Comparison of carcass traits and meat quality of intensively reared geese from a Polish genetic resource flock to those of commercial hybrids

Małgorzata Gumułka,[*,1] and Katarzyna Połtowicz[†]

*Department of Animal Reproduction, Anatomy and Genomics, University of Agriculture in Krakow, Kraków, Poland; and †Department of Poultry Breeding, National Research Institute of Animal Production, Balice, Poland

ABSTRACT The aim of the study was to determine slaughter yield and meat quality of native Zatorska (**ZG**) goose and compare them to those of commercial hybrid White Koluda® goose (**WKG**) after fattening in an intensive production system. The experiment was carried out on 500 birds of each group and lasted up to 10 wk of age. The birds were kept on deep litter with access to free range and were fed with the same complete feed mixtures, according to dietary requirements for broiler geese. Body weight, carcass composition, and technological properties of breast and thigh muscles were evaluated (pH_{24}, L*a*b* color, water holding capacity, thermal loss, drip loss, and shear force). In addition, chemical composition of breast and thigh muscles, fatty acid profile of muscle lipids, and amino acids of proteins were determined. The body weight, weight of eviscerated carcass, and dressing percentage of ZG were lower ($P < 0.05$) than those in WKG. However, breast and thigh muscles of both groups of geese were characterized by similar technological and nutritive values. The differences in meat quality traits concerned only the shear force of breast muscles, with higher values ($P < 0.05$) for WKG. Moreover, dry matter content in breast muscles of ZG was higher than that in WKG. The effect of goose genotype on the level of oleic acid and monounsaturated fatty acids in breast muscles was shown. Also, the amino acid proportion of meat protein depended on goose breed. Breast muscles of ZG were characterized by higher ($P < 0.05$) content of some nonessential (Glu, Asp, Ala) and essential amino acids (Val, Thr), and thigh muscles contained less ($P < 0.05$) Gly, Lys, and Leu and more Pro and Ile than WKG. The present results indicate that the meat of both ZG and WKG broilers showed good technological properties and basic chemical composition and fatty acid profile, and the protein was characterized by high nutritional value. Moreover, the smaller carcasses produced from ZG can better meet the needs of the current market.

Key words: geese, broilers, slaughter yield, meat quality, amino acid profile

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INTRODUCTION

Currently, consumers of poultry meat expect high-quality products obtained from birds kept under controlled environmental conditions. They also increasingly ask for products with health-promoting properties and original taste, which come from less popular species of poultry. Meat obtained from geese can meet these expectations. Health benefits of goose meat and its consistent growth in consumption (FAO, 2016; Utnik-Banaś and Żmija, 2018) fully warrant research into the dressing percentage and meat quality of this poultry species.

In goose meat production, there are 2 alternatives for fattening the birds. One is to produce young geese with slaughter age of 8–10 wk and the other is to produce geese slaughtered after 16 wk of age (Tilki et al., 2005), which also applies to obtaining a specific product known as the oat goose. Geese reared under intensive conditions are called broilers. This type of production is practiced in Turkey (Isguzar and Pingel, 2003; Tilki et al., 2005, 2009; Saatci et al., 2009), China (Liu et al., 2011), and the Czech Republic (Tůmová and Uhlířová, 2013; Uhlířová and Tůmová, 2014; Uhlířová et al., 2018, 2019). In Poland, production of goose meat based on intensive rearing is not widespread, with one reason being the lack of tradition for farming broiler geese. A Polish specialty is production of oat-fed geese, which combines semi-intensive system

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[1]Corresponding author: m.gumulka@ur.krakow.pl

of rearing with fattening by feeding whole oat grain (Buzała et al. 2014).

The ever-changing poultry meat market has made producers of goose increasingly interested in broiler fattening. Geese have a relatively rapid growth rate during the first wk of life. At 9 wk of age, they already reach 70–80% of adult weight (Tilki et al. 2005). Moreover, up to 10 wk of age, there is a very rapid growth in muscle weight (Bochno et al. 2006). According to the study by Tilki et al. (2005), the best fattening duration for native Turkish geese, in terms of fat content and meat quantity, was 10–12 wk. Moreover, Biesiada-Drzazga (2006a) showed that both the meat and fat of White Koluda® goose (**WKG**) broilers were characterized by a relatively good nutritive and processing value and could diversify the range of poultry products on the market.

The goose carcass traits are affected by many different factors including rearing system (Liu et al., 2011), genotype (Isguzar and Pingel, 2003; Kapkowska et al., 2011; Tůmová and Uhlířová, 2013; Uhlířová and Tůmová, 2014; Uhlířová et al., 2018, 2019), and variety (Boz et al., 2019). Also values of some physicochemical parameters of breast and leg muscles change differently during postmortem aging depending on goose breed (Okruszek et al., 2008; Okruszek, 2012a; Tůmová and Uhlířová, 2013) and variety (Boz et al., 2019). Moreover, Okruszek (2011, 2012b) and Haraf et al. (2014) have shown the effect of goose breed on fatty acid profile in muscles and abdominal fat lipids. Most recently, Uhlířová et al. (2019) confirmed the effect of goose genotype on fatty acid composition of meat, and Boz et al. (2019) found differences in fatty acid composition among the studied goose varieties. Also nutritive value of meat determined by amino acid composition depends on the genetic origin of geese (Okruszek et al., 2013). Moreover, amino acid content of meat differs in locally raised Turkish goose varieties (Boz et al. 2019).

In Poland, goose meat production is based almost exclusively on commercial hybrids (W31) of 2 breeding lines of WKG (♂W-33 × ♀W-11), which are typically kept in accordance with oat feeding technology. Irrespective of this, research is also being conducted on the utilization of geese kept in flocks covered by the program for the conservation of genetic resources of waterfowl (Okruszek et al., 2008; Okruszek, 2011; Okruszek, 2012a,b; Okruszek et al., 2013). In Poland, 14 breeds of these birds are currently raised. In recent years, interest in the use of native, noncommercial breeds of geese for meat production has increased (Tilki et al., 2005; Saatci et al., 2009; Kapkowska et al., 2011; Kirmizibayrak et al., 2011; Tůmová and Uhlířová, 2013; Uhlířová and Tůmová, 2014; Uhlířová et al., 2018, 2019; Boz et al., 2019). Moreover, traditional goose breeds can be used to produce crosses with increased meatiness and reduced carcass fat (Isguzar and Pingel, 2003).

