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The effect of different housing system on quality parameters of eggs in relationship to the age in brown egg-laying hens

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Abstract

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This study was made because of the dominant use of cage housing systems in poultry husbandry worldwide. The aim was to evaluate the quality parameters of eggs of brown egglaying hybrid Lohmann Brown-Classic depending on age and housing system. The eggs were collected from 32, 42 and 64-week-old hens. In total, 1080 eggs from the enriched cages and 540 eggs from the litter were analysed. The evaluation of technological value included egg weight and shape index, eggshell surface, weight, proportion, thickness, strength and colour, albumen weight, proportion and index, Haugh units, yolk weight, proportion, index and yolk to albumen ratio. The significant effect of both, age and housing system, was found in all observed parameters except for the egg shape index, where significant effect was not found in the housing system. The significant interaction of age and housing system was found in all observed parameters except for the eggshell strength.

The results did not confirm a trend of deteriorating egg quality with the age. In terms of the housing system, it is not possible to unambiguously claim that one housing system produced eggs with superior quality, but most of the values of the main parameters were higher in eggs from enriched cages. It is necessary to continue to monitor the quality of eggs, depending on the age and housing system, in context of the cage systems replacement.

Keywords: age; enriched cages; egg quality; litter; Lohmann Brown-Classic

Introduction

As a result of society's concerns over the welfare of hens, housing systems in poultry breeding have changed (Shini et al., 2019). European Commission Directive 1999/74/EC prohibits the use of conventional cages for poultry husbandry from 1.1.2012 in the European Union. Therefore, it is necessary to use enriched cages or alternative housing systems, including litter, free-range and aviaries (Tůmová et al., 2009). Despite this fact, cages are still the most used housing system in the vast majority of countries. Alternative housing systems have been introduced especially in the past twenty or thirty years (Shini et al. 2019).

There are many factors that have an effect on the final quality of eggs. The age of the hens, genotype and nutrition are the most important ones (Tang et al. 2015). The hens' age obviously influences both internal and external quality parameters of the eggs (Padhi et al., 2013). Lee et al. (2016) classify the age of the hens as the major factor that has an effect on the quality of fresh eggs. Travel et al. (2010) state that egg weight increases with the age of hens. Moreover, Krawczyk (2009) adds that the older the hens are, the less cholesterol the eggs have. Bozkurt & Tekerli (2009) describe the effect of age on the quality of the internal egg components and claim that eggs that are laid at the end of the laying period have lower values of Haugh units and both, albumen and yolk index. Many other authors, for example Zita et al.

(2018) and Matt et al. (2009) also include the housing system among these factors. The effect of different housing systems is particularly evident in eggshell quality (Vlčková et al., 2018). In general, eggs with better eggshell quality come from cage systems. These eggs usually have higher eggshell thickness and strength (Samiullah et al., 2014). Basmacioglu & Ergul (2005) claim that the type of housing system has an effect on albumen quality parameters. Tůmová & Ebeid (2005) also confirm the effect of the housing system on albumen quality. Zemková et al. (2007) state that not only yolk quality, but also cholesterol concentration is influenced by the housing system. Yilmaz Dikmen et al. (2017) confirm the effect of the housing system on the quality of eggs from Lohmann Brown-Classic hens. Last but not least, the housing system considerably affects the total amount of microorganisms on the egg surface and microbial contamination with *Enterococcus* and *Escherichia coli* (Englmaierová et al., 2014).

This study was made because of the dominant use of cage systems in poultry husbandry worldwide. The aim was to evaluate quality parameters of eggs of brown egg-laying hybrid Lohmann Brown-Classic depending on age and housing system. Concretely, comparison of enriched cage and litter systems was observed. Expectation is that age and housing system will significantly influence basic egg quality parameters.

Materials and Methods

Bird management

The eggs were collected from Lohmann Brown-Classic hens. Lohmann Brown-Classic hens are commercial hybrids that belong to the group of egg-laying hens. These hens can lay up to 433 brown shelled eggs and are capable of laying until 17 months of age. The average weight of one egg from Lohmann Brown-Classic hen is 64.75 g (Lohmann Tierzucht, 2016). Both housing systems, enriched cages and litter, were arranged in the Demonstration and Experimental Center. Criteria set by European Commission Directive 1999/74/EC that determines the minimum of 750 cm^2 per hen in enriched cages and a maximum density of 9 hens per m^2 of floor area in halls with litter were met in this study. The temperature was set to 18–20°C and humidity to 50–60% in both housing systems. The birds were provided with 14 hours of light and the intensity of lightning was from 10 to 15 lx in both housing systems as well. Throughout the duration of the study a feed mixture was used that contained 16.4% of crude protein and 11.42 MJ of metabolizable energy. The access to feed and water was *ad libitum* in both housing systems for the whole monitored period.

