Influence of Housing System on Egg Weight and Shell Physical Quality Indicators of Laying Hens Eggs

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Abstract

In this experiment the effects of different housing systems on physical indicators of egg yolk and egg albumen quality of table eggs were studied. Hens of laying hybrid Lohmann Brown Lite were housed in two different housing systems, in enriched cage or on floor housing system. In both systems, the hens were kept under standard bioclimatic conditions. Eggs (n = 1080) were collected from the first phase of the laying cycle, at monthly intervals, at the age of laying hens 30-42 weeks. Egg weight (g), egg specific weight (g.cm-3), egg shape index (%), eggshell weight (g), eggshell percentage (%), and average eggshell thickness (μm) were evaluated.

In the indicators of the whole egg quality was statistically significantly higher (P<0.001) the average weight of eggs produced by laying hens kept in enriched cage (66.3 ± 3.6) mean ± SD in comparison with the eggs from laying hens housed on litter (64.3 ± 4.0) mean ± SD. Similarly, in eggshell quality indicators (weight, proportion, average thickness) there were significantly higher differences in favor of the eggs from caged breeding. The values of the average egg shell thickness (μm) in the order of groups (392 ± 24.6; 377 ± 24.3) (mean ± SD). The results obtained show that the eggs from caged breeding achieved better results in more quality indicators compared to the eggs from litter breeding.

Key words: laying hens, egg weight, eggshell quality, enriched cage housing system, floor housing system

1. Introduction

According to EC Directive 1999/74/EE, in all European countries consumption eggs can be produced in cage, litter, free-range and organic housing systems [1]. Although there are many potential hen housing systems, there is no system that dominates when all production, environmental, and welfare aspects are considered [2].

In a 2011 study, Lay et al. found no single superior housing system and concluded the right combination of housing design, breed, rearing conditions, and management was essential to optimize hen welfare and productivity [3]. It is critical to align documented welfare conditions with the values perceived by the public and resulting product demand [4].

Among other components of enrichment such as the provision of perches and nest boxes, open

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litter area is the hallmark of the cage-free systems [5].

Cage-free (CF) egg production has been a topic of increasing importance in the United States due to pledges made by food retailers and restaurants to source only cage-free eggs by certain year [6]. However, issues or challenges associated with CF production remain to be addressed with regard to food quality and safety [8]; litter usage and dust bathing motivation [9], disease and health of poultry [10]; bone stability [11]; bone properties[12]; indoor air quality [1,13-17,]; storage of eggs [18]; emissions [19]; and welfare [20-23]. One of the debated criteria is concerning litter access, namely whether the laying hens should be provided full litter access throughout the day to be qualified as CF egg production, as compared to temporarily confining the hens in the aviary system (one type of CF system) during oviposition period in early morning. Research is lacking regarding the impact of such practice on hens' welfare, floor eggs, litter, and environmental conditions [24]. One of the main improvements of CF systems is the inclusion of litter floor area, allowing the hens to express their natural behavior of dust bathing [25]. Oviposition place is one of the biggest concerns in CF systems because floor eggs are directly linked to food safety and economic issues [8,26]. Therefore, it is essential to develop and test strategies to reduce the incidence of floor eggs in commercial CF systems.

Eggs and egg products form an integral part of the food chain. As such, research into egg structure, function, and production has made an important contribution to the field of poultry science. The past decade has seen significant advances in avian egg science research, with work supplementing our understanding of the nature of the avian egg, and its biological, chemical, and physical properties. Eggshell color, strength, and chemical composition, poultry nutrition, and genetics have all been intensively studied recently, with significant progress being made in a number of these areas. Indeed, with the prevalence of robust theoretical techniques, it is now commonplace to combine experimental investigations with theory, providing a balanced and interdisciplinary perspective [27].

