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RESEARCH OF SELECTED PHYSICAL INDICATORS OF TABLE EGGS IN THE SMALL-SCALE BREEDINGS FROM THE ASPECT OF HEALTH SAFETY

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ABSTRACT

The purpose of this study was to investigate selected indicators of the table eggs in small-scale breedings, focusing mainly on the eggshell and its contamination and damage. Our object of study was eggs, shell, damage, and contamination of table eggs. Four small-scale breedings were randomly selected in Slovakia. These breeds were alternatively with an outdoor free-range. Laying hens Dominant was bred under conditions small-scale breeds No.1, No. 2 and No. 3 in the 1st laying cycle, and No. 4 in the 2nd laying cycle. Egg weight was balanced in three small-scale breedings. Egg weight was significantly higher in the fourth small-scale breeding, statistically significant (p <0.05) compared to egg weight in the studied 3 small-scale breedings. Shell weight and shell thickness in the equatorial plane of the egg were balanced in three small-scale breedings and in the fourth small-scale breedings were significantly higher, statistically significant (p <0.05). The higher egg weight per breeding is related to the higher laying hens age that was in the 2nd laying cycle compared to laying hens 3 small-scale breedings in the 1st laying cycle. Higher eggshell weight in three farms may be related to improved conditions in breeding hygiene, as confirmed by the results of investigations into contamination and damage to table eggs. These differences may also be related to nutrition.

Keywords: small-scale breeding; egg; eggshell; contamination; damage

INTRODUCTION

Improved animal welfare is the sum of physical and mental well-being. Many factors affect the welfare of laying hens. The results obtained from research into improved living conditions may be contradictory. In this context, experts agree that a suitable approach to assessing the welfare of laying hens is to integrate the information across disciplines, using several different methodologies **(Scientific Panel on Animal Health and Welfare, 2005)**.

The assessment of the indicators of egg external quality raised laying hens in the system of alternative environments, such as on litter, is fundamental for the promotion of this rearing system. To determine the effects of the rearing environment on the performance and welfare of hen laying, the analysis of productive parameters and egg quality and safety are examples of some measures adopted **(Alves, Silva and Piedade, 2007)**.

According to the knowledge previously published, it is known that laying hens kept in domestic conditions (small-scale breeding) they largely preserve kinds of natural behavior, generally according to their wild ancestor **(Fraser and Broom, 1990)**.

Laying hens have been bred for several thousand years in some properties. Domestication and selection took place. Some types of behavior originate in genetics and persist in the environment, that it requires to prepare conditions for satisfying hen laying needs. This type of behavior is known as instinct. Ethologists (scientists who specialize in animal behavior studies) explain that, in terms of motivation and ethological needs, strongly motivated behavior is largely controlled by internal factors (such as changes in hormone levels), which are available regardless of the type of outdoor environment **(Duncan, 1998)**.

Behavior identified as important for improved welfare laying hens includes nesting, examination, perch, raking and nutritional behavior, dusting, engaging in comfortable behavior (such as over lighting, etc.) **(Petherick and Rushen, 1997)**.

Laying hens are biologically able to adapt to environmental conditions when the environment is appealing to them. At that time, they increase interest in such an environment, which in turn increases the quality of their living conditions. The environment is engaging, increases interest, and adds to the quality of animal life.

A rich and diverse environment stimulates exploratory behavior and allows pecking and raking **(Knierim, 2006)**.

According to **Baer (1998)**, an enriched environment has a positive impact on the physical, mental, and social well-being of animals, including laying hens and can improve their health. European Food Safety Authority, Panel on Animal Health and Welfare (AHAW), an independent an advisory body providing the scientific basis for European policy and legislation, based on the processing of scientific literature, it has come to the following conclusion: stabling systems differ in the possibilities for laying hens to show species-specific behavior, such as raking, dusting, exploring and selecting a suitable nest. Sufficient space must be provided for laying hens, to carry out the above-mentioned natural activities. A free-range breeding system in nature can pose a risk of laying hens and endanger their health. Layers in outdoor free-range may be exposed to wild birds, insects, and other potentially infectious agents **(Scientific Panel on Animal Health and Welfare, 2005)**.

The laying hens may come into contact with bacteria and intestinal parasites and coccidia **(McDougald, 2003; Scientific Panel on Animal Health and Welfare, 2005)**.

The object of social interest in the context of the welfare of laying hens, it is largely focused on farm conditions, most for breeding systems, conditions for natural behavior, and limited conditions associated with stress and mutilation. However, the impact of genetics on the welfare of laying hens is clear, with strong genetic effects on traits including immune function **(Bridle et al., 2006)**, bone strength **(Stratmann et al., 2016; Candelotto et al., 2017)**, feather pecking, feather condition and associated mortality **(Su et al., 2005; Brinker et al., 2014; Muir et al., 2014)** and fear **(Uitdehaag et al., 2008; de Haas et al., 2014)**.

Bacteria belong to the main cause of human foodborne diseases v worldwide and infected poultry flocks are the most common cause of human infection through the storage of foods.

Human salmonellosis is more often associated with the consumption of poultry and poultry products, including eggs, than with the consumption of food from other animals. All producers of table eggs, regardless of the type of breeding system, are subject to strict safety requirements **(Gast, 2003)**.

De Reu et al. (2006) note that the high risk of transmission of infection to table eggs is the higher the microbial contamination in the environment, such as in *Salmonella enteritidis*.

De Knegt et al. (2015) reported that in a laying hen flock, it was caused by human Salmonella as the main source of infections. They attributed approximately 40% of all Salmonella cases to *Salmonella enterica* serovar Enteritidis.

The incidence of human *S. enteritidis* infections is related to the prevalence of this pathogen in commercial flock eggs **(Arnold et al., 2014)**.

For extensive implementation, comprehensive risk reduction programs and testing of laying hens in flocks intended for the production of table eggs are attributed to a reduction in the incidence of human *S. enteritidis* infections **(Wright et al., 2016)**.

Verhallen-Verhoef and Rijs (2003) reported that hygiene in breeding conditions is one of the most important factors for laying hens. If there is a large number of laying hens in a small area, it is a great problem to maintain hygiene and then the hens are exposed to a lot of stress.

Otter (2015) notes that in the conditions of the small-scale breedings there is common breeding with a free-range system, which has proved its worth. In the breeding area, it is very appropriate to provide the facilities necessary for carrying out the natural activities of the laying hens, e.g. such as perch for rest, litter material for raking, and others. Hygiene and cleanliness in the breeding environment are the basis for the good health of laying hens, but also for the laying of non-harmful eggs concerning the consumer. The application of welfare aspects is also important for laying hens under small-scale conditions. These aspects support the healthy development of laying hens and the production of quality and health-safe table eggs.

