The effect of genotype, housing system and egg collection time on egg quality in egg type hens

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ABSTRACT: The effect of egg collection time, genotype and housing system on egg quality characteristics was evaluated in an experiment with laying hens of ISA Brown, Hisex Brown and Moravia housed on litter and in conventional cages. The experiment was conducted from 20 to 64 weeks of age. Eggs were collected and recorded daily at 06:00, 10:00 and 14:00 h. Once every four weeks, two days in row, all eggs laid from each pen or cage at each oviposition time were used for egg quality analyses (total 1 694 eggs). Egg collection time was dependent on genotype. Significantly more eggs were laid at 06:00h by ISA Brown while Moravia laid eggs mainly at 10:00 and 14:00 h. Housing on litter postponed the time of oviposition. The highest egg weight (62.09 g) was recorded in Hisex Brown genotype placed in cages and at 06.00 h. Interactions of all factors were determined also in Haugh units ($P \leq 0.041$). Eggshell strength was affected by housing system, genotype and egg collection time ($P \leq 0.049$). It was higher in cages than on litter, and lower in the Moravia genotype in comparison with the other two strains.

Keywords: egg quality; genotype; housing system; collection time; hens

Egg quality is influenced by many internal and external factors, of which genotype, housing system and time of oviposition are of major importance. Egg weight is one of the most important characteristics because each of the components of the egg depends on egg weight (Romanoff and Romanoff, 1949; Hussein et al., 1993; Hartmann et al., 2000). The proportion of yolk is negatively related to egg size but positively associated with hen's age (Hartmann et al., 2000; Johnston and Gous, 2007a).

Egg weight and eggshell quality vary according to oviposition time. Numerous studies have indicated that eggs laid early in the morning are heavier than eggs laid during the later periods of the day, but that eggshell characteristics are better (Yannakopoulos et al., 1994; Novo et al., 1997; Pavlovski et al., 2000; Tůmová and Ebeid, 2005; Tůmová et al., 2007), yolk percentage is slightly lower (Tůmová and Ebeid, 2005; Tůmová et al., 2007) and Haugh units increase (Pavlovski et al., 2000; Tůmová and Ebeid, 2005) in eggs laid in the afternoon. Oviposition times may be estimated from ovulation times. Internal ovulations take place at random, further disrupting oviposition. All these events are influenced by the age of the birds, the strain, level of nutrition and other environmental factors (Johnston and Gous, 2007b).

It seems that genotype is important in determining the time of oviposition. In spite of the fact that Schmidt et al. (1997) stated that selection for egg production had no significant effect on the oviposition interval, Lewis et al. (1995) revealed large differences between broiler breeder and egg type

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hens. These deviations were greater than between white-egg and brown-egg hybrids. Consequently, dissimilarities in egg weight, eggshell quality and component percentages are likely between genotypes (Lillpers and Wilhelmson, 1993; Garces and Casey, 2003; Tůmová et al., 2007).

In recent years in Europe there has been a significant trend to develop and use alternative housing systems rather than cages. Data from a number of studies revealed differences in egg quality depending on the housing system. In many cases, results are contradictory. Moorthy et al. (2000), Leyendecker et al. (2001) and Jenderal et al. (2004) reported higher egg weights in cages, while Tůmová and Ebeid (2005), Pištěková et al. (2006), Zemková et al. (2007) recorded heavier eggs on litter. Quality traits such as eggshell thickness, Haugh unit score and yolk index were reported to be higher in cages than on deep litter (Roland et al., 1997; Moorthy et al., 2000; Tůmová and Ebeid, 2005, Lichovníková and Zeman, 2008). Egg quality in different housing systems is also influenced by genotype. Leyendecker et al. (2001) reported genotype and housing system interactions between Lohmann LSL and Lohmann Brown housed in conventional cages, aviaries or intensive free-range housing. Vits et al. (2005) pointed out that eggshell quality characteristics were lower in enriched cages than in conventional cages, and that Lohmann Brown hens showed better results compared to Lohmann LSL.

