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Institute of Genetics and Animal Breeding, Jastrzębiec, Poland

The genetic background of slaughter value and quality of goose meat – a review

Katarzyna Nowicka, Wiesław Przybylski*

Department of Food Gastronomy and Food Hygiene, Faculty of Human Nutrition and Consumer Sciences, Warsaw University of Life Sciences, Warsaw, Poland

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Goose production is particularly popular in Eastern European countries. The largest producers of geese are Poland and Hungary as well as Czechia, Slovakia and Bulgaria. The results of research in available literature concerning geese show that the genotype has a significant impact on slaughter value and meat quality. Significant differences were also noted in the basic chemical composition of the muscles, particularly in protein and fat content, as well as the cholesterol, lipid fatty acid profile and the amino acid composition of proteins. Moreover, the genetic effects on technological quality of meat were confirmed (particularly on thermal drip and water holding capacity) and on selected sensory quality attributes.

KEYWORDS: genotype / goose meat / meat quality / slaughter value

Geese production in the world is estimated at approximately 2.5 million tons per year, of which 95.6% is produced in Asian countries, mainly China (94.1%), while the remaining 4.4% in the other parts of the world. Geese raising in Europe is relatively popular, although it does not exceed 0.03% of live poultry production. The major goose producers in this region include Poland, Hungary and Germany. Also Slovakia and the Czechia raise geese on a larger scale [FAOSTAT 2016, Rosiński 2003].

Quality is a multidimensional concept. In a discussion on the quality of poultry meat the following qualities need to be considered: nutritional value, technological suitability and sensory characteristics. In turn, a carcass is assessed based on the

*Corresponding author: wieslaw_przybylski@sggw.pl

extent of the muscular system, weight of individual cuts, fat content and appearance [Boutten 2003].

The aim of this study was to sum up the results of research concerning the quality of meat from different goose breeds kept in Europe, focusing on the impact of goose genotype on slaughter value and meat quality.

Meat traits in goose populations

White Italian

The White Italian is a very popular breed in Europe and one often finds reference to it in the formation of local stocks. The White Italians reported on in this publication are those kept at the Koluda Wielka Experimental Station in Poland, where they have been kept under genetic selection since the 1960s and where separate male and female lines have been developed. In 2012 the White Koluda geese were recognised as a distinct breed, following 50 years of breeding work on Italian White geese imported from Denmark in 1962. In the male line, the average body weight of males is 7.0 kg and of females is 6.5 kg, while in the female line the average is 6.5 kg for the males and 6.2 kg for the females, respectively. In 1997 the WD-3 and WD-1 strains of White Italian geese were called White Koluda geese and marked as W33 and W11.

White Koluda goose

The White Koluda goose stems from the White Italian goose, which was brought to Poland from Denmark in 1962. As a result of intensive breeding works carried out at the National Goose Research and Breeding Centre in Koluda Wielka, two strains of those geese were created: maternal (W11) and paternal (W33), along with their crosses. The White Koluda goose is kept mainly as an oat goose. This name is used to refer to a special manner of goose breeding and feeding developed by Bieliński [1984] which consists in the feeding of animals with whole oat grains for three weeks prior to slaughter. The aim of rearing of oat geese is to obtain after 15 weeks an average weight of about 5 kg, while the final fattening with oats is applied in order to further increase body weight of the birds by approximately 1.5 kg. Currently, oat goose carcasses are traditional national products and are export products in Europe [Kokoszyński *et al.* 2014].

White Hungarian

The physical characteristics of this goose are very close to those of the White Italian, but its body weight is lower. An improved line of this breed has been selected for feather production, but it may also be used in crosses both for the production of fatty liver and meat. The males weigh 5.5 kg and the females 4.7 kg [Rosiński2003].

Rhenish goose

The Rhenish goose was created by German breeders. In Hungary it constitutes the main part of the population of geese. The birds grow fast. Twelve-week old ganders weigh 5.2 to 5.3 kg, while female geese weigh 4.4 to 4.5 kg. Adult ganders can grow to a weight of 6.5 to 7 kg, while female geese to a weight from 5.5 to 6.5 kg. In a study conducted by Mazanowski *et al.* [2000], twelve-week old ganders and geese were selected in terms of increasing the muscular system and reducing fat content of the carcass; a favourable effect of the selection could be seen in the positive time trends for the length of the breastbone and percentage of meat, as well as the negative time trends for the weight and percentage of fat in the carcass. The breed produces very good results in intensive farming [Mazanowski 2012].

Chinese goose

The Chinese goose (Swan goose) was produced as a result of selection of the Garbonosa goose. They are popular all over the world and are used for cross-breeding with other goose breeds in order to increase the egg yield of cross-breeds. In Europe, White Chinese goose is preferred. The meat of Chinese geese is not marbled (the geese are not easy to fatten), so the opinions on the quality and taste of their meat ate mixed. In some countries these geese are improved in terms of increasing their body weight, but in such cases reproductive rates are reduced. An adult gander weighs up to 5.5 kg, while an adult goose - up to 4.5 kg [Mazanowski *et al*. 2000].