In the commercial egg industry, the eggshell protects the egg from mechanical damage and contamination of the internal contents. Failure of the shell for any reason compromises the value of an egg as a food product. Egg producers must be aware of these factors because the economic consequences of shell failures are significant. At the time when the eggshell is formed, all of the investment of nutrients has already been made, and the loss of nutritional value potentially represents a total loss to the farmer [28].There are many factors that affect the functional quality of the eggshell, mostly prior to when the egg is laid, such as the strain, the age of the bird, nutrition, stress, disease, and the housing system.

The housing system can have a considerable effect on eggshell quality. However, the results of the effect of the housing systems on eggshell quality are ambiguous. Eggshell quality is characterized by many indicators, such as eggshell weight, specific weight, share, thickness, defor-mation or strength. Major economic losses for egg producers are associated with lower eggshell strength leading to eggshell breakage [29]. Inconsistent results explainable by structural differences of the eggshell are related to the interaction of the housing system, age, genotype, oviposition time, and mineral nutrition [30]. Contradictory data on the effect of the hous-ing system on the eggshell quality need further research. It might be expected that there is an interaction between the housing system and the other factors [29].

The aim of this study was to compare the technological parameters of the quality of table eggs (egg weight, shape and eggshell quality) coming from laying hens kept in enriched cages, which are currently the most commonly used housing system in Slovakia, with the quality of laying hen eggs housed in the litter hall, in the first phase of the laying.

2. Materials and methods

Animals, diets and treatments

The experiment was conducted with Lohmann Brown Lite hens. Hens from which eggs were collected for quality analysis were kept on the selected farm in two different types of housing systems. In the first hall, laying hens were housed in enriched cages. In the second hall, the hens were kept in floor–management.

Cage housing system

During the rearing period, pullets up to the age of 17 weeks were housed in one-store cages. Feeding was provided by trough feeders with a chain conveyor, water supply was provided by nipples placed directly in the cage. At the age of 17 weeks, the pullets were moved to the breeding (production) halls to have time to adapt to the breeding environment before the start of laying. In the breeding halls, the hens were housed in groups (60 hens per cage, 750 cm2 per hen)., in three-store enriched cage technologies, which met the requirements set by the European Union, Directive 1999/74 EC for enriched cages. The cages were equipped with two nipple drinkers, claw abrasion device, a pop-up and a screen made of opaque material, which separated the laying nest, located in the back of the cage. The eggs were transported from the individual floors in each row to the vertical conveyors and from there, by the elevator automatic conveyor out of the hall to the sorting room. Hens were reared under standard bioclimatic conditions throughout the laying period. Accession to feed mixture or drinking water was *ad libitum*.

Floor-management system housing

During rearing, hens were housed in breeding halls on cut straw bedding until the age of 17 weeks. The hall was equipped with tube feeders and nipple drinkers. After reaching the age of 17 weeks, the hens were moved to the production hall to get used to the new environment. The laying hens in the floor–management (9 hens per m2) were placed in deep-litter with cut straw (without the possibility of free range to the exterior). Laying hens had perches available.

The feeding and watering technology was the same as in the rearing hall. In contrast to the rearing hall, the production hall was additionally equipped with laying nests. Eggs were collected manually. Hens were breed under standard bioclimatic conditions throughout the laying period. The microclimate conditions were in accordance with the laying hen's requirements. The daily photoperiod consisted of 15 h of light and 9 h of darkness. Accession to feed mixture or drinking water was *ad libitum*.

Laying hens were fed identical commercial feed mixtures. The composition of the basal diet (BD) fed to the laying hens is shown in Table 1 and Table 2.

Sample analysis

The analysis of selected indicators of egg quality was performed in the laboratory of the Department of Small Animal Science, Faculty of Agrobiology and Food Resources, Slovak University of Agriculture in Nitra.

During the experiment produced eggs were collected at the same stage of laying in laying hens in both housing systems, at 30-42 weeks of age to determine the quality of the whole egg and eggshell quality. In whole eggs the egg weight (g), specific egg weight (g/cm3) and egg shape index were evaluated. In eggshell – eggshell weight (g), eggshell portion (%), egg shell strength (N/cm3) and average eggshell thickness (μm).

