Acta Sci. Pol. Technol. Aliment. 19(1) 2020, 101–107

www.food.actapol.net pISSN 1644-0730 eISSN 1898-9594 http://dx.doi.org/10.17306/J.AFS.2020.0757

ORIGINAL PAPER

Received: 17.01.2020
Accepted: 23.03.2020

THE EFFECT OF THE GENETIC ORIGIN OF HENS ON SELECTED EGG TRAITS

Barbara Biesiada-Drzazga✉, Dorota Banaszewska, Karolina Wielogórska, Sabina Kaim-Mirowski

Institute of Animal Sciences and Fisheries, Siedlce University of Natural Sciences and Humanities
Prusa 14, 08-110 Siedlce, **Poland**

ABSTRACT

Background. Eggs have been considered an important component of the human diet for centuries. There is currently a wide assortment of eggs available to consumers, varying in terms of weight (from S to XL), housing system (0 to 3), diet, packaging, etc. Although the egg's nutritional value is most important to consumers, their perceptions are unfortunately generally based not on facts, but on popular opinion. Most commercial lines of laying hens used in Poland are of foreign origin. However, some farms use commercial lines from Polish breeding farms. Therefore, research was undertaken to determine selected characteristics of eggs obtained from hens of different origins raised in an intensive system, i.e. industrial production of eggs.
Material and methods. The research material consisted of eggs from Hy-Line Brown and Messa 43 hens from large-scale production. The eggs were obtained from hens at the ages of 35, 40 and 45 weeks. The analysis included selected external and internal characteristics of eggs laid during the study period. The eggs were evaluated immediately after laying, and the following quality parameters were determined: egg weight, shell weight, shell thickness, white weight, yolk weight, and pH of white and yolk. Chemical analysis of dry matter, total protein, crude fat and crude ash content in the whites and yolks was performed. The cholesterol content and fatty acid profile in the yolk were analysed as well. A statistical analysis of the results was performed.
Results. The analyses revealed significant differences in the weight and morphological composition of eggs depending on the genotype of the hens. Compared to eggs obtained from Hy-Line Brown hens, eggs from Messa 43 hens had significantly lower shell thickness, greater weight between 35 and 45 weeks of age, a larger proportion of shell, and a smaller proportion of albumen. Yolks and whites of eggs from Hy-Line Brown hens contained significantly more dry matter and total protein than those of Messa43 chickens, while the cholesterol content in the yolks of both groups was similar. The fatty acid profile of the egg yolk was similar irrespective of the origin of the hens.
Conclusions. Significant differences in egg weight and the parameters of morphological components of eggs were found between the experimental groups. Genotype did not influence cholesterol content or the fatty acid profile in the yolk.

Keywords: hen, genotype, egg, quality

INTRODUCTION

Eggs have been considered an important component of the human diet for centuries (Calik, 2011; Czaja and Gornowicz, 2006; Hocking et al., 2003; Silversides et al., 2006; Szablewski et al., 2013). In the last twenty

✉barbara.biesiada-drzazga@uph.edu.pl, https://orcid.org/0000-0002-6748-1932

years, however, conflicting opinions about the influence of eggs on human health have been observed, especially regarding their recommended quantity in the diet (Kijowski et al., 2013; Mc Namara, 2010; Wężyk and Gilewski, 2018). This was mainly due to fears that the cholesterol and fat in egg yolk have a negative effect. Currently, however, eggs are not considered a food that should be restricted in the human diet, but are regarded as functional food. According to Kijowski et al. (2013), for the modern consumer eggs are not only food, but a source of life-giving substances. There is currently a wide range of eggs available to consumers, varying in terms of weight (from S to XL), housing system (0 to 3), diet, packaging, etc. While the egg's nutritional value is most important to consumers, their perceptions are too often based not on facts, but on popular opinion (Biesiada-Drzazga and Janocha, 2009; Krawczyk, 2009; Krawczyk and Gornowicz, 2010; Strojny et al., 1998). The majority of eggs currently available on the market are from large-scale production and are erroneously regarded as less valuable. Egg quality is determined by several factors, e.g. lighting programme, rearing conditions and microclimate, diet during the laying period, age and health of hens, and storage conditions (Banaszewska et al., 2018; Biesiada-Drzazga, 2009; Krawczyk and Obrzut, 2016; Trziszka et al., 2011; Silversides and Scott, 2001; Sokołowicz et al., 2012, Van den Brand et al., 2004). However, significant differences in the parameters of the morphological components of eggs occur even in identical environmental conditions, which is linked to the hen's breed (Biesiada-Drzazga, 2009; Dykiel et al., 2019; Hocking et al., 2003; Sosnówka-Czaja et al., 2014; Wlaź and Nowaczewski, 2018). Most commercial lines of laying hens used in Poland are of foreign origin. Some farms, however, use commercial lines from Polish breeding farms. These include Messa 45, Messa P, and Rosa. The most popular lines of foreign origin are Hy-Line Brown, Hy-Line White W-36, Lohmann Brown Clasic, Lohmann White, ISA Brown, and Tetra SL.