Cuban goose

The Cuban goose stems from the Chinese goose and resembles it to a large extent. Cuban geese were imported to Europe in the 1970s from the Soviet Union. They are currently covered by the poultry genetic resources conservation programme. Cuban geese are light, but they are relatively well-muscled. Their meat is lean. The content of skin with fat does not exceed 20 %. Adult ganders weigh 5 to 6 kg, while adult geese weigh 4.5 to 5 kg. In twelve-week old Cuban ganders and geese selected for their reproductive features positive time trends were found in terms of their body weight and the length of keel as well as the weight of meat and fat in the carcass [Mazanowski *et al*. 2000].

Slovak goose

The Slovak goose has been bred in Slovakia from the local geese upgraded with Hungarian, Emden and other geese. The breed has been included in the poultry genetic resources conservation programme. Adult ganders weigh 6 to 7 kg, while adult geese 5 to 6 kg. Slovak geese are characterized by a good muscular system and meat with a fine fibrous structure. They are very suitable for commercial cross-breeding and for rearing in large flocks [Mazanowski *et al*. 2000].

Roman goose

Roman geese are similar to White Italian geese. They are distinguished by their good muscular system and low fat content. They are suitable for commercial cross-breeding with other geese. In twelve-week old Roman geese, positive time trends were observed for the weight and percentage of fat content in the carcass [Mazanowski *et al*. 2000].

Emden goose

Emden geese originate from Holland (East Frisia). In the 19th century they were mated in England with Toulouse geese and gave rise to a new breed, with a larger weight and a changed body shape. In this way an English variety of Emden geese was produced, similar to Toulouse geese. The German variety, on the other hand, with a more harmonious build, was produced as a result of cross-breeding Emden geese with the English variety of the geese. The body weight of adult ganders ranges from 11 to 15 kg, while that of geese is from 8 to 9 kg [Mazanowski 2012].

Toulouse goose

Toulouse geese come from the south west of France. Next to Emden geese they are considered to be some of the heaviest geese. They are characterised by high meat and fat productivity. They are also used in the production of fatty livers (*foie gras*), which weight reaches as much as 2 kg. Adult males weigh 9 to 12 kg, while adult females 8 to 10 kg, respectively [Mazanowski2012].

Landes goose

The Landes goose originates from France. These geese are used primarily in the production of fatty livers. They are very suitable for rearing in large flocks and for producing commercial cross-breeds. The body weight of adult ganders reaches 7.0 to 7.5 kg, while that of adult geese is from 6.0 to 6.5 kg. The carcass of this breed has a medium meat content, but a significant content of skin with subcutaneous fat [Mazanowski 2012].

Synthetic Ukrainian

The Synthetic Ukrainian is an example of a relatively new synthetic line that has been developed at the Ukrainian Poultry Research Station, Borki, Ukraine. It is autosexing at eight weeks of age, because the females have grey primaries, while the males are white. It is a medium sized breed with the males weighing 6.0 kg and the females 5.4 kg [Rosiński 2003].

Slaughter value

Research results show that body weight (BW) and growth rate of geese are determined by their genotype as well as environmental and nutritional factors [Biesiada-Drzazga 2008, Kapkowska *et al*. 2011]. In an experiment conducted by

Kokoszyński *et al.* [2014], 17-week-old White Koluda W31 oat geese weighed 7.47 -7.68 kg. Kapkowska *et al.* [2011] showed that W31 hybrids reach higher BW as compared with the native breeds. After having completed the oat fattening phase in the 17th week of age, they reach an average weight of 6.81 kg [Buzała *et al*. 2014, Mazanowski 1999a, 1999b]. In turn, Wężyk *et al.* [2003] and Kłos *et al.* [2010] demonstrated that female and male geese of the W33 strain have greater BW than those of the W11 strain, i.e. 293.0-258.0 g and 200.0-314.0 g, respectively. Kłos *et al.* [2010] reported variation in most of the goose body dimensions depending on genotype. All of the body dimensions in males of the W33 strain, as compared with the females of the W11 strain, were greater with the exception of the length of shank and shank circumference. Highly significant interactions between genotype and sex of goose in terms of the initial live weight, final live weight, daily weight gain, feed conversion and hot carcass weight were found by Uhlířová and Tůmová [2014], where significantly higher values were observed in the hybrid goose than in the Czech Goose. Also in an experiment conducted by Ulhirova *et al.* [2018] significant interaction effects were observed between the age genotype and sex ($p<0.001$) in the slaughter weight of geese. Similar dependences were also recorded for the live weight and carcass weight in a study by Tůmová and Uhlířová work [2013], where the hybryd of Novohradská geese were approximately 900 g heavier than the Czech geese.

Fattening geese are raised to produce heavy carcasses with a favourable ratio of muscles to the fat tissue. Literature sources show that carcass weight and tissue composition depend mostly on genotype [Biesiada-Drzazga 2008, Kapkowska *et al*. 2011].

Dressing percentage (DP), as the percentage of carcass weight in the body weight, is determined by genotype [Mazanowski *et al.* 2006, Biesiada-Drzazga 2008, Kłos *et al.* 2010]. Changes in carcass composition, important from the consumer's perspective, includinga decreased fat tissue content (the proportion of skin with fat) and an increased muscle tissue content (the proportion of breast and leg muscles), were observed in a study by Kokoszyński *et al.* [2014] conducted on W31 White Koluda geese hybrids.

