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COMPARATIVE EVALUATION OF CHEMICAL COMPOSITION, AMINO ACID PROFILE, FATTY ACID COMPOSITION AND LIPID QUALITY INDICES IN *MUSCULUS LONGISSIMUS DORSI* OF WILD BOAR (*Sus scrofa*) AND LARGE WHITE PIGS

SUMMARY

The present study evaluated differences in the chemical composition, amino acid profile, fatty acid composition, and lipid nutritional indices of *musculus longissimus dorsi* obtained from wild boars (*Sus scrofa*) and Large White pigs. A total of 50 muscle samples (25 wild boars and 25 domestic pigs) were analysed. Wild boar meat was characterised by a significantly higher protein content (24.68 vs. 23.45 g/100 g) and a lower intramuscular fat content (1.12 vs. 1.81 g/100 g) than that of Large White pigs ($P<0.05$). Significant differences were also observed in amino acid composition, particularly in the concentrations of histidine, valine, phenylalanine, leucine, and threonine. Wild boar meat exhibited significantly higher proportions of polyunsaturated fatty acids (13.85 vs. 8.54%) and α-linolenic acid (0.97 vs. 0.23%), together with a higher PUFA/SFA ratio (0.40 vs. 0.22). In contrast, Large White pigs showed a significantly higher oleic acid content (42.73 vs. 31.66%) and higher proportions of MUFA and SFA. Significant differences were observed in the lipid nutritional indices AI, TI, PUFA/SFA ratio, and PI, whereas the h/H ratio, DFA, and OFA did not differ significantly between the groups. Principal component analysis revealed a clear separation between wild boar and domestic pig samples based on fatty acid composition. The findings indicate that wild boar meat represents a lean and nutritionally valuable alternative to conventional pork due to its lower intramuscular fat content, higher protein concentration, and more favourable polyunsaturated fatty acid profile.

Keywords: Wild boar meat; pork quality; amino acid composition; fatty acid profile; lipid nutritional indices; *musculus longissimus dorsi*

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INTRODUCTION

Growing interest in the relationship between nutrition and human health has increased consumer demand for meat with improved nutritional quality and a favourable lipid composition. Besides conventional pork, game meat has attracted considerable attention due to its high biological value, lower fat content, and distinctive sensory properties (Hoffman and Wiklund, 2006; Sales and Kotrba, 2013). Among game species, wild boar (*Sus scrofa*) is one of the most important and widely consumed animals in Europe, and its meat is increasingly regarded as a nutritionally valuable alternative to conventional pork.

Previous studies have demonstrated clear differences between wild boar and domestic pig meat in terms of chemical composition and lipid characteristics. Marchiori and Felício (2003), Quaresma *et al.*, (2011), and Razmaitė *et al.*, (2012) reported lower intramuscular fat contents together with higher protein levels in wild boar meat than in commercial pig breeds. These differences are generally associated with genotype, feeding behaviour, increased locomotor activity, and environmental variability. Unlike domestic pigs receiving standardised compound diets, wild boars consume a diverse range of natural feed resources, including roots, grasses, seeds, and fruits, which may substantially influence muscle metabolism and nutrient deposition (Schley and Roper, 2003).

Fatty acid composition is considered one of the principal nutritional parameters affecting the biological and dietetic value of meat. Particular attention has been focused on the balance between saturated (SFA), monounsaturated (MUFA), and polyunsaturated fatty acids (PUFA), especially omega-3 fatty acids, because of their relationship with cardiovascular and metabolic diseases in humans (Ulbricht and Southgate, 1991). Previous studies have demonstrated that wild boar meat generally contains higher PUFA levels and lower proportions of saturated fatty acids than conventional pork (Marsico *et al.*, 2007; Quaresma *et al.*, 2011). Razmaitė *et al.*, (2012) additionally reported more favourable PUFA/SFA and n-6/n-3 ratios in wild boar meat, suggesting improved lipid nutritional quality.

The nutritional importance of meat is also closely related to its amino acid composition. Meat proteins are characterised by high digestibility and contain all essential amino acids required for growth and the maintenance of physiological functions. However, amino acid composition may vary according to genotype, muscle type, and feeding system (Lawrie and Ledward, 2006). Brudnicki *et al.*, (2012) described wild boar meat as a valuable source of essential amino acids with favourable nutritional properties. Despite the increasing number of studies investigating game meat quality, comprehensive comparisons simultaneously evaluating chemical composition, amino acid profile, fatty acid composition, and lipid quality indices remain relatively limited.

The *musculus longissimus dorsi* (MLD) is one of the most economically important muscles in carcass evaluation and is frequently used as a reference muscle in meat quality studies due to its relatively uniform structure and practical relevance to the meat industry. Therefore, the aim of the present study was to compare the chemical composition, amino acid profile, fatty acid composition, and

lipid quality indices of *musculus longissimus dorsi* obtained from wild boars (*Sus scrofa*) and Large White pigs. In addition, multivariate statistical analyses were performed to identify the nutritional parameters contributing most strongly to the differentiation between the two animal groups.

MATERIAL AND METHODS

The biological material consisted of 25 wild boars obtained from hunting areas located in the Piešťany and Trnava regions of Slovakia. The animals originated from free-ranging populations and consumed only natural feed resources available in their environment. The estimated age of the wild boars was approximately 12 months, with live body weights ranging from 45 to 60 kg. The wild boars were legally hunted in accordance with the Hunting Act of the Slovak Republic No. 274/2009 Coll.