In the **Council of the European Union (2006)** it was noted that table eggs are sold worldwide. On the European Union market, eggs are classified in quality class A or quality class B. Quality class A is classified for direct human consumption. On the contrary, class B eggs are marked as technical and are not intended for direct human consumption. Laying hen nutrition and post-laying egg handling are factors that play a very important role in determining the safety and quality of table eggs. The eggshell is characterized by being a natural external packing table of laying hens, the task of which is to prevent the penetration of contaminants into the internal egg content. The system of rearing, but also the type of feed administered by laying hens, affects egg composition to a very large extent.

Surai and Sparks (2001) report that there is a lack of knowledge about factors of the table egg chemical composition concerning a free-range or a range consisting of grassland.

Eggshell quality has a major economic impact on quality egg production because broken and cracked eggs mean an economic loss for farmers **(Yoho et al., 2008)**.

The abnormalities can be observed sometimes on the egg surface, on the shell. Eggshell surface abnormalities are assessed by altered shell surface, shell dilution, increased translucence, cracks, and cracks in the eggshell. These abnormalities, changes in quality and ultrastructure have been observed in flocks of hen laying in the experiment by **(Kursa et al., 2019)**.

The purpose of this study was to investigate selected indicators of the table eggs in small-scale breedings, focusing mainly on the eggshell and its contamination and damage.

Scientific hypothesis

Scientific hypothesis: balanced results selected indicators of table eggs in small-scale breedings, due to the small numbers of animals in breeding and outdoor free-range for carrying out natural activities.

MATERIAL AND METHODOLOGY

Object of research

Our object of study was eggs, shell, damage, and contamination of table eggs. Four small-scale breedings were randomly selected in Slovakia. These breeds were alternatively with an outdoor free-range.

Rearing conditions of the laying hens

Laying hens Dominant was bred in conditions of 4 small-scale breeders in Slovakia. Breeding conditions as well as nutritional conditions were ensured in these small-scale breedings of small-scale breeds in accordance with laying hens needs. Laying hens Dominant was reared in small-scale breedings No. 1, No. 2, and No. 3 in the 1^{st} laying cycle, and No. 4 in the 2^{nd} laying cycle. Henhouse with deep litter and free-range was a breeding house for laying hens. Laying hens had the opportunity to run daily in the summer from 6:00 am to about 7:00 pm. pm and in winter until 5:00 pm. The hen house equipment consisted of a watering-place, a feeder, a nest, and perch. To lay eggs, a nest was made for them to be made by hand collection. Drinking water and feed were part of the free-range. Laying hens were fed with a conventional feed mixture intended for laying hens, which was replenished at least 2 times a day. Sometimes laying hens were fed with food from the kitchen or crushed eggshells. Drinkers and feeders were washed daily. The eggs produced were harvested once a day in the summer in the afternoon and twice a day in the winter in the morning and afternoon.

Egg samples of 80 pieces were obtained from four selected small-scale breeders, i.e. 20 eggs from each small-scale breeder. Investigation of egg samples was carried out in a laboratory at the Department of Food Hygiene and Safety.

Characteristics to be collected on egg samples

Physical indicators of table eggs from small-scale breeders No. 1, No. 2, No. 3 and No. 4:

- the weight of egg – KERN PLE scales, max. 420 g, d = 0.001 g,
- the weight of eggshell – KERN PLE scales, max. 420 g, d = 0.001 g, dried eggshells in a drier at a temperature of 55 °C,
- shell thickness in 3 parts of the equatorial plane of the egg – DIAL INDICATOR, max. thickness 30 mm, d = 0.01 mm, dried eggshells in drier at 55 °C.

Contamination and egg damage under the light of a 100W table lamp from small-scale breedings 1, No. 2, No. 3, and No. 4: blood spots, droppings, pigment dots, other deposits, calcium deposits, bumps on the surface, and deformed egg shape.

Figure 1 Laying hens in the free-range.

Figure 2 Breeding equipment of hen house.

Statistical analysis

The results in the study are presented as mean – arithmetic mean ($\bar{x}$), variance range (R), which determines the difference between the minimum value (Min) and the maximum value (Max), the standard deviation (*SD*), and the coefficient of variation (cv, %).

Hypotheses about equality of mean values were tested using a one-factor analysis of variance (F) at significance levels $\alpha = 0.05$, $\alpha = 0.01$ and $\alpha = 0.001$. One-factor variance analysis (ANOVA) is the simplest form of ANOVA that examines the relationship between interval and nominal variables. It tests the null hypothesis of the mean equivalence, assuming that the selections have the same variance. The null hypothesis indicates that there is no relation between the interval and the nominal variable. If the calculated statistical value F is greater than the corresponding character value that divides the statistical set of a group with the same number of Fisher-Snedecor distribution elements FI-1, n-I, the hypothesis of equality of mean values is rejected.

Scheffe's test was used at a significance level of $\alpha = 0.05$ to compare the difference in the indicator between small-scale breedings. The Pearson correlation coefficient (r) reflects the relation between the two egg variable variables. The Pearson correlation coefficient (r) reflects the degree of the linear relation between the data of the two egg indicators. Its value is between -1 and +1. A +1 indicates that there is a high positive linear relationship between the two indicator data. A value of -1 means that there is a high negative linear relation, and value of 0 means that there is no linear relation between the two indicator data. The interpretation of the size of the correlation coefficient is given by **Cohen (1988)**.

Values of correlation coefficient (r) and strength of dependence between two variables: below 0.1 trivial (simple, light), 0.1 – 0.3 weak, 0.3 – 0.5 medium, above 0.5 strong. It is often reported in the publications that the correlation coefficient values of 0.7 – 0.9 represent a very strong relation and 0.9 – 1 as an almost perfect relation between two variables. The correlation coefficient results are statistically significant at $\alpha = 0.05$, $\alpha = 0.01$ and $\alpha = 0.001$. The SAS statistical package, version 8.2, was used to statistically evaluate the results.

RESULTS AND DISCUSSION

Egg weight

Average egg weight in individual small-scale breedings is given in Figure 3. Statistically evaluation of egg weight in individual small-scale breedings is given in Table 1.

