

# Meat quality parameters of wild boar and commercial pig breeds

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**Abstract:** In recent decades pork production has increased in Serbia, and pork is the most widely consumed meat. Pig meat quality is affected by several factors: breed, sex, production performance, stress adaptation, and factors related to animal management. The aim of this study was to compare the meat quality characteristics from wild boar and pig breeds improved by selection. Samples of *m. longissimus dorsi* were obtained from three different pig breeds — Yorkshire, Landrace and wild boar. Chemical composition, pH, fatty acid profile, volatile compounds, color, and overall sensory meat quality were determined. Chemical composition, pH, fatty acid profile, and volatile compounds differed significantly ( $p < 0.05$ ) among the pig breeds. Yorkshire meat had the most favorable ratio of unsaturated to saturated fatty acids and the highest nutritional value. On the other hand, wild boar meat had the lowest intramuscular fat content. Determined differences among different pig breeds indicated the impact of breed on meat quality of pork. The results obtained could be used to meet consumer's needs regarding fatty acid composition and sensory properties of meat.

**Keywords:** meat quality, Yorkshire, Landrace, wild boar.

## Introduction

Pork is the most commonly consumed meat in Serbia. Pork accounts for 66.2% of meat production, followed by beef (31%), poultry (14.4%), and sheep and goat meat (8.4%) (Statistical Office of the Republic of Serbia, 2019). Furthermore, pig production is almost entirely based on Yorkshire and Landrace breeds that are used for production of F1 gilts and further cross-breeding with some of the terminal meat pig breeds, such as the Pietrain, Duroc and Hampshire.

Meat from Landrace and Yorkshire pigs, the most common pig meat breeds farmed in Serbia, is available in trade markets, while wild boar meat is mainly prepared as traditional products for the hunters' own consumption, or is sold through local restaurants, agritourism or semi-legal direct marketing (Stevanović and Milošević, 2018). Wild boar meat is of increasing importance in human nutrition worldwide due to consumers' preference for lean meat. It is considered as naturally organic and is highly appreciated. Wild boar meat is characterized by higher heme iron content and lower fat level than meat from domestic pig breeds. In many studies, a low fat content was determined in wild boar meat (2.62%

(Szymańko et al., 2007); 2.27% (Jukna and Valaitienė, 2012); 1.8%–3.5% (Postolache et al., 2011); 2.82% (Strazdina et al., 2013); 1.87% (Ivanović et al., 2013)), but low total fat did not contribute to a beneficial ratio of saturated to unsaturated fatty acids.

On the other hand, some of the major breeding goals are to reduce carcass fatness, fattening time, and feed to gain ratio (Furman et al., 2010). Achieving these goals can provoke changes in fatty acid profiles of intramuscular fat. Furthermore, intramuscular fat cannot be removed before consumption. Nowadays, consumer concerns about the quality and healthfulness of meat and meat products have greatly increased during recent decades (Min and Ahn, 2005), especially regarding the health impact of consumed animal fats. The recommended ratio between all polyunsaturated to saturated fatty acids in human diets is 0.4 or higher (Wood et al., 2008), and the total fat intake should provide 15–30% of total energy intake or less (FAO, 2010).

Pig meat quality is affected by several factors, including biological factors: breed, sex, production performance, and stress adaptation, along with; factors related to production systems: environmental conditions, animal management, nutrition, and body

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weight; slaughter factors and; treatment of carcasses after the slaughter (Kasprzyk, 2007; Ivanović et al., 2012; Mukumbo et al., 2014; Nuernberg et al., 2015; Čobanović et al., 2016; Cirne et al., 2019).

The aim of this study was to compare meat quality parameters (chemical composition, pH, fatty acid composition, volatile compound content, color, and sensory properties) for wild boar meat and meat from two commercial breeds (Landrace and Yorkshire).

## Materials and Methods

All the experimental procedures and animal handling used in this study were in accordance with European Community guidelines (Directive 86/609/EEC).

## Animals and sampling

A total of 30 male pigs were included in the study: 10 castrated Yorkshire pigs, 10 castrated Landrace pigs, and 10 wild boars. All Yorkshire and Landrace pigs were bred under the same environmental and feeding conditions. Compositions of feed mixtures are presented in Table 1. Animals were slaughtered at final live weight of 89–93 kg, at the age of 180 days. The animals were slaughtered in accordance with legally approved procedures (the distance from the farm to the slaughterhouse was 200 km, pigs underwent a rest period of about 2 h in the lairage, and automatic electric stunning and exsanguination in a vertical position were used). After evisceration and washing, pig carcasses were chilled at 2°C for up to 24 h. Samples of *m. longissimus*

**Table 1.** Composition and analyzed nutrient content of complete feed mixtures for Yorkshire and Landrace pigs

Diet composition (%)	Pigs 20–40 kg	Pigs 40–70 kg	Pigs >70 kg
Ground wheat	39.7	51.1	57.5
Ground barley	22.0	20.0	18.6
Ground corn	20.0	-	-
Extracted ground soybean	20.0	22.0	17.5
Fish meal	2.5	-	-
VG60	3.0	4.5	4.5
Phosphate 17.5%	0.8	0.8	0.3
Calcium carbonate	1.1	0.8	0.8
Salt	0.3	0.3	0.3
Lysine HCl	0.1	0.075	0.05
Methionine	-	0.015	-
Premix	0.4	0.4	0.4
Copper sulfate	0.05	-	-
Salocin 12%	0.05	-	-
Analyzed nutrient content (%)			
Energy, MJ/kg	9.35	9.39	9.32
Crude protein	18.3	17.7	16.5
Crude fat	4.0	4.5	4.7
Crude cellulose	4.5	4.8	5.0
Crude ash	6.0	5.2	4.8
Daily feed intake (kg/day)			
Feed intake Landrace	1.89	2.25	2.97
Feed intake Yorkshire	1.88	2.23	2.89

**Legend:** VG60 — minimum 5.0% protein, minimum 60.0% fat, maximum 0.8% cellulose, maximum 1.2% ash, minimum 7.5% linoleic acid, energy 24.0 MJ/kg

*dorsi* were collected and stored at  $-20^{\circ}\text{C}$  until determination of chemical composition, fatty acid content, volatile compound content, color, and sensory analyses.