Zatorska goose (ZG) is a native Polish breed kept as a part of poultry genetic resources conservation program (Rabsztyn, 2006) and registered in the FAO World Watch List (2000). This native breed has been already the subject of comprehensive oat fattening research (Szado et al., 1991; Gumułka et al., 2009; Kapkowska et al., 2011). To date, the results of broiler production based on this breed have been presented only in one publication (Szado et al., 1991). It was shown that ZG broilers supplied more dietetic product because of the lower fat content in the carcass than the values obtained after oat fattening.

As already noted, there are not many studies describing the use of geese for broiler production. In particular, there are no recent studies on dressing percentage and meat quality of young fattening geese from local populations from Polish genetic resource flocks. Therefore, it seems important to supplement research on indigenous breeds reared in intensive conditions as a potential source of new products for the poultry market.

The aim of the study was to determine the slaughter yield and meat quality of native ZG compared with WKG commercial hybrid after fattening up to 10 wk of age.

MATERIALS AND METHODS

Birds, Diets, and Management

The experiment was carried out on ZG and WKG. The birds were kept in the Research and Education Center of the Faculty of Animal Sciences of the University of Agriculture in Kraków. Geese were raised in 2 groups (n = 500), with the same number of female and male birds. One genetic group was kept in 2 pens on deep litter in a light-proof building with access to free range. The birds used the free range from the second wk of age from 08:00 to 14:00 if the weather conditions were favorable. The lighting program and temperature were as specified by universally accepted standards for geese in Poland (Puchajda-Skowrońska, 2012). The fattening was carried out up to the 10th wk of age. The density of birds in pens was 2 geese/m^2 and in free range 0.5 geese/m^2 at the end of the fattening period. Geese were fed *ad libitum* complete concentrated diets in accordance with the requirements of the Poultry Feeding Standards (Smulikowska and Rutkowski, 2018). The broiler growing period was divided into 2 feeding phases: 0–4 and 5–10 wk of age. According to the data provided by the producer, mixture used in the period of 0–4 wk contained 12 MJ MEN/kg and 195 CP/kg, and after this period, the mixture contained 11.5 MJ MEN/kg and 165 CP/kg. Results of chemical analysis of commercial mixtures are given in Table 1.

Slaughter and Dissection Procedures

At 10 wk of age, 10 male and 10 female birds from each group were selected. The birds had a body weight close to the average value of the group. Birds were slaughtered in a local slaughterhouse according to the relevant regulations applied in the poultry industry. After 24 h of cooling, the carcasses were subjected to slaughter analysis in accordance with the methodology of Ziołecki and Doruchowski (1989). Dressing percentage was

Table 1. Chemical composition and major fatty acids of lipids diets.

Commercial mixtures fed in period		
Item	1–4 wks	5–10 wks
Chemical composition (%)		
Dry matter	85.55	87.88
Crude protein	18.31	15.75
Crude fat	2.12	2.94
Crude fiber	4.01	5.13
Crude ash	6.24	8.09
Fatty acid (% of total fatty acid)		
C14:0	0.11	0.15
C16:0	14.18	13.09
C18:0	3.47	2.00
C20:0	0.22	0.43
C16:1 *n-7*	0.53	0.22
C18:1 *n-9*	34.53	30.01
C20:1	0.34	0.63
C18:2 *n-6*	44.18	51.21
C18:3 *n-3*	2.15	2.05

estimated as the ratio of chilled carcass with neck to live body weight. Dressing percentage with giblets was calculated as the ratio of chilled carcass with neck, edible giblets (heart, liver, gizzard), and abdominal fat to live body weight. The percentages of breast muscle and leg muscle (thigh and drumstick) were calculated as a percentage of the cold carcass weight.

Meat Technological Analyses

Breast and thigh muscles (n = 20 samples/group) were evaluated in terms of selected technological parameters, including pH, color (CIE L*a*b*), water holding capacity defined as expressible juice, drip loss, thermal loss, and Warner-Bratzler shear force.

The pH values of the breast (pectoral major) and thigh muscles were determined 24 h postmortem after air-chilling at 4°C, using a portable CyberScan10 pH meter (Eutech Instruments Pte Ltd, Singapore) equipped with a glass electrode and a temperature probe for automatic temperature adjustments. The pH meter had been calibrated at 4°C using 2 calibration buffers (pH 4.01 and pH 7.00), and then, measurements were taken by placing the electrode at a 45° angle midway through the body of the muscle.

The color of the inner surface of each breast and thigh muscle was determined immediately after dissection using the reflectance spectrophotometer Minolta CR 310 Chroma Meter (Konica Minolta Sensing Business Unit, Osaka, Japan) equipped with a 50-mm reading head. The Chroma Meter was calibrated to the white calibration plate CR-A44 (Y = 93.50, x = 0.3114, y = 0.3190). Four consecutive measurements were taken to analyze entire surface area of the muscle and calculate the mean values for muscle lightness (L*), redness (a positive a* value), and yellowness (a positive b* value), according to the CIE 1976 L*a*b* color space (Colorimetry–Part 4, 2007). However, special care was taken to avoid areas containing visible bruises, hemorrhages, or superficial blood vessels (Fletcher, 2002).

