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How genotype influences the egg quality in the second half of laying cycle?

Jak genotyp ovlivňuje kvalitu vajec ve druhé polovině snáškového cyklu?

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ABSTRACT

The objective of this study was to determine and compare egg quality from two genotypes of brown egg-laying hens in the second half of laying cycle (from 46 to 74 weeks of age). Commercial hybrids Hisex Brown and Lohmann Brown Classic were used in this study. Both genotypes were kept in enriched cages. 1920 eggs were evaluated. The significant effect of genotype was found in all evaluated traits except for the eggshell proportion and reflectivity. Results show that eggs from Lohmann Brown Classic hens had a superior quality in majority of the evaluated traits. Higher values were observed in main egg quality traits, such as egg weight (by 1.45 g, $P \leq 0.0001$), eggshell strength (by 2.48 $N*cm^{-2}$, $P \leq 0.0005$) and Haugh units (by 3.27, $P \leq 0.0001$). The significant effect of age was determined in all selected egg quality traits. The egg weight increased with the age, meanwhile other traits such as egg shape, albumen and yolk index, Haugh units and eggshell strength decreased. The trend of the rest of evaluated traits was ambiguous. Furthermore, the interactions between genotype and age were determined. Regarding the extension of laying cycle, further research is required, because the egg quality rapidly decreases with the age.

Keywords: age, albumen, egg, eggshell, genotype, layer, technological value, yolk

ABSTRAKT

Cílem této studie bylo stanovit a porovnat vybrané fyzikální vlastnosti vajec od dvou genotypů hnědovaječných nosnic ve druhé polovině snáškového cyklu (od 46 do 74 týdnů věku). V této studii byli použiti komerční hybridi Hisex Brown a Lohmann Brown Classic. Oba genotypy byly ustájeny v obohacených klecích. Bylo hodnoceno 1920 vajec. Signifikantní vliv genotypu byl zjištěn ve všech hodnocených parametrech kromě podílu skořápky a reflektivity skořápky. Výsledky ukazují, že vejce od slepic Lohmann Brown Classic měla vyšší kvalitu ve většině hodnocených parametrů. Lepší hodnoty byly zjištěny u hlavních parametrů technologické hodnoty vajec, jako jsou hmotnost vejce (o 1,45 g, $P \leq 0{,}0001$), pevnost skořápky (o 2,48 $N*cm^{-2}$, $P \leq 0{,}0005$) a Haughovy jednotky (o 3,27, $P \leq 0{,}0001$). Signifikantní vliv věku byl stanoven u všech vybraných kvalitativních parametrů vejce. Hmotnost vajec se s věkem zvyšovala, zatímco se snižovaly hodnoty ostatních parametrů, jako jsou index tvaru vejce, bílku a žloutku, Haughovy jednotky a pevnost skořápky. Trend u ostatních hodnocených parametrů byl kolísavý. Dále byly stanoveny interakce mezi genotypem a věkem. Z hlediska prodloužení snáškového cyklu je nutný další výzkum, protože kvalita vajec se s věkem rapidně snižuje.

Klíčová slova: věk, bílek, vejce, skořápka, genotyp, nosnice, technologická hodnota, žloutek

INTRODUCTION

Eggs of laying hens belong to basic animal products with a rich nutritional value. Eggs are a great source of essential fatty acids, proteins, choline, vitamin A and B_{12} and more health beneficial substances (Iannoti et al., 2014). The egg quality is important from both, producers' and consumers' point of view. Among the most important quality factors for consumers belong safety and freshness followed by nutritional value and sensory characteristics. One of the most significant factors for producers is eggshell quality. Hence, defects and unusual changes in egg appearance such as cracks or atypical shape are not desirable (Hernandez et al., 2005). The invisible threat could be bacterial contamination of eggs (Rodríguez-Navarro et al., 2013). Numerous internal (e.g. production type, genotype, age) and external (e.g. nutrition, ambient temperature, housing system) factors have a direct impact on egg quality. Especially genotype and age of layers belong to the most important ones (Kraus and Zita, 2019).