Hunted wild boars weighed between 120 and 140 kg and were about one year old. Animals were hunted by shotgun during the hunting season in 2018 in accordance with the hunting law in Serbia (*Official Gazette*, 18/2010 and 95/2018), and the carcasses were not polluted by digestive tract contents. Carcasses were eviscerated in the 24 h after hunting, and were marked according to Regulation 853 (2004) and 854 (2004). Ten samples of *m. longissimus dorsi* were collected and stored at  $-20^{\circ}\text{C}$  until determination of chemical composition, fatty acid content, volatile compound content, color, and sensory analyses. Wild boars were hunted from the southwest and southeast parts of the Šumadija region in Serbia. Nutrition of wild boars was determined by the region's feed sources, which primarily consisted of deciduous trees – oak, elk, linden, Austrian oak, chestnut and hazel. Herbaceous species in the region were dominated by *Graminaceae*, *Asteraceae*, and *Poaceae*, and corn, wheat, and barley were the most common species of grains (Jovanović, 1992). This region is also known for fruit cultivation – apple, plum, pear, apricot, peach, and cherry, which form a significant part of wild boars' diets.

## Chemical composition of meat

Moisture content was determined by *ISO 1442* (1998), fat content by *ISO 1443* (1992) and ash content by *ISO 936* (1999). The protein content was calculated by multiplying the nitrogen content by 6.25 using *ISO 937* (1992), and pH, at 45 min post-mortem, was measured by *ISO 2917* (2004).

### Fatty acids in meat

The *AOAC* (2001) method was applied for lipid extraction from the tissue. After lipid hydrolysis, the fatty acids were esterified to methyl esters, evaporated to dryness in a stream of nitrogen and stored at  $-18^{\circ}\text{C}$ . Analysis of fatty acid methyl esters (FAMES) was performed by an internal standard method using a gas chromatograph (GC6890N, Agilent Tech., USA) with column DB-23 (60 m  $\times$  0.25 mm ID, 0.15  $\mu\text{m}$ ) and comparing peak areas and retention times with a standard mix of FAMES 37 (Supelco, USA). Conditions of analyses: detector temperature =  $250^{\circ}\text{C}$ ; injector temperature =  $225^{\circ}\text{C}$ ; column temperature =  $200^{\circ}\text{C}$ ; carrier gas = helium;

carrier gas flow rate = 50 mL/min. Data obtained for fatty acid composition were expressed as a percentage by weight of the identified total fatty acids.

### Volatile compounds in meat

Volatile compound analysis was conducted using the Likens-Nickerson extraction procedure (Likens and Nickerson, 1964) and *ISO 15303* (2001) using a GCMS-QP2010 Ultra (EIMS, electron energy = 70 eV, scan range = 30–350 amu, and scan rate = 3.99 scans/s) with a SUPELCOWAX® 10 capillary GC column (30 m  $\times$  0.25 mm ID, particle size 0.25  $\mu\text{m}$ ). The carrier gas was helium with a flow rate of 1 mL/min, and the injection temperature was  $200^{\circ}\text{C}$ . The oven temperature was programmed to initially hold for 10 min at  $40^{\circ}\text{C}$ , and subsequently programmed from  $40^{\circ}\text{C}$  to  $120^{\circ}\text{C}$  at a rate of  $3^{\circ}\text{C}/\text{min}$  and at a rate of  $10^{\circ}\text{C}/\text{min}$  from  $120^{\circ}\text{C}$  to  $250^{\circ}\text{C}$  where it was held for another 5 min. Identification of the peaks was based on comparison of their mass spectra with the spectra of the WILEY library and in addition, in some cases, by comparison of their retention times with those of standard compounds.

### Meat color

Meat color was measured on *m. longissimus dorsi* at 45 min post-mortem. CIE  $L^*a^*b^*$  (CIE Colorimetry, 1986) color coordinates were determined using a Minolta Chromameter CR 400 (Minolta Co. Ltd., Osaka, Japan) in D-65 lighting, with standard angle of 2 degrees of shelter and 8 mm aperture of the measuring head. CIE  $L^*a^*b^*$  color coordinates were given as mean values:  $L^*$  (lightness),  $a^*$  (redness) and  $b^*$  (yellowness).

### Sensory analysis

Sensory analyses were carried out in a sensory testing laboratory equipped with individual booths. Each booth was walled on three sides in order to prevent panelists influencing each other. All booths were provided with fluorescent lights to mask color differences between samples. Sensory tests were performed at room temperature ( $22\text{--}24^{\circ}\text{C}$ ). After a cooling period ( $4^{\circ}\text{C}$  for 24 h), meat samples were cut to approximately  $2.5 \times 2.5 \times 2.5$  cm and labelled with random three-digit numbers. Meat samples were served in plastic bowls, in separate randomized order and individually to each of the 20 trained panelists. Panelists were selected according to ISO standard (*ISO 8586*, 2012, 2015).