MATERIAL AND METHODS

The test material consisted of eggs from hens of the commercial lines Hy-Line Brown and Messa 43 raised in an intensive system. The hens were kept in a closed henhouse on litter (chopped rye straw). The stocking density was 6 m^2. The henhouse was equipped with Big Deutchman feeders and drinkers. The nests were two-tiered and placed along the long walls of the building. There was one nest for every 5 hens. Eggs were collected by hand twice a day. The chickens were fed only a complete feed ration, 140–145 g per day per hen. The nutritional value of the feed is presented in Table 1.

Table 1. Nutritional value of hens' diet

Ingredients	Content in 1 kg of feed
Total protein, %	14.5–15.5
ME, MJ	11.7
Fat, %	4.0–5.0
Lysine	0.56
Methionine+cysteine	0.53
Methionine	0.29
Ca	3.0
P (available)	0.34

The eggs included in the study were obtained from chickens at 35, 40 and 45 weeks of age. At each age, 30 eggs from each line of hens were assessed, for a total of 90 eggs from Hy-Line Brown hens and 90 eggs from Messa 45 hens. Eggs were analysed no later than 24 hours after being laid.

The analysis included selected external and internal characteristics of eggs laid by hens during the study period. The eggs were evaluated immediately after laying. Their quality parameters included those which required the egg to be broken and those that did not. The following characteristics of the eggs and their components were evaluated:

- egg weight – measured with an Ohaus electronic scale to within 0.01
- length of long and short axes – measured with an electronic calliper to within 0.01 (Stainless Hardened 0–150 mm); the egg shape index was calculated from the length and width
- shell weight – measured with an Orhaus electronic scale to within 0.01

- shell thickness – measured at the equator a micrometer (MMZb-C 0–25/0.01 mm DIN 863-1, HELIOS.PREISSER, Germany)
- white weight – measured with an Orhaus electronic scale to within 0.01
- yolk weight – measured with an Orhaus electronic scale to within 0.01
- pH of white and yolk – measured with a CP-401 pH-meter.

The data were used to calculate the percentage share of each morphological component of the egg. Chemical analysis of dry matter, total protein, crude fat and crude ash content in the whites and yolks was performed. Cholesterol content and the fatty acid profile of the yolk were analysed as well. The following methods were used:

- dry matter by the oven-dry method according to PN-ISO 649:2002
- crude protein by Kjeldahl's method according to PN-EN ISO 8968-1:2014-03
- crude fat by the Soxhlet method according to PN--ISO 1444:2000
- ash by combustion in a furnace at 550ºC according to PN-ISO 936:2000
- fatty acid profile by gas chromatography GCMS--QP210 Ultra, SHIMADZU
- quantitative determination of cholesterol by a modification of the Liebermann-Burchard calorimetric method (Strzeżek and Wołos, 1997)

The influence of the genetic origin of the hens on the content of elements was assessed by one-way analysis of variance using the following mathematical model:

$$Y_{ij} = \mu + a_i + e_{ij}$$

where:

Y_{ij} – value of trait tested,
μ – mean for population,
a_i – effect of i-th level of factor (genetic origin),
e_{ij} – sampling error.

The significance of differences between groups was verified by Tukey's test at $P \leq 0.05$.

