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Quality parameters of table eggs depending on genotype and age in selected laying hens

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The aim of this study was to perform a comparative analysis of table egg quality in relation to the genotype and age of laying hens. A total of 180 eggs were analysed, comprising 30 eggs from Lohmann Brown hens and 30 eggs from Lohmann LSL hens at 25, 50, and 72 weeks of age. Morphometric traits (egg weight, length, width, and shape index), shell characteristics (eggshell surface area, shell thickness, and shell strength), and quantitative traits of egg components (percentage of shell, albumen, and yolk; thick albumen height; Haugh units; and yolk colour parameters L*, a*,b* and Roche score) were evaluated. In addition, feed conversion ratio, egg production rate, and total egg number per hen were recorded throughout the laying period. The results showed a significant effect of hen genotype on egg weight (Lohmann Brown: 64.70 g vs. Lohmann LSL: 59.97 g), egg length and width, egg shape index, eggshell surface area and strength, albumen proportion (65.09 vs. 63.23%), yolk proportion (24.90 vs. 26.72%), thick albumen height, Roche score, Haugh units, and yolk b* colour. Hen age significantly affected egg weight (25 weeks: 56.77 g vs. 72 weeks: 66.20 g), egg width and length, the proportion of shell, albumen (25 weeks: 65.71% vs. 50 weeks: 62.71%), and yolk, eggshell surface area (25 weeks: 70.08 cm² vs. 72 weeks: 77.58 cm²), as well as yolk colour parameters L* and a*. Significant genotype × age interactions were observed for egg weight and width, egg shape index, and also eggshell surface area and strength, Haugh units, and yolk colour parameters a* and b*.

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In 2022, world egg production reached 87 million tons, an increase of 70% since 2000 [FAO, 2023]. The most important region, accounting for over 63% of world production, is Asia (China, Indonesia, India), followed by the Americas (USA, Brazil, Mexico) with 20%, Europe (France, Spain, Germany) with 12% and Africa with 5%. Notably, in most regions, egg production growth in 2022 exceeded 50%, however in Europe it was only 14%, which resulted in a decrease in Europe's world egg market share from 18 to 12% [FAO, 2023].

Poland ranks fifth in Europe in egg production, accounting for 8.2% of the total, and is also the second-largest European egg exporter owning the 15.2% of European market [Food Business, 2024]. The main commercial laying hen breeds kept in Poland include Rosa, Hy-Line, Bovans, Lohmann, Messa, and ISA Brown [KRD, 2023].

Leghorn and Lohmann Brown lines are among the leading commercial laying hen lines worldwide [Habig *et al*. 2012]. The Lohmann Brown line was developed through crossbreeding Rhode Island and White Rock chickens. Egg production begins at around 19 weeks of age and continues under commercial conditions until approximately 72 weeks. During one laying cycle, a Lohmann Brown hen lays an average of 315 brown-shelled eggs, while a Lohmann LSL hen lays around 321 white-shelled eggs [Wegner *et al*. 2024].

Apart from non-genetic factors (age, nutrition, housing system), genetic factors influence egg quality [Hejdysz *et al*. 2024]. Genetic factors related to egg quality include a higher level of polyunsaturated fatty acids (PUFA) in the yolk, differences in eggshell thickness, and variations in albumen Haugh units (HU) [Romero *et al*. 2024]. Additionally, the weight and diameter of the egg, as well as the colour and strength of the shell, are genetically determined [Lordelo *et al*. 2020, Hammershoj *et al*. 2021, Zhang *et al*. 2021 Herranz *et al*. 2024].

Studies in genetic factors indicate relationships between specific genomic regions and traits such as HU and eggshell colour in older hens (approximately 72-80 weeks). This highlights the molecular basis of genotype effects on egg quality [Liu *et al*. 2018]. Other authors also observed the effect of the genotype of laying hens on the albumen and yolk mass, as well as the height of the thick albumen [Krawczyk, 2017; Hammershoj *et al*. 2021, Zhang *et al*. 2021, Herranz *et al*. 2024]. Importantly, Lordelo *et al*. [2020] showed that eggs from native breeds were characterized by a lighter shell and yolk colour and higher HU compared to eggs from commercial hens.