Measured parameters

The egg quality parameters were assessed in eggs from 32, 42 and 64-week-old hens in the laboratory of the Department of Animal Science of the Faculty of Agrobiology, Food and Natural Resources. In total, 1080 eggs from the enriched cage system from 300 hens and 540 eggs from the litter system from 150 hens were analysed. Eggs were collected two days in a row, stored under controlled conditions and analyzed the next day.

All laboratory analysis and measurements were made according to Zita et al. (2018). Moreover, the eggshell surface (ES) was calculated by the formula $ES = 4.68 \times EW^{2/3}$ [cm^2], where EW is the egg weight in g (Ahmed et al., 2005). Yolk to albumen ratio (YAR) was calculated by the formula $YAR = (YW / AW)$, where YW is the yolk weight in g and AW is the albumen weight in g (Dottavio et al., 2005).

Statistical Analysis

The computer software SAS 9.4 was used for data evaluation. The effect of age and housing system on selected parameters of the technological value of the eggs was evaluated by the mixed model using the MIXED procedure of SAS: $y_{ijk} = \mu + A_i + HS_j + (A \times HS)_{ij} + e_{ijk}$, where y_{ijk} was the value of the sign, A_i was the effect of age (32, 42, 64 weeks of age), HS_j was the effect of housing system (enriched cages, litter), $(A \times HS)_{ij}$ was the effect of interaction between age and housing system and e_{ijk} was the random residual error. The significance of differences between the groups was tested by the multiple Duncan test. The value of $p \leq 0.05$ was considered as statistically significant.

Results

Final results of this experiment are shown in Tables 1 and 2 and Figure 1. Parameters of the whole egg and eggshell are shown in Table 1, parameters of the albumen and yolk are shown in Table 2. Figure 1 shows the proportion of individual egg components.

The egg weight was significantly ($p \leq 0.001$) influenced by age, housing system and their interaction (Table 1). A constant increase of the egg weight with the age was discovered in both housing systems. Eggs from enriched cages were heavier than eggs from litter in all observed periods. The heaviest eggs came from 64-week-old hens from enriched cages (69.19 g), while the lightest eggs came from 32-week-old hens from litter (60.13 g). The egg shape index was significantly influenced by age ($p \leq 0.001$) but was not significantly influenced by housing system ($p > 0.05$). Also, a statistically significant interaction ($p \leq 0.001$) between age and housing system was determined. Unlike the

Table 1. Quality of egg and eggshell parameters depending on age and housing system

Parameter	Age (weeks)	Housing system		Significance			SEM
		Enriched cages	Litter	Age	Housing system	Age × Housing system	
Egg weight (g)	32	62.13^{c}	60.13^{d}	***	***	***	0.239
	42	67.77^{b}	63.66^{bc}				
	64	69.19^{a}	64.92^{bc}				
Egg shape index (%)	32	78.05^{ab}	78.80^{a}	***	NS	***	0.108
	42	77.03^{b}	76.35^{bc}				
	64	76.47^{bc}	75.33^{c}				
Eggshell surface (cm^2)	32	73.22^{c}	71.66^{d}	***	***	***	0.184
	42	77.61^{ab}	74.40^{bc}				
	64	78.68^{a}	75.39^{b}				
Eggshell weight (g)	32	6.09^{bc}	5.97^{c}	***	***	***	0.022
	42	6.54^{ab}	6.28^{b}				
	64	6.73^{a}	6.44^{ab}				
Eggshell thickness (mm)	32	0.346^{ab}	0.344^{b}	***	***	**	0.001
	42	0.343^{b}	0.349^{ab}				
	64	0.346^{ab}	0.361^{a}				
Eggshell strength (N/cm^2)	32	42.07	43.23	***	**	NS	0.398
	42	38.26	38.55				
	64	37.57	38.98				
Eggshell colour (%)	32	25.18^{c}	29.29^{ab}	***	***	**	0.181
	42	26.39^{bc}	27.85^{b}				
	64	28.47^{b}	31.97^{a}				

Values marked with different superscript letters for each parameter are significantly different ($p \leq 0.05$).

