Comparison of some meat and liver quality traits in Muscovy and Pekin ducks

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**ABSTRACT**

The objective of the study was to compare Muscovy and Pekin ducks for proximate analysis, colour attributes, tenderness, meat microstructure, and content of some minerals in meat and liver. The material of the study was sexed 51 Muscovy ducks and 47 Pekin ducks. At the end of the rearing period, 40 birds were selected for dissection. Duck genotype influenced the content of water, protein, fat, collagen, zinc, iron, haematin, and redness, chroma, hue angle, WB shear force, muscle fibre diameter and density of the breast muscle, and also protein, fat, magnesium, iron, haematin content, WB shear force and lightness of the leg muscle. The sex of ducks had an impact on the content of water, protein, fat, potassium, copper, on redness, chroma and muscle fibre diameter of breast muscle, and on water, protein, fat, sodium, potassium, magnesium and copper in liver content of the leg muscle. The genotype-sex interaction was significant for water, protein and sodium content, redness, chroma of breast muscles; for water, protein, sodium, magnesium and haematin content, redness and chroma of leg muscles; and for phosphorus content in the liver. Muscovy ducks had more favourable chemical composition and poorer tenderness and microstructural characteristics compared to the meat of Pekin ducks.

**Introduction**

In 2018, world duck meat production totalled 4,464,925 tons, accounting for around 3.5% of the overall poultry meat available. The number one duck meat producer was China, which produced 67.5% of the total world production. France ranked second, with a production of 246,209 tons (5.5%), and Myanmar third (157,366 tons, 3.5%). The majority of duck meat around the world was produced in Asia (83.0%, 3,705,427 tons), followed by Europe (11.7%, 520,456 tons) and the other continents (5.3%) (FAOSTAT 2018).

In most European countries, just as in China, commercial Pekin ducks are most often reared for meat. In France, production is dominated by mule ducks (a crossbreed of Muscovy drakes and Pekin ducks) and Muscovy ducks (Kokoszyński et al. 2015; Michalczuk et al. 2017).

The Pekin duck was created in the second half of the nineteenth century. Its wild ancestor is the mallard (*Anas platyrhynchos*). Pekin ducks have a snow-white plumage. Pekin-type broiler ducks are raised intensively from 6 to 7 weeks, and under a backyard system from 9 to 10 weeks. These ducks are characterized by a fast growth rate, high slaughter weight, good feed conversion, and are less demanding in terms of their feeding and environmental conditions compared to Muscovy and mule ducks (Kokoszyński et al. 2015). However, Pekin ducks tend to accumulate too much fat and exhibit lower breast muscle content, especially after 8 weeks of growth (Kuźniacka et al. 2019; Banaszak et al. 2020).

The Muscovy duck is derived from the wild Muscovy duck native to South America (*Cairina moschata*). Muscovy ducks were imported into Europe in the sixteenth century and were initially considered as ornamental fowls. Available in several colour varieties, Muscovy ducks are predominantly black and white (piebald) or white. They are characterized by marked sexual dimorphism, have red caruncles around the bill and eyes, a long, wide, but shallow trunk, strong legs located in the middle of the trunk, and a long tail (Różewicz and Kaszperuk 2017). In an intensive system, the rearing period is 9–10 weeks in females and 11–12 weeks in males (Kokoszyński et al. 2020). Compared to Pekin ducks, Muscovy ducks have a slower growth rate and poorer feed conversion and are more demanding in terms of the required feeding and environmental conditions and prevention costs. They also produce fewer eggs per layer per year, need a longer incubation period, and show poorer incubation results (Retailleau 1999; Różewicz and Kaszperuk 2017; Tamzil 2018). The advantages of Muscovy ducks include higher breast and leg muscle percentages in the carcass, a lower percentage of skin with subcutaneous fat and of abdominal fat, and meat of better quality compared to Pekin ducks (Paci et al. 1993; Baéza et al. 1998; Pingel 1997; Wawro et al. 2004; Damaziak et al. 2014; Różewicz and Kaszperuk 2017; Hassan et al. 2018). Breast muscles from Muscovy ducks have a higher protein and mineral content and a lower lipid content in comparison to the muscles of Pekin ducks.
Materials and methods

Birds and housing

The study material here consists of 51 commercial Muscovy ducks (24 males and 27 females) derived from a crossing of MMLCF CZCK drakes and CK ducks, which are parents imported from the French Grimaud Frères, as well as 47 AF51 commercial Pekin ducks (30 males and 17 females), which are of Polish stock obtained from A55 drakes and F11 ducks, distributed by the Waterfowl Breeding and Hatching Establishment in Tuchola, Poland.