Water holding capacity, defined as expressible juice, was determined based on the volume of free water squeezed from a ground meat sample by measuring the surface area of the squeezed meat juice using the filter paper method (Grau and Hamm, 1953). Small samples of ground meat (weighing about 300 mg) were placed on a filter paper between 2 glass tiles. A force of 2 kg was applied on each sample for 5 min. At the end of squeezing, the areas of the meat sample were outlined, and the areas of the pressed sample and expressed moisture were planimetered. Water holding capacity was calculated according to the following formula:

$$\text{Water holding capacity } (\%) = [\text{expressed moisture area } (\text{cm}^2) - \text{sample area } (\text{cm}^2)] / [\text{sample mass } (\text{mg})] \times 1000$$

Drip loss was measured 48 h postmortem, after 24-h cold storage of samples at 4°C. Meat samples (weighing about 80 g) were placed in tightly sealed containers and stored in a refrigerator. Drip loss was expressed as the percentage of sample weight loss in relation to its weight recorded before refrigeration.

The cooking loss was defined as the percentage loss of meat weight after cooking in a water bath at 100°C until the attainment of a core temperature of 78°C (measured in the thickest portion of the sample). All samples (about 80 g each) were cooked individually in small plastic bags, then chilled at room temperature for 30 min, and finally kept at 4°C for 45 min before determining the relative thermal loss (expressed as the percentage of initial, precooking weight).

After weighing for the determination of thermal loss, the chilled breast meat samples were prepared for shear force measurements. Three cores measuring 1.27 cm in diameter and about 3 cm in length were removed from each sample parallel to the fiber orientation through the thickest portion of the cooked muscle. The Warner-Bratzler shear force was determined using an Instron 5,542 system (Instron, High Wycombe, Buckinghamshire, UK) as the maximum force (N) perpendicular to the fibers.

Chemical Analysis, Fatty Acid and Amino Acid Profiles

The basic chemical composition of the diets and muscles was analyzed in duplicate based on Association of Official Analytical Chemists International procedures (Latimer, 2016).

The content of fatty acids in breast and thigh muscles (n = 20 samples/group) and diets was analyzed using gas chromatography by determining the acids as methyl esters. Samples were prepared based on a method described by Folch et al. (1957). Separation and quantitative determination of individual fatty acids were performed using a gas chromatograph Varian Star 3,400 Cx (Varian Medical Systems, Palo Alto, CA) with flame

Table 2. Body weight, dressing percentage, and dissecting data (mean, SEM) of Zatorska goose (ZG) (n = 20) and White Koluda goose (WKG) (n = 20) at the age of 10 wk.

Item	Zatorska	White Koluda®	SEM
Body weight before slaughter (g)	4,775.5[a]	5,340.0[b]	74.2
Weight of eviscerated carcass with neck (g)	3,155.5[a]	3,700.5[b]	67.6
Dressing percentage without giblets (%)	66.1[a]	69.3[b]	0.6
Dressing percentage with giblets (%)	73.3[a]	76.3[b]	0.6
Breast muscles in carcass (%)	15.8	15.6	0.1
Thigh muscles in carcass (%)	7.9	7.5	0.2
Drumstick muscles in carcass (%)	7.7	7.7	0.1
Leg muscles (thigh and drumstick) in carcass (%)	15.6	15.3	0.1

Means in the same row with different superscripts are different ($P < 0.05$).
Abbreviation: SEM, standard error of mean.

ionization detector FID and fused capillary column DB-23 (30-m long, 0.53 mm in diameter). Working conditions were as follows: argon was used as a carrier gas, injector temperature 200°C, and detector temperature 240°C. The operating temperature for the column was 90–205°C at a rate of 25°C/min.

The amino acid composition of breast and thigh muscles was determined using an automatic amino acid analyzer AAA 400 (INGOS Ltd, Prague, Czech Republic) equipped with an Ostion LG ANB (370 mm) column. The acid hydrolysis of meat samples was made with 6 Mol HCl (INGOS Ltd, Prague, Czech Republic) at 110°C for 24 h. Amino acids were separated by stepwise gradient elution using a Na/K-citric buffer system and post-column derivatization with (amine-)ninhydrin reagent followed by a photometric detection (at 570 and 440 nm). The resultant values of amino acids were recalculated to 100% dry matter for the purpose of comparison.

Statistical Analysis

All variables were examined for normality and homogeneity of variance using the Shapiro-Wilk test of normality and Levene test. Data obtained were subjected to one-way ANOVA. The mathematical model was as follows: $Yij = \mu + GEi + \varepsilon ij$, where Yij represents slaughter and carcass traits, meat technological parameters, chemical composition, and fatty acid and amino acid parameters; μ overall mean; GEi genotype (i = ZG, WKG); Ɛij residual effect. Significant differences between means were assessed by Duncan's multiple range test. Values were expressed as mean and standard error of mean. Differences were considered significant at the level of $P < 0.05$. For statistical analyses, the individual bird was the experimental unit. The statistical analyses were processed using the Statistica data analysis software system, version 9.0 (TIBCO Software Inc., Palo Alto, CA).

RESULTS AND DISCUSSION

Slaughter and Carcass Parameters

The results for body weight and carcass traits of the ZG and WKG are presented in Table 2. The intensively fed 10-week-old ZG weighed an average of 4,776 g and were lighter ($P < 0.05$) than the WKG (5,340 g). Both the body weight and slaughter yield of the ZG obtained in the present study were higher than those previously reported by Szado et al. (1991). The differences could be a result of different feeding levels as well as the environmental conditions and preslaughter handling of the birds. In turn, the WKG body weight was similar to that obtained for broilers by Biesiada-Drzazga et al. (2006) and higher than those reported by Biesiada-Drzazga et al. (2007) and Murawska (2013). It is worth noting that the body weight of both groups of broiler geese conformed to Polish industry standards for broiler geese.