NS = non-significant ($p > 0.05$); ** $p \leq 0.01$; *** $p \leq 0.001$; SEM = Standard Error of the Mean.

egg weight, the egg shape index decreased with the age in both housing systems. The higher egg shape index had eggs from enriched cages, with the only exception of eggs from 32-week-old hens, where higher egg shape index had eggs from litter. The highest values of egg shape index were in eggs from 32-week-old hens from litter (78.80%) and the lowest in eggs from 64-week-old hens from litter (75.33%).

The first measured eggshell parameter (Table 1) was the eggshell surface, which was significantly ($p \leq 0.001$) influenced by age, housing system and their interaction. The eggshell surface had the same trends as the egg weight. The eggshell surface regularly increased with the age in both housing systems. Higher values of the eggshell surface were in eggs from enriched cages than in eggs from litter in all observed periods. The highest eggshell surface was in eggs from 64-week-old hens from enriched cages (78.68 cm^2), on the contrary, the lowest in eggs from 32-week-old hens from litter (71.66 cm^2). The significant effect ($p \leq 0.001$) of age, housing system and their interaction was discovered in the eggshell weight. The increase of eggshell weight with the age occurred in both housing systems. Eggs that came from enriched cages had heavier eggshell in all three monitored periods. The heaviest eggshell had eggs from 64-week-old hens from enriched cages (6.73 g) and the lightest had eggs from 32-week-old hens from litter (5.97 g). The eggshell proportion was significantly ($p \leq 0.001$) influenced by age, housing system and their interaction. The eggshell propor-

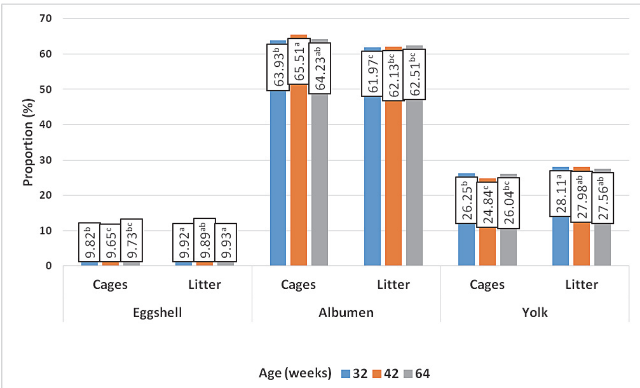

Figure 1. Proportion of individual egg components depending on age and housing system

Values marked with different superscript letters in each parameter are significantly different ($p \leq 0.05$).

tion fluctuated with the age in eggs from both housing systems (Figure 1). A higher eggshell proportion had eggs from litter in comparison with eggs from enriched cages in the whole monitored period. The highest eggshell proportion had eggs from 64-week-old hens from litter (9.93%), the lowest had eggs from 42-week-old hens from enriched cages (9.65%). Subsequent measured eggshell parameter was its thickness. Eggshell thickness was significantly ($p \leq 0.001$) affected by age and housing system. The interaction ($p \leq 0.01$) between age and housing system was also determined. Eggshell thickness increased with the age in eggs from litter but fluctuated in the eggs from enriched cages. The values of eggshell thickness were higher in eggs from litter, except for the eggs from 32-week-old hens. The highest values of eggshell thickness had eggs from 64-week-old hens from litter (0.361 mm) and the lowest had eggs from 42-week-old hens from enriched cages (0.343 mm). The eggshell strength was significantly influenced by age ($p \leq 0.001$) and also by housing system ($p \leq 0.01$), but there was not discovered any interaction ($p > 0.05$) between age and housing system. A constant decrease of eggshell strength with the age occurred in eggs from enriched cages, but it fluctuated in eggs from litter. Higher values of eggshell strength had eggs that came from litter in all monitored periods. The highest eggshell strength was in eggs from 32-week-old hens from litter (43.23 N/cm^2) and the lowest in eggs from 64-week-old hens from enriched cages (37.57 N/cm^2). The eggshell colour was significantly ($p \leq 0.001$) affected by observed factors, age and housing system. The statistically significant interaction ($p \leq 0.01$) between age and housing system was found. Eggshell colour of eggs from enriched cages regularly increased with the age, but the eggshell colour of eggs from litter fluctuated during the monitored period. Darker eggshell colour had eggs that came from enriched cages in comparison with eggs from litter in all three monitored periods. The darkest eggshell colour had eggs from 32-week-old hens from enriched cages (25.18%) and the lightest had eggs from 64-week-old hens from litter (31.97%).