Table 1. Composition of the trial diets

Component	Participation in the Diet (%)
Wheat	26.30
Rye	15.00
Barley	20.00
Soybean meal (47% crude protein)	22.00
Soybean oil	2.50
Fat	2.00
Monocalcium phosphate	1.70
Calcium carbonate	9.14
Natrium chloride (38 % Na)	0.30
Sodium bicarbonate (28 % Na)	0.10
Methionin (99 % DL-Methionin)	0.16
Vitamin Premix	0.40
Mineral Premix	0.10
Choline chloride	0.20
Caroten premix	0.10

Table 2. Nutrient content in the trial diets

Nutrient	Nutrient Content in Mixture
MEN (MJ.kg^{-1} of DM)	11.5
CP (g.kg^{-1} of DM)	177
LYS (g.kg^{-1} of DM)	8.81
MET (g.kg^{-1} of DM)	4.17
M + C (g.kg^{-1} of DM)	7.41
THR (g.kg^{-1} of DM)	6.27
LA (g.kg^{-1} of DM)	19.0
Ca (g.kg^{-1} of DM)	39.1
Pavail. (g.kg^{-1} of DM)	3.8
Na (g.kg^{-1} of DM)	1.5

* MEN: metabolisable energy for poultry, CP: crude protein, LYS: lysine, MET: methionine, M+C: methionine plus cysteine, THR: threonine, LA: linoleic acid, Ca: calcium, Pavail.: available phosphorus, Na: natrium.

In egg quality analysis these parameters were detected using routine methods: Weight parameters were detected using analytical weighting machine and the growth intensity and percentage contents were calculated from weight data. Index of shape was calculated as the width: lenght ratio times 100. Eggshell strength was detected using Egg Crusher 1.1 (VEIT Electronics, Czech Republic). The eggshell thickness at the equatorial plane was evaluated using a QCT micrometre (TSS Ltd.) after removing the inner and outer eggshell membranes. A total of 270 eggs were collected from each housing system (thus totally 540 eggs were analyzed).

Statistical analysis

Statistical analysis was done using one–way analysis of variance (ANOVA) across the General linear model in the program SAS.

3. Results and discussion

Table 3 provides the average egg weight, specific egg weight and egg shape in each housing system for the monitored laying period. Eggshell quality indicators in each system for the observed laying period expresses Table 4.

Table 3. Influence of the housing system on the alterations of Lohmann Brown Lite laying hen's whole egg quality

Characteristic		Enriched cage	Litter	Significance
Egg weight	g	66.3 ± 3.6	64.3 ± 4.0	0.001
Specific egg weight		1.08 ± 0.1	1.05 ± 0.07	0.4138
Egg shape	%	76.7 ± 3.9	77.3 ± 4.7	0.0435

n=270; Values shown are mean±SD (standard deviation)

The egg weight was affected by the housing system (P<0.001). The egg weight was significantly higher in enriched cages compared to litter (values were 66.3±3.6; 64.3±4 g±SD) and increased with advancing age. These results are in agreement with [31][32] who observed higher egg weights from hens housed in cages. Similar, to the results reported by [33] the egg weight of the eggs laid by layers reared in cages was higher compared to the eggs from the layers kept on deep litter. On the other hand, [34,35] demonstrated significantly higher egg weight for eggs from hens housed on litter. The lower weight of eggs from hens housed in conventional cages is likely related to greater egg production. The housing system significantly (P<0.001) affected egg weight in the experiment [36]. Higher values in Czech hen were detected in litter on other hand in Lohmann white were found in cage. In the experiment [29] the egg weight was significantly higher in enriched cages compared to free range. An insignificant increase in egg weight was observed as a result of a comparison of the egg quality from the conventional cage housing system and the floor litter system in the experiment of [37].