Age effect has also been the focus of many studies. Authors analysing the effect of hen age on the quality characteristics of table eggs observed that the weight, length, and width of the egg increased with hen age while the egg index decreased [Krawczyk and Calik 2018, Sirri *et al*. 2018, Vlčková *et al*. 2019, Kuźniacka *et al*. 2020]. Moreover, the age of birds affects shell thickness and strength, thick albumen height, and the HU [Sirri *et al*. 2018, Vlčková *et al*. 2019, Kuźniacka *et al*. 2020, Hammershoj *et al*. 2021]. Studies have shown that as hens age, egg weight increases and certain internal quality parameters, such as albumen height and HU, change accordingly [Krawczyk and Calik 2018].

Consequently, the aim of this study was to further the understanding of the effects of genotype and age on egg quality of laying hens.

Materials and method

Materials

The eggs used for analysis originated from a single henhouse housing two laying hen genotypes: **Lohmann Brown** and **Lohmann LSL**. According to the breeder, hens were kept in a cage system with 30 birds per cage, totalling 5,000 hens per genotype, and were fed the same diet. Birds were fed *ad libitum* a complete feed containing 16.5% crude protein, 11.6 MJ ME, 0.34% methionine, 0.81% lysine, 3.5% calcium, 0.61% phosphorus, and 0.15% sodium. The henhouse temperature was maintained at 20 °C, and relative humidity ranged from 65 to 75%.

Average egg production over the 52-week experimental period was 81.2% for Lohmann Brown and 79.8% for Lohmann LSL. Cumulative mortality at the end of the production period was 6.56% and 7.20%, respectively, while the number of eggs produced per hen was 294.9 for Lohmann Brown and 293.1 for Lohmann LSL. The average feed conversion ratio for the entire laying period was 2.12 kg feed per kg egg mass for Lohmann Brown and 1.96 kg feed per kg egg mass for Lohmann LSL.

Eggs were collected at 25, 50, and 72 weeks of hen age. At each time point, 30 eggs per genotype were sampled, resulting in a total of 180 eggs analysed.

Morphometric features of the egg

Egg mass (g) was determined individually for each egg using an electronic scale (WPS 210C, Radwag, Radom, Poland) with an accuracy of 0.01 g. Egg length (long axis) and width (short axis) were measured using an electronic calliper (Vorel, Toya S.A., Wrocław, Poland) with an accuracy of 0.01 cm. The egg shape index (%) was calculated as the ratio of egg width to egg length.

The following formula was used to calculate the eggshell area: $PS = 4.835 \times W^{0.662}$, where: PS – eggshell area (cm^2); W – egg mass (g).

For eggshell measurements, eggs were broken and their contents carefully separated onto a glass plate. Eggshells were rinsed, and the shell membranes were removed manually using a scalpel. The shells were then dried in a laboratory dryer (SUP 100 M, Poch S.A., Gliwice, Poland) at 105°C for 3 h. After drying, shell mass was measured using the same electronic scale with an accuracy of 0.01 g.

Eggshell thickness was measured at the equatorial region of the shell using a micrometre screw gauge with an accuracy of 0.01 mm. Eggshell strength was determined using an Egg Force Reader (Orka Food Technology Ltd.).

Qualitative characteristics of egg components

Egg components, including albumen height and HU, were analysed using an EggAnalyzer (Orka Food Technology Ltd.). Yolk colour was measured with a Konica Minolta colorimeter (CR-400, Japan), calibrated using a white calibration plate (no. 21033065) and the D65 illuminant (Y = 86.1, x = 0.3188, y = 0.3362). Colour measurements were expressed in the CIE L*a*b* colour space, where L* indicates lightness, a* redness, and b* yellowness.