Overall acceptability was evaluated based on appearance, texture and aroma. For evaluation, a scoring range from one to five was used, with half and quarter points available. For each selected quality property, the coefficient of importance was determined in order to correct evaluations obtained by multiplication of means. The coefficients of importance were chosen according to the influence of specific properties on the overall quality (surface color — 4, visually evaluated structure — 3, palpatorily evaluated firmness — 3, and olfactory evaluated odor — 10), and their sum was 20. By combining individual scores, a complex indicator was obtained that represented the overall sensory quality and was expressed as “percentage of the maximum possible quality” (maximum possible quality was 100%). By dividing this value with a set of coefficients of importance, a weighted average score was obtained, which also represented the total sensory quality of the meat from the three pig breeds. Total sensory quality scores were: 1.00 = very pronounced errors; 2.00 = clearly expressed mistakes; 3.00 = noticeable deviations; 4.00 = minor deviations and; 5.00 = fully meets the quality requirements.

## Statistical analysis

Data were analyzed by descriptive and analytical statistical parameters, mean (M) and standard deviation (SD), using Graph Pad Prism 6.0. software (Graph Pad Software Inc., San Diego, CA, USA) and one-way analysis of variance (one-way ANOVA). The differences between means were compared by Tukey’s post-hoc test. Levels of  $p < 0.05$  and  $p < 0.01$  were considered as significant and highly significant, respectively. The D’Agostino-Pearson normality test was used to verify the normal distribution of data.  $p > 0.05$  was considered as normal data distribution.

## Results

Live weights and carcass weights after evisceration of wild boar, Landrace and Yorkshire pigs are presented in Table 2. There were significant differences among weights of the different pig breeds ( $p < 0.05$ ).

Chemical composition and pH of meat from wild boar, Landrace and Yorkshire pigs are presented in Table 3. Water content did not significantly

**Table 2.** Live weight and hot carcasse weight of wild boar, Landrace and Yorkshire pigs

	No of animals	Live weight	P value (D’Agostino-Pearson test)	Hot carcass weight	P value (D’Agostino-Pearson test)
Wild Boar	10	130.50±1.871 <sup>a</sup>	P = 0.93	87.00 ±1.449 <sup>a</sup>	P = 0.85
Landrace	10	90.50±1.871 <sup>b</sup>	P = 0.89	60.33±1.633 <sup>b</sup>	P = 0.79
Yorkshire	10	92.30±2.160 <sup>b</sup>	P = 0.87	61.53±1.237 <sup>b</sup>	P = 0.88

**Legend:** <sup>a,b</sup> Means within the same column with different superscripts differ significantly ( $p < 0.05$ )

**Table 3.** Chemical composition and pH of *m. longissimus dorsi* of wild boar, Landrace, and Yorkshire pigs

	Wild boar	P value (D’Agostino-Pearson test)	Landrace	P value (D’Agostino-Pearson test)	Yorksire	P value (D’Agostino-Pearson test)
Moisture,%	73.56±3.500 <sup>ns</sup>	p = 0.83	73.51±3.004 <sup>ns</sup>	p = 0.97	74.31±2.393 <sup>ns</sup>	p = 0.75
Crude fat,%	1.76±0.216 <sup>a</sup>	p = 0.69	3.83±0.224 <sup>b</sup>	p = 0.99	2.53±0.230 <sup>a</sup>	p = 0.77
Crude protein,%	23.30±1.167 <sup>A</sup>	p = 0.91	21.20±1.402 <sup>B</sup>	p = 0.71	21.80±1.437 <sup>A,B</sup>	p = 0.93
Crude ash,%	0.86±0.052 <sup>a</sup>	p = 0.90	1.17±0.019 <sup>b,A</sup>	p = 0.70	1.09±0.076 <sup>B</sup>	p = 0.86
pH	6.06±0.055 <sup>a</sup>	p = 0.84	6.36±0.217 <sup>b</sup>	p = 0.92	6.43±0.074 <sup>b</sup>	p = 0.80

**Legend:** <sup>a,b,c,d</sup> Means within the same row with different superscripts differ significantly ( $p < 0.05$ ); <sup>A,B</sup> Means within the same row with different superscripts differ significantly ( $p < 0.01$ ); ns - non significant

differ among the pig breeds ( $p>0.05$ ). The contents of crude fat, crude ash and the pH differed significantly among the three pig breeds ( $p<0.05$  and  $p<0.001$ ), while protein content differed in Landrace and Yorkshire meat ( $p<0.01$ ), but not compared to that of wild boar. The fat content was the lowest for wild boar and the highest for Landrace meat. The protein content of wild boar meat was significantly higher than that of Landrace meat ( $p<0.05$ ), but did not differ from that of Yorkshire meat ( $p>0.05$ ). The

pH of Landrace and Yorkshire meat did not differ significantly, but was different to that of wild boar meat ( $p<0.05$ ).

The fatty acid composition of wild boar, Landrace, and Yorkshire meat is presented in Table 4. There were some differences in fatty acid composition between the three pig breeds ( $p<0.05$ ). In Yorkshire meat, only caprylic acid (C8:0) was not detected. In Landrace meat, caprylic (C8:0), margaric (C17:0), heptadecenic (C17:1), elaidic (C18:1n9t),