Regarding the specific egg weight, no significantly lower difference between eggs on litter compared to the enriched cages eggs has been reported in our experiment (P>0.05).

Regarding the egg shape, significantly higher difference for litter eggs compared to the eggs from enriched cages were recorded (P<0.05) in our experiment. Findings of the study are similar to [38] who indicated that the shape of eggs from free range system was higher than from enriched cages but the study of [39] presented different which indicated that the shape of eggs from enriched cages was significantly different from other systems.

Table 4. Influence of the housing system on the alterations of Lohmann Brown Lite laying hen's eggshell quality

Characteristic		Enriched cage	Litter	Significance
Eggshell weight	g	6.3 ± 0.8	6.1 ± 0.7	0.001
Eggshell percentage	%	9.5 ± 1.2	9.2 ± 1.1	0.001
Eggshell strength	N/cm2	28.44 ± 6.34	27.82 ± 6.12	0.0687
Eggshell thickness	µm	392 ± 24.6	377 ± 24.3	0.001

n=270; Values shown are mean±SD (standard deviation)

Regarding to eggshell quality characteristics, the statistically significant influence of the housing system (P<0.001) was observed in the eggshell weight, eggshell percentage and eggshell thickness. Thicker eggshells were found in eggs from hens in an enriched cage. Eggs with insignificantly stronger eggshells (28.44 N/cm2) were laid by hens housed in enriched cages. [40] concluded that eggshell quality was one of the most important parameters for the technology of further egg manipulation. In addition, numerous studies focused on eggshell quality indicated a higher quality of eggs from cages [41,13].

The eggshell weight was also affected by the laying hen housing system. Significantly heavier (P<0.001) eggshells were observed in eggs laid in cages compared to litter. The shell of eggs from an enriched cage were heavier than eggs from litter and we found out there was higher shell deformation in enriched cages than in litter. Egg weight was significantly greater in cages and this is reflected in increased shell width, length and volume in eggs from enriched cages. There was a significant effect depending on the housing system on shell weight, deformation and thickness. Shell thickness was significantly lower in eggs of enriched cages and in eggs with higher deformation. The highest value of eggshell weight was measured in litter from Lohmann [42].

The proportion of eggshells (%) in our experiment was statistically significantly higher (P<0.001) in eggs from cages compared to eggs from litter. Also [35] proved that the highest percentage of eggshell was characteristic of eggs from caged hens. The significantly highest proportion of eggshell was found in Czech hens on litter and Oravka hens in cages, while the significantly lowest proportion of eggshell was in Czech hens in cages in the study of [16].

The eggshell thickness was significantly affected by the housing system in several study. [13] provided that eggs from cage systems have a thicker shell. Moreover, eggshell strength is higher in eggs from cages than on litter. Shell thickness was significantly less affected in eggs of enriched cage and in eggs with higher deformation. Although eggshell thickness was lower in eggs that were produced in cages, the eggshell strength was higher [43]. On the other hand, several authors reported a higher number of cracked eggs from cage systems compared to aviaries [44], litter [45], free range and organic systems [46]. In line with our findings [32] showed that eggs with a higher strength of eggshell were produced by hens from the cage system. The eggshell thickness in the eggs laid by layers reared in cages was greater compared to the eggs from the layers kept on litter.

The strongest eggshells found [29] eggs in younger hens in the enriched cage, whereas the weakest occurred in the free range and in younger hens. Significantly heavier eggshells were observed in eggs laid in cages compared to free range and in eggs from 51-week-old hens. Eggshell thickness and density were higher for hens kept on litter in the study of [47].

4. Conclusions

The results indicate that most of the monitored quality parameters of the whole egg as well as the quality of the eggshell were significantly affected by the housing system used. A statistically significant difference in favor of eggs from enriched cage technology was observed for egg weight, egg shape, eggshell weight, eggshell proportion as well as average eggshell thickness. In the case of shell strength, statistically insignificantly higher values were also found for eggs from an enriched cage.

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