Albumen thickness and yolk height (mm) were measured on a glass plate using a QCD device (TSS Ltd., York, UK). Following separation of the yolk and albumen, their masses (g) were determined using an electronic scale (WPS 210, Radwag, Radom, Poland). Albumen mass was calculated as the sum of thin and thick albumen fractions. The proportions of albumen, yolk, and shell were expressed as percentages of the fresh egg weight prior to analysis.

Statistical analyses

Means, standard deviations were calculated for each trait. Statistical analyses were performed using SAS software (version 9.4). Differences between assessment dates (weeks 25, 50, and 72) and between laying hen genotypes (Lohmann Brown and Lohmann LSL) were evaluated using Tukey's post hoc test, with statistical significance set at $P < 0.05$.

Results and discussion

Egg quality is influenced by egg mass and shape. In the present study, both genotype and age of laying hens significantly affected egg mass, length, and width ($P < 0.05$, Tab. 1). Genotype also had a significant effect on the egg shape index. Eggs from Lohmann Brown hens were characterized by greater mass, width, length, and egg shape index compared with those from Lohmann LSL hens ($P<0.001$).

These findings are consistent with previous studies on genotype effects. Herranz *et al*. [2024] reported that eggs from ISA Brown hens had a higher mass than those from ISA White hens. The influence of laying hen genotype on egg weight has also been confirmed in several other studies [Sirri *et al*. 2018, Gu *et al*. 2021, Hammershoj *et al*. 2021, Zhang *et al*. 2021, Hejdysz *et al*. 2024, Romero *et al*. 2024]. In addition, earlier research showed that layer-type crossbreeds producing brown-shelled eggs were characterized by a significantly larger egg diameter compared with other breeds [Hammershoj *et al*. 2021].

Additionally, multiline studies reported genotype × age interactions consistent with the present results, showing that egg weight, yolk-to-albumen ratio, shell traits, and egg shape index are significantly influenced by both age and genotype, thereby supporting the combined effects of these factors on egg quality characteristics [Ledvinka *et al*. 2012]. Similarly, Shaker *et al*. [2017] demonstrated that both age and genotype significantly affect the egg shape index, highlighting their joint influence on egg morphology.

Table 1. Egg weight and dimensions, morphological composition of eggs from Lohmann laying hens in the first egg production season

Item	Egg weight (g)	Egg width (mm)	Egg length (mm)	Egg shape index (%)	Egg shell content in whole egg (%)	Yolk content in whole egg (%)	Albumen content in whole egg (%)
Genotype							
Lohmann Brown	64.7 ±4.31	44.63±1.11	57.15±2.30	78.09±3.37	10.01±0.59	24.90±2.43	65.09±2.53
Lohmann LSL	59.97*±6.10	43.34*±1.73	56.25*±2.79	77.04*±2.67	10.05±0.58	26.72*±2.80	63.23*±2.85
Age							
25 wk	56.77^{b}±4.47	42.71^{a}±1.68	54.32^{b}±2.07	78.62±2.36	10.25^{a}±0.51	24.04^{b}±2.32	65.71^{a}±2.44
50 wk	64.03^{a}±3.68	44.50^{b}±1.07	57.16^{a}±1.38	77.85±2.26	10.02^{a}±0.53	27.27^{a}±2.40	62.71^{b}±2.48
72 wk	66.20^{a}±4.26	44.70^{b}±1.18	58.62^{a}±2.27	76.25±3.68	9.82^{b}±0.63	26.13^{a}±2.58	64.05^{a}±2.75
25 wk of age							
Lohmann Brown	60.64^{a}±2.23	43.76^{a}±0.74	54.92±1.28	79.43^{a}±2.21	10.11±0.55	22.79^{b}±1.30	67.10^{a}±1.27
Lohmann LSL	52.91^{b}±2.18	41.66^{b}±1.71	53.73±2.52	77.81^{b}±2.26	10.39±0.43	25.29^{a}±2.46	64.32^{b}±2.54
50 wk of age							
Lohmann Brown	66.87^{a}±2.75	45.20^{a}±0.83	57.63±1.26	78.43±2.19	10.11±0.57	26.21^{b}±2.14	63.68^{a}±2.39
Lohmann LSL	61.20^{b}±1.83	43.80^{b}±0.59	56.68±1.34	77.28±2.18	9.93±0.47	28.33^{a}±2.19	61.74^{b}±2.25
72 wk of age							
Lohmann Brown	66.58±4.38	44.84±1.16	58.90±2.43	76.13±4.03	9.82±0.61	25.70^{b}±2.19	64.48±2.32
Lohmann LSL	65.82±4.19	44.56 ± 1.11	58.35±2.11	76.37±3.31	9.81±0.66	26.55^{a}±2.90	63.64±3.13
P value							
Genotype	<0.001	<0.001	<0.001	<0.001	0.680	< 0.001	< 0.001
Age	<0.001	<0.001	0.002	0.112	0.001	< 0.001	< 0.001
Interaction	<0.001	<0.001	0.649	0.026	0.073	0.113	0.059