The second experimental group consisted of 25 Large White fattening pigs reared under conventional production conditions at the School Agricultural Enterprise Žirany near the Slovak University of Agriculture in Nitra. The animals were fed standard commercial feed mixtures (OŠ-01, OŠ-02, OŠ-03, and OŠ-06) appropriate for the individual growth phases from 30 to 120 kg live weight. The pigs were slaughtered at approximately 4.5–5 months of age, with an average live weight of approximately 100 kg.

Following hunting and slaughter, the carcasses were weighed using an FCW electronic scale (FCW Slovakia) with an accuracy of 50 g. Subsequently, the carcasses were transported under refrigerated conditions (4 °C) to the Institute of Food Sciences, Slovak University of Agriculture in Nitra, where further analyses were performed.

Animal handling, hunting, slaughter procedures, and sample manipulation were carried out in accordance with Slovak legislation and the principles of animal welfare protection under Directive 2010/63/EU of the European Parliament and of the Council.

Slaughter and sample collection

Wild boars were hunted during the regular hunting season in accordance with Slovak hunting legislation. Immediately after shooting, the animals were bled and eviscerated under field conditions by qualified personnel. Domestic pigs were slaughtered under standard commercial slaughterhouse conditions following routine procedures used in pig production. Prior to slaughter, the pigs were subjected to a fasting period with free access to water.

After slaughter and evisceration, the carcasses were chilled at 4 °C for 24 h. Carcass weight was determined using an FCW animal scale (FCW Slovakia) with an accuracy of 50 g. Subsequently, the carcasses were dissected into individual cuts and tissues for the evaluation of carcass characteristics. Samples intended for chemical analyses were collected from the *musculus longissimus dorsi* (MLD), one of the most valuable and frequently evaluated muscles in meat quality studies.

Muscle samples were excised 24 h post mortem from the thoracolumbar region of each carcass. Visible connective tissue and external fat were carefully removed prior to analysis. The collected samples were packed into sterile polyethylene bags and transported under refrigerated conditions (4 °C) to the laboratory of the Institute of Food Sciences, Slovak University of Agriculture in Nitra, where subsequent physicochemical, amino acid, and fatty acid analyses were performed.

Chemical composition

basic chemical composition of the *musculus longissimus dorsi* samples, including water, crude protein, intramuscular fat, and cholesterol contents, was determined using an INFRATEC 1265 analyser (Germany) operating in transmittance mode within the near-infrared spectral range of 850–1050 nm. Prior to analysis, the muscle samples were homogenised using a laboratory homogeniser to ensure a uniform consistency.

Approximately 50 g of homogenised sample was placed into a glass sample cup (90×90×15 mm) and scanned twice. Each spectrum represented the average of five scanning positions and was calculated as log 1/T, where T denotes transmittance. Instrument calibration and settings were performed according to the manufacturer's recommendations.

The contents of water, protein, and intramuscular fat were expressed as g/100 g fresh matter, whereas cholesterol content was expressed as g/kg fresh matter. Each analysis was performed in triplicate.

Amino acid composition

The amino acid composition of the *musculus longissimus dorsi* (MLD) samples was determined using an automatic amino acid analyser (L-8900; Hitachi High-Tech Co., Ltd., Tokyo, Japan) equipped with ion-exchange chromatography and post-column ninhydrin derivatisation. Prior to analysis, the muscle samples were homogenised, freeze-dried, and finely ground.

Approximately 100 mg of dried muscle sample was subjected to acid hydrolysis in 6 N HCl at 110 °C for 24 h under anaerobic conditions. For the determination of sulphur-containing amino acids (cysteine and methionine), the samples were oxidised with performic acid prior to hydrolysis. Following hydrolysis, the samples were cooled, filtered, and diluted with citrate buffer according to the manufacturer's recommendations.

Individual amino acids, including arginine, cysteine, phenylalanine, histidine, isoleucine, leucine, lysine, methionine, threonine, and valine, were separated by ion-exchange chromatography and quantified based on their colour reaction with ninhydrin. Amino acid concentrations were expressed as g/100 g protein. All analyses were performed in duplicate.

Essential amino acids (EAA) were calculated as the sum of histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, valine, and arginine, whereas non-essential amino acids (NEAA) were calculated as the sum of the remaining quantified amino acids. The EAA/NEAA ratio was subsequently determined.

Fatty acid composition

Fat was extracted from lyophilised *musculus longissimus dorsi* samples using Soxhlet extraction with petroleum ether according to the methodology described by Luque de Castro and Priego-Capote (2010), modified in accordance with ISO 12966-2:2017 for the preparation of fatty acid methyl esters (FAME).

The chemical reagents used for fat extraction and fatty acid determination were petroleum ether (40–65 °C; Sigma–Aldrich, Steinheim, Germany), chromatographic-grade methanol (Sigma–Aldrich, Steinheim, Germany), NaHSO4.H2O (Centralchem, Bratislava, Slovakia), Na2SO4 (Centralchem, Bratislava, Slovakia), KOH (Centralchem, Bratislava, Slovakia), HCl (33–36%; Centralchem, Bratislava, Slovakia), Hyflo Super Cel filter medium (diatomaceous earth; Sigma–Aldrich, Steinheim, Germany), chromatographic-grade anhydrous n-hexane (Sigma–Aldrich, Steinheim, Germany), and a 42-component FAME standard mixture (10 mg/mL in methylene chloride containing C4–C24 FAME; 2–4% relative concentration; Supelco, catalogue no. 47885-U; Sigma–Aldrich, Steinheim, Germany).

The equipment used included a temperature-adjustable vacuum oven (100±3 °C; Fisher Scientific, Waltham, MA, USA) and a Tecator Soxtec System HT 1043 extraction unit (Gemini, Apeldoorn, the Netherlands) operating at a flow rate of 10 cycles/h or 10 mL/min. All analyses were performed in duplicate.

