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# THE EFFECT OF AGE AND GENOTYPE ON QUALITY OF EGGS IN BROWN EGG-LAYING HYBRIDS

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## Abstract

The aim was to assess the internal and external quality of consumer eggs of egg-laying hens of two selected genotypes depending on their age. All of these hens were kept in enriched cages. There were compared eggs from Hy-Line Brown and ISA Brown hens at the age from 36 to 64 weeks. In total, 3840 eggs from 300 hens were evaluated. Quality of eggs was determined by their technological value. Statistically significant interactions ($P = 0.001$) between age and genotype were found in all evaluated parameters except for the yolk colour ($P = 0.044$), whereas there was not found interaction ($P = 0.072$) between age and genotype in eggshell strength. The significant effect of hens' age was found in all evaluated parameters, with the only exception of the yolk colour. The results showed that the average weight of eggs, eggshell, albumen and yolk increased with the age. Also the eggshell proportion, its colour and yolk index values increased, whereas the egg shape index, eggshell thickness and strength, albumen proportion, Haugh units, the albumen and the yolk index decreased. Statistically significant effect of the genotype was found in all evaluated parameters except for the yolk index. When comparing both genotypes, the eggs from ISA Brown hens had a better quality. The trend of deteriorating egg quality with age was confirmed.

Keywords: egg, quality, age, yolk, albumen, eggshell, brown-egg layers, ISA Brown, Hy-Line Brown

## INTRODUCTION

Eggs are considered to be multifunctional and worldwide food. In terms of nutrition, eggs are almost complete food. They contain all the essential nutrients that are important for humans in development and also in later stages of life in a balanced amount (Iannotti *et al.*, 2014).

The quality of eggs is influenced by large number of factors, among the most important belong hens' age, genotype and nutrition (Tang *et al.*, 2015). Also housing system is a factor that has a significant effect on the final quality of eggs (Matt *et al.*, 2009). According to Johnston et Gous (2007) the age is one of the main internal factors that influences quality of eggs. The weight of eggs is therefore influenced by the age. In general, the weight of eggs significantly increases during the first three months of laying period. The hens' age also influences egg shape index (Ledvinka and

Klesalová, 2002), which decreases with the age (Rakib *et al.*, 2016). Quality of eggshell is also influenced by age. The eggshell is getting gradually thinner with the age, thus percentage proportion of eggshell is decreasing as well (Ledvinka and Klesalová, 2002). Also the quality of the internal parts is influenced by hens' age, eggs that are laid at the beginning of the laying period have higher Haugh units, albumen and yolk index (Bozkurt and Tekerli, 2009). Genotype is also undoubtedly one of the most important internal factors, which influences technological value of eggs. It mainly influences egg weight, but genotype has also influence on other egg characteristics. For example, composition of eggs (dry matter, fat, etc.) is also influenced to some extent by genotype, thus hereditary dispositions have a significant impact on the quality of eggs (Jones *et al.*, 2010). Ledvinka and Klesalová (2002) confirm the influence of the genotype on the quality of fresh eggs as well, genotype clearly influences internal indicators of egg quality.

This research that is focused on quality of eggs from enriched cages, was made because the enriched cage system is still the most used not only in the Czech Republic, but also in the European Union. The aim was to assess the internal and external quality of consumer eggs of brown egg-laying hens of two selected genotypes depending on their age.

## MATERIALS AND METHODS

There were compared eggs from Hy-Line Brown and ISA Brown hens at the age from 36 to 64 weeks. All these hens were kept in enriched cages that meet the criteria set by Directive 1999/74/EC, which indicates minimum standards for protection of laying hens. The microclimate conditions were the same throughout the whole experiment. The temperature ranged from 18 to 20 °C and humidity from 50 to 60%. There was applied 16-hour photoperiod and the lighting intensity was from 5 to 10 lux. Hens were fed by feed mixture that contained 16.1% of crude protein and 11.40 MJ of metabolizable energy. Access to feed and water was ad libitum. In this period the eggs were collected in regular intervals (every four weeks) three days in a row. The eggs were stored at constant temperature of 6 °C and the following day were analyzed. The technological value of eggs was assessed in the laboratory of the Department of Animal Sciences at the Czech University of Life Sciences Prague. During the laboratory analysis 1920 eggs from each genotype were evaluated. In total, 3840 eggs from 300 hens were evaluated. All of these hens came from the same animal management.

