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Quality of chicken eggs in relation to their weight category

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The purpose of this study was to evaluate selected quality traits of chicken eggs in relation to their weight (weight categories). The experimental material comprised eggs from 250 laying hens (♂ New Hampshire x ♀ Barred Rock). The birds were kept in a poultry house on litter in identical hygienic conditions and fed ad libitum the same compound feed, of appropriate nutritional value, during the rearing and egg production period. At 36 weeks of age 160 eggs were taken at random from the hens and divided into four weight categories: below 57.0 g (group A); 57.1 to 60.0 g (group B); 60.1 to 63.0 g (group C) and above 63.0 g (group D). The quality of the albumen, yolk and shell was evaluated and the concentration and hydrolytic activity of lysozyme was determined in individual albumen fractions. Eggs from group D had the highest share of albumen (60.92%) and the smallest share of shell (10.56%). Furthermore, the albumen of these eggs had the greatest weight (40.19 g) and height (6.61 mm), and the yolks had the highest weight (18.13 g) and darkest colour (13.65 pts). The eggs assigned to group B had greater shell thickness (352.46 µm) and strength (38.2 N). Detailed analysis of lysozyme activity showed that the albumen of the group A eggs had the highest lysozyme concentration and hydrolytic activity in both albumen fractions analysed (0.61%; 131,105 U/ml – thin albumen and 0.38%; 80,705U/ml – thick albumen). The study showed that the heaviest eggs had the most favourable traits for the consumer. They were distinguished by good albumen quality (the greatest weight and height) and yolk quality (the greatest weight and darkest colour). Moreover, their shells were fairly thick (352.37 µm) and the least susceptible to deformation (70.90 µm). On the other hand, the albumen of the eggs in the lowest weight category had the highest concentration and hydrolytic activity of lysozyme.

KEY WORDS: chicken eggs / egg weight / quality / physical characteristics / lysozyme

Contemporary consumers are increasingly aware of questions involving the quality of food products. They increasingly choose products that not only are of high quality but also have certificates of origin. The potential buyer evaluating a product before purchase considers three main quality characteristics. The first is how healthy it is, i.e. the safety of the product and its nutritional value, including calorific and dietetic value. The other two are sensory attractiveness (aroma, palatability, etc.) and convenience (unit size, ease of preparation, etc.) [14].

The chicken egg is perceived as the most nutrient-rich and valuable basic food product [2, 21]. This value is assessed on the basis of its chemical composition, the ease of utilization of each of its components by the human body, and its content of numerous valuable bioactive components, including lysozyme, cystatin, ovotransferrin, lecithin, and lutein [2, 11].

The quality of table eggs approved for sale is defined in European Union regulations [18, 19]. In addition, in Poland terminology pertaining to eggs and egg products is defined by standard PN-90/A-86505 [17].

According to Trziszka et al. [25], the average consumer's demands in terms of egg quality mainly have to do with their external appearance; consumers prefer large eggs with a strong, brown shell. Other authors [5, 6, 24, 25] have reported that the basic element of evaluation of table eggs is their weight. This is the main physical characteristic of chicken eggs that potential buyers take into account. It is also a basic quality characteristic in regulations concerning trade in eggs and their classification into four categories. Furthermore, egg weight is a fundamental selection trait in the breeding of laying hens and is one of the most important traits in breeding of dual-purpose chickens, especially since this parameter, among all egg quality characteristics, is determined to the greatest extent by genotype [3, 12, 28]. Other significant factors influencing egg weight are diet, the age of the laying hens, housing system, environmental conditions, time of year, and certain individual characteristics of laying hens (e.g. age of sexual maturity or body weight) [3, 7, 9, 13, 26, 27].

A fundamental determinant of the quality of table eggs is freshness, which can be evaluated on the basis of the size of the air chamber, the degree of thinning of the albumen, and pH [6, 24].

The aim of the study was to assess selected quality characteristics of chicken eggs in relation to their weight category.

Material and methods

A total of 250 commercial crosses of laying hens (♂ New Hampshire x ♀ Barred Rock) were kept in an experimental henhouse on litter, in accordance with general principles governing the raising of commercial flocks of laying hens [16]. During the rearing and laying period the hens were fed ad libitum appropriate balanced compound feed. When the hens reached 36 weeks of age 160 eggs were randomly selected for analysis from one day's collection. The eggs were assigned to four weight categories: under 57.0 g (group A); from 57.0 to 60.0 g (group B); from 60.0 to 63.0 g (group C) and over 63.0 g (group D).