Lipid nutritional indices

Based on the obtained fatty acid composition, selected lipid nutritional indices were calculated to evaluate the nutritional and health-related quality of the lipid fraction of the analysed meat samples. The following indices were determined: atherogenic index (AI), thrombogenic index (TI), polyunsaturated-to-saturated fatty acid ratio (PUFA/SFA), omega-6-to-omega-3 fatty acid ratio (n-6/n-3), hypocholesterolaemic/hypercholesterolaemic ratio (h/H), desirable fatty acids (DFA), undesirable fatty acids (OFA), and peroxidability index (PI).

The atherogenic index (AI) and thrombogenic index (TI) were calculated according to the equations proposed by Ulbricht and Southgate (1991), whereas the remaining lipid quality parameters were determined according to Chen and Liu (2020) and related meat science studies. The indices were calculated using the following equations:

$$AI = \frac{C12{:}0 + (4 \times C14{:}0) + C16{:}0}{\sum MUFA + \sum PUFA}$$

$$TI = \frac{C14{:}0 + C16{:}0 + C18{:}0}{(0.5 \times \sum MUFA) + (0.5 \times \sum n\text{-}6) + (3 \times \sum n\text{-}3) + \left(\frac{\sum n\text{-}3}{\sum n\text{-}6}\right)}$$

$$h/H = \frac{C18{:}1 + C18{:}2\ n\text{-}6 + C18{:}3\ n\text{-}3 + C20{:}4\ n\text{-}6 + EPA + DPA + DHA}{C14{:}0 + C16{:}0}$$

Desirable fatty acids (DFA) and undesirable fatty acids (OFA) were calculated according to the following equations:

$$DFA = \Sigma UFA + C18{:}0$$

$$OFA = C12{:}0 + C14{:}0 + C16{:}0$$

The polyunsaturated/saturated fatty acid ratio (PUFA/SFA) and peroxidability index (PI) were calculated using the following equations:

$$PUFA/SFA = \frac{\Sigma PUFA}{\Sigma SFA}$$

$$PI = 0.025(MUFA) + 1(C18{:}2) + 2(C18{:}3) + 4(C20{:}4) + 6(C20{:}5 + C22{:}5) + 8(C22{:}6)$$

These indices provide integrated information regarding the potential impact of dietary lipids on cardiovascular health and are commonly used for evaluation of the nutritional quality of meat and meat products.

Statistical analysis

All analytical determinations were performed in duplicate or triplicate according to the respective methodological procedures. The results are presented as mean values ± standard deviation (SD).

Prior to statistical analysis, the normality of data distribution was assessed using the Shapiro–Wilk test. Differences between wild boar and Large White pig groups were analysed using an independent Student's t-test. Statistical significance was established at $P<0.05$.

To evaluate the magnitude of differences between the experimental groups, effect sizes were calculated using Cohen's d and interpreted as small (d=0.2), medium (d=0.5), and large (d≥0.8). To reduce the probability of Type I error associated with multiple comparisons, the false discovery rate (FDR) correction was additionally applied.

Relationships among variables and the differentiation between experimental groups were further evaluated using multivariate statistical analysis. Principal component analysis (PCA) was applied to identify the major sources of variability in fatty acid composition and to visualise the separation between wild boar and Large White pig samples.

Statistical analyses were performed using XLSTAT® software (version 2018.5.52280; Addinsoft, New York, NY, USA), whereas PCA plots were generated using R software (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS AND DISCUSSION

Chemical Composition

The chemical composition of *musculus longissimus dorsi* obtained from wild boars and Large White pigs is presented in Table 1 and Figure 1. Significant differences between the experimental groups were identified primarily for protein, intramuscular fat, and cholesterol contents. Wild boar meat contained significantly higher protein levels (24.68 vs. 23.45 g/100 g; $P<0.001$), whereas Large White pigs exhibited significantly greater intramuscular fat deposition (1.81 vs. 1.12 g/100 g; $P=0.004$). Cholesterol concentration was also significantly higher in wild boars (0.42 vs. 0.28 g/kg; $P<0.001$), whereas water content was not significantly affected by animal group ($P>0.05$). Large effect sizes further confirmed the biological relevance of the differences observed in protein ($d=1.48$), intramuscular fat ($d=-0.83$), and cholesterol content ($d=1.40$), indicating a substantial influence of genotype and production system on muscle composition.

Table 1. Chemical composition of *musculus longissimus dorsi* from wild boars and Large White pigs (water, protein and intramuscular fat expressed in g/100 g; cholesterol expressed in g/kg)

Parameter	Wild boar (n=25)	Large White (n=25)	P-value	FDR-adjusted P-value	Cohen's *d*	Effect size
Water	72.83±0.90	73.34±0.63	0.061	0.081	-0.67	Medium
Protein	24.68±1.07	23.45±0.52	<0.001	<0.001	1.48	Large
Intramuscular fat	1.12±0.63	1.81±1.01	0.004	0.008	-0.83	Large
Cholesterol	0.42±0.10	0.28±0.10	<0.001	<0.001	1.40	Large

Notes: Values are presented as mean ± SD. Differences between groups were evaluated using an independent Student's t-test. False discovery rate (FDR) correction was applied for multiple comparisons. Effect size was assessed using Cohen's d and interpreted as small (0.2), medium (0.5), and large (≥ 0.8)

The present findings are consistent with previous studies characterising wild boar meat as a lean and protein-rich raw material. Marchiori and Felício (2003) and Marsico *et al.,* (2007) similarly reported higher protein concentrations together with lower intramuscular fat deposition in wild boar meat than in conventional pig breeds. Marsico *et al.,* (2007) reported protein and fat contents of 25.87% and 1.55%, respectively, in hunted wild boars, values that closely correspond to those obtained in the present study. Comparable physicochemical characteristics were also reported by Bozhko *et al.,* (2023), who observed 22.98% protein, 1.84% intramuscular fat, and 73.59% moisture content in the *musculus longissimus dorsi* of wild boars. Migdał *et al.,* (2026) further summarised that protein concentrations in European wild boar meat generally range from 21.2 to 25.9%, whereas intramuscular fat content usually remains below 3%, depending on environmental conditions, season, feed availability, and animal age. Similar variability in the physicochemical characteristics of wild boar meat was also reported by Postolache *et al.,* (2010).

