





Article

Carcass Composition and Physicochemical Characteristics of Meat from Pork Chains Based on Native and Hybrid Pigs

Goran Kušec¹ , Miodrag Komlenić², Kristina Gvozdanović¹ , Velimir Sili², Marina Krvavica³ ,
Žarko Radišić¹ and Ivona Djurkin Kušec^{1,*} 

¹ Faculty of Agrobiotechnical Sciences Osijek, Josip Juraj Strossmayer University of Osijek, Vladimira Preloga 1, 31000 Osijek, Croatia; gkusec@fazos.hr (G.K.); kgvozdanovic@fazos.hr (K.G.); zradisic@fazos.hr (Ž.R.)

² Belje Plus, Ulica Svetog Ivana Krstitelja 1A, 31326 Darda, Croatia; miodrag.komlenic@belje.hr (M.K.); velimir.sili@belje.hr (V.S.)

³ Polytechnic Marko Marulić in Knin, Petra Krešimira IV 30, 22300 Knin, Croatia; mkrvavica@veleknin.hr

* Correspondence: idurkin@fazos.hr; Tel.: +385-31554868

Abstract: The purpose of the research was to investigate the carcass composition, meat quality and chemical composition of pigs from two pork chains for the production of traditional dry/cured products in Croatia. The trial involved 24 Black Slavonian barrows reared outdoors (NAT chain) and 24 PIC hybrid barrows kept under industrial conditions (INT chain); all animals were raised to 160 kg of live weight. After slaughter, carcass and meat quality traits were measured and samples for chemical composition were taken. After that, a full dissection of the carcasses was performed. The pigs from the INT pork chain had leaner carcasses, higher bone percentages, and lower fatness levels than the NAT carcasses. Pigs from the NAT chain exhibited a more desirable meat quality. No differences were found in moisture, and samples from the INT chain exhibited higher collagen and protein percentage. Muscles from the NAT chain had higher IMF and MUFA levels, and the SFA content was lower than in INT pork. Despite the superior carcass traits of the pigs from the INT chain, pigs from the NAT chain demonstrated better suitability for the production of dry/cured products.

Keywords: production system; carcass composition; meat quality; fat quality



Citation: Kušec, G.; Komlenić, M.; Gvozdanović, K.; Sili, V.; Krvavica, M.; Radišić, Ž.; Kušec, I.D. Carcass Composition and Physicochemical Characteristics of Meat from Pork Chains Based on Native and Hybrid Pigs. *Processes* **2022**, *10*, 370. <https://doi.org/10.3390/pr10020370>

Academic Editor: Dariusz Dziki

Received: 14 December 2021

Accepted: 11 February 2022

Published: 14 February 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Most of the pork today comes from modern breeds or hybrids exhibiting certain advantages over native breeds, such as a high prolificacy, very fast growth and increased lean meat percentages in the carcasses. On the other hand, those animals are extremely sensitive to microclimatic condition changes and are often prone to stress and diseases. For these reasons, the production of such pigs requires very strict management and housing conditions. Additionally, their meat is often characterized by unsatisfactory quality traits such as high drip loss, colour deterioration and reduced intramuscular fat content (IMF), thus making it less suitable for processing into products [1], especially high-quality those of high quality or labelled with protected denomination of origin (PDO) or protected geographic indication (PGI).

It is a growing trend that consumers today demand tasty, locally produced food originating from environment- and animal-friendly production systems [2]. Over 80 pork production systems in European countries have been recognized, with approximately half of them considered conventional and half considered alternative based on claims on improved eating quality, animal welfare, environmental impact, local impact, etc. [3]. Claims of higher meat quality rely on the assumption that it can be improved by choosing the appropriate breed, rearing system, and/or feeding strategy combined into a specific quality pork chain.

Some pork chains are based on local breeds kept in extensive rearing conditions, and in some chains, conventional hybrids are reared in an intensive production system

with limited specifications such as higher slaughter weight and specified minimum age at slaughter. Such management practices in this kind of pig production can lead to the improvement of meat quality [4,5], resulting in meat that is more suitable for processing into high-quality products.

Nonetheless, a number of studies have shown that a much better response to consumers' demands, in terms of animal-friendly and environmentally sustainable pig production, can be provided by local pig breeds reared in their specific traditional production systems than commercial crossbreeds from intensive production systems [6,7]. Studies involving modern and native pig breeds have demonstrated the enhanced meat and fat quality of the latter when reared in outdoor rearing systems [8], especially regarding the intramuscular fat (IMF) content and fatty acid composition [9]. Generally, it is believed that meat is tastier when IMF is higher than 1.5% [10], but for the production of pork destined for high-quality cured products, optimal fat levels are 3.5–4.0% [11]. The deposition and composition of fat are highly heritable and vary among and within breeds [12] and the age at slaughter [6]. Generally, the IMF content tends to be higher in native than in cosmopolitan breeds or hybrids. For example, it was found that crosses with Pietrain exhibited IMF values under 1.0% [10], while studies on Iberian pigs have shown IMF percentages of 3.00% up to even 19.70% [13].

The fatty acid (FA) profile, whether in adipose or muscle tissue, plays a significant role in the formation of taste but also contributes to various aspects of meat quality and the nutritional status of meat. Muscle contains significant proportions of long-chain (C20–22) PUFAs. Due to the higher incorporation of 18:2n-6 acids, pig muscle produces higher levels of 20:4n-6, resulting in higher n-6/n-3 PUFA content compared to the muscle of the ruminants [14].

Many factors influence the fatty acid profile in pigs, including breed/genetic type [14], the proportion of fat in the carcass [15], and the pig's diet. Gan et al. (2020) [6] found that the FA profile of animals raised outdoors was richer in MUFA compared to the meat of intensively raised animals due to natural feed sources rich in unsaturated fatty acids. The Black Slavonian (Crna slavonska) pig is one of the Croatian native breeds created in the early 19th century by planned crossings between the Mangalitsa, Berkshire, Poland China, and Large Black pig [16]. This is a combined meat–fatty type of pig characterized by excellent meat quality traits and rather high IMF content [17], because of which its meat is considered a delicacy when prepared as a dish, though it is much more often processed into highly valued traditional dry/cured products. The best performance of this breed is achieved when raised in extensive or semi-intensive conditions, which can lead to a higher slaughter weight of approximately 135–160 kg [18].

Therefore, the aim of the present study was to investigate and compare carcass composition and meat quality traits of pigs from two different pork chains for the production of traditional dry/cured products. One is based on a native breed, Black Slavonian (BS) pig, reared in the outdoor farming system with *ad libitum* access to feed; the other chain involves modern, hybrid pigs reared in the intensive system typical for industrial pig production, only with a prolonged fattening period.

2. Materials and Methods

2.1. Animals, Production Chains, and Slaughter Procedure

The experimental protocol was approved by the Bioethics Committee of the Faculty of Agrobiotechnical Sciences Osijek (602-04/21-01/07), and all procedures were performed in accordance with the Croatian Animal Welfare Act and other legal acts regulating animal husbandry and welfare.

Animals used in the present study originated from two production chains: one based on a Croatian native pig breed (NAT) and the other based on hybrid pigs reared in a prolonged fattening period (INT). The NAT pork chain sample consisted of Black Slavonian pig barrows ($n = 24$) and the INT chain Pietrain involved PIC (Pig Improvement Company; P337 (Pietrain \times Duroc \times Pietrain) \times Camborough 23) ($n = 24$) hybrids. The animals from

both pork chains were littermates originating from six litters farrowed within two weeks. The animals were randomly assigned to each of the treatments, and the treatments were performed in duplicate.

