The age of the geese from the parent flock and the laying period affect the features of the eggs

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ABSTRACT The study aimed to assess the goose hatching egg features in four reproductive seasons from 3 stages of laying. Three hundred sixty eggs were used in the study from geese in the first, second, third, and fourth laying season. From each group, 90 eggs were analyzed (30 eggs from the beginning, the peak, and the end of the laying cycle). The structure of the egg and morphological and physical features of the yolk, albumen, and eggshell were analyzed. It was shown that the weight and structure of eggs increased, but the shape index was lower in 2-yr-old geese, as well Haugh's units decreased. The yolk share was lower in the first year, but albumen and eggshell were higher than in other groups. The eggshell whiteness was higher in the first year than in the second, and third. The pores' quantity was higher in the first year in the blunt and equatorial parts, but the total number in the egg was the highest in the fourth year. The yolk, albumen, and eggshell' density increased with the age. Changes in laying periods were inversely proportional to the changes shown depending on the layers' age. Geese's age and laying period impact the eggs' features. Based on the egg quality features, the incubation conditions could be adapted, as well as it can be treated as an indicator of the effectiveness of hatching and goslings quality. Research has shown that the biological value of hatching eggs changes with the age of the geese and the laying period.

Key words: albumen, eggshell, structure of shell egg, waterfowl, yolk

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INTRODUCTION

Geese (*Anser anser* L.) are popularly kept in parent flocks or intended for meat production (Utnik-Banaś and Żmija, 2018). Goose eggs are mainly produced for reproductive purposes (hatching eggs). The production of table goose eggs is mainly limited to Asian countries. Its structure and morphological composition are very important for embryos (Gogoi et al., 2021). The correct structure of the egg and the nutrients it contains in the right amount ensure the development of the embryo outside the female body. These ingredients are used as a building material for the formation of all tissues and are located in the yolk, albumen, and eggshell of the egg. The content of individual ingredients depends on genetic and environmental factors. The most important are nutrition, housing system, egg storage conditions and time, and the age of the female (Yair and Uni, 2011; Nasri et al., 2020).

Previous studies aimed to analyze the relationship between the age of females and the weight of eggs (Liu et al., 2021). Mainly, it concerned different laying stages of one production cycle. It has been shown that there is an increase in quality characteristics at the beginning of the laying period, including egg weight. Then, at the peak of laying, stabilization in terms of reproductive performance is evident (Toboev et al., 2020). During the progressive production cycle, the layers deposit less albumen in favor of the yolk (proportion of thick albumen decreases and proportion of yolk increases) (Adamski, 2008). Yadgary et al. (2010) found that with the age of broiler breeder hens, the yolk concentration increases, but also the proportion of albumen increases. Egg albumen content increased by 13.3%, and yolks by 40% in the period from the 30th to the 50th wk of the birds' life. Eggs from young layers are characterized by higher albumen quality and a thicker eggshell. Consequently, this reduces the necessary moisture loss during storage, which limits the availability of nutrients to the embryo. In the case of hatching eggs, the high albumen quality may lead to higher mortality of the embryos at the beginning of development. This is due to the limited

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condensation of the albumen fraction, which equates to a higher barrier to the necessary gas diffusion (Benton and Brake, 1996; Peebles et al., 2000; Onbasilar et al., 2014). Bednarczyk and Rosiński (1999) investigated the hatchability of goose eggs of various origins depending on the characteristics of the eggs. The authors described that the egg weight influenced the hatchability results. Egg weight affects the amount of water lost during incubation. This was also related to the permeability of the eggshell and its thickness.

With the age of layers, the physical parameters of the eggshell decrease (Zhang et al., 2022). It is estimated that the percentage of the eggshell is reduced by approximately 7.5% and its surface area is reduced by 8% compared to the beginning of the laying period. The strength of the eggshell also decreases, even by 43% (Panheleux et al., 2000). The weight of the eggshell increased directly with the weight of the egg. However, this trend only continued until the 26th wk of the life of the hens. The age of the females also influenced the thickness of the eggshell. The eggshells of eggs from young laying hens at 30 wk of age were thicker by 0.011 mm than eggs from layers at 60 wk. According to Gualhanone et al. (2012), with the age of breeders, the thickness of the eggshell deteriorates. These studies showed that the eggshell in more than 90% of eggs from older (55-wk-old) layers was characterized by a density below 1.080 g/cm^3, which proves its poor quality. A previous study in terms of the age of the parent flock of White Kołuda geese (from first to fourth year) showed that the weight of the egg, yolk, and total albumen increased significantly with the age of the flock. However, eggs from 1-yr-old females were characterized by a higher proportion of albumen and eggshell. At the same time, more favorable physical features of these fractions were demonstrated. The yolk share was lower compared to the older flocks. However, this study was only carried out at the beginning of the laying of the geese (Adamski et al., 2016). Razmaite et al. (2014) also showed an increase in egg weight in 3-yr-old geese than in 1-yr-old geese.

