Effect of parent flock age on hatching, growth rate, and features of both sexes goose carcasses

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ABSTRACT The study aimed to assess the hatchability of goslings from parent flocks of geese in 4 laying seasons and to analyze the growth, carcass, and muscles characteristics. The hatching eggs from the White Kołuda geese from the 1st to 4th laying season were incubated by the waterfowl hatching technology. Hatchability rates were calculated. 40 goslings were selected from each group. The geese were reared and fattened for 16 wk, (sex ratio of 1:1). From the 1-day-old goslings and at the end of the fattening period, the pectoral muscles were sampled to evaluate the muscle fibers. The body weight of the geese and the growth rate were analyzed. Body measurements were taken on the day of slaughter (6 birds/each group). The dissection was performed and the tissue composition of the carcasses was analyzed, including the percentage of carcass elements. The results were analyzed in terms of the age of the parent flock and the sex of oat geese. Hatchability performance was similar in all groups. Lower body weight of geese from group I was demonstrated at 0, 1, 7, 10 to 12 wk compared to birds from older geese. The growth rate in this group was higher than in groups III (2nd wk) and IV (1st wk). From 4 wkof age, the males had a higher body weight. In 1-day-old male goslings, a higher diameter of muscle fibers was demonstrated than in females. The body measurements of ganders were significantly higher compared to females, except for the length of the jump. Males were characterized by a higher weight of carcass parts. However, the share of abdominal fat was higher in females. No significant differences were found in the remaining features. Geese from different ages' parent flocks don't differ in the carcass features (the compensation phenomenon). The sex of the geese was influenced. It is reasonable to hatch goslings for fattening from parent flocks during 4 years of reproductive use.

Key words: geese, muscles, oat fattening, seasonal reproduction, slaughter yield

2022 Poultry Science 101:101920
https://doi.org/10.1016/j.psj.2022.101920

INTRODUCTION

A commonly kept goose in Poland is White Kołuda. It is a commercial W31 hybrid made from the W11 and W33 lines (Gumułka and Połtowicz, 2020). Sisteen-wk-old geese are characterized by a body of approx. Six to 7 kilos (Łukaszewicz et al., 2008; Janicki et al., 2011), and their characteristic feature is a relatively higher proportion of fat (subcutaneous or abdominal fat) compared to other poultry species (Murawska, 2013; Haraf et al., 2014). Despite this, the popularity of the goose industry is growing in European countries. Goose meat is popular on the food market, and its properties are considered beneficial for consumers due to its high protein quality, low cholesterol content, and high concentration of polyunsaturated fatty acids (Razmaitė et al., 2022; Wereńska et al., 2022).

The reproductive flocks of geese are kept for four years, and their offspring make up about 98% of the geese used for meat production, known as the "oat goose" (Kłopotek, 2018). Geese are characterized by a seasonal reproductive cycle. In Europe, it is the season from February to June (Gumułka and Połtowicz, 2020). As scientists point out, the quality of hatched goslings depends on many factors, including the age of the parent flock. Geese are characterized by a low level of laying, as well as hatchability and high embryo mortality (Łukaszewicz et al., 2019). The further growth of the birds depends on the quality of the hatched goslings, which affects the quality of the obtained raw material (Damaziak et al., 2021). The weight of the hatching egg is correlated with the weight of the chick (Mitrović et al., 2018). According to Kuźniacka et al. (2019), the smallest hatching eggs are obtained from geese in the 1st year of reproduction, compared to the 2nd, 3rd, or 4th yr. Therefore, it can be suggested that goslings from

Received March 4, 2022.
Accepted April 5, 2022.

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such geese will be smaller. The weight of hatching goose eggs may have an impact on the quality of 1-day-old goslings in the short and long term (Salamon, 2020). The weight of the goslings is one of the quality elements of the newly hatched offspring. It also determines the growth opportunities and condition of the birds during rearing (Lin et al., 2018). Sklan et al. (2003) described that the performance of broilers depends on the age of the parent flock and the weight of the chicks.

The production results (body weight, growth rate) and carcass characteristics are also influenced by the sex of the geese. According to Lisiak et al. (2021) ganders are characterized by a higher body weight compared to females, and there are also visible differences in the muscles and fatness of the carcasses. Research on the influence of the sex of Czech Goose and Eskildsen Schwer on slaughter traits also confirmed the differences, including the slaughter weight (Uhlírová et al., 2018). In the case of Lindovskaya geese, similar results were shown between sex (Akbaş et al., 2020).

Previous studies on the growth and tissue composition of geese focused mainly on nutritional factors. Kokoszyński et al. (2014) analysed the effect of maize silage on the traits of the White Kołuda goose carcass. The subject of previous studies was also the assessment of the quality of goose meat from reproductive flocks of W11 and W33 (Wężyk et al., 2003), and analyzed these features to the origin of geese, for example, hybrids of Graylag with White Kołuda and Slovak goose (Mazanowski et al., 2005a), whether the slaughter performance of Zatorska geese (domestic breed) was compared with the commercial hybrid W31 (Gumułka and Połtowicz, 2020). The slaughter yield of geese and their tissue composition depending on the aforementioned factors have been described.

This subject is important because it relates to the economics of broiler goose production. It could be suggested that depending on the initial weight of the goslings, different weights of geese will be obtained after the end of rearing and fattening (Kucharska-Gaca et al., 2016). Boz et al. (2017) described that the growth of geese could be affected by the factors from the hatching stage. Therefore, the question arises whether the geese from the reproductive flocks of different ages differ in terms of weight and carcass characteristics?