The NAT pork chain is a local specific system for Black Slavonian pigs kept in pastures that allow 300 m² space per pig with 80 m² of the canopy to protect animals from uncomfortable climate conditions. Feeding was based on alfalfa ad libitum, with the daily addition of 2 kg whole grains.

The INT pork chain sample consisted of PIC hybrid pigs that were reared in an intensive indoor production system with ad libitum access to food and water in a prolonged fattening period. The fatteners were group-penned. During the experiment, pigs were fed five different commercial diets consisting of 13.58 MJ/ME and 17.36 g/kg of crude protein (CP) to 30 kg of live weight (LW), 13.50 MJ/ME and 16.00 g/kg of CP from 30 to 55 kg LW, 13.05 MJ/ME and 14.00 g/kg of CP from 55 to 85 kg LW, 13.00 MJ/ME and 13.99 g/kg of CP from 85 to 115 kg LW, and 12.81 MJ/ME and 13.01 g/kg of CP from 115 to 160 kg slaughter weight.

The composition of the supplemented feed for BS fatteners and diet fed from 115 kg to approximately 160 kg LW for PIC porkers is presented in Table 1.

Table 1. Nutritional value of pig diets used in the study.

Composition	Finisher-BS	Finisher-PIC
Dry matter, %	-	88.340
Crude protein, %	13.230	13.008
ME, MJ/kg	12.91	12.81
Crude fibre, %	5.840	5.999
Crude fat, %	2.840	3.224
Ash, %	4.360	4.406
Methionine, %	-	0.265
Methionine + cysteine, %	0.410	0.476
Lysine, %	0.710	0.696
Threonine, %	-	0.452
Thryptofane, %	-	0.1498
Ca, %	0.740	0.7458
Phosphate, %	-	0.365
Moisture, %	-	11.312
Vitamin K, mg/kg	-	4877.530
Vitamin A, IJ/kg	5200.000	6400.401
Vitamin D3, IJ/kg	960.000	960.000
Vitamin E, mg/kg	-	40.000
Phytase	400.000	400.000
Neutral detergent fibre, %	-	14.677
Acid detergent fibre, %	-	9.500

BS—Black Slavonian pig; PIC—Pig Improvement Company.

After reaching the designated LW of 160 ± 3 kg (at the approximate age of 2 years for pigs from the NAT chain and 7 months for pigs from the INT chain), the animals were transported to a near abattoir where they were exsanguinated following stunning with CO₂. To enhance pig welfare, food safety and meat quality, animals were fasted for 18 h before slaughter.

2.2. Carcass Traits

After 24 h of cooling, carcass length (distance from the cranial edge of *Os pubis* to the cranial edge of the 1st rib) and ham length (from the anterior edge of the *Symphysis ossis pubis* to the hock joint), together with the ham circumference at its widest point, were measured. The ham index was determined as the ratio between ham length and ham circumference. Muscle thickness and fat thickness were determined using the “Two points (TP)” method approved in Croatia [19].

At the slaughterhouse after 24 h of cooling, the left sides of the pig carcasses were dissected according to the modified “Kulmbach” method [20], as schematically presented in Figure 1. The main parts were then further dissected into muscle tissue, fatty tissue (intermuscular and subcutaneous with skin) and bone, and then they were weighed. The weights of the parts (dissected and non-dissected) were measured using a Mettler-Toledo Viper SW 15 scale (Mettler-Toledo, Greifensee, Switzerland).

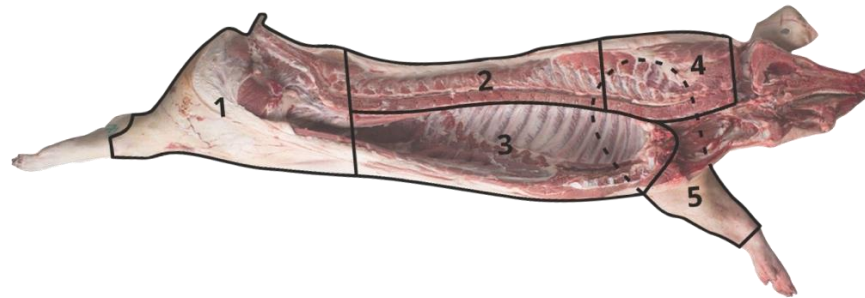


Figure 1. Dissection scheme for the modified “Kulmbach” method (1. ham; 2. loin; 3. belly/rib; 4. neck; 5. shoulder).

2.2.1. Meat Quality Traits

Post mortem measurements of muscle pH were determined at *longissimus thoracis et lumborum* (LTL) muscle 45 min (pH_{45}) and 24 h (pH_{24}) after slaughter with an HI 99613 portable meat pH meter (Hanna Instruments, Woonsocket, RI, USA). Drip was measured using the EZ-DripLoss method [21] after 48 h of cooling at 4 °C. The Colour of the LTL samples (the average of three measurements) was evaluated after 20 min of blooming using a Minolta CR-410 colourimeter (Minolta Camera Co. Ltd., Osaka, Japan) with a D65 light source and 10-degree standard observer. Light reflectance scores for CIE $L^*a^*b^*$, chroma (saturation; C^*) and hue angle (h°) were determined.

2.2.2. Chemical Composition and Fatty Acids

The chemical composition of the samples was determined using standard analytical methods (moisture, [22]; total fat, [23]; nitrogen, [24]). The fatty acid composition of subcutaneous fat and IMF was determined with gas chromatography following lipid transesterification. Samples of LL muscle were homogenized and prepared according to ISO 3100-1:1991 [25]. Total fat content was determined using the Soxhlet method [23], in which the samples are digested with acid hydrolysis and the fats are then extracted with petroleum ether using a Soxtherm 2000 automated device (Gerhardt, Munich, Germany). The obtained lipids were converted into fatty acid methyl esters (FAMES) for gas chromatography (GC) analysis [26]. Approximately 60 mg (± 10 mg) of the extracted fat were dissolved in 4 mL of isoctane. A methanolic potassium hydroxide solution (13.6 g KOH in 100 mL of methanol; 200 μL) was added and shaken vigorously twice for 30 sec with a 30-sec interval. The solution was then neutralized with 1 g of sodium hydrogen sulphate monohydrate. When crystals precipitated, 500 μL of the solution were transferred into a vial, and 1 mL of isoctane was added. The container was sealed and shaken for 30 s. The fatty acid composition was determined with the procedure described by Petrović et al. (2010) [27] using a GC/MS 5975C device (Agilent Technologies, Palo Alto, CA, USA) equipped with a flame ionization detector and split/splitless injector. For injection, a TriPlus auto-sampler (Thermo Scientific, Austin, TX, USA) was used. Individual fatty acids in the sample were identified from the retention times of authentic standards (F.A.M.E C8–C24, Supelco, Bellefonte, PA, USA). Peak areas were determined using a Varian 4290 integrator, and the results were expressed as percentages of total identified fatty acids. The index of atherogenicity (IA) was calculated according to the formula proposed by Chen and Liu (2020) [28].

2.3. Statistical Analysis

The obtained data were analysed using the one-way ANOVA procedure of Dell Statistica (2015) [29]; the Tuckey HSD test was used for the determination of significance between the investigated groups of pigs. Violin plots were plotted using the ggpubr [30] and ggplot2 [31] package in the R environment [32].

3. Results and Discussion

3.1. Carcass Traits

Carcass traits of the investigated pigs are presented in Table 2. At the predetermined LW of 160 kg, the Black Slavonian pigs from the NAT pork chain had lower muscle thickness and significantly higher ($p < 0.001$) fat thickness than the INT fatteners, and the fatteners from the NAT chain showed a higher production of fat ($p < 0.05$) and lower leanness ($p < 0.05$) those from the INT chain. These results are in line with the results reported for other European and Asian native breeds, which are not selected for leaner carcasses and so exhibit higher fat thickness values than different genetic lines of modern pig breeds [33,34].

