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Effect of Genotype and Sex on Chemical Composition, Physicochemical Properties, Texture and Microstructure of Spent Broiler Breeder Meat

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Abstract: The aim of this research is to compare the carcass composition and meat quality characteristics of spent Cobb 500 and Ross 308 broiler breeders. A total of 28 carcasses were evaluated—7 female and 7 male carcasses from each genotype. Dissection was performed, and the percentages of neck, wings, skin with subcutaneous fat, abdominal fat, residual components, breast and leg muscles were calculated relative to the eviscerated carcass weight. The breast and leg muscles were evaluated for their chemical composition, color attributes (Lab), acidity (pH_{24}), and electrical conductivity (EC_{24}). Analysis of the structure and texture of the pectoralis major muscle was performed. The genotype of the birds had an impact on the eviscerated carcass weight, percentage of skin with subcutaneous fat, leg muscles, wings, and neck. Broiler breeder genotypes differed in terms of the chemical composition of the breast and leg muscles, except for the water content in the breast muscle and the collagen content in both the breast and leg muscles. The breast muscles of Cobb 500 exhibited lower cooking loss, pH_{24}, redness, and yellowness, while the leg muscles of Ross 308 had lower EC_{24} but higher cooking loss and lightness values. The pectoralis major muscle of Cobb 500 was firmer and more tender, with a smaller cross-sectional area of the muscle fiber and a smaller vertical (V) diameter of the muscle fiber. Males were characterized by a greater carcass weight and a higher percentage of leg muscles, neck, and carcass remains. On the other hand, females had a higher percentage of breast muscles, skin with subcutaneous fat, and abdominal fat. The sex of the birds affected the chemical composition of the breast and leg muscles, with the exception of the water content in the breast muscles and collagen content in the breast and leg muscles. The breast muscles of females were characterized by higher values of yellowness, although they also exhibited lower pH and cooking loss. In terms of texture analysis of the pectoralis major muscle, the meat of females was characterized by higher tenderness and firmness. However, the analysis of the structure showed that males had a thicker perimysium and endomysium. Regardless of broiler origin and sex, significant differences were found between the breast and leg muscles in terms of the assessed physicochemical features (pH_{24}, EC_{24}, cooking loss), color attributes (Lab) and chemical composition (protein, intramuscular fat, and collagen contents). Genotype and sex interactions were significant for the chemical composition of the breast muscles (protein, fat, collagen) and leg muscles (fat), as well as for the yellow color saturation of the breast muscles and springiness of the pectoralis major muscle. The study produced results that showed the meat and carcasses of spent hens and roosters to be suitable for processing due to their favorable chemical composition, high nutritional value and good technological properties, as assessed based on the results of meat texture and structure.

Keywords: broiler breeders; meat texture; microstructure; chemical composition; physical and chemical properties

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1. Introduction

The year 2020 in Poland saw a total of 11.2 million broiler breeder hens placed for rearing, while in 2021 the number increased to 12.0 million [1]. This represents a year-on-year increase of 7%. Over 85% of broiler breeder flocks maintained in Poland consist of Ross 308 breeders [2]. The average production period was found to be 256 days, during which time the flock achieved an average laying rate of 64.9% and 152.5 eggs per hen [3]. Broiler breeder Ross 308 was characterized by a 4.3 percent higher laying capacity and 6 more hatching eggs than the Cobb 500 broiler breeder, with an average fertilization rate of 90.5% obtained from one hen in the entire reproductive cycle [3]. Breeding hens achieving the end of their egg laying cycle are produced worldwide every year. Differences in the perception of spent hens by people as food can lead to varied utilization practices in different countries. In Asian countries such as Korea, Thailand China and India, spent hens are consumed either whole or processed into meat products. However, in Western societies, spent hens are most commonly treated as a byproduct and utilized, among others, for animal feed production [4]. Despite that, spent hens and roosters are a rich source of animal lipids and proteins and are suitable materials for the production of consumable products. Broiler breeder flocks of Ross 308 and Cobb 500 are supplied by two companies worldwide: Aviagen and Cobb-Vantress, respectively. Ross was started in Scotland in Edinburgh when Chunky Chicks Limited opened. Subsequently, Aviagen continued its genetic development and global expansion, which has led to Ross being present in over 100 countries on six continents [5]. The Cobb breed, on the other hand, was selected and developed in England in the 1970s because retailers were looking for a product that would look good on fresh meat shelves. The Cobb 500 broiler is a modern commercial breed with rapid initial growth and high yields of breast meat at different processing ages compared to other commercial varieties currently grown worldwide [6].

Adult females typically reach a body weight of approximately 4 kg, while males around 5 kg [7,8]. On a global scale, the amount of meat obtained from broiler breeder flocks after the laying period is significant. It is estimated that about 7% of all poultry produced worldwide comprises broiler breeder flocks and spent laying hens [9]. Poultry meat is of great importance due to the increasing demand for protein as an essential food source. A possible solution to the continuously growing demand for poultry meat may be increasing the possibility of introducing spent laying hens into the poultry meat supply chain [10].

Many factors contribute to the quality of poultry meat, including the selection of appropriate genetic material, age, gender, and nutrition [11–16]. Many studies have found that the quality of poultry meat is also significantly influenced by sensory attributes such as color and taste, as well as by juiciness and tenderness (meat texture). Other factors include pH, protein, water, collagen, fat (chemical composition), and the content of connective tissue [17–19].