According to the reports, with the age of geese, their ability to reproduce and the hatching value of eggs decreases. It is connected with worse hatching results and a limited level of broiler goose production. Ultimately, this affects the economy of the farm. In the first year of use and the last (fourth), White Kołuda geese carry the least valuable eggs (Badowski, 2007; Biesiada-Drzazga, 2014; Wencek et al., 2017). As described by Akin and Celen (2022), hatching eggs, to be incubated, should be characterized by the absence of defects and deformations. The quality features, including the dimensions and shape of the egg and the features of the eggshell, should be consistent with the results obtained in scientific research and practice. The quality characteristics of goose eggs should be an indicator during their incubation. More specifically, the dimensions of the egg or its other features should allow the use of appropriate environmental conditions in incubators.

The literature on the characteristics of goose hatching eggs obtained from four different reproductive seasons is very limited. Most studies compare the morphological and physical characteristics of eggs between periods of one laying cycle. It also relates to the comparison of the characteristics of geese eggs of regional varieties or breeds derived from wild geese (greylag goose). The remaining studies concern the use of goose meat. Therefore, in this study, a comparison was also made in the field of Gallinaceous poultry and other species, including hens. The presented results allow us to deepen the existing knowledge and this study aimed to assess the eggs' quality features obtained from geese in four reproductive seasons, and in the beginning, the peak, or the end of the laying cycle. The features of goose hatching eggs were described in terms of suitability for incubation.

The tested hypothesis is as follows: The age of the parent flock and the laying period of geese have an impact on the structure of eggs, morphological composition, and their physical features.

MATERIAL AND METHODS

The research was carried out with the consent of the Local Ethical Committee in Bydgoszcz No. 30/2015.

Samples Collection

Goose hatching eggs were obtained from the four different flocks of White Kołuda geese, which were in the first, second, third, and fourth reproduction seasons, respectively. The geese were kept on one farm (a private farm in the Kuyavian-Pomeranian Voivodeship, Poland). It was a reproductive farm that produced geese commercially. Each flock consisted of 1,500 geese. The birds were kept in buildings with permanent access to the enclosure. Each group of birds was housed in the same way (divided into age groups), at the same time and place. All of the geese were obtained from one hatchery house and one breeder. Geese nests were provided in the buildings. The nests were 60 × 70 cm. One nest was for 4 geese. The housing system was according to the standards of geese's laying utility. The feeding of the reproductive flocks was in line with the current recommendations (Mazanowski, 2012). A complete feed was used for geese in their reproductive season. The complete feed for each group was characterized by the same composition of components. The geese were fed ad libitum. Egg quality analysis was performed three times for each age group, that is, at the beginning (fourth wk of laying), at the peak (13th wk of laying), and the end of the laying cycle (20th wk). The goose laying cycle was from January to June. Sexual maturity (laying) of geese begins after approx. 7 mo of life. The peak of laying was estimated in April. The eggs were collected on the same day and at the same time from each flock. Eggs were chosen randomly from each group. On each date, 120 eggs were assessed (30 eggs from each age group). A total of 360 eggs were examined in the experiment. The qualitative analysis of the experimental material included the determination of the physical characteristics and morphological composition of the egg. The quality of the eggs was assessed 24 h after laying them. After harvesting, the eggs were stored. They were placed in a warehouse with an average temperature of 10°C and a humidity of 65%. To sum up, the housing system, nutrition, as well as storage conditions, and time were the same for all the groups. Due to mentioned, the experimental factors were the age of geese from the parent flock and the stage of the laying cycle.