Upon arrival at the farm, one-day-old sexed ducklings were individually tagged with padlock tags in the left wing. Next, ducklings were placed into 4 pens, each with an area of 12 m², according to genotype and sex. Birds were kept on litter straw in a conventional livestock building and had no outdoor access. Incandescent light was provided in the building and birds were maintained under a 16 h light:8 h dark (16L:8D) photoperiod, except for the first three days of life (24 h light). From weeks 1 to 3 inclusive, infrared lamps were used as heat sources. During the first week of rearing, the temperature was 30–32°C in the rearing area and 23–24°C in the building. In the following weeks, the temperature was reduced by 2–3°C per week under the heaters and by 1°C in the rearing area. From 22 days of age, the temperature in the rearing area was 21 ± 1°C. During the rearing period, the relative humidity in the duck house was 60–70%. This experiment was approved by the Local Ethics Committee for Animal Experimentation in Bydgoszcz, Poland (no. 27/2012).

Throughout the study, ducks had 24-hour ad libitum access to feed and water. Until 21 days of age, ducks were fed a complete commercial starter diet in crumbled form. The starter diet contained 20.62% crude protein and 12.19 MJ metabolizable energy per kg. From 22 d of age until the end of rearing (49 d for Pekin ducks, 70 d for female Muscovy ducks, and 84 d for male Muscovy ducks), the birds received a complete commercial grower/finisher diet in pelleted form. The grower/finisher diet contained 17.59% CP and 12.68 MJ ME per kg. Data on the ingredient and chemical compositions and energy contents of the starter and grower/finisher diets are presented in Table 1.

Evaluation of meat and liver quality

To obtain samples of breast and leg meat and of livers, male and female Pekin ducks were slaughtered at 49 d, female Muscovy ducks at 70 d, and male Muscovy ducks at 84 d, i.e. at the typical market age. A total of 40 birds, including 10 male and 10 female Muscovy and Pekin ducks each were slaughtered to evaluate the meat and liver quality traits. Feed but not water was withdrawn 10 h prior to slaughtering. Birds whose body weights were closest to the mean arithmetic weight of male or female Muscovy or Pekin ducks were selected for slaughtering. Birds were slaughtered manually, defeathered, and eviscerated at an experimental farm. Ducks were stunned with a club and bled from the neck vessels. After evisceration, the carcasses and giblets (heart, gizzard, livers) were chilled in a refrigerated cabinet (Hendi, Gdańsk, Poland) for 18 h at 4°C. After removal from the refrigerated cabinet, each carcass was sampled for the breast muscles (pectoralis major muscle), leg muscles (all thigh and drumstick muscles), and liver to determine quality traits.

The water, protein, fat, and collagen content of the breast and leg muscles was determined with a FoodScan analyser (FoodScan Laboratory, Foss, Cheshire, UK) by near-infrared transmission spectroscopy. FOSS FoodScan with an artificial neutral network method has been granted AOAC Official method status (AOAC International 2007). Meat colour was determined on the inner side of raw pectoralis major muscle, leg muscles (all thigh and drumstick muscles), and liver to determine quality traits.