The first of the albumen measured parameters was albumen weight (Table 2), which was significantly ($p \leq 0.001$) influenced by age, housing system and their interaction. The albumen weight constantly increased with the age in both housing systems. Heavier albumen was determined in eggs from enriched cages in the whole monitored period. The heaviest albumen had eggs from 64-week-old hens from enriched cages (44.44 g), the lightest albumen had eggs from 32-week-old hens from litter (37.27 g). The subsequent measured parameter was albumen proportion, which was significantly ($p \leq 0.001$) influenced by age, housing system and their interaction. The albumen proportion fluctuated with the age in eggs from enriched cages and constantly increased in eggs from litter (Figure 1). The higher albumen proportion

Table 2. Quality of albumen and yolk parameters depending on age and housing system

Parameter	Age (weeks)	Housing system		Significance			SEM
		Enriched cages	Litter	Age	Housing system	Age × Housing system	
Albumen weight (g)	32	39.76^{bc}	37.27^{c}	***	***	***	0.205
	42	44.42^{a}	39.59^{bc}				
	64	44.44^{a}	40.61^{bc}				
Albumen index (%)	32	7.95^{b}	5.17^{d}	***	***	***	0.088
	42	9.17^{a}	5.41^{c}				
	64	8.69^{ab}	7.48^{b}				
Haugh Units	32	79.70^{ab}	62.14^{c}	***	***	***	0.436
	42	82.38^{a}	67.63^{bc}				
	64	82.22^{a}	76.18^{b}				
Yolk weight (g)	32	16.28^{c}	16.89^{bc}	***	**	***	0.067
	42	16.81^{bc}	17.79^{ab}				
	64	18.02^{a}	17.87^{ab}				
Yolk index (%)	32	41.63^{c}	42.97^{b}	***	***	***	0.135
	42	43.91^{a}	38.20^{d}				
	64	42.40^{bc}	43.58^{ab}				
Yolk to Albumen ratio	32	0.41^{b}	0.46^{a}	***	***	**	0.002
	42	0.38^{c}	0.45^{a}				
	64	0.41^{b}	0.44^{ab}				

Values marked with different superscript letters for each parameter are significantly different ($p \leq 0.05$).
NS = non-significant ($p > 0.05$); $**p \leq 0.01$; $***p \leq 0.001$; SEM = Standard Error of the Mean.

had eggs from enriched cages in all monitored periods. The highest albumen proportion had eggs from 42-week-old hens from enriched cages (65.51%) and the lowest had eggs from 32-week-old hens from litter (61.97%). The albumen index was significantly ($p \leq 0.001$) influenced by age, housing system and their interaction. The values of albumen index increased with the age only in eggs from litter, in eggs from enriched cages these values fluctuated with the age. The higher albumen index was in eggs from enriched cages in all monitored periods. The highest albumen index was in eggs from 42-week-old hens from enriched cages (9.17%) and the lowest in eggs from 32-week-old hens from litter (5.17%). Haugh units were significantly ($p \leq 0.001$) influenced by age, housing system and their interaction. Haugh units had the same trends as the albumen index. Haugh units increased with the age only in eggs from litter, in eggs from enriched cages Haugh units fluctuated. Haugh units were higher in eggs from enriched cages in all three monitored periods. The highest Haugh units were in eggs from 42-week-old hens from enriched cages (82.38), the lowest were in eggs from 32-week-old hens from litter (62.14).