Eggs Quality Analyzes

Egg weight measurements were performed on a PS 750/X weight (Radwag, Radom, Poland). The width (short axis) and length (long axis) of the egg were measured using an electronic caliper. Based on the data, the egg shape index (%) was calculated. Eggshell color was assessed with a QCR reflectometer (TSS, Dunnington, York, England). The value was expressed in the percentage of whiteness. The surface of an egg was calculated using the formula of Paganelli et al. (1974): $P = 4.835 \times W^{0.662}$, where: W - egg weight. After breaking the egg contents onto a glass table with a mirror, the thick albumen height (mm) was measured with a QCD kit (TSS, Dunnington, York, England). Measurement of albumen height (**H**) and egg weight (**W**) allowed to calculate of Haugh units (**HU**) according to the formula given by Williams (1997): $HU = 100 \log s (H + 7.57 - 1.7 W^{0.37})$. This formula was also used in goose eggs research conducted by (Tilki and İnal, 2004). To determine the morphological composition of the egg, the yolk, albumen, and eggshell were weighed on a PS 750/X weight (Radwag, Radom, Poland). Then the percentage of their content in the egg was calculated by referring to the weight of the fresh egg according to the formula: component share (%) $= \frac{\text{component weight (g)}}{\text{egg weight (g)}} \times 100$. Albumen and yolk density were determined using the PS 750/X solids and liquids density determination kit (Radwag, Radom, Poland).

After breaking the contents, the eggshells were dried for 3 h at 105°C in a SUP 100M dryer. Then, eggshells were weighed (g). In the equatorial part of the egg, the thickness of the eggshell (without the testaceous membranes) was measured using an electronic micrometer screw. After drying, the testaceous membrane changed its structure (elasticity), which caused spontaneous detachment from the inner surface of the eggshell. Membrane debris was removed with a scalp so as not to damage the eggshell surface. The eggshell density was tested after separating 1 to 2 g of samples of material from the equatorial part of the egg with a kit for determining the density of solids, using a PS 750/X weight (Radwag, Radom, Poland). For the eggshell density analysis, distilled water at 25°C was used as the standard liquid. The pores in the dried shells were determined according to the Tyler method (1953). Pieces of eggshells with an area of approximately 2 cm^2 were isolated from the blunt, middle, and sharp parts of the egg. The eggshells were boiled for 25 min in a 5% sodium hydroxide solution. Then it was rinsed with distilled water. After drying, it was immersed in a 65% nitric acid solution. The dry pieces of eggshells were covered with methyl blue on the inside of the eggshell. The porosity was determined using a Nikon 106 type stereoscopic microscope, at 4 times magnification, on an area of 0.25 cm^2. Based on the number of pores from 3 different eggshell surfaces, the mean values were calculated and multiplied by the area of the egg. The total quantity of pores in the eggshell is an estimated value.

Statistical Calculation

The collected data were statistically processed using Statistica 12.5 PL (Statsoft TIBCO Software Inc., Cracow, Poland). The mean values of all examined features and their standard deviation (±SD) were calculated. A 2-way analysis of variance was used in the calculations (effect of parent flock age, and laying period of geese). Compliance with the assumptions for ANOVA was checked: samples are selected randomly and independently of each other from each group; each of the studied groups has a normal distribution; in the analyzed groups the variances were the same (homogeneity of variances−−Levene's test). The significance of the differences was verified using the Kolmogorov-Smirnov test (the normality of data distribution). Formula transformations were not performed. When the data met the assumptions of parametric analyzes, HSD Tukey's test was used. The level of significance was taken as a *P*-value <0.05. Interaction between parent flock age and laying period was also analyzed (*P*-value <0.05). The results in the tables are presented by age (mean, ±SD) and for the laying period (mean, ±SD). Interaction data between factors are indicated as *P*-value.

RESULTS

Based on the results, it was found that the age of the parent flock and the laying period differentiated goose eggs in terms of their structure (Table 1). The study of the morphological features of hatching eggs showed that the egg weight increased significantly until the fourth year of reproductive use of geese ($P < 0.001$). Similarly, the surface of the eggs increased ($P < 0.001$). Significant differences in the case of the above-mentioned traits were demonstrated between the eggs from laying geese in the first and fourth season of reproductive use. The value of the egg shape index was different concerning the age of the parent flock ($P = 0.006$). The lowest index value was recorded for laying geese in the second and third laying season, respectively: 63.8% and 64.2%. In the remaining experimental groups, the eggs had a similar shape, and the obtained index values were 65.5%.

The analysis of the features of goose eggs in individual laying periods showed that the weight of the egg and surface decreased significantly during the laying period ($P < 0.001$). At the beginning of production, the average egg weight of all analyzed flocks was 188.5 g. At the end of laying, the egg weight decreased by 8.5% from the

Table 1. Features of the structure of a goose egg.