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| Table 1. Ingredients and chemical composition of the diets for ducks. |
|-------------------------------------------------------------|
| Ingredients (g/kg as fed) | Starter | 1–21 d | Grower/finisher | 22–84 d |
|----------------------------|---------|--------|-----------------|--------|
| Corn                       | 350.6   | 438.0  |                 |        |
| Wheat, ground              | 184.5   | 250.0  |                 |        |
| Wheat meal                 | 30.0    | 25.0   |                 |        |
| Wheat middlings            | 28.0    | -      |                 |        |
| Triticale, ground          | 14.0    |        |                 |        |
| Soybean meal (475 g CP/kg) | 280.9   | 173.0  |                 |        |
| Sunflower meal seed meal (385 g CP/kg) | 20.0 | 20.0 | |        |
| Rapeseed meal (357 g CP/kg) | 25.0    | 10.0   |                 |        |
| Corn DDGS (280 g CP/kg)    | 15.0    | 30.0   |                 |        |
| Soybean oil                | 19.0    | 26.0   |                 |        |
| Limestone                  | 11.4    | 9.8    |                 |        |
| Monocalcium phosphate      | 10.7    | 7.4    |                 |        |
| Sodium chloride            | 2.42    | 2.37   |                 |        |
| Sodium bicarbonate         | 1.6     | 1.4    |                 |        |
| DL-methionine              | 0.85    | 1.05   |                 |        |
| L-Lysine                   | 0.68    | 0.98   |                 |        |
| Threonine                  | 0.35    | -      |                 |        |
| Vitamin-mineral premix     | 5.0     | 5.0    |                 |        |
| Chemical composition (g/kg as fed) |         |        |                 |        |
| DM (%)                     | 90.63   | 90.01  |                 |        |
| CP (g/kg as fed)           | 206.2   | 175.9  |                 |        |
| Crude fat (g/kg as fed)    | 44.6    | 45.0   |                 |        |
| Crude fibre (g/kg as fed)  | 42.0    | 43.4   |                 |        |
| Crude ash (g/kg as fed)    | 50.5    | 47.3   |                 |        |
| N-free extracts (g/kg as fed) | 563.0 | 588.5 | |        |
| ME (MJ/kg of fed)          | 12.19   | 12.68  |                 |        |
| Calculated composition (g/kg as fed) |         |        |                 |        |
| Lysine                     | 10.7    | 8.9    |                 |        |
| Methionine                 | 3.9     | 4.1    |                 |        |
| Threonine                  | 7.5     | 6.2    |                 |        |
| Tryptophan                 | 2.6     | 2.1    |                 |        |
| Calcium                    | 10.1    |        |                 |        |
| Phosphorus soluble         | 6.2     | 5.2    |                 |        |

Note: DM – dry matter, CP – crude protein, ME – metabolizable energy.

1 kg of vitamin-mineral premix provided: retinol 10,000 IU, cholecalciferol 2500 IU, α-tocopherol 20.00 mg, thiamine 0.5 mg, riboflavin 5.00 mg, niacinamide 20.00 mg, pyridoxine 1.0 mg, cobalamin 0.02 mg, folic acid 0.5 mg, menadione 2.5 mg, choline chloride 200.00 mg, Fe 45.00 mg, Mn 62.5 mg, Zn 50.00 mg, Cu 5.00 mg, Se 0.25 mg, I 1.3 mg.

The values are calculated from ingredient AME values.
CR310, Konica Minolta, Osaka, Japan). Colour lightness (L*), relative redness (a*) and relative yellowness (b*) were determined based on the CIE Lab system (CIE, 1986). The measured area was 50 mm in diameter. The chroma meter was calibrated against a CR310 white reference tile (Y = 92.80, x = 0.3175, y = 0.3333). The redness (a*) and yellowness (b*) values were used to calculate chroma (C*) and hue angle (h*). C* and h* colour parameters were calculated from the following formulae: C = (a*² + b*²)½, h = arctan (b*/a*).

The breast and leg muscle samples were also analysed for the total pigments, which were calculated as haematin according to the procedure of Hornsey (1956). The optical density values of the filtrate (E) were multiplied by 680 to calculate the concentration of haem pigments (haematin) in ppm, i.e. μg haematin per g of meat.

Breast and leg meat tenderness was found via instrumental analysis using an Instron 3342 testing machine (Instron Corp. U.S.A.) with a Warner–Bratzler attachment. The samples were stored frozen until determination. After thawing, the samples were heated in a water bath in a 0.85% sodium chloride solution until the temperature reached 70°C in the geometric centre. Next, cylindrical cores of the muscles were cut using a cork borer in a parallel orientation to the muscle fibres. During the determinations, the maximum shear strength needed to cut the muscle fibres was recorded and expressed as N (Szala et al. 1999).

The selected minerals (sodium, potassium, phosphorus, magnesium, zinc, iron, and copper) were determined according to Polish standards. The meat and liver samples were freeze-dried and wet-mineralized in an Ethos Plus microwave digester (Milestone, Sorisole, Italy). The determinations of sodium, potassium, magnesium, zinc, iron, and copper were made by an atomic absorption spectrometer (IC 3000 series, Thermo Scientific, Cambridge, United Kingdom), and phosphorus was determined colorimetrically using a Marcel Media Eko spectrometer (Marcel, Warsaw, Poland).