Poultry meat is characterized by a high proportion of high-value protein (24.8%) and by a low fat content (1.8%) [20]. Meat from broiler chickens is rich in B vitamins, and it also contains potassium, magnesium, and zinc [20]. Poultry meat is tender and easily digestible. It is also characterized by a high content of unsaturated fatty acids, including linolenic and linoleic acid [20]. Due to its nutritional value, physical properties, and chemical composition, poultry meat is considered more valuable compared to meats from other animal species [17]. Consumers choose poultry meat for its juiciness and tenderness, as well as its low intramuscular fat content, which should not exceed 2.5% [21]. Available research has shown that the fat content of poultry meat can be under the influence by the birds' nutrition [22,23]. Tenderness and cooking loss are other important meat quality characteristics from a consumer's perspective during the selection process [24–26].

The objective of this study was to determine the impact of the genotype and sex of two commercial broiler breeder chickens, Ross 308 and Cobb 500, on the physicochemical properties, texture, chemical composition and microstructure of the meat they produce. The results provide important information for consumers of chicken meat, as well as for the processing and food service industries, regarding the usability of carcasses and meat from spent broiler breeders. Our findings have allowed us to determine which of the aforementioned genotypes is characterized by meat with better properties.

2. Materials and Methods

2.1. Carcass Analysis

The eviscerated carcasses of the broiler breeder flocks of Ross 308 and Cobb 500 broiler chickens, which were purchased from a commercial slaughterhouse, consisted of 28 carcasses (7 females and 7 males from each strain). These carcasses were transported to the laboratory at the university, where they were chilled. The carcasses were sourced from birds that had completed their reproductive period and were at 61 weeks of age. According to information from the contracting department of the slaughterhouse during the reproductive period, these birds were kept on the same farm and fed with complete feeds for parent flocks, in accordance with instructions for managing the flocks of Ross 308 and Cobb 500 in regulated environmental conditions. The carcasses were chilled for 18 h at 2 °C in a refrigerated cabinet (Hendi, Gądki, Poland). Dissection was subsequently performed using a simplified method described by Ziołecki and Doruchowski [27]. The dissected carcass parts were weighed on an electronic scale with accuracy to 1 g, and subsequently their weight percentage was calculated in relation to the cold eviscerated carcass weight determined prior to dissection.

2.2. Physicochemical Analysis

Before dissection and at 24 h postmortem, the acidity (pH) and electrical conductivity of the superficial breast muscle and thigh muscle were determined (pH_{24} and EC_{24}). Acidity was measured using a CX-701 pH meter with a glass electrode in a steel knife (Elmetron, Zabrze, Poland). The pH meter was previously calibrated in calibration buffers (pH 7.0 and 4.0). The measurement result was read from the liquid crystal display with an accuracy of 0.01. The electrical conductivity of the meat (EC_{24}) was measured using an LF-Star CPU conductivity meter (Ingenieurbüro R. Matthäus, Nobitz, Germany), with an accuracy of 0.1 mS/cm. The device's electrode was placed in the breast muscle and thigh muscle at a 90-degree angle along the muscle fibers. Subsequently, the breast and leg muscles were evaluated in terms of color. Color was evaluated using a MINOLTA CR 400 colorimeter (Konica Minolta Poland, Japan). The breast and leg muscles were evaluated in a color system of L* (lightness), a* (redness), and b* (yellowness). For the determination of cooking loss, meat samples (weighing 20 $\pm$ 2 g each) from the breast and leg muscles were wrapped in gauze and placed in a water bath at a temperature of 85 °C for 10 min. Subsequently, the samples were removed and cooled at a temperature of 2 °C in a refrigerated cabinet for 30 min. After cooling, the samples were weighed using an electronic scale. Using the difference in sample weight before and after the thermal treatment, sample weight loss was calculated and expressed as a percentage of the initial weight [28].

2.3. Chemical Analyses

The basic chemical meat composition (water, protein, fat and collagen content) was determined via near-infrared (NIR) transmission spectroscopy using a FoodScan instrument (FoodScan, Hillerød, Denmark). A total of 90 g of breast meat and 90 g of leg meat (from each carcass) were collected, and each sample was minced using an electric meat grinder (Zelmer, Rzeszów, Poland).

2.4. Meat Texture

Twenty-eight samples (14 Ross 308 and 14 Cobb 500, 7 females and 7 males each) of the pectoralis major muscle were heat-treated to assess their textural properties. The texture of muscles was evaluated in compliance with the texture profile analysis (TPA) and Warner-Bratzler (WB) procedure [29] using a Stable Micro Systems TA.XT Plus apparatus (Stable Micro Systems, Godalming, UK). In the TPA test, a 0.61 cm diameter shaft was driven twice parallel to the sample muscle fiber until reaching 80% of its original height (16 mm). A crosshead speed of 50 mm min^{-1} and a load cell of 50 N were applied. The force–deformation curve obtained during the TPA test was used to calculate meat hardness, cohesiveness, springiness, chewiness, and gumminess [29]. In the WB test, a muscle of about 0.6 × 0.6 × 70 mm was cut using a triangle knife perpendicular to the muscle fiber at a crosshead speed of 50 mm min^{-1} and a load cell of 500 N [29]. The TPA and WB tests were repeated 15 times for each sample.

2.5. Microstructure Analysis

The muscle structural elements were measured for the raw pectoralis major muscle collected from 28 carcasses. Three cuts of about 6 × 6 × 10 mm were taken from each muscle, dehydrated in alcohol, fixed in Sannomiya solution, and embedded in paraffin blocks. The blocks were sectioned with a microtome, and sections of 10 µm were placed onto glass slides and then contrast-stained [30]. Multi Scan Base v.13 computer image analysis software was used to measure the fiber cross-sectional area, fiber circumference, horizontal fiber diameter (H), and vertical fiber diameter (V), as well as the endomysium and perimysium thickness, per muscle fiber bundle. Additionally, 10 primary muscle fiber bundles were analyzed per muscle. Furthermore, more than 200 muscle fiber and endomysium and perimysium thickness/samples were analyzed. A magnification of 100× was applied.