Both commercial hybrids belong to the egg-laying hens. ISA Brown is one of the most reliable hybrids, which is, apart from high egg production, known for a very good feed conversion. These hens are able to adapt to different temperature conditions and also to different housing systems without any problems (Hendrix Genetics, 2018). Hy-Line Brown hens are considered as the world most balanced egg layers. Their feed conversion is very good as well. In general, Hy-Line Brown hens are very similar to ISA Brown hens. Hy-Line Brown hens produce more eggs in comparison to ISA Brown hens, but their eggs are smaller and lighter (Hy-Line, 2018).

The weight of eggs and egg components was measured by laboratory scale Ohaus (Portable Advanced, Model No. CT600V, Florham Park, N. J. 0732, US). Egg shape index (ESI) was determined by formula ESI = (width/length) × 100 (in mm). An electronic sliding calliper (JOBI® profi) with 0.01 mm precision was used for the measurement. The proportions of the individual egg components were defined by calculation from the whole egg weight and concrete egg components × 100. Eggshell thickness (in mm) was determined by a digital micrometer (Digimatic Outside Micrometer, Mitutoyo Corporation, Japan) with 0.01 mm precision. The thickness was measured in the non-desiccated eggshells at their center and without eggshell membranes. Eggshell strength was defined by a destructive method, where the required force ($N/cm^2$) to crack the eggshell was measured (Instron Universal Testing Machine; model 3342; Instron Ltd., US). Eggshell colour was determined by reflectometer (TSS QCR reflectometer, Chessingham Park Dunnington, YORK YO19 5SE, England). Reflectometer uses light reflection for colour determination. The lower the value is, the darker the colour of eggshell is. Albumen index (AI) was defined by formula AI = (height in mm/average of length and width in mm) × 100 (in %). Various types of sliding electronic devices were used for measurement. Haugh units (HU) were defined by formula HU = 100 × log (height of albumen in mm – 1.7 × weight of egg in g $^{0.37}$ + 7.6). Yolk index (YI) was defined by formula YI = (height in mm/average of two mutually vertical values of width in mm) × 100 (in %). Yolk colour was determined by colour scale (DSM YolkFanTM, DSM, Netherlands). The higher the value is, the darker the yolk colour is.

The computer statistical program SAS (SAS Institute Inc. 2011. SAS User's Guide. Statistics. Version 9.4 ed. SAS Inst. Inc., Cary, NC, US) was used to statistically evaluate data obtained from the laboratory analysis of the eggs. Effect of age and genotype on selected parameters of technological value of eggs was evaluated by the mixed model using the MIXED procedure of SAS: $y_{ijk} = \mu + A_i + G_j + (A \times G)_{ij} + e_{ijk}$, where $y_{ijk}$ was the value of the sign, $A_i$ was the effect of age, $G_j$ was the effect of genotype, $(A \times G)_{ij}$ was the effect of interaction between age and genotype, $e_{ijk}$ was the random residual error. The significance of differences between the groups was tested by the multiple Duncan test. A value of $P \leq 0.05$ was considered as a statistically significant for all measurements.

## RESULTS

Results of the effect of the age and genotype on selected parameters are shown in the Tab I. and II. Egg weight, egg shape index, eggshell proportion, thickness, strength and colour values are shown in the Tab. I. Yolk and albumen proportion, yolk and albumen index, yolk colour and Haugh units are shown in the Tab. II.

It is obvious that egg weight was significantly (P = 0.001) influenced by both, age and genotype (Tab. I.). There was found the interaction (P = 0.001) between age and genotype in egg weight, where the heaviest eggs were from 44, 48, 52 and 64-week-old ISA Brown hens (72.94, 73.10, 72.33 and 72.27 g) and 60-week-old Hy-Line Brown hens (72.99 g) and the lightest eggs were from