RESULTS AND DISCUSSION

Mean values of egg weights and shape indexes are presented in Table 2. Eggs from Messa 43 hens were statistically heavier ($P \leq 0.05$) than those of Hy-Line Brown hens. Several studies have confirmed the influence of genotype on egg size (Biesiada-Drzazga, 2009; Biesiada-Drzazga and Janocha, 2009; Silversides and Scott, 2001). However, results regarding the influence of housing system and diet on this trait are varied (Batkowska et al., 2019; Rossi, 2007; Sekeroglu et al., 2008; Van den Brand et al., 2004). Egg size is also determined by the age of the hen (Sokołowicz et al., 2012). The size of eggs is commonly taken into consideration by consumers, because it determines their cost.

Shape index is important for classification of hatching eggs. While of less significance for table eggs, it is still worth evaluating. Eggs with a shape index higher than 74% are more often broken or cracked (Narushin, 2005; Popova-Ralcheva, 2009). Shape index is thus an important trait not only in production, but in trade as well.

Table 2. Means ($\bar{x}$) and standard deviation (Sd) of selected egg traits

Traits	Line	
	Hy-Line Brown means ±Sd	Messa 43 means ±Sd
Egg weight, g	62.4^b ±3.51	63.8^a ±4.03
Egg length, mm	55.3^a ±3.01	54.7^b ±2.05
Egg width, mm	44.9 ±2.03	45.0 ±1.87
Shape index	1.23 ±0.11	1.21 ±0.32
Shape index, %	81.2 ±2.99	82.2 ±2.21

Means in groups marked with different letters differ significantly: a, b – $P \leq 0.05$.

Irrespective of the breed of hen, among the morphological components the share of white was the highest and that of the shell was the lowest, which is in agreement with other studies (Banaszewska et al., 2018; Biesiada-Drzazga and Janocha, 2009; Hrnćar et al., 2016; Roberts, 2004). The analysis of parameters of morphological components revealed statistical differences depending on the hen's genotype (Table 3). In a study by Kopacz and Drażbo (2018), eggs from Lohmann Brown hens at the peak of laying performance had a 25.0% share of yolk, 65.7% of white, and 9.38% share of shell. In comparison, the eggs

Table 3. Means ($\bar{x}$) and standard deviation (Sd) of the proportion of morphological components of eggs

Component	Line	
	Hy-Line Brown means ±Sd	Messa 43 means ±Sd
Shell	11.56^{b} ±0.92	12.55^{a} ±1.02
White	59.53^{a} ±4.03	58.39^{b} ±3.21
Yolk	28.86 ±2.17	29.04 ±2.09

Means in groups marked with different letters differ significantly: a, b – $P \leq 0.05$.

Table 4. Means ($\bar{x}$) and standard deviation (Sd) of white and yolk pH and shell thickness

Parameter	Line	
	Hy-Line Brown means ±Sd	Messa 43 means ±Sd
pH of white	8.73^{a} ±0.14	8.21^{b} ±0.07
pH of yolk	5.41 ±0.11	5.51 ±0.20
Shell thickness, mm	0.345^{a} ±0.01	0.311^{b} ±0.21

Means in groups marked with different letters differ significantly: a, b – $P \leq 0.05$.

tested in the present study had a higher share of yolk and shell. A slightly higher proportion of yolk than in the study by Kopacz and Drażbo (2018) was noted by Krawczyk and Obrzut (2016) in hens covered by the Gene-pool Protection Programme. The results of the present study and others have confirmed the influence of genotype on the parameters of the morphological components of eggs (Biesiada-Drzazga and Janocha, 2009; Millet et al., 2006; Odabasi et al., 2007; Olawumi, 2011; Suk and Park, 2001; Tůmowa et al., 2007).

Several physical and chemical processes begin after an egg is laid. Measurement of yolk and white pH provides information about these processes and thus about the egg's freshness. After the egg is laid, the pH of the albumen is about 8, while yolk pH is about 6 (Silversides and Budgell, 2004). The pH of the yolk and white depends on storage conditions, e.g. humidity and temperature. In the present study, the pH of the white was statistically higher ($P \leq 0.05$) in the eggs of Hy-Line Brown hens than Messa 43, while the yolk pH was similar in both experimental groups (Table 4). Eggs of higher weight collected from Messa 43 hens had statistically thinner shells in comparison with Hy--Line Brown hens (Table 3). The shell thickness was in the recommended range of 0.25–0.45 mm. Biesiada-Drzazga and Janocha (2009) report similar results for Hy-Line Brown, but Hrnćar et al. (2016) noted thicker shells and determined that this parameter was influenced by the hen's genotype. It should be noted that shell thickness depends on genetic and environmental factors, mainly diet (Biesiada-Drzazga et al., 2014; Czaja and Gornowicz, 2006; Roberts, 2004; Van Den Brand et al., 2004).