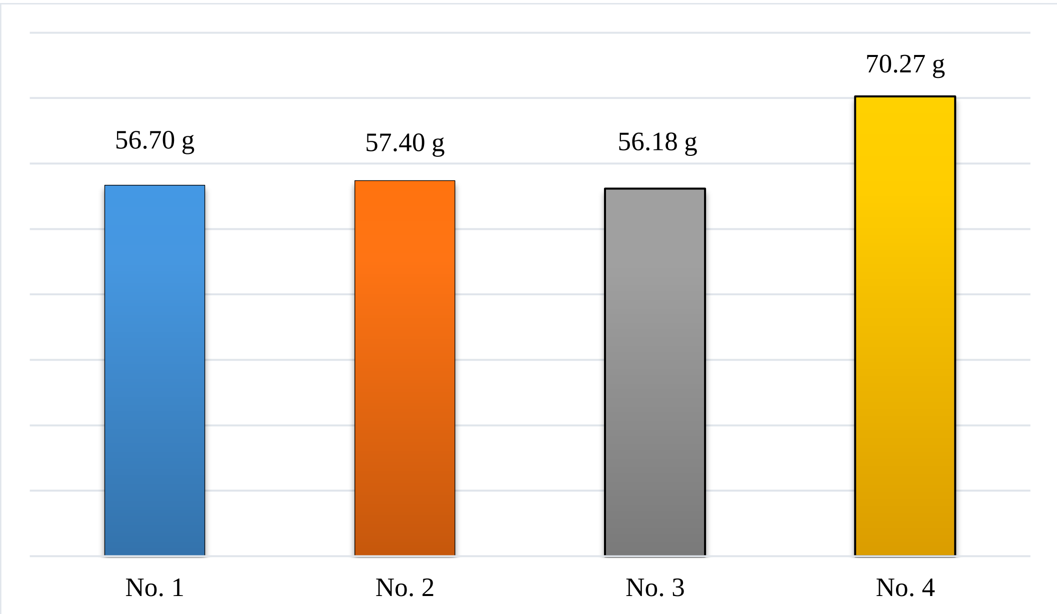

Figure 3 Average egg weight in individual small-scale breedings No. 1, 2, 3 and 4, g.

Table 1 Statistical evaluation of egg weight in individual small-scale breedings No. 1, 2, 3, and 4.

Small-scale breeding	F-test 61.97^{+++}				Scheffe´s test $p_{0.05}$		
	n	*SD*	c_v, %	R, g	No. 2	No. 3	No. 4
No. 1	20	3.03	5.35	53.08 – 64.11	-	-	+
No. 2	20	4.36	7.59	46.78 – 65.45		-	+
No. 3	20	4.07	7.25	51.98 – 66.72			+
No. 4	20	3.81	5.42	62.88 – 78.79			

Note: n – multiplicity; *SD* – standard deviation; c_v – coefficient of variation; R – variation range as the difference between the smallest and the largest value of the data distribution; +++: statistically significant difference among group means by analysis of variance (p <0.001); +: statistically significant difference among groups by Sheffe´s test (p <0.05); –: no statistically significant difference among groups by Sheffe´s test (p >0.05).

The average egg weight was found to be either the same or relatively balanced in small-scale breedings No. 1, No. 2 and No. 3. The measured values of egg weight were largely balanced in small-scale breeding No. 4. The values of the egg weight in this small-scale breeding were statistically significant (p <0.05) higher compared to the values of the egg weight of small- scale breedings No. 1, No. 2, and No. 3. Conclusions of the research and the knowledge published in scientific journals are not uniform as regards the impact of factors on eggshell quality.

Huber-Eicher and Sebö (2001) took the view that they showed a higher weight of eggs and their egg components, which were in a negative correlation with the stocking intensity (r = -0.27, p <0.01). The authors pointed out that if laying hens produced more eggs under industrial conditions, the lower the egg weight was recorded. At the end of their investigation, the authors concluded that laying hens that were kept under organic farming conditions, they laid eggs which were generally heavier due to the lower production intensity.

Eggshell weight

Average eggshell weight in individual small-scale breedings is given in Figure 4. Statistically, evaluation of eggshell weight in individual small-scale breedings is given in Table 2.

Egg colour is also an important factor in egg production, in our case brown. Colour shell of eggs can affect consumer choice due to regional or national cultural preferences for different colours, directly affecting eggs' production **(Wei and Bitgood, 1990; Joseph et al., 1999)**.

Thus, the determination of egg colour and eggshell strength is of importance. The average weight of eggshell was found to be either the same or relatively balanced in small-scale breedings No. 1, No. 2 and No. 3. The measured values of eggshell weight were largely balanced in small-scale breeding No. 4. The values of the eggshell weight in this small-scale breeding were statistically significant (p <0.05) higher, compared to the values of the eggshell weight of small-scale breedings No. 1, No. 2 and No. 3. Conclusions of the research and the knowledge published in scientific journals is not uniform as regards the impact of factors on egg shell quality.

Authors **Monira et al. (2003); Alsobayel et al. (2003)** and **Anderson et al. (2004)** agreed in a statement that the quality of the eggshell is sufficiently affected by the genotype and age of laying hens. In characterizing the effect of genotype on egg shell quality, the authors emphasize the significance of genotypic differences in egg weight and shell quality.

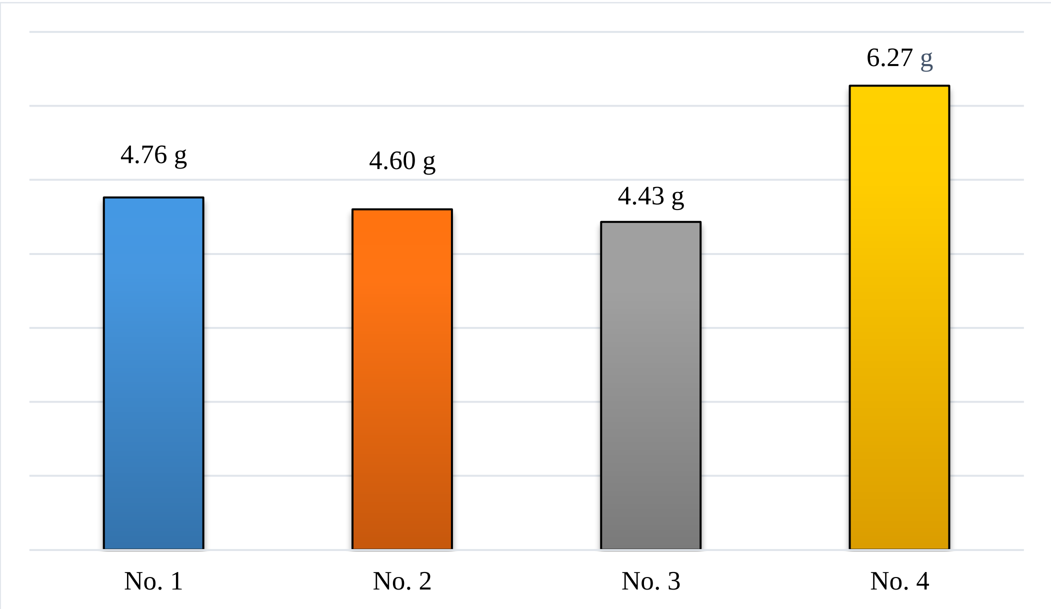

Figure 4 Average eggshell weight in individual small-scale breedings No. 1, 2, 3 and 4; g.