I: *Technological value of egg and eggshell parameters depending on age and genotype*

| Item | | Parameter | | | | | |
|---|---|---|---|---|---|---|---|
| **Genotype** | **Age (weeks)** | **Egg weight (g)** | **Egg shape index (%)** | **Eggshell proportion (%)** | **Eggshell thickness (mm)** | **Eggshell strength (N/cm²)** | **Eggshell colour (%)** |
| **ISA** | **36** | $69.85^{c}$ | $78.82^{a}$ | $10.04^{bc}$ | $0.345^{d}$ | 43.85 | $26.16^{e}$ |
| | **40** | $71.72^{ab}$ | $78.08^{ab}$ | $10.19^{b}$ | $0.343^{de}$ | 43.28 | $27.57^{cde}$ |
| | **44** | $72.94^{a}$ | $78.00^{abc}$ | $10.05^{bc}$ | $0.293^{f}$ | 44.54 | $27.12^{de}$ |
| | **48** | $73.10^{a}$ | $77.12^{cd}$ | $10.08^{b}$ | $0.361^{bc}$ | 43.09 | $26.84^{de}$ |
| | **52** | $72.33^{a}$ | $77.75^{bc}$ | $10.11^{b}$ | $0.364^{abc}$ | 45.21 | $31.02^{a}$ |
| | **56** | $70.06^{bc}$ | $77.23^{bcd}$ | $10.21^{b}$ | $0.368^{ab}$ | 41.75 | $32.06^{a}$ |
| | **60** | $71.52^{abc}$ | $77.58^{bc}$ | $10.26^{ab}$ | $0.361^{bc}$ | 43.66 | $32.63^{a}$ |
| | **64** | $72.27^{a}$ | $76.34^{de}$ | $10.13^{b}$ | $0.372^{a}$ | 41.06 | $31.81^{a}$ |
| **HL** | **36** | $61.70^{f}$ | $75.83^{efg}$ | $9.63^{de}$ | $0.333^{e}$ | 37.94 | $29.19^{b}$ |
| | **40** | $65.18^{d}$ | $77.49^{bc}$ | $9.49^{e}$ | $0.337^{de}$ | 37.40 | $28.37^{bcd}$ |
| | **44** | $62.70^{ef}$ | $75.42^{fg}$ | $9.66^{de}$ | $0.357^{c}$ | 38.88 | $29.07^{bc}$ |
| | **48** | $65.01^{d}$ | $76.03^{ef}$ | $9.83^{cd}$ | $0.342^{de}$ | 38.93 | $27.03^{de}$ |
| | **52** | $63.91^{de}$ | $76.40^{de}$ | $10.47^{a}$ | $0.339^{de}$ | 34.86 | $27.32^{de}$ |
| | **56** | $70.28^{bc}$ | $75.75^{efg}$ | $9.72^{d}$ | $0.334^{e}$ | 35.55 | $29.00^{bc}$ |
| | **60** | $72.99^{a}$ | $74.97^{g}$ | $9.72^{de}$ | $0.335^{e}$ | 35.38 | $27.01^{de}$ |
| | **64** | $71.51^{abc}$ | $74.97^{g}$ | $9.67^{de}$ | $0.274^{g}$ | 36.29 | $29.31^{b}$ |
| **SEM** | | 0.203 | 0.090 | 0.023 | 0.001 | 0.280 | 0.157 |
| **Significance** | **A** | 0.001 | 0.001 | 0.001 | 0.001 | 0.026 | 0.001 |
| | **G** | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| | **A × G** | 0.001 | 0.001 | 0.001 | 0.001 | 0.072 | 0.001 |

Values marked with different superscript letters in each column are significantly different (P ≤ 0.05); ISA – ISA Brown; HL – Hy-Line Brown; A – Age; G – Genotype; A × G – Interaction between age and genotype; SEM – Standard Error of the Mean

36-week-old Hy-Line Brown hens (61.70 g). Also the egg shape index was significantly (P = 0.001) influenced by age and genotype. The highest (P = 0.001) egg shape index was at eggs from 36-week-old ISA Brown hens (78.82%) and the lowest at eggs from 60 and 64-week-old Hy-Line Brown hens (74.97%).