In the present study, no differences were noted in the chemical composition of the yolk, including cholesterol content, between Hy-Line Brown and Messa 43 hens (Table 5). According to Dziadek et al. (2003), the content of dry matter in the yolk of laying hens is 54.89–59.64%, which is higher than in our study. Similar results to those of Dziadek et al. (2003) are reported by Biesiada-Drzazga et al. (2014) for Green-legged Partridge hens. The yolks had similar total

Table 5. Means ($\bar{x}$) and standard deviation (Sd) of the chemical composition of the yolk and white

Parameter	Line	
	Hy-Line Brown means ±Sd	Messa 43 means ±Sd
Yolk		
Dry matter	44.70 ±3.02	43.8 ±12.17
Total protein	15.74 ±0.95	14.99 ±0.37
Crude fat	1.68 ±0.03	1.72 ±0.20
Crude ash	27.02 ±2.71	26.94 ±1.83
Cholesterol, mg/g yolk	14.58 ±0.25	14.93 ±1.02
White		
Dry matter	12.31^{a} ±0.75	11.33^{b} ±1.04
Total protein	11.63^{a} ±1.21	10.53^{b} ±1.02
Crude ash	0.62 ±0.01	0.70 ±0.03

Means in groups marked with different letters differ significantly: a, b – $P \leq 0.05$.

protein and crude fat content, so the hen's genotype did not affect the chemical composition of the egg yolk in laying hens. On the other hand, analysis of the chemical composition of eggs showed a significantly higher content of dry matter and total protein in the white of eggs laid by Hy-Line Brown hens compared to Messa 45.

The yolk of a medium-sized egg contains about 200–215 mg of cholesterol, and according to Kijowski et al. (2013), breeding and biological methods can be used to reduce its content by as much as 30%. Similar cholesterol content was noted in all analysed yolks. The yolk of eggs from Hy-Line Brown hens contained 262.6 mg of cholesterol, compared to 276.6 mg for Messa 43 hens. Sokołowicz et al. (2012) found similar cholesterol content in egg yolks from Green-legged Partridge hens, irrespective of their age. Cywa-Benko and Krawczyk (2004) found the average cholesterol content in 1 g of egg yolk from 19–45 week Leghorn H22 hens to be 15.37 mg. The authors also found that cholesterol content in egg yolk decreases with the hen's age. Research by Batkowska et al. (2019) showed that the hen housing system affects cholesterol content in egg yolks. The American Heart Association (AHA) recommends maximum cholesterol intake of 300 mg in the human diet, irrespective of it source (Kijowski et al., 2013). The results of the present study showed no significant influence of the hen's genotype on cholesterol content in egg yolks. According to Simčič et al. (2009), cholesterol content in egg yolk is generally constant and does not change with the hen's age.

Eggs are a source of SFA and UFA, whose ratio should be 2:1 (Kijowski et al., 2013). In the present study, the genotype of the hen did not influence the fatty acid profile of the yolk (Table 6). The proportion of SFA in the yolks was 39.74–40.40%, while that of UFA was 59.22–58.69%. Among unsaturated fatty acids, the highest share was noted for C18:1 (40.17–41.12%) and C18:2 (10.95–11.02%), which was in agreement with results obtained by Hidalgo et al. (2008), Kirubakaran et al. (2011) and Sokołowicz et al. (2012). The highest share of SFA in the present study was noted for C16:0, which was also in agreement with the results of the studies cited above. The results of the present study show that in hens of the same age fed the same diet, their genotype did not affect the fatty acid profile in the yolk. The origin of hens was not found to affect the proportions of monounsaturated and polyunsaturated fatty acids in egg yolk.