2.6. Statistical Analyses

The instrumental measurement data were analyzed statistically using the SAS ver. 9.4 software, with the single effects given by genotype (G) and sex (S) of broilers and the fixed effects by G, S and their interaction. The mean values and standard error of means (SEM) for each sample, as well as the differences in carcass composition, texture, structure, and some physical properties between genotype and sex of broilers, as assessed using the RIR–Tukey test.

3. Results and Discussion

The analysis of carcass weight showed the significant effects of genotype and sex on the trait under study (Table 1). At the end of the reproductive period, Cobb 500 and males exhibited higher carcass weights compared to Ross 308 and females. In the study by Biegniewska et al. [31], the average carcass weight of Ross 308 at 64 weeks of age was 3549.5 g, which was 116.9 g lower compared to the carcass weight of birds of the same genotype in our study.

Table 1. Carcass weight and weight percentage of carcass elements in the carcass of Cobb 500 and Ross 308 broiler breeders at 61 weeks of age.

Trait	Genotype (G)—Sex (S)				SEM	*p* Values		
	Cobb 500	Ross 308	Male	Female		G	S	G × S
Carcass weight (g)	4300.6 [a]	3642.4 [b]	4599.3	3364.9 *	166.7	<0.001	<0.001	0.099
Breast muscle (%)	27.0	28.0	26.5	28.5 *	0.5	0.294	0.001	<0.001
Leg muscles (%)	29.3 [a]	26.1 [b]	29.0	26.4 *	0.6	<0.001	0.001	0.003
Skin with fat (%)	7.9 [b]	9.0 [a]	8.1	8.8 *	0.2	0.002	0.025	0.067
Abdominal fat (%)	1.0	1.0	-	2.0 *	0.2	0.928	<0.001	0.928
Neck (%)	3.7 [a]	3.2 [b]	3.9	3.0 *	0.1	0.004	<0.001	0.398
Wings (%)	8.7 [b]	9.4 [a]	9.1	9.0	0.1	<0.001	0.445	0.015
Remainders (%)	22.4	23.3	23.4	22.3 *	0.3	0.262	0.016	0.251

[a,b] means with different superscripts are statistically different between genetic groups ($p < 0.05$). * statistical differences between males and females ($p < 0.05$). n = 14/genotype or sex.

However, the carcass weight of Cobb 500 (4300.6 g) in the aforementioned study was higher than the carcass weight of Hubbard Hi-Y (3782.0 g) and Ross 508 (3823.0 g) birds at 58 weeks of age [32]. When comparing the genotype of birds in terms of the percentage distribution of breast muscles, wings, neck, abdominal fat, and remains, no significant differences were observed. However, the percentage distribution of skin with subcutaneous fat and wings was significantly higher in Ross 308 chickens. In an experiment conducted by Biegniewska et al. [33], the percentage of wings (9.95%) and skin with subcutaneous fat (10.2%) in 64-week-old Ross 308 birds was higher than in our study into birds of the same genotype (9.4% and 9.0%, respectively). Cobb 500 birds, on the other hand, exhibited a higher percentage of leg muscles (29.3%) than Ross 308 birds (26.1%). In another assessment by Kokoszyński et al. [9], the authors demonstrated a lower percentage of leg muscles (22.95%) in 64-week-old Ross 308 birds. The genotype did not have a significant impact on the other studied traits, namely, abdominal fat and carcass remains. The percentage of breast muscles and abdominal fat was significantly ($p < 0.05$) higher in females compared to males. A similar relationship was observed in other studies [9,31] but the obtained results were significantly lower compared to birds of the same genotype in our study. Males exhibited a significantly higher percentage of leg muscles, neck, and carcass remains, as indicated by the p values ($p = 0.025$, $p < 0.001$, $p = 0.016$, respectively). In contrast, females were characterized by a higher percentage of abdominal fat and breast muscle in carcass weight compared to males.

One of the primary factors affecting meat quality traits is pH (Table 2), which is strongly correlated with color and appearance traits [33]. The level of acidity in the breast and leg muscles in our study was significantly lower compared that that seen in the results obtained in other works [34].

Table 2. Selected physicochemical parameters of meat from Cobb 500 and Ross 308 broiler breeders at 61 weeks of age.

Trait		Genotype (G)—Sex (S)				SEM	***p* Values**		
		Cobb 500	**Ross 308**	**Male**	**Female**		**G**	**S**	**G × S**
pH_{24}	BM	5.90 [b]	6.21 [a]	6.12	5.99 *x	0.1	<0.001	0.024	0.357
	LM	6.16	6.37	6.32	6.22	0.1	0.163	0.612	0.102
EC_{24} (mS/cm)	BM	11.4	10.4	10.9	10.9 x	0.4	0.149	0.911	0.219
	LM	8.9 [b]	9.7 [a]	9.4	9.1	0.3	0.041	0.661	0.154
Cooking loss (%)	BM	23.6 [b]	30.1 [a]	29.5	24.6 *x	1.4	0.006	0.047	0.230
	LM	38.6 [a]	26.5 [b]	32.6	32.1	1.6	<0.001	0.589	0.487

[a,b] means with different superscripts are statistically different between genetic group ($p < 0.05$). * statistical differences between males and females ($p < 0.05$). x statistical differences between breast muscle and leg muscle ($p < 0.05$). Abbreviations: BM, breast muscle; LM, leg muscle. n = 14/genotype or sex.

