Wild Boar Carcass Characteristics and Meat Quality

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Globally, wild boar is a primary food resource, mostly for remote rural communities outside of large urban centers located in Latin America, Asia, and Africa. In Chile, the production of meat from European wild boar (*Sus scrofa* L.) is expanding together with the export of this "exotic" meat. Furthermore, in the Finno-Scandinavian peninsula, and central and Mediterranean Europe, wild boar (*Sus scrofa*) and other game species meat (reindeer, red deer, roe deer, fallow deer, moose, and chamois) can be found in local restaurants and fairs, indicating an already consolidated gastronomic interest in this type of meat.

Keywords: wild boar ; wild boar expansion ; wild boar management systems

1. Wild Boar Carcass Characteristics and Meat Quality

Globally, wild boar is a primary food resource, mostly for remote rural communities outside of large urban centers located in Latin America, Asia, and Africa [1][2]. In Chile, the production of meat from European wild boar (*Sus scrofa* L.) is expanding together with the export of this "exotic" meat [3]. Furthermore, in the Finno-Scandinavian peninsula, and central and Mediterranean Europe, wild boar (*Sus scrofa*) and other game species meat (reindeer, red deer, roe deer, fallow deer, moose, and chamois) can be found in local restaurants and fairs, indicating an already consolidated gastronomic interest in this type of meat [2][4][5][6].

The price per kg of wild boar meat is rapidly increasing and the online sale of frozen European wild boar meat is currently EUR 26.56/kg (online search 22 June 2023). However, prices may vary in different countries and in different regions of each country (personal survey in Italy).

2. Carcass Characteristics

Studies concerning slaughter yields and meat quality of wild ungulates are numerically more limited than those carried out on domestic species. Furthermore, there is considerable variability among results obtained in different studies concerning wild boar meat production potential and its quality, due both to environmental, nutritional, and genetic factors as well as the adoption of different slaughtering and cutting systems for the carcasses [1].

Low growth rates are the main limiting factor for wild boar meat production [7]. Different slaughter weights between wild boars and domestic pigs (including crosses) can be explained by karyotypes, i.e., the different number of chromosomes (2n = 36, 37, or 38) due to chromosomal translocations (chromosomes 13 and 17 or 15 and 17) [8]. European purebred wild boars have 2n = 36 chromosomes, while wild boars from Eastern Europe and Asia, as well as domestic pigs, have 2n = 38 [9]. The different karyotypes lead to high values of live weight, food intake, and fat deposition and low meat conductivity values [10], quantitative carcass characteristics, and fat depth in *Sus scrofa* [11]. The proportion of fat in the carcass of wild boar with the 2n = 36 karyotype was lower (17.7%) than in phenotypically similar crossbreeds (2n = 37 and 2n = 38; 22.7%) [8]. Moreover, in the study by Skewes et al. (2014) [12], wild boars with 2n = 37 and 2n = 38 karyotypes had higher final live weights (270 days; 80.1 and 80.4 kg, respectively) than 2n = 36 (47.2 kg). The average daily weight gains were also higher in 2n = 37 and 2n = 38 crossbreeds (400.2 and 416.8 g day^{-1}, respectively) than in the 2n = 36 group (246.7 g day^{-1}), which showed values very similar to those reported for the European wild boars (range between 160 and 233 g day^{-1}) [3][12].

It has been reported that increased cortisol values could be an additional factor contributing to a slower growth rate in wild boars than in domestic pigs [1].

The slow growth rate of wild boars has prompted farmers to cross them with domestic pigs [13] to obtain a higher final live weight [14] as well as less aggressive animals [9][15]. The growth rates reported for 2n = 37 and 2n = 38 crossbreeds were close to results reported in the literature for crosses between domestic pigs and wild boars (330 to 470 g day^{-1}) [12][16].

Wild boars, like all wild ungulates, are capable of providing satisfactory slaughter yields with well-developed bacon and shoulder cuts but which would be less acceptable than those of domestic pigs due to greater contributions of the head and hard skin, which is densely covered with thick black bristles [1][17].