Table 2. Means \pm standard deviations for carcass traits of pigs from two pork chains.

Trait	NAT Pork Chain	INT Pork Chain	F Value	Significance (p)
Hot half-carcass weight, kg	69.81 \pm 3.81	69.51 \pm 1.62	0.116	0.7382
Dressing percentage, %	86.29 \pm 1.56	85.48 \pm 1.13	1.380	0.2612
TP fat thickness, mm	60.63 \pm 6.72	28.13 \pm 4.22	1.615	0.0001
TP muscle thickness, mm	66.25 \pm 8.61	81.00 \pm 7.80	17.067	0.0031
Carcass length, cm	97.63 \pm 2.83	101.88 \pm 3.83	4.470	0.0244
Ham length, cm	34.38 \pm 2.72	37.75 \pm 1.75	10.332	0.0107
Ham circumference, cm	78.00 \pm 2.88	84.38 \pm 2.33	29.600	0.0004
Ham weight, kg	15.99 \pm 1.24	17.28 \pm 1.03	5.121	0.0401
Ham in the carcass, %	22.94 \pm 1.95	24.92 \pm 1.29	5.773	0.0308
Loin weight, kg	12.70 \pm 1.26	11.38 \pm 0.48	7.743	0.0148
Loin in the carcass, %	18.18 \pm 1.29	16.42 \pm 0.58	12.456	0.0034
Shoulder weight, kg	10.68 \pm 1.07	11.60 \pm 1.06	3.036	0.1034
Shoulder in the carcass, %	15.34 \pm 1.88	16.74 \pm 1.51	2.665	0.1250
Belly/rib weight, kg	14.69 \pm 1.46	13.20 \pm 1.10	5.344	0.0366
Belly/rib in the carcass, %	21.02 \pm 1.38	19.04 \pm 1.42	8.083	0.0131
Neck weight, kg	5.49 \pm 0.91	5.51 \pm 0.51	0.004	0.9520
Neck in the carcass, %	7.88 \pm 1.42	7.94 \pm 0.67	0.013	0.9109
Tenderloin weight, kg	0.40 \pm 0.04	0.75 \pm 0.11	68.092	0.0001
Tenderloin in the carcass, %	0.57 \pm 0.07	1.08 \pm 0.16	69.702	0.0001

TP—Two points method.

Compared to the INT fatteners, pigs from the NAT chain exhibited shorter carcass lengths, shorter ham lengths, and smaller circumferences. In line with the results obtained for the carcass traits, the dissection of the carcasses showed that the INT pigs were characterised by higher weights of ham, shoulder, neck, and tenderloin. On the other hand, pigs from the NAT pork chain produced carcasses with a higher weight of the belly/rib part, which corresponds to the combined production type of this breed with the affinity for a more pronounced production of adipose tissue in their carcasses. These results are similar to those reported by Wojtysiak and Połtowicz (2014) [34] for the native Puławska breed and Polish Large White pigs slaughtered at 100 kg LW. Interestingly, a higher loin weight (and its share in the carcass) in BS pigs from the NAT chain than in heavy fatteners from the INT pork chain was observed. Contrary to the results of this study, both Puławska and Creole breeds exhibited lower loin weights compared to modern pig breeds when slaughtered at 100 and 90 kg LW, respectively [34,35]. The disagreement between our findings and results on Puławska and Creole breeds probably occurred due to the lower age and slaughter weight of pigs from these trials compared to the LW and the age of animals from the present study.

The composition of pig carcasses obtained by dissection, providing thorough insight into different tissues of the main parts, is presented in Table 3.

Table 3. Means \pm standard deviations of dissected tissues originating from investigated half-carcasses.

Cut	Tissue	NAT Pork Chain		INT Pork Chain		F Value	Significance (<i>p</i>)
		Weight, kg	Share, %	Weight, kg	Share, %		
Ham	Muscle	6.77 \pm 0.48	42.44 \pm 3.11	10.61 \pm 0.76	61.42 \pm 1.97	145.744	0.0001
	Fat	7.85 \pm 0.95	48.97 \pm 3.32	4.67 \pm 0.49	27.05 \pm 2.82	70.114	0.0001
	Bones	1.37 \pm 0.16	8.58 \pm 0.78	1.99 \pm 0.24	11.53 \pm 1.09	36.543	0.0001
Loin	Muscle	3.05 \pm 0.45	24.06 \pm 2.78	5.50 \pm 0.55	48.35 \pm 3.96	96.252	0.0001
	Fat	8.42 \pm 1.04	66.18 \pm 3.86	4.21 \pm 0.48	37.01 \pm 4.34	107.214	0.0001
	Bones	1.24 \pm 0.16	9.77 \pm 1.32	1.67 \pm 0.19	14.64 \pm 1.34	23.554	0.0004
Shoulder	Muscle	4.99 \pm 1.03	46.43 \pm 5.86	6.45 \pm 0.67	55.59 \pm 3.06	11.257	0.0048
	Fat	4.78 \pm 0.56	45.08 \pm 5.94	3.92 \pm 0.52	33.76 \pm 2.58	10.121	0.0068
	Bones	0.90 \pm 0.10	8.49 \pm 0.83	1.23 \pm 0.10	10.65 \pm 1.02	41.786	0.0001
Belly/rib	Muscle	3.97 \pm 0.59	26.98 \pm 2.76	6.15 \pm 0.8	46.59 \pm 4.42	37.432	0.0001
	Fat	9.80 \pm 1.09	66.66 \pm 2.65	5.66 \pm 0.62	42.96 \pm 4.25	86.938	0.0001
	Bones	0.93 \pm 0.10	6.36 \pm 0.84	1.39 \pm 0.37	10.45 \pm 2.27	11.484	0.0045
Neck	Muscle	2.21 \pm 0.39	40.44 \pm 3.78	3.09 \pm 0.38	56.03 \pm 3.26	20.853	0.0005
	Fat	2.58 \pm 0.52	46.82 \pm 2.73	1.51 \pm 0.23	27.34 \pm 3.43	28.210	0.0002
	Bones	0.69 \pm 0.15	12.75 \pm 2.19	0.91 \pm 0.11	16.63 \pm 1.92	10.823	0.0055
Total in cuts	Muscle	21.38 \pm 1.53	35.68 \pm 2.11	32.56 \pm 2.03	54.51 \pm 2.00	334.414	0.0001
	Fat	33.42 \pm 2.41	55.74 \pm 2.48	19.96 \pm 1.48	33.45 \pm 2.45	327.792	0.0001
	Bones	5.13 \pm 0.47	8.58 \pm 0.83	7.19 \pm 0.57	12.04 \pm 0.74	77.405	0.0001