However, the pH_{24} results obtained in the present study (5.90–6.21) fell within the range of meat suitable for technological processing. According to Mahmoudi et al. [11], meat with a pH below 5.7, characterized by pale color and a firm texture after cooking and commonly referred to as "acid" meat, is not suitable for processing. Meat with excessively high pH (>6.20) tends to be darker in color and more tender but is also considered less suitable for processing [11]. In addition to the aforementioned physicochemical characteristics, cooking loss is of great importance in assessing the suitability of meat. According to Abubakar et al. [35], meat with high cooking loss has poorer quality traits owing to cooking leading to the loss of nutritional components. In our study, the breast muscles of Ross 308 showed higher cooking loss, while Cobb 500 birds had higher cooking loss in the leg muscles (Table 2). However, such significant differences in the leg muscle were not observed when females were compared to males. Nevertheless, the breast muscles of females were characterized by significantly ($p = 0.047$) lower water loss. A study conducted by Choe and Kim [34] demonstrated that cooking loss in the breast muscles in 75-week-old broiler breeders was higher than CL in our study (Cobb BM—23.6%). However, the analyzed trait in the leg muscles was higher in Cobb 500 birds (OBH—35.0%, Cobb 500 LM—38.6%). In another study, the latter authors showed that water loss during cooking was influenced by bird nutrition [9]. In the experimental group of that study, corn was replaced with carob pulp powder (*Ceratonia siliqua* L.) in the diet of Cobb 500 broiler chickens at a dose of 3% in the grower feed and 7% in the finisher feed. A lower cooking loss was observed in the breast and leg muscles of the experimental group compared to the control group, with reductions of 4.5% and 5.2%, respectively [9]. Sari et al. [26] demonstrated that the storage time had an impact on meat losses during cooking. Meat loses approximately 10% more weight during cooking when it is stored in the refrigerator for 4 days versus when it is fresh [26]. Electrical conductivity is an important characteristic that also affects the quality of meat. In our study, we did not observe any influence of genotype and sex on the electrical conductivity of breast muscles. However, genotype had a significant (p = 0.041) effect on the electrical conductivity of leg muscles. The values obtained in our study (9.7 mS/cm) were higher than those in a study of Stęczny and Kokoszyński [36] on Ross 308 broilers (4.5 mS/cm;) and a study of Biegniewska et al. [32] on 64-week-old Ross 308 broilers (6.3–6.8 mS/cm).

In our study, the lower level of acidity (pH) in the breast muscle (BM) significantly increased redness (a*) and yellowness (b*) saturation values. Higher levels of leg muscle pH caused the lower lightness (L*) of the analyzed trait. When analyzing the effect of genotype on the color saturation of breast and leg muscles represented by L*, a*, and b* values, significant differences (p < 0.05) were observed, as shown in Table 3.

Table 3. Color of breast and leg muscles of Cobb 500 and Ross 308 broiler breeders at 61 weeks of age.

Trait		Genotype (G)—Sex (S)				SEM	*p* Values		
		Cobb 500	Ross 308	Male	Female		G	S	G × S
L*—lightness	BM	46.9	45.1	46.4	45.6 ^{x}	0.5	0.081	0.413	0.924
	LM	42.4 ^{a}	36.4 ^{b}	37.2	41.3 *	1.1	0.001	0.020	0.069
a*—redness	BM	2.0 ^{b}	5.8 ^{a}	3.8	4.1 ^{x}	0.5	<0.001	0.514	0.157
	LM	14.6	16.3	16.4	14.7	0.8	0.259	0.269	0.515
b*—yellowness	BM	1.4 ^{b}	3.8 ^{a}	2.1	3.2 ^{*x}	0.4	<0.001	0.010	0.021
	LM	5.9	6.4	6.6	5.8	0.8	0.559	0.465	0.236

^{a,b} means with different superscripts are statistically different between genetic groups (p < 0.05). * statistical differences between males and females (p < 0.05). ^{x} statistical differences between breast muscle and leg muscle (p < 0.05). Abbreviations: BM, breast muscle; LM, leg muscle, n = 14/genotype or sex.

The leg muscles (LM) of Cobb 500 exhibited higher lightness (L*) compared to Ross 308, while the genotype did not significantly influence the remaining parameters (a*, b*). However, it did have an effect on the redness (a*) and yellowness (b*) values in the analyzed breast muscles (BM). BM of Ross 308 birds showed significantly higher a* and b* values compared to Cobb 500, as indicated by the respective p values (p < 0.001 and p < 0.001). It was also demonstrated that sex had a significant influence on the L* saturation of LM and b* saturation of BM. LM in females demonstrated significantly higher lightness (L*) (p = 0.020), and BM in females showed higher saturation with yellow color (b*) (p = 0.010). There was no interaction observed between genotype and sex in the above traits, except for yellow color saturation (b*) in BM. A study by Choe and Kim [35] analyzed the physicochemical properties of the breast and leg muscles of spent laying hens and broiler hens in the context of utilizing the meat as a raw material for ham production. The authors obtained higher values of L* (55.34), a* (12.49) and b* (6.78) for the breast muscles of broiler hens from broiler breeder flocks at 75 weeks of age compared to the results of our study (L*—45.1, a*—5.8, b*—3.8, respectively). In contrast, a* and b* saturation values of the leg muscles in our study were higher than those reported by Choe and Kim [35], while the L* color saturation (47.45) was lower in our study (LM—36.4). The results obtained by the latter authors were influenced by the genotype of the birds, as the pH_{24} of the leg muscles (OBH—6.3) was at a comparable level to the results obtained in our study (pH LM—6.37). The color of meat has a significant impact on consumer choice because it is related to nutritional conditions and also indicates the freshness of meat [23].