The literature on the influence of the reproductive season of the parent flock of geese on the growth of offspring and the quality of carcasses is limited. Because of the above knowledge about the quality and carcass characteristics of geese, research was undertaken to assess the hatchability rates of geese of both sexes from the parent flock of geese in 4 laying seasons, and to analyze the growth, slaughter yield, and carcass characteristics, as well as the microstructure of the breast muscle from 1-day-old and 16-wk-old geese.

MATERIALS AND METHODS

The research was carried out with the consent of the Local Ethical Committee in Bydgoszcz No. 30/2015. All activities were performed following directive no. 2010/63/EU of 22 September 2010 on the protection of animals used for scientific purposes.

Hatching

A total of 2,040 hatching eggs of the White Kołuda geese were intended for the research. Hatching eggs were divided depending on the age of the parent flock into 4 experimental groups – I, II, III, and IV (numbers are equal to the season of reproduction). Hatching was carried out in a single-stage incubator of the Jartom company (Jarson, Gostyń, Poland). The air temperature in the hatching chamber was 37.7°C and the relative humidity was 55%. The hatcher was set to a temperature of 37.4°C and a humidity of 75%. From the 2nd day of hatching, the cooling of the chamber began. It consisted of opening the hatching chamber for 20 min twice a day. The treatment was repeated until the eggs were transferred to the hatcher. From the 9th d, the procedure of airing and sprinkling the eggs outside the chamber in a well-ventilated hall was carried out. From the 16th day of incubation, the eggs were manually rotated 180° along the long axis of the egg. Rotation and airing were performed once a day. On d 27, the eggs were put into the hatcher. During the last 3 to 4 days of incubation, hatchers were aired once a day for 20 min. Incubation lasted 30 to 31 d. After hatching, all indicators were described: percentage of fertilized eggs, dead embryos, healthy, crippled, and weak chicks to the total amount of eggs and fertilized eggs.

One hundred ninety-two goslings of White Kołuda (W31) geese were selected for the study. After hatching, the geese have divided into 4 groups. In group I goslings were from laying geese in the first year of reproductive use, in group II – the second year, III – the third year, and IV – the fourth year.

After hatching, samples of the superficial pectoral muscle were taken from 8 goslings (4♂ and 4♀) from each group. Muscle samples were placed in cryovials and frozen in liquid nitrogen (−196°C). The samples were used for the analysis of the muscle microstructure.

Growth Performance and Carcass Features

Forty birds from each group were intended for rearing. Males and females were kept in a 1:1 ratio per group. The goslings were weighed (Radwag PS 750/X, Radom, Poland) and marked with padlocks. In the 1st wk of the birds' life, the air temperature in the facility was from 30 to 26°C, in the 2nd wk from 26 to 22°C, and in the 3rd wk from 22 to 18°C. Relative air humidity was on average 65%. The birds were provided with access to the enclosures.

Geese were kept until 16 wk of age, under the commonly used technology of rearing and fattening oat geese. The birds were reared in a semi-intensive system, until the age of 13 wk, then the birds were fattened with oat grains for 3 wk. The body weights of the geese were

Table 1. Hatchability of goslings.

Item			Parent flock age				P-value*
			I	II	III	IV	
Fertilized eggs (%)			76.67 ± 18.15	86.00 ± 10.00	90.67 ± 11.02	84.00 ± 8.00	0.598
% share of chicks in ratio to the total amount of eggs (L) and fertilized eggs (F)	dead embryos	L	6.67 ± 3.06	10.67 ± 6.43	14.00 ± 5.29	10.67 ± 4.16	0.395
		F	9.77 ± 7.09	13.03 ± 9.26	15.97 ± 7.53	13.07 ± 6.05	0.800
	not hatched chicks	L	4.00 ± 2.00	5.33 ± 2.31	5.33 ± 2.31	6.00 ± 2.00	0.723
	crippled and weak chicks	F	5.03 ± 1.56	6.33 ± 2.80	5.83 ± 2.19	7.23 ± 3.00	0.742
		L	0.00 ± 0.00	0.67 ± 1.15	2.67 ± 3.06	1.33 ± 1.15	0.341
		F	0.00 ± 0.00	0.87 ± 1.50	3.27 ± 3.98	2.30 ± 2.17	0.398
	healthy chicks	L	66.00 ± 19.29	69.33 ± 16.17	68.67 ± 18.04	66.00 ± 14.00	0.992
		F	85.20 ± 5.73	80.53 ± 10.55	74.90 ± 11.93	77.40 ± 10.15	0.629

*Lack of statistically significant differences between parent flock age, P-value > 0.05.

monitored each week. Growth rate (%) was calculated with the formula:

$$\frac{\text{final weight} - \text{initial weight}}{0.5(\text{final weight} + \text{initial weight})} \times 100.$$

The birds were slaughtered at 16 wk of age. Randomly selected 3 females and 3 males from each group. In total, 24 birds were assessed.

Samples of the superficial pectoral muscle were taken from each goose immediately after slaughter (on the left, at the height of $\frac{2}{3}$ of the length of the sternum in the area of the crest). Muscle samples were fixed in liquid nitrogen (−196°C). Then they were cut in a cryostat (Thermo Shandon, Waltham, MA) into 10-μm thick sections at a temperature of approx −25°C. Assessment of the microstructure of the goose pectoralis superficialis muscle was performed on histological slides subjected to the H + E reaction (hematoxylin and eosin) to determine the number and diameter of muscle fibers in three randomly selected bundles. Muscle histometric analyses were performed using the MultiScan Base v. 18.03 computer program (Computer Scanning System II, Warsaw, Poland). A Delta Optical Evolution 300 microscope equipped with a ToupCam camera was used to save the histological images on the computer's hard drive. The procedure of these studies also concerned the histological evaluation of samples collected from 1-day-old geese.