In general, the quality of eggs deteriorates with the age of hens. This fact was previously confirmed in many studies including Ledvinka et al. (2011), Zita et al. (2013) and Kraus and Zita (2019). Currently, one of the trends in management practices of laying hybrids is that the laying cycle of hens is being extended despite the inferior egg quality. Thus, it is essential to work on the improvements of egg quality when considering prolonged laying cycle (Liu et al. 2018).

Both used hybrids belong to the group of brown egg-laying type hens. Hisex Brown hens are well known for their high egg production, because they can lay up to 422 eggs during the laying period (from 18 to 90 weeks of age) with average egg weight 62.5 g (Hisex, 2019). Lohmann Brown Classic are capable of laying up to 433 eggs until 17 months of age. The average egg weight is 64.75 g (Lohmann Tierzucht 2016).

The purpose of this study was to evaluate egg quality of hens in the second half of the laying cycle. The reason is that differences in egg quality are considerably higher in the second half of laying cycle than in the first one. The objective was to determine and compare selected physical characteristics of eggs from two selected brown egg-laying genotypes in the second half of laying cycle (from 46 to 74 weeks of age).

MATERIALS AND METHODS

Animals and housing

Commercial hybrids Hisex Brown and Lohmann Brown Classic were used in the study. Layers from both genotypes were kept in enriched cages, where all requirements for hen protection, which are set by the Directive 1999/74/EC, were met. The cages were installed in laying halls and in each cage, 10 hens were placed. In total, 150 hens of each genotype were included. The lighting program was set to 14 hours of light with the intensity of light of 5 lx. The constant temperature of 21 °C was kept in the hall with enriched cages. Hens had an unlimited access to water and feed within the duration of the whole experiment. There was used feed mixture N2-T that contained 16.3% of crude protein, 2.5% of fibre, 3% of oils and fat, 12.5% of ash, 0.76% of lysine, 0.36% of methionine, 3.65% of calcium, 0.5% of phosphorus and 0.15% of sodium. The content of metabolizable energy was calculated at 11.47 MJ.

Laboratory evaluation

Eggs for the laboratory analysis were collected in regular 28 days intervals from both genotypes of hens in the second half of laying cycle, specifically from 46 to 74 weeks of age. The egg collection took place two days in a row to reach required number of eggs for the analysis. Immediately after the collection, eggs were placed into the cooling room, where the temperature was set to 6 °C. The laboratory assessment of the egg quality was realized the following day after the collection in the laboratory of Department of Animal Science. For the purpose of the analysis, 120 eggs from each genotype were evaluated at each age group, which means that 960 eggs from each genotype were used.

Laboratory scale Ohaus (Portable Advanced, Model No. CT600V, Florham Park, N. J. 0732, US) with 0.1 g precision was used for the measurement of the egg weight and individual egg components. 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 egg components were calculated from the weight of the egg and concrete egg component * 100 (in %). 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 three different parts of the eggshell and without eggshell membranes. The average value was calculated from the measured data. 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). Reflectometer (TSS QCR reflectometer, Chessingham Park Dunnington, YORK YO19 5SE, England) was used for the determination of eggshell reflectivity. 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 calculated by formula YI = (height in mm/average of two mutually vertical values of width in mm) * 100 (in %). There were used same sliding electronic devices for measurement as for the albumen index. Colour scale (DSM YolkFan™, DSM, Netherlands) was used for the determination of the yolk colour.

Statistical evaluation

The statistical computer program SAS 9.4 (SAS Inst., 2011) was used for the evaluation of obtained data that were determined by two-way analysis of variance. The effect of age and genotype on selected traits of egg quality was calculated by the mixed model by MIXED PROC of SAS: $y_{ijk} = \mu + A_i + G_j + AG_{ij} + e_{ijk}$, where y_{ijk} was the value of the sign, A_i was the effect of age (from 46 to 74 weeks of age), G_j was the effect of genotype (Hisex Brown, Lohmann Brown Classic), AG_{ij} was the effect of interaction between age and genotype and e_{ijk} was the random residual error. The significance of statistical differences was calculated by Scheffe test ($P \le 0.05$). The interactions that were calculated are not listed in the tables but were commented when significant.