**Table 4.** Fatty acid composition (%) of *m. longissimus dorsi* from wild boar, Landrace, and Yorkshire pigs

Fatty acid	Wild boar	P value (D'Agostino- -Pearson test)	Landrace	P value (D'Agostino- -Pearson test)	Yorkshire	P value (D'Agostino- -Pearson test)
C8:0 Caprylic acid	0.78±0.004	p = 0.49	nd	-	nd	-
C14:0 Myristic acid	0.99±0.007 <sup>a</sup>	p = 0.37	1.27±0.006 <sup>b</sup>	p = 0.51	0.96±0.005 <sup>c</sup>	p = 0.32
C15:0 Pentadecanoic acid	1.38±0.009 <sup>a</sup>	p = 0.39	1.74±0.009 <sup>b</sup>	p = 0.42	1.27±0.008 <sup>c</sup>	p = 0.38
C16:0 Palmitic acid	22.45±0.040 <sup>a</sup>	p = 0.34	21.09±0.040 <sup>b</sup>	p = 0.69	19.53±0.028 <sup>c</sup>	p = 0.47
C16:1 Palmitoleic acid	2.97±0.011 <sup>a</sup>	p = 0.51	2.61±0.010 <sup>b</sup>	p = 0.57	3.17±0.012 <sup>c</sup>	p = 0.44
C17:0 Margaric acid	0.70±0.003 <sup>a</sup>	p = 0.43	nd	-	0.81±0.004 <sup>b</sup>	p = 0.39
C17:1 Heptadecenic acid	0.44±0.003 <sup>a</sup>	p = 0.48	nd	-	0.75±0.005 <sup>b</sup>	p = 0.32
C18:0 Stearic acid	16.04±0.016 <sup>a</sup>	p = 0.36	11.94±0.012 <sup>b</sup>	p = 0.50	10.22±0.014 <sup>c</sup>	p = 0.51
C18:1n9t Elaidic acid	Nd	-	nd	-	0.45±0.003	p = 0.36
C18:1n9c Oleic acid	40.78±0.070 <sup>a</sup>	p = 0.37	33.41±0.075 <sup>b</sup>	p = 0.73	41.28±0.088 <sup>c</sup>	p = 0.88
C18:2n6t Linolelaidic acid	Nd	-	nd	-	5.40±0.006	p = 0.59
C18:2n6c Linoleic acid	8.30±0.018 <sup>a</sup>	p = 0.47	18.63±0.023 <sup>b</sup>	0.70	10.81±0.019 <sup>c</sup>	p = 0.80
C20:0 Arachidic acid	0.46±0.003 <sup>a</sup>	p = 0.49	4.45±0.012 <sup>b</sup>	p = 0.39	0.46±0.004 <sup>c</sup>	p = 0.45
C20:1n9 Eicosenoic acid	0.68±0.004 <sup>a</sup>	p = 0.46	nd	-	0.46±0.004 <sup>b</sup>	p = 0.39
C18:3n3 Linolenic acid	1.36±0.008 <sup>a</sup>	p = 0.32	nd	-	1.23±0.005 <sup>b</sup>	p = 0.43
C20:2 Eicosadienoic acid	0.58±0.005 <sup>a</sup>	p = 0.33	nd	-	0.66±0.004 <sup>b</sup>	p = 0.41
C20:3n3 Eicosatrienoic	2.09±0.008 <sup>a</sup>	p = 0.52	4.85±0.012 <sup>b</sup>	p = 0.40	2.52±0.008 <sup>c</sup>	p = 0.50

**Legend:** <sup>a,b,c</sup> Means within the same row with different superscripts differ significantly ( $p<0.05$ ); ns - non significant; nd — not detected

**Table 5.** Nutritional values and indicators of health benefits according to fatty acid profiles of pig meat

Indicator	Wild boar	Landrace	Yorkshire
ΣSFA	42.80	40.49	33.26
ΣUFA	57.20	59.51	66.74
ΣMUFA	44.87	36.03	46.11
ΣPUFA	12.33	23.48	20.63
UFA/SFA	1.34	1.47	2.01
MUFA/SFA	1.05	0.89	1.39
PUFA/SFA	0.29	0.58	0.62
DFA	73.24	71.45	76.96
OFA	26.76	28.55	23.04
EFA	9.66	18.63	17.44
Nutritional value*	2.52	2.15	2.66

**Legend:** SFA — saturated fatty acids, UFA — unsaturated fatty acids, MFA — monounsaturated fatty acids, PUFA — polyunsaturated fatty acids, DFA- hypocholesterolemic fatty acids (UFAs + C18:0); OFA — hypercholesterolemic fatty acids (SFAs — C18:0); EFA - essential fatty acids (C18:2 + C18:3); \*Nutritional value was calculated according to the equation (C18:0 + C18:1)/C16:0

linolelaidic (C18:2n6t), eicosenoic (C20:1n9), linolenic (C18:3n3) and eicosadienoic (C20:2) acids were not detected. In wild boar meat, elaidic (C18:1n9t) and linolelaidic (C18:2n6t) acids were not detected. Myristic acid occurred only in very small amounts in the pig meat (0.99, 1.27 and 0.96%, for wild boar, Landrace and Yorkshire, respectively). The most abundant saturated fatty acid was stearic acid.

Regarding overall fatty acid contents, wild boar meat had the highest total saturated fatty acid content (Table 5).

The volatile compounds in wild boar, Landrace and Yorkshire meat are presented in Table 6. There were significant differences among all determined volatile substances in meat from the three pig breeds ( $p < 0.05$ ). From the group of aldehydes, furfural and

