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Differences in Oviposition and Egg Quality of Various Genotypes of Laying Hens

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ABSTRACT

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The differences in egg production traits in six laying hen genotypes (brown-egg hens Bovans Brown, Bovans Sperwer, ISA Sussex; white-egg hen Dekalb White; laying hens with tinted shells Moravia Barred and Moravia BSL) and the interactions of genotype and oviposition on egg quality were evaluated. The genotype affected the laying rate ($P \leq 0.003$), mean sequence length ($P \leq 0.001$), and time of oviposition ($P \leq 0.001$). The brown-egg genotypes laid eggs approximately 1 h earlier than the white-egg genotypes and approximately 2 h earlier than the tinted-egg genotypes. Egg shell strength was the lowest in tinted-egg genotypes ($P \leq 0.001$) and declined with the time of oviposition ($P \leq 0.002$). Egg shell percentage ($P \leq 0.011$) and thickness ($P \leq 0.011$) were affected by the interaction of genotype and oviposition. None of the effects affected egg weight; however, the proportion of egg components was significantly influenced by the interaction of genotype and oviposition. The study confirmed that the differences in the egg production and egg quality of various genotypes are associated with the laying pattern.

Keywords: layers; genotype; sequence; time of collection; egg quality

Egg production as well as external and internal egg quality depend on many factors including genotype and age, which are considered natural influences. In laying hens, egg production starts at approximately 18 weeks of age. The production peaks at approximately 26 weeks of age, and then it gradually decreases. Total egg production is positively correlated with the length of laying sequence. The laying sequence refers to the number of eggs laid between two consecutive interval periods (Samiullah et al. 2017). Its length affects the time of oviposition because if the first egg in the sequence is laid early in the morning, then successive oviposition occurs later each day (Johnston and Gous 2007). The time of oviposition affects mainly egg weight and egg shell quality (Pavlovski et al. 2000; Zakaria et al. 2005; Tumova and Ledvinka 2009; Tumova et al. 2014).

Genotypic differences in total egg production can be explained by a variable sequence length. Johnston and Gous (2007) observed differences in the sequence length between Hy-line Brown and Hy-line Silver Brown hens. Data concerning the effect of genotype on sequence length are limited; however, the influence of genotype on oviposition time is well described. Lewis et al. (1995) found that the mean oviposition time was by 1.2 to 1.4 h earlier in brown-egg hybrids than in the white-egg ones. Observations by Campo et al. (2007) showed that white and tinted eggs tended to be laid in the afternoon and brown eggs tended to be laid in the morning. Tumova et al. (2009) found differences in

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oviposition time also with brown-egg genotypes. Besides genotype, the egg production traits are affected also by egg weight and egg composition. Commercially available genotypes produce eggs of different weights, and the proportion of egg components varies as well (Johnston and Gous 2007; Tumova and Ledvinka 2009). Notwithstanding, differences among genotypes in albumen quality (Suk and Park 2001; Tumova et al. 2011), yolk quality (Tumova et al. 2011), and egg shell quality (Suk and Park 2001; Tumova et al. 2011; Kaur et al. 2013; Blanco et al. 2014) have been observed.

Egg laying is distributed between 7:30 and 16:00 h during the day under a standard lighting regime (Campo et al. 2007) with the majority of eggs being laid between 8:00 and 12:00 h (Tumova and Ebeid 2005; Tumova et al. 2009; Tumova and Gous 2012). Regarding oviposition time, egg weight declines from the morning till the afternoon (Tumova and Ebeid 2005; Tumova and Gous 2012, Zakaria and Omar 2013; Samiullah et al. 2017). There is a vital role of oviposition in determining the egg shell quality. Shell deposition is a linear function of time spent in the shell gland (Ebeid and Tumova 2004). This is presumably one of the reasons for the better egg shell quality parameters of eggs laid in the afternoon (Tumova and Ebeid 2005; Tumova and Gous 2012). Oviposition time may affect the proportion of egg components and internal quality; however, the results are ambiguous. Tumova and Ebeid (2005) observed yolk percentage decreasing with oviposition time in cages but no effect on litter. According to Yannakopoulos et al. (1994), yolk percentage was not affected by oviposition time. A similarly inconsistent impact of oviposition is seen with the albumen content and its quality. Yannakopoulos et al. (1994) observed more albumen in the afternoon eggs, whereas Tumova and Ebeid (2005) and Tumova and Ledvinka (2009) observed more albumen in the morning eggs. Additionally, in a study by Tumova and Gous (2012), the albumen percentage was not affected. A better quality albumen in the afternoon eggs was described by Tumova and Ebeid (2005), however this effect was not observed in the following studies (Tumova et al. 2009; Tumova and Gous 2012). The results indicate that the oviposition time does not act independently, and the egg quality parameters may be affected by the interaction of different factors. For example, Tumova et al. (2009) and Tumova and Gous (2012) described the interaction of oviposition and genotype, Tumova and Ledvinka (2009) assessed the interaction of oviposition and age of laying hens, and Tumova et al. (2009) the interaction of oviposition and housing. With respect to the data focused on the interaction of variable factors influencing egg quality, the aim of the present study was to evaluate the differences in egg production traits in six laying hen genotypes and the interaction of oviposition and genotype on egg quality.