RESULTS AND DISCUSSION

The results obtained from the observation of the effect of age and genotype on the egg quality are presented in Tables 1 and 2. Egg quality traits related to the whole egg and eggshell are listed in the first table (Table 1), while traits related to albumen and yolk are listed in the second one (Table 2).

The obtained data show that vast majority of selected quality traits differed significantly based on genotype of laying hens. The non-significant differences between eggs from Hisex Brown and Lohmann Brown Classic were discovered only in two evaluated traits, the eggshell proportion and reflectivity. The significant effect of age was found in all assessed traits. The interactions between age and genotype were observed in all traits apart from the egg shape index, the eggshell proportion and reflectivity.

Comparing the effect of genotype, Lohmann Brown Classic hens had a superior egg quality in most of the evaluated traits than Hisex Brown hens. Higher values were observed in main egg quality traits, such as egg weight (by 1.45 g), eggshell strength (2.48 $N*cm^{-2}$) and Haugh units (by 3.27). Other traits, where the higher values were found in eggs from Lohmann Brown Classic hens, were eggshell proportion (by 0.1 percentage points), thickness (by 0.009 mm) and reflectivity (by 0.47 percentage points), albumen proportion (by 0.39 percentage points), albumen index (0.62 percentage points) and yolk index (by 2.15 percentage points). Vice versa, values of egg shape index (by 1.01 percentage points), yolk proportion (by 0.47 percentage points) and yolk colour (by 0.8) were higher in eggs from Hisex Brown hens. The fact that genotype significantly influences egg quality traits was previously verified by large number of

Table 1. The effect of age and genotype on the whole egg and eggshell quality traits

		Trait					
		EW (g)	ESI (%)	EP (%)	EST ($N*cm^{-2}$)	ET (mm)	ER (%)
Age (weeks)	46	64.72^{ab}	77.72^{a}	9.79^{b}	37.91^{ab}	0.338^{c}	31.34^{a}
	50	64.89^{ab}	77.25^{ab}	10.15^{a}	42.31^{a}	0.354^{ab}	31.25^{a}
	54	64.28^{ab}	76.69^{ab}	10.07^{a}	38.86^{ab}	0.347^{abc}	30.63^{ab}
	58	63.08^{b}	76.09^{b}	9.96^{ab}	38.94^{ab}	0.342^{bc}	30.58^{ab}
	62	64.51^{ab}	76.89^{ab}	10.04^{a}	38.06^{ab}	0.359^{a}	30.71^{ab}
	66	64.09^{ab}	76.52^{ab}	10.05^{a}	38.32^{ab}	0.347^{abc}	29.29^{b}
	70	64.31^{ab}	76.28^{ab}	9.79^{b}	38.11^{ab}	0.339^{bc}	31.71^{a}
	74	65.74^{a}	75.97^{b}	9.94^{ab}	35.43^{b}	0.341^{bc}	31.41^{a}
Genotype	HB	63.73^{b}	77.18^{a}	9.92	37.25^{b}	0.341^{b}	30.63
	LB	65.18^{a}	76.17^{b}	10.02	39.73^{a}	0.350^{a}	31.10
Significance	A	0.0011	0.0003	0.0014	0.0010	0.0001	0.0123
	G	0.0001	0.0001	0.0521	0.0005	0.0001	0.1652
	AG	0.0001	0.1852	0.2143	0.0020	0.0001	0.5025
SEM		0.1484	0.1080	0.0253	0.3645	0.0011	0.1680