According to Brunel et al. [37], the water content in breast muscles should range from 71.5% to 78.4%. In our study, however, the percentage of water content was lower regardless of the genotype or sex, ranging from 67.2% to 70.8% (Table 4). On the other hand, the water content in the leg muscles in our study ranged from 72.2% to 74.0%, which was a similar result to that obtained in broiler chickens [37]. It can be concluded that the water content of the breast muscle is affected by the age of the birds. Protein levels in the breast and leg muscles were higher in Ross 308 and male birds. In other studies comparing chickens of different genotypes (Ross 308 and Cobb 500), authors also found higher protein levels in Ross 308 chickens. Additionally, females had higher protein content in the breast muscle, while males had higher protein content in the leg muscles [20]. Another important characteristic from the consumer's perspective is the intramuscular fat content. Many authors have shown that the fat content of muscle is influenced by bird nutrition [22,23,38,39]. In a study by Osek et al. [22], the intramuscular fat content in the breast muscle was reduced by 0.4% compared to the control group when bean was supplemented in the diet instead of soybean meal. Other research demonstrated that the use of probiotic supplementation in the diet of broiler chickens resulted in a reduction of 0.35% in the intramuscular fat content of the breast muscle [38]. In our study, we observed significant differences in the intramuscular fat content of the breast muscle and leg muscle depending on the genotype and sex of the birds. Cobb 500 and females exhibited a higher percentage of fat content in the breast muscle and leg muscle compared to Ross 308 and male birds, as indicated by the *p* values (p = 0.001 and p = 0.043, respectively).

Table 4. Basic chemical composition of meat from Cobb 500 and Ross 308 broiler breeders at 61 weeks of age.

Trait		Genotype (G)—Sex (S)				SEM	*p* Values		
		Cobb 500	Ross 308	Male	Female		G	S	G × S
Water (%)	BM	70.5 ^{a}	67.5 ^{b}	70.8	67.2 *	1.0	0.029	<0.001	0.175
	LM	73.3	73.0	74.0	72.2	0.7	0.644	0.169	0.396
Protein (%)	BM	23.1 ^{b}	23.8 ^{a}	23.7	23.2 ^{*x}	0.2	0.001	0.002	<0.001
	LM	20.8 ^{b}	21.7 ^{a}	21.7	20.8 *	0.2	<0.001	<0.001	0.468
Fat (%)	BM	2.3 ^{a}	1.4 ^{b}	1.7	2.0 ^{*x}	0.2	<0.001	0.043	<0.001
	LM	3.2 ^{a}	2.9 ^{b}	1.8	4.3 *	0.3	0.005	<0.001	0.001
Collagen (%)	BM	1.5	1.6	1.5	1.6 ^{x}	0.1	0.092	0.206	0.017
	LM	1.9	2.0	1.9	2.0	0.1	0.088	0.538	0.638

^{a,b} means with different superscripts are statistically different between genetic groups ($p < 0.05$). * statistical differences between males and females ($p < 0.05$). ^{x} statistical differences between breast muscle and leg muscle ($p < 0.05$). Abbreviations: BM, breast muscle; LM, leg muscle. n = 14/genotype or sex.

Many factors affect the texture of meat, including breed, sex, meat chemical composition, muscle fiber structure, nutrition, pre-slaughter stress, carcass cooling conditions, and proper meat maturation process [40]. In our study, we found that the genotype and sex of the birds had an impact on the texture of the pectoralis major muscle, as expressed by hardness, chewiness, gumminess, and shear force values (Table 5).

The Ross 308 genotype (33.3 N) and male birds (34.0 N) showed significantly higher hardness in the pectoralis major muscle compared to Cobb 500 (28.2 N) and female birds (27.9 N), indicating that the meat was firmer in texture. The same trend as seen above was observed when analyzing the characteristic of chewiness, as indicated by the *p* values of 0.015 and 0.003, respectively. Ross 308 and males had significantly higher gumminess and WB shear force compared to Cobb 500 and females, as evidenced by *p* values ranging from 0.001 to 0.013. There was no significant effect of genotype and sex on the springiness and cohesiveness of the breast muscle. Moreover, there was an interaction observed between genotype and sex in the springiness of the breast muscle. In another study, it was demonstrated that the post-slaughter carcass dissection time had a significant impact on the texture of the breast muscle (hardness, cohesiveness, springiness, chewiness) [41]. The authors examined the texture of the breast muscle in spent broiler chickens on the basis of the time from slaughter to the separation of the breast muscle from the bones. The best results in terms of indicating meat firmness, as expressed in the aforementioned characteristics, were obtained 24 h after slaughter. Thus, it can be concluded that the dissection time significantly affects the texture of the breast muscle taken from spent birds. Other authors demonstrated that the age of birds had a significant impact on the texture of breast meat [42]. The study analyzed the impact of age, expressed as shear force, on the texture of breast meat in roosters derived from laying hen breeds. The higher shear force values observed with age in the birds' muscles indicated decreases in meat tenderness. Choe and Kim [34] utilized the breast muscle and leg muscles of spent broiler chickens (75 weeks) for the production of hams. They found that the hams composed of 50% breast muscle and 50% leg muscles from laying hens had the highest hardness. In contrast, significantly lower hardness was measured for hams produced from 50% breast muscle and 50% leg muscle derived from broiler breeder flocks of spent broiler hens. It can be concluded that meat from spent broiler chickens has better characteristics and is suitable for meat processing.

Table 5. Texture characteristics of the pectoralis major muscle of Cobb 500 and Ross 308 broiler breeders at 61 weeks of age.