**Table 6.** Volatile compounds (VOC) in *m. longissimus dorsi* from wild boar, Landrace, and Yorkshire pigs

VOC, µg/kg	Wild boar	P value (D'Agostino- -Pearson test)	Landrace	P value (D'Agostino- -Pearson test)	Yorkshire	P value (D'Agostino- -Pearson test)
Aldehydes						
Hexanal	1.00±0.030 <sup>a</sup>	p = 0.34	nd	-	0.70±0.050 <sup>b</sup>	p = 0.41
Furfural	nd		nd	-	nd	-
Heptanal	0.31±0.010 <sup>a</sup>	p = 0.27	0.01±0.001 <sup>b</sup>	p = 0.29	0.01±0.001 <sup>b</sup>	p = 0.39
Octanal	0.32±0.030 <sup>a</sup>	p = 0.25	nd	-	0.5±0.020 <sup>b</sup>	p = 0.51
Phenylacetaldehyde	0.30±0.020 <sup>a</sup>	p = 0.33	0.10±0.030 <sup>b</sup>	p = 0.40	0.20±0.010 <sup>c</sup>	p = 0.48
Benzaldehyde	nd	-	nd	-	nd	-
Ketones						
2-Butanone	0.39±0.040 <sup>a</sup>		0.19±0.030 <sup>b</sup>	p = 0.43	0.19±0.030 <sup>b</sup>	p = 0.44
2,3-Butanedione	0.73±0.090 <sup>a</sup>	p = 0.61	nd	-	0.05±0.010 <sup>b</sup>	p = 0.47
2-Heptanone	0.20±0.030 <sup>a</sup>	p = 0.49	0.10±0.010 <sup>b</sup>	p = 0.33	nd	-
3-Methyl-2(5H)-furanone	0.85±0.070 <sup>a</sup>	p = 0.71	1.20±0.110 <sup>b</sup>	p = 0.80	2.60±0.140 <sup>c</sup>	p = 0.81
Heterocyclic compounds						
Furan	0.62±0.040 <sup>a</sup>	p = 0.77	1.18±0.080 <sup>b</sup>	p = 0.59	1.09±0.070 <sup>c</sup>	p = 0.59
β-Butyrolactone	0.01±0.003	p = 0.39	nd	-	nd	-
2-Pentylfuran	0.31±0.040	p = 0.47	nd	-	nd	-

VOC, µg/kg	Wild boar	P value (D'Agostino- -Pearson test)	Landrace	P value (D'Agostino- -Pearson test)	Yorkshire	P value (D'Agostino- -Pearson test)
2-Methyl pyrazine	0.20±0.040 <sup>a</sup>	p = 0.60	0.50±0.060 <sup>b</sup>	p = 0.81	0.80±0.110 <sup>c</sup>	p = 0.79
2,5-Dimethyl pyrazin	0.01±0.001 <sup>ns</sup>	p = 0.28	0.01±0.001 <sup>ns</sup>	p = 0.36	nd	-
2,6-Dimethyl pyrazin	0.10±0.020 <sup>a</sup>	p = 0.33	0.11±0.020 <sup>b</sup>	p = 0.44	0.12±0.030 <sup>c</sup>	p = 0.50
Thiophene	nd	-	nd	-	0.13±0.010	p = 0.59
Phenolic compounds						
Guaiacol	0.02±0.003 <sup>a</sup>	p = 0.25	0.02±0.001 <sup>b</sup>	p = 0.29	0.01±0.001 <sup>b</sup>	p = 0.23
Aromatic hydrocarbons						
1,2-Dimethoxybenzene	0.04±0.002 <sup>a</sup>	p = 0.31	0.01±0.001 <sup>b</sup>	p = 0.30	0.01±0.001 <sup>b</sup>	p = 0.34
Sulfuric compounds						
2,5-Dimethyl thiophene	0.10±0.020	p = 0.28	nd	-	nd	-
2-Methyl thiophene	nd	-	0.20±0.010 <sup>ns</sup>	p = 0.46	0.20±0.020 <sup>ns</sup>	p = 0.34
2-Buthanethiol	0.01±0.001 <sup>a</sup>	p = 0.43	0.01±0.001 <sup>a</sup>	p = 0.45	0.02±0.003 <sup>b</sup>	p = 0.35
2-Methyl-3-furanthiol	nd	-	nd	-	nd	-
Alcohols						
2-butanol	0.04±0.003 <sup>a</sup>	p = 0.27	0.16±0.020 <sup>b</sup>	p = 0.39	0.01±0.002 <sup>c</sup>	p = 0.28
2-pentanol	nd	-	nd	-	0.14±0.020	p = 0.47
3-methyl –1-butanol	0.31±0.040	p = 0.22	nd	-	nd	-
2,3-Butanediol	0.10±0.010	p = 0.25	nd	-	nd	-
1-Octen-3-ol	1.33±0.110 <sup>a</sup>	p = 0.65	0.10±0.030 <sup>b</sup>	p = 0.25	nd	-
Organic acids						
Propionic acid	nd	-	0.21±0.030	p = 0.35	nd	-
3-Methylbutanoic acid	0.01±0.001 <sup>ns</sup>	p = 0.30	nd	-	0.01±0.001 <sup>ns</sup>	p = 0.26
Hexanoic acid	0.04±0.004 <sup>a</sup>	p = 0.24	0.03±0.003 <sup>b</sup>	p = 0.31	nd	-
Nonanoic acid	0.17±0.020 <sup>a</sup>	p = 0.51	0.07±0.010 <sup>b</sup>	p = 0.42	0.15±0.030 <sup>a</sup>	p = 0.50
Esters						
Isopropenyl acetate	nd	-	0.04±0.002	p = 0.38	nd	-
Ethyl acetate	nd	-	nd	-	nd	-
Isobutyl acetate	0.10±0.020	p = 0.41	nd	-	nd	-
Butyl acetate	nd	-	nd	-	0.21±0.030	p = 0.53
2-methylbutyl acetate	0.45±0.040 <sup>a</sup>	p = 0.26	0.02±0.003 <sup>b</sup>	p = 0.27	0.05±0.010 <sup>c</sup>	p = 0.29
3-methylbutyl acetate	0.20±0.03 <sup>a</sup>	p = 0.33	0.10±0.02 <sup>b</sup>	p = 0.42	nd	-
Hexyl acetate	0.03±0.002 <sup>a</sup>	p = 0.27	0.01±0.001 <sup>b</sup>	p = 0.28	0.02±0.002 <sup>c</sup>	p = 0.38
Ethyl butanoate	nd	-	nd	-	nd	-
Ethyl isovalerate	nd	-	nd	-	nd	-
Ethyl 2-methylbutanoate	nd	-	nd	-	nd	-
Ethyl octanoate	nd	-	nd	-	nd	-
Alkanes						
Heptane	0.09±0.010 <sup>a</sup>	p = 0.29	0.10±0.020 <sup>b</sup>	p = 0.39	nd	-