The yolk weight (Table 2) was significantly influenced by age ($p \leq 0.001$) and by housing system ($p \leq 0.01$). There was also found the interaction ($p \leq 0.001$) between age and housing system. The yolk weight constantly increased with the age in both housing systems. Heavier yolk was in eggs from litter, with the only exception of eggs from 64-week-old hens, where heavier yolk was in eggs from enriched cages. The heaviest yolk was in eggs from 64-week-old hens from enriched cages (18.02 g) and the lightest was in eggs from 32-week-old hens from enriched cages (16.28 g). The yolk proportion was significantly ($p \leq 0.001$) influenced by age and housing system. The significant interaction ($p \leq 0.01$) between age and housing system was discovered. Yolk proportion decreased with the age in both housing systems (Figure 1). Higher yolk proportion had eggs from litter in comparison with eggs from enriched cages in all three monitored periods. The highest yolk proportion was in eggs from 32-week-old hens from litter (28.11%), the lowest was in eggs from 42-week-old hens from enriched cages (24.84%). Yolk index was significantly ($p \leq 0.001$) influenced by age, housing system and their interaction ($p \leq 0.001$). The yolk index fluctuated during the monitored period in both housing systems. The yolk index was higher in eggs from litter, except for the eggs from 42-week-old hens, where higher yolk index was in eggs from enriched cages. The highest yolk index had eggs from 42-week-old hens from enriched cages (43.91%) and the lowest had eggs from 42-week-old hens from litter (38.20%). Another measured parameter was yolk to albumen ratio, which was significantly ($p \leq 0.001$) influenced by age and housing system. There was determined the interaction ($p \leq 0.01$) between age and housing system. The yolk to albumen ratio fluctuated with the age in eggs from enriched cages, but regularly decreased in eggs from litter. Higher yolk to albumen ratio was in eggs from litter in all monitored periods. The highest yolk to albumen ratio was in eggs from 32-week-old hens from litter (0.46) and the lowest was in eggs from 42-week-old hens from enriched cages (0.38).

Discussion

Various authors, for example Ahmadi & Rahimi (2011), Holt et al. (2011) or Ledvinka et al. (2012) include effect of age and housing system among the most important factors that influence egg quality.

The egg weight regularly increased with the age in eggs from both housing systems. When comparing housing systems, the egg weight values were higher in eggs from enriched cages. Zita et al. (2009) discovered the significant effect of age, while Englmaierová et al. (2014) discovered the significant effect of housing system on egg weight in their study. The fact that egg weight increases with the age was confirmed by other authors, such as Bozkurt & Tekerli (2009) or Krawczyk (2009). Lewko & Gornowicz (2011) claim that eggs from enriched cages are heavier than eggs from litter. On the other hand, Zita et al. (2018) found out that eggs from litter were heavier than eggs from enriched cages. This difference can be caused by the use of different breeds of hens. Zita et al. (2018) used original breeds in their study, while this study was made with commercial hybrid. Vlčková et al. (2018) determined the interaction between age and housing system in egg weight. The egg shape index regularly decreased with the age in eggs from both housing systems. When comparing housing systems, the egg shape index fluctuated. Van Den Brand et al. (2004) confirms that the egg shape index decreases with the age, but Padhi et al. (2013) claim the opposite. Unlike our results, other authors such as Englmaierová et al. (2014) or Zita et al. (2018) found out that the housing system has a significant effect on egg shape index. Van Den Brand et al. (2004) did not find the interaction between age and housing system in the egg shape index.

The eggshell surface and weight regularly increased with the age in eggs from both housing systems. The eggshell surface and weight were higher in eggs from enriched cages. Vlčková et al. (2018) claim that age and housing system significantly influences the eggshell weight and also confirms the interaction between age and housing system. Englmaierová & Tůmová (2009) claim that the housing system has a significant effect on the eggshell surface. The eggshell strength decreased with the age in eggs from enriched cages and fluctuated in eggs from litter. Eggshell proportion fluctuated with the age in eggs from both housing systems. Both parameters were higher in eggs from litter. The significant effect of age on eggshell proportion was confirmed by Samiullah et al. (2014), but Padhi et al. (2013) did not find any significant effect of age on eggshell proportion in their study. Zita et al. (2018) claim that the type of housing system significantly affects eggshell proportion, while results from Samiullah et al. (2014) show the opposite. Samiullah et al. (2014) determined a significant interaction between age and housing system in eggshell proportion. Vlčková et al. (2018) claim that eggshell strength is affected by age. Eggshell strength decreases with the age because egg weight significantly increases, while production of eggshell remains the same or increases only very slightly. Englmaierová & Tůmová (2009) or Sokołowicz et al. (2018) confirm that housing system significantly influences eggshell strength. Vlčková et al. (2018) found the interaction between age and housing system in eggshell strength. The eggshell thickness regularly increased with the age only in eggs from litter, while the eggshell colour regularly increased with the age only in eggs from enriched cages. The eggshell thickness fluctuated with the age only in eggs from enriched cages and the eggshell colour fluctuated with the age only in eggs from litter. When comparing housing systems, the eggshell thickness fluctuated, and the eggshell colour was higher in eggs from litter. Vlčková et al. (2018) discovered that eggshell thickness was not significantly influenced by age but was significantly influenced by housing system. Zita et al. (2018) claim that eggshell thickness is significantly affected by housing system. Samiullah et al. (2014) found the interaction between age and housing system in eggshell thickness. However, Vlčková et al. (2018) did not find any interaction between age and housing system in their study. Samiullah et al. (2015) state that age influences eggshell colour. The significant effect of housing system on eggshell colour was confirmed by a number of authors, for example by Lewko & Gornowicz (2011) or by Zita et al. (2018). On the contrary, Sokołowicz et al. (2018) claim that the effect of housing system on eggshell colour is nonsignificant. This difference can be caused by the fact that Sokołowicz et al. (2018), unlike other mentioned authors, did not use cage systems in their study. Samiullah et al. (2014) determined interaction between age and housing system in eggshell colour.