Factors	Reproduction season	Egg weight (g)	Egg shape index (%)	Egg surface (cm^2)
Parent flock age	First	$151.1^{d} \pm 7.0$	$65.5^{a} \pm 5.2$	$134.3^{d} \pm 5.0$
	Second	$171.1^{c} \pm 9.1$	$63.8^{b} \pm 3.4$	$145.4^{c} \pm 5.1$
	Third	$190.4^{b} \pm 8.8$	$64.2^{ab} \pm 2.8$	$156.1^{b} \pm 4.8$
	Fourth	$207.4^{a} \pm 8.4$	$65.5^{a} \pm 3.1$	$165.2^{a} \pm 4.4$
	P-value	<0.001	0.006	<0.001
Laying stage	Beginning	$188.5^{a} \pm 22.0$	65.4 ± 3.0	$155.1^{a} \pm 11.9$
	Peak	$178.9^{b} \pm 21.4$	64.6 ± 5.0	$149.6^{b} \pm 11.8$
	End	$172.4^{c} \pm 21.7$	64.9 ± 2.9	$146.0^{c} \pm 12.2$
	P-value	<0.001	0.236	<0.001
Parent flock age × laying stage	*P*-value	0.034	0.104	0.210

[a,b]Mean values marked with different letters differ statistically significantly, *P*-value <0.05; statistically significant interactions: age of the flock: laying period, *P*-value <0.05; ±SD, standard deviation; On each laying stage, 120 eggs were assessed (30 eggs from each age group). A total of 360 eggs were examined in the experiment.

initial value. The change in the weight of eggs decreased the mean values of their surface: 155.1 > 149.6 > 146.0 cm^2. There were no statistically significant differences between the tested laying periods ($P = 0.236$). In the structure of goose eggs, interactions were found between the age of the parent flock and the laying periods in egg weight ($P = 0.034$).

The thick albumen height (Table 2) did not change significantly in the individual years of reproductive use of geese ($P = 0.157$) and during the laying period ($P = 0.091$). The mean values of the features ranged from 9.1 to 9.6 mm. However, in the case of Haugh units, it was found that from the second year of use, the layers laid eggs with poorer quality content (first−−74.1, second−−68.3, third−−65.4, and fourth−−66.3) ($P = 0.014$). It was shown that the eggs of the youngest geese (1 yr old) had significantly the lowest share of yolk compared to other age groups ($P < 0.001$) (Table 2). From the second year of laying, the yolk share increased on average by 3.3% and remained at a similar level in the following production years. The opposite tendencies were shown in the case of the share of albumen and eggshell in the egg. Eggs of 1-yr-old geese were characterized by the highest share of albumen and eggshell to other age groups ($P < 0.001$). The share of the above-mentioned components in the eggs of the youngest females was, on average, higher by 1.9% (albumen) and 1.3% (eggshell) compared to the other groups. Yolk and albumen density was shown to be the lowest in goose eggs in the first year of reproduction, and then increased compared to eggs from 3- and 4-yr-old geese ($P < 0.001$, $P = 0.006$, respectively).

Eggs obtained at the beginning and the peak of the laying cycle were characterized by a significantly lower value of Haugh units compared to those obtained at the end of the laying period ($P = 0.003$). It was found that with the progress of laying, the share of yolk and eggshell in the egg decreased ($P < 0.001$). The differences in these characteristics between the beginning and the end of the laying cycle were 0.9% for the yolk and 1.7% for the eggshell. The lowest albumen content was found in eggs obtained at the beginning of laying−51.8% ($P < 0.001$). At the peak, its share increased by an average of 2.5% and remained at a similar level until the end of the laying period. The yolk and albumen of the eggs obtained at the end of laying were characterized by a statistically significantly higher density compared to the other laying dates ($P < 0.001$).

A significant interaction was demonstrated between the age of the parent flock and the laying period in the

Table 2. Physical features and share of morphological components of goose eggs.