After slaughter, zoometric measurements of the 24 (6 per group) carcasses were made with an accuracy of 1 mm using tape (cm). The following were measured: chest circumference (behind the wings, through the front edge of the sternum crest and middle thoracic vertebra), the body length (between the first cervical vertebra and the posterior edge of the ischial bone), the length of the trunk (between the shoulder joint and the posterior edge of the ischium), the length of the crest sternum (from the front to the rear edge), the length of the forearm, the length of the jump (between the ankle joint and the lower back surface of the first toe at its root). Whole goose carcasses were dissected, including the pectoral muscles, leg muscles, neck, wings with skin, skin with subcutaneous fat, abdominal fat, and carcass remains (leg bones and trunk).

Statistical Calculation

The collected numerical data were statistically processed using Statistica 12.5 PL (Statsoft, Cracow, Poland, 2017). The mean values of all examined features and their standard deviations (±SD) were calculated. In the calculations, the two-way analysis of variance ANOVA (factors: age of the parent flock, sex) was used. The significance of the differences was verified using the Kolmogorov-Smirnov test, with a P-value <0.05.

RESULTS

Hatching

No statistically significant differences between the groups in the share of dead, unhatched, crippled, weak, and healthy chicks in ratio to the total amount of eggs and fertilized eggs (P > 0.05) were found (Table 1). Quantitatively, the highest fertilization of eggs was found in group III (90.67%) and the lowest in the first year of reproductive use of geese (I, 76.67%). The share of healthy chicks obtained from fertilized eggs was the highest in group I (85.20%), and the lowest in group III (74.90%).

Growth Performance and Carcass Features

The bodyweight of randomly selected day-old chicks intended for rearing and fattening with oats differed statistically significantly (Table 2). The higher body weight of goslings was found in the group coming from 4-yr-old laying geese (139.8 g) compared to the group I − by 42.2 g less. The difference in body weight between goslings from females of different ages remained in the 0, 1, 7, and 10 to 12 wk of life (P < 0.05). In all of the above-mentioned dates, it was found that geese from the youngest layers showed a lower body weight compared to other age groups. Groups II, III, and IV did not differ significantly in terms of the examined feature (P > 0.05), except for wk 1, where in group II, the birds were characterized by lower body weight (P = 0.030). In the 16th wk of goose life, no statistically significant differences in body weight were found between the studied groups (P = 0.309).

Table 2. Body weight of geese (g) in individual weeks of rearing and oats fattening depending on the age of the parent flock and sex.

	Parent flock age (PFA)				Sex (S)		*P*-value		
Age [wk]	I	II	III	IV	♂	♀	PFA	S	Interaction
0	97.6^{c} ± 3.4	115.5^{b} ± 4.6	132.1^{a} ± 4.8	139.8^{a} ± 8.3	121.9 ± 18.3	120.5 ± 17.2	0.001	0.568	0.566
1	320.7^{b} ± 31.7	353.1^{a,b} ± 22.2	394.4^{a} ± 22.8	366.0^{a,b} ± 55.4	359.9 ± 45.7	357.1 ± 41.7	0.030	0.859	0.693
2	898.6 ± 70.5	876.8 ± 59.4	960.3 ± 72.9	931.5 ± 134.7	935.2 ± 73.6	898.4 ± 102.8	0.442	0.344	0.639
3	1,707.0 ± 180.5	1,722.4 ± 118.9	1,872.5 ± 144.2	1,799.5 ± 177.9	1,823.2 ± 110.3	1,727.5 ± 193.5	0.271	0.153	0.528
4	2,518.4 ± 297.4	2,547.4 ± 103.1	2,709.4 ± 227.1	2,602.1 ± 202.2	2,727.2^{a} ± 118.9	2,461.5^{b} ± 214.6	0.260	0.001	0.497
5	3,321.4 ± 432.0	3,210.4 ± 102.2	3,476.5 ± 250.4	3,493.9 ± 346.2	3,480.0 ± 224.7	3,271.1 ± 357.7	0.374	0.121	0.871
6	3,689.6 ± 393.0	3,767.7 ± 287.3	4,084.2 ± 370.6	3,917.7 ± 319.5	4,078.6^{a} ± 308.6	3,651.0^{b} ± 267.0	0.067	<0.001	0.252
7	3,904.6^{b} ± 545.4	4,254.9^{a,b} ± 336.2	4,534.7^{a} ± 445.5	4,330.6^{a,b} ± 325.8	4500.6^{a} ± 380.5	4,011.7^{b} ± 403.3	0.018	0.001	0.112
8	4,556.7 ± 392.4	5,136.2 ± 780.2	5,020.3 ± 441.9	4,905.3 ± 294.3	5208.6^{a} ± 539.4	4,600.6^{b} ± 291.2	0.120	0.002	0.520
9	4,906.5 ± 462.9	5,160.3 ± 333.1	5,263.6 ± 698.8	5,256.6 ± 394.7	5457.5^{a} ± 332.6	4,836.0^{b} ± 406.1	0.280	<0.001	0.270
10	5,252.6^{b} ± 578.8	5,618.0^{a,b} ± 387.0	5,688.3^{a} ± 475.6	5,565.1^{a,b} ± 343.8	5877.9^{a} ± 257.6	5,199.1^{b} ± 348.2	0.032	0.001	0.116
11	5,689.3^{b} ± 573.2	5,942.8^{a,b} ± 297.8	6,118.6^{a} ± 484.8	6,151.5^{a} ± 445.6	6347.8^{a} ± 252.4	5,603.3^{b} ± 306.7	0.004	0.001	0.113
12	5,778.3^{b} ± 642.7	6,069.0^{a,b} ± 330.0	6225.6^{a} ± 460.3	6169.5^{a} ± 578.5	6477.0^{a} ± 242.2	5,657.6^{b} ± 359.4	0.023	0.001	0.163
13	5,869.8 ± 528.1	6,176.0 ± 311.7	6,328.5 ± 553.7	6,285.83 ± 647.6	6561.6^{a} ± 289.5	5,768.4^{b} ± 3.79	0.069	0.001	0.370
14	5576.0 ± 510.4	5724.2 ± 243.6	5,945.3 ± 742.0	5,828.6 ± 486.3	6104.7^{a} ± 448.4	5,432.3^{b} ± 309.5	0.300	<0.001	0.056
15	6,183.8 ± 406.8	6,122.7 ± 182.9	6,315.7 ± 723.7	6,124.0 ± 604.6	6,507.7^{a} ± 369.1	5,765.3^{b} ± 297.1	0.215	<0.001	0.010^{x}
16	6,412.0 ± 231.5	6,455.2 ± 223.2	6,511.54 ± 456.3	6,462.0 ± 445.8	6,740.2^{a} ± 234.5	6,168.4^{b} ± 208.9	0.309	<0.001	0.037^{x}