As expected, the carcasses of commercial hybrids from the INT pork chain were superior to those of the BS pigs from the NAT chain regarding muscle tissue. These carcasses also had more bone in all of the cuts. On the other hand, native breeds, which are not subjected to selection based on accelerated growth rates and increased muscle production, are prone to produce more fat in the carcasses [36], as in the present case. In all dissected cuts, pigs from the NAT chain had higher weights and shares of fat tissue, demonstrating their ability to deposit adipose tissue, especially in terms of subcutaneous and intermuscular fat. This greater affinity for the accretion of adipose tissue is even more pronounced at higher slaughter weights when the proportion of adipose tissue increases and lean tissue declines [37]. In the present study, pigs were slaughtered at approximately 160 kg LW, which is considered to be optimal for the production of dry/cured products [38], so a higher share of adipose tissue in all dissected parts of the carcasses originating from both pork chains was observed. In the investigation comparing the carcass traits of Iberian pigs (IB) with F1 crossbreds of the Large White \times Landrace (LW \times L) cross raised to approximately 160 kg LW, lower mean weights ($p < 0.05$) of ham, neck, and tenderloin in the IB pigs relative to LW \times L crosses were found; these results comply with those of the present study, although the difference for the neck weight in our study was not significant ($p > 0.05$). The mean weight of the belly was higher in IB pigs than in F1 LW \times L pigs ($p < 0.05$), which is also consistent with the findings of the present study. Additionally, in their research on the local Basque breed, Le Bret et al. (2014) [39] found that the Basque breed exhibited a lower proportion of hams than Large White pigs, which is in accordance with the results of our study. Despite the differences in the presentation of cuts, the results regarding the shares of ham and shoulder of Spanish native breed (Cerdo Iberico) slaughtered at heavy weights (156–170 kg) were similar to those obtained in this study [40,41]. Similar relations of main tissues in local unselected breeds were also found by other authors [42,43].

The carcass composition of pigs from the INT pork chain in terms of cuts in the present study was similar to those in other populations of pigs selected for high lean yields slaughtered at heavier live weights, e.g., in Brazilian crossbred pigs researched by Bertol et al. (2015) [42].

3.2. Meat Quality

The differences in meat quality traits between fatteners from investigated pork chains are presented in Table 4.

Table 4. Meat quality traits (means \pm standard deviations) of animals from two pork chains.

Trait	NAT Pork Chain	INT Pork Chain	F Value	Significance (<i>p</i>)
pH ₄₅	6.44 \pm 0.11	6.08 \pm 0.19	22.010	0.0005
pH ₂₄	5.92 \pm 0.39	5.45 \pm 0.05	11.670	0.0043
EZ drip, %	2.40 \pm 2.44	7.46 \pm 3.18	12.719	0.0032
L*	45.94 \pm 4.11	56.29 \pm 3.78	27.479	0.0003
a*	10.46 \pm 1.41	11.23 \pm 2.68	0.519	0.4834
b*	2.18 \pm 1.22	3.85 \pm 2.08	3.827	0.0708
c*	10.72 \pm 1.55	11.93 \pm 3.13	0.956	0.3450
h ^o	11.23 \pm 5.76	17.84 \pm 6.63	4.528	0.0517

The Black Slavonian pigs from the NAT chain had higher pH values (both initial and final), lower drip, lightness (L*), yellowness (b*) and hue angle (h^o) than the INT hybrids. It is well-known that the pH value significantly contributes to the overall quality of meat and is dependent on many pre-slaughter factors, with genetic background and stress being predominant [44]. Although the pH measured 45 min post mortem was at an acceptable level in both breeds, the ultimate pH value measured 24 h after the slaughter was quite low in pigs from the INT chain (<5.5 ; $p = 0.0043$) indicating a faster rate of post mortem glycolysis due to higher amount of fast twitch oxidative fibres observed in modern breeds, as well as their higher stress susceptibility compared to native breeds [45]. In agreement with the present results, the local Basque breed also exhibited higher initial and final pH values compared to fatteners originating from the modern Large White breed [39]. On the other hand, in research comparing the meat quality of Casertana native pig and modern breeds (Duroc and Large White), Maiorano et al. (2013) [46] reported higher initial pH values in the Casertana breed, though no difference was found between breeds in pH₂₄ value. The observed pH₂₄ of the Black Slavonian pig was shown to be higher than that of both Bisaro and Alentejano pigs [47], as well as Cinta Senese pigs [48], indicating the lower glycolytic capacity of the Black Slavonian pig compared to these two Portuguese and one Italian indigenous pig breeds.

A significant difference in drip loss between meat samples from investigated pork chains was observed, with meat from the NAT chain showing a favourable value for this trait. On the other hand, meat from the INT pork chain exhibited excessively high drip ($p = 0.0032$). The low drip-loss values determined in the NAT chain were associated with the higher pH of their LL muscles compared to modern hybrids, but the age of the animals, which was higher in animals in the NAT chain than those in the INT pork chain, also contributed. On the other hand, the drip loss of the meat from the NAT chain was higher than that reported for Cinta Senese pigs (1.89%; [48]), Basque pig (0.55–1.11%; [47]) and both Bisaro and Alentejano pigs (1.92% and 0.59%; [47]). However, this difference between native pig breeds has no practical importance, as it was favourable in all cases. Compared to PIC pigs from the INT chain, meat originating from the NAT pork chain was darker (lower L* values); however, no significant difference was observed for a* values. In line with the results of this study, Serra et al. (1998) [49] determined lower L* values in Iberian pigs (Guadyerbas line) compared to Landrace pigs, but no significant differences between the two breeds were observed for a*. The authors concluded that the darker meat of the Iberian pig is probably a result of the higher percentage of haem pigments found in this breed. On the other hand, opposite to the results of our study, meat from the Casertana breed had darker meat, though it also had a more pronounced red colour, than the meat from Duroc crosses and Large White animals [46].

Meat from the NAT pork chain animals tended to be less yellow with a lower hue angle compared to meat from the INT chain ($p = 0.0517$), indicating that meat from

BS pigs diverged less from the true red axes [50]. In concordance with our results, Serra et al. (1998) [49] also reported lower h° values in meat from Iberian pigs compared to meat from modern breeds. The obtained h° values of meat originating from BS pigs was lower than values obtained for the Casertana breed [46], as well as Alentejano pig and Bisaro pigs [47].

3.3. Chemical Composition and Fatty Acid Profile

As shown in Table 5, significant differences between analysed groups for most of the chemical compounds were observed. Meat samples from the INT chain had a higher collagen content ($p = 0.0002$) and protein percentage ($p = 0.0006$) compared to the NAT chain pork. On the other hand, no significant differences were found for the moisture content between investigated groups.

Table 5. Chemical composition of LTL muscle (means \pm standard deviations) according to pork chain.

Trait	NAT Pork Chain	INT Pork Chain	F Value	Significance (p)
Collagen, %	1.11 \pm 0.03	1.30 \pm 0.06	51.983	0.0002
Moisture, %	72.11 \pm 2.27	73.27 \pm 2.45	0.730	0.4129
Protein, %	21.75 \pm 0.94	24.57 \pm 0.98	25.885	0.0006
IMF, %	5.16 \pm 3.34	1.60 \pm 0.78	6.467	0.0294

IMF—intramuscular fat content.

In agreement with the present results, lower collagen contents were reported for the French native Basque pig compared to the Large White breed [46] and for the Nero Siciliano breed compared to the Landrace breed [51]. As argued by Lebret et al. (2015) [45] the difference between autochthonous and conventional breeds in collagen content indicates its lower ‘dilution rate’ by muscle fibres in autochthonous breeds, as well as the higher thermal stability of collagen. Opposite to the present results, Kasprzyk and Bogucka (2020) [1] found a higher protein content in the Puławska breed than in the DanBred commercial hybrid. The lower protein content found in meat from the NAT pork chain could be due to the larger adipogenic profile of BS pigs compared to the leaner PIC hybrids from the INT chain.