In our study, the effect of the goose genotype on body weight, weight of the eviscerated carcass, and dressing percentage was shown. As expected, based on previous oat fattening studies (Gumułka et al., 2009; Kapkowska et al., 2011), lower values were noted for the ZG. Both the body weight and weight of the eviscerated carcass of the ZG were about 565 g (12%) and 545 g (17.5%) lower ($P < 0.05$), respectively, than those of the WKG. Similarly, lower body and carcass weights of the traditional Czech Goose compared with those of Eskildsen Schwer and Novohradská goose hybrids were noted by Uhlířová and Tůmová (2014), Tůmová and Uhlířová (2013), and Uhlířová et al. (2018, 2019). The dressing percentage with and without giblets for the ZG ranged from 66.1 to 73.3% respectively, and was about 3 percentage points lower ($P < 0.05$) than that for the WKG. In contrast, in studies with the Czech goose and commercial hybrids (Tůmová and Uhlířová, 2013; Uhlířová and Tůmová, 2014; Uhlířová et al., 2018, 2019), the dressing percentage was not dependent on goose genotype and was similar to the results for the ZG obtained in our study. In studies on Turkish native geese, the dressing percentage ranged from 69% to 71% (Isguzar and Pingel, 2003) and from 66% to 67% (Tilki et al., 2005; Saatci et al., 2009). Higher values for eviscerated carcass yield of approximately 72% were noted by Liu et al. (2011) and Liu and Zhou (2013) for Yangzhou goose and Dongbei White goose, respectively, which were maintained in different rearing systems. In addition, Boz et al. (2019) reported that in local Turkish goose varieties, dressing percentage ranged from 63% to 67%, but birds were reared in an extensive production

Table 3. Chemical composition (%) of breast and thigh muscles (mean, SEM) of Zatorska goose (ZG) (n = 20) and White Koluda goose (WKG) (n = 20) at the age of 10 wk.

	Zatorska	White Koluda®	SEM	Zatorska	White Koluda®	SEM
Item	Breast muscles			Thigh muscles		
Dry matter (%)	26.33[a]	24.98[b]	1.14	24.99	25.31	0.22
Ash (%)	1.27	1.31	0.03	1.08	1.13	0.02
Crude protein (%)	22.03	21.21	0.26	20.91	21.07	0.23
Crude fat (%)	2.66	2.23	0.60	3.35	3.15	0.17

Means in the same row with different superscripts are different ($P < 0.05$).
Abbreviation: SEM, standard error of mean.

system. Notably, the white goose variety exhibited the highest dressing percentage, as well as slaughter and carcass weight. The obtained results provide clear proof of the high slaughter value and suitability of the ZG for intensive fattening, especially because the proportion of breast and leg muscles, the most valuable component of the bird carcass, did not differ from that observed in WKG hybrids. The total proportion of both muscle types in the carcasses of the ZG and WKG investigated in our study was 31.4% and 30.9%, respectively. In the ZG, the proportion of breast muscle was higher than that reported by Tilki et al. (2005) for native Turkish geese (15.4%) but lower in the case of leg muscles (16%). In turn, the proportion of leg muscle in the carcasses of the ZG was lower than that in intensively fed geese of 6 other Polish breeds of geese included in the genetic resources conservation program, which were maintained until 12 wk of age (Haraf, 2014). Furthermore, the proportion of breast muscle varied according to breed from 16.2% (Suwalska goose) to 19.7% (Kielecka goose), with 15.8% breast muscle in the ZG. The observed differences may arise from both the genetic origin of the birds and their age at slaughter. Murawska (2013) reported that the weight of lean meat increased until the 10th week of age, but the muscle growth rate in different body parts of the birds varied widely. According to the study by Bochno et al. (2006), after 10 wk of age, the breast and leg muscles continue to grow in geese, but there is a redistribution of muscle from the leg to the breast, whereas the study by Biesiada-Drzazga (2014) holds that breast muscles show the most intensive development between 8 and 10 or 11 wk of age. Similar to the present study, Tůmová and Uhliřová (2013) and Uhlířová et al. (2018) showed a similar proportion of breast muscles in geese of different genotypes. However, differences were noted concerning the percentage of leg muscles, in favor of the traditional Czech goose breed compared with the Novohradská (Tůmová and Uhliřová, 2013) and Eskildsen Schwer commercial hybrid (Uhlířová et al. 2018). Moreover, Boz et al. (2019) noted differences in breast and thigh percentage between local Turkish goose varieties reared until 28 wk of age.

Chemical Composition of Meat

The chemical composition of breast and leg muscles in the ZG and WKG is shown in Table 3. It is evident that the birds did not differ in this respect. The data obtained for the WKG support the findings of Biesiada-Drzazga (2006b), but its comparison with another study by the same author (Biesiada-Drzazga, 2006a) indicates a more beneficial crude protein and crude fat proportion in the thigh muscles of the WKG evaluated in the present study. Furthermore, in both the ZG and WKG, the proportion of crude protein and crude fat in the breast muscles was higher than that in the muscles of Yangzhou goose (Liu et al., 2011). Moreover, the level of crude protein determined in the present study was similar to that reported by Isguzar and Pingel (2003), Okruszek et al. (2013), Uhlířová et al. (2018), and Boz et al. (2019).

The present study showed no effect of goose genotype on the chemical composition of the muscles, except for a 1.35 percentage point higher ($P < 0.05$) dry matter content in the breast muscles of the ZG than in those of the WKG. The content of the other nutrients (crude protein, crude fat, and ash) was similar. Likewise, Okruszek et al. (2013) demonstrated no differences in the content of crude protein in the breast and thigh muscles of Rypińska and Garbonosa goose from Polish genetic resource flocks, but they found differences in the proportions of crude fat and moisture. On the contrary, an effect of goose genotype on protein content in thigh meat, with higher values in the traditional breed of the Czech goose compared with a commercial hybrid, was observed by Uhlířová and Tůmová (2014). However, these results were not confirmed for breast muscle in a subsequent study with the Czech goose (Uhlířová et al. 2018). Although the level of fat in the muscles of this traditional goose breed, compared with a commercial hybrid, tended to be lower, the analyses were performed with older (16 wk old) birds than those in the present study. On the other hand, in a recent study by Uhlířová et al. (2019), there was no effect of the goose genotype on fat content. However, in the study conducted on local Turkish goose varieties, Boz et al. (2019) showed that the crude fat value of thigh meat differs in geese.