Values are expressed as mean ± standard deviation. n = 90/genotype and 60/the age of the hen.
[a,b]Means bearing different superscript differ significantly due to the age of hens at $p < 0.05$.
*Statistically significant differences between genotypes ($p < 0.05$).

The present study showed that egg weight, width, and length increased significantly with hen age (25 weeks: 56.77 g vs. 72 weeks: 66.20 g), which is consistent with the findings of Krawczyk and Calik [2018]. In their study, egg weight increased with the age of the hens, while albumen height and HU also showed age -dependent changes. Similar observations have been reported by other authors [Sirri *et al*. 2018, Vlčková *et al*. 2019, Kuźniacka *et al*. 2020].

Specifically, Vlčková *et al.* [2019] reported that ISA Brown eggs at 26 weeks of age had a lower weight (58.0 g) than eggs produced at 51 weeks (63.3 g). Similarly, Sirri *et al.* [2018] found that Hy-Line Brown eggs at the onset of lay (30 weeks) had a lower weight (61.2 g) compared with eggs produced at the end of the laying period (81 weeks; 64.5 g). In the same study, egg width and length increased with hen age, whereas the egg shape index decreased.

In the present study, laying hen genotype significantly influenced yolk and albumen proportions in the whole egg ($P<0.001$). Eggs from Lohmann Brown hens exhibited a lower yolk proportion and a higher albumen proportion compared with those from Lohmann LSL hens. Similarly, Dikmen *et al*. [2025] demonstrated that both age and genotype affected albumen index, HU, and yolk colour across multiple age groups, indicating that these traits remain sensitive to age-related physiological changes in laying hens. Lordelo *et al*. [2020] also reported that eggs from Amarela layers were characterized by a significantly higher yolk proportion, whereas eggs from Hybrid layers showed the highest albumen proportion.

In addition, the present study showed that with increasing hen age, the proportion of egg shell decreased while the proportion of yolk increased ($P = 0.001$ and $P<0.001$, respectively). Extending these findings, Li *et al.* [2025] reported that egg quality parameters, including shell strength and yolk colour, continue to change during the later stages of the laying cycle.

In the present study, the percentage of albumen in the egg was lowest at 50 weeks of hen age. Similarly, Kuźniacka *et al*. [2020] reported that egg albumen content decreased with increasing hen age. The present study also revealed significant genotype × age interactions for egg weight, width, and shape index ($P<0.001$ and $P = 0.026$, respectively). Comparable genotype × age interactions affecting egg weight and diameter were reported by Hammershoj *et al*. [2021]. Importantly, Vlčková *et al.* [2019] observed an interaction between hen age and housing system for egg weight, suggesting that age may not be the sole influencing factor.

The eggshell protects egg contents from microbial contamination [Sirri *et al.* 2018]; therefore, shell strength is an important trait for egg producers. This parameter can also be influenced by the genotype of laying hens. In the present study (Tab. 2), eggs from Lohmann LSL hens were characterized by higher shell strength, whereas hen age did not significantly affect this trait ($P = 0.793$). Similar observations were reported by Hammershøj *et al*. [2021] and Zhang *et al.* [2021]. For example, Zhang *et al.* [2021] reported the highest shell strength in Hy-Line Brown eggs and the lowest in White Leghorn eggs.