Table 2 Statistically evaluation of egg weight in individual small-scale breedings No. 1, 2, 3 and 4.

Small-scale breeding	F-test 40.47+++				Scheffe´s test		
	n	*SD*	c_v, %	R, g	No. 2	No. 3	No. 4
No. 1	20	0.65	13.58	3.82 – 5.82	-	-	+
No. 2	20	0.74	16.11	2.67 – 5.60		-	+
No. 3	20	0.55	12.40	3.29 – 5.27			+
No. 4	20	0.39	6.24	5.48 – 6.72			

Note: n – multiplicity; *SD* – standard deviation; c_v – coefficient of variation; R – variation range as the difference between the smallest and the largest value of the data distribution; +++: statistically significant difference among group means by analysis of variance (p <0.001); +: statistically significant difference among groups by Sheffe´s test (p <0.05); –: no statistically significant difference among groups by Sheffe´s test (p >0.05).

Such contradictory aspects may also be related to ensuring that laying hens are kept in line with their needs. Therefore, in our research, we focused on characterizing the laying hens and compared them with four small-scale breeders in Slovakia with a focus on selected indicators of the table eggs. Avian eggshells are commonly used in studies focusing on bioindication and environmental monitoring **(Lam et al., 2005; Ayas et al., 2008; Kim and Oh, 2014; Khademi et al., 2015; Simonetti et al., 2015)**.

Shell thickness in the equatorial plane of egg

The average thickness in the equatorial plane of egg in individual small-scale breedings is given in Figure 5.

Statistically evaluation of shell thickness in equatorial plane of egg is given in Table 3.

The average thickness in equatorial plane of egg was found to be either the same or relatively balanced in small-scale breedings No. 1, No. 2 and No. 3. The measured values in the three parts of the equatorial plane of egg were largely balanced in small-scale breeding No. 4. The values of the equatorial plane of the egg in this small-scale breeding were statistically significant (p <0.05) higher compared to the values of the equatorial planes of egg of small- scale breedings No. 1, No. 2 and No. 3

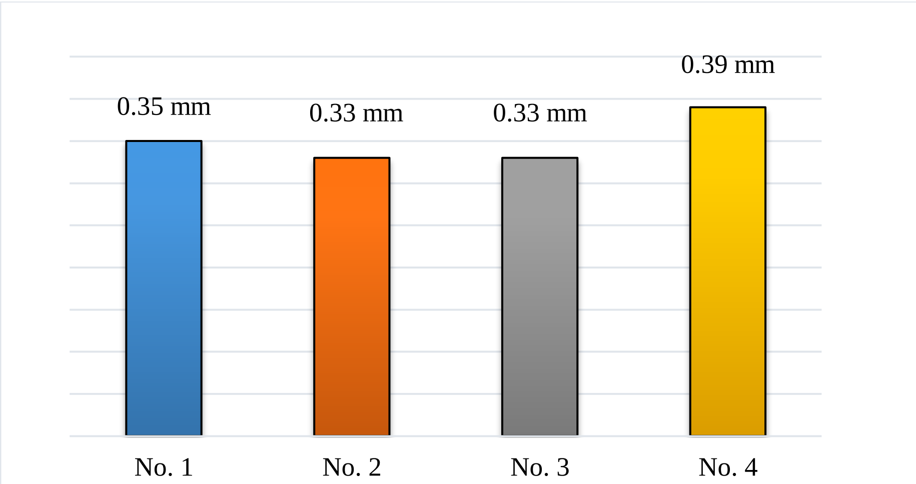

Figure 5 in equatorial plane of egg in individual small-scale breedings No. 1, 2, 3 and 4; mm.

Table 3 Statistically evaluation of shell thickness in equatorial plane of egg in individual small-scale breedings No. 1, 2, 3 and 4.

Small-scale breeding	F-test 10.44^{+++}				Scheffe´s test		
	n	*SD*	c_v, %	R, g	No. 2	No. 3	No. 4
No. 1	20	0.04	11.92	0.28 – 0.44	-	-	+
No. 2	20	0.04	12.23	0.24 – 0.39		-	+
No. 3	20	0.04	10.82	0.27 – 0.39			+
No. 4	20	0.03	7.96	0.31 – 0.43			

Note: n – multiplicity; *SD* – standard deviation; c_v – coefficient of variation; R – variation range as the difference between the smallest and the largest value of the data distribution; +++: statistically significant difference among group means by analysis of variance (p <0.001); +: statistically significant difference among groups by Sheffe´s test (p <0.05); –: no statistically significant difference among groups by Sheffe´s test (p >0.05).

Table 4 Correlation relation (r) between indicators of the eggs in small scale breedings No. 1, 2, 3 and 4, and statistically significant difference between the two variables.

Indicator of egg	S-C B	Eggshell weight				Shell thickness in equatorial plane of egg			
		No. 1	No. 2	No. 3	No. 4	No. 1	No. 2	No. 3	No. 4
Egg weight	No. 1	0.46^{+}				0.17^{-}			
	No. 2		0.18^{-}				-0.16^{-}		
	No. 3			0.42^{-}				-0.11^{-}	
	No. 4				0.53^{+}				0.21^{-}
Eggshell weight	No. 1					0.89^{+++}			
	No. 2						0.83^{+++}		
	No. 3							0.80^{+++}	
	No. 4								0.74^{++}

Note: **S-C B** – Small-scale breeding; numeric value – value r; $^{+++}$: statistically significant difference between the two variables (p <0.001); $^{+}$: statistically significant difference between the two variables (p <0.05); $^{-}$: no statistically very highly significant difference between the two variables (p >0.05).

Correlation relation between egg indicators in small-scale breedings

Correlation relation between indicators of the eggs in small scale breedings and statistically significant difference between the two variables are given in Table 4.

