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Short Report

Nutritional value of and element content in meat from various pig breeds

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The present study focuses on two aspects of meat quality: the concentration of trace elements and nutritional value. In 2016, total pigmeat slaugtherings in the EU increased by 0.2% despite a significant reduction in the EU sow herd (-228 000 heads) over the last two years. Nevertheless, pigmeat is one of the most consumed meats worldwide, its consumption in the EU countries in 2016 was 32.25 kg/per capita annualy. As one of the most important factors affecting meat quality prior to slaughter is breed, therefore, it is important to evaluate the content of trace elements significant for human health, and meat nutritional value, of various pig breeds. The aim of this study was to describe the nutritional value (dry matter, proteins, intramuscular fat and total minerals) and contents of elements (sodium, magnesium, calcium, zinc, selenium, iron, copper, nickel and barium) in the *longissimus dorsi* muscle (MLD), obtained from pigs of eight pure breeds and from crossbred pigs, reared under the same conditions. The correlation between tissue composition and element contents was estimated. Element concentrations were assayed by inductively coupled plasma mass spectrometry (ICP-MS) after microwave digestion. Composition of MLD collected from pigs of various breeds did not considerably differ except for the amount of fat. Meat of pigs of different breeds and their crosses differed in terms of element contents. The highest amounts of Na (P<0.05),

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Mg (P<0.001) and Ba were recorded in meat of Yorkshire and White Large crossbreeds; those of Ca (P<0.001), Fe (P<0.05) and Ni (P<0.05) were highest in Landrace and White Large crosses; while levels of Zn and Se (P<0.05) were highest in Pietrain pigs, and that of Cu (P<0.01) – in Yorkshire and Pietrain crosses. The correlation of element contents with meat quality indexes in the MLD of the purebred pigs and crosses of these breeds was low or moderate. However, pork nutritional value and element contents were affected by pig breed.

KEY WORDS: crossbred / *longissimus dorsi* / mineral elements / nutritional value / purebred swine

Meat plays important role in human nutrition because of its nutritive value. Meat is an important source of protein, fat, essential amino acids, minerals as well as vitamins and other nutrients [Biesalski *et al*. 2005, Zhang *et al*. 2010, Karakök *et al*. 2010, Avramescu *et al*. 2014]. Trace elements are micro-nutrients that are essential for a variety of their biochemical functions in living organisms [Horita *et al*. 2011, Bilandzic *et al*. 2012]. Critically important to life, the essential elements act as enzyme cofactors (e.g., Zn, Cu, Fe), organic molecule stabilis (e.g. Zn, Cu for proteins; Mg for DNA; Co in vitamin B-12), structural components of bones (e.g. Ca, P, Mg), second messengers (e.g. Ca), acid-base balance regulators (e.g. Na, K), and reactants in redox reactions (e.g. Mn, Fe, Cu, Se), and in the maintenance of cellular pH and electrical gradients (e.g., Na, K) [Fleet *et al*. 2011, Batista *et al*. 2012, Soto *et al*. 2013, Pereira *et al*. 2013]. Some of the most important micronutrients are most readily available from meat e.g. iron, selenium, vitamins A, B12 and folic acid, either because they are not found in plant-derived food or because of their poor bioavailability [Biesalski *et al*. 2009, Troy *et al*. 2010].

In the recent years, consumer demand for healthier meat and meat products has been rapidly increasing worldwide [Zhang *et al*. 2010]. Pork quality has become the primary concern for producers, researchers, meat packers, processors, retailers, and ultimate consumers [Alonso *et al*. 2009]. Despite intensive research, considerable variation in meat quality is still observed in most meat producing species [Lefaucheur *et al*. 2010]. Meat composition is determined by the following factors: animal species, muscle type, age, gender growth rate and maturation, diet, genetic defects and disease status, medication and hormone usage, housing and rearing conditions, particulary temperature and relative humidity, as well as general husbandry practices [Troy *et al*. 2010, Tomovic *et al.* 2011]. While all of these factors play an important role in determining meat composition, they can be manipulated in most cases to alter the nutritional profile of such products [Lynch *et al*. 2000, Troy *et al.* 2010, Poławska *et al*. 2013]. In the present investigation, we determined the nutritional value (dry matter, contents of protein, intramuscular fat) and total element contents (Na, Mg, Ca, Zn, Se, Fe, Cu, Ni, Ba) in the *longisimus dorsi* muscle, obtained from eight pure breeds and crossbred pigs, reared under the same conditions.