Because of the interaction between these various factors influencing egg quality, certain combinations of these factors may result in either a reduction or an enlargement of the effect of any of the components on egg quality. For example, Campo et al. (2007) stated that white eggs inclined to be laid in the afternoon, whereas brown eggs tended to be laid in the morning, that brown egg hens had a lower incidence of floor laying, and that first year hens kept on deep litter should lay fewer floor eggs than second year hens in free range housing.

The aim of the study was to evaluate the effect of housing in conventional cages and on litter, genotype and egg collection time on the technological value of eggs in egg type hens.

MATERIAL AND METHODS

An experiment with 132 laying hens from 20 to 64 weeks of age was carried out. Laying hens were housed in conventional Eurovent cages (72 hens, 550 cm^2/hen, 8 cages/genotype) and in six littered pens (60 hens, 7 hens/m^2, 10 hens/pen and 2 pens for each genotype). Three genotypes were used in both housing systems (44 hens each of ISA Brown, Hisex Brown and Moravia BSL). The daily photoperiod consisted of 16 h light and 8 h darkness. The lights were turned on at 03:00 h and off at 19:00 h. Laying hens in both housing systems were fed identical commercial feed mixtures, N1 (176 g crude protein (CP), 11.6 MJ of metabolizable energy (ME) and 33 g of calcium/kg feed) from 20 to 40 weeks and N2 (154 g CP, 11.6 MJ ME and 36 g calcium/kg feed) from 41 to 64 weeks of age. Feed and water were supplied *ad libitum*.

In all groups, eggs were recorded daily at three collection times: 06:00, 10:00 and 14:00 h. Once every four weeks, two days in row, all eggs laid from each pen or cage at each oviposition time were used for egg quality analyses (total 1 694 eggs). Eggs were weighed, and the shell strength was determined by the shell-breaking method using a QC-SPA device (TSS England). Albumen height and Haugh units were evaluated with a QCH apparatus (TSS England). Haugh units were automatically calculated within the system based on egg weight and albumen height (Haugh, 1937). The weight of each egg and of its components was measured. Eggshell weight was determined after drying. Eggshell colour was measured with a QCR colour reflectometer (TSS England). The reflectometer works by taking a percentage reading between black and white with the former expressed as 0% and the latter pure white 100%. Yolk colour was determined by the colorimetric method and with a QCC device (TSS England) and results are expressed in standard DSM Roche. Eggshell thickness was evaluated with a QCT shell thickness micrometer (TSS England).

Egg quality data were evaluated by three-way (housing, genotype, and collection time) analysis of variance using the GLM procedure of SAS (SAS Institute Inc., 2003).

RESULTS

The number of eggs recorded at each collection differed significantly between genotypes (Table 1). In ISA Brown the highest number of eggs was at 06:00 h while the quantity of eggs collected from Hisex Brown was similar at 06:00 and 10:00 h. However, the majority of eggs from Moravia were collected at 10:00 and 14:00 h. The time of ovi-

Table 1. Mean number of eggs from three genotypes and two housing systems at each collection time (%)

Time of collection	Housing	Genotype			Significance time of collection × housing × genotype
		ISA Brown	Hisex Brown	Moravia	
06:00	cage	38.0	30.4	17.8	0.001
	litter	24.8	17.6	7.8	
10:00	cage	13.2	28.5	27.5	
	litter	15.9	13.5	19.4	
14:00	cage	4.7	5.8	14.9	
	litter	3.4	3.8	12.6	

position was influenced by genotype whereas the housing system affected the laying pattern. In all genotypes housed on litter the number of eggs collected early in the morning was lower than from cages. Nevertheless, the quantity of eggs laid in the afternoon (14:00 h) decreased. Both factors influenced the number of eggs collected at each time, and there were significant interactions among genotype, housing system and egg collection time.