Technological Parameters of Meat

The parameters of the technological quality of breast and thigh muscles for the ZG and WKG are presented in Table 4. Our results are slightly different from the values of the indicators that had been determined for the same genetic groups of geese subjected to oat fattening (Kapkowska et al. 2011). In the present study,

Table 4. Technological properties of breast and thigh muscles (mean, SEM) of Zatorska goose (ZG) (n = 20) and White Koluda goose (WKG) (n = 20) at the age of 10 wk.

	Zatorska	White Koluda®	SEM	Zatorska	White Koluda®	SEM
Item	Breast muscles			Thigh muscles		
pH_{24}	6.15	6.09	0.04	6.18	6.12	0.04
L*	46.61	46.49	0.61	44.28	43.54	0.52
a*	15.35	14.44	0.21	16.21	15.36	0.31
b*	3.19	3.00	0.27	3.81	3.62	0.28
WHC (%)	18.17	18.07	1.00	17.21	18.42	0.91
Drip loss 24 h (%)	0.84	0.89	0.10	0.68	0.72	0.90
Thermal loss (%)	35.08	34.13	0.79	29.61	30.12	0.75
WB shear force (N)	50.22^{a}	55.57^{b}	1.31	–	–	–

Means in the same row with different superscripts are different ($P < 0.05$).
Abbreviations: SEM, standard error of mean; WHC, water holding capacity.

we noted higher L* and a* values, especially with regard to breast muscles, which suggests that the meat from younger, intensively raised geese was lighter and more red. This may indicate that younger, intensively raised birds were probably more susceptible to preslaughter stress which may affect bleeding results. The discussed differences also applied to drip loss values, which were higher and less favorable for broilers. These differences could be due to both the age of the geese and the different fattening system, despite the fact that Kirmizibayrak et al. (2011) and Liu et al. (2011) reported no effect of age or rearing system on the technological parameters of goose meat. In contrast, Uhlířová et al. (2018) observed that the age of geese had an effect on the L* value, which was higher in 8-week-old compared with 16-week-old geese. Sari et al. (2015) demonstrated that different fattening systems had effects on the pH_{15}, drip loss, and the cooking loss of goose muscle.

With regard to most of the evaluated technological parameters of the meat, no differences were found between the ZG and WKG. The similar pH values of the breast and leg muscles in both genetic groups of geese possibly suggest that glycolysis in the muscles after slaughter followed a similar pathway. The evaluated muscles also did not differ in color and water-holding capacity. Only the shear force of the cooked breast muscle from the WKG was higher ($P < 0.05$) by 5.35 N than that in the ZG. This confirms the results of an earlier study which showed a higher tenderness of ZG meat, although it was unrelated to the greater cross-section area of muscle fiber, compared with WKG meat (Kapkowska et al. 2011). Contrary to our results, Okruszek et al. (2008) observed that the genetic origin of geese had a significant effect on postmortem changes and showed differences in pH values measured at different time points postmortem between Kartuska goose and 3 other breeds (Suwalska, Podkarpacka, and

Table 5. Major fatty acids composition (% of total FA) of breast and thigh muscles lipids (mean, SEM) in Zatorska goose (ZG) (n = 20) and White Koluda goose (WKG) (n = 20) at the age of 10 wk.

	Zatorska	White Koluda®	SEM	Zatorska	White Koluda®	SEM
Item	Breast muscles			Thigh muscles		
C 14:0	0.43	0.41	0.04	0.50	0.46	0.04
C 16:0	21.74	21.72	0.20	20.24	19.81	0.20
C 18:0	9.38	10.53	0.70	7.98	8.85	0.20
C 20:0	0.10	0.09	0.03	0.10	0.08	0.03
∑ SFA	31.65	32.75	0.31	28.82	29.20	0.30
C 14:1	0.36	0.41	0.10	0.31	0.27	0.10
C 16:1n–7	2.56	2.44	0.07	3.34	2.94	0.07
C 18:1n–9	43.02^{a}	41.08^{b}	0.55	44.22	45.21	0.51
C 20:1	0.41	0.46	0.02	0.56	0.65	0.02
∑ MUFA	46.35^{a}	44.39^{b}	0.47	48.43	49.07	0.41
C18:2n–6	14.12	14.27	0.27	15.02	15.05	0.31
C18:3n–3	0.93	0.99	0.07	1.21	1.08	0.08
C 20:4n–6	3.75	4.08	0.20	3.20	2.49	0.12
C 20:5n–3	1.15	1.07	0.10	0.98	0.89	0.09
C 22:4n–6	0.29	0.32	0.04	0.28	0.33	0.05
C 22:6n–3	0.44	0.58	0.01	0.45	0.52	0.01
∑ PUFA	20.68	21.31	0.45	21.14	20.36	0.52
∑ PUFA n–6	18.16	18.67	0.25	18.50	17.87	0.20
∑PUFA n–3	2.52	2.64	0.01	2.64	2.49	0.03
∑ n–6/∑n–3	7.21	7.07	0.19	7.01	7.18	0.17

Means in the same row with different superscripts are different ($P < 0.05$).
Abbreviations: FA, fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; SEM, standard error of mean; SFA, saturated fatty acids.

Table 6. Amino acids composition of breast and thigh muscles (mean, SEM) of Zatorska goose (ZG) (n = 20) and White Koluda goose (WKG) (n = 20) at the age of 10 wk (mg/g dry matter).