Material and methods

Pig growth was monitored at the Lithuanian National Pig Breeding Station under standardised feeding and managenent conditions. AB "Joniškio grűdai" compound feed and additives were used in pig feeding (Tab. 1).

Table 1. Chemical composition of the basal diet

Chemical composition	%
Crude protein	16.00
Raw oil and fat	2.74
Crude fibre	3.37
Ash	4.19
Calcium (Ca)	0.70
Phosphorus (P)	0.46
Sodium (Na)	0.17
Lysine	1.02
Methionine	0.35

Contents per kg of diet: Fe 100 mg; I 2.5 mg; Cu 12 mg; Mn 80 mg; Zn 100 mg; Se 0.3 mg; Vit. A 12500 IU; Vit. D3 1500 IU.

Fatteners were slaughtered after they reached 180 days of age, approximately at weight 100-110 kg and at equal proportions with regard to sex. One sample of the MLD (500-550 g) per each animal were collected. The animals were slaughter after 24 hours of starvation. Water was not supplied starting from 3 hours before the slaughter.

A total of 10-12 meat samples from carcasses of each breed or cross: Large White (LW); Landrace (L); Pietrain (P); Yorkshire (Y); Landrace x Large White (LxLW); Yorkshire x Large White (YxLW); Yorkshire x Pietrain (YxP); and Landrace x Yorkshire (LxY) were taken for analysis.

Pig meat samples of 500-550g were collected from behind the 9th-11th rib 24 hours after carcass cooling from *musculus longissimus dorsi,* for analyses of the chemical composition and technological attributes. Samples were kept in a refrigerator at +4°C.

In order to determine the pig meat chemical composition according to the certified methodology, the following parameters were measured:

– dry matter – by drying meat samples to constant mass with automatic dry matter scales (Scaltec SM – 1);
– proteins' content – according to Kjeldahl [King-Brink, Sebranek 1993];
– fat content – according to Soxhlet (ISO 1443:1973 Meat and meat products
– determination of total fat content);
– ash content – by roasting meat organic matter at 600-800°C (ISO 936:1998 Meat and meat products – determination of total ash);
– pig meat technological attributes – pH (recorded with the INOLAB3 pH-meter
– H ISO 2917:1999 Meat and meat products – measurement of pH), meat color (analysed with the CIE–LAB method), meat colour indexes: lightness (L*),

redness (a*), yellowness (b*) (Minolta Chroma Meter 410), meat tenderness (the Bratzler method in both cases [Bratzler 1949].

Mineral contents in pig meat were assayed at the State Food and Veterinary Service Institute of Risk Assessment, the Laboratory of Chemical Analyses, after 48h

carcass cooling. Samples (10g each) were collected from *musculus longissimus* dorsi and held in a refrigerator at +4°C.

To determine the mineral contents in the pig meat, the following analyses were performed:

- sample mineralisation using an ETHOS 900 microwave system (European standard LST EN 13805:2002. Processed food. Microelement evaluation. Mineralization in high pressure);
- assays of elements with inductively coupled plasma mass spectrometry (ICP–MS) (by LST EN 15763:2010. Processed food. Microelement evaluation). Element contents were estimated (mg/kg) for: Na, Mg, Ca, Ni, Cu, Zn, Ba, Se, Fe (the amount of Fe was determined using the DRC (dynamic reaction cell) mode, additionally emitting methane which eliminates interferences).