Eggshell proportion was significantly (P = 0.001) influenced by age and genotype. The highest (P = 0.001) eggshell proportion was at eggs from 52-week-old Hy-Line Brown hens (10.47%) and the lowest at eggs from 40-week-old Hy-Line Brown hens (9.49%). Another measured eggshell parameter was its thickness. Effect of age and genotype was also statistically significant (P = 0.001). The highest (P = 0.001) eggshell thickness was at eggs from 64-week-old ISA Brown hens (0.372 mm), whereas, the lowest at eggs from 64-week-old Hy-Line Brown hens (0.274 mm). Eggshell strength was another parameter that was evaluated and was significantly influenced by age (P = 0.026) and genotype (P = 0.001). There was not found interaction (P = 0.072) between age and genotype in eggshell strength. The last eggshell parameter that was evaluated was eggshell colour. Eggshell colour, as well as all other measured eggshell parameters, was significantly (P = 0.001) influenced by the age and genotype and their interaction. The darkest (P = 0.001) eggshell colour was at eggs from 36-week-old ISA Brown hens (26.16%) and the lightest colour at eggs from 52, 56, 60 and 64-week-old ISA Brown hens (31.02, 32.06, 32.63 and 31.81%).

Statistically significant effect (P = 0.001) in the yolk proportion was confirmed in both age and genotype (Tab. II). There was found the interaction (P = 0.001) between age and genotype in yolk proportion, where the highest yolk proportion was

II: *Technological value of yolk and albumen parameters depending on age and genotype*

| **Item** | | **Parameter** | | | | | |
|---|---|---|---|---|---|---|---|
| **Genotype** | **Age (weeks)** | **Yolk proportion (%)** | **Yolk index (%)** | **Yolk colour** | **Albumen proportion (%)** | **Albumen index (%)** | **Haugh units** |
| **ISA** | **36** | 25.23$^{ef}$ | 43.05$^{cdef}$ | 11.65$^{cdef}$ | 64.73$^{abc}$ | 10.25$^{def}$ | 85.91$^{gh}$ |
| | **40** | 25.41$^{cdef}$ | 43.91$^{bc}$ | 12.05$^{ab}$ | 64.40$^{abc}$ | 10.44$^{cdef}$ | 87.81$^{efg}$ |
| | **44** | 25.19$^{ef}$ | 41.91$^{gh}$ | 11.95$^{abc}$ | 64.75$^{ab}$ | 10.25$^{def}$ | 87.38$^{efg}$ |
| | **48** | 25.84$^{bcde}$ | 43.96$^{b}$ | 11.68$^{bcde}$ | 64.08$^{bc}$ | 9.96$^{ef}$ | 85.44$^{gh}$ |
| | **52** | 25.33$^{def}$ | 44.33$^{b}$ | 11.82$^{abcd}$ | 64.56$^{abc}$ | 10.78$^{bcd}$ | 89.18$^{cdef}$ |
| | **56** | 25.15$^{f}$ | 43.83$^{bc}$ | 11.90$^{abc}$ | 64.64$^{abc}$ | 10.96$^{bcd}$ | 88.48$^{defg}$ |
| | **60** | 25.48$^{cdef}$ | 42.94$^{def}$ | 12.08$^{a}$ | 64.27$^{bc}$ | 9.68$^{fg}$ | 86.02$^{fgh}$ |
| | **64** | 25.35$^{def}$ | 40.68$^{i}$ | 12.17$^{a}$ | 64.52$^{abc}$ | 10.38$^{cdef}$ | 88.46$^{defg}$ |
| **HL** | **36** | 25.59$^{cdef}$ | 44.41$^{b}$ | 11.28$^{f}$ | 64.77$^{ab}$ | 11.48$^{ab}$ | 92.55$^{ab}$ |
| | **40** | 25.89$^{bcd}$ | 45.47$^{a}$ | 11.48$^{def}$ | 64.63$^{abc}$ | 12.12$^{a}$ | 95.04$^{a}$ |
| | **44** | 26.32$^{b}$ | 42.56$^{efg}$ | 11.43$^{def}$ | 64.02$^{c}$ | 11.11$^{bc}$ | 91.26$^{bcd}$ |
| | **48** | 25.16$^{f}$ | 43.70$^{bcd}$ | 11.78$^{abcd}$ | 65.01$^{a}$ | 11.02$^{bcd}$ | 91.95$^{abc}$ |
| | **52** | 28.63$^{a}$ | 42.39$^{efg}$ | 11.60$^{cdef}$ | 60.90$^{d}$ | 9.01$^{g}$ | 83.44$^{h}$ |
| | **56** | 25.94$^{bcd}$ | 42.15$^{fg}$ | 11.62$^{cdef}$ | 64.34$^{abc}$ | 11.16$^{bc}$ | 90.41$^{bcde}$ |
| | **60** | 26.01$^{bc}$ | 42.87$^{def}$ | 11.68$^{bcde}$ | 64.27$^{bc}$ | 10.61$^{cde}$ | 87.34$^{efg}$ |
| | **64** | 26.31$^{b}$ | 41.18$^{hi}$ | 11.30$^{ef}$ | 64.02$^{c}$ | 9.87$^{ef}$ | 86.25$^{fgh}$ |
| **SEM** | | 0.064 | 0.088 | 0.035 | 0.071 | 0.076 | 0.301 |
| **Significance** | **A** | 0.001 | 0.001 | 0.191 | 0.001 | 0.001 | 0.001 |
| | **G** | 0.001 | 0.902 | 0.001 | 0.001 | 0.002 | 0.001 |
| | **A × G** | 0.001 | 0.001 | 0.044 | 0.001 | 0.001 | 0.001 |