The main physical characteristics of the egg and its fractions (weight, colour, shape, and shell thickness) were tested according to a method described by Gornowicz et al. [7]. A TA.XT PLUS texture analyser (Stable Micro Systems) was used to determine shell characteristics: elastic deformation (μm) induced by a load of 1 kg and strength (N) under pressure on the blunt end of the egg, which was gradually increased until the shell cracked. Elastic deformation and shell thickness were measured with accuracy to 1 µm, at three measuring points (the blunt end, the narrow end, and the equator), and the arithmetic mean of the three measurements was used as the final result. An Ovolux lamp for manual illumination of eggs and a calliper with a millimetre scale were used to measure the height of the air chamber. A Metler Toledo pH meter was used to determine the pH of the albumen and yolk, after they had been extracted into weighing bottles. A method presented by Kijowski and Leśnierowski [10] was used to determine the content and hydrolytic activity of lysozyme in each fraction of the albumen. The percentage share of albumen, yolk and shell in the weight of the egg were calculated from these data.

Statistical analysis of the results was performed using the Statistica 10.0 package [22]. Analysis of variance was used to determine the significance of differences between means for groups. Duncan's test was used to show the significance of differences ($p \leq 0.05$) between them. Means ($\overline{x}$) and standard deviations (SD) were estimated as well.

Results and discussion

The heaviest eggs (>63.0 g – group D) has the largest percentage share of albumen (60.92%) and the smallest share ($p \leq 0.05$) of shell (10.56%). The percentage share of yolk showed little variation, ranging from 27.20% (57.0-60.0 g – group B) to 27.59% (60.0-63.0 g – group C) – Table 1.

These results differ from those obtained by Lee et al. [15]. The authors of this study, who evaluated the quality of eggs of Hy-Line Brown hens in five weight categories (<44.0 g,

Table 1

Percentage composition of chicken eggs depending on their weight category

Trait	Egg weight category				Total
	A <57.0 g	B 57.0-60.0 g	C 60.0-63.0 g	D >63.0 g	
n	17 $\overline{x}$ ±SD	47 $\overline{x}$ ±SD	47 $\overline{x}$ ±SD	49 $\overline{x}$ ±SD	160 $\overline{x}$ ±SD
Content of albumen (%)	60.26 ±2.52	60.47 ±2.31	60.39 ±2.59	60.92 ±3.39	60.56 ±2.77
Content of yolk (%)	27.45 ±2.36	27.20 ±2.50	27.59 ±2.40	27.50 ±3.57	27.44 ±2.81
Content of shell (%)	11.15^{a} ±0.99	10.95^{a} ±0.64	10.61^{b} ±0.67	10.56^{b} ±0.75	10.75 ±0.75

n – number of eggs
$\overline{x}$ – mean
SD – standard deviation
a, b – different letters in rows indicate a statistically significant difference at $p \leq 0.05$

44.0-51.0 g, 52.0-59.0 g, 60.0-67.0 g, and >68.0 g), found that eggs from the two lowest weight classes had the highest percentage share of albumen, i.e. 65.37% (44.0-51.0 g) and 64.87% (<44.0 g), and of shell—14.18% (<44.0 g). A similar pattern was observed by Hidalgo et al. [8]. Casiraghi et al. [5] also demonstrated that among eggs divided into four weight categories (S, M, L and XL), the eggs from class S had the highest percentage share of shell (11.8%). A similar relationship was confirmed in the present study, in which the highest percentage share of shell was noted for the eggs with the lowest unit weight (a difference of only 0.65 p.p. with respect to the cited study). These results do not correspond, however, with those obtained by Anderson et al. [1], who demonstrated the highest percentage share of shell (9.16%) in the heaviest eggs.

The mean weight of the eggs analysed ranged from 56.18 to 65.96 g. The eggs in group B had the roundest ($p \le 0.05$) shape, with a shape index of 77.87% (Tab. 2). Studies by Calik [4] and Casiraghi et al. [5] showed that as egg weight increased, the eggs had a more elongated shape, as indicated by a lower shape index. This was not confirmed by Anderson et al. [1], who found that the shape index increased with egg weight.

Table 2

Physical traits of chicken eggs depending on their weight category

Trait	Egg weight category				Total
	A <57.0 g	B 57.0-60.0 g	C 60.0-63.0 g	D >63.0 g	
n	17 $\bar{x}$ ±SD	47 $\bar{x}$ ±SD	47 $\bar{x}$ ±SD	49 $\bar{x}$ ±SD	160 $\bar{x}$ ±SD
Egg weight (g)	56.18^{d} ±0.78	58.65^{c} ±0.89	61.44^{b} ±0.80	65.96^{a} ±2.94	61.44 ±3.82
Egg shape index (%)	75.82^{b} ±1.91	77.87^{a} ±2.66	77.00^{ab} ±3.43	76.10^{ab} ±2.79	76.86 ±2.96
Air chamber heigh (mm)	2.23 ±0.44	2.15 ±0.36	2.21 ±0.41	2.22 ±0.42	2.20 ±0.40

n – number of eggs
$\bar{x}$ – mean
SD – standard deviation
a, b – different letters in rows indicate a statistically significant difference at $p \le 0.05$

In the present study the height of the air chamber did not exceed 2.23 mm in any of the groups. The smallest air chamber height (2.15 mm) was noted for the group B eggs, which had the thickest shell (352.46 µm), causing slower transpiration from their interior. Hidalgo et al. [8] showed that the lightest eggs had the shortest air chambers (3.5 mm) and the largest percentage of shell (11.6%).