MATERIAL AND METHODS

The experiment carried out with 90 laying hens at 20–70 weeks of age was conducted at the Central Institute for Supervising and Testing in Agriculture, Havlíčkův Brod, Czech Republic. Laying hens of six genotypes (15 birds per genotype) were housed on a medium floor of a three-stage battery in individual cages (550 cm^2 per bird). The laying hen genotypes differed in egg shell colour. The brown-egg hens included Bovans Brown, Bovans Sperwer, and ISA Sussex; the white-egg hens were represented by Dekalb White; and the laying hens with tinted shells included Moravia Barred and Moravia BSL. Before the experiment, all hens had been reared under the same conditions until 16 weeks of age when they were placed into individual cages. Environmental conditions were similar to those described by Skrivan et al. (2015). Hens were fed two types of commercial feed mixtures: N1 in weeks 20–56 of age (176 g crude protein, 11.0 MJ of metabolizable energy, and 33.2 g Ca) and N2 from week 57 onward (156 g crude protein, 9.9 MJ of metabolizable energy and 36.8 g Ca). Feed and water were available *ad libitum* during the whole experiment. A 16-hour lighting regime was used (lights were switched on at 3:00 h and off at 19:00 h).

Throughout the experiment, egg production was recorded daily and was used to calculate the rate of lay using the method of Tumova et al. (2016). The time of oviposition was estimated as the length of time since the lights were switched on until an egg was laid. Eggs were collected at 6:00, 9:00, 12:00, and 17:00 h. Records of each egg collection time were used to determine the mean number of eggs at the collection time for each genotype. The mean sequence length was calculated as the number of days in which eggs were laid before a pause day.

The egg quality parameters were evaluated over a four-week interval (starting at 24 weeks of age) for all laid eggs from each genotype and for each collection time (totalling 876 eggs). Freshly laid eggs were individually weighed and then the length and width of each egg were measured to calculate the egg shape index (width/length × 100). Egg shell strength was measured by the shell-breaking method using a QC-SPA device (TSS York, UK). After egg breaking, the yolks and shell were weighed. Egg shell weight was determined after drying. Albumen weight was calculated by subtracting the yolk and shell weight from the egg weight. The individual weight of each egg component was used to calculate the proportion of shell, yolk, and albumen from the egg weight. A QCT shell thickness micrometer (TSS York) was used to determine the egg shell thickness using the method described by Skrivan et al. (2016). Haugh unit score was evaluated with a QCH apparatus (TSS York).

The experimental data were evaluated by the GLM procedure of the SAS software (Statistical Analysis System, Version 9.4, 2013). Production traits were analyzed using one-way analysis of variance with the Scheffé's test for the determination of differences between genotypes. Egg quality parameters were evaluated by two-way analysis of variance with the interaction of genotype and oviposition time. A P-value ≤ 0.05 was considered significant for all measurements.