A significantly higher IMF percentage ($p = 0.0294$) was observed in the meat of NAT chain pigs than in the INT chain (Table 5). According to Bejerholm and Barton-Gade (1986) [52], only an IMF content higher than 2% can have noticeable effects on sensory attributes of pork, and the benchmark for optimal taste and consumer acceptability is between 2.5 and 3.0% [53]. The mean value for meat from the NAT chain in this study was well-above this range, while the INT chain meat exhibited an IMF average even lower than 2.0%, indicating the lower sensory acceptability of their meat compared to meat originating from the NAT pork chain. The observed capacity for increased IMF content in BS pigs is predominantly a consequence of the breed’s history and the contribution of Chinese breeds to its development, but it could also be attributed to the fact that native pig breeds have a higher capacity for lipid deposition [54] and a higher oxidative muscle metabolism compared to modern breeds, as reviewed by Poklucar et al. (2020) [36].

The obtained IMF values for the meat from the NAT chain were higher than those reported for Krškopolje [55], Celta [56] and Prestice Black-Pied [57] pigs, but they were lower than those for Iberian [58] and Laiwu [59] pigs.

We noted a high variability in IMF content of meat from the NAT pork chain (Table 5), indicating the need to carefully select individuals for crossbreeding. This variation in IMF seems, however, to be quite characteristic for local unselected breeds, as similar variations have also been reported in other European local pig breeds, e.g., Alentejano pig, Majorcan Black pig, Mora Romagnola pig, Swallow-belly Mangalitza, Cinta Senese pig, Iberian pig, Nero siciliano pig, Turopolje pig and Nero Casertano breed [13].

The fatty acid profile of LTL muscle in the two investigated pork chains is presented in Table 6.

Table 6. Fatty acid profile (means \pm standard deviations) of longissimus thoracis et lumborum muscle according to pork chain.

Fatty Acid, % of Total Fatty Acids	Pork Chain		F Value	Significance (<i>p</i>)
	NAT	INT		
C10:0	0.089 \pm 0.04	0.000 \pm 0.00	Inf.	0.0036
C12:0	0.077 \pm 0.03	0.000 \pm 0.00	Inf.	0.0002
C14:0	1.459 \pm 0.04	1.430 \pm 0.02	0.003	0.5894
C14:1	0.016 \pm 0.01	0.000 \pm 0.00	8.100	0.3770
C15:0	0.014 \pm 0.10	0.260 \pm 0.10	0.986	0.0001
C16:0	26.534 \pm 0.90	28.690 \pm 0.10	0.693	0.0009
C16:1 n-7	4.353 \pm 0.69	2.710 \pm 0.59	1.251	0.0013
C17:0	0.131 \pm 0.10	0.370 \pm 0.08	3.500	0.0005
C17:1	0.155 \pm 0.03	0.210 \pm 0.03	3.300	0.0538
C18:0	11.891 \pm 1.78	16.120 \pm 1.90	18.902	0.0013
C18:1 n-9	48.410 \pm 3.68	40.410 \pm 2.90	16.664	0.0185
C18:2 n-6	5.100 \pm 1.34	7.730 \pm 1.25	21.516	0.0560
C18:3 n-3	0.108 \pm 0.05	0.000 \pm 0.00	Inf.	0.0041
C19:0	0.010 \pm 0.01	0.000 \pm 0.00	Inf.	0.4011
C20:0	0.240 \pm 0.04	0.330 \pm 0.03	5.000	0.0208
C20:4 n-6	1.191 \pm 0.50	0.340 \pm 0.44	1.645	0.1259
C22:0	0.064 \pm 0.18	0.490 \pm 0.20	1.569	0.0001
C22:1 n-9	0.025 \pm 0.10	0.260 \pm 0.08	0.986	0.0001
C22:2 n-6	0.015 \pm 0.01	0.000 \pm 0.01	Inf.	0.3809
C24:0	0.059 \pm 0.03	0.000 \pm 0.02	Inf.	0.1189
C24:1 n-9	0.057 \pm 0.03	0.000 \pm 0.02	Inf.	0.0420
Σ MUFA, %	53.017 \pm 1.826	43.867 \pm 0.514	67.932	0.0001
Σ PUFA, %	6.4140 \pm 1.297	8.280 \pm 0.187	5.754	0.0533
Σ SFA, %	40.569 \pm 0.690	46.856 \pm 0.370	187.588	0.0001
Σ n-6, %	6.306 \pm 1.285	8.280 \pm 0.187	6.5708	0.0423
Σ n-3, %	0.108 \pm 0.107	0.000 \pm 0.00	117.946	0.0001
PUFA/SFA	0.158 \pm 0.031	0.177 \pm 0.007	1.0568	0.3430
IA	1.260 \pm 0.312	1.189 \pm 0.024	0.1424	0.7189

SFA—saturated fatty acids; MUFA—monounsaturated fatty acids; PUFA—polyunsaturated fatty acids; IA—index of atherogenicity.

Meat samples from the NAT chain significantly differed from those from the INT chain in almost all investigated fatty acids. It is known that saturated fatty acids increase the risk of diabetes and cardiovascular diseases, while unsaturated fatty acids are beneficial for human health and associated with meat flavour [14,60]. Compared to the INT samples, NAT chain LTL muscles had significantly lower proportions of potentially harmful palmitic acid (C16:0) and higher proportions of beneficial unsaturated fatty acids, such as palmitoleic acid (C16:1n-7), oleic acid (C18:1n-9), gamma-linoleic acid (C18:3n-6) and nervonic acid (24:1n-9). Additionally, the NAT chain samples exhibited lower proportions of stearic C18:0 fatty acid, which (together with palmitic C16:0) is an indicator of *de novo* lipogenesis, suggesting not only a lower activity of the malic enzyme in their fatty tissue [39] but also that meat from the NAT pork chain is more tender than INT chain samples, as this is a fatty acid with the largest influence on meat firmness [13].

It is known that one of the key factors influencing fatty acid composition is the animal's diet, as animals fed on grass or in woodland usually exhibit higher levels of polyunsaturated and monounsaturated fatty acids, as well as decreased levels of saturated fatty acids, compared to animals reared indoors and fed conventional diets. It can be observed from Table 6 that compared to the INT chain, meat from BS animals from the NAT chain exhibited a higher share ($p = 0.001$) of monounsaturated fatty acids and lower shares of PUFA ($p = 0.0533$) and SFA ($p = 0.0001$) in their total fatty acids.

The results of the present study are consistent with the results regarding other local breeds reared outdoors and fed either grass, acorn, or chestnut [48], as well as with reports on the fatty acid composition of Prestice Black-Pied breed and Puławska pig

breeds raised indoors [1,57]. Furthermore, in their investigation on the differences between the French local Basque breed and the Large White breed reared in conventional and production systems to LW of 145 kg, Lebret et al. (2014) [39] found that Basque pigs reared outdoors had increased MUFA and PUFA levels and a decreased SFA share in total fatty acids compared to both Basque animals reared intensively and Large White pigs kept in a conventional production system. The authors concluded that alternative production systems (mainly outdoor) influenced the fatty acid composition within each of the studied breeds. Opposite to our findings, Yu et al. (2013) [61] found a significantly lower MUFA percentage in the Lantang breed than in Landrace pigs, while Barea et al. (2013) [62] and Serra et al. (1998) [49] found that Iberian pigs raised in intensive production system to up to 100–115 kg of LW had higher proportions of SFA and PUFA compared to modern breeds kept in the same production system. The observed discrepancy in PUFA content between those studies and our investigation can be attributed to the higher age of the animals in the present study at which the deposition rate of MUFA is much larger than PUFA. It is well-known that pigs cannot produce PUFA and their content in fatty tissue is dependent on the PUFA incorporated into their diet. High dietary PUFA has the ability to decrease de novo fat synthesis and total SFA content [63]. From Table 6, it can be observed that the LTL muscle of animals from the INT chain had higher total PUFA and SFA content compared to those from the NAT chain, indicating the possibility to optimise the contents of fatty acids in both breeds through diet.