[a]Mean values marked with different letters in the columns differ statistically significantly ($P < 0.05$).
[b]Mean values marked with different letters in the columns differ statistically significantly ($P < 0.05$).
[x]Statistically significant interaction age of the flock × sex ($P < 0.05$).

Moreover, it was found that sex influenced the body weight of birds at the 4th wk of age and from the 6th wk of age. Later on, males were heavier than females ($P < 0.05$). Males at the 16th wk of age were significantly higher body weight (by 572 g) compared to females ($P < 0.001$). The interaction between the age of the reproductive flock and the sex of the birds was demonstrated in the body weight in the last 2 wk of rearing ($P = 0.010$; $P = 0.037$, respectively).

The growth rate of geese in the 1st two weeks of rearing depended on the age of laying geese from the parent flock (Table 3). The highest rate was found in goslings from the flock of 1-yr-old females (104.63%). In geese from the oldest layers, the growth rate was 23.71 percentage points lower ($P = 0.004$). Similar trends were shown in the second week, however, the lowest index was found in group III ($P = 0.002$). At the remaining evaluation dates, the growth rate index was similar and did not depend on the age of laying hens ($P > 0.05$). Sex did not influence the growth rate ($P > 0.05$), excluded 4th wk. Males were characterized by a higher growth rate than females (by 4.55 percentage points, $P = 0.030$). With each week of the birds' life, the value of the growth rate decreased, and the lowest value was found at 12 to 13 wk of age (from 0.56 to 2.08%). During the fattening with oats, the growth rate increased to 3.41 to 7.55% ($P > 0.05$).

Analyzing the results from Table 4 on the 1st day of life, significant differences in the diameter of muscle fibers depending on sex were found. Female muscle fibers were 0.30 μm smaller in diameter compared to males ($P = 0.007$). After the rearing and fattening period, in 16-wk-old geese, no statistically significant differences were found in the mean number of fibers in the muscle bundle and the diameter of the muscle fibers ($P > 0.05$). Comparing the quantitative features of the

Table 3. The growth rate of geese (%) in individual weeks of rearing and oats fattening depending on the age of the parent flock and sex.

	Parent flock age (PFA)				Sex (S)		*P*-value		
Age [wk]	I	II	III	IV	♂	♀	PFA	S	Interaction
1	104.63^{a} ± 7.87	95.57^{a,b} ± 10.75	92.78^{a,b} ± 9.55	80.92^{b} ± 11.50	95.32 ± 13.07	91.63 ± 12.66	0.004	0.345	0.140
2	94.74^{a} ± 8.16	85.12^{a,b} ± 3.28	81.31^{b} ± 8.24	86.54^{a,b} ± 16.15	88.90 ± 10.32	85.95 ± 10.73	0.002	0.490	0.433
3	61.60 ± 12.42	64.98 ± 6.55	64.33 ± 7.14	63.87 ± 11.66	64.36 ± 9.03	63.03 ± 9.79	0.927	0.730	0.138
4	38.28 ± 3.02	38.74 ± 5.37	36.46 ± 3.63	36.57 ± 7.41	39.79^{a} ± 3.58	35.24^{b} ± 5.13	0.775	0.030	0.502
5	27.37 ± 6.36	23.05 ± 3.25	24.88 ± 2.83	29.03 ± 9.50	24.14 ± 4.56	28.03 ± 7.09	0.380	0.147	0.848
6	10.73 ± 8.83	15.75 ± 5.72	15.94 ± 2.94	11.55 ± 11.41	15.74 ± 4.75	11.25 ± 9.60	0.508	0.197	0.830
7	5.31 ± 10.12	12.12 ± 3.39	10.39 ± 1.23	10.05 ± 4.60	9.77 ± 3.71	9.16 ± 7.88	0.303	0.812	0.670
8	15.89 ± 9.51	17.97 ± 18.0	10.24 ± 1.60	12.52 ± 1.80	14.36 ± 12.82	13.95 ± 6.78	0.576	0.923	0.284
9	7.32 ± 1.90	1.18 ± 13.43	4.24 ± 8.07	6.83 ± 2.15	4.95 ± 9.96	4.83 ± 5.40	0.562	0.927	0.445
10	6.67 ± 2.46	8.45 ± 4.61	8.25 ± 8.66	6.31 ± 3.11	7.49 ± 3.93	7.35 ± 6.11	0.874	0.949	0.552
11	8.05 ± 2.56	5.71 ± 3.25	7.31 ± 1.94	9.41 ± 2.46	7.70 ± 3.35	7.54 ± 2.23	0.140	0.880	0.294
12	1.46 ± 2.81	2.08 ± 0.65	1.76 ± 2.25	0.56 ± 6.10	2.02 ± 3.10	1.91 ± 3.67	0.906	0.479	0.644
13	1.74 ± 2.92	1.76 ± 0.60	1.54 ± 2.95	1.33 ± 2.44	1.27 ± 1.59	1.92 ± 2.82	0.986	0.491	0.143
14	5.13 ± 2.62	7.55 ± 6.04	6.56 ± 6.75	7.35 ± 9.04	7.36 ± 6.36	5.94 ± 6.16	0.922	0.611	0.474
15	7.21 ± 2.80	6.76 ± 4.95	6.13 ± 2.51	4.81 ± 4.05	6.48 ± 4.02	5.97 ± 3.24	0.701	0.735	0.276
16	5.66 ± 3.00	3.85 ± 4.52	3.41 ± 3.65	4.07 ± 3.88	3.31 ± 3.83	5.19 ± 3.35	0.705	0.207	0.154