Middle, a positive linear relation (small-scale breeding No. 1 and at the lower limit a strong positive linear relation (small-scale breeding No. 4) was found between egg weight and eggshell weight, statistically significant (p <0.05). A very strong relationship in all small-scale breedings (p <0.01, p <0.001) was found between eggshell weight and shell thickness in the equatorial plane of the egg.

Shell thickness in individual parts of the equatorial plane of the egg in small-scale breedings

Average shell thickness in individual parts of the equatorial plane of the egg in small-scale breedings is given in Figure 6. A statistically significant difference between the two variables is given in Table 5. The average thickness in equatorial planes 1, 2, and 3 of the egg was found to be either the same or relatively balanced in small-scale breedings 1, No. 2, and No. 3. The measured values in the three parts of the equatorial plane of egg were largely balanced in small-scale breeding No. 4. The values of the equatorial planes of the egg in this small-scale breeding were statistically significant (p <0.05) higher compared to the values of the equatorial planes of the egg of small- scale breedings No. 1, No. 2, and No. 3.

The eggshell is a natural protection for the egg, and thus it is significant to get a high value of eggshell strength **(Bain, 1990)**.

The eggshell strength, reflecting the resistance ability to

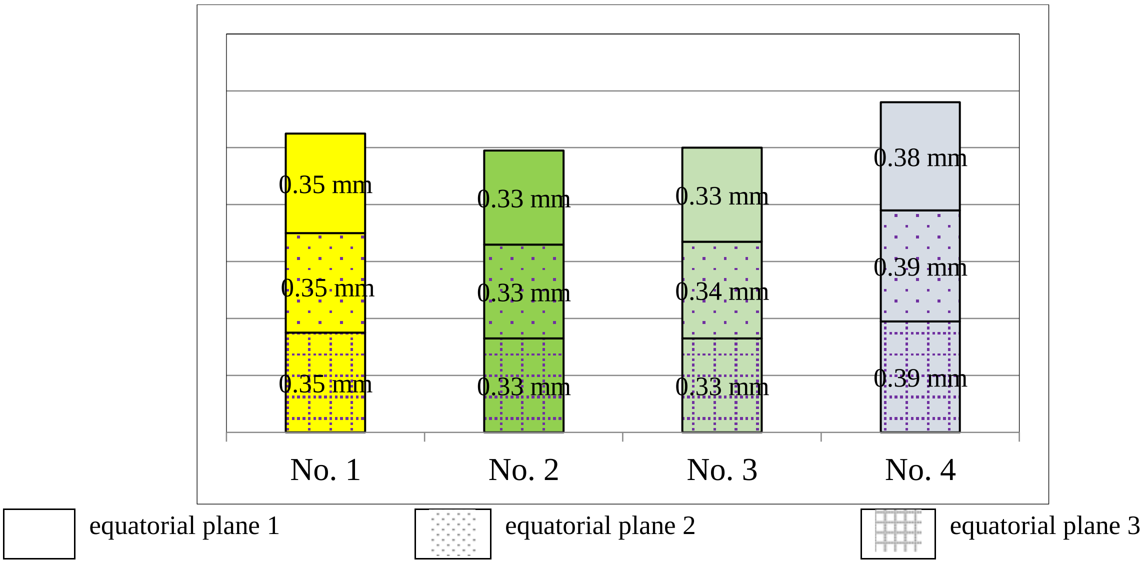

Figure 6 Average shell thickness in individual parts of the equatorial plane of the egg according to small-scale breedings No. 1, 2, 3, and 4, mm.

Table 5 Statistically evaluation of shell thickness in individual parts of the equatorial plane of the egg according to small-scale breedings No. 1, 2, 3 and 4.

Small-scale breeding					**Scheffe´s test**		
	n	***SD***	**c_v, %**	**R, mm**	**No. 2**	**No. 3**	**No. 4**
F-test 10.32^{+++}	Equatorial plane 1						
No. 1	20	0.04	11.65	0.29 – 0.44	-	-	+
No. 2	20	0.04	12.28	0.25 – 0.40		-	+
No. 3	20	0.04	10.73	0.26 – 0.39			+
No. 4	20	0.03	8.26	0.31 – 0.43			
F-test 10.32^{+++}	Equatorial plane 2						
No. 1	20	0.04	11.84	0.28 – 0.44	-	-	+
No. 2	20	0.04	12.67	0.23 – 0.39		-	+
No. 3	20	0.03	10.15	0.27 – 0.40			+
No. 4	20	0.03	7.12	0.32 – 0.43			
F-test 10.32^{+++}	Equatorial plane 3						
No. 1	20	0.04	11.94	0.28 – 0.44	-	-	+
No. 2	20	0.04	12.59	0.23 – 0.39		-	+
No. 3	20	0.04	11.46	0.26 – 0.40			+
No. 4	20	0.03	7.93	0.31 – 0.43			

Note: n – multiplicity; SD – standard deviation; c_v – coefficient of variation; R – variation range as the difference between the smallest and the largest value of the data distribution; +++: statistically significant difference among group means by analysis of variance (p <0.001); +: statistically significant difference among groups by Sheffe´s test (p <0.05); –: no statistically significant difference among groups by Sheffe´s test (p >0.05).

damage, can protect eggs when they are in collecting, packaging, storage, and transportation. It can be found the higher the eggshell strength, the stronger the resistance to damage. Cracked eggs can finally cause economic loss in two ways, one is that they cannot be sold at a high price, another is cracked eggs may raise the risk of bacterial contamination to intact eggs, which can even produce food quality and safety problems **(Bain, 2005; Mertens et al., 2006; Li, Dhakal and Peng, 2012)**.

Correlation relation between shell thicknesses in individual parts of the equatorial plane of the egg according to small-scale breedings

Correlation relation between shell thickness in individual parts of the equatorial plane of the egg according to small-scale breedings and statistically significant difference between the two variables are given in Table 6.

In shell thickness between individual parts of the equatorial plane of the egg in small-scale breedings, No. 1, No. 2, No. 3, and No. 4, an almost perfect positive linear relation was found, statistically very highly significant (p <0.001).

Correlation relation between shell thicknesses in individual parts of the equatorial plane of the egg together for all small-scale breedings

Correlation relation between shell thickness in individual parts of the equatorial plane of the egg together for all small-scale breedings and statistically significant difference between the two variables is given in Table 7.

Almost perfect positive linear relation, statistically very high significant (p <0.001), was found in the shell thickness between the individual parts of the equatorial plane of the egg in all examined small-scale breedings together.

Contamination and damage of table eggs

The percentage and number of eggs with damaged egg surface but also deformed and contaminated on the eggshell are given in Table 8.