The data from the analysis were processed using the „R“, ver. 2.0.1. statistical package [Geniene *et al*. 1998]. Excel spreadsheet tools were used for statistical data analysis. The effect of the breed was estimated using one-way ANOVA. The ANOVA results were considered statistically significant at $P<0.05$.

Estimation of **c**orrelations between various minerals and meat quality indexes followed.

Results and discussion

Basic composition of the MLD in the studied pig populations is given in Table 2. During the analysis it was determined that meat of LW pigs contained the greatest

Table 2. Mean basic composition and their standard errors (SE) of the MLD by breed/cross*

Breed	Component (%)							
	dry matter		protein		fat		ash	
	mean	SE	mean	SE	mean	SE	mean	SE
LW	27.33[a]	0.33	24.43	0.26	1.93	0.15	0.97[a]	0.02
L	25.79b	0.48	22.71	0.58	1.98	0.28	1.10[b]	0.03
P	26.62	0.20	22.81	0.22	2.74	0.23	1.08	0.02
Y	27.18	0.23	24.40	0.29	1.69	0.11	1.10	0.02
LxLW	26.23	0.14	23.57	0.25	1.63[a]	0.15	1.03	0.02
YxLW	25.99[b]	0.40	23.11	0.39	1.82	0.19	1.06	0.02
YxP	26.79	0.50	22.41[a]	0.40	3.33[b]	0.46	1.05	0.03
LxY	26.23	0.41	24.53[b]	0.45	1.70	0.09	1.09	0.02

[ab]Within column means bearing different superscripts differ significantly at $P<0.05$.
*LW – Large White; L – Landrace; P – Pietrain; Y – Yorkshire; LxLW, YxLW, YxP, LxY – adequate crosses of the purebreds.

amount of dry matter. The lowest amount of dry matter was recorded in meat of L and YxLW pigs, and comparing to LW the differences were 1.5% (P<0.05) and 1.3% (P<0.05). Comparable findings were reported by Jukna *et al*. [2007] and Meskinyte-Kausiliene *et al*. [2012].

While comparing the amount of protein, contained in meat, the meat of LxY crossbred pigs was found to have its highest content, with its level in meat of LW and Y purebred pigs being slightly lower, with the difference of only 0.10% and 0.13%. Meat of the YxP crossbreds and P purebred pigs was found to have lower amounts of protein, in comparison to meat of the LxY crossbreds; the differences were 2.1% (P<0.01) and 1.8% (P<0.05). The results of this study are in agreement with the conclusion of Sorapukdee *et al*. [2013].

Large inter-breed differences were estimated while analysing fat content in meat. TheYxP crossbreeds had the biggest fat content in *musculus longissimus* dorsi, of the smallest difference with that in meat of the P pigs amounting to 0.59%. The greatest difference in comparison to YxP pigs was observed for LxLW, Y and LxY, amounting to 1.7% (P<0.01),1.64% (P<0.05) and 1.63% (P<0.05), respectively. Comparable findings were reported by Plastow et al. [2005], who reported the highest intramuscular fat content in meat of the P purebred pigs. Oczkowicz *et al*. [2009] obtained almost identical intramuscular fat levels.

Crude ash content in meat of the analysed pig genotypes was almost identical, within the range of 0.97-1.1%. Meat of pigs LW had the lowest ash content, while meat of L pigs was distinguished for containing the highest amount of ash, with the difference amounting to 0.13% (P<0.01). Almost identical findings were reported by Jukna et al. [2007] and Meskinyte-Kausiliene *et al*. [2012] in their papers.