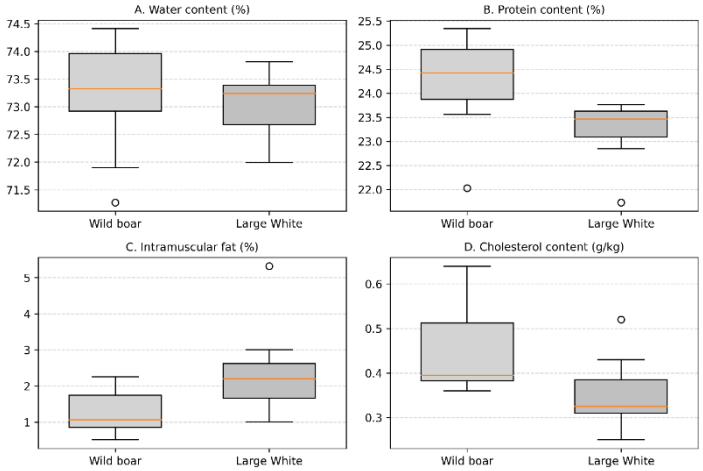

Figure 1. Chemical composition of *musculus longissimus dorsi* from wild boars and Large White pigs

Comparable trends have been reported in domestic pigs. Debrecéni *et al.*, (2016) observed approximately 1.24% intramuscular fat and cholesterol concentrations of around 20 mg/100 g in the *musculus longissimus dorsi* of Slovak Large White pigs, whereas Mangalitsa and Mangalitsa × Duroc genotypes exhibited substantially higher cholesterol concentrations. Sales and Kotrba (2013) similarly characterised wild boar meat as a lean raw material with a relatively high protein concentration associated with increased locomotor activity and natural feeding behaviour.

The lower intramuscular fat content observed in wild boars is most likely associated with free-ranging conditions and greater physical activity. Schley and Roper (2003) demonstrated that wild boars consume highly variable natural diets consisting mainly of roots, grasses, seeds, fruits, and animal matter, factors that may considerably influence nutrient deposition and lipid metabolism. Migdał *et al.*, (2026) likewise emphasised the importance of seasonal feed availability and environmental conditions in regulating muscle composition and lipid accumulation in free-ranging wild boars. In contrast, domestic pigs are reared under intensive production systems characterised by restricted locomotor activity and nutritionally standardised diets formulated to maximise growth performance and carcass yield. Bozhko *et al.*, (2023) additionally suggested that wild boar meat contains a higher proportion of myofibrillar proteins and connective tissue structures, contributing to firmer muscle texture and lower fat deposition.

Although cholesterol concentration was significantly higher in wild boar meat, the recalculated values corresponded to approximately 42 mg/100 g in wild boars and 28 mg/100 g in Large White pigs, remaining within the physiological range previously reported for pork and game meat. Quaresma *et al.*, (2011) reported cholesterol concentrations of approximately 55.6–58.7 mg/100 g in feral wild boar meat, whereas Strazdina *et al.*, (2014) observed values of around 98.11

mg/100 g in the longissimus muscle of wild boars. Migdał *et al.*, (2026) further summarised that cholesterol concentrations in European wild boar meat commonly range from 45 to 98 mg/100 g, depending on carcass fatness, environmental conditions, and analytical methodology.

Overall, the findings confirm that wild boar meat represents a lean and nutritionally valuable raw material characterised by a higher protein concentration and lower intramuscular fat deposition than conventional pork.

Amino acid composition

The amino acid composition of *musculus longissimus dorsi* obtained from wild boars and Large White pigs is presented in Table 2. Significant differences between the experimental groups were observed primarily for histidine, valine, phenylalanine, leucine, and threonine. Large White pigs exhibited significantly higher concentrations of leucine (1.98 vs. 1.87 g/100 g protein), valine (1.03 vs. 0.94 g/100 g protein), histidine (1.17 vs. 0.98 g/100 g protein), phenylalanine (1.02 vs. 0.93 g/100 g protein), and threonine (1.09 vs. 1.01 g/100 g protein). Large effect sizes were observed particularly for histidine (d = -1.71), valine (d = -1.26), phenylalanine (d = -1.03), and total essential amino acids (d = -1.02), indicating biologically meaningful differences in amino acid deposition between the experimental groups. In contrast, the EAA/NEAA ratio remained relatively stable, suggesting a comparable overall biological quality of muscle proteins in both wild boars and domestic pigs.