The DP of oat White Koluda geese ranges from 65.2 to 66.1% [Łukaszewicz *et al*. 2008, Kapkowska *et al*. 2011]. In turn, Biesiada-Drzazga [2008] showed that in 17-week-old oat W31 hybrids breast muscles accounted for 17.5% and leg muscles - 16.3% of eviscerated carcass with neck. In a study by Kapkowska *et al.* [2011], breast muscles of 17-week-old birds constituted 17.4% and leg muscles 15.3% of eviscerated carcass. In the carcasses of W31 oat geese hybrids the share of skin with subcutaneous and abdominal fat ranged from 28.6 to 35.9% in the case of breast muscles and from 17.4 to 17.5% in leg muscles [Kapkowska *et al.*, 2011]. The W31 hybrids had greater muscle tissue contents, at the simultaneously greater fat tissue contents than native breeds.

Gumułka *et al.* [2009] stated that the DP of the W31 hybridwas 76.9% significantly higher than that of the Zatorska breed (73.7%). The proportion of breast was similar in both genotypes at around 8.6%, while the proportion of thigh meat was higher in the Zatorska breed (8.8%) than in the W31 hybrid goose (7.7%). Kapkowska *et al.* [2011] reported no significant differences between genotypes. Irrespective of genotype, the DP was insignificantly higher in females. It corresponds with results obtained by Tilki *et al.* [2005] and Saatci *et al.* [2009]. In contrast, Isguzar and Pingel [2003] stated an insignificantly higher DP in males and recorded no significant differences between individuals.

An experiment conducted by Łukaszewicz *et al.* [2008] demonstrated that increased selection pressure resulted in negative correlation between the length of the breast bone and the weight of skin with subcutaneous fat, which should result in lesser fat contents in carcasses of W31 hybrids. In order to increase the value of performance traits and reduce fat content, geese from the reserve flocks may be used to produce hybrids with a share of genes from White Koluda geese [Mazanowski 2005].

Apart from commercial flocks of geese (White Koluda, White Italian), there are also domestic goose flocks kept in Poland. In 2016 the genetic resources conservation programme covered 14 breeds of geese kept at 4 centres: 12 breeds are maintained by the Waterfowl Genetic Resources Station in Dworzyska, belonging to the KoludaWielka Experimental Station of the National Research Institute of Animal Production in Cracow (Lubelska, Kielecka, Podkarpacka, Garbonosa, Kartuska, Rypińska, Suwalska, Pomorska, Roman, Slovakian, Landes and Kuban geese), Zatorska geese by the University of Agriculture in Cracow, Bilgorajska geese by the Wroclaw University of Environmental and Life Sciences and Bilgorajska geese (another flock) by Maria Kołodziej at the "Majątek Rutka" farm in Puchaczów.

In domestic goose breeds one can clearly distinguish between heavier northern breeds and lighter southern ones. The largest body weights and sizes were observed in the Kartuska goose, while the Kielecka goose and the Podkarpacka goose are the lightest and the smallest. A relatively high body weight was also found to be a characteristic of the Lubelska goose, Podkarpacka goose and the Kielecka goose in an experiment conducted by Mazanowski [1999c] (12-week-old ganders: 4.29-4.57 kg, geese: 3.58-3.91 kg).

According to Kłosowicz and Kukiełka [1958], the heavy types include for instance the Suwalska goose, Rypinska goose and the Kartuska goose, while the Podkarpacka goose as well as the Kielecka and Lubelska geese are of the light type. The body weight of 12-week-old geese is approximately 3.82 kg - 3.96 kg for southern breeds, while it is 4.21-4.48 kg for northern breeds. Slightly higher values were recorded by Faruga and Majewska [1982] as well as Smalec in their studies (southern breeds: 3.75-3.88 kg, northern breeds: 4.47-4.78 kg) [Faruga and Majewska 1982, Smalec 1991]. In turn, 17-week-old animals of northern breeds reached the weight of 4.50 kg (Rypinska goose) to 4.90 kg (Kartuska goose), while lighter southern breeds weighed from 4.1 kg (Kielecka goose) to 4.3 kg (Lubelska goose) [Mazanowski*et al*. 2006].

The highest dressing percentage was reported in 12-week-old geese of southern breeds (66.7% on average) [Mazanowski 1986]. In geese of all breeds, dressing percentage and the percentage of leg muscles in eviscerated carcasses with neck diminishes with the increase in body weight. However, at the same time the share of breast muscle sincreases (20.2-22.1%). The largest share of skin with subcutaneous fat is a characteristic trait of the Lubelska goose (21.0%), while it is lowest in the Kielecka goose (17.9%) [Mazanowski 1986]. According to Smalec [1991], the share of breast and leg muscles in 12-week-old geese of southern breeds amounts to 38.5%, while that of skin with subcutaneous fat is 14.1% (in comparison to 24-week-old geese with 38.9% and 17.7%, respectively). For northern breeds of geese these values are 37.3% and 15.8% (37.6%, 19.8%, respectively). A study carried out by Mazanowski [1986] also showed that the Kielecka goose is characterised by the smallest share of fat (18.4%) and the largest share of breast muscles (21.7%) in the carcass. Geese of the other breeds have a larger fat content and at the same time lower share of breast muscles. In a study conducted by Smalec [1991], the share of breast muscles in all breeds of geese is similar, while the share of skin with subcutaneous fat is lower in the Kielecka goose(16.5%) and the Podkarpacka goose (18.5%), while it is slightly lower in the Suwalska goose and the Kartuskagoose.