Differences in dressed weights (kg), assumed to include heads and skins but without thoracic and abdominal organs, were found in wild boars hunted in different European countries due to animal age (7–12 months, 24.6–30.8 kg; 13–24 months, 53.0–64.9 kg) and gender (>24 months old, 87.2–103.8 kg for males and 66.3–84.2 kg for females) [1]. In agreement with these results, different dressed weights have been recorded for males (65–108 kg) and females (50–80 kg) aged 3–4 years, hunted in Romania [1].

No differences were found for carcass weight (CW) and backfat thickness (BT) among Chilean purebred wild boars (male and female) fed 20% (*w*/*w*) acorns in their diet or a commercial acorn-free diet [18]. The differences were significant for wild boars eating 40% acorns in their diet, and the values were 37.6, 40.1, and 44.6 kg for CW and 11.8, 14.0, and 15.6 mm for BT for wild boars consuming a commercial diet, 20% and 40% acorn diets, respectively.

Summarizing the data published in Polish by different authors [1], the carcass yields of wild boars harvested in Poland ranged between 59.9 and 74.3% (skin contributed 15.7–29.4% of the initial weight) and increased with body weight. Comparable values for piglets (<1 year; 75.1–77.4%), yearlings (1–2 years; 73.7–79.6%), sub-adults (2–3 years; 74.9–80.1%), and adults (63.2–81.9%) were reported for wild boars hunted in Croatia and for wild boar × wild pig crosses (76.5–78.6%) hunted in the United States of America [19].

Higher carcass yields (82.8–84.0%) were instead reported for wild boars of medium live weight hunted in Italy [17]. The carcass characteristics of wild boars were almost always influenced by the age of the animals and other variables through the interaction with sex [17]. Head and hind leg (as a proportion of half carcass weight) of wild boars hunted in Europe (Karpaty and Maremma subspecies) decreased with animal age (8.48/24.93, 7.40/23.98, and 7.75/23.78%, head/hind leg in animals aged 7, 9, and 12 months, respectively). In contrast, loins and steaks increased with increasing age of the animals (7.37/12.37, 7.61/14.82, and 9.26/15.08% in 7, 9, and 12 months, respectively) [17].

Greater liver and heart weights were reported in wild boars compared to domestic pigs (Pietrain, a selection result for high meat production) and in their crossbreeds, after the same fattening period of 210 days [14]. This is related to the physiological states of the animals in the wild, which are different from those of domesticated animals. In wild boar × Pietrain crosses, the F1 and F2 hybrids gave lower meat and higher fat yields than the average of the parent breeds [1][14].

Studies have indicated that the adipose tissue and loin area increased in crossbreeds with an increasing proportion of wild boar heredity, while other authors reported lower ham weights [1][13]. These differing findings could likely be related to differences in chromosomal traits that code for the composition and/or proportion of body parts [16].

3. Meat Quality

The literature has outlined microstructural differences in wild boar meat compared to domestic pork meat. In regard to the proportions of the different types of muscle fibers, which are related to the physical, chemical, and morphological characteristics of the meat [20], muscles from wild boars show a higher proportion of slow oxidative (I) fibers compared to domestic pigs and this has been explained by the behaviors of wild boars in the wild involved in foraging for food with attention to predators [1].

Skewes et al. (2014) [12] compared the fiber characteristics of *M. longissimus dorsi* (LD) and *M. semimembranosus* (SM) of European wild boars, which are phenotypically similar but differ in karyotypes (2n = 36, 37 or 38). Differences in the distribution of type IIA fibers in LD muscle were observed, being higher in the 2n = 37 than in the 2n = 38 karyotype. An intermediate proportion was detected for the 2n = 36 karyotype. No differences due to chromosome number were found between the groups for the other fiber types, i.e., I, IIB, IIB oxidative, and IIB non-oxidative. Differences in fiber proportions between SM and LD muscles were also noted. More intense red meat color was found for karyotype 2n = 36 than for 2n = 37 and 2n = 38. Moreover, there was a smaller muscle fiber cross-sectional area in the 2n = 36 karyotype than in the 2n = 38, and this could be related to the darker color of the wild boar meat. It has been argued that muscle fibers are modified continuously during the life of the animal due to different circumstances; the higher percentage of red, slow-twitch, oxidative (I) fibers in wild boar meat could be related to the animals' increased exercise [12][21]. The information obtained from the study could be useful in improving the quality of wild boar meat.