This study also determined microstructural characteristics (percentage, diameter, density of white and red muscle fibres) in the pectoralis major muscle. For histological analyses, 24 samples of the pectoralis major muscle were collected from 6 males and 6 females of each genotype. Immediately after slaughtering, the feathers were removed from the front left breast and samples of the pectoralis superficialis muscle were collected using a scalpel. The collected sections of the breast muscle were frozen in liquid nitrogen (−196°C) and placed in vials labelled for later identification. The muscle sample vials were stored in liquid nitrogen until analysis. Prior to histochemical analysis, the muscle samples were cut into sections (10-μm thick) on a cryostat (at −25°C) and mounted on glass slides. These preparations were subjected to a NADH-tetrazolium reductase (NADH-TR) reaction to identify white (ωW) and red muscle fibres (BR) (Ziegan and Dippold 1985). Images captured with a Carl Zeiss microscope coupled to a digital camera TouCam™ were saved on a computer disc (125 × magnification). Next, the muscle fibre diameters were measured in an area of 1.5 mm² using the Multiscan 18.03 software package (Computer Scanning Systems II, Warsaw, Poland).

Statistical analysis

The numerical data collected for the proximate chemical composition, mineral content, physicochemical traits of breast and leg muscles, microstructure of the pectoralis major muscle, and mineral contents of the meat and livers were verified with generally accepted statistical methods (means, standard error of mean). Two-way analysis of variance was used to determine the effect of genotype and sex on the analysed meat and liver quality traits. To this end, the following linear model was used: yijk = µ + aij + bijk + ejk, where yijk is the value of the analysed trait, µ is the overall mean for the analysed trait, aij is the effect of i-th duck genotype, bijk is the effect of the j-th sex, (a×b)ijk refers to genotype-sex interaction, and eijk is the random error.

Descriptive statistics for the meat and liver quality traits were produced using SAS version 9.4 (SAS Institute Inc. 2013). Significant differences between the compared duck genotypes and between males and females were analysed by Tukey’s test. The level of significance was at P = 0.05. The individual bird was the experimental unit for all the traits under analysis.

Results and discussion

Here, Muscovy and Pekin ducks differed (P = 0.001) in their water, protein, fat, and collagen contents in breast muscles and in the protein, and fat contents of leg muscles. Muscovy ducks contained significantly more protein and collagen and less water and fat in the breast muscles compared to Pekin ducks. The leg muscles of Muscovy ducks had significantly more protein and less fat than the leg muscles of Pekin ducks. Regardless of the genotype, males had a significantly higher protein content and lower (P = 0.001) water content in the breast and leg muscles compared to females. The male breast muscles contained significantly less fat and the male leg muscles had a higher (P = 0.001) fat content when compared to female muscles. The genotype-sex interaction was significant for the water and protein content of the breast and leg muscles (Table 2). The significantly higher protein content and the lower fat content in male compared to female breast muscles were probably due to the activity of androgenic hormones in males. In turn, the higher fat content in male leg muscles (despite the action of androgenic hormones) could result from the lower motor activity of heavier males compared to females, especially in Muscovy ducks. In the study by Hassan et al. (2018), Muscovy and Pekin ducks had a higher water and fat content, and a lower protein content in breast and leg muscles compared to the muscles of ducks from our study. The same experiment (Hassan et al., 2018) found a higher protein content and lower fat content in the breast and leg muscles of Muscovy ducks compared to Pekin ducks, which is consistent with our findings. In turn, Marzioni et al. (2014) observed more water (from 76.12% to 76.41%) and fat (from 1.50% to 1.52%) and less protein (from 21.73% to 21.96%) in the breast muscles of 69-d-old Muscovy ducks in comparison with the contents of these components in the meat of Muscovy ducks in our study. Baltić et al. (2015) noted a higher water content (from 74.37% to 76.04%) and lower
protein (from 20.56% to 22.24%) and fat contents (from 2.22% to 2.48%) in the breast muscles of 49-d-old Pekin ducks compared to the AF51 ducks from our experiment. In our study, breast and leg meat of Muscovy ducks was characterized by higher nutritive and dietetic value compared to the meat of Pekin ducks. This may suggest that the meat of Muscovy ducks contained more protein and less fat. The results of statistical analysis show that the sex of ducks had a considerable effect on basic chemical composition of the breast and leg meat.