Significant interactions ($P \leq 0.026$) between genotype, housing system, egg collection time and egg weight were evident (Table 2). Egg weight was influenced mainly by the egg collection time and genotype. The heaviest eggs were laid early in the morning (06:00 h) and by caged Hisex Brown hens.

Table 2. Mean weight, index and albumen quality of eggs collected at three times during the day from three genotypes housed in cages or on litter

Housing	Time of egg collection	Genotype	Egg weight (g)	Egg index (%)	Albumen weight (g)	Haugh units	Albumen index (%)
Cage	06:00	ISA Brown	$61.16^{a,c}$	76.01	36.62	83.19^{b}	7.82
		Hisex Brown	62.09^{a}	76.50	38.16	84.64^{a}	8.81
		Moravia	58.91^{b}	77.13	35.49	87.64^{a}	8.81
	10:00	ISA Brown	$59.83^{b,c}$	75.88	36.23	83.35^{b}	7.80
		Hisex Brown	$60.03^{b,c}$	76.99	36.77	82.06^{b}	7.99
		Moravia	58.57^{b}	77.23	35.27	81.94^{b}	8.30
	14:00	ISA Brown	56.69^{b}	75.96	34.33	75.98^{c}	7.80
		Hisex Brown	58.86^{c}	77.16	35.73	75.92^{c}	7.60
		Moravia	61.39^{a}	77.41	36.79	78.42^{c}	8.32
Litter	06:00	ISA Brown	60.65^{a}	76.59	36.38	84.82^{a}	8.08
		Hisex Brown	59.80^{a}	77.29	36.61	84.73^{a}	9.13
		Moravia	60.28^{a}	76.69	36.30	87.90^{a}	9.39
	10:00	ISA Brown	58.58^{b}	76.47	35.66	80.36^{b}	8.24
		Hisex Brown	58.96^{a}	78.85	36.26	85.33^{ab}	9.94
		Moravia	60.49^{a}	77.66	36.81	86.25^{a}	10.14
	14:00	ISA Brown	58.84^{a}	78.12	35.31	77.23^{c}	8.44
		Hisex Brown	59.07^{a}	78.95	36.38	81.67^{b}	9.22
		Moravia	60.26^{a}	77.44	36.44	83.54^{b}	10.05
Significance							
Genotype × collection time			0.002	0.129	0.004	0.524	0.475
Housing × collection time			0.536	0.667	0.256	0.061	0.001
Housing × genotype × collection time			0.026	0.478	0.086	0.041	0.236

Table 3. Mean yolk quality of eggs collected at three times during the day from three genotypes housed in cages or on litter

Housing	Time of egg collection	Genotype	Yolk weight (g)	Yolk index (%)	Yolk colour
Cage	06:00	ISA Brown	16.58	44.92	6.81
		Hisex Brown	16.42	44.82	6.88
		Moravia	16.48	46.91	6.78
	10:00	ISA Brown	15.98	44.65	6.77
		Hisex Brown	16.05	44.45	6.76
		Moravia	16.54	46.85	6.99
	14:00	ISA Brown	14.98	43.95	6.70
		Hisex Brown	15.73	43.31	6.73
		Moravia	17.41	46.63	7.13
Litter	06:00	ISA Brown	16.63	45.29	6.69
		Hisex Brown	15.79	45.73	6.50
		Moravia	17.01	47.92	7.11
	10:00	ISA Brown	15.54	45.36	6.84
		Hisex Brown	15.30	46.68	6.58
		Moravia	16.80	47.98	6.93
	14:00	ISA Brown	16.02	44.46	6.68
		Hisex Brown	15.44	44.87	6.42
		Moravia	17.04	47.45	7.00
Significance					
Genotype × collection time			0.004	0.681	0.351
Housing × collection time			0.520	0.277	0.628
Housing × genotype × collection time			0.230	0.889	0.337

The lightest eggs were produced in cages in the afternoon (14:00 h) by ISA Brown hens. Egg weight decreased with egg collection time in Hisex Brown and ISA Brown and in both housing systems, whereas egg weight increased significantly ($P \leq 0.002$) in Moravia with collection time. Moravia produced heavier eggs on litter in comparison with cages while the eggs laid by Hisex Brown in cages were heavier than those on litter.