Table 2. Amino acid profile of *musculus longissimus dorsi* from wild boars and Large White pigs (g/100 g protein)

Amino acid	**Wildboar(n=25)**	**LargeWhite(n=25)**	**P-value**	**FDR-adjusted P-value**	**Cohen's *d***	**Effect size**
Arginine	1.49±0.18	1.57±0.11	0.084	0.112	-0.55	Medium
Cysteine	0.32±0.03	0.34±0.03	0.091	0.119	-0.49	Medium
Phenylalanine	0.93±0.10	1.02±0.07	0.003	0.011	-1.03	Large
Histidine	0.98±0.13	1.17±0.09	<0.001	<0.001	-1.71	Large
Isoleucine	0.93±0.11	0.95±0.08	0.421	0.448	-0.20	Small
Leucine	1.87±0.20	1.98±0.14	0.028	0.044	-0.66	Medium
Lysine	2.01±0.23	2.11±0.16	0.067	0.097	-0.53	Medium
Methionine	0.75±0.08	0.79±0.05	0.073	0.101	-0.57	Medium
Threonine	1.01±0.10	1.09±0.07	0.009	0.023	-0.91	Large
Valine	0.94±0.08	1.03±0.06	<0.001	0.002	-1.26	Large
EAA	7.51±0.74	8.14±0.49	0.002	0.009	-1.02	Large
NEAA	3.72±0.33	4.10±0.24	<0.001	0.004	-1.31	Large
EAA/NEAA ratio	2.02±0.11	1.99±0.09	0.287	0.327	0.29	Small

Notes: Values are presented as mean ± SD. Differences between groups were evaluated using an independent Student's t-test. False discovery rate (FDR) correction was applied for multiple comparisons. Effect size was assessed using Cohen's d and interpreted as small (0.2), medium (0.5), and large (≥ 0.8). EAA – essential amino acids; NEAA – non-essential amino acids.

The higher concentrations of several amino acids observed in Large White pigs may reflect more intensive muscle growth and enhanced anabolic metabolism associated with commercial pig production systems. Branched-chain amino acids, particularly leucine and valine, are closely associated with skeletal muscle protein synthesis and postprandial anabolic signalling, which may partially explain their elevated concentrations in domestic pigs reared under controlled nutritional conditions.

In contrast, wild boars are exposed to natural feeding regimes, greater locomotor activity, and fluctuating environmental conditions that may substantially influence muscle metabolism and protein turnover. Brudnicki *et al.*, (2012) similarly demonstrated variability in leucine, valine, phenylalanine, and histidine concentrations in wild boar meat depending on muscle type and physiological status. These observations support the view that the amino acid composition of wild boar meat is strongly influenced by muscle-specific metabolism, habitat conditions, feeding behaviour, and seasonal variability. Comparable variability associated with environmental conditions and muscle characteristics was also reported by Postolache *et al.*, (2010) and Migdał *et al.*, (2026).

Despite the lower concentrations of several individual amino acids observed in wild boars, these findings should not be interpreted as evidence of inferior nutritional quality. Wild boar samples simultaneously exhibited significantly higher total protein content, lower intramuscular fat deposition, and a balanced EAA/NEAA ratio, indicating favourable nutritional characteristics of muscle proteins. Similar conclusions were drawn by Sales and Kotrba (2013), who described wild boar meat as a lean raw material containing proteins of high biological value and favourable nutritional properties.

Overall, the findings indicate that genotype and production system substantially influence amino acid deposition and muscle protein composition in *musculus longissimus dorsi*. Domestic pigs exhibited slightly higher concentrations of several amino acids may be associated with intensive muscle growth, whereas wild boar meat maintained favourable protein quality together with a leaner chemical composition.

Fatty acid composition

The fatty acid composition of *musculus longissimus dorsi* from wild boars and Large White pigs is presented in Table 3 and Figure 2. Significant differences between the experimental groups were observed for most of the evaluated fatty acids and fatty acid groups. Wild boar meat contained significantly higher proportions of PUFA (13.85 vs. 8.54%), whereas Large White pigs exhibited higher proportions of SFA (38.34 vs. 34.41%) and MUFA (53.34 vs. 48.59%). Among the individual fatty acids, the most pronounced differences were observed for oleic acid (42.73 vs. 31.66%), linoleic acid (10.06 vs. 6.69%), α-linolenic acid (0.97 vs. 0.23%), and stearic acid (11.37 vs. 10.77%). Wild boar meat additionally exhibited a significantly higher PUFA/SFA ratio (0.40 vs. 0.22), indicating a more favourable nutritional quality of the intramuscular lipid fraction.

Table 3. Fatty acid profile of *musculus longissimus dorsi* from wild boars and Large White pigs (% FAME)

Fatty acid / parameter	Wild boar (n=25)	Large White (n=25)	P-value	FDR-adjusted P-value	Cohen's *d*	Effect size
C16:0 Palmitic	24.37±0.20	24.36±0.21	0.764	0.764	0.09	Small
C18:0Stearic	10.77±0.24	11.37±0.23	<0.001	<0.001	-2.54	Large
C18:1Oleic	31.66±8.70	42.73±2.48	<0.001	<0.001	-1.73	Large
C18:2n-6Linoleic	6.69±1.92	10.06±0.96	<0.001	<0.001	-2.22	Large
C18:3n-3α-Linolenic	0.97±0.13	0.23±0.03	<0.001	<0.001	7.64	Large
Arachidonicacid (C20:4n-6)	1.60±0.20	1.53±0.21	0.226	0.245	0.35	Small
EPA(C20:5n-3)	0.08±0.02	0.10±0.01	0.001	0.001	-0.98	Large
DPA(C22:5n-3)	0.13±0.01	0.14±0.01	<0.001	<0.001	-1.14	Large
DHA(C22:6n-3)	0.03±0.01	0.04±0.01	<0.001	<0.001	-1.50	Large
SFA	34.41±1.98	38.34±1.64	<0.001	<0.001	-2.16	Large
MUFA	48.59±1.52	53.34±2.64	<0.001	<0.001	-2.21	Large
PUFA	13.85±1.41	8.54±1.96	<0.001	<0.001	3.11	Large
PUFA/SFAratio	0.40±0.05	0.22±0.05	<0.001	<0.001	3.41	Large

Notes: Values are presented as mean ± SD. Differences between groups were evaluated using an independent Student's t-test. False discovery rate (FDR) correction was applied for multiple comparisons. Effect size was assessed using Cohen's d and interpreted as small (0.2), medium (0.5), and large (≥ 0.8). SFA – saturated fatty acids; MUFA – monounsaturated fatty acids; PUFA – polyunsaturated fatty acids; EPA – eicosapentaenoic acid; DPA – docosapentaenoic acid; DHA – docosahexaenoic acid.