EW – Egg weight; ESI – Egg shape index; EP – Eggshell proportion; EST – Eggshell strength; ET – Eggshell thickness; ER – Eggshell reflectivity; Values with the same superscript letter in each trait differ non-significantly (P>0.05); HB – Hisex Brown; LB – Lohmann Brown Classic; A – Age; G – Genotype; AG – Interaction between age and genotype; SEM – Standard Error of the Mean

authors such as Rizzi and Marangon (2012), Ledvinka et al. (2015) or Zita et al. (2018). Some of the studies were even focused on the physical features of eggs from the same hybrids, Hisex Brown and Lohmann Brown Classic. Zita et al. (2009) measured, beside other hybrids, the egg quality of Hisex Brown hens, while Blanco et al. (2014) studied egg quality of Lohmann Brown Classic hens.

The significant effect of age was found in egg weight, which increased with the age of layers. Even though the increase of egg weight was not constant, the heaviest eggs came from the oldest hens. The significant effect of age and the simultaneously increasing trend of egg weight with the age determined Zita et al. (2009). The average egg weight varied from 63.08 to 65.74 g during the monitored period, which fits into the optimal range of egg weight that is, according to Nys et al. (2011), between 53 and 73 g. The significant effect of age was found not only in egg shape index, but also in albumen and yolk index, which confirmed findings from Kraus and Zita (2019). The age significantly influenced all selected eggshell quality traits. Ledvinka et al. (2011) found the significant effect of age on eggshell proportion, while Kraus and Zita (2019) discovered that the age significantly affects eggshell strength, thickness and reflectivity. The trend of eggshell proportion was not regular during the monitored period. On the other hand, the trend of eggshell strength was evident. The decrease of eggshell strength with the age was not constant, but the difference between the first and last measured value is obvious. The values of eggshell reflectivity fluctuated throughout the duration of the experiment. The statistically significant effect of age was determined in albumen proportion. Mitrovic et al. (2010) found that age significantly influences albumen proportion. Haugh units were significantly affected by age, which is in accordance with the results from Kim et al. (2012). Values of Haugh units decreased in the major

Table 2. The effect of age and genotype on the albumen and yolk quality traits

		Trait					
		AP (%)	AI (%)	HU	YP (%)	YI (%)	YC
Age (weeks)	46	62.22^{ab}	7.37^{a}	77.22^{a}	27.99^{bc}	41.64^{a}	10.54^{ab}
	50	61.93^{ab}	6.41^{b}	72.45^{ab}	27.92^{bc}	41.57^{ab}	10.99^{ab}
	54	61.49^{abc}	5.91^{cb}	70.33^{bc}	28.44^{abc}	39.77^{cd}	11.08^{ab}
	58	60.64^{c}	5.46^{cd}	66.84^{cd}	29.40^{a}	40.83^{abc}	11.22^{a}
	62	61.30^{bc}	5.58^{cd}	67.67^{bcd}	28.66^{ab}	39.05^{d}	10.17^{b}
	66	61.30^{bc}	5.62^{cd}	67.76^{bcd}	28.65^{ab}	40.61^{abc}	10.25^{b}
	70	61.40^{bc}	5.18^{cd}	66.51^{cd}	28.81^{ab}	39.60^{cd}	11.33^{a}
	74	62.68^{a}	5.11^{d}	65.12^{d}	27.38^{c}	40.31^{bc}	10.83^{ab}
Genotype	HB	61.43^{b}	5.52^{b}	67.60^{b}	28.65^{a}	39.35^{b}	11.20^{a}
	LB	61.82^{a}	6.14^{a}	70.87^{a}	28.16^{b}	41.50^{a}	10.40^{b}
Significance	A	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	G	0.0178	0.0001	0.0001	0.0016	0.0001	0.0001
	AG	0.0001	0.0010	0.0017	0.0001	0.0001	0.0001
SEM		0.0855	0.0571	0.3507	0.0811	0.0945	0.0638