Nutritional value

Many researchers found that genotypic effects on nutritional value of muscle and abdominal fat in geese. A study conducted by Biesiada-Drzazga [2008], which was limited to the analyses of total protein, fat, ash and dry matter contents, shows a more favourable composition of muscles in geese from the W31 hybrid than in those from the W11 strain. This is indicated by a higher total protein content in breast muscles (W31 – 21.95%, W11 – 21.04%) as well as thigh and drumstick muscles (W31 – 20.38%, W11 – 20.15%). Moreover, carcasses of W31 crosses showed lower crude fat contents in breast muscles (5.21%) and in thigh and drumstick muscles (7.49%) when compared with geese from the W11 strain (6.01% and 8.17%, respectively). Similar results were obtained by Rosiński *et al.* [1999a], with the total protein content amounting to 22.0-22.8%. There are also literature data that point to a more favourable fatty acid profile of goose depot fat. Studies by Rosiński *et al.* [1999b] and Skrabka-Błotnicka *et al.* [1999] showed that oleic acid (which constitutes approximately 50-60% of all fatty acids) is the dominant acid in depot fat. Furthermore, a study by Rosiński *et al.* [1999a] confirmed that the impact of genotype on the share of oleic acid is non-significant. The largest content of C18:1 fatty acid may be found in depot fat obtained from geese from the W33 strain, W13 and W31 hybrids and from ganders of the W33 strain.

A study conducted by Okruszek *et al.* [2013] showed that muscle proteins of seventeen-week-old Garbonosa and Rypinska geese (except for breast muscles of Rypinska geese) were complete proteins, since they included all essential amino acids at the ratio recommended in the FAO/WHO 1991 protein standard. Moreover, breast muscles in Garbonosa geese were shown to have a larger water content, but a smaller fat content when compared with those of Rypinska geese (at an identical feeding regime for all the animals included in the study). Breast muscle proteins in Rypinska geese were found to be of a limited nutritional value due to an insufficient content of tryptophan (the limiting amino acid index was 90%) [Okruszek*et al*. 2013]. A study conducted by Mazanowski and Kisiel [2004] showed that breast and leg muscles in 24-week-old geese of southern breeds (Kielecka and Podkarpacka) contained more proteins than those of northern breeds (Kartuska goose and Suwalska goose). The lowest lipid content among the analysed geese was found in the muscles of Kielecka geese, while the lowest water content was recorded in leg muscles of Podkarpacka geese.

Analyses showed that breast muscles of Kartuska and Lubelska geese contain less cholesterol (by approx. 11 mg/100g) than breast muscles of the White Koluda goose [Skrabka-Błotnicka *et al*. 1997], but more (by approx. 20 mg/100g) when compared to those of the White Koluda strain W33 [Wężyk *et al*. 2003]. In a study by Haraf *et al.* [2014] cholesterol content in abdominal fat of Kartuska geese was lower than that of the Lubelska strain. Compared to the results presented by Haraf *et al.* [2014], Rosiński *et al.* [1999b] and Skrabka-Błotnicka *et al.* [1999] reported cholesterol content in abdominal fat of the White Koluda strains to be higher by approx. 18 mg/100g (W11, W33 and their hybrids – W13 and W31). Depot fat is characterised by a lower cholesterol content than it is the case in subcutaneous fat [Pikul 1996]. Furthermore, Rosiński*et al.* [1999b] examined cholesterol content in breast muscles of geese from the W11 and W33 strains and from the W13 and W31hybrids. The results showed the smallest cholesterol content in the muscles of ganders from the W11 strain (52 mg/g) and of females from the W13 hybrid (53 mg/g). In contrast, it was highest in ganders from the W13 hybrid (76 mg/g). However, no relationship between fat content and cholesterol content was found. These differences indicate that cholesterol content in goose muscles is determined genetically. Further results by Rosiński *et al.* [1999b] points to a significant difference in cholesterol contents in depot fat in females and males from the W33 strain (81 mg/100 g and 97 mg/100 g), W11 strain (105 mg/100 g and 96 mg/100 g) and in the W31 hybrid (87 mg/100 g, 97 mg/100 g). Moreover, cholesterol content in ganders from the W13 hybrid (86 mg/100 g) is considerably lower than in males from the other strains (86-97 mg/100 g). Among females, the greatest cholesterol content was recorded in the W11 strain (105 mg/100 g), while it was lowest in the W33 strain (81 mg/100 g).

Okruszek [2012] examined the fatty acid composition of muscle and adipose tissue in indigenous Polish geese breeds – Garbonosa and Rypinska. Unsaturated fatty acids were predominant in the total fatty acid composition of breast and leg muscles and the adipose tissue of both geese breeds. Similar results were obtained by Haraf *et al.* [2014], who examined the fatty acid profiles of muscles and abdominal fat in geese of native Polish varieties – Kartuska and Lubelska. The major fatty acids were oleic acid, linoleic acid (LA) and arachidonic acid (Tab. 1). In a study by Okruszek [2012], the concentrations of LA and arachidonic acid in breast and leg muscles as well as adipose tissue of the Kartuska and Lubelska geese were higher, while oleic

Table 1. Total fat, cholesterol content and fatty acids profile of muscles and abdominal fat in geese of different breeds