RESULTS AND DISCUSSION

The egg-laying distribution during the day (Table 1) shows significant differences between the genotypes. The brown-egg hybrids (Bovans Brown, Bovans Sperwer, and ISA Sussex) laid their eggs early in the morning. The white-egg hybrid Dekalb White laid the majority of eggs in the morning, with more than 30% laid between 6:00 and 9:00 h. Moravia Barred, the tinted-egg hybrid, produced the majority of eggs at 9:00 h. The egg-laying distribution of the second tinted-egg hybrid Moravia BSL was similar, at 6:00 and 9:00 h, but approximately 25% of its eggs were laid in the afternoon, which was the highest number of all the genotypes. The results reveal the individual laying pattern of each genotype, similar to that described by Lewis et al. (1995) and Tumova et al. (2009), and the genotypic origin of the hens was expressed by egg shell colour. The data on the egg-laying distribution correspond with the significant effect of genotype on the rate of lay ($P \leq 0.003$), mean sequence length ($P \leq 0.001$), and time of oviposition ($P \leq 0.001$) (Table 2). Brown-egg genotypes had a significantly higher rate of lay than white- and tinted-egg genotypes, and the rate of lay significantly differed between white- and tinted-egg genotypes. The same trends were observed for the mean sequence length and the time of oviposition. The results indicate that the highest producing hens lay their eggs earlier than less productive hens. The sequence length is an external indicator of the ovarian follicular growth, and in longer sequences, eggs are laid early in the morning (Zakaria and Omar 2013). The brown-egg genotypes laid their eggs approximately 1 h earlier

Table 1. Mean number of eggs from six genotypes at each collection time (%)

Genotype	Time of collection			
	6.00	9.00	12.00	17.00
Bovans Brown	82.6	13.8	2.62	0.96
Bovans Sperwer	76.9	19.6	2.72	0.77
ISA Sussex	75.6	20.0	2.77	1.65
Moravia Barred	41.3	43.6	10.7	4.43
Dekalb White	58.3	36.0	4.76	0.88
Moravia BSL	39.6	36.9	14.2	9.27

Time of collection and genotype significance $P = 0.001$

Table 2. Results of the rate of lay, mean sequence length, and oviposition time^{1} in six genotypes

Genotype	Rate of lay (%)	Mean sequence length (days)	Oviposition time^{1} (h)
Bovans Brown	87.44^{a}	21.11^{a}	3.65^{c}
Bovans Sperwer	82.85^{ab}	19.94^{a}	3.85^{c}
ISA Sussex	86.93^{a}	20.60^{a}	4.03^{bc}
Moravia Barred	75.03^{c}	14.85^{b}	5.41^{a}
Dekalb White	80.27^{b}	20.30^{a}	4.47^{b}
Moravia BSL	73.50^{c}	13.24^{b}	5.90^{c}
RMSE	20.26	10.81	2.16
Significance	0.003	0.001	0.001

RMSE = root mean square error

$^{a-c}$statistically significant differences ($P \leq 0.05$) within columns are indicated by different superscripts

^{1}oviposition time after light switched on than the white-egg genotype and approximately 2 h earlier than the tinted-egg genotypes. The results are in line with those of Lewis et al. (1995) and Campo et al (2007). However, there were no significant differences in oviposition time within hybrids of the same origin.

Results of the external egg quality parameters are presented in Table 3. Egg weight was not affected by genotype, time of oviposition or their interaction. Different hybrids showed variable trends in egg weight in respect to oviposition time; however, in our previous study (Tumova et al. 2009), a significant interaction between oviposition time and genotype was found. The literature mostly indicates that egg weight decreases with oviposition time (Yannakopoulos et al. 1994; Pavlovski et al. 2000; Tumova and Ledvinka 2009). The difference between the presented results and those found in the literature may be due to different genotypes, housing systems, environmental conditions, and egg collection time, which all affect egg weight.

The lowest egg shape index (Table 3), which indicates longer eggs, was for Bovans Sperwer ($P \leq 0.048$). Rounder eggs were observed in the morning ($P \leq 0.001$), and the measurement was also affected by the interaction between genotype and oviposition time ($P \leq 0.007$), with the highest values for Bovans Brown at 12:00 h and the lowest

Table 3. External egg quality parameters depending on genotype and oviposition time