Table 6. Means ($\bar{x}$) and standard deviation (Sd) of the proportions of fatty acids in egg yolks

Fatty acids	Line	
	Hy-Line Brown means ±Sd	Messa 43 means ±Sd
Saturated		
C12:0	0.04 ±0.01	0.10 ±0.01
C14:0	0.54 ±0.05	0.41 ±0.02
C15:0	0.02 ±0.01	0.09 ±0.02
C16:0	30.98 ±3.14	31.65 ±3.98
C17:0	0.04 ±0.01	0.01 ±0.01
C18:0	8.12 ±1.00	8.14 ±0.97
SFA	39.74 ±4.86	40.40 ±4.99
Unsaturated		
C14:1	0.02 ±0.01	0.07 ±0.01
C16:1	4.28 ±0.76	4.36 ±0.21
C18:1	41.12 ±4.03	40.70 ±5.02
C18:2	10.95 ±1.76	11.02 ±1.04
C18:3	0.93 ±0.02	0.45 ±0.09
C20:4	1.94 ±0.30	1.87 ±0.76
C20:5	0.04 ±0.01	0.02 ±0.01
UFA	59.22 ±4.08	58.69 ±5.02
Monounsaturated	45.40 ±3.02	45.06 ±4.32
Polyunsaturated	13.88 ±2.12	13.63 ±2.15
Other fatty acids	0.98 ±0.04	0.91 ±0.07

CONCLUSIONS

Genotype significantly affected egg weight, and parameters of morphological components between flocks.

Eggs from Messa 43 hens had lower shell thickness, higher egg weight between 35 and 45 week of age, a higher percentage share of shell, and a lower percentage share of white.

Egg yolks and whites from Hy-Line Brown hens had higher dry matter and total protein content in comparison with Messa 43 hens, but cholesterol content in the yolks of eggs from both flocks was similar.

The fatty acid profile of the egg yolks was similar irrespective of the origin of the hens.

REFERENCES

Banaszewska, D., Biesiada-Drzazga, B., Janocha, A., Ostrowski, D., Długołęcka, M. (2018). Analysis of morfological egg characteristics and hatching of selected breeds of ornament al chickens. Eur. Poult. Sci., 82.

Batkowska, J., Drabik,. Vasiukov, K., Skałecki, P. (2019). The rearing system of laying hens and cholesterol content in egg yolks. XXXV Intern. Poult. Sci. Symp. PB WPSA, 4–6.09. Polańczyk, 63.

Biesiada-Drzazga, B. (2009). Estimation of morfological composition and physical traits of hatching eggs in the selected meat hen stocks. Rocz. Nauk. PTZ, 5, 1, 35–42.

Biesiada-Drzazga, B., Janocha, A. (2009). Wpływ pochodzenia i systemu utrzymania kur na jakość jaj spożywczych [Impact of hen breed and reading system on the quality of eggs for consumption]. Żywn. Nauka Technol. Jakość, 3, 64, 67–74 [in Polish].

Biesiada-Drzazga, B., Banaszewska, D., Andraszek, K., Bombik, E. Kałuża, H., Rojek, A. (2014). Comparison of egg quality of free range araucana and Green-legged Partridge chickens. Europ. Poult. Sci., 78.

Calik, J. (2011). Ocena jakości jaj sześciu rodów kur nieśnych w zależności od ich wieku [The assessment of egg quality of six laying hen families depending on their age]. Żywn. Nauka Technol. Jakość, 5, 78, 85–93 [in Polish].

Cywa-Benko, K., Krawczyk, J., Wężyk, S. (2000). Poziom cholesterolu w jajach rodzimych ras kur [Cholesterol levels in eggs of native breeds of chicken]. Zesz. Nauk. Przeg. Hod., 49. 268–270 [in Polish].

Cywa-Benko, K., Krawczyk, J. (2004). Wpływ dodatków paszowych na wybrane cechy jakości jaj kur leghorn i zielononóżka kuropatwiana [Effect of feed supplements on some egg quality traits of Leghorn and Greenleg Partridge hens]. Zesz. Nauk. Przeg. Hod., 72, 4, 171–176 [in Polish].

Czaja, L., Gornowicz, E. (2006). Wpływ genomu oraz wieku kur na jakość jaj spożywczych [Influence of genome and nutrition of chickens on the quality of food eggs]. Rocz. Nauk. Zoot., 33, 1, 59–70 [in Polish].