Furthermore, wild boar meat has a darker color than that of swine, stronger muscles, lean meat, and in general, is considered less juicy and tender [1][22].

Flavor, often referred to as a "game meat" flavor, is another crucial element distinguishing pork from wild boar meat [23]. Lammers et al. (2009) [24] reported that the typical aroma of wild boar meat could be due to Maillard reactions followed by Strecker degradations of the sulfur-containing essential amino acid methionine and phenylacetaldehyde (derived from phenylalanine). However, the castration of males, before reaching sexual maturity, prevents the meat from taking on the characteristic flavor [17]. In females, on the other hand, this problem is not present because the meat of non-ovariectomized subjects, as occurs in the swine species, possesses organoleptic properties that are appreciated by the consumer [17]. Castration would be necessary only if the production cycle extends beyond the puberty age of the animals to reach heavier final live weights [17]. The purchase of this type of meat is highly conditioned by its sensory properties, among which, tenderness is a very important requirement for consumers. Sensory evaluations attribute higher average scores for flavor (intensity and desirability) and taste (intensity, desirability, juiciness, and tenderness) to domestic pig meat and crossbreeds compared to wild boar meat [1]. However, recent studies found a different acceptability and an increasing demand for wild boar meat by consumers, due to its healthiness, specific sensory profile, and low environmental impact [25][26][27]. A sensory evaluation has recently judged that wild boars fed with acorns produced juicier and more tender meat [18].

A greater initial pH (>6) at 45 min (pH_{45}) post-mortem is measured in wild boar meat compared to that in the meat of European domestic breeds (<6) [14]. The authors also reported a greater pH at 24 h (pH_{24}) post-mortem in wild boars than in domestic pigs [1][17]. In contrast, pH values measured in the medial part of the hindlimb region of wild boars hunted in the Western Italian Alps, between 30 min and 6 h after killing, did not differ from those obtained in domestic species [28]. Furthermore, when subsequently comparing the pH of the *M. longissimus dorsi* in carcasses of Brazilian commercial wild boars and domestic pigs stored at 0–2 °C, the values decreased more slowly in wild boars than in pigs [1]. This would indicate a greater resistance to stress in wild animals compared to domestic ones, and has been related to the higher proportion of slow-twitch fibers (I) and lower proportion of fast-twitch fibers (IIB) in the *M. longissimus dorsi* of wild boars compared to pigs [1]. It has been remarked that higher contents of oxidative fibers (I) slows the rapid postmortem glycolysis and the development of the pale, soft, exudative (PSE) condition in meat [29]. Furthermore, comparative studies of boar, pork, and crossbreed meat revealed lower drip losses for wild boar muscles than those of pigs and crossbreeds [1][17][25].

The average chemical composition of wild boar meat shows high levels of proteins (22–26%) and low total lipid contents (2–5%), which are composed of oleic (36–43%), linoleic (13–19%), linolenic (0.6–1%), and palmitic (20–21%) acids [1][21][23]. The lipid and cholesterol levels (55–59 mg/100 g meat) are lower than meats from other ruminants [1][30][31]. The cholesterol content of meat from animals with different karyotypes (2n = 36, 37, and 38) reported in the study by Skewes et al. (2009) [9] varied between 20.9 and 37.2 mg/100 g and between 34.4 and 36.9 mg/100 g, for the semimembranosus (SM) and longissimus dorsi (LD) muscles, respectively. There were no significant differences in the meat cholesterol content due to chromosome number. However, higher percentages of polyunsaturated fatty acids (27.8, 13.17, and 7.53% for 2n = 36, 37, and 38, respectively) and lower C16:0 (20.87, 23.02, and 23.78% for 2n = 36, 37, and 38, respectively) and C18:0 (9.59, 15.12, and 16.85% for 2n = 36, 37, and 38, respectively) were reported in SM muscles from wild boars (2n = 36) compared to crossbreeds (2n = 37, 38). On the other hand, karyotype did not affect the fatty acid composition of LD muscles.