Although Kuźniacka *et al.* [2020] observed an age-related decline in shell strength and thickness, our study found that the genotype and age did not affect shell thickness significantly (P = 0.111, 0.181, respectively).

However, reports on the effects of genotype and age on eggshell characteristics vary among studies [Hammershøj *et al*. 2021, Zhang *et al*. 2021, Hejdysz *et al*. 2024, Herranz *et al.* 2024]. Herranz *et al*. [2024] reported that ISA Brown eggs had thicker

Table 2. Selected egg quality characteristics of Lohmann laying hens in the first egg production season

Item	Egg shell surface area (cm^2)	Egg shell thickness (mm)	Egg shell strength (N)	Thick albumen height (mm)
Genotype				
Lohmann Brown	76.42±4.30	0.282±0.05	39.67±12.14	5.44±1.44
Lohmann LSL	72.67*±4.86	0.277 ± 0.05	40.41*±9.59	5.28*±1.15
Age				
25 wk	70.08[b]±4.15	0.244±0.02	44.94±7.25	5.76±1.38
50 wk	75.89[a]±2.94	0.250±0.03	40.20 ±9.77	5.37±1.19
72 wk	77.58[a]±3.87	0.244±0.03	35.40±11.79	4.95±1.20
25 wk of age				
Lohmann Brown	73.21[a]±4.17	0.248±0.03	47.36±6.63	5.85±1.56
Lohmann LSL	66.89[b]±1.82	0.241±0.02	42.61±7.18	5.67±1.19
50 wk of age				
Lohmann Brown	78.11[a]±2.09	0.255±0.02	40.69±11.74	5.64±1.30
Lohmann LSL	73.66[b]±1.43	0.246±0.03	39.71±7.46	5.09±1.02
72 wk of age				
Lohmann Brown	77.88±3.36	0.243±0.03	31.89±12.07	4.84±1.26
Lohmann LSL	77.29±3.44	0.245±0.05	38.91±10.56	5.06±1.15
P value				
Genotype	<0.001	0.111	<0.001	0.003
Age	<0.001	0.181	0.793	0.370
Interaction	<0.001	0.470	0.004	0.246

Values are expressed as mean ± standard deviation. n = 90/genotype and 60/the age of the hen.
[a,b]Means bearing different superscript differ significantly due to the age of hens at $p<0.05$.
*Statistically significant differences between genotypes ($p<0.05$).

shells than ISA White eggs. Similarly, Hejdysz *et al*. [2024] showed that the shell thickness of Hy-Line Brown eggs (0.41 mm) was greater than that of other breeds, such as Sussex (0.31 mm). In contrast, several studies have demonstrated that eggshell thickness decreases with increasing hen age [Sirri *et al*. 2018, Kuźniacka *et al.* 2020, Hammershøj *et al.* 2021].

In the present study, egg shell surface area was significantly larger in eggs from Lohmann Brown hens, while the lowest values were observed at the beginning of the laying period ($P < 0.001$). A similar age-related increase in eggshell surface area was reported for Hy-Line Brown hens by Sirri *et al.* [2018].

Considering the qualitative characteristics of egg components, the morphological composition of the egg is strongly influenced by hen age, nutrition, and genotype [Lordelo *et al*. 2018, Kuźniacka *et al*. 2020, Zhang *et al*. 2021, Hejdysz *et al.* 2024, Herranz *et al*. 2024].

In the present study (Tab. 3), laying hen genotype significantly affected the Roche score, HU, and yolk b* colour ($P < 0.001$-0.040). Eggs from Lohmann Brown hens were characterized by greater thick albumen height and higher HU, but lower yolk b* values compared with those from Lohmann LSL hens. The influence of genetic factors on egg quality traits, including yolk colour and HU, has also been reported in other studies [Lordelo *et al*. 2018, Kraus and Zita 2019, Zhang *et al*. 2021; Hejdysz *et al*. 2024, Herranz *et al*. 2024].