Dykiel, M., Sokołowicz, Z., Augustyńska-Prejsnar, A. (2019). Effect of layer genotype on phisical characteristic and nutritive value of free-range. XXXV Intern. Poult. Sci. Symp. PB WPSA, 4–6.09. Polańczyk, 61.

Dziadek, K., Gornowicz, E., Czekalski, P. (2003). Chemical composition of table eggs as influenced the origin of laying hens. Pol. J. Food Nutr. Sci., 12/53, (1), 21–24.

Hidalgo, A., Rossi, M., Clerci, S., Ratti, S. (2008). A market study on the quality characteristics of egg from different housing systems. Food Chem., 106, 1031–1038.

Hocking, P., Bain, M., Channing, C., Fleming, R., Wilson, S. (2003). Genetic variation for egg production, egg quality and bone strength in selected and traditional breeds of laying fowl. Br. Poult. Sci., 44, 3, 365–373.

Hrnćar, C., Biesiada-Drzazga, B., Nikolova, N., Hanusova, E., Hanus, A., Bujko, J. (2016). Comparitive analysis of the extremal and integraf egg quality in different pure chicken breeds. Acta Fytotechn. Zootechn., 19 (Special Issue), 123–127. https://doi.org/10.15414/afz.2016.19.si.123-127

Keshavarz, K., Nakjima, S. (1995). The effect of dietary manipulations of energy, protein and fat during the growing and laying period on early egg weight and egg components. Poult. Sci., 74, 50–61.

Kijowski, J., Leśnierowski G., Cegielska-Radziejewska, R. (2013). Jaja cennym źródłem składników bioaktywnych [Chicken eggs: Skurce of valuable bioactive components]. Żywn. Nauka Technol. Jakość, 5(90), 29–41 [in Polish].

Kirubakaran, A., Narahari, D., Ezhil Valavan, T., Sathish Kumar, A. (2011). Effects of flaxseed, sardines, pearl millet and holy basil leaves on production traits of layers and fatty acid composition of egg yolks. Poult. Sci., 90, 147–156.

Kopacz, M., Drażbo, A. (2018). Zmiany jakości jaj konsumpcyjnych w zależności od sposobu i czasu przechowywania [Changes in the quality of table eggs depending on storage metod and time]. Rocz. Nauk. PTZ, 14, 3, 37–45 [in Polish]

Krawczyk, J. (2009). Effect of layer age and egg production level on changes in quality traits of eggs from hems of conservation breeds and commercial hybrids. Ann. Anim. Sci., 9, 2, 185–193.

Krawczyk, J., Gornowicz, E. (2010). Quality of eggs from hens kept in two different free-range systems in comparison with barn system. Arch. Geflugelk., 74, 3, 151–157.

Krawczyk J., Obrzut, J. (2016). Kształtowanie się jakości jaj przechowywanych w zróżnicowanych waru kach pochodzących od wybranych populacji kur objętych programem ochrony [Quality of eggs stored und er different conditions from hens covered by the gene-pool protection programme]. Wiad. Zootechn., 54, 1, 53–60 [in Polish].

Millet, S., De Ceulaer, K., Van Paemel, M., Raes, K., De Smet, S., Janssens, G. (2006). Lipid profile in eggs of Araucana hens compared with Lohmann Selected Leghorn and ISA Brown hens given diets with different fat sources. Br. Poult. Sci., 47, 294–300.

Mc Namara, D. J. (2010). A world of possibilities. World Poult., 26, 7, 36–37.

Narushin, V. (2005). Egg geometry calculation using the measurements of length and breadth. Poult. Sci., 84, 482–484.

Odabasi, A., Miles, R., Balaban, M., Portier, K. (2007). Changes in brown eggshell colour as the hen ages. Poult. Sci., 86, 356–363.

Olawumi, S. (2011). Influence of breed and season on reproductive traits on there strains commercial layers in the Derived Savannah zone of Nigeria. Int. J. Agric. Food Sci., 2, 97–104.

Popova-Ralcheva, S. (2009). The effects of the age and genotype on morphological egg quality of parent stock hens. Arch. Zootechn., 12, 24–30.