Factors	Reproduction season	Thick albumen height (mm)	Haugh units	Share in egg (%) Yolk	Albumen	Eggshell	Yolk density ($g \times cm^{-3}$)	Albumen density ($g \times cm^{-3}$)
Parent flock age	First	9.1 ± 1.9	$74.1^{a} \pm 5.2$	$33.4^{b} \pm 2.2$	$54.9^{a} \pm 2.3$	$11.7^{a} \pm 1.4$	$1.032^{b} \pm 0.008$	$1.056^{b} \pm 0.020$
	Second	9.1 ± 2.0	$68.3^{ab} \pm 22.1$	$36.5^{a} \pm 2.6$	$52.7^{b} \pm 2.6$	$10.7^{ab} \pm 1.0$	$1.039^{ab} \pm 0.023$	$1.060^{ab} \pm 0.018$
	Third	9.5 ± 1.9	$65.4^{b} \pm 20.2$	$36.5^{a} \pm 2.3$	$53.1^{b} \pm 2.6$	$10.4^{b} \pm 1.0$	$1.041^{a} \pm 0.020$	$1.063^{a} \pm 0.018$
	Fourth	9.6 ± 1.8	$66.3^{b} \pm 20.7$	$36.7^{a} \pm 2.7$	$53.2^{b} \pm 3.0$	$10.1^{b} \pm 1.0$	$1.054^{a} \pm 0.024$	$1.065^{a} \pm 0.018$
	P-value	0.157	0.014	<0.001	<0.001	<0.001	<0.001	0.006
Laying stage	Beginning	9.1 ± 1.8	$65.4^{c} \pm 19.4$	$36.7^{a} \pm 2.9$	$51.8^{b} \pm 2.4$	$11.5^{a} \pm 1.1$	$1.025^{b} \pm 0.013$	$1.054^{b} \pm 0.021$
	Peak	9.1 ± 2.0	$66.8^{b} \pm 22.4$	$35.5^{b} \pm 2.5$	$54.2^{a} \pm 2.3$	$10.9^{a} \pm 1.0$	$1.030^{b} \pm 0.019$	$1.053^{b} \pm 0.015$
	End	9.6 ± 1.9	$73.4^{a} \pm 16.7$	$35.8^{b} \pm 2.8$	$54.4^{a} \pm 2.7$	$9.8^{b} \pm 1.0$	$1.070^{a} \pm 0.038$	$1.074^{a} \pm 0.019$
	P-value	0.091	0.003	<0.001	<0.001	<0.001	<0.001	<0.001
Parent flock age × laying stage	*P*-value	0.927	0.679	0.006	0.105	0.005	<0.001	0.002

[a,b]Mean values marked with different letters differ statistically significantly, *P*-value <0.05; statistically significant interactions: age of the flock: laying period, *P*-value <0.05; ±SD, standard deviation; On each laying stage, 120 eggs were assessed (30 eggs from each age group). A total of 360 eggs were examined in the experiment.

Table 3. Physical features of the eggshell of goose eggs.

Factors	Reproduction season	Color (% whiteness)	Thickness (mm)	Density (g × cm^{-3})	Pores in the eggshell (pcs./0,25 cm^2) Blunt part	Equatorial part	Sharp part	Estimated total number of pores
Parent flock age	First	$78.1^{a} \pm 3.4$	0.526 ± 0.066	$2.005^{c} \pm 0.272$	$32.2^{a} \pm 3.6$	$19.3^{a} \pm 2.1$	12.2 ± 2.0	$10{,}985.2^{b} \pm 423.1$
	Second	$76.5^{b} \pm 3.5$	0.517 ± 0.055	$2.108^{b} \pm 0.165$	$28.1^{b} \pm 2.7$	$16.5^{b} \pm 2.0$	11.5 ± 2.9	$10{,}175.8^{b} \pm 404.3$
	Third	$76.2^{b} \pm 3.3$	0.516 ± 0.051	$2.109^{b} \pm 0.152$	$28.1^{b} \pm 3.5$	$15.9^{b} \pm 2.5$	12.1 ± 1.0	$11{,}188.1^{ab} \pm 450.0$
	Fourth	$77.0^{ab} \pm 3.6$	0.515 ± 0.051	$2.226^{a} \pm 0.421$	$28.4^{b} \pm 4.4$	$16.0^{b} \pm 1.2$	12.0 ± 2.1	$12{,}074.3^{a} \pm 467.5$
	P-value	0.001	0.505	0.000	0.010	<0.001	0.143	<0.001
Laying stage	Beginning	$76.4^{b} \pm 3.7$	$0.562^{a} \pm 0.057$	$2.047^{b} \pm 0.259$	$27.3^{b} \pm 3.4$	$17.6^{a} \pm 2.2$	$12.3^{ab} \pm 2.0$	$11{,}093.0^{c} \pm 379.6$
	Peak	$76.8^{b} \pm 2.9$	$0.505^{b} \pm 0.086$	$2.216^{a} \pm 0.189$	$27.0^{b} \pm 3.3$	$14.8^{b} \pm 1.9$	$11.0^{b} \pm 1.9$	$10{,}049.7^{b} \pm 331.6$
	End	$77.8^{a} \pm 3.7$	$0.489^{c} \pm 0.045$	$2.068^{b} \pm 0.213$	$33.6^{a} \pm 2.9$	$18.7^{a} \pm 2.1$	$13.2^{a} \pm 2.3$	$12{,}175.5^{a} \pm 539.3$
	P-value	0.004	<0.001	<0.001	<0.001	<0.001	0.002	<0.001
Parent flock age × laying stage	*P*-value	<0.001	0.020	0.005	0.027	0.126	0.179	0.006