The genetic origin of the ducks had a significant effect on the zinc ($P = 0.005$) and iron ($P = 0.002$) contents of the breast muscles, and also on the magnesium and iron contents of the leg muscles. The zinc and magnesium contents were significantly higher in the breast or leg muscles of Muscovy ducks and additionally for the iron content in Pekin ducks. Regardless of the bird origin, the potassium ($P = 0.024$) and copper ($P = 0.009$) contents of male breast muscles were significantly lower than in females. The male leg muscles contained significantly less sodium and magnesium than the female leg muscles. The genotype-sex interaction was significant for the sodium content of breast muscles and for the sodium and magnesium content of leg muscles (Table 3). Lucia et al. (2008) reported higher zinc and copper contents and lower cadmium and copper contents in the breast muscles of farmed Muscovy ducks compared to Pekin ducks. According to the authors (Lucia et al. 2008, in particular), a differential lipidic metabolism leads to a differential content (accumulation) of metals in the tissues of ducks of different genotypes. In the study by Kokoszyński et al. (2020), breast muscles collected from 10-wk-old female and 12-wk-old male Muscovy ducks (commercial hybrids) contained more sodium, potassium, phosphorus, and iron, and less magnesium, copper, and zinc compared to the breast muscles of the studied Muscovy ducks of the same age. The same experiment (Kokoszyński et al. 2020) found higher potassium and zinc contents, similar phosphorus and magnesium contents, and lower iron and copper contents in the leg muscles of Muscovy ducks compared to the muscles of Muscovy ducks in our study. Regardless of the duck genotype, they found potassium, phosphorus, magnesium, and iron to be higher in breast muscles than in leg muscles. Our results indicate that apart from genotype also sex has a considerable effect on some mineral content, which may contribute to the differences in the nutritional value of duck meat.

Muscovy and Pekin ducks did not differ significantly ($P > 0.05$) in minerals determined in the liver, with the exception of the copper content. A significantly higher copper content was observed in the liver of Pekin ducks compared to Muscovy ducks. The sexes of birds here had no significant effect on the sodium, potassium, phosphorus, magnesium, zinc, iron, and copper contents of the liver. The genotype-sex interaction was significant for phosphorus content in the liver (Table 4). Duman et al. (2019) noted higher contents (in

### Table 2. Basic chemical composition of the breast and leg muscles of ducks of different genotype.

| Trait          | Genotype (G) – sex (S) | Pekin | Muscovy | P-value |
|---------------|------------------------|-------|---------|---------|
|               | Male (n = 10)           |       | Male (n = 10) |       |
|               | Female (n = 10)         |       | Female (n = 10) |       |
|               |                       | SEM   | G       | S       | G × S    |
| Water (%)     | BM 72.5                | 0.2   | 0.001   | 0.001   | 0.001    |
|               | LM 70.7                | 0.2   | 0.136   | 0.001   | 0.001    |
| Protein (%)   | BM 25.5                | 0.4   | 0.001   | 0.001   | 0.001    |
|               | LM 23.0                | 0.3   | 0.001   | 0.001   | 0.001    |
| Fat (%)       | BM 3.0                 | 1.2   | 0.001   | 0.013   | 0.001    |
|               | LM 5.1                 | 2.4   | 0.001   | 0.013   | 0.001    |
| Collagen (%)  | BM 1.1                 | 1.3   | 0.001   | 0.001   | 0.438    |
|               | LM 1.3                 | 1.3   | 0.001   | 0.001   | 0.013    |

Note: BM – breast muscles, LM – leg muscles.