The albumen of the heaviest eggs (group D) had significantly the highest ($p \leq 0.05$) weight (40.19 g) and height (6.61 mm). The most Haugh units (79.52) and lowest pH (9.06) were noted in the albumen of the group C eggs (Tab. 3).

Table 3
Physical traits of chicken egg albumen depending on egg weight category

Trait	Egg weight category				Total
	A <57.0 g	B 57.0-60.0 g	C 60.0-63.0 g	D >63.0 g	
n	17	47	47	49	160
	$\bar{x}$ ±SD	$\bar{x}$ ±SD	$\bar{x}$ ±SD	$\bar{x}$ ±SD	$\bar{x}$ ±SD
Albumen weight (g)	33.86^{d} ±1.60	35.46^{c} ±1.32	37.10^{b} ±1.67	40.19^{a} ±2.92	37.22 ±2.99
Albumen height (mm)	5.76^{b} ±0.88	6.23^{ab} ±1.21	6.42^{a} ±1.01	6.61^{a} ±1.09	6.36 ±1.10
Haugh units	76.78 ±6.28	78.85 ±8.80	79.52 ±7.30	79.37 ±7.44	78.98 ±7.69
Albumen pH	9.08 ±0.03	9.08 ±0.04	9.06 ±0.07	9.07 ±0.05	9.07 ±0.05

n – number of eggs
$\bar{x}$ – mean
SD – standard deviation
a, b – different letters in rows indicate a statistically significant difference at $p \leq 0.05$

Şekeroğlu and Altuntaş [20] evaluated the quality of eggs from Lohmann hens in four weight categories: medium – 52.36 g, large – 57.44 g, extra large – 64.17 g, and jumbo – 71.51 g. The authors showed that albumen height significantly depended on egg weight, reaching a value of 7.70 mm in the heaviest eggs. A similar relationship was observed in the present study. A study by Lee et al. [15] found the most favourable albumen quality characteristics ($p \leq 0.05$), i.e. the greatest height and the most Haugh units, in the smallest eggs. Hidalgo et al. [8] also showed that the lightest eggs had the most Haugh units (78.0). These results do not correspond with those obtained in the present study, in which the eggs in group A has the least favourable albumen quality characteristics, i.e. significantly ($p \leq 0.05$) the smallest height (5.76 mm) and weight (33.86 g) and the fewest Haugh units (76.78).

Evaluation of the yolk quality characteristics (Tab. 4) showed that the group D eggs had yolks with the highest ($p \leq 0.05$) weight (18.13 g) and the darkest colour (13.65 pts.). The pH of the yolk ranged from 6.31 (group D) to 6.36 (group A), and the differences were significant ($p \leq 0.05$) for groups A vs B, C and D. Toritsina and Stanishevskaya [23] reported that eggs from Rhode Island Red hens with a mean unit weight of 63.0 g had higher yolk weight (on average by 1.75 g) and a higher percentage share of yolk (on average by 4.0 p.p.), than the heaviest eggs (66.0 g). Şekeroğlu and Altuntaş [20], evaluating yolk colour, found that it was darkest (12.58 pts. on the YolkFan DSM scale) in the eggs with the highest unit weight. This is confirmed by the present study.

Table 4
Physical traits of chicken yolks depending on egg weight category

Trait	Egg weight category				Total
	A <57.0 g	B 57.0-60.0 g	C 60.0-63.0 g	D >63.0 g	
n	17 $\bar{x}$ ±SD	47 $\bar{x}$ ±SD	47 $\bar{x}$ ±SD	49 $\bar{x}$ ±SD	160
Yolk weight (g)	15.42^{c}±1.33	15.96^{bc}±1.54	16.95^{b}±1.48	18.13^{a}±2.37	16.86 ±2.04
Yolk pH	6.36^{a}±0.07	6.32^{b}±0.05	6.32^{b}±0.04	6.31^{b}±0.05	6.32 ±0.05
Colour (La Roche scale)	13.23^{a}±1.48	12.96^{ab}±2.06	13.11^{a}±1.29	13.65^{a}±1.36	13.24 ±1.60

n – number of eggs
$\bar{x}$ – mean
SD – standard deviation
a, b – different letters in rows indicate a statistically significant difference at p≤0.05