Item	Zatorska	White Koluda®	SEM	Zatorska	White Koluda®	SEM
	Breast muscles			Thigh muscles		
Nonessential amino acid (N–EAA)						
Glutamic acid (Glu)	104.41[a]	100.21[b]	1.80	97.52	94.41	2.71
Aspartic acid (Asp)	68.83[a]	63.46[b]	1.41	60.51	59.72	1.46
Arginine (Arg)	53.86	51.62	1.38	59.35	60.18	1.81
Alanine (Ala)	39.72[a]	37.67[b]	1.01	42.0 1	41.26	0.88
Glycine (Gly)	32.58	30.05	0.75	33.91[a]	36.21[b]	0.70
Proline (Pro)	30.91	28.13	0.78	37.48[a]	30.91[b]	0.72
Serine (Ser)	26.17	25.19	0.61	24.46	23.64	0.71
Essential amino acid (EAA)						
Lysine (Lys)	61.47	65.03	1.61	68.23[a]	72.03[b]	1.93
Leucine (Leu)	60.62	57.37	1.20	54.36[a]	65.44[b]	1.40
Valine (Val)	38.52[a]	36.52[b]	0.77	44.78	44.71	0.57
Isoleucine (Ile)	35.33	33.01	0.72	27.61[a]	25.82[b]	0.68
Phenylalanine (Phe)	31.35	29.67	0.80	36.84	36.84	0.84
Tyrosine (Tyr)	25.78	24.35	0.79	38.15	37.05	0.89
Threonine (Thr)	32.12[a]	29.61[b]	0.77	25.47	26.25	0.72
Histidine (His)	26.91	25.42	0.95	32.21	30.02	0.95
Methionine (Met)	14.82	15.71	1.05	15.90	14.24	1.15
Cystine (Cys)	5.20[a]	6.11[b]	0.31	6.63	5.46	0.40
Σ EAA	332.12	322.80		350.18	357.86	

Means in the same row with different superscripts are different ($P < 0.05$).
Abbreviation: SEM, standard error of mean.

Kielecka) from Polish genetic resource flocks. However, the authors did not observe differences in the pH values of the muscles between the 3 breeds. Much greater differences between the genotypes occurred for the rate of pH changes at different postmortem times. In another study, Okruszek (2012a) confirmed that the genotype of geese from genetic resource flocks (Suwalska vs. Kartuska) had an effect on pH values, on color parameters (a*, b*), and also on the rate of postmortem changes in meat quality parameters. Moreover, Tůmová and Uhlířová (2013) demonstrated that goose genotype had an effect on meat color parameters in the thigh muscles, with the higher values for a* and b* found in the commercial hybrid Novohradská goose than in the Czech goose breed. However, consistent with our findings, Uhlířová et al. (2018) showed no significant differences in the pH values and color parameters. Neither did they observe any differences in the shear force of breast muscles between a traditional Czech goose breed and a commercial hybrid. The only differences between these breeds occurred for cooking loss and could result from different protein solubility and fat content. Contrary to our results Boz et al. (2019) noted that varieties of geese had an effect on color (L, a*, b*) and pH values in breast and thigh meat.

Fatty Acid Content of Meat

The fatty acid compositions of the breast and thigh muscles of the ZG and WKG are summarized in Table 5. In both genetic groups of geese, saturated (**SFA**) and monounsaturated fatty acids (**MUFA**) were the predominant components, whereas the level of polyunsaturated fatty acids (**PUFA**) was relatively lower. The major SFA were palmitic (C16:0) and stearic acids (C18:0), the major MUFA was oleic acid (18:1n-9), and the major PUFA was linoleic acid (C18:2 n-6). Similar results for goose meat were obtained by Okruszek (2011), Okruszek et al. (2012 b), Haraf et al. (2014), Sari et al. (2015), Boz et al. (2019), and Uhlířová et al. (2019). In the present study, the level of PUFA, which is crucial for human health, was higher than that reported by Biesiada-Drzazga (2006a) in WKG broilers. Similar PUFA values were noted in studies with the meat of geese from Polish genetic resource flocks (Haraf et al. 2014) and in native Turkish geese (Sari et al. 2015; Boz et al. (2019). Higher and more beneficial PUFA levels than in the present study were noted by Okruszek (2011) and Okruszek et al. (2012b) for other breeds of geese in Polish genetic resource flocks and by Uhlířová et al. (2019) in the Czech Goose and a commercial hybrid. The ratio of n-6/n-3 PUFA is considered to be a risk factor in cancers and coronary heart disease, and it is recommended that this ratio be less than 4.0 (Simopoulos, 2002). In the present study, the n-6/n-3 PUFA ratio was higher than recommended and ranged from 7.01 in thigh muscle to 7.21 in breast muscle. Our values were similar to those reported by Haraf et al. (2014) for the meat of the Kartuska goose. However, our values were lower than those reported for other goose genotypes from Polish genetic resource flocks (Okruszek, 2011; Okruszek et al. 2012b; Haraf et al. 2014), for geese raised in the Czech Republic (Uhlířová et al. 2019), and for different Turkish goose varieties (Boz et al. 2019), so they can be considered more beneficial than these breeds. Lower n-6/n-3 PUFA ratios than those in the present study were reported by Sari et al. (2015) for native Turkish geese. These differences might be due to variations in feeding methods, fattening duration, and the breed of goose.

The present study demonstrated the effect of goose genotype on the level of MUFA. The obtained results indicate that the lipids of the breast muscles of the ZG contained about 2% ($P < 0.05$) more MUFA than those of the WKG. This contradicts an earlier study (Gumułka et al. 2006) in which the ZG had a higher PUFA content than the WKG. However, in the cited study, birds were fattened with oats under semi-intensive conditions. In turn, Okruszek (2011) and Okruszek et al. (2012b) demonstrated differences in SFA and PUFA between the muscle lipids of native Polish Rypińska and Garbonosa geese. Similar to our study, Haraf et al. (2014) observed differences in the level of MUFA in geese of different genotypes. In addition, their study found that the lipids of Kartuska goose muscles were characterized by a more favorable n-6/n-3 ratio compared with those from Lubelska goose. Also, Uhlířová et al. (2019) observed the effect of goose genotype on PUFA content and the n-6/n-3 ratio. Surprisingly, the latter indicator was higher for the traditional Czech goose than for commercial hybrids. Furthermore, Boz et al. (2019) stated that local Turkish goose varieties reared in extensive conditions differ in SFA, MUFA, and PUFA content of breast and thigh meat. Some disparities observed between our findings and those of other authors may be due to the age, rearing system, and diet differences between the birds.