Trait	Genotype (G)—Sex (S)				SEM	*p* Values		
	Cobb 500	Ross 308	Male	Female		G	S	G × S
Hardness (N)	28.2 [b]	33.3 [a]	34.0	27.9 *	1.1	0.005	0.001	0.950
Cohesiveness	0.4	0.4	0.4	0.4	0.1	0.618	0.142	0.556
Springiness (cm)	1.6	1.6	1.6	1.6	0.1	0.117	0.658	0.038
Chewiness (N × cm)	15.9 [b]	19.7 [a]	20.4	15.5 *	0.9	0.015	0.003	0.386
Gumminess (N)	10.1 [b]	12.1 [a]	12.5	9.8 *	0.5	0.013	0.001	0.590
WB shear force (N)	48.1 [b]	60.2 [a]	62.8	46.5 *	2.9	0.006	0.001	0.351

[a,b] means with different superscripts are statistically different between genetic groups ($p < 0.05$). * statistical differences between males and females ($p < 0.05$). n = 14/genotype or sex.

In our study, we also analyzed the structure of the pectoralis major muscle and demonstrated the influence of genotype and sex (Table 6).

Table 6. Microstructure features of the pectoralis major muscle of Cobb 500 and Ross 308 broiler breeders at 61 weeks of age.

Trait	Genotype (G)—Sex (S)				SEM	*p* Values		
	Cobb 500	Ross 308	Male	Female		G	S	G × S
Fiber cross-sectional area (μm^2)	1403.2 [b]	1620.4 [a]	1441.6	1584.8	68.4	0.007	0.206	0.214
Fiber perimeter (μm)	155.0	169.4	158.0	166.6	3.9	0.040	0.185	0.310
Fiber diameter H (μm)	41.8 [b]	43.8 [a]	41.3	44.4	1.1	0.263	0.108	0.117
Fiber diameter V (μm)	44.2 [b]	48.7 [a]	45.3	47.7	1.2	0.046	0.241	0.614
Perimysium thickness (μm)	16.5	19.4	20.1	16.1 *	1.0	0.105	0.033	0.138
Endomysium thickness (μm)	1.4	1.6	1.6	1.3 *	0.1	0.104	0.010	0.479

[a,b] means with different superscripts are statistically different between genetic groups ($p < 0.05$). * statistical differences between males and females ($p < 0.05$). n = 14/genotype or sex.

Cobb 500 had a smaller fiber cross-sectional area, circumference, and vertical fiber diameter compared to Ross 308 birds. The cross-sectional area of the fiber was significantly larger in Ross 308 compared to Cobb 500 (p = 0.007). Additionally, the circumference and vertical fiber diameter were greater in the breast muscle of Ross 308 (169.4 µm and 48.7 µm, respectively) compared to Cobb 500 (155.0 µm and 44.2 µm, respectively). In addition, males were characterized by thicker connective tissue and intramuscular fat compared to females. Kokoszyński et al. [20] showed that the genotype of birds influenced the diameter of H-fiber. Ross 308 broiler chickens had a larger H-fiber diameter compared to Cobb 500 broiler chickens. In the present study, the H-fiber diameter was also larger in Ross 308 compared to Cobb 500 birds. It can be concluded that the diameter of H-fiber is genetically determined, because significant differences were observed in young 42-day-old birds. Other authors showed that the age of birds had a greater impact on fiber structure and, ultimately, meat tenderness than sex or body weight [43]. In the study by Liu et al. [44], it was demonstrated that the thickness of the perimysium in broiler chickens varied depending on the muscle type but was strongly correlated with shear force.

4. Conclusions

To sum up, it can be said that the breast parts and legs of spent broilers, regardless of genotype and sex, were characterized by a high amount of meat and a low content of fat. The breast muscles were characterized by lower water content, high protein content, and a low intramuscular fat compared to the leg muscles. The comparison of genotypes showed that the Cobb 500 breast muscle had a lower cooking loss, higher fat content, a more delicate structure, and thus a lower hardness. This kind of meat was also more chewy, less gummy and required less force to cut it than meat obtained from Ross 308 broilers. It can be also concluded that meat derived from spent broiler breeder flocks can be considered as a good material for further technological processing.

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References

1. KRD-IG. Number of Breeding Meat Hen Chicks (Parental Flocks—Females) Accepted for Breeding in 2015–2022 along with the Dynamics of Changes in the Size of the Facilities (%). 2023. Available online: https://krd-ig.com.pl/dzial-hodowli-i-oceny-drobiu//wstawienia/ (accessed on 9 June 2023).
2. Wegner, M.; Kokoszyński, D.; Biegniewska, M. Effect of litter system and nest box type on egg production and performance of Ross 308 broiler breeders. *Anim. Prod. Sci.* **2022**, *62*, 1600–1606. [CrossRef]
3. Wencek, E.; Grzelak, M.; Kałużna, I.; Koźlecka, M.; Miszkiel, I.; Pałyszka, M.; Prokopiak, H.; Radziszewska, J.; Suchocki, W.; Winiarski, K.; et al. *Results of the Evaluation Usability Value of Poultry in 2020*; Wiadomości Drobiarskie: Poznan, Poland, 2021.
4. Fan, H.; Wu, J. Conventional use and sustainable valorization of spent egg-laying hens as functional foods and biomaterials: A review. *Bioresour. Bioprocess.* **2022**, *9*, 43. [CrossRef]
5. Mitchell, A. Ross Celebrates 60 Years of Success. *The Poultry Site*, 4 January 2016.
6. Coneglian, J.L.B.; Vieira, S.L.; Berres, J.; de Freitas, D.M. Responses of fast and slow growth broilers fed all vegetable diets with variable ideal protein profiles. *R. Bras. Zootec.* **2010**, *39*, 327–334. [CrossRef]
7. Aviagen, European Parents Stock, Performance Objectives. 2016, pp. 1–10. Available online: https://www.coursehero.com/file/39101161/Ross308-PS-PO-EN-2016pdf/ (accessed on 9 June 2023).