Flores Ahumada et al. (2021) [18] found that purebred Chilean wild boars (male and female) consuming acorns (20 and 40% of diet, *w*/*w*) had lower percentages (23.11 and 23.51% with 20 and 40% acorns, respectively) of C 16:0 in longissimus lumborum (LL) muscles than those consuming a commercial acorn-free diet (24.56%). In contrast, the proportions of monounsaturated (MUFAs) and polyunsaturated fatty acids (PUFAs) were higher in LL muscles from wild boars fed with acorns (48.03 and 48.11% and 14.43 and 14.47% for MUFA and PUFA, and for 20 and 40% acorns, respectively) than those found in animals fed only the commercial diet (47.3 and 14.06% for MUFA and PUFA, respectively). Also, the meat cholesterol contents were lower in wild boars fed acorns (21.6 and 22.2 mg/100 g meat, for 20 and 40% acorn diet, respectively) than in meat from animals fed a diet without acorns (23.9 mg/100 g meat). This study highlights the importance of acorns in wild boars' diets in the quality of wild boar meat products.

Overall, the protein content of wild boar meat is similar to that of domestic animals such as chicken (20%), sheep (20.27%), and rabbit (22.23%) [17]. Differences in intramuscular fat content correlated with differences in food availability between seasons and/or estrus, which could influence food intake [1].

Table 1 (using data from [31][32][33]) compares the chemical compositions of the longissimus dorsi muscle of wild boars hunted in Italy (WB), reared wild boar (RWB), wild boar × domestic pig crosses (WBDP), and domestic pigs (DP). Marsico et al. (2007) [31] found lower moisture and fat (ether extracted) contents and higher protein concentrations in meat from

WB compared to RWB, WBDP, or DP. Moreover, WB meat had a higher percentage of n − 3 fatty acids (2.9%) than animals reared on complete diets (RWB, WBDP, and DP; 1.3, 1.28, and 1.03%, respectively).

Table 1. Physicochemical measures of *M. longissimus dorsi* of wild boars hunted in Italy (WB), reared wild boar (RWB), wild boar × domestic pig crosses (WBDP), and domestic pigs (DP) [31][32][33].

Characteristic	WB (n = 4)	RWB (n = 4)	WBDP (n = 4)	DP (n = 4)	SED [a]
Physical					
pH_{45}	6.35	6.41	6.61	6.04	0.251
pH_{24}	5.48	5.94	5.74	5.49	0.193
L* (lightness) [b]	43.62	45.92	47.85	50.42	2.591
a* (redness)	12.39	7.26	6.37	5.28	0.968
b* (yellowness)	11.97	10.64	10.23	9.61	1.539
WBS (kg/cm^2) [c]	2.42	2.54	2.85	4.39	1.041
Cooking loss (%)	31.22	18.52	14.96	11.86	3.476
Chemical (%)					
Moisture	70.50	73.41	73.65	71.37	1.367
Protein	25.87	22.50	22.24	21.35	0.893
Fat	1.55	2.00	2.15	4.56	1.010
Ash	1.23	1.30	1.27	0.86	0.127

[a] Standard error of difference. [b] Color evaluated according to the CIELAB L*a*b* scale [32]. [c] Warner–Bratzler shear force values of samples cooked in microwave to internal temperature of 75 °C [33].

Diversity in eating behavior or differences in food availability between different habitats were related to variable contents of oleic and linoleic acids in *M. psoas major* from wild boars hunted in Portugal [30]. The percentages of the linoleic acid isomer C18:2 *cis*–9 *trans*–11 (conjugated linoleic acid, CLA) were also greater in wild boar meat than in pig meat, most likely deriving from the biosynthesis of intestinal bacteria [34].