On the other hand, the attempts to enhance the nutritional quality by increasing MUFA and PUFA contents can lead to a range of problems, including the reduced shelf life caused by the rapid lipid oxidation for which PUFA are susceptible. Moreover, the oxidation of lipids can significantly deteriorate the sensory traits of pork products such as flavour, texture, mouth feel, and juiciness [64].

The main parameters used for the assessment of lipid nutritional quality are the PUFA/SFA ratio, which should be around 0.4 [65], and the index of atherogenicity (IA), which characterizes the atherogenic potential of fatty acids and in meat ranges from 0.165 to 1.32 [28]. In meat samples originating from both chains studied here, the PUFA/SFA ratio was around 0.16, which is well-below the proposed threshold and also in line with the results of studies on other local and modern pig breeds [66,67]. The atherogenic potential of the investigated meat samples was within the expected range. No significant differences ($p > 0.05$) were observed between investigated pork chains for the two nutritional quality indices.

4. Conclusions

The results of this study showed major differences in carcass traits, meat quality, and chemical composition between the meat from the NAT and INT pork chains, with NAT chain samples presenting overall better meat quality traits and higher IMF percentages. Additionally, NAT samples had a higher MUFA content and decreased SFA content compared to INT chain meat, indicating a need for the optimization of the diet composition administered as either additional in case of BS pigs from NAT or base in PIC hybrid pigs from the INT chain. Additionally, the improvement of a production system environment with more movement and less fighting could be beneficial for the improvement of meat quality traits in the INT chain.

Due to the observed differences, predominantly in meat quality and chemical composition (especially regarding the fatty acid profile), it can be concluded that meat from the NAT chain, despite the lower leanness of their carcasses, is more suitable for the production of dry/cured products. These results can serve as a basis for the branding of special commodities for a niche market originating from pork chains based on native pig breeds kept in extensive production systems.

Author Contributions: Conceptualization, G.K., V.S. and M.K. (Miodrag Komlenić); methodology, Ž.R. and M.K. (Marina Krvavica); software, K.G.; validation, G.K., I.D.K. and K.G.; formal analysis, M.K. (Marina Krvavica); investigation, Ž.R., G.K. and I.D.K.; resources, V.S. and M.K. (Miodrag

Komlenić); writing—original draft preparation, G.K., I.D.K. and K.G.; visualization, K.G.; funding acquisition, G.K. All authors have read and agreed to the published version of the manuscript.

Funding: This work was funded by Croatian Science Foundation (grant number 3396 (“SciBra Pork)) and co-financed by the European Union’s Horizon 2020 research and innovation programme, (grant number 634476 (project acronym TREASURE)) and QualSec research team of Faculty of Agrobiotechnical Sciences Osijek.

Institutional Review Board Statement: The study was conducted in accordance with the Croatian Animal Welfare Act and other legal acts regulating animal husbandry and welfare, and approved by the Bioethics Committee of the Faculty of Agrobiotechnical Sciences Osijek (602-04/21-01/07; 17 March 2021).

Data Availability Statement: The data obtained in the experiment can be retrieved from the corresponding author upon reasonable request.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Kasprzyk, A.; Bogucka, J. Meat quality of Pulawska breed pigs and image of longissimus lumborum muscle microstructure compared to commercial DanBred and Naima hybrids. *Arch. Anim. Breed.* **2020**, *63*, 293–301. [[CrossRef](#)]
2. Pietroseoli, S.; Tang, C. Animal Welfare and Production Challenges Associated with Pasture Pig Systems: A Review. *Agriculture* **2020**, *10*, 223. [[CrossRef](#)]
3. Bonneau, M.; Lebret, B. Production systems and influence on eating quality of pork. *Meat Sci.* **2010**, *84*, 293–300. [[CrossRef](#)] [[PubMed](#)]
4. Candek-Potokar, M.; Zlender, B.; Lefaucheur, L.; Bonneau, M. Effects of age and/or weight at slaughter on longissimus dorsi muscle: Biochemical traits and sensory quality in pigs. *Meat Sci.* **1998**, *48*, 287–300. [[CrossRef](#)]
5. Durkin, I.; Dadić, M.; Brkić, D.; Lukić, B.; Kušec, G.; Mikolin, M.; Jerković, I. Influence of gender and slaughter weight on meat quality traits of heavy pigs. *Acta Agric. Slov.* **2012**, *100*, 3.
6. Gan, M.; Shen, L.; Chen, L.; Jiang, D.; Jiang, Y.; Li, Q.; Chen, Y.; Ge, G.; Liu, Y.; Xu, X.; et al. Meat Quality, Amino Acid, and Fatty Acid Composition of Liangshan Pigs at Different Weights. *Animals* **2020**, *10*, 822. [[CrossRef](#)] [[PubMed](#)]
7. Nevrkla, P.; Kapelański, W.; Václavková, E.; Hadaš, Z.; Cebulska, A.; Horký, P. Meat Quality and Fatty Acid Profile of Pork and Backfat from an Indigenous Breed and a Commercial Hybrid of Pigs. *Ann. Anim. Sci.* **2017**, *17*, 1215–1227. [[CrossRef](#)]
8. Galian, M.; Poto, Á.; Santaella, M.; Peinado, B. Effects of the rearing system on the quality traits of the carcass, meat and fat of the Chato Murciano pig. *Anim. Sci. J.* **2008**, *79*, 487–497. [[CrossRef](#)]
9. Ambrosio, R.L.; Smaldone, G.; Di Paolo, M.; Vollano, L.; Ceruso, M.; Anastasio, A.; Marrone, R. Effects of Different Levels of Inclusion of Apulo-Calabrese Pig Meat on Microbiological, Physicochemical and Rheological Parameters of Salami during Ripening. *Animals* **2021**, *11*, 3060. [[CrossRef](#)]
10. Fortin, A.; Robertson, W.M.; Tong, A.K.W. The eating quality of Canadian pork and its relationship with intramuscular fat. *Meat Sci.* **2005**, *69*, 297–305. [[CrossRef](#)]
11. Sadurní, J.R. Joint genetic improvement of lean meat content and intramuscular fat in pork. *Prod. Anim.* **2004**, *199*, 50–62.
12. Kasprzyk, A. Characteristics of genetic parameters and genetic gain in breeding herd of PL pigs over 25-year breeding work period. *Arch. Tierz.* **2007**, *50*, 107–115.
13. Nieto, R.; García-Casco, J.; Lara, L.; Palma-Granados, P.; Izquierdo, M.; Hernandez, F.; Dieguez, E.; Luis Duarte, J.; Batorek-Lukač, N. Ibérico (Iberian) Pig. In *European Local Pig Breeds—Diversity and Performance. A Study of Project Treasure*; Čandek Potokar, M., Nieto, R.M., Eds.; IntechOpen: London, UK, 2019; pp. 115–141.
14. Wood, J.D.; Richardson, R.I.; Nute, G.R.; Fisher, A.V.; Campo, M.M.; Kasapidou, E.; Sheard, P.R.; Enser, M. Effects of fatty acids on meat quality: A review. *Meat Sci.* **2004**, *66*, 21–32. [[CrossRef](#)]
15. Wood, J.D.; Enser, M.B.; MacFie, H.J.H.; Smith, W.C.; Chadwick, J.P.; Ellis, M.; Laird, R. Fatty acid composition of backfat in large white pigs selected for low backfat thickness. *Meat Sci.* **1978**, *2*, 289–300. [[CrossRef](#)]
16. Margeta, V.; Gvozdanović, K.; Kušec, G.; Djurkin Kušec, I.; Batorek-Lukač, N. Black Slavonian (Crna slavonska) Pig. In *European Local Pig Breeds—Diversity and Performance. A Study of Project Treasure*; Čandek Potokar, M., Nieto, R.M., Eds.; IntechOpen: London, UK, 2019; pp. 87–101.
17. Karolyi, D.; Salajpal, K.; Sinjeri, Ž.; Kovačić, D.; Jurić, I.; Đikić, M. Meat quality, blood stress indicators and trimmed cut yield comparison of Black Slavonian pig with modern pigs in the production of Slavonian kulen. *Acta Agric. Slov.* **2004**, *1*, 67–72.
18. Gvozdanović, K.; Margeta, V.; Kušec, I.D.; Margeta, P.; Radišić, Ž.; Kušec, G. Comparison of carcass and meat quality traits of Black Slavonian pigs regarding the duration of fattening period. *Arch. Zootec.* **2018**, *1*, 205–208.
19. FAO. *Regulation on Classification and Identification of Beef, Pig and Sheep Carcasses and on Labelling of Meat from Beef Younger Than 12 Months*; Pub. L. No. NN 71/2018, LEX-FAOC135783; FAO: Rome, Italy, 2018.
20. Commission of the European Communities. *Development of Uniform Methods of Pig Carcase Classification in EC*; Information on Agriculture Series No. 70; CEC: Brussels, Luxembourg, 1979.

