), International Organisation for Standardisation, Geneva, Switzerland, 1999.

ISO 8586: Sensory analysis – General guidelines for the selection, training and monitoring of selected assessors and expert sensory assessors, International Organisation for Standardisation, Geneva, Switzerland, 2012.

ISO 936: Meat and meat products, Determination of total ash, International Organisation for Standardisation, Geneva, Switzerland, 1998.

ISO 937: Meat and meat products, Determination of nitrogen content (reference method), International Organisation for Standardisation, Geneva, Switzerland, 1978.

Keeton, J. T. and Eddy, S.: Chemical and physical characteristics of meat/Chemical composition, in: Encyclopedia of meat sciences, edited by: Jensen, W. K., Carrick, D., and Dikeman, M., Elsevier Ltd., Oxford, UK, 210–218, 2004.

Labroue, F., Goumy, S., Gruand, J., Mourot, J., Neelz, V., and Legault, C.: Comparaison au Large White de quatre races locales porcines françaises pour les performances de croissance, de carcasse et de qualité de la viande, Journées Recherche Porcine en France, 32, 403–411, 2000.

Lawrie, R. A. and Ledward, D. A.: Lawrie's meat science (7th ed.), Woodhead Publishing Ltd. and CRC Press LLC, Cambridge, UK, 2006.

Lindahl, G., Lundström, K., and Tornberg, E.: Contribution of pigment content, myoglobin forms and internal reflectance to the colour of pork loin and ham from pure breed pigs, Meat Sci., 59, 141–151, 2001.

Lopez-Bote, C. J.: Sustained utilization of the Iberian pig breed, Meat Sci., 49, 17–27, 1998.

Maiorano, G., Gambacorta, M., Tavaniello, S., D'Andrea, M., Stefanon, B., and Pilla, F.: Growth, carcass and meat quality of Casertana, Italian Large White and Duroc × (Landrace × Italian Large White) pigs reared outdoors, Ital. J. Anim. Sci., 12, 426–431, 2013.

Mayoral, A. I., Dorado, M., Guillén, M. T., Robina, A., Vivo, J. M., Vazquez, C., and Ruiz, J.: Development of meat and carcass quality characteristics in Iberian pigs reared outdoors, Meat Sci., 52, 315–324, 1999.

McCormick, R. J.: The flexibility of the collagen compartment of muscle, Meat Sci., 36, 79–91, 1994.

Morcuende, D., Estévez, M., Ramírez, M., and Cava, R.: Effect of the Iberian × Duroc reciprocal cross on productive parameters, meat quality and lipogenic enzyme activities, Meat Sci., 76, 86–94, 2007.

Muriel, E., Ruiz, J., Ventanas, J., Petrón, M. J., and Antequera, T.: Meat quality characteristics in different lines of Iberian pigs, Meat Sci., 67, 299–307, 2004.

NPPC (National Pork Producers Council): Pork Composition and Quality Assessment Procedures, National Pork Producers Council Publication, Des Moines, IA, USA, 2000.

Parunović, N., Petrović, M., Matekalo-Sverak, V., Radojković, D., Vranić, D., and Radović, Č.: Cholesterol and total fatty acid content in *M. longissimus dorsi* of Mangalitsa and Swedish Landrace, Acta Aliment. Hung., 41, 161–171, 2012.

Petrović, M., Wähner, M., Radović, Č., Radojković, D., Parunović, N., Savić, R., and Brkić, N.: Fatty acid profile of *m. longissimus dorsi* of Mangalitsa and Moravka pig breeds, Arch. Tierzucht, 57, 1–12, 2014.

Polak, T., Rajar, A., Gašperlin, L., and Žlender, B.: Cholesterol concentration and fatty acid profile of red deer (Cervus elaphus) meat, Meat Sci., 80, 864–869, 2008.

Poto, A., Galián, M., and Peinado, B.: Chato Murciano pig and its crosses with Iberian and Large White pigs, reared outdoors. Comparative study of the carcass and meat characteristics, Livest. Sci., 111, 96–103 2007.

Pugliese, C. and Sirtori, F.: Quality of meat and meat products produced from southern European pig breeds, Meat Sci., 90, 511–518, 2012.

Pugliese, C., Calagna, G., Chiofalo, V., Moretti, V., Margiotta, S., Franci, O., and Gandini, G.: Comparison of the performances of Nero Siciliano pigs reared indoors and outdoors, 2. Joints composition, meat and fat traits, Meat Sci., 68, 523–528, 2004.

Pugliese, C., Bozzi, R., Campodoni, G., Acciaioli, A., Franci, O., and Gandini, G.: Performance of Cinta Senese pigs reared outdoors and indoors, 1. Meat and subcutaneous fat characteristics, Meat Sci., 69, 459–464, 2005.

Rahelic, S. and Puac, S.: Fibre types in *Longissimus dorsi* from wild and highly selected pig breeds, Meat Sci., 5, 439–450, 1981.

Ramírez, R. and Cava, R.: Carcass composition and meat quality of three different Iberian × Duroc genotype pigs, Meat Sci., 75, 388–396, 2007.

Renaudeau, D. and Mourot, J.: A comparison of carcass and meat quality characteristics of Creole and Large White pigs slaughtered at 90 kg BW, Meat Sci., 76, 165–171, 2007.

Renaudeau, D., Hilaire, M., and Mourot, J.: A comparison of carcass and meat quality characteristics of Creole and Large White pigs slaughtered at 150 days of age, Anim. Res., 54, 43–54, 2005.