Table eggs obtained from a small-scale breeder were subjected to an assessment of the hygiene aspect of the breeding environment. Table eggs can be considered as naturally packaged food. The eggshell serves to contain the egg contents. It is also the first barrier against bacterial penetration and must be free from defects in the order to optimize the safety of human consumption **(Mabe et al., 2003)**.

We found that table eggs were contaminated with blood (from 5 to 45%) and dropping (from 20 to 60%). We found sediments, pigment dots and calcium deposits on the surface of table eggs. Also table eggs from two farms had a deformed shape.

Solomon (2010) reported that the coated eggshell, it is common surface defect observed on the eggshell. There are observed additional calcium deposits or extra-cuticular coverings and possibly reflects the timing and magnitude of the stress or disturbance experienced by the flock. It is commonly observed an incidence of this defect of 1% and could be caused by the age of the laying hens, often younger flocks coming into production **(Coutts and Graham, 2007)**.

Table 6 Correlation relation between shell thickness in individual parts of the equatorial plane of the egg according to small-scale breedings No. 1, 2, 3 and 4, and statistically significant difference between the two variables.

Indicator of shellegg	S-C B	Shell thickness in equatorial plane of egg 2				Shell thickness in equatorial plane of egg 3			
		No. 1	No. 2	No. 3	No. 4	No. 1	No. 2	No. 3	No. 4
Shell thickness in equatorial plane of egg 1	No. 1	0.97^{+++}				0.99^{+++}			
	No. 2		0.97^{+++}				0.99^{+++}		
	No. 3			0.95^{+++}				0.97^{+++}	
	No. 4				0.96^{+++}				0.97^{+++}
Shell thickness in equatorial plane of egg 2	No. 1					0.99^{+++}			
	No. 2						0.99^{+++}		
	No. 3							0.97^{+++}	
	No. 4								0.99^{++}

Note: **S-C B** – Small-scale breeding; numeric value – value r; +++: statistically significant difference between the two variables (p <0.001); +: statistically significant difference between the two variables (p <0.05); –*:* no statistically very highly significant difference between the two variables (p >0.05).

Table 7 Correlation relation between shell thickness in individual parts of the equatorial plane of the egg together for all small-scale breedings and statistically significant difference between the two variables and statistically significant difference between the two variables.

Indicator of shellegg	Shell thickness in equatorial plane of egg 2	Shell thickness in equatorial plane of egg 3
Shell thickness in equatorial plane of egg 1	0.97^{+++}	0.98^{+++}
Shell thickness in equatorial plane of egg 2		0.99^{+++}

Note: numeric value – value r; +++: statistically significant difference between the two variables (p <0.001).

Table 8 The percentage and number of eggs with damaged egg surface but also deformed and contaminated on the egg shell (n = 20 for each small-scale breeding).

Smal-scale breeding	No. 1		No. 2		No. 3		No. 4	
Indicator	**pcs**	**%**	**pcs**	**%**	**pcs**	**%**	**pcs**	**%**
Blood stains	2	10	9	45	8	40	1	5
Dropping stains	9	45	6	30	12	60	4	20
Pigment dots	9	45	7	35	13	65	9	45
Sediments – other	5	25	6	30	8	40	3	15
Calcium deposits	2	10	0	0	4	20	3	15
Small bumps	2	10	1	5	2	10	1	5
Deformed egg shape	1	5	0	0	0	0	3	15

Blood stains Calcium deposits Small bumps

Figure 7 Contamination and damage of table eggs in small-scale breedings.

These damaged table eggs, but also deformed and contaminated on the surface, are related both to internal factors and to external factors, which the farmer can influence and take measures to improve laying hens living conditions. **Hincke et al. (2000)** reported that there are multiple factors affecting eggshell quality like the genetics of the hen, nutrition, and management of feed intake, disease, and environment challenge, and also equipment insult.

A decline in eggshell quality is detected as hens approach the end of a laying period **(Mazzuco and Hester, 2005)**. In this way, the condition of the eggshell at the oviposition time can influence the incidence of shell breakage. An interesting insight presents **Alves et al. (2007)**. When the laying hens are raised in conditions of greater thermal comfort, it can promote eggshell quality and decrease egg losses through cracks.

Hulzebosch (2004) states in his study that eggshell plays a very important role. It must form a good barrier against the intrusion of microorganisms into the internal egg content. Many research results confirm increased microbial contamination in alternative breeding compared to laying hens.

In alternative breeding, laying hens lay eggs more extensively outside the nest, into the litter. Such eggs show excessive contamination of their surface. Such eggs have a damaged shell, which can lead to the deterioration of the internal content of the egg and its contamination. There are two ways in which the contents of a table egg can be infected. It can be infected by an endogenous route and an exogenous route. **Engelmaierová, Tůmová and Charvátová (2010)** state that endogenous contamination occurs through sick laying hens, which affect the egg through the bloodstream. Exogenous contamination of table eggs is caused by microorganisms that are in the outdoor environment.

Görner and Valík (2004) in the study point out that there is a large number of spores on the surface of the eggshell that are highly permeable to air. The cuticle is an outer layer whose main function is to prevent microorganisms from entering the egg. When the eggs are brought into contact with the air, the cuticle is drawn into the spores, changing its shape, which results in deformation, causing penetration of the microorganisms through the shell into the internal contents of the egg. An important protective barrier is also represented by the membrane membranes. Their fibrous structure acts as a filter.

Their protective properties are associated with the chemical action of lysozyme and ovotransferrin. Microorganisms, by means of proteolytic enzymes, disrupt the membranes and penetrate the whites. The main role of egg white is to protect the egg yolk from contamination. Gram-positive bacteria are affected by egg white due to their antimicrobial and bactericidal effects. Egg yolk that has no antimicrobial properties is the perfect breeding ground for the reproduction of microorganisms. If a high incidence of contamination has been observed on the surface of the eggshell, there is a higher risk of contaminants penetrating the egg content. **Křepelka (2012)** points out that contaminated eggs are a major problem in terms of consumer protection, which must be constantly eliminated. In most cases, gram-negative bacteria, e.g. *Pseudomonas* spp., *Alcaligenes* spp. *Salmonella enteritidis* and *Escherichia coli* and gram-positive bacteria such as e.g. *Bacillus* spp. and *Staphylococcus*.

CONCLUSION

Table eggs from small-scale breeding are preferred by the consumer. Literary sources are poor and inconsistent in the knowledge of laying hens breeding conditions in small-scale breeding, and the quality and safety of table eggs. Because the food consumer likes table eggs from small-scale breeders, we have researched this issue. Based on the obtained and statistically evaluated results there were formulated the following conclusion:

(a) The average egg weight was equalized in three small-scale breedings and the fourth small-scale breeding was significantly higher. Higher egg weight is related to the higher age of laying hens.