Fatty acids (%)	Rypinska breast (1)	Rypińska leg (1)	Garbonosa breast (1)	Garbonosa leg (1)	Rypińska abdominal fat (1)	Garbonosa abdominal fat (1)	Rypińska breast (2)	Rypińska leg (2)	Garbonosa breast (2)	Garbonosa leg (2)	Rypińska adipose tissue (2)	Garbonosa adipose tissue (2)	Kartuska muscles (3)	Lubelska muscles (3)	Kartuska Abdominal fat (3)	Lubelska abdominal fat (3)
SFA																
C14:0	0.612±0.071	0.580±0.033	0.746±0.090	0.514±0.021	0.844±0.010	0.713±0.010	0.54±0.07	0.53±0.03	0.63±0.08	0.50±0.02	0.82±0.02	0.70±0.01	0.55±0.05	0.62±0.06	0.54±0.04	0.53±0.02
C16:0	23.1±1.100	21.2±1.051	22.9±0.332	22.0±0.101	23.0±0.070	21.2±0.061	24.17±1.21	23.02±1.12	23.78±0.41	22.54±0.99	22.50±0.06	20.75±0.08	21.68±0.75	20.48±1.42	22.24±0.89	22.04±0.30
C18:0	6.81±0.491	7.53±0.612	6.36±0.360	7.81±0.431	3.48±0.201	3.412±0.142	7.31±0.50	8.01±0.51	6.94±0.30	8.29±0.40	3.92±0.22	3.88±0.12	8.87±0.91	9.47±0.95	7.27±0.56	6.56±0.16
∑SFA	30.5	29.3	30.1	30.3	27.4	25.3	32.02	31.56	31.35	31.33	27.24	25.33	31.11±1.61	30.57±1.61	29.39±1.29	28.84±0.98
MUFA																
C14:1 cis-9													0.27±0.30	0.33±0.04	0.05±0.01	0.04±0.01
C16:1 cis-9	3.45±0.390	3.83±0.281	4.03±0.273	3.92±0.262	4.51±0.050	3.76±0.051	3.32±0.34	3.68±0.23	3.90±0.22	3.75±0.21	4.01±0.04	3.23±0.04	2.60±0.30	2.46±0.27	2.37±0.19	2.52±0.09
C16:1 trans-9	0.612±0.021	0.581±0.023	0.672±0.031	0.546±0.033	0.791±0.020	0.764±0.022	0.92±0.02	0.78±0.02	0.99±0.02	0.74±0.02	0.82±0.01	0.85±0.02				
C18:1 cis-9	39.8±1.12	40.0±0.951	38.7±1.642	39.7±0.794	49.1±0.182	52.0±0.202	37.21±1.07	37.64±0.75	36.12±1.21	37.33±0.78	49.98±0.17	52.78±0.20	41.97±2.80	39.70±3.36	49.22±2.26	49.38±1.58
C18:1 trans-11	0.393±0.061	0.332±0.022	0.345±0.024	0.242±0.017	0.371±0.020	0.422±0.012	0.42±0.08	0.38±0.02	0.37±0.03	0.29±0.20	0.41±0.018	0.44±0.10	0.35±0.04	0.36±0.04	0.32±0.04	0.36±0.01
C20:1 cis-9									41.40	42.11	55.22	57.29	0.40±0.04	0.27±0.03	0.48±0.03	0.43±0.01
∑MUFA	44.3	44.8	43.7	44.4	54.7	56.9	41.87	42.48					45.60±3.02	43.11±3.56	54.84±2.21	54.71±0.44
PUFA																
C18:2 n-6	14.24±1.11	16.27±0.900	16.98±0.941	16.07±0.250	16.02±0.043	17.54±0.092	14.76±1.06	16.26±0.89	15.87±1.01	15.97±0.21	16.09±0.04	17.57±0.08	14.00±1.05	15.52±1.04	13.13±1.26	14.56±0.25
C18:3 n-3	1.01±0.010	0.822±0.012	0.981±0.021	0.794±0.020	1.19±0.040	1.28±0.033	1.04±0.01	0.83±0.02	1.00±0.02	0.80±0.02	1.26±0.04	1.34±0.03	1.43±0.10	1.35±0.13	1.28±0.06	1.03±0.01
C20:4 n-6	6.41±0.350	7.81±0.381	7.04±0.180	8.01±0.091	0.17±0.022	0.39±0.032	6.36±0.34	7.63±0.32	6.96±0.18	7.79±0.10	0.22±0.02	0.41±0.02	3.69±0.40	4.15±0.39		
C20:5 n-3	1.12±0.020	1.57±0.051	1.17±0.030	1.54±0.072			1.10±0.02	1.49±0.05	1.16±0.02	1.51±0.06			0.77±0.03	0.60±0.06		
C22:4 n-6	0.530±0.022	0.723±0.021	0.582±0.033	0.744±0.031			0.64±0.03	0.75±0.02	0.69±0.03	0.76±0.03			0.81±0.18	0.80±0.16		
C22:6 n-3	0.334±0.023	0.523±0.021	0.424±0.034	0.451±0.051			0.38±0.02	0.54±0.03	0.44±0.02	0.54±0.04			0.42±0.09	0.41±0.05		
∑PUFA	23.6	27.7	27.1	27.6	17.3	19.2	24.28	27.50	26.11	27.38	17.57	19.32	21.39±1.73	22.83±1.78	14.52±1.23	15.52±0.25
n-3	2.46	2.91	2.57	2.78	1.19	1.28	2.52	2.87	2.59	2.85	1.26	1.34	2.61±0.27	2.36±0.30	1.24±0.06	1.02±0.01
n-6	21.2	24.8	24.6	24.8	16.2	17.9	21.79	24.64	23.52	24.52	16.31	17.98	18.78±1.68	20.47±1.47	13.281.26	14.49±0.25
Total fat (%)	2.32±0.071	2.56±0.052	2.41±0.083	2.69±0.101	97.1±1.02	97.4±1.11	3.32±0.04	3.56±0.05	3.41±0.08	3.69±0.99	98.2±1.22	98.7±1.34	3.51±0.24	2.67±0.28	97.3±9.10	97.2±8.45
Cholesterol (g/100g)													62.51±5.51	73.85±2.36	70.16±1.02	79.89±5.66