Table 3. Selected egg quality characteristics of Lohmann laying hens in the first egg production season

Item	Roche score(pts)	Haugh Units (HU)	Yolk lightness (*L**)	Yolk redness (*a**)	Yolk yellowness (*b**)
Genotype					
Lohmann Brown	10.72±0.98	71.51±18.10	48.52±2.44	8.08±2.28	30.65±3.52
Lohmann LSL	10.49*±1.25	67.06*±12.59	50.06 ±5.40	7.23 ± 2.26	31.03* ± 4.69
Age					
25 wk	10.42±1.21	70.57±13.36	48.78^{b}±6.40	7.30^{b}±2.63	29.58±2.77
50 wk	10.50±1.30	66.56±13.34	50.29^{a}±2.40	7.75^{a}±2.04	30.46±2.96
72 wk	10.90±0.70	59.96±16.11	48.82^{b}±2.55	8.06^{a}±2.16	32.47 ± 6.57
25 wk of age					
Lohmann Brown	10.47±1.50	69.71±14.90	48.20^{b}±2.83	8.05^{a}±2.96	30.13±3.07
Lohmann LSL	10.37±0.82	71.43±12.53	49.37^{a}±8.64	6.55^{b}±2.03	29.03±2.38
50 wk of age					
Lohmann Brown	10.83±0.59	66.49±15.39	49.23^{b}±1.70	8.42^{a}±1.77	30.59±2.74
Lohmann LSL	10.17±1.76	66.63±11.02	51.35^{a}±2.55	7.07^{b}±2.09	30.34±3.20
72 wk of age					
Lohmann Brown	10.87±9.51	59.72±18.31	48.19^{b}±2.57	7.76^{b}±1.97	31.22±4.52
Lohmann LSL	10.93±9.91	60.19±11.68	49.45^{a}±2.41	8.36^{a}±2.32	33.71±6.29
P value					
Genotype	0.040	<0.001	0.079	0.176	0.001
Age	0.158	0.141	0.016	0.016	0.520
Interaction	0.165	0.034	0.796	0.018	0.035

Values are expressed as mean ± standard deviation. n = 90/genotype and 60/the age of the hen.
^{a,b}Means bearing different superscript differ significantly due to the age of hens at $p < 0.05$.
*Statistically significant differences between genotypes ($p < 0.05$).

In the present study, eggshell surface area increased with hen age, and age also significantly affected yolk colour parameters L* and a* ($P < 0.001$-0.016). The highest yolk lightness (L*) was observed at 50 weeks of age, whereas the highest a* values occurred at the end of the laying period. Previous studies have reported an age-related increase in HU [Vlčková *et al.* 2019, Kuźniacka *et al*. 2020]; however, this effect was not confirmed in the present study. Similarly, no significant effect of hen age on thick albumen height was observed ($P = 0.370$), in contrast to the findings of Kuźniacka *et al*. [2020], who reported higher albumen height in eggs from younger hens.

Notably, significant genotype × age interactions were identified for eggshell surface area and strength, HU, and yolk colour parameters a* and b* ($P < 0.001$-0.035), indicating a combined influence of genetic background and hen age on these egg quality traits.

Conclusions

In summary, both genotype and age were found to significantly influence egg characteristics. In the present study, eggs from hens maintained under identical housing and feeding conditions were evaluated. The results demonstrated that Lohmann Brown hens produced heavier eggs with higher albumen content and HU, but lower yolk proportion and weaker shell strength compared with eggs from Lohmann LSL hens. Egg weight, yolk proportion, and eggshell surface area increased with hen age, whereas shell proportion decreased. Overall, genotype and age significantly affected egg dimensions, morphological composition, and shell traits. Moreover, several significant genotype × age interactions were identified, confirming the combined influence of these factors on multiple egg quality parameters.

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