Albumen weight (Table 2) decreased with egg collection time and interacted with genotype. Hisex Brown produced the highest albumen weight whilst the lowest was produced by Moravia. On the other hand, albumen weight from Hisex Brown was not affected by the housing system but albumen weight in Moravia was higher from eggs produced on litter than in cages. Haugh units are used as the main internal egg quality indicator, and significant interactions ($P \leq 0.041$) between all factors were found. Eggs collected at 06:00 h from Moravia hens housed on litter had the highest Haugh unit score whereas those from Hisex Brown in cages had the lowest. Moravia hens produced eggs with higher Haugh units in comparison with Hisex Brown or ISA Brown. Haugh units were higher in eggs produced on litter than in cages.

Yolk weight and quality are mainly related to genotype, yet in our results (Table 3) none of the evaluated factors had any effect on yolk quality. The highest yolk weights were recorded from eggs produced by Moravia hens, and to a lesser extent from eggs produced in cages rather than on litter. There were no significant interactions in yolk colour, but eggs with darker yolk were produced in cages and by Moravia.

Shell quality was influenced by each of the factors included in this trial (Table 4), and significant interactions ($P \leq 0.005$ and $P \leq 0.049$) occurred between these factors to influence eggshell weight and strength. Shell weight decreased significantly ($P \leq 0.05$) with egg collection time, the lowest weight being measured in eggs from Moravia hens,

Table 4. Mean shell quality measurements of eggs collected at three times during the day from three genotypes housed in cages or on litter

Housing	Time of egg collection	Genotype	Eggshell weight (g)	Eggshell thickness (mm)	Eggshell strength (g/cm^2)	Eggshell colour (%)
Cage	06:00	ISA Brown	6.38^a	0.37	4 683^b	34.21
		Hisex Brown	6.26^a	0.39	4 874^b	30.09
		Moravia	5.66^{b,c}	0.33	4 597^b	43.62
	10:00	ISA Brown	6.38^a	0.38	4 693^{a,b}	33.49
		Hisex Brown	5.93^b	0.35	4 806^b	29.92
		Moravia	5.40^c	0.32	4 358^c	47.13
	14:00	ISA Brown	6.23^a	0.38	5 099^a	34.94
		Hisex Brown	6.07^b	0.36	5 210^a	28.62
		Moravia	5.74^{b,c}	0.33	4 712^b	46.92
Litter	06:00	ISA Brown	6.43^a	0.37	4 770^b	31.66
		Hisex Brown	6.05^b	0.35	4 856^b	31.27
		Moravia	5.73^b	0.34	4 235^c	42.96
	10:00	ISA Brown	6.20^{a,b}	0.37	4 783^b	31.58
		Hisex Brown	6.06^b	0.36	4 835^b	29.66
		Moravia	5.48^c	0.32	4 243^c	44.35
	14:00	ISA Brown	6.34^a	0.37	5 143^a	33.06
		Hisex Brown	5.83^b	0.35	4 486^{b,c}	30.06
		Moravia	5.48^c	0.32	4 123^c	44.51
Significance						
Genotype × collection time			0.154	0.653	0.045	0.129
Housing × collection time			0.014	0.703	0.002	0.667
Housing × genotype × collection time			0.005	0.829	0.049	0.478

and the highest from birds in cages. Shell strength correlated with eggshell weight and was higher in cages than on litter and lower in the Moravia genotype in comparison with ISA Brown or Hisex Brown. The highest shell strength was in eggs laid in cages by Hisex Brown and collected at 14:00 h, whereas the lowest was in eggs collected at the same time, but from Moravia hens on litter. Although shell colour is related mainly to genotype, some other factors also affected this trait. Moravia eggs had the lightest shells, eggs collected at 06:00 h were significantly darker than the others, and the lightest shells were produced on litter in comparison with those from cages.