Technological quality indexes for the analysed pig breeds are given in Table 3. Meat of the LxJ crosses had the highest pH, while pH was lowest in meat of L pigs (P<0.05). The JxLW crosses were distinguished for having the lightest meat, while the darkest meat was found in the LxLW crossbreds, with the difference amounting to 4.73

Table 3. Technological meat quality indexes of meat from purebreeds and crossbreeds and their standard errors

Genotype	pH		color						Tenderness (kg/cm^2)	
			L*		a*		b*			
	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE
LW	5.44	0.03	59.80	1.08	12.66[a]	0.68	9.23[a]	0.66	1.96	0.16
L	5.43[a]	0.01	61.09	0.66	14.80	0.44	7.55	0.66	2.07	0.19
P	5.51	0.01	57.18	0.98	15.11	0.25	8.05	0.31	2.09	0.12
Y	5.53	0.02	59.81	0.54	15.21	0.43	6.31	0.33	2.74	0.07
LxLW	5.44	0.01	56.96[a]	0.42	14.53	0.34	7.43	0.19	1.95	0.11
YxLW	5.50	0.03	61.69[b]	0.84	13.31	0.43	8.43	0.54	1.87[a]	0.22
YxP	5.47	0.02	57.95	0.87	14.68	0.42	8.24	1.02	1.87[a]	0.12
LxY	5.58[b]	0.05	58.23	0.99	15.52[b]	0.32	5.78[b]	0.34	2.93[b]	0.18

[ab]Within column means bearing different superscripts differ significantly at P<0.05.

*LW – Large White; L – Landrace; P – Pietrain; Y – Yorkshire; LxLW, YxLW, YxP, LxY – adequate crosses of the purebreds.

L* units (P<0.001). The greatest intensity of the red colour was found in the meat of the LxJ pigs, while it was lowest in the meat of the LW breed (P<0.01). Meat of the LW purebred pigs had the greatest intensity of yellowness, whereas it was lowest in the meat of the LxJ crosses, with the difference being as high as 3.45 b* units (P<0.001). Comparable findings were reported by Ryu *et al*. [2008] and Lee *et al.* [2012].

Mineral contents in meat of various purebreds and crossbreds are given in Table 4. From the data given it can be seen that the greatest amount of Na was recorded in the meat of the YxLW crosses, while the least – in meat of the L and LxY pigs, with the differences of 12.4 % or 56.6 mg/kg (P<0.05) and 11.7 % or 53.7 mg/kg (P<0.05).

Table 4. Amounts of elements in the MLD of pure- and crossbred pigs

Breed	Element (mg/kg)								
	Na	Mg	Ca	Zn	Se	Cu	Ni	Fe	Ba
LW	434.1	290.0	55.9	9.2	0.14[a]	0.40	0.15	9.3	0.02
	15.7	5.0	1.5	0.2	0.00	0.02	0.02	0.5	0.00
L	400.7[a]	260.6	51.6	11.2	0.15	0.40[a]	0.20	7.1[a]	0.02
	10.6	6.1	1.7	0.5	0.01	0.03	0.02	0.2	0.00
P	441.4	274.7	54.6	12.4	0.15[a]	0.49	0.23	9.5	0.02
	11.3	3.6	1.4	0.3	0.004	0.02	0.04	0.7	0.00
Y	425.7	285.8	58.1	10.7	0.14	0.49	0.15[a]	8.0	0.02
	6.1	7.0	2.7	0.5	0.01	0.01	0.02	0.4	0.00
LxLW	446.5	274.6	59.1[a]	10.7	0.14	0.45	0.24[b]	10.2[b]	0.02
	8.2	3.9	1.5	0.2	0.00	0.02	0.03	0.6	0.00
YxLW	457.6[b]	302.3[a]	58.3	10.1	0.14[b]	0.45	0.19	8.5	0.03
	17.2	4.6	2.7	0.3	0.01	0.01	0.54	0.6	0.00
YxP	418.8	266.1	50.5[b]	11.9	0.14	0.51[b]	0.20	9.6	0.02
	8.2	8.2	1.2	0.6	0.01	0.02	0.04	0.1	0.00
LxY	403.9	250.3[b]	53.2	10.9	0.14	0.41	0.23	8.3	0.02
	9.3	9.7	1.5	0.4	0.00	0.02	0.05	0.4	0.00

[ab]Within column means bearing different superscripts differ significantly at P<0.05.