[a]Mean values marked with different letters in the columns differ statistically significantly ($P < 0.05$).
[b]Mean values marked with different letters in the columns differ statistically significantly ($P < 0.05$). No statistically significant interactions were found parent flock age × sex ($P > 0.05$).

Table 4. Features of the microstructure of *m. pectoralis superficialis* in geese W31 at different ages depending on the age of the parent stock and sex.

		Muscle fibers			
		1-day-old		16-wk-old	
Factors		Number of fibers	Fiber diameter (μm)	Number of fibers	Fiber diameter (μm)
Parent flock age	I	252.16 ± 59.66	2.82 ± 0.23	167.83 ± 12.15	23.36 ± 1.19
	II	269.62 ± 73.03	2.65 ± 0.26	164.33 ± 40.12	22.61 ± 2.77
	III	260.00 ± 27.17	2.46 ± 0.29	161.50 ± 46.33	22.80 ± 2.95
	IV	255.25 ± 23.26	2.47 ± 0.29	164.66 ± 42.68	22.14 ± 2.29
	P-value	0.680	0.161	0.920	0.907
Sex	♂	254.43 ± 44.37	2.78[a] ± 0.38	165.42 ± 32.29	22.67 ± 2.01
	♀	264.37 ± 51.02	2.48[b] ± 0.23	163.75 ± 39.62	22.79 ± 2.61
	P-value	0.331	0.007	0.994	0.883
Interaction	*P*-value	0.083	0.690	0.650	0.969

[a]Mean values marked with different letters in the columns differ statistically significantly ($P < 0.05$).
[b]Mean values marked with different letters in the columns differ statistically significantly ($P < 0.05$). No statistically significant interaction age of the flock × sex ($P > 0.05$).

microstructure of the superficial pectoral muscle in 1-day-old chicks and 16-wk-old geese, it was found that the number of muscle fibers decreased on average by 94.68, and their diameter increased approx 8 times.

Geese derived from layers at different ages did not differ in terms of chest circumference, body length, trunk, sternum, forearm, and jump ($P > 0.05$). Males had a larger chest circumference by 0.9 cm compared to females ($P = 0.029$), as was the length of the body ($P < 0.001$), trunk ($P = 0.049$), sternum ($P = 0.013$), and forearm ($P = 0.020$; Table 5).

Geese from parent flocks of different ages did not differ statistically significantly in terms of carcass traits ($P > 0.05$) (Tables 6 and 7). Ganders were characterized by a 462 g higher weight of the gutted carcass with the neck compared to the females ($P = 0.001$). Slaughter yield, in all of the groups, was 69.09 to 70.77 (from different parent flocks) and according to the sex: 69.90 to 69.99%, without significant differences ($P > 0.05$). The weight of the pectoral, leg, and the total muscles of the males was significantly higher than that of the females ($P = 0.020$; $P = 0.040$ $P = 0.002$), as well as the percentage of the muscles of the legs in the carcass ($P = 0.001$). Similarly, the higher weight of wings, neck, skin with subcutaneous fat, and carcass remains in males compared to females ($P < 0.05$). The females had a significantly higher proportion of abdominal fat ($P = 0.026$). There was an interaction of factors in the percentage of pectoral muscles and total muscles ($P = 0.026$; $P = 0.029$, respectively).

DISCUSSION

The results of geese hatching in our research indicate a trend of changes in egg fertilization and the hatching of healthy chicks, despite the lack of statistically significant differences between the groups of geese of various ages (Table 1). The results were presented at a similar level by Mitrović et al., 2018 after incubation of Italian white goose eggs. Fertilization was 88% and hatching was 89.77% in ratio to the fertilized eggs. Mazanowski et al. (2005b) showed that the fertilization of eggs from native geese was 53.8 to 71.7% and the hatching of fertilized eggs was 77.0 to 86.4%. The differences between the breeds show that the White Kołuda geese are characterized by a higher value in terms of reproduction.

Previous research on geese growth has focused, as already mentioned in the introduction section, on environmental or genotypic factors. The heaviest goslings in our research were found in the group of birds from the reproductive flock in the 3rd and 4th laying seasons (Table 2). Scientists researched the age of the hens and their influence on the final weight of the chicks.

Table 5. Body measurements of geese depending on the age of the parent flock and sex.