### Table 3. Content of some minerals in mg/100 g of breast or leg meat from ducks of different genotype.

| Trait          | Genotype (G) – sex (S) | Pekin | Muscovy | P-value |
|---------------|------------------------|-------|---------|---------|
|               | Male (n = 10)           |       | Male (n = 10) |       |
|               | Female (n = 10)         |       | Female (n = 10) |       |
|               |                       | SEM   | G       | S       | G × S    |
| Na – sodium   | BM 90.6                | 3.9   | 0.443   | 0.097   | 0.044    |
|               | LM 73.1                | 3.0   | 0.096   | 0.004   | 0.020    |
| K – potassium | BM 338.1               | 6.1   | 0.845   | 0.024   | 0.081    |
|               | LM 275.7               | 5.8   | 0.293   | 0.008   | 0.257    |
| P – phosphorus| BM 47.3                | 0.7   | 0.672   | 0.498   | 0.756    |
| Mg – magnesium| BM 34.2                | 0.7   | 0.676   | 0.061   | 0.583    |
| Zn – zinc     | BM 0.8                 | 0.1   | 0.005   | 0.107   | 0.606    |
|               | LM 1.9                 | 0.1   | 0.610   | 0.841   | 0.089    |
| Fe – iron     | BM 5.8                 | 0.2   | 0.002   | 0.745   | 0.901    |
| Cu – copper   | BM 0.3                 | 0.1   | 0.232   | 0.009   | 0.482    |

Note: BM – breast muscles, LM – leg muscles.
terms of mg/100 g liver) of sodium, potassium, phosphorus, iron, and zinc, and similar or higher amounts of magnesium and copper in the liver of native Turkish ducks compared to the Muscovy and Pekin ducks in our study. In turn, Kokoszyński et al. (2015) found significant differences between the broiler ducks SM3 Heavy, Star 53 HY, and AF51 (commercial Pekin crosses) in the iron and zinc contents of breast muscles and in the sodium, potassium, phosphorus, and iron contents of leg muscles. Lucia et al. (2008) reported higher liver zinc and copper content) and sex had no significant effect on the liver mineral content, which may suggest similar nutritive value of the liver from the analysed Muscovy and Pekin ducks.

The compared groups of ducks differed in the redness, chroma, hue angle, haematin content, WB shear force of breast muscles, and lightness, haematin content and WB shear force of leg muscles. Higher values of traits were found in Muscovy ducks than in Pekin ducks, except for most of the colour coordinates of the breast and leg muscles. Regardless of the genetic origin, males showed significantly lower redness ($P = 0.002$) and chroma ($P = 0.002$) of breast muscles. The genotype-sex interaction was significant for the redness and chroma of breast muscles and for the redness, chroma, and haematin content of leg muscles (Table 5). Earlier studies (Baéza et al. 2005; Chartrin et al. 2006; Huda et al. 2011) established higher lightness ($L^*$) of breast muscles in Muscovy ducks than in Pekin ducks, which was not confirmed in our study. However, the authors reported above determined the lightness values of breast muscles in older ducks that were aged 14 (Baéza et al. 2005; Chartrin et al. 2006) or 16 weeks (Huda et al. 2011), regardless of genotype. In our study, the colour lightness of breast muscles was measured in ducks of a different age, i.e., the age when slaughtered at the typical market age. This caused differences in the degree of muscle vascularization and in the content of haemoglobin, myoglobin, and cytochrome C, which determine meat colour. Bang et al. (2010) reported lower lightness ($L^* = 34.66$) and redness ($a^* = 17.88$) values of breast muscles in Pekin ducks aged 8 weeks compared to birds at the age of 6 weeks ($L^* = 39.04, a^* = 22.39$). In turn, Witak (2008) found the colour lightness ($L^*$) of breast muscles from Pekin ducks to decrease between 7 and 9 weeks of age. Michalczuk et al. (2016) noted significantly higher redness ($a^*$) values of breast muscles in females than in males, while Gornowicz et al. (2015) did not observe any significant differences in the redness of breast muscles between males and females, unlike in our study. The darker colour of pectoralis major muscle from the analysed Muscovy ducks resulted from a significantly higher content of haem pigments compared to the breast muscles of Pekin ducks. This was probably related to better blood supply to the muscles (greater number of capillaries) in older Muscovy ducks. It was also not without significance that the fat content of breast muscles was significantly lower in Muscovy ducks than in Pekin ducks.