**Legend:** <sup>a,b,c</sup> Means within the same row with different superscripts differ significantly (p<0.05); nd - not detected; ns — non significant

benzaldehyde were not detected in any analyzed sample, and from the group of phenolic compounds 2-Methyl-3-furanthiol was not detected. From the group of esters, ethyl acetate, butyl acetate, ethyl butanoate, ethyl isovalerate, ethyl 2-methylbutanoate and ethyl octanoate were not detected. The most abundant group of volatile compounds was heterocyclic compounds in Landrace meat, with furan being the predominant compound. In wild boar and Yorkshire meat, the predominant volatiles were ketones, and within this group, 3-Methyl-2(5H)-furanone had the highest content in all three pig breeds. The relative amounts of volatile compounds in wild boar meat were 25.86%, 23%, 21.22%, 18.64% and 14.89% of ketones, aldehydes, alcohols and heterocyclic compounds, respectively. In Landrace meat, heterocyclic compounds, ketones, organic acids, alcohols and aldehydes constituted 40.18%, 33.26%, 6.92%, 5.80% and 2.45% of the volatiles, respectively. In Yorkshire meat, ketones predominated (39.33%) among the volatiles, followed by heterocyclic compounds (29.64%) and aldehydes (19.53%).

Color parameters ( $L^* a^* b^*$ ) of wild boar, Landrace and Yorkshire pig meat are presented in Table 7. There were significant differences among all

examined parameters in the CIE  $L^* a^* b^*$  system that defined color.

In Table 8, sensory evaluation of individual sensory attributes, the percentage of the maximum score for all evaluated characteristics, and the weighted mean values of ratings are shown. The quality of wild boar, Landrace, and Yorkshire meat did not significantly differ in the main sensory characteristics (surface color, visually evaluated structure, palpatory evaluated firmness, and olfactory evaluated odor). Landrace meat achieved the highest numeric color score, followed by Yorkshire meat, which was slightly darker, and wild boar meat. The visually evaluated structure and palpatory evaluated firmness of Yorkshire meat (13.90 and 15.5, respectively), were the highest among the three pig breeds. Visual evaluations of Landrace (12.50) and wild boar meat (13.00) produced similar scores. The olfactory evaluated odor of meat from the three pig breeds showed that wild boar meat had the highest odor score (Table 8), followed by Landrace and Yorkshire meat. Overall sensory quality followed the order: Yorkshire (95.50%/ weighted average 4.77), Landrace (L) (92.00/4.60) and wild boar (90.50/4.52).

**Table 7.** Color of *m. longissimus dorsi* from wild boar, Landrace and Yorkshire pigs

	Wild boar	P value (D'Agostino- -Pearson test)	Landrace	P value (D'Agostino- -Pearson test)	Yorkshire	P value (D'Agostino- -Pearson test)
$L^*$	38.79±0.767 <sup>a</sup>	p = 0.90	51.67±0.711 <sup>b</sup>	p = 0.98	39.07±1.150 <sup>a</sup>	p = 0.94
$a^*$	15.32±0.73 <sup>0a</sup>	p = 0.88	11.9±0.258 <sup>b</sup>	p = 0.91	12.82±0.44 <sup>4b</sup>	p = 0.89
$b^*$	7.89±0.282 <sup>a</sup>	p = 0.82	7.67±0.308 <sup>b</sup>	p = 0.87	4.66±0.186 <sup>c</sup>	p = 0.86

**Legend:** <sup>a,b,c,d</sup> Means within the same row with different superscripts differ significantly (P<0.05)

**Table 8.** Sensory evaluation of *m. longissimus dorsi* from wild boar, Landrace, and Yorkshire pigs

	Attributes				Percentage of maximal possible quality	Weighted average
	Appearance	Texture		Flavor		
	Color Surface	Visually evaluated structure	Palpatory evaluated firmness	Olfactory evaluated odor		
	Coefficient of importance					
	4	3	3	10	100	100/20
Wild boar	18.00±0.28	13.00±0.16	11.00±0.39	48.50±0.20	90.50	4.52
Landrace	20.00±0.25	12.50±0.18	12.00±0.18	47.50±0.13	92.00	4.60
Yorkshire	19.10±0.28	13.90±0.25	15.50±0.23	47.00±0.32	95.50	4.77



## Discussion

The pigs' live weights were in line with breed characteristics (Furman *et al.*, 2010), and the chemical composition of the meats were in line with our previous findings. In a study of meat quality characteristics of Duroc x Yorkshire, Duroc x Yorkshire x wild boar and wild boar meat, significant differences in meat chemical composition between breeds were observed (Ivanović *et al.*, 2013). Václavková and Bečková (2007) examined the impact of different feed additives on chemical composition of *M. longissimus dorsi* in (Czech Large White x Czech Landrace) x (Hampshire x Pietrain). The fat content (2.1%) in the control pigs fed a basal diet was similar to our results for Yorkshire meat. However, the fat contents determined in the current study were not in line with the results of Šimek *et al.* (2004), who reported their pigs had 1.6% intramuscular fat. Choi *et al.* (2016) reported *m. longissimus dorsi* from Yorkshire pigs had a higher fat content than that from Landrace, which could be a consequence of differences in final weight and nutrition. In our study, proximate meat composition and pH varied significantly among the compared breeds. Similar results have been reported by other authors (Kosovac *et al.*, 2009; Kasprzyk *et al.*, 2015).