[a,b]Mean values marked with different letters differ statistically significantly, *P*-value <0.05; statistically significant interactions: age of the flock: laying period, *P*-value <0.05; ±SD, standard deviation; On each laying stage, 120 eggs were assessed (30 eggs from each age group). A total of 360 eggs were examined in the experiment.

case of such features as the share of yolk ($P = 0.006$) and eggshell ($P = 0.005$) in the egg, as well as the density of the yolk ($P < 0.001$) and albumen ($P = 0.002$).

The age of laying geese significantly contributed to the change in the color of the eggshells (Table 3). The lighter color of the eggshell by about 2% was characteristic for the eggs of 1-yr-old geese (78.1%) compared to 2-yr-old and 3 yr old geese ($P = 0.001$). Examination of the quality of hatching eggshells did not show any significant influence of the female's age (Table 3). Despite the lack of significant differences between the studied groups ($P > 0.05$), it was found that from the second year of reproductive use there was a quantitative reduction in the thickness of the eggshell. The eggshells of the youngest layers, compared to the older ones, were on average thicker by 0.10 mm. With the age of the females, the eggs showed an increase in the thickness of the eggshell. In 1-yr-old geese, the eggshell density was 2.005g × cm^{-3}, while in the oldest geese it was 2.226 g × cm^{-3} ($P < 0.001$). Significant differences between the age groups were also noted in the porosity of the eggshell. Calculated per eggshell surface unit (0.25 cm^2), eggs from the youngest layers were characterized by the highest number of pores in the blunt and equatorial part of the egg ($P = 0.010$; $P < 0.001$, respectively). Taking into account the entire surface of the eggshell, the highest number of pores was found in the oldest layers and the lowest in the eggs of 2-yr-old geese ($P < 0.001$).

The color of the eggshell also changed during laying periods. At the beginning and the peak of production, the laying geese laid eggs, the eggshells of which were characterized by significantly more intense color, and then with each subsequent week, they turned brighter ($P = 0.004$). The thickness of the eggshell decreased with the laying date ($P < 0.001$). A higher eggshell density was found at the peak of laying ($P < 0.001$). A higher number of pores per unit area was found in eggs obtained at the end of the laying cycle in the blunt and equatorial part ($P < 0.001$), as well as in the sharp part ($P = 0.002$). The total pores in the eggshell were in the following order: peak < beginning < end of laying cycle ($P < 0.001$).

The interaction between the factors was demonstrated for most of the eggshell's physical properties (color, thickness and density, total surface porosity, and the number of pores in the blunt part of the egg, $P < 0.05$).

DISCUSSION

The weight of the egg in own research was increasing with the age of the females. In the first year it was 151.1 g, and in the fourth year−207.4 g. In the study by Pakulska et al. (2003) the weight of a goose egg in the first reproductive season was 158.1 g and in the fourth −185.0 g. It is related to the development of the female organism and reproductive tract. The intensity of oocyte growth and albumen secretion in the oviduct is of high importance (Yin et al., 2020). Liu et al. (2021) suggested that ovulation and uterine secretions, which change over time, may affect egg weight in different laying seasons. The dimensions of the egg in our research were also similar to the results obtained by Pakulska et al. (2003). The egg shape index is important, in the case of hatching eggs, for the proper embryonic development during incubation. The shape of the egg influences the correct positioning of the embryo, and successful hatching (Zhang et al., 2017; Dey et al., 2019). Salamon (2020) reviewed the studies and found that the researchers found that hatching goose eggs that were too oval or too elongated resulted in lower hatchability. Mitrović et al. (2018a) found that the shape index and the weight of goose eggs influenced the quality of goslings. The authors showed the interaction of these factors. In our research egg shape index (63.8%−65.5%) was similar to the results of the Italian White goose (65.42%) reported by Mitrović et al. (2018a). Similarly, Eroglu and Erisir (2022) reported that the age of laying geese influences the weight and shape of eggs.