21. Christensen, L.B. Drip loss sampling in porcine m. longissimus dorsi. *Meat Sci.* **2003**, *63*, 469–477. [[CrossRef](#)]
22. ISO 1442:1997; Meat and Meat Products—Determination of Moisture Content (Reference Method). ISO: Geneva, Switzerland, 1997.
23. ISO 1443:1973; Meat and Meat Products—Determination of Total Fat Content. ISO: Geneva, Switzerland, 1993.
24. ISO 937:1978; Meat and Meat Products—Determination of Nitrogen Content (Reference Method). ISO: Geneva, Switzerland, 1978.
25. ISO 3100-1:1991; Meat and Meat Products—Sampling and Preparation of Test Samples—Part 1: Sampling. ISO: Geneva, Switzerland, 1991.
26. Aldai, N.; Kramer, J.K.G.; Cruz-Hernandez, C.; Santercole, V.; Delmonte, P.; Mossoba, M.; Dugan, M.E.R. Appropriate extraction and methylation techniques for lipids analysis. In *Fat and Fatty Acids in Poultry Nutrition and Health*; Cherian, G., Poureslami, R., Eds.; Context Products Ltd.: Packington, UK, 2012; pp. 249–278.
27. Petrović, M.; Kezić, N.; Bolanča, V. Optimization of the GC method for routine analysis of the fatty acid profile in several food samples. *Food Chem.* **2010**, *122*, 285–291. [[CrossRef](#)]
28. Chen, J.; Liu, H. Nutritional Indices for Assessing Fatty Acids: A Mini-Review. *Int. J. Mol. Sci.* **2020**, *21*, 5695. [[CrossRef](#)]
29. Dell Inc. *Dell Statistica (Data Analysis Software System), Version 12*; Dell: Round Rock, TX, USA, 2015; Volume 12.
30. Kassambara, A.; Kassambara, M.A. *Package 'ggpubr'*. R Package Version 0.3.5; R Foundation for Statistical Computing: Vienna, Austria, 2012.
31. Gómez-Rubio, V. ggplot2-elegant graphics for data analysis. *J. Stat. Softw.* **2017**, *77*, 1–3. [[CrossRef](#)]
32. R Development Core Team. *R: A Language and Environment for Statistical Computing Version 4.0.2*; R Development Core Team: Vienna, Austria, 2020.
33. Dai, F.; Feng, D.; Cao, Q.; Ye, H.; Zhang, C.; Xia, W.; Zuo, J. Developmental differences in carcass, meat quality and muscle fibre characteristics between the Landrace and a Chinese native pig. *S. Afr. J. Anim. Sci.* **2010**, *39*, 267–273. [[CrossRef](#)]
34. Wojtysiak, D.; Poltowicz, K. Carcass quality, physico-chemical parameters, muscle fibre traits and myosin heavy chain composition of m. longissimus lumborum from Puławska and Polish Large White pigs. *Meat Sci.* **2014**, *97*, 395–403. [[CrossRef](#)] [[PubMed](#)]
35. Renaudeau, D.; Mourot, J. A comparison of carcass and meat quality characteristics of Creole and Large White pigs slaughtered at 90 kg BW. *Meat Sci.* **2007**, *76*, 165–171. [[CrossRef](#)] [[PubMed](#)]
36. Poklukar, K.; Čandek-Potokar, M.; Batorek Lukač, N.; Tomažin, U.; Škrlep, M. Lipid Deposition and Metabolism in Local and Modern Pig Breeds: A Review. *Animals* **2020**, *10*, 424. [[CrossRef](#)]
37. Almeida, J.M.; Bressan, M.C.; Amaral, A.J.; Bettencourt, C.; Santos-Silva, J.; Moreira, O.; Gama, L.T. Body weight and ultrasound measurements over the finishing period in Iberian and F1 Large White × Landrace pigs raised intensively or in free-range conditions. *Livest. Sci.* **2019**, *229*, 170–178. [[CrossRef](#)]
38. Latorre, M.A.; Lázaro, R.; Valencia, D.G.; Medel, P.; Mateos, G.G. The effects of gender and slaughter weight on the growth performance, carcass traits, and meat quality characteristics of heavy pigs. *J. Anim. Sci.* **2004**, *82*, 526–533. [[CrossRef](#)]
39. Lebret, B.; Dourmad, J.Y.; Mourot, J.; Pollet, P.Y.; Gondret, F. Production performance, carcass composition, and adipose tissue traits of heavy pigs: Influence of breed and production system. *Sci. J. Anim. Sci.* **2014**, *92*, 3543–3556. [[CrossRef](#)]
40. García-Gudiño, J.; Izquierdo, M.; Ayuso, D.; del Rosario, A.I.; Duarte, J.L.; Pérez, M.A.; Hernández-García, F.I. Effect of pre-slaughter weight and sex on commercial meat cut yields of Iberian pigs. *Acta Agric. Slov.* **2013**, *4*, 101–104.
41. Mayoral, A.I.; Dorado, M.; Guillén, M.T.; Robina, A.; Vivo, J.M.; Vázquez, C.; Ruiz, J. Development of meat and carcass quality characteristics in Iberian pigs reared outdoors. *Meat Sci.* **1999**, *52*, 315–324. [[CrossRef](#)]
42. Bertol, T.M.; Oliveira, E.A.; Coldebella, A.; Kawski, V.L.; Scandolera, A.J.; Warpechowski, M.B. Meat quality and cut yield of pigs slaughtered over 100kg live weight. *Arq. Bras. Med. Vet. Zootec.* **2015**, *67*, 1166–1174. [[CrossRef](#)]
43. Bressan, M.C.; Almeida, J.; Santos Silva, J.; Bettencourt, C.; Francisco, A.; Gama, L.T. Carcass characteristics and fat depots in Iberian and F1 Large White × Landrace pigs intensively finished or raised outdoors in oak-tree forests. *J. Anim. Sci.* **2016**, *94*, 2592–2602. [[CrossRef](#)] [[PubMed](#)]
44. Grandin, T. The effect of stress on livestock and meat quality prior to and during slaughter. *Int. J. Study Anim. Probl.* **1980**, *1*, 313–337.
45. Lebret, B.; Ecolan, P.; Bonhomme, N.; Méteau, K.; Prunier, A. Influence of production system in local and conventional pig breeds on stress indicators at slaughter, muscle and meat traits and pork eating quality. *Animal* **2015**, *9*, 1404–1413. [[CrossRef](#)] [[PubMed](#)]
46. Maiorano, G.; Gambacorta, M.; Tavaniello, S.; D'andrea, M.; Stefanon, B.; Pilla, F.; Andrea, M.D. Growth, carcass and meat quality of Casertana, Italian Large White and Duroc × (Landrace × Italian Large White) pigs reared outdoors. *Ital. J. Anim. Sci.* **2013**, *12*, 69. [[CrossRef](#)]
47. Martins, J.M.; Fialho, R.; Albuquerque, A.; Neves, J.; Freitas, A.; Nunes, J.T.; Charneca, R. Growth, blood, carcass and meat quality traits from local pig breeds and their crosses. *Animal* **2020**, *14*, 636–647. [[CrossRef](#)]
48. Sirtori, F.; Crovetto, A.; Zilio, D.M.; Pugliese, C.; Acciaioli, A.; Campodoni, G.; Bozzi, R.; Franci, O. Effect of sire breed and rearing system on growth, carcass composition and meat traits of Cinta Senese crossbred pigs. *Ital. J. Anim. Sci.* **2011**, *10*, e47. [[CrossRef](#)]
49. Serra, X.; Gil, F.; Pérez-Enciso, M.; Oliver, M.A.; Vázquez, J.M.; Gispert, M.; Díaz, I.; Moreno, F.; Latorre, R.; Noguera, J.L. A comparison of carcass, meat quality and histochemical characteristics of Iberian (Guadyrberbas line) and Landrace pigs. *Livest. Prod. Sci.* **1998**, *56*, 215–223. [[CrossRef](#)]
50. Estévez, M.; Morcuende, D.; Cava, R. Oxidative and colour changes in meat from three lines of free-range reared Iberian pigs slaughtered at 90 kg live weight and from industrial pig during refrigerated storage. *Meat Sci.* **2003**, *65*, 1139–1146. [[CrossRef](#)]
51. Alfeo, V.; Velotto, S.; de Camillis, S.; Stasi, T.; Todaro, A. Variation in meat quality characteristics between Landrace and Sicilian pig. *Ital. J. Food Sci.* **2019**, *31*, 800–807.