1 – Okruszek [2011]; 2 – Okruszek [2012]; 3 – Haraf *et al*. [2014].

acid content was lower than the data reported by Gumułka *et al.* [2006] for 17-week-old Zatorska and White Koluda geese.

Okruszek [2011] found the genotypic effect on fatty acids in muscles and abdominal fat. The lipids of breast muscles in Garbonosa geese contained more myristic and palmitoleic acids as well as PUFA, i.e. LA, arachidonic acid and docosahexaenoic acid (DHA), at lower contents of oleic acid in comparison to the Rypinska goose. In the case of leg muscles higher contents of myristic, oleic and vaccenic acids were detected in the lipids of the Rypinska in comparison to the Garbonosa goose. The abdominal fat of Rypinska geese was characterised by higher contents of SFA: myristic, palmitic and palmitoleic acids, as well as lower contents of oleic, linoleic, arachidonic and vaccenic acids compared to the Garbonosa goose. Moreover, differences in fatty acid composition of lipids were observed depending on the type of muscles (breast vs. leg). Higher concentrations of myristic, palmitic and palmitelaidic acids as well as alpha-linolenic acid (ALA),and lower PUFA concentrations, i.e: arachidonic, eicosapentaenoic (EPA), arachidonic acids and DHA in both breeds were detected in breast muscle lipids compared to leg muscles. The lipids in the muscles and abdominal fat in the Rypinska goose were characterised by lower UFA contents (by 2.90% - breast muscle, 0.50% - leg muscle, and 4.00% – abdominal fat, respectively) and PUFA contents – except for leg muscles (by 3.50% – breast muscle and 1.90% – abdominal fat, respectively) compared to the Garbonosa goose (Tab. 1).

Moreover, lipids of breast muscles in the Garbonosa goose contained significantly higher percentages of myristic and palmitoleic acids as well as unsaturated fatty acids, i.e. LA, arachidonic acid, DHA at lower contents of oleic acid in comparison to the Rypinska goose [Okruszek2012]. In the case of leg muscles higher contents of myristic, oleic and trans- vaccenic acids were recorded in the lipids of the Garbonosa and Rypinska geese. The adipose tissue of the Rypinska goose was characterised by significantly higher contents of saturated fatty acids, e.g. myristic, palmitic as well as vaccenic acids compared to the Garbonosa goose. Stearic acid contents in breast and leg muscles as well as adipose tissue for Garbonosa and Rypinska geese were lower than those reported by Gumułka *et al.* [2006] (7.31% Rypinska and 6.94% - Garbonosa vs. 9.68% – Zatorska and 8.74% – White Koluda; 3.92% – Rypinska and 3.88% – Garbonosa vs. 5.61% – Zatorska and 6.60% – White Koluda, respectively). However, the level of palmitic acid was generally similar (Tab. 1) [Okruszek2012].

Rosiński *et al.* [1999b] when analyzing the fatty acid profile of adipose tissue lipids from 17-week-old females of the White Koluda goose (W11 and W33 strains as well as interbred hybrids W13 and W31), reported higher concentrations of palmitic acid (by 1.82%) and lower levels of UFAs and PUFAs (except for oleic acid) in comparison to the results obtained by Okruszek [2012] for the Kartuska and Lubelska geese. In turn, Biesiada-Drzazga [2006a,b] also found that when compared to 17-week-old White Koluda geese (W31), muscle tissue lipids of the Kartuska and Lubelska geese contained less MUFAs (by approx. 15%), but more PUFAs (by approx. 11%).

The differences were due to the lower amounts of oleic acid (by approx. 15%) and higher levels of LA (by approx. 15%), ALA (by approx. 1%) and arachidonic acid (by approx. 3%) in muscle tissue of the Kartuska and Lubelska geese.