Significant differences were found between the amount of Mg in meat of purebred and crossbred pigs. The YxLW crossbreds had the highest Mg levels in the meat, while the Mg levels were lowest in the meat of the LxY and L pigs, with the difference of 17.2% or 52 mg/kg (P<0.001) and 13.8% or 41.7 mg/kg. The smallest difference in the Mg levels in the meat pigs was found between the YxLW crossbreds and the DB pigs, amounting to 5% or 12.3 mg/kg. Meat of the P and LxLW pigs was distinguished for having almost equal amounts of Mg, with the difference between those populations amounting to as little as 0.04 mg/kg. Different results were obtained by Tomovič *et al.* [2011], as the highest amount of Na was found in meat of the L pigs, and that of Mg – in the LW pigs.

The amount of another mineral element, Ca, ranged from 50.5 to 59.1 mg/kg in meat of various pig breeds. Meat of the LxLW pigs contained the greatest amount of Ca, although its levels in the meat of the YxLW crossbreds and Y pigs were only slightly lower, with the difference amounting to as little as 1.4% and 1.8%. The lowest amount of Ca was recorded in the meat of the YxP and L pigs, while, when comparing the Ca amount in the meat of the LxLW pigs the difference was 14.5% or 8.6 mg/kg ($P<0.001$) and 12.7% or 7.5 mg/kg ($P<0.01$).

The purebred pigs were distinguished for having significantly higher amounts of Zn in their meat, while comparing to the amount of Zn in the meat of the LW purebreds, in the meat of the P pigs it was 25.4% or 3.1 mg/kg higher, although the difference was not statistically significant. Comparing the Zn levels in meat of the P pigs the smallest differences were recorded for the YxP and L pigs, i.e. 3.5% or 0.4 mg/kg, and 9.6% or 1.2 mg/kg. The meat of the Y and LxLW pigs had almost equal amounts of Zn, with the difference of only 0.02 mg/kg.

When comparing meat samples of various pig breeds, the greatest amount of Se was recorded in the meat of the P and L pigs, with the difference amounting to 0.01% or

0.00 mg/kg, and comparing to pig breeds which Se levels in meat was lowest, i.e. LW and YxLW, the difference equaled to 8.6% or 0.013 mg/kg ($P<0.05$) and 7.8% or 0.012 mg/kg. Ponnampalam *et al*. [2009] obtained almost identical findings as in this study.

The meat of the YxP crossbred pigs contained the greatest amounts of Cu, while that of L, LW and LxY pigs contained its lowest amounts. The difference was 21.3% or 0.11 mg/kg ($P<0.01$), 21.3% or 0.11 mg/kg ($P<0.01$) and 19.1% or 0.10 mg/kg ($P<0.01$), respectively. The smallest difference in the Cu level in meat was found between the YxP crossbreds and the P and L purebreds – 3.4 % or 0.02 mg/kg and 4.7% or 0.02 mg/kg, although the differences were statistically non-significant.

The meat of the LxLW pigs was distinguished for having the biggest amount of Ni, while the Y pigs had the lowest amount of Ni, with the difference being as high as 38.9% or 0.09 mg/kg ($P<0.05$). The same results were obtained by Tomovic *et al*. [2010], who compared Ni levels in various pig breeds.

The amount of Fe in meat of different pig genotypes ranged from 7.1 to 10.2 mg/kg. The meat of the LxLW crossbreds was distinguished for having the greatest amount of Fe, 5.9% or 0.60 mg/kg, while lower Fe amounts were found in meat of the YxP crossbreds, 7.3% or 0.75 mg/kg – in the meat of the P pigs, and 9.4% or 0.95 mg/kg ($P<0.01$) in the meat of the LW purebred pigs. The lowest amount of Fe was found in muscle of L pigs when comparing to that of the LxLW pigs, with the difference being as high as 30.4% or 3.10 mg/kg ($P<0.05$).