Factors		Chest circumference (cm)	Body length (cm)	Trunk length (cm)	Sternum length (cm)	Forearm length (cm)	Jump length (cm)
Parent flock age	I	44.83 ± 1.25	61.67 ± 2.52	31.58 ± 2.51	18.59 ± 1.31	17.58 ± 0.73	8.16 ± 0.68
	II	45.25 ± 0.68	60.75 ± 2.92	31.83 ± 1.53	18.83 ± 0.75	17.25 ± 0.68	7.91 ± 0.58
	III	45.08 ± 1.28	60.33 ± 3.28	31.75 ± 2.39	19.08 ± 0.73	17.17 ± 0.87	7.66 ± 0.98
	IV	44.91 ± 1.20	62.00 ± 4.13	33.50 ± 1.90	19.25 ± 1.08	17.58 ± 0.80	7.66 ± 0.60
	P-value	0.887	0.485	0.430	0.617	0.609	0.564
Sex	♂	45.50[a] ± 1.10	63.58[a] ± 2.27	33.13[a] ± 2.58	19.45[a] ± 0.91	17.75[a] ± 0.69	8.12 ± 0.74
	♀	44.54[b] ± 0.72	58.79[b] ± 1.65	31.21[b] ± 1.58	18.41[b] ± 0.73	17.04[b] ± 0.65	7.58 ± 0.59
	P-value	0.029	<0.001	0.049	0.013	0.020	0.076
Interaction	*P*-value	0.388	0.590	0.852	0.915	0.311	0.533

[a]Mean values marked with different letters in the columns differ statistically significantly ($P < 0.05$).
[b]Mean values marked with different letters in the columns differ statistically significantly ($P < 0.05$). No statistically significant interaction age of the parent flock × sex ($P > 0.05$).

Table 6. Body weight and slaughter yield of 16-wk-old geese.

Factors		Weight of live body weight (g)	Weight of carcass with the neck (g)	Slaughter yield (%)	Weight and percentage share in carcass: Pectoral muscle (g)	Pectoral muscle (%)	Leg muscle (g)	Leg muscle (%)	Total muscle (g)	Total muscle (%)
Parent flock age	I	6,328.0 ± 330.6	4,370.68 ± 238.35	69.09 ± 2.33	639.27 ± 107.93	14.56 ± 1.82	562.28 ± 88.18	12.81 ± 1.45	1201.55 ± 189.38	27.37 ± 3.06
	II	6,365.2 ± 243.26	4,505.07 ± 182.72	70.77 ± 1.03	635.85 ± 42.99	14.12 ± 0.91	581.16 ± 38.49	12.90 ± 0.75	1217.02 ± 67.54	27.02 ± 1.32
	III	6,519.0 ± 557.61	4,604.83 ± 423.61	70.61 ± 1.18	679.13 ± 123.69	14.67 ± 1.58	589.01 ± 100.62	12.72 ± 1.22	1268.15 ± 213.19	27.39 ± 2.36
	IV	6,366.67 ± 457.81	4,409.33 ± 365.04	69.30 ± 3.83	657.73 ± 61.87	14.95 ± 1.33	568.23 ± 104.17	12.83 ± 1.64	1225.97 ± 151.87	27.78 ± 2.33
	P-value	0.309	0.180	0.936	0.717	0.703	0.990	0.890	0.800	0.920
Sex	♂	6,721.00^{a} ± 224.16	4,703.02^{a} ± 245.80b	69.99 ± 3.17	690.99^{a} ± 87.26	14.49 ± 1.46	625.90^{a} ± 68.60	13.29^{a} ± 1.14	1316.89^{a} ± 140.57	27.95 ± 2.06
	♀	6,068.42^{b} ± 205.62	4,241.94^{b} ± 157.25	69.90 ± 1.21	615.00^{b} ± 68.66	14.66 ± 1.36	524.45^{b} ± 60.52	12.34^{b} ± 1.14	1139.45^{b} ± 117.95	26.83 ± 2.29
	P-value	<0.001	0.001	0.936	0.020	0.734	0.040	0.001	0.002	0.170
Interaction	*P*-value	0.073	0.242	0.990	0.069	0.026^{x}	0.259	0.222	0.071	0.029^{x}

[a]Mean values marked with different letters in the columns differ statistically significantly ($P < 0.05$).
[b]Mean values marked with different letters in the columns differ statistically significantly ($P < 0.05$).
[x]Statistically significant interaction age of the flock × sex ($P < 0.05$).

Reis et al. (1997) compared the bodyweight of chicks hatched from hatching eggs obtained from meat-type hens at the age of 32 to 34 and 48 to 50 wk. The authors found that chicks from older hens had higher body weight ($P < 0.01$). Similar conclusions were obtained in studies where hatching eggs were obtained from the Hubbard Classic flock at 30, 45, and 60 wk of age (Iqbal et al., 2014). Also, studies on the weight of ducklings showed the influence of the age of the flock. Heavier chicks were obtained from hatching eggs from 40-wk-old ducks compared to 28- and 34-wk-old ducks (Onbaşilar et al., 2014). The cited authors found that the weight of the chicks was positively correlated with the weight of the hatching egg.

In the 3rd wk of rearing (own research), the body weight of the geese was equalized (Table 2). It is related to the phenomenon of body weight compensation (Kucharska-Gaca et al., 2016). It is based on the fact that chicks with lower body weight during rearing can balance their body weight in comparison to heavier birds. Alkhair (2019) described that such a phenomenon is also visible after the end of restrictive feeding during the growth of broiler chicks.