Amino Acid Content of Meat

The amino acid compositions of the breast and thigh muscles of the ZG and WKG are presented in Table 6. The protein of the breast and thigh muscles from both goose genetic groups was characterized by Glu and Asp having the highest occurrence among the nonessential amino acids and Lys and Leu among the essential amino acids (**EAA**). Moreover, among the EAAs, the amino acids with the lowest occurrence were Met and Cys. Similar results for goose meat were noted by Okruszek et al. (2013), except for the low values of Trp, which was not determined in the present study. Contrary to our results, Boz et al. (2019) showed Tyr to be the most abundant amino acid in breast and thigh meat in geese.

The amino acid proportions of the meat proteins depended on the goose genetic group. The proteins of the ZG breast muscle contained more Glu, Asp, Ala, and Val ($P < 0.05$) than those of the WKG. Furthermore, a higher ($P < 0.05$) content of Thr was also found, which is very favorable nutritionally. However, in the proteins of the thigh muscles of the ZG, less Gly, Lys, and Leu ($P < 0.05$) were noted than in the WKG. Okruszek et al. (2013) also showed differences in the amino acid profiles in the breast and thigh muscles of 2 (Rypińska and Garbonosa) native Polish goose breeds. The authors suggested that probably different physiological mechanisms associated with the synthesis of amino acids resulted in these differences. However, the values of the EAA index of the breast muscle proteins were similar in both flocks. Furthermore, Boz et al. (2019) demonstrated differences in the same nonessential amino acids and most of EAA in the breast and thigh muscles of 4 Turkish goose varieties.

In conclusion, the goose genotype affected the carcass weight and yield. The lower body weight of the ZG compared with that of the WKG after 10 wk of fattening shows that it is less efficient and likely to be less profitable. However, a comparison of all the results describing the carcass traits and the technological meat quality parameters of ZG and WKG reveals that both goose breeds exhibited similar values. Moreover, the lower carcass weight of ZG with similar meat quality parameters may be an advantage, considering the current expectations of the consumers. It is also relevant that the fat and protein of meat from both intensively reared goose breeds were characterized by high nutritional values.

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REFERENCES

Biesiada-Drzazga, B. 2006a. Description of selected characteristics of muscle and fat tissue of 10-week White Kołuda W31 geese. Acta Sci. Pol. Technol. Aliment. 5:47–54.
Biesiada-Drzazga, B. 2006b. Analysis of feeding influence on chemical composition of selected muscles and on fatty acid profile in skin with subcutaneous fat and abdominal fat of broiler geese. Acta Sci. Pol. Zootech. 5:3–12 (in Polish).
Biesiada-Drzazga, B. 2014. Growth and slaughter value of W11, W33 and W31 White Kołuda geese®. Europ. Poult. Sci. 78:1–11.
Biesiada-Drzazga, B., A. Grużewska, and A. Markowska. 2007. Impact of feeding based on concentrated mixtures with different shares of soyabean and sunflower oil meals on growth and body conformation in geese. Arch. Geflugelk. 72:19–24.
Biesiada-Drzazga, B., J. Górski, and A. Górska. 2006. Analysis of slaughter value and muscle fiber thickness of selected muscles in geese broilers as related to feeding applied during the rearing period. Anim. Sci. Pap. Rep. 24(Suppl 2):37–44.
Bochno, R., D. Murawska, and U. Brzostowska. 2006. Age-related changes in the distribution of lean fat with skin and bones in goose carcasses. Poult. Sci. 85:1987–1991.
Boz, M. A., F. Oz, U. S. Yamak, M. Sarica, and E. Cilavdaroglu. 2019. The carcass traits, carcass nutrient composition, amino acid, fatty acid, and cholesterol contents of local Turkish goose varieties reared in an extensive production system. Poult. Sci. 98:3067–3080.
Buzała, M., M. Adamski, and B. Janicki. 2014. Characteristics of performance traits and the quality of meat and fat in Polish oat geese. Worlds Poult. Sci. J. 70:531–542.
Colorimetry – Part 4: CIE 1976 L*a*b* colour space. Pages 1–8 in CIE Draft Standard 014-4.3/E:2007. Vienna, Austria.
FAO. 2016. Food and Agriculture Organization of the United Nations Statistics Division data-base. Accessed December 2, 2019. http://faostat3.fao.org.
Fletcher, D. L. 2002. Poultry meat quality. Worlds Poult. Sci. J. 58:131–145.
Folch, J., M. Lees, and S. G. H. Stanley. 1957. A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem. 226:497–509.
Grau, R., and R. Hamm. 1953. Eine einfache Methode zur Bestimmung der Wasserbindung im Muskel. Naturwissenschaften 40:29–30 (in German).
Gumułka, M., D. Wojtysiak, E. Kapkowska, K. Połtowicz, and A. Rabsztyn. 2009. Microstructure and technological meat quality

of geese from conservation flock and commercial hybrids. Ann. Anim. Sci. 9:205–213.

Gumułka, M., E. Kapkowska, F. Borowiec, A. Rabsztyn, and K. Połtowicz. 2006. Fatty acid profile and chemical composition of muscles and abdominal fat in geese from genetic reserve and commercial flock. Anim. Sci. 1(Suppl.):90–91.

Haraf, G. 2014. Influence of feeding and geese genotype on carcass dissection and meat quality – the review of research. Nauki Inż. Technol. 1:24–42 (in Polish).

Haraf, G., J. Wołoszyn, A. Okruszek, A. Orkusz, and M. Wereńska. 2014. Fatty acids profile of muscles and abdominal fat in geese of Polish native varieties. Anim. Sci. Pap. Rep. 32:239–249.