In a study by Haraf *et al.* [2014] the concentrations of palmitoleic acid, erucic acid and EPA were higher, while those of LA lower in the Kartuska goose muscle lipids when compared to those in muscle tissue of Lubelska geese. Lipids in muscle tissue of the Kartuska goose were also characterised by lower contents of n-6 and higher contents of n-3 acids. Higher percentages of unsaturated fatty acids (UFA) and thus monounsaturated fatty acids (MUFA) were recorded in lipids of thigh muscles, while lower percentages of total saturated fatty acids (SFA) and n-3 fatty acids were found compared to breast muscles. Moreover, the abdominal fat of the Kartuska goose contained more stearic and erucic acids and less LA than in the case of the Lubelska goose abdominal fat. In comparison with the Lubelska goose the Kartuska goose abdominal fat contained also a lower percentage of PUFA, lower n-6 and higher n-3 fatty acid contents. In their study Gumułka *et al.* [2006], when analysing muscles of Kartuska and Lubelska geese recorded total contents of MUFAs (including oleic acid), lower by approx. 5% ,but PUFA contents higher by approx. 5% in relation to muscles of 17-week-old White Koluda geese. Compared to the data provided by Łukaszewicz and Kowalczyk [2008], the muscle lipids of Kartuska and Lubelska geese were higher in UFA by 6% and lower in SFA by approx. 9% than the respective contents in the White Koluda goose. Moreover, White Koluda geese (10 and 17-week-old, W31) were characterised by higher oleic acid and total MUFA contents (by approx. 4 and 0.06%, respectively) than it was in Kartuska and Lubelska geese. The abdominal fat of the White Koluda goose (W11, W31) contained also lower levels of ALA (by 0.6%) in comparison to that of Kartuska and Lubelska geese [Rosiński*et al*. 1999b,Skrabka-Błotnicka*et al*. 1999, Biesiada-Drzazga 2006a,b, Gumułka *et al*. 2006, Biesiada-Drzazga *et al*. 2011]. The total fat contents in breast and thigh muscles of Kartuska and Lubelska geese were comparable or lower than those reported for White Koluda geese (2.54-3.93% for breast and 4.16-10.52% for thigh muscle, respectively) [Skrabka-Błotnicka *et al*. 1997, Gumułka *et al*. 2006, Puchajda-Skowrońska *et al*. 2006a,b].

Goose fat may be considered to be relatively healthy in terms of its nutritional value, as it contains large amounts of unsaturated fatty acids (UFA), including oleic, linoleic, linolenic and arachidonic acids, which are products of enzymatic desaturation of stearic acid [Wężyk *et al*. 2003].Results presented by Okruszek *et al.* [2007] confirmed that breast muscle lipids of 17-week-old Podkarpacka geese had a greater UFA content (by approximately 4 percentage points – pp), including poly-unsaturated fatty acids (PUFA) (by approximately 4.5 pp) than breast muscle lipids of the Suwalska goose fed in the same manner. They were also characterised by a greater content of n-6 fatty acids. In turn, in leg muscle lipids of the Suwalska goose more saturated acids were found (myristic acid by 0.2 pp and palmitic acid by 0.15 pp) as well as more long-chain PUFAs than in leg muscle lipids of the Podkarpacka goose. Muscle lipids of 17-week-old Rypinska geese contained more UFAs (breast muscle lipids by 2.9 pp, while leg muscle lipids by 0.5 pp) and more PUFAs (by 3.5 pp in breast muscle lipids) than muscle lipids of the Garbonosa goose.

By contrast, breast muscle lipids of 24-week-old Rypinska geese, as compared with those of the Garbonosa geese, contained less acids: myristic acid (by approx. 1 pp), palmitoleic acid (by approx. 0.6 pp), PUFAs (by 1.8 pp), including n-6 PUFA (by 1.7 pp), while they contained more oleic acid - by 1 pp. Their leg muscle lipids were found to have a larger content of myristic acid (by 1 pp) and oleic acid (by approx. 1 pp) than the muscle lipids of the Garbonosa goose [Okruszek *et al*. 2007].

Also the mineral composition of goose meat varies depending on genetic factors [Doyle 1980]. So far only Geldenhuys *et al.* [2013, 2015] examined the mineral content of goose meat. Those studies showed that phosphorus was found to be the most abundant mineral present in Egyptian breast goose meat (166.9±17.3-173.7±17.1 mg/100g), followed by potassium (156.4±18.4-165.7±19.8 mg/100g), magnesium (30.3±2.7-31.9±3.0 mg/100g) and sodium (20.9±3.1-23.5±4.7 mg/100g). The mineral content in meat of SM3 heavy Pekin ducks was determined by Kokoszyński *et al.* [2014]. The breast muscle of those ducks contained less phosphorus (46.7±1.9-47.0±1.9), magnesium (22.1±0.9-20.8±0.9) and more potassium (375.4±15.2-371.8±15.5) and sodium (86.0±3.5-90.5±3.8), as compared with the breast muscle of geese.In relation to meat of other species goose meat could also be a better source of Fe (5.3±0.8-5.4±1.2 mg/ 100g of breast meat) [Geldenhuys *et al*. 2013, Pisula and Pospiech 2011]. When the Fe content in breast portion of the Egyptian goose is compared to that of the SM3 Heavy Pekin Ducks, the levels are much higher than what was reported by Kokoszyński *et al.* [2014] (2.9±0.11-3.1±0.12/100 mg of breast meat).This high level of Fe goose meat is related to their metabolic type and muscle fibre composition [Geldenhuys *et al*. 2016]. This muscle mainly consists of type IIa fast twitch oxidative fibres, with high myoglobin contents for oxygen supply [Geldenhuys *et al*. 2015].

Technological suitability and sensory quality

Research conducted by Rosiński *et al.* [1999a] concerning water holding capacity and thermal drip loss confirmed that the genotype of females has a greater effect on the above-mentioned functional properties than it is in the case of males. Muscles of hybrid females are characterised by a smaller thermal drip and smaller water holding capacity, while the lowest values can be found in the meat of females from the W31 hybrid. Furthermore, a study carried out by Rosiński *et al.* [1999a] showed differences in the tenderness, elasticity and juiciness of boiled breast muscles. The highest scores in the sensory analysis (indicating high desirability) were given to muscles of ganders from the W11, W33 strains and W31, W13 hybrids. However, the lowest juiciness was found in the muscles of goose females from the W11 strain [Rosiński *et al*. 1999a].