Our study found a significantly ($P = 0.001$) greater diameter of the white ($\alpha W$) and red muscle fibres ($\beta R$) in the pectoralis major muscle of Muscovy compared to Pekin ducks. Muscle fibre density (fibres/mm$^2$) was significantly lower in the pectoralis major muscle of Muscovy ducks compared to Pekin ducks. Males were characterized by significantly greater diameter of both muscle fibre types compared to females. The genotype-sex interaction was not significant for the microstructural characteristics of the pectoralis major muscle (Table 6). The differences observed in the muscle fibre percentage and diameter were most likely determined by the different genotype and age of the study ducks. Klosowska et al. (1999) found the proportion of glycolytic fibres ($\alpha W$) and the diameter of white ($\alpha W$) and red fibres ($\beta R$) to increase significantly in ducks between 6 and 8 weeks of age. Chen et al. (2007) reported that increased muscle weight is associated with increases in muscle fibre diameter and length and in the percentage of glycolytic muscle fibres. In turn, Górski and Gòrska (2006) noted the weight of breast muscles to increase the most during the last two weeks of rearing Pekin, Muscovy, and mule ducks. Damaziak et al. (2014) noticed greater diameters of white and red fibres of the pectoralis major muscle in 10-wk-old female and 12-wk-old male Muscovy ducks compared to Pekin ducks aged 7 weeks, which is consistent with our findings. Witkiewicz et al. (2004) found a significantly higher percentage of white fibres ($\alpha W$) and diameters of red fibres ($17.5 \mu m^2$) and white fibres ($33.1 \mu m^2$) in the pectoralis major muscle of Pekin ducks from the A44 pedigree flock, which are improved for

### Table 4. Content of some minerals in mg/100 g of liver from ducks of different genotype.

| Trait         | Genotype (G) – sex (S) | Pekin Male (n = 10) | Pekin Female (n = 10) | Muscovy Male (n = 10) | Muscovy Female (n = 10) | SEM G | SEM S | SEM G × S | P-value |
|---------------|------------------------|---------------------|-----------------------|-----------------------|-------------------------|-------|-------|-----------|---------|
| Na – sodium   |                        | 91.4                | 111.0                 | 98.8                  | 94.3                    | 5.0   | 0.689 | 0.517     | 0.309   |
| K – potassium |                        | 206.0               | 221.1                 | 225.7                 | 195.7                   | 5.9   | 0.825 | 0.568     | 0.095   |
| P – phosphorus|                        | 48.4                | 56.6                  | 52.1                  | 45.8                    | 1.4   | 0.216 | 0.724     | 0.019   |
| Mg – magnesium|                        | 13.6                | 14.7                  | 14.0                  | 15.2                    | 0.5   | 0.682 | 0.269     | 0.969   |
| Zn – zinc     |                        | 3.0                 | 4.0                   | 3.7                   | 4.0                     | 0.3   | 0.579 | 0.217     | 0.587   |
| Fe – iron     |                        | 39.4                | 50.1                  | 49.8                  | 34.9                    | 0.3   | 0.716 | 0.745     | 0.082   |
| Cu – copper   |                        | 1.8                 | 2.6                   | 1.3                   | 1.4                     | 0.6   | 0.015 | 0.717     | 0.825   |
Density of fi

β

Diameter of α

WB shear force, ducks, which is less preferred by meat consumers. Furthermore, poorer tenderness, and lower fi

the meat of Muscovy ducks is characterized by darker colour, bres

content of fat in the breast and leg muscles compared to fi

have a signi

in females than in males (33.91 and 15.35 µm², respectively), but this was not in males (36.15 µm²) and red fibres (16.14 µm²) in females than in males (33.91 and 15.35 µm², respectively), but this was not confirmed by our findings. Our results may suggest the greatest effect of genotype on microstructural characteristics of pectoralis major muscle in ducks of different genotype.

In conclusion, the physicochemical and microstructural traits of the meat were found to be influenced more by duck genotype. The sex of birds had a greater impact on chemical composition of the meat than duck genotype. Muscovy ducks have a significantly higher content of protein and lower content of fat in the breast and leg muscles compared to breast fillets from Pekin ducks, which may suggest higher nutritive and dietetic values of the meat of Muscovy ducks, and thus they better met the expectations of most consumers. However, the meat of Muscovy ducks is characterized by darker colour, poorer tenderness, and lower fibrillarity compared to Pekin ducks, which is less preferred by meat consumers. Furthermore, the meat quality was evaluated at different ages of the ducks slaughtered at the typical market age, which had an effect on the results obtained.