Robina, A., Viguera, J., Perez-Palacios, T., Mayoral, A. I., Vivo, J. M., Guillen, M. T., and Ruiz, J.: Carcass and meat quality traits of Iberian pigs as affected by sex and crossbreeding with different Duroc genetic lines, Span. J. Agric. Res., 11, 1057–1067, 2013.

Rodríguez-Sánchez, J. A., Ripoll, G., and Latorre, M. A.: The influence of age at the beginning of Montanera period on meat characteristics and fat quality of outdoor Iberian pigs, Animal, 4, 289–294, 2010.

Salvatori, G., Filetti, F., Di Cesare, C., Maiorano, G., Pilla, F., and Oriani, G.: Lipid composition of meat and backfat from Casertana purebred and crossbred pigs reared outdoors, Meat Sci., 80, 623–631, 2008.

Scherf, B. D.: World watch list for domestic animal diversity (3rd ed.), FAO, Rome, Italy, 2000.

Serra, X., Gil, F., Pérez-Enciso, M., Oliver, M. A., Vázquez, J. M., Gispert, M., Díaz, I., Moreno, F., Latorre, R., and Noguera, J. L.: A comparison of carcass, meat quality and histochemical characteristics of Iberian (Guadyerbas line) and Landrace pigs, Livest. Prod. Sci., 56, 215–223, 1998.

Serrano, M. P., Valencia, D. G., Nieto, M., Lázaro, R., and Mateos, G. G.: Influence of sex and terminal sire line on performance and carcass and meat quality of Iberian pigs reared under intensive production systems, Meat Sci., 78, 420–428, 2008.

Šević, R.: Interaction between genotype and technologies and it's effects on production traits and meat quality of Mangalitsa, MSc thesis, University of Novi Sad, Serbia, 2014.

Sirtori, F., Crovetti, A., Zilio, D. M., Pugliese, C., Acciaioli, A., Campodoni, G., Bozzi, R., and Franci, O.: Effect of sire breed and rearing system on growth, carcass composition and meat traits of Cinta Senese crossbred pigs, Ital. J. Anim. Sci., 10, 188–193, 2011.

StatSoft, Inc.: STATISTICA (data analysis software system), version 12, available at: http://www.statsoft.com/ (last access: 14 April 2016), 2015.

Straadt, I. K. Aaslyng, M. D., and Bertram, H.C.: Sensory and consumer evaluation of pork loins from crossbreeds between Danish Landrace, Yorkshire, Duroc, Iberian and Mangalitza, Meat Sci., 95, 27–35, 2013.

Tejeda, J. F., Gandemer, G., Antequera, T., Viau, M., and García, C.: Lipid traits of muscles as related to genotype and fattening diet in Iberian pigs: total intramuscular lipids and triacylglycerols, Meat Sci., 60, 357–363, 2002.

Tomović, V. M., Petrović, L. S., and Džinić, N. R.: Effects of rapid chilling of carcasses and time of deboning on weight loss and technological quality of pork semimembranosus muscle, Meat Sci., 80, 1188–1193 2008.

Tomović, V. M., Žlender, B. A., Jokanović, M. R., Tomović, M. M., Šojić, B. V., Škaljac, S. B., Kevrešan, Ž. S., Tasić, T. A., Ikonić, P. M., and Šošo, M. M.: Sensory, physical and chemical characteristics of meat from free-range reared Swallow-belly Mangulica pigs, J. Anim. Plant Sci., 24, 704–713, 2014a.

Tomović, V. M., Žlender, B. A., Jokanović, M. R., Tomović, M. S., Šojić, B. V., Škaljac, S. B., Tasić, T. A., Ikonić, P. M., Šošo, M. M., and Hromiš, N. M.: Technological quality and composition of the *M. semimembranosus* and *M. longissimus dorsi* from Large White and Landrace Pigs, Agr. Food Sci., 23, 9–18, 2014b.

Van Oeckel, M. J., Warnants, N., and Boucqué, C. V.: Comparison of different methods for measuring water holding capacity and juiciness of pork versus on-line screening methods, Meat Sci., 51, 313–320, 1999.

Ventanas, S., Ventanas, J., Jurado, Á., and Estévez, M.: Quality traits in muscle biceps femoris and back-fat from purebred Iberian and reciprocal Iberian × Duroc crossbred pigs, Meat Sci., 73, 651–659, 2006.

Weston, A. R., Rogers, R. W., and Althen, T. G.: Review: The role of collagen in meat tenderness, The Professional Animal Scientist, 18, 107–111, 2002.

Wojtysiak, D. and Połtowicz, K.: Carcass quality, physico-chemical parameters, muscle fibre traits and myosin heavy chain composition of *m. longissimus lumborum* from Puławska and Polish Large White pigs, Meat Sci., 97, 395–403, 2014.

Wood, J. D., Enser, M., Fisher, A. V., Nute, G. R., Sheard, P. R., Richardson, R. I., Hughes, S. I., and Whittington, F. M.: Fat deposition, fatty acid composition and meat quality: A review, Meat Sci., 78, 343–358, 2008.

Zemva, M., Ngapo, T. M., Malovrh, S., Levart, A., and Kovac, M.: Effect of sex and slaughter weight on meat and fat quality of the Krškopolje pig reared in an enriched environment, Anim. Prod. Sci., 55, 1200–1206, 2015.

Zsolnai, A., Radnóczy, L., Fésüs, L., and Anton, I.: Do Mangalica Pigs of Different Colours Really Belong to Different Breeds?, Arch. Tierzucht, 49, 477–483, 2006.