The height of thick albumen is a determinant of quality depending on the age of the female and the storage period (Chung and Lee, 2014; Lewko, 2015). In this study, no significant differences were found between the age groups of geese, as well as in particular laying stages. This corresponds to the results of the research by Lewko (2015), where the features of egg albumen from ducks were compared in the first and second seasons of use. Nevertheless, it has been shown that Haugh units (**HU**) changed with the age of the females and with the laying phase. In the first year of reproduction, the eggs were characterized by a 7.4% higher HU index compared to other age groups. Tilki and İnal (2004) found similar results when examining French goose eggs. According to Vlčková et al. (2019), the value of HU is mainly determined by the method and duration of storage. Since egg weight is necessary to calculate HU, the age of females indirectly influences the discussed parameter.

The morphological composition in the own research changed in individual age groups. In the group of 1-yr-old females, and at the beginning of laying, the highest proportion of yolk and the lowest share of albumen were found. The opposite proportions were found in the group of older geese at the peak and the end of the laying period. Razmaite et al. (2014) also showed the influence of the laying season of females on the share of the egg fraction. However, a significant effect was only shown at the beginning of laying. Tilki and İnal (2004) found that in each year of use, the share of albumen and yolk increased. In turn, Rakonjac et al. (2017) showed that the share of yolk increased significantly and albumen decreased in eggs from laying hens from the 30th to the 42nd wk of laying. Many authors have described that changes in egg yolk and white deposition are disproportionate during laying (Mazanowski and Adamski, 2006; Adamski, 2008; Yadgary et al., 2010). As in the case of the yolk, changes were found in the eggshell fraction of goose eggs. According to Okruszek et al. (2006) and Congjiao et al. (2019), the share of the eggshell can be shaped at different levels and depends mainly on the genotype and species of the birds.

With the age of layers, the density of the yolk and albumen in goose eggs increased. The available study describes that the fraction density may be of importance during incubation. The yolk in the egg is located in the centre. During incubation, it moves to the blunt part (Meuer and Egbers, 1990). This may suggest that the increase in the density of individual fractions in the eggs may be related to the displacement of the yolk toward the air chamber. Egg properties, including density, may also be dependent on the chemical composition of the egg (Xie et al., 2020). The stability of the morphological components in the egg (yolks and albumen) is ensured by their appropriate density, the strength of the vitelline membrane, and the albumen gel structure. These features affect the appropriate gas exchange and nutrient utilization. From a practical point of view, they are important for the use of appropriate incubation technology. Incorrect features of the yolk and albumen may lead to the loss of the proper orientation of the embryo, and faster or slower evaporation of water. Consequently, it may also affect the improper sorption of the yolk sac by the embryo. Incorrect density and structure of the yolk and albumen could cause the embryo to stick to the membranes and the eggshell (Guo et al., 2021; Mitrović et al., 2018b).

The physical characteristics of the eggshell are interdependent. In the case of hatching eggs, they affect the growth and development of the embryo (Peebles and McDaniel, 2013; Kibala et al., 2020). In a study on the influence of the eggshell thickness of guinea fowl and pheasants, it was described that it did not affect statistical differences in hatchability (Yamak et al., 2016). The eggshell of the youngest geese had a higher share in the egg and decreased with the age of the geese. Similar results were found by Pakulska et al. (2003). This could be related to an increase in the weight of the egg. Depending on the laying period, the share of the eggshell was similar to the laying peak and then decreased, which was confirmed by other authors (Mazanowski and Adamski, 2006; Adamski, 2008). Likewise, the thickness of the eggshell decreased with the laying period. This trend was also demonstrated by Lee et al. (2016). With the age of the laying hen, the ability of the intestines to absorb calcium decreases, and the weight of the egg increases, which results in a lower ability to produce the necessary calcium carbonate, a thinner eggshell, and its smaller share in the egg (Alfonso-Carrillo et al., 2021). The thickness of the eggshell is also influencing hatchability. Goose eggs with thicker eggshells had higher hatchability than eggs with thinner eggshells. It is associated with higher susceptibility to bacterial infections (Gogoi et al., 2021). As cited authors described, the thickness of the eggshell also ensures a longer shelf life. On the other hand, the environmental conditions have to be adapted to this feature. This is related to the piping time which increases hatching. Inadequate eggshell thickness (too thick or thin) may result in a reduced respiratory surface of the embryos (El-Hanoun et al., 2012).