In the sex aspect, in the 1st week of rearing, the birds were similar. However, from the 4th week of rearing, the ganders' body weight was higher until the end of oat fattening (Table 2). These differences indicate sexual dimorphism in geese (Uhlířová et al., 2019), although the growth rate in our studies was similar, except for the 4th wk, in both sexes (Table 3). The growth rate of the body in birds varies over time (Murawska, 2013). In the first weeks of life, waterfowl are characterized by a very intensive metabolism and rapid growth and development. Moreover, among the used poultry species, geese are characterized by the highest growth rate in the first 3 wk. Geese's body weight doubles after 5 d of rearing, and growth slows down in the 10th wk (Mazanowski, 2012; Murawska, 2013). The study by Łukaszewicz et al. (2011) showed a higher body weight gain in the first week (107.55%). In the following weeks, the growth rate decreased, and its lowest values were recorded between 7−9 and 11−13 wk of life, which corresponds to the results in our research (Table 3). The experiment showed that the age of females had a significant effect on the growth rate of birds in the first 2 wk. Wilson (1991) showed the effect of egg weight on the growth of chickens. The cited author stated that the relationship between egg size and growth rate is significantly higher until the 2nd wk, and then it decreases. There was no significant effect of sex on the growth rate of geese (excluded 4th wk). The study by Łukaszewicz et al. (2011) also showed similar growth rates in males and females. On the other hand, in the works of other authors (Janiszewska, 1993; Biesiada-Drzazga and Grużewska, 2004), the growth rate of males was higher during the first 3 wk of rearing, and then the differences between the groups decreased with each week. At the end of the rearing and fattening of geese, the value of the growth rate index for both sexes was similar.

Pectoral muscle microstructure was similar in 1-day-old birds as well as 16-wk-old birds from different parent flocks. Only a higher diameter of the fibers was demonstrated in 1-day-old males compared to females (Table 4). The number of pectoral muscle fibers in birds is established at the stage of embryonic development and the beginning of life (Remignon et al., 1995; Halevy et al., 2006; Zammit et al., 2006). This may indicate that the other factors may only indirectly influence the course of myogenesis. The increase in muscle weight is due to hypertrophy. There is also a process of increasing the number of muscle fibers, that is, hyperplasia. It is found that in geese, due to hypertrophy, there was an increase in the diameter of the muscle fibers. There is also the possibility of a reduction in the number of muscle fibers in the muscle bundle. Such a phenomenon can occur due to the fusion of fibers. The size of the cross-section of the pectoral muscles may increase with the age of the birds (Tůmová and Teimouri, 2009). Differences in muscle microstructure concerning sex may result from the fact that the selection between the W33 (paternal) and W11 (maternal) lines had a different emphasis. Males from the W33 line had significantly heavier pectoral muscle and thinner muscle fibers than males from the W11 line (Rosiński, 2000). 16-wk-old geese are characterized by a lower diameter of muscle fibers than 42-day-old chickens (approx 46 μm) (Cygan-Szczegielniak et al., 2019), but higher diameter than 112-day-old ducks (7.2−8.3 μm) (Kokoszyński et al., 2020).

The weight of the carcass and elements of the carcass was also higher in the male group. Similar results were obtained by Boz et al. (2019) during the rearing of Turkish geese in extensive conditions, as well as in studies with Egyptian geese (Geldenhuys et al., 2013). However, no statistically significant differences were found in the percentage of elements in the carcass, which indicates a similarity in tissue composition and the slaughter yield of ganders and geese. Sexual dimorphism in geese becomes more visible with the age of birds (Murawska and Bochno, 2008), which corresponds to the results of our research in terms of geese body weight. In studies where the research material was the White Kołuda geese, similar trends were shown in terms of significant differences in slaughter yield by comparing males and females (Łukaszewicz et al., 2008, 2011). The differences in body dimensions between the sexes also indicate an increase in the significance of sexual dimorphism in 16-wk-old birds (Table 5). In previous studies, the body dimensions of the offspring were not analyzed in the context of the age or period of reproductive use of layers. Our research showed sexual dimorphism in terms of most body dimensions of 16-wk-old geese (Table 5). The study by Łukaszewicz et al. (2011) showed that males were characterized by a longer length of the trunk, sternum, jump, and higher circumference of the chest. However, no differences between the sexes in the length of the forearm were found. On the other hand, in other studies, Łukaszewicz et al. (2008) showed that sexual dimorphism applies to all measured parts of the carcass (body length, sternum, jump, forearm, and chest circumference). Similar results were obtained by Kłos et al. (2010). The mean values of the abovementioned zoometric carcass measurements were similar to the data presented in the own research. The data were similar to those in the studies where the White Kołuda geese were kept (Kokoszyński et al., 2014). The differences between sexes are due to the aforementioned sexual dimorphism and the development of geese.