Isguzar, E., and H. Pingel. 2003. Growth, carcass composition and nutrient content of meat of different local geese in Isparta region of Turkey. Arch. Tierz. 46:71–76.

Kapkowska, E., M. Gumułka, A. Rabsztyn, K. Połtowicz, and K. Andres. 2011. Comparative study on fattening results of Zatorska and White Kołuda® geese. Ann. Anim. Sci. 11:207–217.

Kirmizibayrak, T., K. Önk, B. Ekiz, H. Yalçintan, H. Alçintan, A. Yilmaz, K. Yazici, and A. Altinel. 2011. Effects of age and sex on meat quality of Turkish native geese raised under a free-range system. Kafkas Univ. Vet. Fak. Derg. 17:817–823.

Latimer, Jr, G.W. 2016. Official Methods of Analysis of AOAC International, 20th ed. Association of Official Analytical Chemistry International, Maryland, USA.

Liu, B. Y., Z. Y. Wang, H. M. Yang, J. M. Wang, D. Xu, R. Zhang, and Q. Wang. 2011. Influence of rearing system on growth performance, carcass traits, and meat quality of Yangzhou geese. Poult. Sci. 90:653–659.

Liu, H. W., and D. W. Zhou. 2013. Influence of pasture intake on meat quality, lipid oxidation, and fatty acid composition of geese. J. Anim. Sci. 91:764–771.

Murawska, D. 2013. The effect of age on the growth rate of tissues and organs and the percentage content of edible and inedible components in Koluda White geese. Poult. Sci. 92:1400–1407.

Okruszek, A. 2011. Comparison of fatty acids content in muscles and abdominal fat lipids of geese from different flocks. Arch. Geflugelk. 75:61–66.

Okruszek, A. 2012a. Effect of genotype on the changes of selected physicochemical parameters of geese muscles. Arch. Geflugelk. 76:155–161.

Okruszek, A. 2012b. Fatty acid composition of muscle and adipose tissue of indigenous Polish geese breeds. Arch. Geflugelk. 55:294–302.

Okruszek, A., J. Ksiażkiewicz, J. Wołoszyn, G. Haraf, A. Orkusz, and G. Szukalski. 2008. Changes in selected physicochemical parameters of breast muscles of geese from Polish conservation flocks depending on duration of the post slaughter period. Arch. Tierz 51:255–265.

Okruszek, A., J. Wołoszyn, G. Haraf, A. Orkusz, and M. Wereńska. 2013. Chemical composition and amino acid profiles of goose muscles from native Polish breeds. Poult. Sci. 92:1127–1133.

Puchajda-Skowrońska, H. 2012. Breeding and husbandry in geese. In: J. Jankowski (Ed.), Breeding and Husbandry in Poultry. PWRiL, Warszawa, Polska, pp. 355–375 (in Polish).

Rabsztyn, A. 2006. Zatorska Goose Population as a Part of the Polish Genetic Resources of Waterfowl. Habilitation Thesis. University of Agriculture in Cracow, Poland (in Polish).

Saatci, M., M. Tilki, I. Kaya, and T. Kirmizibayrak. 2009. Effects of fattening length, feather colour and sex on some traits in native Turkish geese. II. Carcass traits. Arch. Geflugelk. 73:61–66.

Sari, M., K. Onk, T. Sisman, M. Tilki, and A. Yakan. 2015. Effects of different fattening systems on technological properties and fatty acid composition of goose meat. Europ. Poult. Sci. 79:1–12.

Simopoulos, A. P. 2002. The importance of the ratio of omega-6/omega-3 essential fatty acids. Biomed. Pharmacother 56:365–379.

S. Smulikowska and A. Rutkowski (Eds.), 2018. Recommended Allowances and Nutritive Value of Feedstuffs for Poultry, 5th ed. Kielanowski Institute of Animal Physiology and Nutrition, PAS, Jabłonna and PB WPSA, Poznań, Poland, pp. 58–65 (in Polish).

Szado, J., A. Rabsztyn, and E. Kapkowska. 1991. Evaluation of Zatorska geese for fattening. II. Effect of fattening method on carcass quality. Zesz. Nauk. Przeg. Hod. 2:225–233 (in Polish).

Tilki, M., M. Saatci, T. Kirmizibayrak, and A. Aksoy. 2005. Effect of age on growth and carcass composition of Native Turkish Geese. Arch. Geflugelk. 69:77–83.

Tilki, M., T. S achin, M. Sari, S. I s ik, and M. Saatci. 2009. Effect of age and sex on fattening performance and carcass characteristics of native Turkish geese. Kafkas Univ. Vet. Fak. Derg. 15:245–250.

Tůmová, E., and L. Uhlířová. 2013. The evaluation of meat yield and physical properties in the Czech goose and the commercial hybrid the Novohradská goose. Maso. Intern. 2:133–138.

Uhlířová, L., E. Tůmová, D. Chodová, J. Vlčková, M. Ketta, Z. Volek, and V. Skřivanová. 2018. The effect of age, genotype and sex on carcass traits, meat quality and sensory attributes of geese. Asian-australas J. Anim. Sci. 31:421–428.

Uhlířová, L., and E. Tůmová. 2014. The effect of genotype and sex on performance and meat composition of geese. Acta Fytotechn. Zootechn 17:52–54.

Uhlířová, L., E. Tůmová, D. Chodová, Z. Volek, and V. Machander. 2019. Fatty acid composition of goose meat depending on genotype and sex. Asian-australas J. Anim. Sci. 32:137–143.

Utnik-Banaś, K., and J. Żmija. 2018. The geese market in Poland. Ann. PAAAE 20:157–163.

World Watch list for Domestic animal diversity. In: B. D. Scherf (Ed.), 2000, 3rd ed. Food and Agriculture Organization of the United Nations, Rome, pp. 351–373.

Ziołecki, J., and W. Doruchowski. 1989. In: Poznań. COBRD (Ed.), Methods for Slaughter Quality Assessment in Poultry, pp. 1–22. Poland (in Polish).