Values marked with different superscript letters in each column are significantly different (P ≤ 0.05); ISA – ISA Brown; HL – Hy-Line Brown; A – Age; G – Genotype; A × G – Interaction between age and genotype; SEM – Standard Error of the Mean at eggs from 52-week-old Hy-Line Brown hens (28.63%) and the lowest at eggs from 56-week-old ISA Brown hens (25.15%) and 48-week-old Hy-Line Brown hens (25.16%). The next evaluated yolk parameter was yolk index. Significant effect (P = 0.001) of age was confirmed in the yolk index. Effect of genotype was not significant (P = 0.902). There was found the interaction (P = 0.001) between age and genotype in yolk index, where the highest yolk index was at eggs from 40-week-old Hy-Line Brown hens (45.47%) and the lowest at eggs from 64-week-old ISA Brown hens (40.68%). The last measured yolk parameter was yolk colour. Yolk colour was not significantly influenced by the age (P = 0.191), but was significantly influenced by genotype (P = 0.001). There was found the interaction (P = 0.044) between age and genotype in yolk colour, where the darkest colour was at eggs from 60 and 64-week-old ISA Brown hens (12.08 and 12.17) and the lightest at eggs from 36-week-old Hy-Line Brown hens (11.28).

Albumen proportion was one of the albumen parameters that were evaluated. Statistically significant effect (P = 0.001) of both age and genotype was found in the albumen proportion. Also the significant interaction (P = 0.001) was found between age and genotype in albumen proportion, where the highest albumen proportion was at eggs from 48-week-old Hy-Line Brown hens (65.01%), whereas, the lowest albumen proportion was at eggs from 52-week-old Hy-Line Brown hens (60.90%). Albumen index was also observed. Significant effect of age (P = 0.001) and genotype (P = 0.002) and their interaction (P = 0.001) was found in this parameter as well. The highest albumen index was at eggs from 40-week-old Hy-Line Brown hens (12.12%) and the lowest at eggs from 52-week-old Hy-Line Brown hens (9.01%).

The last evaluated albumen parameter were Haugh units. Haugh units were significantly (P = 0.001) influenced by age, genotype and their interaction. The highest Haugh units were at eggs from 40-week-old Hy-Line Brown hens (95.04), whereas, the lowest at eggs from 52-week-old Hy-Line Brown hens (83.44).

## DISCUSSION

Final quality not only of the whole eggs, but also of the individual egg components, is influenced by numerous factors. The most important factors are undoubtedly age and genotype (Tang *et al.*, 2015). Our results confirm that age and genotype have impact on quality of the whole egg and also on quality on its components. Almost all of the measured parameters were significantly influenced by both age and genotype.