Table 6 showed no significant differences in the weight and percentage share of muscles in the carcass, as well as in the slaughter efficiency, in relation to the age of the parent stock. Differences between males and females have been demonstrated. Biesiada-Drzazga et al. (2006) found sex differences in leg muscle weight. Males of W31 may be characterized by a higher proportion of pectoral and leg muscles (Biesiada-Drzazga, 2014). Mazanowski et al. (2005a) concluded that the weight of pectoral and leg muscles was positively correlated with all the body dimensions. The slaughter yield of geese in the experiment was approx 70%. In the other study, authors reported similar values, 71.3% (Kowalczyk et al., 2013), and 69.3% (Gumułka and Połtowicz, 2020). Differences in muscle weight between males and females may be related to muscle development and the content of red and white muscle fibers (Haščík et al., 2010). As described by Zhang et al. (2021), muscle development and weight are already determined during embryonic development. The authors compared 2 native breeds (from China). They showed significant differences in the size and density of myofibrils. In our research, one commercial hybrid line was used, so the differences in muscle weight could be affected by the sex of the geese. Our research showed a significantly higher proportion of the abdominal fat share in female carcasses compared to male carcasses (Table 7). Yu et al. (2020) also showed a higher proportion of abdominal fat in the carcass of females. According to the authors, geese have a predisposition to higher fatness compared to other poultry species. However, this is not harmful, as goose fat is considered to be beneficial for the consumers' health. The high level of unsaturated acids plays a role here. Females are predisposed to accumulate abdominal fat faster than males (Liu et al., 2011). This trait may also be influenced by the age of the birds, environmental conditions, and breed (Liu et al., 2022). Different levels of the share of abdominal fat in both sexes of geese may be the result of different use of energy and the ability to accumulate adipose tissue (Madsen and Klaassen, 2006). The differences in the results and conclusions of the cited authors may result from the different origins of the broiler geese. Nutrition and environmental conditions, which may have differed between the described studies, are also of high importance for the production results and the

Table 7. Carcass features of 16-wk-old geese.

Factors		Weight and share of the gutted carcass with neck									
		Wings		Neck		Skin with subcutaneous fat		Abdominal fat		Carcass remains	
		(g)	(%)	(g)	(%)	(g)	(%)	(g)	(%)	(g)	(%)
Parent flock age	I	612.73 ± 82.61	13.97 ± 1.18	267.83 ± 42.69	6.10 ± 0.67	862.23 ± 113.82	19.89 2.70	201.02 ± 41.87	4.64 ± 1.17	975.78 ± 88.83	22.31 ± 1.43
	II	623.20 ± 33.25	13.83 ± 0.40	255.45 ± 16.27	5.67 ± 0.33	981.00 ± 65.87	21.77 1.11	202.82 ± 23.38	4.50 ± 0.49	999.98 ± 75.72	22.19 ± 1.31
	III	644.17 ± 70.11	13.99 ± 1.01	257.23 ± 27.79	5.58 ± 0.29	907.20 ± 90.78	19.37 1.31	245.10 ± 26.68	5.36 ± 0.79	1073.82 ± 88.02	23.35 ± 1.03
	IV	616.85 ± 76.56	13.97 ± 1.10	274.00 ± 43.19	6.19 ± 0.71	850.25 ± 72.52	19.37 2.12	206.40 ± 45.38	4.65 ± 0.79	1000.88 ± 133.72	22.68 ± 2.15
	P-value	0.718	0.990	0.693	0.180	0.180	0.188	0.140	0.218	0.650	0.470
Sex	♂	668.88[a] ± 51.42	14.21 ± 0.73	279.37[a] ± 32.02	5.93 ± 0.60	909.26[a] ± 111.03	19.36 1.82	208.88 ± 44.46	4.42[b] ± 0.82	1028.9[a] ± 62.75	23.04 ± 1.15
	♀	579.59[b] ± 42.77	13.67 ± 1.02	247.88[b] ± 26.62	5.84 ± 0.55	891.08[b] ± 84.99	21.03 1.80	218.78 ± 31.53	5.16[a] ± 0.76	942.33[b] ± 77.92	22.22 ± 1.74
	P-value	<0.001	0.185	0.020	0.662	<0.001	0.056	0.506	0.026	<0.001	0.160
Interaction	*P*-value	0.641	0.510	0.470	0.433	0.240	0.121	0.360	0.291	0.176	0.113

[a]Mean values marked with different letters in the columns differ statistically significantly ($P < 0.05$).
[b]Mean values marked with different letters in the columns differ statistically significantly ($P < 0.05$). No statistically significant interaction age of the flock × sex ($P > 0.05$).

characteristics of the carcasses (Boz et al., 2017). However, the discussed data on the growth and characteristics of a goose carcass is characterized by a similar tendency and relationships.

The own study showed a significant interaction between the sex and age of the parent flock on the total weight in the last two weeks of fattening geese, the share of pectoral muscles, and total muscles. Uhlířová et al. (2018) showed an interaction of sex with age and genotype of geese on slaughter body weight, similar to the studies by Uhlířová and Tůmová (2014). Lewko et al. (2017) noticed that the quality of goose meat depends on sex and origin. The authors showed a statistically significant interaction between the factors. This may suggest that the sex of geese is important in terms of obtaining goslings from parent flocks of different years of use, or, as described by other authors, on genotype and origin.

Based on the obtained results, it can be concluded that although the goslings obtained from the parent flock of geese in four different seasons of use were characterized by similar growth and carcass characteristics. After the goose rearing and fattening, similar body weight was noticed, which was related to the phenomenon of compensation. Thus, it is justified to produce broiler goslings from the 1-, 2-, 3-, and 4-yr-old geese kept in the parent flock. The conducted research shows that the sex of the White Koluda geese plays an important role in the production results in terms of the weight of the pectoral and leg muscles, body dimensions (beneficial effect of ganders), as well as abdominal fat content (in females' carcasses). However, slaughter yield was similar, regardless of sex. This allows for balanced rearing and fattening of the White Koluda commercial hybrids of both sexes.

ACKNOWLEDGMENTS

This research was part of the doctoral dissertation of the first author. Thesis: Joanna Kucharska-Gaca. 2018. The analysis of embryonic and post-embryonic development of geese depends on the age of the parent flock. Publisher: UTP - University of Science and Technology in Bydgoszcz. This article has been supported by the Polish National Agency for Academic Exchange under Grant No. PPI/APM/2019/1/00003.

DISCLOSURES

The authors declare(s) no conflicts of interest.

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