The ideal intramuscular fat content of fresh meat is between 2 and 3%, whereas meat with a fat content >3.5% can be rejected by consumers (Fernandez *et al.*, 1999; Kasprzyk *et al.*, 2015). In the current study, the fat content of Yorkshire meat was acceptable. However, Landrace meat had a higher fat content (3.83%) and wild boar meat had a lower fat content (1.76%), which could indicate the meat from these pigs was of low quality (Tyra and Zak, 2010; Kasprzyk *et al.*, 2015). In spite of that, consumers nowadays prefer low fat and low cholesterol levels in food, and therefore, wild boar meat could be considered as favorable food for human consumption. Postolache *et al.* (2011) examined the chemical composition of *m. longissimus dorsi* from three- to four-year-old wild boar hunted in Romania. The proximate composition (water content of 75.36%, protein content of 21.81%, and fat content of 2.58%) and ultimate pH (5.56) of their boar meat differ from our current results. Those discrepancies could be a consequence of different ages and nutrition of the examined animals.

The most prevalent fatty acid was oleic acid in all examined breeds, followed by palmitic and stearic acid. The highest oleic acid content was determined in Yorkshire meat, followed by wild boar and Landrace meat. Regarding palmitic and stearic acid, wild boar meat contained the most, followed

by Landrace and Yorkshire meat. The linoleic acid content was the highest in Landrace meat, and lowest in wild boar meat. Furthermore, there were significant differences between all determined fatty acids, which highlighted the impact of breed on fatty acid profile of meat, as others have said. Wood *et al.* (2004) examined intramuscular fat content and fatty acid composition of *M. longissimus dorsi* from Berkshire and Tamworth, a Large White line and a Duroc line, and found breed significantly impacted the examined parameters. Furman *et al.* (2010) studied hybrid Large White × Slovenian Landrace mated with Pietrain, Duroc or Piertain × Slovenian Landrace and came to a similar conclusion.

Furthermore, animals' diet can affect chemical composition, fatty acid profile and volatile compound content in meat (Wood *et al.*, 2008; Čitek *et al.*, 2015). The complete feed mixtures used in this study were the same for the two commercial breeds (Landrace and Yorkshire). Differences in fatty acid content between Landrace and Yorkshire meat occurred, regardless of the same diet being used. However, fatty acid content also differed between the pure breeds and wild boar meat. It should be noted that diet has an impact on meat quality, in conjunction with several different factors. Thus, diet (feed additives) can affect the fatty acid profile of meat, but does not have a crucial effect on intramuscular fat content (Čitek *et al.*, 2015); Kouba *et al.*, 2003; Okrouhla *et al.*, 2013).

Among the saturated fatty acids, not all have the same effect on human health. It is considered that lauric (C12:0), myristic (C14:0) and palmitic (C16:0) acids can increase the concentration of cholesterol in plasma. Myristic acid had the most adverse effect, four times more pronounced than the effects of lauric and palmitic acids, on the cardiovascular system (Hegsted *et al.*, 1959). Our pig meat contained only small amounts of myristic acid. Stearic acid, which was the most abundant saturated fatty acid in our study, is considered as neutral (Webb and O'Neill 2008; Kasprzyk *et al.*, 2015).

Indicators of the nutritional value and health benefits of fat depend on the amounts of particular fatty acid groups. Regarding overall fatty acid contents, wild boar meat had the highest total saturated fatty acid content. The ratio of polyunsaturated to saturated fatty acids should be higher than 0.4 (Wood *et al.*, 2008), and in our study, only wild boar meat did not fulfill this human health indicator.

Aldehydes are commonly found in the pig meat, as high as 50% (Xie *et al.*, 2008; Lorenzo *et al.*, 2013), or even 75% (Hou *et al.*, 2018) of total volatile compounds. In contrast, in our study, aldehydes

were not the most abundant volatiles, particularly in Landrace meat that contained just 2.45% aldehydes. Within the group, linear aldehydes are products of fat oxidative degradation, with the exception of phenylacetaldehyde, which is a product of amino acid degradation (Belitz and Grosch, 1987; Xie et al., 2008). Aldehydes, regardless of their amount, have a low aroma threshold and intensive and specific aroma, which can make them important contributors to meat's aromatic profile. Aldehydes, especially hexanal that is the most abundant and derived from linoleic and arachidonic acid, have grease, green grass, and apple flavors, (Yang et al., 2017; Hou et al., 2018). In our study, among the aldehydes, hexanal predominated in wild boar and Yorkshire meat, but it was not detected in Landrace meat. Aldehyde content is determined by fatty acid and protein content, and furthermore, is affected by several factors: chilling conditions, storage time, heat treatment of meat etc. Thus, the aldehyde content can vary significantly along with conditions of meat manipulation.

Ketones are considered to have a significant impact on meat aroma, especially when they occur in large amounts. Ketones have a specific aroma that is described as ether-like, buttery, spicy notes or blue cheese notes (Creuly et al., 1992; Lecanu et al., 2002). Furthermore, methyl ketones, and among them 3-Methyl-2(5H)-furanone that was the most abundant in our study, has buttery and creamy notes (Xie et al., 2008). Ketones can be produced by lipid oxidation as a consequence of autoxidation (Belitz and Grosch, 1987; Flores et al., 1997) or microbiological activity (Sunesen and Stahnke, 2003). For example, the  $\beta$ -oxidation activity of molds growing on the surface of dry-cured products results in 2-pentanone production. Ketones have high odor thresholds, and so we presume their contribution to the meats' total aroma profiles was significant, considering the large amount of ketones in the meats.

Heterocyclic compounds are significant odorants, and among them furan compounds, due to their low thresholds, might be major contributors to pig meat odor. Furan is derived from n-6 fatty acids, particularly linoleic acid (Elmore et al., 1999; Yang et al., 2017). These compounds were detected in various pig meat breeds (Zhao et al., 2017; Hou et al., 2018), and furan is described as having vegetable, green, earthy, and beany notes (Stetzer et al., 2008). In the current study, Yorkshire and Landrace meat contained more furan than did wild boar meat. Commercial breeds in our study received in their diets linoleic acid that is precursor for furan synthesis. Linoleic acid from pig diets will accumulate in

muscles (Ramsay et al., 2001; Čítek et al., 2015; Pinnelli-Saavedra et al., 2019), and thus affects the fatty acid and volatile profiles of meat.