The albumen weight regularly increased with the age in eggs from both housing systems. The albumen proportion fluctuated with the age in eggs from enriched cages and regularly increased in eggs from litter. The albumen weight and proportion were higher in eggs from enriched cages. Results from Yilmaz Dikmen et al. (2017) show the significant effect of age and housing system on albumen weight. Padhi et al. (2013) claim that age influences the albumen weight. Yilmaz Dikmen et al. (2017) found the interaction between age and housing system in the albumen weight. Zita et al. (2009) and Padhi et al. (2013) state that age influences albumen proportion. Zita et al. (2018) confirm the significant effect of housing system on albumen proportion, while results from Englmaierová & Tůmová (2009) show the opposite. Yilmaz Dikmen et al. (2017) discovered the interaction between age and housing system in the albumen proportion. The albumen index and the Haugh units regularly increased with the age in eggs from litter and fluctuated in eggs from enriched cages. When comparing housing systems, the albumen index and the Haugh units were higher in eggs from enriched cages. Padhi et al. (2013) state that age influences the albumen index. The effect of the housing system was confirmed by many other authors, including Englmaierová et al. (2014) and Zita et al. (2018). Yilmaz Dikmen et al. (2017) determined the significant interaction between age and housing system in the albumen index. Padhi et al. (2013) claim that age significantly influences Haugh units and Zita et al. (2018) confirm the significant effect of housing system. Samiullah et al. (2014) found the interaction between age and housing system in Haugh units.

The yolk weight regularly increased with the age in eggs from both housing systems. It is common fact that yolk weight increases with the age, while albumen weight decreases. When comparing housing systems, the yolk weight fluctuated. Krawczyk (2009) confirms the effect of age on the yolk weight. The results from Sokołowicz et al. (2018) show that housing system influences the yolk weight. Yilmaz Dikmen et al. (2017) discovered significant the interaction between age and housing system in the yolk weight. The yolk proportion and yolk to albumen ratio fluctuated with the age in eggs from enriched cages and regularly decreased in eggs from litter. The yolk proportion and yolk to albumen ratio were higher in eggs from litter. The results from Padhi et al. (2013) show the significant effect of age on the yolk proportion. Englmaierová et al. (2014) state that housing system influences the yolk proportion. Yilmaz Dikmen et al. (2017) found the interaction between age and housing system in the yolk proportion, but Van Den Brand et al. (2004) did not find this interaction.

The yolk index fluctuated with the age in eggs from both housing systems. When comparing housing systems, the yolk index fluctuated. Bozkurt &Tekerli (2009) claim that age influences the yolk index. The significant effect of housing system on the yolk index confirms Englmaierová et al. (2014) or Zita et al. (2018). On the contrary, Yilmaz Dikmen et al. (2017) did not find the interaction between age and housing system in the yolk index. Unlike our results, Suk & Park (2001) determined that the yolk to albumen ratio is not influenced by the age. Englmaierová et al. (2014) claim that housing system has a significant effect on the yolk to albumen ratio. Van Den Brand et al. (2004) did not find the interaction between age and housing system in yolk to albumen ratio.

Conclusions

Results of this study did not confirm the trend of deteriorating egg quality with the age. In terms of housing system, it is not possible to unambiguously claim that one housing system produced eggs with a superior quality, but most of the values of the main parameters were higher in eggs from enriched cages. It is necessary to continue to monitor the quality of eggs, depending on the age and housing system, in context of the discussions of the cage systems replacement.

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