Roberts, J. R. (2004). Factors affecting egg internal quality and egg shell quality in laying hens. Poult. Sci., 41, 3, 161–177.

Rossi, M. (2007). Influence of the laying hen housing systems on table egg characteristics. In XVIII European Symposium on the Quality of Poultry Meat and XII European Symposium on the Quality of Eggs and Egg Products (pp. 49–51). September 2–5, Prague.

Sekeroglu, A., Sarica, M., Demir, E., Ulutas, Z., Tilki, M., Saatci, M. (2008). The effects of housing system and storage lenght on the quality of eggs produced by two lines of laying hens. Arcg. Geflugelk., 72, 106–109.

Silversides, F., Scott, T. (2001). Effect of storage and leyer age on quality of egg from two lines of hens. Poultry Sci., 80, 1240–1245.

Silversides, F., Budgell, K. (2004). The relationships among measures of egg albumen height, pH and whipping volume. Poult. Sci., 83, 1619–1623.

Silversides, F., Korver, D., Budgell, K. (2006). Effect of strain of layer and age AT photostimulation on egg production, egg quality, and bone strength. Poult. Sci., 85, 1136–1144.

Simčič, M., Stibilj, V., Holcman, A. (2009). The cholesterol content of eggs produced by the Slovenian autochthonous Styrian hen. Food Chem., 114, 1–4.

Sokołowicz, Z., Krawczyk, J., Herbut, E. (2012). Jakość jaj z chowu ekologicznego w pierwszym i drugim roku użytkowania niosek [Quality of eggs from organically reared laying hens Turing their first and secondo year of production]. Żywn. Nauka Technol. Jakość, 4(83), 185–194 [in Polish].

Sosnówka-Czaja, E., Skomorucha, I., Herbut, E. (2014). Kształtowanie się wybranych cech jakościowych jaj kur rodzimego pochodzenia [Development of selected quality features of eggs of chickens of native origin]. Rocz. Nauk. Zoot., 41, 2, 93–105.

Strojny, J., Krawczyk, J., Cywa-Benko, K., Wężyk, S. (1998). Upodobania konsumentów jaj [Egg consumers' preferences]. Pol. Drob., 6, 3–5 [in Polish].

Strzeżek, J., Wołos, A. (1997). Steroidy. Ćwiczenia z biochemii [Steroidia. Biochemistry execises]. Olsztyn: ART [in Polish].

Suk, Y., Park, C. (2001). Effect of breed and age of hens on the yolk to albumen ratio in two different genetic stocks. Poult. Sci., 80, 855–858.

Szablewski, T., Gornowicz, E., Stuper-Szablewska, K., Kaczmarek, A., Cegielska-Radziejewska, R. (2013). Skład mineralny treści jaj kur ras zachowawczych z chowu ekologicznego [The mineral composition of eggs from hens of conservative breeds from organic farming]. Żywn. Nauka Technol. Jakość, 5(90), 42–51 [in Polish].

Trziszka, T. (Ed., 2000). Jajczarstwo [Egg production]. Nauka – technologia – praktyka. Wrocław: Wyd. AR.

Trziszka, T., Dobrzański, Z., Kaźmierska, M., Tronina, L., Skiba, M. (2011). Effect of dietary humic – fatty preparations on egg quality Lohmann Brown hens. Arch. Geflugelk., 75(2), 84–90.

Tůmova, E., Zita, L., Hybeny, M., Skrivan, M., Ledvinka, Z. (2007). The effect of oviposition time and genotype on egg quality characteristics in egg type hens. Czech. J. Anim. Sci., 52, 26–30.

Wlaź, M., Nowaczewski, S. (2018). Czy jaja od kur różnych ras różnią się znacznie jakością [Do eggs from chickens of different breeds differ significantly in quality]. Pol. Drob., 5, 6–9 [in Polish].

Wężyk, S., Gilewski, R. (2018). Spożycie jaj a zdrowie konsumentów [Egg consumption and consumer health]. Pol. Drob., 10, 36–38 [in Polish].

Van den Brand, H., Parmentier, H., Kemp, K. (2004). Effect of housing system (outdoor vs cages) and age of laying hens on egg characteristicks. Br. Poult. Sci., 45(6). 745–752.