AP – Albumen proportion; AI – Albumen index, HU – Haugh units; YP – Yolk proportion; YI – Yolk index, YC – Yolk colour; Values with the same superscript letter in each trait differ non-significantly (P>0.05); HB – Hisex Brown; LB – Lohmann Brown Classic; A – Age; G – Genotype; AG – Interaction between age and genotype; SEM – Standard Error of the Mean

part of the monitored period. Krawczyk (2009) stated that Haugh units should range between 59 and 72, which corresponds with findings of this study. Yolk proportion was significantly affected by age. However, the trend of yolk proportion was unclear because the values distinctly fluctuated during the monitored period. The significant effect of age was found also in yolk colour. The findings from Mitrovic et al. (2010) confirmed that age influences yolk colour, but Kraus and Zita (2019) stated the opposite. Contrary results from these studies might be caused by using different laying hybrids.

The interactions between age and genotype were determined in majority of the selected traits. Egg shape index, eggshell proportion and reflectivity were the only exceptions. Several authors (Zita et al., 2009; Ledvinka et al., 2011) also calculated and simultaneously confirmed the significant effect of interactions between age and genotype in some egg quality traits. The heaviest eggs were from 46 and 50-week-old Lohmann Brown Classic hens (66.54 and 66.35 g), while the lightest eggs were from 62 and 46-week-old Hisex Brown hens (62.62 and 62.90 g). The highest value of eggshell strength was found in eggs from 50-week-old Hisex Brown hens (42.64 N*cm^{-2}) and the lowest in eggs from 74-week-old Hisex Brown hens (39.90 N*cm^{-2}). The eggs with the highest eggshell thickness came from 62-week-old Hisex Brown hens (0.369 mm). On the other hand, the eggs with the lowest eggshell thickness came from 70 and 46-week-old hens from Hisex Brown hens (0.327 and 0.329 mm). The highest albumen proportion was found in eggs from 46-week-old Lohmann Brown Classic hens (63.18%), contrary to eggs from 54-week-old hens from the same genotype (60.01%). The highest albumen index was detected in eggs from 46-week-old Lohmann Brown Classic hens

(7.88%), while the lowest in eggs from 58-week-old Hisex Brown hens (4.93%) and from 74-week-old Lohmann Brown Classic hens (5.01%). The eggs with the highest value of Haugh units were from 46-week-old Lohmann Brown Classic hens (79.66) and the eggs with the lowest value were from 74-week-old Lohmann Brown Classic hens (64.84) and from 58-week-old Hisex Brown hens (64.95). The highest yolk proportion was found in eggs from 70-week-old Hisex Brown hens (29.96%), while the lowest in eggs from 46-week-old Lohmann Brown Classic hens (26.96%). The eggs with the highest value of yolk index came from 50-week-old Lohmann Brown Classic hens (43.89%). Vice versa, the eggs with the lowest value of yolk index came from 62-week-old Hisex Brown hens (37.91%). The darkest yolk colour had eggs from 70 and 50-week-old Hisex Brown hens (11.65 and 11.58) and the lightest had eggs from 66-week-old Lohmann Brown Classic hens (8.70).

CONCLUSIONS

The results confirmed that genotype has a significant effect for selected physical features of eggs. Lohmann Brown Classic hens had a superior egg quality in most of the evaluated traits in comparison with Hisex Brown hens. Higher values were observed in main egg quality traits, such as egg weight (by 1.45 g), eggshell strength (by 2.48 N*cm^{-2}) and Haugh units (by 3.27). The significant effect of age was determined in all selected egg quality traits. In general, overall quality of eggs deteriorates with the age, which was also confirmed. The egg weight increased with the age, meanwhile many other traits such as egg shape, albumen and yolk index, Haugh units and eggshell strength decreased. The trend of the rest of evaluated traits was ambiguous. Furthermore, there were determined interactions between genotype and age. Except for the egg shape index, eggshell proportion and reflectivity, all these interactions were calculated as statistically significant. The effect of age was found as more significant than the effect of genotype.

It is necessary to further evaluate egg quality characteristics and to understand factors, which affect the overall egg quality. Regarding the extension of laying cycle, the research is required, because the egg quality rapidly decreases with the age.

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