(b) The average eggshell weight and shell thickness in the equatorial plane of the egg was balanced in three small-scale breedings and the fourth small-scale breeding was significantly higher. Higher eggshell weight may be related to improved conditions in breeding hygiene, as confirmed by the results of the investigation of contamination and damage of table eggs. These differences may also be related to nutrition.

REFERENCES

Alsobayel, A. A., Al-Batshan, H. A., Albadry, M. A. 2003. Effect of Salicornia Bigelovii Torr Meal and age on egg quality characteristics of Baladi and Leghorn Laying Hens. *Journal of King Saud University – Science*, vol. 15, no. 2, p. 101-113.

Alves, S. P., Silva, I. J., Piedade, S. M. 2007. Avaliação do bem-estar de aves poedeiras comerciais: efeitos do distema de criação e do ambiente bioclimático sobre o desempenho das aves e a qualidade de ovos. *Revista Brasileira de Zootecnia*, vol. 36, no. 5, p. 1388-1394. https://doi.org/10.1590/s1516-35982007000600023

Anderson, K. E., Tharrington, J. B., Curtis, P. A., Jones, T. 2004. Shell characteristics of eggs from historic strains of single comb white leghorn chickens and the relationship of egg shape to shell strength. *Journal Poultry Science*, vol. 3, no. 1, p. 17-18. https://doi.org/10.1093/ps/78.4.591

Arnold, M. E., Martelli, F., McLaren, I., Davies, R. H. 2014. Estimation of the rate of egg contamination from *Salmonella*-infected chickens. *Zoonoses Public Health*, vol. 61, no. 1, p. 18-27. https://doi.org/10.1111/zph.12038

Ayas, Z., Celikkan, H., Aksu, M. L. 2008. Lead (Pb) and copper (Cu) concentration in the eggshells of Audouin's gull (*Larus audouinii*) in Turkey. *Turkish Journal of Zoology*, vol. 32, p. 379-384.

Baer, J. F. 1998. A veterinary perspective of potential risk factors in environmental enrichment. In Shepherdson, D. J., Mellen, J. D. Hutchins, M*: Second Nature*, 2nd. Washington : Smithsonian Institution Press, 565 p. ISBN-13 978-0-226-44009-5.

Bain, M. M. 1990. Eggshell strength: A mechanical/ultrastructural evaluation : PhD. Thesis. University of Glasgow, Scotland, UK.

Bain, M. M. 2005. Recent advances in the assessment of eggshell quality and their future application. *World Poultry Science Jornal*, vol. 61, no. 2, p. 268-277. https://doi.org/10.1079/wps200459

Bridle, B. W., Julian, R., Shewen, P. E., Vaillancourt, J.-P., Kaushik, A. K. 2006. T lymphocyte subpopulations diverge in commercially raised chickens. *Canadian Journal of Veterinary Research*, vol. 70, p. 183-190.

Brinker, T., Bijma, P., Visscher, J., Rodenburg, T. B., Ellen, E. D. 2014. Plumage condition in laying hens: genetic parameters for direct and indirect effects in two purebred layer lines. *Genetics Selection Evolution*, vol. 46, no. 1, p. 33. https://doi.org/10.1186/1297-9686-46-33

Candelotto, L., Stratmann, A., Gebhardt-Henrich, S. G., Rufener, C., van de Braak, T., Toscano, M. J. 2017. Susceptibility of keel bone fracture in laying hens and the role of genetic variation. *Poultry Science,* vol. 96, no. 10, p. 3517-3528. https://doi.org/10.3382/ps/pex146

Cohen, J. 1988. *Statistical power analysis for the behavioral sciences*, 2nd ed. New York : Academic Press, 590 p. ISBN-13 978-0805802832.

Council of the European Union. 2006. Council Regulation (EC) No. 1028/2006 of 19 June 2006 on marketing standards for eggs. *Official Journal of the European Union*, L 186, p. 1-5.

Coutts, J. A., Graham, C. W. 2007. *Optimum Egg Quality-A practical approach*. Queesland : Publishing, Sheffield, GB, 65 p. ISBN-13 978-0953015061.

de Haas, E. N., Bolhuis, E., de Jong, I. C., Kemp, B., Janczak, A. M., Rodenburg, T. B. 2014. Predicting feather damage in laying hens during the laying period. Is it the past or is it the present? *Applied Animal Behaviour Science*, vol. 160, no. 1 p. 75-85. https://doi.org/10.1016/j.applanim.2014.08.009

De Knegt, L. V., Pires, S. M., Hald, T. 2015. Attributing foodborne salmonellosis in humans to animal reservoirs in the European Union using a multi-country stochastic model**.** *Epidemiology* and *Infection*, vol. 143, no. 6, p. 1175-1186. https://doi.org/10.1017/s0950268814001903

De Reu, K., Grijspeerdt, K., Messens, W., Heyndrickx, M., Uyttendaele, M., Debevere, J., Herman, L. 2006. Eggshell factors influencing eggshell penetration and whole egg contamination by different bacteria, including Salmonella enteritidis. *International Journal of Food Microbiology*, vol. 112, no. 3, p. 253-260. https://doi.org/10.1016/j.ijfoodmicro.2006.04.011

Duncan, I. J. 1998. Behavior and behavioral needs. *Poultry Science*, vol. 77, no. 12, p. 1766-1772. https://doi.org/10.1093/ps/77.12.1766

Engelmaierová, M., Tůmová, E., Charvátová, M. 2010. Penetrace mikroorganismů do vejce II. In *Veterinářství*, vol. 10, no. 4, p. 213-215.

Fraser, A. F., Broom, D. M. 1990. *Farm Animal Behaviour and Welfare*, 3rd ed. London, England : Bailliere Tindall, 437 p. ISBN 0851991602. Available at: https://trove.nla.gov.au/version/46242841.

Gast, R. K. 2003. Salmonella infections. In Saif, Y. M., Barnes, H. J., Gilsson, J. R., Fadly, A. M., McDougald, L. R., Wayne, D. E.: *Diseases of Poultry*, 11th ed. Ames, IA : Iowa State Press, p. 567-583.

Görner, F., Valík, L. 2004. *Applied microbiology of foodstuffs (Aplikovaná mikrobiológia požívatín)*. Bratislava, Slovakia : Malé centrum, 528 s. ISBN 8096706497.