8. Cobb-Vantress, Cobb Breeder Management Guide. 2017, pp. 1–160. Available online: https://www.cobb-vantress.com/assets/Cobb-Files/management-guides/ca1b2a76ed/Cobb-Breeder-Management-Guide.pdf. (accessed on 9 June 2023).
9. Kokoszyński, D.; Bernacki, Z.; Stęczny, K.; Saleh, M.; Wasilewski, P.D.; Kotowicz, M.; Wasilewski, R.; Biegniewska, M.; Grzonkowska, K. Comparison of carcass composition, physicochemical and sensory traits of meat from spent broiler breeders with broilers. *Europ. Poult. Sci.* **2016**, *80*, 1–11. [CrossRef]
10. Semwogerere, F.; Neethling, J.; Muchenje, V.; Hoffman, L.C. Meat quality, fatty acid profile, and sensory attributes of spent laying hens fed expeller press canola meal or a conventional diet. *Poult. Sci.* **2019**, *98*, 3557–3570. [CrossRef]
11. Mahmoudi, S.; Mahmoudi, N.; Benamirouche, K.; Estevez, M.; Mustapha, M.A.; Bougoutaia, K.; El Houda, N.; Djoudi, B. Effect of feeding carob (*Ceratonia siliqua* L.) pulp powder to broiler chicken on growth performance, intestinal microbiota, carcass traits, and meat quality. *Poult. Sci.* **2022**, *101*, 102186. [CrossRef] [PubMed]
12. Maynard, C.J.; Jackson, A.R.; Caldas-Cueva, J.P.; Mauromoustakos, A.; Kidd, M.T.; Rochell, S.J.; Owens, C.M. Meat quality attributes of male and female broilers from four commercial strains processed for two market programs. *Poult. Sci.* **2023**, *102*, 102570. [CrossRef]
13. Maynard, C.J.; Maynard, C.W.; Jackson, A.R.; Kidd, M.T.; Rochell, S.J.; Owens, C.M. Characterization of growth patterns and carcass characteristics of male and female broilers from four commercial strains fed high or low density diets. *Poult. Sci.* **2022**, *102*, 102435. [CrossRef] [PubMed]
14. Orlowski, S.K. Characterization of Broiler Lines Divergently Selected for Breast Muscle Color. Master's Thesis, University of Arkansas, Fayetteville, AR, USA, 2016. Available online: https://scholarworks.uark.edu/etd/1669 (accessed on 9 June 2023).
15. Trocino, A.; Piccirillo, A.; Birolo, M.; Radaelli, G.; Bertotto, D.; Filiou, E.; Petracci, M. Effect of genotype, gender and feed restriction on growth, meat quality and the occurrence of white striping and wooden breast in broiler chickens. *Poult. Sci.* **2015**, *94*, 2996–3004. [CrossRef]
16. Weng, K.; Huo, W.; Li, Y.; Zhang, Y.; Zhang, Y.; Chen, G.; Xu, Q. Fiber characteristics and meat quality of different muscular tissues from slow and fast-growing broiler. *Poult. Sci.* **2022**, *101*, 101537. [CrossRef]
17. Janocha, A.; Milczarek, A.; Łaski, K.; Głuchowska, J. Slaughter value and meat quality of broiler chickens fed with rations containing a different share of pea seed meal. *Acta Sci. Pol. Technol. Aliment.* **2021**, *20*, 265–276.
18. Połtowicz, K.; Doktor, J. Effect of slaughter age on performance and meat quality of slow-growing broiler chickens. *Ann. Anim. Sci.* **2012**, *12*, 621–631. [CrossRef]
19. Zdanowska-Sąsiadek, Ż.; Michalczuk, M.; Marcinkowska-Lesiak, M.; Damiziak, K. Czynniki kształtujące cechy sensoryczne mięsa drobiowego [Factors determining thesensory quality of poultry meat]. *Bromat. Chem. Toksykol.* **2013**, *46*, 344–353.
20. Kokoszyński, D.; Żochowska-Kujawska, J.; Kotowicz, M.; Sobczak, M.; Piwczyński, D.; Stęczny, K.; Majrowska, M.; Saleh, M. Carcass characteristics and selected meat quality traits from commercial broiler chickens of different origin. *J. Anim. Sci.* **2022**, *93*, 13709. [CrossRef]
21. Nowak, M.; Trziszka, T. Zachowania konsumentów na rynku mięsa drobiowego [Consumer behaviour on the poultry meat market]. *Żywn. Nauk. Technol. Jakość.* **2010**, *1*, 114–120.
22. Osek, M.; Milczarek, A.; Klocek, B.; Turyk, Z.; Jakubowska, K. Effectiveness of mixtures with the fabaceae seeds in broiler chicken feeding. *Ann. Univ. Mariae Curie-Skłod. Sec. EE Zootech.* **2013**, *31*, 77–86.
23. Grigore, D.; Mironeasa, M.; Ciurescu, S.; Ungureanu-Iuga, G.; Batariuc, A.; Babeanu, N.E. Carcass Yield and Meat Quality of Broiler Chicks Supplemented with Yeasts Bioproducts. *Appl. Sci.* **2023**, *13*, 1607. [CrossRef]
24. Hidayat, M.N. Improving the Quality of Poultry Meat Through Balanced Regulation of Protein and Energy Rations. *Technosci. Sci. Technol. Inf. Media* **2016**, *10*, 59–68.
25. Jianga, H.; Yoonb, S.C.; Zhuangb, H.; Wanga, W.; Lawrenceb, K.C.; Yang, Y. Tenderness classification of fresh broiler breast fillets using visible and nearinfrared hyperspectral imaging. *Meat Sci.* **2018**, *139*, 82–90. [CrossRef]
26. Sari, A.; Hatta, W.; Maruddin, F. Application of Bay Leves (Syzygium Polyanthum) on Broiler Meat, the Physiochemical Quality of Meat and the Sensory Effect of the Nugget Product. *J. Pharm. Negat.* **2023**, *14*, 1123–1128.
27. Ziołecki, J.; Doruchowski, W. *Evaluation Methods of Poultry Slaughter Values*, 1st ed.; Poultry Research Center: Poznań, Poland, 1989; pp. 1–23.
28. Walczak, Z. Laboratoryjna metoda oznaczania zawartości galarety w konserwach mięsnych [Laboratory method for determining the content of jelly in canned meat]. *Rocz.Nauk. Rol.* **1959**, *74*, 619–621. (In Polish)
29. Bourne, M.C. *Food Texture and Viscosity Concept Andmeasurement*; Academic Press Inc.: New York, NY, USA, 1982.
30. Burck, H.C. *Technologie Histochemiczne*; PZWL: Warsaw, Poland, 1975.
31. Biegniewska, M.; Kokoszynski, D.; Bernacki, Z.; Saleh, M. Carcass composition, physico-chemical and sensory proper-ties of meat of cockerels and broiler breeder hens after reproductive cycle. *Acta Sci. Pol. Zootech.* **2017**, *16*, 31–38. [CrossRef]
32. Robinson, F.E.; Zuidhof, M.J.; Renema, R.A. *Reproductive Efficiency and Metabolism of Female Broiler Breeds as Affected by Genotype, Feed Allocation, and Photostimulation Age*; Project #2002 A162R, Final Report; Alberta Agricultural Research Institute: Calgary, AB, Canada, 2005.
33. Sokoya, O.O.; Babajide, J.M.; Shittu, T.A.; Sanwo, K.A.; Adegbite, J.A. Chemical and color characterization of breast meat from FUNAAB indigenous and marshal broiler chickens. *Trop. Anim. Health Prod.* **2019**, *51*, 2575–2582. [CrossRef] [PubMed]
34. Choe, J.; Kim, H.Y. Physicochemical characteristics of breast and thigh meats from old broiler breeder hen and old laying hen and their effects onquality properties of pressed ham. *Poult. Sci.* **2020**, *99*, 2230–2235. [CrossRef] [PubMed]