Considering that the ratio between polyunsaturated and saturated fatty acids (PUFAs/SFAs) in the meat of wild boars from Portugal (0.52–0.60) or Lithuania (0.43–0.53) was above the minimum ratio of 0.40, this meat may contribute to a reduction in the risk of cardiovascular diseases in humans [30][35]. Furthermore, the atherogenic and thrombogenic indices, indicative of the risk of cardiovascular disease, decreased in the meat of wild animals hunted in Italy (WB) vs. commercially farmed meat (RWB, WBDP, DP) [31]. Weight, sex, or month of hunting did not affect these indices. Factors such as the live weight of animals, sex, and hunting season and region could have a great influence on the meat quality of wild boar, in particular on fatty acid profiles [35][36].

The macro and micro mineral contents in muscles of wild boar are often correlated to differences in soil mineral concentrations in the areas where the animals were hunted [37]. For example, different contents of calcium, phosphorus, and zinc in the meat of Hungarian wild boars, living in parks where different feeding programs were applied (natural diet, supplementary feed, complete commercial diet), were correlated with differences in the mineral content of the park soils [37]. However, the manganese and selenium contents, even with different concentrations in the park soils, did not vary [1]. Recently, there were no differences between Cd and Pb contents of meat from wild boar with different live weights and sexes, hunted in two different areas of the Molise region and those reported in the literature (ranging from 0.001 to 0.355 mg/kg for Cd and ranging from 0.03 to 0.441 mg/kg for Pb) [36][38].

In regard to vitamins, Quaresma et al. (2011) [30] found that in *M. psoas major* from wild boars hunted in Portugal, 71% of the total isomers of vitamin E was represented by α-tocopherol, which increased in adult males (19.2 μg/g meat) and in females (18.1 μg/g meat) compared to younger animals (15.5 μg/g meat). Quaresma et al. (2011) reported a greater α-tocopherol concentration in wild boar meat than the concentrations (15.1–16.3 μg/g) that had been, previously reported [39] in *M. psoas major* of pigs fed high levels of dietary vitamin E (700 mg/kg feed). Recently, Palazzo et al. (2021) [36] found that the α-tocopherol concentrations of longissimus thoracis muscles from wild boars hunted in Italy were two-fold lower than those reported by Quaresma et al. (2011) [30], ranging from 5.87 to 6.05 μg/g meat, without any influence of the live weight or sex of the animals. These differences could mainly be attributed to the genotype and types of muscle, which have different vitamin needs in relation to the functional and metabolic differences of their fibers and different fat contents [40]. It has been reported that higher α-tocopherol concentrations could result in a longer shelf life and a delay in the onset of discoloration in wild boar meat compared to pig meat, due to the increased protection of lipids and myoglobin from oxidation [1].

4. Processed Products

Paleari et al. (2003) [41] stated that if wild boar meat is used without being transformed, it would be unsuitable for large-scale domestic consumption, as it is not easy to cook, and sometimes not easy to sell, even at a low price. Wild boar meat could be conveniently used in processed products (sausages and cooked and/or raw hams), whose ripening would also be favored by an optimal muscle acidification process [1][17]. In dry-cured fermented sausages, textural differences have been mainly related to pH, which explains the variability among different brands of Chorizo de Pamplona. It has been reported that pH evolution during the ripening process strongly affected texture changes and the possibility of obtaining a more consistent product [42][43][44].

Moreover, wild boar meat would be characterized by a greater water-retention capacity than that of domestic pigs, and this would also make it particularly suitable for use in processed products [1][17]. Wild boar ham was also confirmed to be tougher and require more masticating in comparison with pork ham [22].

Massaging wild boar muscles was a technique to test the efficacy of mechanical tenderization for conditioning the meat. Fatter (and therefore structurally more modifiable muscles) showed different rheological values with massage application. However, older animals had less structurally modifiable muscles than younger animals [1][20]. Cold curing of muscles under vacuum, for a 7-day period at 4 °C, with or without marinating agents (red wine, calcium chloride, pineapple juice, and kefir), increased the tenderness and juiciness [20].