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Table 5. Selected physicochemical traits of the breast and leg muscles of ducks of different genotype.

| Trait                      | Genotype (G) – sex (S) | SEM | P-value |
|----------------------------|------------------------|-----|---------|
|                            | Male (n = 10)          | Female (n = 10) | G | S | G × S |
| L* — lightness             | BM 41.1 40.3           | 39.8 41.0 | 0.3 | 0.456 | 0.726 | 0.110 |
|                            | LM 43.3 42.9           | 40.1 38.4 | 0.6 | 0.001 | 0.184 | 0.391 |
| a* — redness               | BM 17.5 17.4           | 14.2 17.1 | 0.3 | 0.001 | 0.002 | 0.001 |
|                            | LM 15.9 15.4           | 14.7 15.6 | 0.1 | 0.163 | 0.529 | 0.041 |
| b* — yellowness            | BM 0.8 0.7             | 0.4 1.8  | 0.3 | 0.313 | 0.130 | 0.292 |
|                            | LM 1.9 1.0             | 0.7 1.1  | 0.2 | 0.235 | 0.560 | 0.141 |
| C* — chroma                | BM 17.5 17.4           | 14.2 17.2 | 0.4 | 0.004 | 0.002 | 0.001 |
|                            | LM 16.0 15.4           | 14.7 15.6 | 0.2 | 0.127 | 0.534 | 0.030 |
| h* — hue angle             | BM 2.6 2.1             | 1.6 6.0  | 0.7 | 0.044 | 0.590 | 0.911 |
|                            | LM 6.8 3.7             | 2.7 4.0  | 0.7 | 0.150 | 0.742 | 0.230 |
| Haematin, µg/g meat        | BM 137.4 145.9         | 183.0 201.6 | 8.6 | 0.002 | 0.348 | 0.724 |
|                            | LM 133.7 127.2         | 147.8 173.0 | 5.0 | 0.001 | 0.214 | 0.040 |
| WB shear force, N          | BM 25.3 29.1           | 30.5 31.5 | 0.9 | 0.039 | 0.075 | 0.421 |
|                            | LM 24.7 23.6           | 36.7 30.0 | 1.4 | 0.001 | 0.075 | 0.188 |

Note: BM – breast muscles, LM – leg muscles.

Table 6. Microstructure of pectoralis major muscle in ducks of different genotype.

| Trait                      | Genotype (G) – sex (S) | SEM | P-value |
|----------------------------|------------------------|-----|---------|
|                            | Male (n = 6)           | Female (n = 6) | G | S | G × S |
| Share of αW fibres, %      | 22.4 23.5              | 27.7 31.1       | 1.7 | 0.068 | 0.508 | 0.736 |
| Share of βR fibres, %      | 77.6 76.5              | 72.3 68.9       | 1.6 | 0.067 | 0.507 | 0.736 |
| Diameter of αW fibres (µm) | 38.9 33.8              | 43.8 39.7       | 0.9 | 0.001 | 0.001 | 0.702 |
| Diameter of βR fibres (µm) | 16.5 16.7              | 22.7 19.2       | 0.6 | 0.001 | 0.001 | 0.702 |
| Density of fibres (pcs/mm²) | 616 647               | 329 399         | 21.9 | 0.001 | 0.135 | 0.619 |

body weight and breast muscle weight compared to unselected P33 ducks (28.0%, 16.2 µm², and 29.2 µm², respectively) from a flock under a conservation programme in Poland. A study (Janiszewski et al. 2018) with wild-living mallards (Anas platyrhynchos) showed significantly higher diameters of white fibres (36.15 µm²) and red fibres (16.14 µm²) in females than in males (33.91 and 15.35 µm², respectively), but this was not confirmed by our findings. Our results may suggest the greatest effect of genotype on microstructural characteristics of pectoralis major muscle. The greater diameter of breast muscle fibres in Muscovy than in Pekin ducks, apart from genotype and sex, was also influenced by the different age of the analysed ducks. Male Muscovy ducks were older by 5 weeks, and female Muscovy ducks by 3 weeks, compared to the other birds under study.

In conclusion, the physicochemical and microstructural traits of the meat were found to be influenced more by duck genotype. The sex of birds had a greater impact on chemical composition of the meat than duck genotype. Muscovy ducks have a significantly higher content of protein and lower content of fat in the breast and leg muscles compared to breast fillets from Pekin ducks, which may suggest higher nutritive and dietetic values of the meat of Muscovy ducks, and thus they better met the expectations of most consumers. However, the meat of Muscovy ducks is characterized by darker colour, poorer tenderness, and lower fibrillarity compared to Pekin ducks, which is less preferred by meat consumers. Furthermore, the meat quality was evaluated at different ages of the ducks slaughtered at the typical market age, which had an effect on the results obtained.

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