On the contrary, 1-octen-3-ol that is generated from oxidative breakdown of linoleic acid was the highest in wild boar meat, despite this meat having the lowest content of linoleic acid. Considering that meat's volatile profile is multifactorial, we conclude that differences in nutrition have significant, but not decisive impacts. 1-octen-3-ol is considered to have sweet, earthy odor (Hong et al., 1988). Furthermore, alcohols are products of lipid oxidation or reduction of aldehydes to alcohols (Lorenzo et al., 2013). They have herbaceous, woody and fatty perception and contribute to flavor and odor meat profile due to their low thresholds (Lorenzo et al., 2013).

Meat's volatile compounds and flavor profile are affected by numerous factors. Volatiles can be derived thermally from fatty and amino acid degradation, so the volatile profile depends on the thermal processes applied (cooking, smoking, roasting). In our study, spices that can significantly contribute to meat flavor development, were not used, which could explain disagreements with other studies (Xie et al., 2008; Lorenzo et al., 2013).

Meat color correlates with myoglobin content, but also is closely related to intramuscular fat content and pH (Lee and Joo, 1999; Mancini and Hunt, 2005; Choi et al., 2016). In our study, Landrace meat had the fat highest content, which logically explains Landrace meat's lightness values. However, wild boar meat had the lowest pH, which could be expected to result in high lightness values, but this was not the case in our study. Wild boar meat had higher  $a^*$  and  $b^*$  values than did Landrace and Yorkshire meat, which could be a consequence of the higher myoglobin content in game meat.

Marchiori and de Felício (2003) instrumentally measured pig meat color (at 24 h post-slaughter in *m. longissimus dorsi*). Their  $L^*$  and  $b^*$  values were higher than ours, but their  $a^*$  values were lower than ours. Meat color, measured after seven days in *m. longissimus lumborum* from Large White Landrace (Lebret and Guillard, 2005), was darker than our Yorkshire meat but lighter than our Landrace meat. Marchiori and de Felício (2003) also measured the color of wild boar meat (48 h post-slaughter in *m. longissimus dorsi*); their  $L^*$  and  $b^*$  values were higher than ours.

The visually evaluated structure of Yorkshire meat indicated this meat had uniform distribution of muscle fibers at the intersection. It is difficult to compare the results of sensory analysis between different authors and between different techniques. Kasprzyk et

*al.*, (2010) evaluated Pulawska meat, wild boar and Pulawska x (Hampshire x Wild boar). In that study, wild boar meat received the lowest rating, while cross-breed meat achieved a perfect score. *Morrison et al.* (2007) investigated the effect of different housing methods on sensory qualities. The scores varied slightly, but did not differ in tenderness, juiciness, pork flavor or overall desirability of pork produced from the two housing treatments. These results (*Morrison et al.*, 2007) are similar to ours. Although we did find slight differences in the sensory evaluation of meat appearance, they did not affect the acceptability of meat.

## Conclusions

Unsaturated fatty acids accounted for 57.20% of total fatty acids in wild boar meat, 59.51% in Landrace meat and 66.74% in Yorkshire meat. Yorkshire

meat had the most favorable unsaturated to saturated fatty acid ratio and the highest nutritional value. On the other hand, wild boar meat had the lowest intramuscular fat content. Regarding overall sensory acceptability, Yorkshire meat achieved the highest score, followed by Landrace and wild boar meat. In conclusion, sensory evaluation and indicators of the nutritional value showed that meat from pure breeds, in particularly Yorkshire, has benefits for consumers, but wild boar meat will satisfy consumers' expectations for lean meat.

The present study is not without limitations. Indeed, some fatty acids and volatile compounds were not identified, indicating that further research is required. Furthermore, evaluation of pork meat quality was conducted, but the study did not include the quality of meat products. Finally, other pig breeds are likely to have other characteristics, so they deserve study.

# Parametri kvaliteta mesa divljih svinja i komercijalnih rasa svinja

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*A p s t r a k t:* Poslednjih decenija u Srbiji se povećala proizvodnja svinjskog mesa, a svinjsko meso je meso koje se najviše konzumira. Na kvalitet svinjskog mesa utiče nekoliko faktora: rasa, pol, proizvodni rezultati, prilagođavanje stresu i faktori koji se odnose na upravljanje životinjama. Cilj ovog istraživanja bio je da se uporede osobina kvaliteta mesa divljih svinja i rasa svinja poboljšanih selekcijom. Uzorci *m. longissimus dorsi* su uzeti od tri različite rase - jorkšir, landras i divlje svinje. Određeni su hemijski sastav, pH, profil masnih kiselina, isparljiva jedinjenja, boja i ukupan senzorni kvalitet mesa. Hemijski sastav, pH, profil masnih kiselina i isparljiva jedinjenja značajno su se razlikovali ( $p < 0,05$ ) između rasa svinja. Meso svinja rase jorkšir je imalo najpovoljniji odnos nezasićenih i zasićenih masnih kiselina i najveću hranljivu vrednost. S druge strane, meso divlje svinje imalo je najmanji sadržaj intramuskularne masti. Utvrđene razlike između različitih rasa svinja ukazuju na uticaj rase na kvalitet svinjskog mesa. Dobijeni rezultati mogu se koristiti u svrhu zadovoljavanja potreba potrošača u pogledu sastava masnih kiselina i senzornih svojstava mesa.

**Ključne reči:** kvalitet mesa, jorkšir, landras, divlja svinja.

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