According to Ledvinka *et al.* (2009), egg weight is influenced by several factors including age and genotype. Our measured values confirm that egg weight was significantly influenced by both age and genotype. In our experiment it was found that egg weight increased with the age. Also Bozkurt and Tekerli (2009) found out that eggs from older egg-laying hens have higher weight. This fact is confirmed by number of other authors, e.g. Johnston and Gous (2007), Krawczyk (2009) or Zita *et al.* (2009). Ledvinka *et al.* (2009) agree with this statement, but they add that egg weight increases gradually with the age which is in contradiction with our results. Zita *et al.* (2009) and Sokołowicz *et al.* (2018) also confirm that genotype has an effect on egg weight. Furthermore, Ledvinka and Klesalová (2002) claim that genotype have effect not only on the technological value of fresh eggs, but also on the technological value of internal components. There was found the interaction between the age and genotype in egg weight. Also Zita *et al.* (2009) found the interaction between the age and genotype in egg weight. Egg shape index was significantly influenced by age and genotype as well. In the second half of the monitored period, the decreasing trend of egg shape index is obvious from the observed results. Eggs had more elongated shape with the age and, therefore, more ideal egg shape index values. Rakib *et al.* (2016) also confirmed that the value of the egg shape index decreases with the age. Results from Molnár *et al.* (2016) show that from the age of 60 weeks egg shape index decreased every other week. Also Zita *et al.* (2009), Halaj and Golian (2011) and Sokołowicz *et al.* (2018) state that egg shape index is influenced by genotype. There was found the interaction between the age and genotype in egg shape index in our study. Also Zita *et al.* (2009) found the interaction between the age and genotype in egg shape index. Kul and Seker (2004) claim that egg shape index values are usually between 63 and 85%, which corresponds with our results.

Significant effect of age and genotype was found in eggshell proportion. Ledvinka and Klesalová (2002) claim that eggshell proportion decreases with the age. However, our results did not clearly show whether eggshell proportion increased or decreased with the age. Also, according to Zita *et al.* (2009), genotype has a significant effect on eggshell proportion. There was found the interaction between the age and genotype in eggshell proportion. Zita *et al.* (2009) also found the interaction between hens' age and genotype in eggshell proportion. Zaheer (2015) states that eggshell represents 9–12% of the whole egg, which corresponds with the results from our analysis. Eggshell thickness was also significantly influenced by age and genotype. The eggshell thickness values fluctuated during the monitored period in relation to genotype. Also Ledvinka and Klesalová (2002) and Bozkurt and Tekerli (2009) agree that eggshell thickness decreases with the age. Vice versa Zita *et al.* (2009) claim that eggshell thickness increases with the age. Zita *et al.* (2009) and Sokołowicz *et al.* (2018) found out that genotype has a significant effect on eggshell thickness as well. There was found the interaction between the age and genotype in eggshell thickness. Results from Zita *et al.* (2009) also show interaction between hens' age and genotype in eggshell thickness. Ketta and Tůmová (2017) state that eggshell thickness varies between 0.28 and 0.41 mm, which corresponds with the results from our analysis. Eggshell strength was significantly influenced by age and genotype. Even though the fluctuations in eggshell strength were obvious during the monitored period, it can be stated that eggshell strength decreased with the age. Also according to Krawczyk (2009), eggshell strength decreases with the age. Kocevski *et al.* (2011) also state that genotype influences eggshell quality, especially eggshell strength. On contrary, Sokołowicz *et al.* (2018) claim that eggshell strength is not influenced by genotype. Unlike our results, Zita *et al.* (2009) found a significant interaction between hens' age and genotype in eggshell strength. Eggshell colour was significantly influenced by age and genotype as well. Eggshell colour varied during the whole monitored period, nevertheless the results show that darker eggshell colour was found in eggs from younger ISA Brown hens than in eggs from older ISA Brown hens. Eggshell colour of eggs from Hy-Line Brown hens fluctuated during the monitored period. This is in agreement with results from Ledvinka *et al.* (2014). Zita *et al.* (2009) claim that eggshell colour is significantly influenced by genotype. Zaheer (2015) and Sokołowicz *et al.* (2018) confirm this fact as well. There was found the interaction between the age and genotype in eggshell colour. Zita *et al.* (2009) also found the interaction between genotype and hens' age in eggshell colour.