52. Bejerholm, A.C.; Barton-Gade, P. Effect of intramuscular fat level on eating quality of pig meat. In Proceedings of the 30th European Meeting of Meat Research Workers, Ghent, Belgium, 24–29 August 1986; pp. 389–391.
53. Fernandez, X.; Monin, G.; Talmant, A.; Mourot, J.; Leuret, B. Influence of intramuscular fat content on the quality of pig meat—2. Consumer acceptability of *m. longissimus lumborum*. *Meat Sci.* **1999**, *53*, 67–72. [[CrossRef](#)]
54. Kühn, H.; Heydeck, D.; Hugou, I.; Gniwotta, C. In Vivo Action of 15-Lipoxygenase in Early Stages of Human Atherogenesis. *J. Clin. Investig.* **1997**, *99*, 888–893. [[CrossRef](#)] [[PubMed](#)]
55. Furman, M.; Malovrh, Š.; Levart, A.; Kovač, M. Fatty acid composition of meat and adipose tissue from Krškopolje pigs and commercial fatteners in Slovenia. *Arch. Anim. Breed.* **2010**, *53*, 73–84. [[CrossRef](#)]
56. Franco, D.; Carballo, J.; Bermúdez, R.; Lorenzo, J.M. Effect of Genotype and Slaughter Age on Carcass Traits and Meat Quality of the Celta Pig Breed in Extensive System. *Ann. Anim. Sci.* **2016**, *16*, 259–273. [[CrossRef](#)]
57. Nevrlka, P.; Václavková, E.; Horký, P.; Kamanová, V.; Hadaš, Z.; Rečková, Z.; Máchal, L. Growth and Meat Quality of Prestice Black-Pied and (Landrace × Large White) × Duroc Pigs. *Acta Univ. Agric. Silvic. Mendel. Brun.* **2018**, *66*, 701–705. [[CrossRef](#)]
58. Ibáñez-Escriche, N.; Magallón, E.; Gonzalez, E.; Tejada, J.F.; Noguera, J.L. Genetic parameters and crossbreeding effects of fat deposition and fatty acid profiles in Iberian pig lines. *J. Anim. Sci.* **2016**, *94*, 28–37. [[CrossRef](#)] [[PubMed](#)]
59. Huang, Y.; Zhou, L.; Zhang, J.; Liu, X.; Zhang, Y.; Cai, L.; Zhang, W.; Cui, L.; Yang, J.; Ji, J.; et al. A large-scale comparison of meat quality and intramuscular fatty acid composition among three Chinese indigenous pig breeds. *Meat Sci.* **2020**, *168*, 108182. [[CrossRef](#)]
60. Connor, W.E. Importance of n–3 fatty acids in health and disease. *Am. J. Clin. Nutr.* **2000**, *71*, 171S–175S. [[CrossRef](#)]
61. Yu, K.; Shu, G.; Yuan, F.; Zhu, X.; Gao, P.; Wang, S.; Wang, L.; Xi, Q.; Zhang, S.; Zhang, Y.; et al. Fatty Acid and Transcriptome Profiling of Longissimus Dorsi Muscles between Pig Breeds Differing in Meat Quality. *Int. J. Biol. Sci.* **2013**, *9*, 108–118. [[CrossRef](#)]
62. Barea, R.; Isabel, B.; Nieto, R.; López-Bote, C.; Aguilera, J.F. Evolution of the fatty acid profile of subcutaneous back-fat adipose tissue in growing Iberian and Landrace × Large White pigs. *Animal* **2013**, *7*, 688–698. [[CrossRef](#)]
63. Hallenstvedt, E.; Øverland, M.; Rehnberg, A.; Kjos, N.P.; Thomassen, M. Sensory quality of short- and long-term frozen stored pork products. Influence of diets varying in polyunsaturated fatty acid (PUFA) content and iodine value. *Meat Sci.* **2012**, *90*, 244–251. [[CrossRef](#)]
64. Rubio, B.; Martínez, B.; García-Cachán, M.D.; Rovira, J.; Jaime, I. Effect of the packaging method and the storage time on lipid oxidation and colour stability on dry fermented sausage salchichón manufactured with raw material with a high level of mono and polyunsaturated fatty acids. *Meat Sci.* **2008**, *80*, 1182–1187. [[CrossRef](#)] [[PubMed](#)]
65. Wood, J.D.; Enser, M.; Fisher, A.V.; Nute, G.R.; Sheard, P.R.; Richardson, R.I.; Hughes, S.I.; Whittington, F.M. Fat deposition, fatty acid composition and meat quality: A review. *Meat Sci.* **2008**, *78*, 343–358. [[CrossRef](#)] [[PubMed](#)]
66. Perna, A.; Simonetti, A.; Intaglietta, I.; Gambacorta, E. Fatty acids composition, cholesterol and vitamin E contents of Longissimus dorsi and Semitendinosus muscles of Suino Nero Lucano pigs slaughtered at two different weights. *Anim. Prod. Sci.* **2015**, *55*, 1037–1043. [[CrossRef](#)]
67. Jiang, Y.Z.; Zhu, L.; Li, X.W.; Si, T. Evaluation of the Chinese indigenous pig breed Dahe and crossbred Dawu for growth and carcass characteristics, organ weight, meat quality and intramuscular fatty acid and amino acid composition. *Animal* **2011**, *5*, 1485–1492. [[CrossRef](#)] [[PubMed](#)]