The best technological value can be observed in the meat of Kartuska and Suwalska geese (high pH). A high water holding capacity is also a characteristic of meat in Kielecka and Bilgoray geese, which at the same time has a high pH_{24} (5.85-

5.91) [Faruga and Majewska 1982]. Studies conducted by Mazanowski *et al.* [2006, 2007] indicate that meat of southern breeds after 24 weeks of rearing is characterised by a higher water holding capacity as compared with meat of White Koluda geese. What is more, meat of southern breeds has a lower fat content (breast muscles: 2.7 %, leg muscles: 3.7%), while meat of domestic breeds from the north of Poland is more alkaline (pH24: 6.0-6.2), with a slightly lower water holding capacity and greater fat content (breast muscles: 3.7 %, leg muscles: 4.4%) [Mazanowski *et al*. 2006, 2007]. Similarly, Uhlířová *et al.* [2018] showed a significant effect of goose genotype on ultimate pH and cooking loss.

Colour components (L*, a*, b*) of the breast muscles in oat-fattened domestic geese of southern varieties were presented by Lewko *et al.* [2017]. The L* parameter was 44.25 for breast muscle and 49.86 for leg muscle. Moreover, it was found that the share of red colour (a* parameter) in the muscles colour ranged from 10.45 (Lubelska) to 11.96 (Kielecka) for breast muscle and from 13.28 (Kielecka) to 14.21 (Subcarpation) for leg muscle, respectively. The highest share of yellow (b* parameter) was demonstrated in the muscles of Kielecka geese – 4.87 for breast muscle and 10.92 for leg muscle [Lewko *et al*., 2017].Okruszek *et al.* [2008] also analysed photometric lightness of breast muscles from geese from conservative flocks. The authors demonstrated that breast muscles of Subcarpation geese were characterised by lighter colour (L* = 38.67), a greater share of red colour (a* = 18.67) and a smaller share of yellow colour (b* = 3.80) when compared to the results presented in their study by Lewko *et al.* [2017], where values of L* and a* parameters of breast muscle from Subcarpation geese were higher (by 3.22 and 0.98, respectively), while the b*value was by 7.08 lower. Gumułka *et al.* [2009] evaluated physical properties of muscles from Zatorska geese and hybrids of W-31 White Koluda geese. Lightness (L*) ranged from 38.52 (breast muscle of Zatorska geese) to 40.54 (leg muscle of W-31 geese). The value of parameter a* ranged from 16.33 (leg muscle of Zatorska geese) to 17.00 (breast muscle of Zatorska geese), while parameter b* ranged from 3.46 (breast muscle of White Koluda geese) to 4.38 (leg muscle of White Koluda geese). Meat colour parameters of Eskildsen and Czech geese were described by Uhlířová *et al.* [2018]. The value of parameter L* ranged from 35.85 (breast muscle of Czech female geese) to 38.92 (breast muscle of Eskildsen male geese), parameter a* from 10.53 (breast muscle of Czech female geese) to 14.50 (breast muscle of Eskildsen male geese) and parameter b* from 10.15 (breast muscle of Eskildsen female geese) to 10.82 (breast muscle of Eskildsen male geese).

Sensory traits of raw and heat-treated goose meat were analysed by Lewko *et al.* [2017]. The study was conducted on meat from domestic geese of Polish southern varieties: Lubelska, Kielecka and Podkarpacka. With regard to the origin of geese, significant differences were observed in the sensory quality of breast muscles for colour (Lubelska and Podkarpacka), overall quality (Kielecka and Podkarpacka) and aroma (all the evaluated populations). In the case of leg muscles, there were significant differences between between Kielecka vs Podkarpacka goose breeds (0.14 pts) and Lu (0.17 pts) in fatness, Podkarpacka vs Lubelska (0.12 pts) and Kielecka (0.08 pts) geese in terms of aroma, and between Lubelska vs Kielecka (0.09 pts) and Podkarpacka geese (0.08 pts) in overall quality. In a study by Uhlířová*et al.* [2018] the mean score for all sensory attributes ranged between 5 to 7 points for both genotypes of geese (Czech and Eskildsen geese). Hamadani *et al.* [2013] recorded a similar score (6+) in all evaluated sensory attributes for the same breeds, but in that study a different methodology was used.

Conclusions

In summary, the genotype affects slaughter productivity and quality of goose meat to a significant extent. The data presented show that Emden and Toulouse geese, which are classified as heavier breeds, had the largest sizes and body weights. What is more, geese in conservation flocks had smaller body weights than geese in commercial flocks (White Italian, White Koluda geese). At the same time, research carried out by those authors shows a significant sexual dimorphism resulting in females having smaller body weights than males, by approximately 0.5-0.7 kg. Depending on the genotype of geese, significant differences were also recorded in the basic chemical composition of the muscles, particularly in protein and fat contents, as well as cholesterol levels, lipid fatty acid profile and amino acid composition of proteins. Moreover, the analyses confirmed the effect of genotype on technological quality of meat (particularly thermal drip and water holding capacity) and selected sensory quality attributes.

It may be stated that goose meat is characterised by high quality. Therefore, this is a very valuable product on the European poultry market, which should attract more interest both from manufacturers and consumers.

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