Results obtained from the laboratory analysis showed that yolk proportion was significantly influenced by age and genotype. Yolk proportion values were relatively balanced during the whole monitored period. However, Nagy *et al.* (2009) state yolk proportion increases with the age. Zita *et al.* (2009) found out that yolk proportion is influenced by genotype as well. There was found the interaction between the age and genotype in yolk proportion. Zita *et al.* (2009) also found interaction between hens' age and genotype in yolk proportion. Zaheer (2015) claims that yolk represents 30–32% of the whole egg, but our results showed that the yolk proportion was only between 25 and 26%. Yolk index was significantly influenced by age, but was not significantly influenced by genotype. Our results show that the yolk index decreased in the second half of the monitored period. Bozkurt and Tekerli (2009) and Ledvinka *et al.* (2014) claim that yolk index decreases with the age as well. Zita *et al.* (2009) and Ledvinka *et al.* (2014) claim that genotype have a significant effect on yolk index unlike our results. There was found the interaction between the age and genotype in yolk index. Zita *et al.* (2009) also found the interaction between hens' age and genotype in yolk index. According to Nagy *et al.* (2009), yolk index values are usually between 32 and 58%, our values also fall into this range. Yolk colour was not significantly influenced by age, but was significantly influenced by genotype. Ledvinka *et al.* (2014) found the exact opposite that yolk colour was significantly influenced by age, but was not significantly influenced by genotype. There was found the interaction between the age and genotype in yolk colour. Ledvinka *et al.* (2014) also found the interaction between hens' age and genotype in yolk colour.

Albumen proportion was significantly influenced by age and genotype. Albumen proportion values were very balanced during the whole monitored period. Zita *et al.* (2009) and Ledvinka *et al.* (2014) also state that both age and genotype influence albumen proportion. There was found the interaction between the age and genotype in albumen proportion. Zita *et al.* (2009) also found the interaction between hens' age and genotype in albumen proportion. According to Guerrero-Legarreta (2010), albumen proportion represents approximately 58.5% of the whole egg, but our values were higher, in average around the 64%. Albumen index was significantly influenced by age and also by genotype. Albumen index values significantly fluctuated during the monitored period, so it is not possible to determine whether albumen index increased or decreased. Bozkurt and Tekerli (2009) state that age have effect on albumen index, their results show that eggs from younger hens have higher albumen index than from older hens. Results from

Zita *et al.* (2009) show that albumen index is not significantly influenced by genotype unlike our results. There was found the interaction between the age and genotype in albumen index. Zita *et al.* (2009) also found the interaction between hens' age and genotype in albumen index. Haugh units were significantly influenced by age and genotype. Haugh units significantly fluctuated during the whole monitored period, nevertheless it is possible to claim that the obtained values were higher in the first half of this period than in the second. Bozkurt and Tekerli (2009) also state that Haugh units are influenced by age, according to their results, eggs from younger hens have higher Haugh units than eggs from older hens. Molnár *et al.* (2016) found out that after 60 weeks of age Haugh units decreased by 0.38 every next week, but our results did not confirm this. According to Tůmová *et al.* (2007) and Zita *et al.* (2009), Haugh units are significantly influenced by genotype as well. There was found the interaction between the age and genotype in Haugh units. Zita *et al.* (2009) also found the interaction between hens' age and genotype in Haugh units. There can be seen relationship between albumen index and Haugh units. As the values of albumen index increased, the values of Haugh units increased as well in the vast majority of cases.

## CONCLUSION

The results show that the significant effect of age was found in all evaluated parameters, with the only exception of the yolk colour. Average weight of eggshell, albumen and yolk increased with the age. Eggshell proportion, eggshell colour and yolk proportion were also higher at the end of the monitored period, whereas egg shape index, eggshell thickness and strength, albumen proportion and index, Haugh units and yolk index decreased. Not all measured values increased or decreased regularly. Also the significant effect of genotype was found in all measured parameters except for the yolk index. There was not found statistically significant interaction (P = 0.072) between age and genotype in eggshell strength. Interactions between age and genotype in all other evaluated parameters were found significant (P = 0.001) except for the yolk colour (P = 0.044). The results evidently show that the most of the measured values were significantly higher in eggs from ISA Brown hens than in eggs from Hy-Line Brown hens. Only values of the albumen index, Haugh units and yolk proportion were found to be higher in Hy-Line Brown eggs. It is obvious that the eggs from ISA Brown hens had a better quality.

In conclusion, it can be stated that the trend of deteriorating egg quality with the age was confirmed regardless of genotype. Simultaneously, effect of age and genotype on egg quality, was confirmed.

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