Genotype	Oviposition time	Egg weight (g)	Egg shape index (%)	Eggshell percentage (%)	Eggshell strength (N)	Eggshell thickness (mm)
Bovans Brown	6^{00}	59.67	79.33^{a}	9.98^{b}	43.53	0.35^{b}
	9^{00}	60.66	75.46^{ab}	9.99^{b}	44.26	0.37^{ab}
	12^{00}	52.05	81.93^{a}	11.56^{a}	44.58	0.41^{a}
	17^{00}	52.10	82.15^{a}	11.97^{a}	44.70	0.42^{a}
Bovans Sperwer	6^{00}	59.07	75.52^{ab}	9.49^{c}	41.21	0.34^{bc}
	9^{00}	57.51	72.71^{b}	9.96^{b}	43.73	0.36^{ab}
	12^{00}	66.50	74.28^{ab}	8.43^{cd}	34.92	0.32^{cd}
	17^{00}	67.10	74.92^{ab}	9.25^{bc}	40.15	0.34^{bc}
ISA Sussex	6^{00}	60.81	79.56^{a}	10.21^{ab}	47.92	0.37^{ab}
	9^{00}	59.74	78.27^{a}	10.14^{ab}	46.19	0.36^{ab}
	12^{00}	59.77	73.55^{b}	10.83^{ab}	47.00	0.40^{a}
	17^{00}	59.85	72.43^{b}	10.77^{ab}	47.23	0.41^{a}
Moravia Barred	6^{00}	53.83	80.16^{a}	9.77^{bc}	41.21	0.34^{bc}
	9^{00}	59.92	74.76^{b}	9.07^{cd}	35.62	0.33^{c}
	12^{00}	61.11	75.03^{ab}	9.12^{cd}	39.96	0.34^{bc}
	17^{00}	63.41	73.98^{b}	9.54^{bc}	39.69	0.35^{b}
Dekalb White	6^{00}	60.23	76.24^{ab}	10.05^{b}	45.88	0.35^{b}
	9^{00}	60.06	77.05^{ab}	9.72^{bc}	41.86	0.35^{b}
	12^{00}	55.60	80.40^{a}	7.96^{d}	38.98	0.28^{d}
	17^{00}	53.20	81.12^{a}	8.43^{cd}	40.12	0.34^{bc}
Moravia BSL	6^{00}	56.89	79.46^{a}	9.05^{cd}	39.18	0.30^{d}
	9^{00}	61.43	76.38^{ab}	9.06^{cd}	38.42	0.32^{cd}
	12^{00}	66.05	76.55^{ab}	8.89^{cd}	35.96	0.33^{cd}
	17^{00}	59.30	77.15^{ab}	8.72^{cd}	38.16	0.33^{c}
RMSE		5.81	3.25	0.75	7.46	0.03
Genotype		0.199	0.048	0.001	0.001	0.001
Oviposition time		0.052	0.001	0.607	0.002	0.369
Genotype × oviposition time		0.067	0.007	0.011	0.055	0.011

RMSE = root mean square error

$^{a-d}$statistically significant differences ($P \leq 0.05$) within columns are indicated by different superscripts for Bovans Sperwer at 9:00 h. This interaction may explain the contradictory results of the effect of oviposition time on egg shape index. Roland (1978) and Blanco et al. (2014) observed rounder eggs in the afternoon, whereas Tumova and Ebeid (2005) observed rounder eggs in the morning. The egg shape index is associated with egg shell quality, as rounder eggs better maintain egg shell quality (Roland 1978). Egg shell quality is expressed by the percentage, thickness, and strength of the shell, which are functional properties of the shell measurements (Ketta and Tumova 2016). Egg shell strength was affected by genotype ($P \leq 0.001$), with lower values in the tinted-egg genotypes. In the same genotypes, the lowest egg shell percentage ($P \leq 0.001$) and thickness ($P \leq 0.001$) were found. The best egg shell quality was observed in brown-egg genotypes, which is in line with Campo et al. (2007). In contrast with Campo et al. (2007), in the current study, the white-egg genotype had a better egg shell quality than the tinted-egg genotypes. The disproportion between both studies with respect to the white- and tinted-egg genotypes may consist in using selected hybrids in the current study, whereas Campo et al. (2007) tested pure breeds. Regarding the oviposition time, egg shell strength ($P \leq 0.002$) declined during the day, which is in contrast with the majority of studies evaluating oviposition time and egg quality (Yannakopoulos et al. 1994; Tumova and Ebeid 2005; Tumova et

Table 4. Internal egg quality parameters depending on genotype and oviposition time