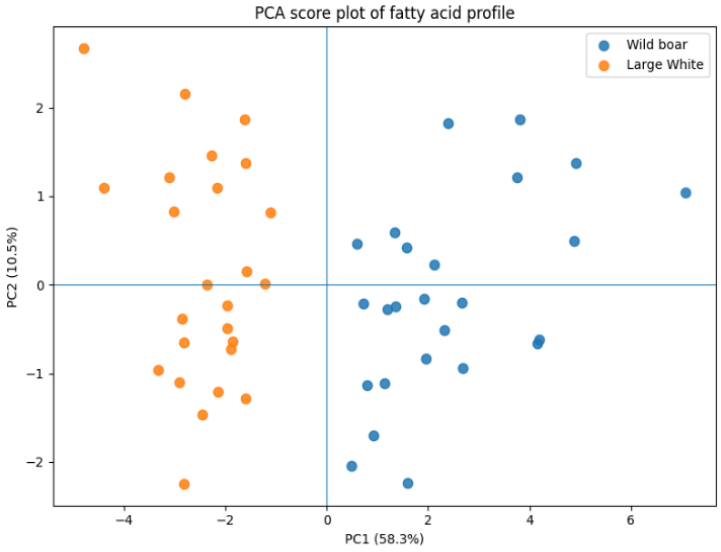

Figure 2. PCA score plot of fatty acid profile

The PCA score plot (Figure 2) demonstrated a clear separation between wild boar and Large White samples based on fatty acid composition. Wild boar samples were primarily distributed along the positive axis of the first principal component (PC1), whereas Large White samples were mainly clustered on the negative side of PC1, indicating marked differences in lipid composition between the experimental groups. The first principal component explained 58.3% of the total variance, while the second principal component accounted for an additional 10.5%. Together, the two components explained 68.8% of the overall variability in the fatty acid dataset, confirming the strong discriminatory power of the analysed fatty acid variables. Comparable chemometric differentiation based on fatty acid composition was also reported by Razmaitė *et al.*, (2011).

The present findings are consistent with previous studies investigating lipid composition in wild boar and pork meat. Quaresma *et al.*, (2011) reported PUFA proportions ranging from approximately 12% to 18% in the longissimus muscle of wild boars, together with lower intramuscular fat deposition than in commercial pig breeds. Similarly, Razmaitė *et al.*, (2012) observed PUFA/SFA ratios ranging from 0.35 to 0.48 in wild boar meat, values that closely correspond to those obtained in the present study. Razmaitė *et al.*, (2011) additionally reported PUFA proportions of 18.21%, SFA levels of 36.42%, and a PUFA/SFA ratio of 0.50 in wild boar intramuscular lipids. Although the present study revealed a similar overall lipid profile, the PUFA proportion (13.85%) and PUFA/SFA ratio (0.40) observed in wild boars were slightly lower than those reported by Razmaitė *et al.*, (2011). These discrepancies may be attributed to differences in feeding conditions, habitat characteristics, geographical origin, seasonal variability, and carcass fatness of the animals evaluated. Pedrazzoli *et al.*, (2017) further demonstrated that feeding area and environmental conditions substantially influence fatty acid deposition in wild boars, whereas Sales and Kotrba (2013) summarised that wild boar meat generally contains higher PUFA and lower SFA proportions than conventional pork.

Domestic pig breeds generally exhibit higher MUFA deposition, which is consistent with the present findings. Klensporf-Pawlik *et al.*, (2012) reported SFA proportions ranging from 39.15% to 41.23% and PUFA levels ranging from 10.75% to 12.62% in the *musculus longissimus dorsi* of commercial pig breeds. The same authors also observed oleic acid concentrations of approximately 39–40%, corresponding closely to the elevated oleic acid deposition detected in Large White pigs in the present study. In contrast, the PUFA proportion observed in Large White pigs in the present study (8.54%) was lower than the values reported by Klensporf-Pawlik *et al.*, (2012), which may reflect differences in feeding strategy, genotype, fattening intensity, and intramuscular fat deposition.

The higher PUFA content observed in wild boar meat is most likely associated with natural dietary variability and an increased intake of plant-derived feed resources rich in unsaturated fatty acids. Schley and Roper (2003), Dimatteo *et al.*, (2003), and Skobrák *et al.*, (2011) demonstrated that feeding conditions, habitat characteristics, and seasonal availability of feed resources substantially

influence lipid deposition and fatty acid composition in wild boars. Razmaitė *et al.*, (2011) and Wood *et al.*, (2008) similarly emphasised the importance of nutrition, genotype, and overall fatness level in regulating fatty acid composition. Klensporf-Pawlik *et al.*, (2012) additionally suggested that leaner animals may exhibit higher proportions of dietary-derived PUFA due to lower endogenous fatty acid synthesis.