DISCUSSION

The number of eggs recorded at each collection time was influenced by the genotype, with each hybrid having a particular laying pattern, which is in agreement with Lillpers and Wilhelmson (1993), Lewis et al. (2001), Garces and Casey (2003) or Tůmová et al. (2007). ISA Brown, the hybrid which reached the highest egg production, laid eggs mainly early in the morning whereas Hisex Brown with smaller eggs than ISA Brown produced the majority of eggs before the 10:00 h collection. The hybrid Moravia with the lowest egg production produced the highest number of eggs between the 10:00 and 14:00 h collection. Tůmová et al. (2007) also revealed that the high-producing genotypes lay eggs earlier than those with lower production. Campo et al. (2007) concluded that eggshell colour was dependent on the time of oviposition and that white or tinted eggs tended to be laid in the afternoon. The same trends were found in this experiment where Moravia, the hybrid with the lightest eggshell colour, produced eggs later than the hybrids with darker egg shells. In addition, the housing system influenced the oviposition pattern: eggs produced by hens on litter were laid later in comparison with those from hens housed in cages mainly in the genotype with lower production.

Significant interactions among all the factors included in this trial on egg weight show that it is not easy to evaluate the importance of each aspect in controlling this important characteristic. In cages, egg weight in ISA Brown decreased with egg collection time, which corresponds with findings of Yannakopoulos et al. (1994), Novo et al. (1997), Pavlovski et al. (2000) and Tůmová et al. (2007) while in Moravia the weight increased. On the other hand, deviations in egg weight from hens on litter were not influenced by the egg collection time in any of the genotypes at all. This is similar to the results of our previous experiment on litter (Tůmová and Ebeid, 2005) where the egg weight did not vary significantly with different times of oviposition.

In albumen quality characteristics significant interactions were found only in Haugh units. Similarly like in the results of Leyendecker et al. (2001) and Tůmová et al. (2007) the genotype played an important role in this quality characteristic. The highest Haugh unit scores were obtained in Moravia. The Haugh unit score declined significantly with egg collection time in cages and in all hybrids, which is contrary to the results of Pavlovski et al. (2000) and our previous experiment (Tůmová and Ebeid, 2005) where no significant effect of oviposition on Haugh units was recorded. However, similar trends were observed in one genotype in Tůmová et al. (2007). The Haugh unit score increased significantly in the afternoon in ISA Brown and Moravia hens housed on litter, which was found also by Tůmová and Ebeid (2005).

Significant interactions between housing, egg collection time and genotype in shell weight and shell strength indicate that all these factors are important in eggshell quality determination. In an experiment with Spanish breeds in a program of genetic resources, Campo et al. (2007) reported a significant effect of genotype on the incidence of cracked eggs. However, the housing by genotype by age interactions were not significant. On the other hand, Leyendecker et al. (2001) and Vits et al. (2005) pointed to the importance of housing by genotype interaction in eggshell quality. A linear relationship between eggshell weight and shell strength with egg collection time corresponds to the results of Novo et al. (1997), Pavlovski et al. (2000) and Tůmová et al. (2007). Deviations in eggshell weight in response to the time of oviposition and genotype were previously described by Lillpers and Wilhelmson (1993), Garces and Casey (2003) and Tůmová et al. (2007).

From the results of this experiment in which the genotype and housing system interacted to affect the time of the day when eggs are laid and where all these factors influenced the important egg quality characteristics, it is important to choose a genotype that performs best in the housing system to be used, if eggs with the highest quality characteristics are to be produced.

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