Genotype	Oviposition time	Albumen percentage (%)	Haugh unit score	Yolk percentage (%)
Bovans Brown	6^{00}	63.50^{bc}	79.67	26.52^{b}
	9^{00}	60.89^{c}	75.25	29.12^{a}
	12^{00}	66.67^{ab}	73.96	21.77^{c}
	17^{00}	67.01^{a}	71.38	21.13^{c}
Bovans Sperwer	6^{00}	63.34^{bc}	80.49	27.16^{ab}
	9^{00}	61.38^{c}	77.09	28.66^{ab}
	12^{00}	65.81^{ab}	86.34	25.75^{bc}
	17^{00}	66.89^{ab}	84.14	23.76^{bc}
ISA Sussex	6^{00}	63.77^{b}	87.48	26.01^{bc}
	9^{00}	64.00^{b}	82.67	25.86^{bc}
	12^{00}	63.04^{bc}	80.83	26.13^{b}
	17^{00}	63.98^{a}	78.14	25.09^{bc}
Moravia Barred	6^{00}	65.89^{ab}	86.42	24.34^{bc}
	9^{00}	63.17^{bc}	78.19	27.76^{ab}
	12^{00}	61.01^{c}	78.71	29.87^{a}
	17^{00}	61.87^{c}	72.62	28.58^{ab}
Dekalb White	6^{00}	62.32^{bc}	86.92	27.63^{ab}
	9^{00}	63.48^{bc}	88.78	26.80^{ab}
	12^{00}	71.79^{a}	86.90	20.25^{c}
	17^{00}	72.13^{a}	84.71	20.19^{c}
Moravia BSL	6^{00}	66.24^{ab}	87.08	24.71^{bc}
	9^{00}	63.76^{b}	78.35	27.17^{ab}
	12^{00}	64.98^{b}	81.86	26.14^{b}
	17^{00}	62.55^{bc}	81.27	28.73^{a}
RMSE		2.95	8.95	3.09
Genotype		0.252	0.140	0.493
Oviposition time		0.003	0.006	0.004
Genotype × oviposition time		0.003	0.586	0.012

RMSE = root mean square error

$^{a-c}$statistically significant differences ($P \leq 0.05$) within columns are indicated by different superscripts

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al. 2009). On the other hand, egg shell percentage and egg shell thickness were not affected by oviposition time, which disagreed with our previous studies (Tumova and Ebeid 2005; Tumova et al. 2009). However, Samiullah et al. (2017) observed a decreasing egg shell thickness with oviposition time. In addition, egg shell percentage ($P \leq 0.011$) and egg shell thickness ($P \leq 0.011$) were affected by the interaction of genotype and oviposition time, while egg shell strength was not significantly affected. These results for the egg shell quality indicate a complicated relationship among the factors affecting these measurements as well as between the individual shell parameters. It may be that the shell thickness is not necessarily affected by a longer egg retention in the shell gland, which is also supported by the findings of Samiullah et al. (2017). We may assume that differences in egg shell quality are not affected by the length of egg formation but by delays in ovulation. The assumption is supported by the results of the current study showing that oviposition time did not affect egg weight and that rounder eggs were laid in the morning, and by the findings of Blanco et al. (2014), which showed positive correlations between egg shape index and egg shell strength were expressed by dynamic stiffness and that there is no correlation between egg shell strength and thickness (Kim et al. 2014). Additionally, the better egg shell strength of the morning eggs may be associated with their higher calcium content (Tumova et al. 2014).

The internal egg quality parameters (Table 4) were not affected by genotype. However, albumen percentage was higher in the afternoon eggs ($P \leq 0.003$). The significant interaction of genotype and oviposition for the albumen percentage showed that in the tinted-egg genotypes, the measured values decreased within the day the eggs were laid. In the ISA Sussex hybrid, the albumen percentage did not change, and in the other genotypes, it increased. The quality of albumen, the Haugh unit score, was affected only by oviposition time, with lower values in the afternoon, which corresponds to the findings of Pavlovski et al. (2000) and Tumova et al. (2009). The higher albumen percentage and lower albumen quality of the afternoon eggs may be attributed to higher water absorption of these eggs during egg formation (Yannakopoulos et al. 1994). In the present study, yolk percentage was affected by oviposition time ($P \leq 0.004$) and the significant interaction between genotype and oviposition time ($P \leq 0.012$). Yolk percentage decreased with the time of oviposition in Dekalb White hens. In ISA Sussex hens, yolk percentage was not affected, however in other genotypes it increased with oviposition time. In our previous experiments (Tumova et al. 2009, Tumova and Gous 2012), yolk percentage was not affected by oviposition time, and this difference is assumed to be related to the interaction of genotype and oviposition time because different genotypes were used in these studies.

CONCLUSION

The research results confirmed that the differences in egg production of various genotypes are associated with the laying pattern. Mean length of the laying sequence and the oviposition time depended on the genotype origin but did not vary within the origin. Presumably, egg shell quality is more affected by the delay in ovulation than by the length of egg formation. Egg weight was not influenced by the evaluated factors; however, the interaction between genotype and oviposition time plays an important role in the proportion of egg components.

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