Oleic acid (C18:1) represented the predominant MUFA in both experimental groups, although Large White pigs exhibited significantly higher oleic acid concentrations than wild boars. Similar observations were reported by Marsico *et al.*, (2007), who associated increased oleic acid deposition in domestic pigs with intensive feeding systems and greater intramuscular fat accumulation. Wild boar meat also exhibited significantly higher proportions of α-linolenic acid (C18:3 n-3), which may reflect greater dietary variability and an increased intake of natural plant-derived feed resources in free-ranging animals. According to Ulbricht and Southgate (1991), elevated PUFA levels together with lower saturated fatty acid proportions are associated with a reduced risk of cardiovascular disease.

Razmaitė *et al.*, (2011) reported PUFA/SFA values of approximately 0.50 in wild boars, exceeding the minimum recommended dietary value of 0.45 proposed by Wood *et al.*, (2004). Although the PUFA/SFA ratio observed in the present study for wild boars (0.40) was slightly lower than the recommended value, it remained substantially higher than that observed in Large White pigs and reflected a more favourable fatty acid composition.

These findings support the view that wild boar meat possesses a more favourable fatty acid profile, characterised by higher PUFA proportions and lower saturated fatty acid deposition than conventional pork.

Lipid nutritional indices

The calculated lipid nutritional indices of *musculus longissimus dorsi* from wild boars and Large White pigs are presented in Table 4 and Figure 3. Significant differences between the experimental groups were observed for the AI, TI, PUFA/SFA ratio, and PI. Wild boar meat exhibited significantly higher AI (0.42 vs. 0.37) and TI (1.09 vs. 1.05) values, whereas the PUFA/SFA ratio was markedly higher in wild boars (0.40 vs. 0.22), reflecting the higher proportion of polyunsaturated fatty acids in the intramuscular lipid fraction. In contrast, PI values were significantly lower in wild boar samples (14.17 vs. 16.21). No statistically significant differences were detected in the h/H ratio, DFA, or OFA between the groups.

The multi-panel boxplot presentation (Figure 3A–G) demonstrated the clearest separation between the experimental groups for the PUFA/SFA ratio and PI. Wild boar samples were associated with higher PUFA/SFA ratios resulting from increased PUFA deposition and lower proportions of saturated fatty acids, whereas Large White pigs exhibited higher PI values associated with a greater contribution of highly unsaturated fatty acids to overall lipid susceptibility. Considerable overlap between the groups was observed for the h/H ratio, DFA, and OFA, confirming the absence of statistically significant differences in these indices.

Table 4. Lipid nutritional indices of *musculus longissimus dorsi* from wild boars and Large White pigs

Lipid index	Wildboar (n=25)	LargeWhite (n=25)	P-value	FDR-adjusted P-value	Cohen's *d*	Effect size
AI	0.42±0.02	0.37±0.02	<0.001	<0.001	2.52	Large
TI	1.09±0.05	1.05±0.04	0.003	0.005	0.88	Large
h/H ratio	2.56±0.07	2.54±0.09	0.363	0.508	0.26	Small
DFA (%)	73.20±1.53	73.25±2.08	0.923	0.923	-0.03	Small
OFA (%)	24.37±0.20	24.36±0.21	0.764	0.892	0.09	Small
PUFA/SFA ratio	0.40±0.05	0.22±0.05	<0.001	<0.001	3.41	Large
PI	14.17±1.98	16.21±1.02	<0.001	<0.001	-1.30	Large

Notes: Values are presented as mean ± SD. Differences between groups were evaluated using an independent Student's t-test. False discovery rate (FDR) correction was applied for multiple comparisons. Effect size was assessed using Cohen's d and interpreted as small (0.2), medium (0.5), and large (≥ 0.8). AI – atherogenic index; TI – thrombogenic index; h/H – hypocholesterolemic/hypercholesterolemic ratio; DFA – desirable fatty acids; OFA – hypercholesterolemic fatty acids; PI – peroxidability index.

The higher PUFA/SFA ratio observed in wild boar meat is primarily associated with the greater proportion of polyunsaturated fatty acids and lower saturated fatty acid deposition in free-ranging animals. According to Ulbricht and Southgate (1991), higher PUFA/SFA values are considered nutritionally desirable because they are associated with improved dietary lipid quality and a reduced risk of cardiovascular disease. Similar observations were reported by Razmaitė *et al.*, (2012), who demonstrated more favourable PUFA/SFA relationships in wild boar meat than in conventional pork. Razmaitė *et al.*, (2011) additionally reported PUFA/SFA values of approximately 0.50 in wild boar intramuscular lipids, which were slightly higher than the value observed in the present study (0.40). These discrepancies may be attributed to differences in feeding regime, habitat conditions, geographical origin, seasonal variability, and carcass fatness of the animals evaluated.

Commercial pig breeds generally exhibit lower PUFA/SFA ratios associated with increased carcass fatness and greater monounsaturated fatty acid deposition. Klensporf-Pawlik *et al.*, (2012) reported TI values ranging from approximately 1.19 to 1.30 in domestic pigs, which were slightly higher than those observed in Large White pigs in the present study. This finding may indicate differences in feeding intensity, lipid metabolism, and intramuscular fat distribution between production systems.

Interestingly, despite the higher PUFA proportion observed in wild boar meat, PI values were lower than those observed in Large White pigs. This observation suggests that lipid peroxidability was influenced not only by the total PUFA content but also by the relative distribution of individual unsaturated fatty acids differing in their degree of unsaturation. Comparable relationships between

fatty acid distribution and oxidative susceptibility were reported by Quaresma *et al.*, (2011) and Pedrazzoli *et al.*, (2017), who emphasised the importance of feeding conditions, environmental variability, and seasonal dietary composition in regulating the lipid composition of free-ranging wild boars.