35. Abubakar, A.; Fitri, C.A.; Koesmara, H.; Mudatsir Ardatami, S. Analysis of pH and cooking losses of chicken meat due to the use of different percentages of turmeric flour. *IOP Conf. Ser. Earth Environ. Sci.* **2021**, *667*, 012042. [CrossRef]
36. Stęczny, K.; Kokoszynski, D. Effects of probiotics and sex on physicochemical, sensory and microstructural characteristics of broiler chicken meat. *Ital. J. Anim. Sci.* **2019**, *18*, 1385–1393. [CrossRef]
37. Brunel, V.; Jehl, N.; Drouet, L.; Portheau, M.C. Viande de volailles sa valeur nutritionnelle presente bien des atouts. *Viandes Prod. Carnes* **2010**, *25*, 18.
38. Abdulla, N.R.; Zamri, A.N.M.; Sabow, A.B.; Kareem, K.Y.; Nurhazirah, S.; Ling, F.H.; Sazili, A.Q.; Loh, T.C. Physicochemical properties of breast muscle in broiler chickens fed probiotics, antibiotics or antibiotic-probiotic mix. *J. Appl. Anim. Res.* **2017**, *45*, 64–70. [CrossRef]
39. Milczarek, A.; Osek, M.; Horoszewicz, E.; Niedziółka, R. Effect of different shares of protein feeds in diets and of cold storage time on the physical properties of broiler chicken's meat. *J. Cent. Eur. Agric.* **2020**, *21*, 7–13. [CrossRef]
40. Kozioł, K.; Pałka, S.; Migdał, Ł.; Derewicka, O.; Kmiecik, M.; Maj, D.; Bieniek, J. Analiza tekstury mięsa królików w zależności od sposobu obróbki termicznej. *Rocz. Nauk. Pol. Tow. Zootech.* **2016**, *12*, 25–32.
41. Lyon, C.E.; Lyon, B.G.; Savage, E.M. Effect of postchill deboning time on the texture profile of broiler breeder hen breast meat. *J. Appl. Poult. Res.* **2003**, *12*, 348–355. [CrossRef]
42. Popova, T.; Petkov, E.; Ignatova, M.; Vlahova-Vangelova, D.; Balev, D.; Dragoev, S.; Kolev, N. Male layer-type chickens–an alternative source for high quality poultry meat: A review on the carcass composition, sensory characteristics and nutritional profile. *Braz. J. Poult. Sci.* **2022**, *24*, 1–10. [CrossRef]
43. Smith, D.P.; Fletcher, D.L. Chicken breast muscle fiber type and diameter as influenced by age and Intramuscular Location. *Poult. Sci.* **1988**, *67*, 908–913. [CrossRef] [PubMed]
44. Liu, A.; Nishimura, T.; Takahashi, K. Relationship between structural properties of intramuscular connective tissue and toughness of various chicken skeletal muscles. *Meat Sci.* **1996**, *43*, 43–49. [CrossRef]