The use of the shoulder instead of the hind legs in a traditional mold-ripened salami made from wild boar meat [45] slightly lowered the protein content but significantly increased the concentrations of hydroxyproline and biogenic amines (histamine, putrescine, and cadaverine) at day 35 of fermentation and drying. The higher content of unsaturated fatty acids and the use of wild boar adipose tissue but not starter bacterial cultures, likely increased the salami TBARS (thiobarbituric acid reactive substances, a common measure of lipid peroxidation products) content by 2–3 times compared to pork back fat. Based on the odor and taste, the salami with pork back fat and bacterial starters was preferred by a semi-trained sensory panel.

Proteolysis indices (non-protein nitrogen/total nitrogen × 100) for saucissons elaborated using wild boar meat were greater (29.9–30.8%) compared to values reported for the same type of processed products prepared with pork or beef (12–20%). The differences were related to different microorganism proteolysis processes during maturation. Furthermore, the authors argued that contamination of wild animal carcasses in the field by microorganisms is higher compared to that in domestic animal carcasses [46].

Instrumental texture parameters (hardness, chewiness, springiness, and cohesiveness) at an internal temperature of 68 °C were higher for cooked wild boar sausages compared to sausages made from pork or beef shoulders [1]. A sensory evaluation confirmed the instrumental results, judging wild boar sausages to be less juicy and gummy, and more springy, than pork ones. Sausages made from the meat of wild boars shot in the autumn–winter season had higher textural values and were juicier compared to wild boar shot in the spring–summer season. However, safety (biogenic amines, microbial load, and polyamines) and quality requirements (physicochemical characteristics, sensorial properties) of a spreadable, raw, processed product elaborated with 60% meat from wild boar shoulder, 40% pork back fat, and microbial starters, were similar to those expected to be obtained with the use of pork only [1].

Paleari et al. (2003) [41] evaluated the physicochemical characteristics of different cured, fermented products, elaborated utilizing different types of meat (beef, horse, wild boar, deer, and goat) but the same manufacturing process similar to that of bresaola. In terms of physicochemical parameters, wild boar end products had lower values of pH (6.30), a_w (0.90), moisture (48.2%), and saturated fatty acids (SFAs, 35.5%) than beef end products (6.72, 0.95, 55.4%, and 47.8% for pH, a_w, moisture, and SFA, respectively). Protein content (39.3%), total free amino acids (2315 mg/100 g), polyunsaturated fatty acids (PUFAs, 16.2%), and monounsaturated fatty acids (MUFAs, 45.7%) were greater in wild boar meat products compared to those with beef (34.6%, 1338 mg/100 g, 6.5, and 43.6%, for protein content, total free amino acids, PUFAs, and MUFAs, respectively).

Different pork ham cooking treatments are clearly capable of altering pork meat consumption and sensory perception due to differences in juiciness, fibrousness, and tenderness, which are of great importance for meat quality acceptance [22][47].

Ilic et al. (2022) [22] examined the impact of boiling, grilling, and sous-vide cooking methods on wild boar meat's textural, oral processing, and sensory qualities. The applied cooking methods affected wild boar texture parameters such as hardness, chewiness, springiness, and cohesiveness, but the wild boar flavor dominance rate remained persistent for all three cooking methods. The used cooking methods similarly affected the dynamic perceptions of firmness, fibrousness, juiciness, and flavor, as in the case of pork ham. The study authors concluded that cooking methods are promising tools for tailoring game meat for consumption and eating experience.

Recently, Freschi et al. (2023) [48] investigated the sensory attributes for ten types of "cacciatore" salamis, one of the most widespread types of salami in Italy, prepared with different mixtures of wild boar/pork (30/50 or 50/50) and spice ingredients. The main findings of the hedonic test revealed that the flavorings used received the highest scores, as well as satisfactory acceptance, regardless of the ratios of wild boar to pork in the salamis. According to the authors, doughs with a high proportion of wild boar meat might be used without affecting product preference and allowing the production of more cost-effective and environmentally friendly products.

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