Qualitative analysis of the shells showed that the group B eggs had the thickest (352.46 µm) and strongest (38.2 N) shells (Tab. 5). The greatest (p≤0.05) elastic deformation of the shell (75.80 µm) was noted in group C. The shells of the group A eggs were denser (90.02 mg/cm^2) and darker (36.23% white). Statistically significant differences (p≤0.05) were observed for shell weight (C vs A and B; D vs A and B) and for elastic deformation (C vs A, B and D). Şekeroğlu and Altuntaş [20] showed that eggs with the lowest weight had the most favourable shell quality parameters, i.e. they were the thickest (400 µm) and strongest (49.11 N). These authors also found that the heaviest eggs had the darkest shells (62.47 on the L*a*b* scale). Similarly, Casiraghi et al. [5] showed that the eggs in the lowest weight category (S) had the strongest shells (43.5 N). This is not confirmed by results obtained by Anderson et al. [1], who reported that the heaviest eggs (63.88 g) had the thickest (470 µm) and strongest shells (3.36 kg).

Table 5
Physical traits of chicken eggshells depending on egg weight category

Trait	Egg weight category				
	A <57.0 g	B 57.0-60.0 g	C 60.0-63.0 g	D >63.0 g	Total
n	17 $\bar{x}$ ±SD	47 $\bar{x}$ ±SD	47 $\bar{x}$ ±SD	49 $\bar{x}$ ±SD	160 $\bar{x}$ ±SD
Shell weight (g)	6.26^{b} ±0.57	6.42^{b} ±0.37	6.52^{a} ±0.42	6.96^{a} ±0.57	6.60 ±0.54
Shell thickness (µm)	345.21 ±32.71	352.46 ±23.22	342.94 ±27.99	352.37 ±28.03	348.86 ±27.33
Shell deformation (µm)	71.80^{b} ±0.005	71.50^{b} ±0.005	75.80^{a} ±0.006	70.90^{b} ±0.005	72.50 ±0.006
Shell strenght (N)	35.2 ±1.54	38.2 ±1.36	37.1 ±1.30	35.8 ±1.38	36.8 ±1.36
Shell density (mg/cm^2)	90.02 ±8.06	89.65 ±5.21	88.28 ±5.66	89.97 ±6.49	89.39 ±6.07
Shell colour (% of white)	36.23 ±8.75	37.08 ±7.52	39.42 ±6.39	38.00 ±7.38	37.96 ±7.31

n – number of eggs
$\bar{x}$ – mean
SD – standard deviation
a, b – different letters in rows indicate a statistically significant difference at p≤0.05

In our study, slightly more favourable shell quality parameters were observed in the eggs with lower unit weight (group B). These shells were just 0.09 µm thicker and their crushing strength was 2.4 N greater than those of the heaviest eggs (group D).

Detailed analysis of the content of lysozyme in individual albumen fractions showed that the eggs with the lowest weight (group A) had the highest lysozyme content (p≤0.05) in the thin albumen (0.61%), and the lysozyme had the highest hydrolytic activity (131,105 U/ml). In the thick albumen as well, the eggs with the lowest weight had the highest percentage content of lysozyme (0.38%) with the highest hydrolytic activity (80.705 U/ml) – Table 6.

To sum up, the results of the study indicate that the eggs with the greatest weight had the most favourable characteristics from the point of view of the consumer. They had good albumen quality (greatest weight and height) and yolk quality (greatest weight and darkest colour). Moreover, they had a fairly thick shell with the lowest elastic deformation, indicating the greatest crushing strength. On the other hand, the albumen of the lightest eggs had the highest lysozyme concentration and lysozyme with the highest hydrolytic activity.

Table 6
Analysis of chicken egg lysozyme in albumen fractions depending on egg weight category

Trait	Egg weight category				Total
	A <57.0 g	B 57.0-60.0 g	C 60.0-63.0 g	D >63.0 g	
n	17 $\bar{x}$ ±SD	47 $\bar{x}$ ±SD	47 $\bar{x}$ ±SD	49 $\bar{x}$ ±SD	160 $\bar{x}$ ±SD
Thin albumen					
lysozyme concentration (%)	0.61^{a} ±0.09	0.55^{b} ±0.07	0.56^{b} ±0.08	0.55^{b} ±0.07	0.56 ±0.08
hydrolytic activity (U/ml)	131 105^{a} ±20 389	118 038^{b} ±16 086	119 655^{b} ±16 850	117 615^{b} ±15 159	119 772±16 860
Thick albumen					
lysozyme concentration (%)	0.38 ±0.08	0.36 ±0.07	0.36 ±0.05	0.35 ±0.06	0.36 ±0.06
hydrolytic activity (U/ml)	80 705 ±16 772	77 673 ±14 450	77 017 ±10 013	74 811 ±13 469	76 926 ±13 250

n – number of eggs
$\bar{x}$ – mean
SD – standard deviation
a, b – different letters in rows indicate a statistically significant difference at $p \leq 0.05$

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