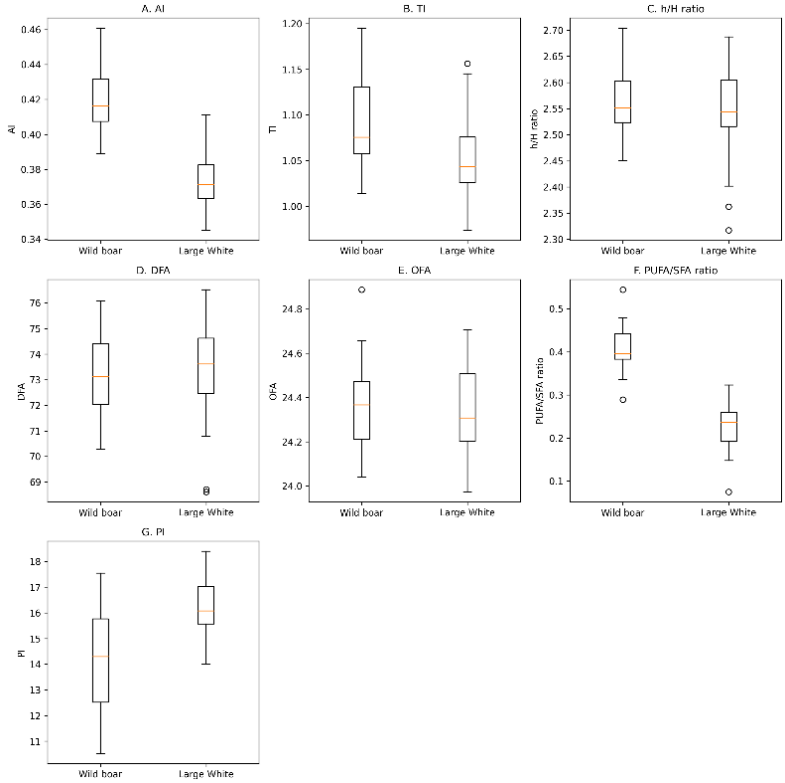

Figure 3. Multi-panel boxplots of lipid nutritional indices: (A) AI, (B) TI, (C) h/H ratio, (D) DFA, (E) OFA, (F) PUFA/SFA ratio, and (G) PI.

No significant differences were observed in the h/H ratio, DFA, or OFA between the groups, indicating a relatively similar balance between hypocholesterolaemic and hypercholesterolaemic fatty acids despite differences in overall fatty acid composition. Interestingly, Large White pigs exhibited slightly lower AI values than wild boars despite their higher saturated fatty acid deposition. This finding may reflect the substantial contribution of oleic acid and total MUFA to the hypocholesterolaemic fatty acid fraction in domestic pigs. Similar trends associated with elevated oleic acid deposition in commercial pig breeds were also reported by Marsico *et al.*, (2007).

Sales and Kotrba (2013) characterised wild boar meat as a lean raw material with a favourable lipid composition associated with increased locomotor activity and natural feeding conditions. The present findings generally support this interpretation, particularly with respect to the higher PUFA proportion and

improved PUFA/SFA ratio observed in wild boar meat. At the same time, the observed variability in lipid nutritional indices confirms that fatty acid quality is influenced by multiple interacting factors, including genotype, feeding regime, environmental conditions, and overall carcass fatness.

From a practical perspective, the favourable nutritional profile of wild boar meat, characterised by higher protein content, lower intramuscular fat deposition, and a more favourable PUFA/SFA ratio, may increase its attractiveness to health-conscious consumers seeking alternatives to conventional pork. In addition, the growing consumer interest in natural, minimally processed, and sustainably sourced foods has contributed to increased demand for game meat in several European countries. Nevertheless, consumer acceptance of wild boar meat may vary depending on cultural preferences, sensory characteristics, product availability, and concerns regarding game meat processing and safety. Therefore, further studies focusing on consumer perception, sensory quality, and market acceptance of wild boar meat products would be valuable.

These findings suggest that wild boar meat possesses a more favourable PUFA/SFA balance and a higher proportion of polyunsaturated fatty acids, whereas domestic pig meat is characterised by greater monounsaturated fatty acid accumulation and lower predicted atherogenicity.

Several limitations of the present study should be acknowledged. The compared animal groups differed not only in genotype but also in age, feeding regime, management conditions, and production system. Wild boars originated from free-ranging populations consuming natural feed resources, whereas Large White pigs were reared under controlled intensive production conditions and fed standardised commercial diets. Consequently, the observed differences cannot be attributed exclusively to species or genotype effects, as environmental and nutritional factors may also have contributed to the variation in muscle composition and lipid characteristics. Future studies using age-matched animals and more controlled feeding conditions would help to further clarify the relative contribution of genetic and environmental factors.

CONCLUSIONS

The present study revealed significant differences in the chemical composition, amino acid profile, fatty acid composition, and lipid nutritional indices of *musculus longissimus dorsi* between wild boars and Large White pigs. Wild boar meat was characterised by a higher protein content, lower intramuscular fat deposition, and a more favourable fatty acid profile, with higher PUFA proportions and a greater PUFA/SFA ratio. In contrast, Large White pigs exhibited higher MUFA and SFA contents, particularly a greater oleic acid concentration. Lipid nutritional indices further demonstrated significant differences between the experimental groups, with wild boar meat showing a more favourable PUFA/SFA balance, whereas domestic pigs exhibited lower AI and TI values. Principal component analysis confirmed a clear differentiation between wild boar and domestic pig samples based on fatty acid composition. Overall, the findings

indicate that wild boar meat represents a lean and nutritionally valuable alternative to conventional pork and confirm that genotype, feeding regime, and production system substantially influence muscle lipid composition and overall meat quality. However, the interpretation of these findings should consider differences in age, feeding regime, and production conditions between the compared animal groups.

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