The color of the eggshell (expressed as % whiteness) was lighter in eggs from 1-yr-old geese, and at the end of laying. The differences may concern the even distribution of the pigment in the eggshell and its intensity (Drabik et al., 2021). This may indicate that less pigment is deposited in younger females and at the end of laying. However, Muruz et al. (2022) reported that the pigment in goose eggs was undetectable. At the end of the laying cycle, the highest whiteness value (77.8%) was found, at the same time the highest number of pores in the eggshell was found. However, the thickness of the eggshell was the lowest compared to the beginning and peak of the laying cycle. This may suggest that along with the thickness of the eggshell, the whiteness of the eggshell was more intense. This relationship was not fully confirmed concerning the age of the parent flock. It is also necessary to take into account the amount of cuticle deposited on the eggshell, which may vary in thickness. The deposition of the cuticle is genetically conditioned (Chen et al., 2021), as is the color of the eggshell. The cuticle contains a thin film of hydroxyapatite crystals in its inner zone and the bulk of the superficial eggshell pigments, as described by Nys et al. (2004). It can also be concluded that there is a relationship between the cuticle thickness and the shade of white in goose eggs. However, this mechanism has not been described in the available literature.

The age of the layers also influences the thickness of the eggshell (Ketta and Tumova, 2016). Eggshell has a function, that is, respiration, and humidity regulation (Karabulut, 2021). In the own research, the thickness of the eggshell was higher in the group of older geese. A growing trend was noticeable. At the same time, the highest variability of this trait was found in the group of 4-yr-old geese. Sharipkulova et al. (2012) showed that the eggshell density of hens' eggs in the 80th wk of life was much higher than that of the hens' eggshells in the 26th wk of life. Adamski (2008) showed that the thickness of the eggshell was the highest at the peak of laying, which corresponds to the results of our research. The thickness of the eggshell may be dependent on the calcium absorption by the laying hen, and the ability to transfer it to the eggshell (Vieco-Galvez et al., 2021). It was suggested also that the calcification process in the shell gland (uterus) in the goose oviduct influences the thickness of the eggshell (Reshag and Khalaf, 2021). This may suggest that the thicker eggshell depends on the intensity of the calcification process in the oviduct, which may increase with the age of the layers.

Both the age of the parent flock and the laying period influence the pores number of the eggshell. In the own research it was found that a higher number of pores on the entire surface of the eggshell was found in the eggs of older geese, and also increased with the laying cycle. This corresponds to the results of research by other authors (Mazanowski and Adamski, 2006; Adamski, 2008; Lewko, 2015). The porosity of the eggshell is important for gas exchange and the evaporation of water from the inside of the egg to the outside environment (Vieco-Galvez et al., 2021). In the cited literature, the authors described that in the natural environment, embryos during development in a dry environment must retain more water, and waterfowl must increase water loss. Inadequate water loss can cause breathing problems when hatching. It may be suggested that the higher number of pores on the eggshell allows for more permeability. The above suggests that the thickness of the eggshell and its porosity may be a clue in the incubation technology of hatching eggs, in terms of the level of humidity and temperature, as well as the air exchange.

The analysis of the features related to the morphological and qualitative composition of eggs enables an indirect assessment of the impact of 4 yr of use of laying geese. Based on the results, it can be concluded that the age of the females influences most of the characteristics of the egg content and the quality of the eggshell. The age (laying season) and laying period (production weeks) affect changes in weight and egg structure features expressed in their morphological composition and physical properties. Changes in most of the characteristics in different laying stages are inversely proportional to the changes shown depending on the age of laying geese. The variability of the biological value of geese hatching eggs, depending on the age of geese in the parent flock and the laying period, may suggest the need to even out the environmental conditions during incubation. Adjusting the appropriate environmental conditions in the incubator, taking into account the processes in the egg (during embryo development), depending on its dimensions and internal structure, would allow refining the hatching technique, which would result in the effective acquisition of the offspring.

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DISCLOSURES

On behalf of all co-authors, I declare that the authors have no conflicts of interest of which they would be aware.

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