The greatest amount of Ba was found in *musculus longissimus dorsi* of the YxLW crossbreds, while the meat of the YxP and LxLW crossbreeds had the lowest amounts of Ba, with the difference reaching 38.3% or 0.011 mg/kg, and 32% or 0.009 mg/kg ($P<0.05$).

Correlation between mineral contents and meat quality attributes in the porcine meat

Correlation between various minerals and meat quality indexes are given in Table 5. The levels of Zn and Cu were found to have a substantial correlation between the mineral matter and meat quality indexes. The bigger the amount of Zn in the meat

Table 5. Correlations between mineral element contents and quality traits of porcine *musculus longissimus dorsi*

Minerals	Na	Mg	Ca	Zn	Se	Cu	Ni	Fe	Ba
Dry matter	0.011	0.060	-0.018	-0.105	0.030	0.049	-0.196	0.134	0.019
Protein	-0.107	0.068	0.047	-0.417##	-0.018	-0.288#	-0.106	0.067	-0.007
Fat	0.096	-0.188	-0.136	0.499##	0.052	0.420##	-0.054	0.041	0.089
Ash	-0.294#	-0.212	-0.222	0.197	-0.048	0.045	-0.023	-0.259#	-0.161
pH	0.134	-0.066	0.095	0.136	-0.023	0.152	0.069	-0.198	0.042
L*	0.073	0.095	0.138	-0.054	-0.093	-0.149	-0.262#	-0.044	0.210
a*	-0.030	-0.174	-0.035	0.362##	0.175	0.277#	-0.040	-0.009	0.051
b*	0.251#	0.171	0.118	0.012	0.056	0.033	-0.021	0.211	0.093
Rigidity	-0.211	-0.025	-0.133	-0.026	-0.126	-0.160	-0.020	-0.254#	-0.080

#P<0.05; ##P<0.01.

of various purebred and crossbred pigs, the lower the amount of protein (P<0.01) and the greater the amount of intramuscular fat (P<0.01) as well as the intensity of meat redness (a*) (P<0.01). For the copper, the bigger the amount of Cu was found in meat of various purebreed and crossbreed pigs, the lower the protein level in meat (P<0.05), the greater the amount of intramuscular fat (P<0.01) and redness intensity (a*) (P<0.05). The amount of ash in meat was greater at lower levels of Na (P<0.05), Mg, Ca and Fe (P<0.05). Shear force was increasing when *musculus longissimus dorsi* contained less mineral elements of Na and Fe (P<0.05). Identical correlation parameters for mineral contents and meat quality attributes were reported by Guang-zhi et al. [2008], pointing to the effect of these minerals (Zn, Cu, Fe, Mn, Ca, K, Na) resulting in the strongest relationship with meat quality traits, similarly as it was in this study for Zn and Cu.

This study indicated that chemical composition of meat in the analysed pig breeds and their crosses did not differ considerably, except for the amount of fat.

Element contents in meat of different pig breeds and their crosses, kept under identical feeding and management conditions recorded in *musculus longissimus dorsi* were different. The results of the study showed that the greatest amounts of Na, Mg and Ba were found in meat of Yorkshire and White Large crossbreeds, those of Ca, Fe and Ni – in Landrace and White Large crossbreeds, those of Zn and Se – in Pietrain pigs, while Cu – in meat of Yorkshire and Pietrain crosses. Positive correlation coefficients of element contents with meat quality indexes in *musculus longissimus dorsi* of the analysed purebreed pigs and their crosses were recorded only between the amounts of fat and Zn, intensity of redness (a*) and water drip loss, the amounts of fat and Cu. A negative correlation was found between contents of protein and Zn in meat.

In conclusion, a precise determination of chemical content is very important for the essentials of human nutrition. Therefore it is very important that the data of nutrients would be regularly renewed and possible changes would be observed with available data.

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