Hincke, M. T., St Maurice, M., Nys, Y., Gautron, J., Panheleux, M., Tsang, C. P. W., Bain, M., Solomon, S., McKee, M. D. 2000. *Eggshell matrix proteins and shell strength: molecular biology of eggshell matrix proteins and industrial applications*. In Sim, J. S., Nakai, S., Guenter, W.: *Egg Nutrition and Biotechnology.* Wallingford : CAB International, p. 447-461. ISBN 0851993303. https://doi.org/10.1016/s0945-053x(00)00095-0

Huber-Eicher, B., Sebö, F. 2001. Reducing feather pecking when raising laying hen chicks in aviary system. *Applied Animal Behaviour Science*, vol. 73, no. 1, p. 59-68. https://doi.org/10.1016/s0168-1591(01)00121-6

Hulzebosch, J. 2004. Chaose the laying nest that fills the bill. *World Poultry*, vol. 20, no. 6, p. 14-15.

Joseph, N. S., Robinson, N. A., Renema, R. A., Robinson, F. E. 1999. Shell quality and color variation in broiler breeder eggs. *Journal of Applied Poultry Research*, vol. 8, no. 1, p. 70-74. https://doi.org/10.1093/japr/8.1.70

Khademi, N., Riyahi-Bakhtiari, A., Sobhanardakani, S., Rezaie-Atagholipour, M., Burger, J. 2015. Developing a bioindicator in the Northwestern Persian Gulf, Iran: trace elements in bird eggs and in coastal sediments. *Archives of Environmental Contamination and Toxicology*, vol. 68, no. 2, p. 274-282. https://doi.org/10.1007/s00244-014-0084-9

Kim, J., Oh, J. M. 2014. Trace element concentrations in eggshells and egg contents of Black-tailed gull (*Larus crassirostris*) from Korea. *Ecotoxicology*, vol. 23, p. 1147-1152. https://doi.org/10.1007/s10646-014-1256-0

Knierim, U. 2006. Animal welfare aspects of outdoor runs for laying hens: a review. *Wageningen Journal of Life Sciences*, vol. 54, no. 2, p. 133-45. https://doi.org/10.1016/s1573-5214(06)80017-5

Křepelka, J. 2012. Housing system and quality of eggs Systém ustajnenia a kvalita vajec). *Zemědělec*. Available at: <http://zemedelec.cz/system-ustajeni-nosnic a-kvalita-vajec-2/>.

Kursa, O., Pakuła, A., Tomczyk, G., Paśko, S., Sawicka, A. 2019. Eggshell apex abnormalities caused by two different *Mycoplasma synoviae* genotypes and evaluation of eggshell anomalies by full-field optical coherence tomography. *BMC Veterinary Research*, vol, 15, no. 1, p. 1-8. https://doi.org/10.1186/s12917-018-1758-8

Lam, J. C., Tanabe, S., Lam, M. H., Lam, P. K. 2005. Risk to breeding success of waterbirds by contaminants in Hong Kong: evidence from trace elements in eggs. *Environmental Pollution*, vol. 135, no. 3, p. 481-490. https://doi.org/10.1016/j.envpol.2004.11.021

Li, Y. Y., Dhakal, S., Peng, Y. K. 2012. A machine vision system for identification of micro-crack in egg shell. *Journal of Food Engineering*, vol. 109, no. 1, p. 127-134. https://doi.org/10.1016/j.jfoodeng.2011.09.024

Mabe, I., Rapp, C., Bain, M. M., Nys, Y. 2003. Supplementation of a corn-soybean meal diet with manganese, copper, and zinc from organic or inorganic sources improves eggshell quality in aged laying hens. *Poultry Science*, vol. 82, no. 12, p. 1983-1913. https://doi.org/10.1093/ps/82.12.1903

Mazzuco, H., Hester, P. Y. 2005. The Effect of an induced molt and a second cycle of lay on skeletal integrity of white leghorns. *Poultry Science*, vol. 84, no. 5, p. 771-781. https://doi.org/10.1093/ps/84.5.771

McDougald, L. R. 2003. Internal parasites. In Saif, Y. M., Barnes, H. J., Gilsson, J. R., Fadly, A. M., McDougald, L. R., Swayne, D. E.: *Diseases of Poultry*, 11th ed. Ames, IA : Iowa State Press, p. 931-956.

Mertens, K., Bamelis, F., Kemps, B., Kamers, B., Verhoelst, E., De Ketelaere, B., Bain, M., Decuypere, E., De Baerdemaeker, J. 2006. Monitoring of eggshell breakage and eggshell strength in different production chains of consumption eggs. *Poultry Science*, vol. 85, no. 9, p. 1670-1677. https://doi.org/10.1093/ps/85.9.1670

Monira, K. N., Salahuddin, M., Miah, G. 2003. Effect of breed and holding period on egg quality characteristics of chicken. *International Journal* of *Poultry Science*, vol. 2, no. 4, p. 261-263. https://doi.org/10.3923/ijps.2003.261.263

Muir, W. M., Cheng, H.-W., Croney, C. 2014. Methods to address poultry robustness and welfare issues through breeding and associated ethical considerations. *Frontiers in Genetics*, vol. 5, p. 407. https://doi.org/10.3389/fgene.2014.00407

Otter, N. 2015. *Hen or egg? First, a chicken*. Available at: http://bzvanie.sme.sk/c/5273897/sliepka/alebovajce/najskor/treba/kurin.html.

Petherick, C. J., Rushen, J. 1997. Behavioural restriction. In Appleby, M. C., Hughes, B. O.: *Animal Welfare*. Wallingford, U.K. : CABI Publishing, p. 89-105.

Scientific Panel on Animal Health and Welfare. 2005. Opinion of the Scientific Panel on Animal Health and Welfare on a request from the Commission related to the welfare aspects of various systems of keeping laying hens. *The EFSA Journal*, vol. 197, p. 1-23. https://doi.org/10.2903/j.efsa.2005.197

Simonetti, P., Botté, S. E., Marcovecchio, J. E. 2015. Exceptionally high Cd levels and other trace elements in eggshells of American oystercatcher (*Haematopus palliatus*) from the Bahía Blanca Estuary, Argentina. *Marine Pollution Bulletin*, vol. 100, no. 1, p. 495-500. https://doi.org/10.1016/j.marpolbul.2015.09.006

Solomon, S. E. 2010. The eggshell: strength, structure and function. *British Poultry Science*, vol. 51, no. 1, p. 52-59. https://doi.org/10.1080/00071668.2010.497296

Stratmann, A., Fröhlich, E. K., Gebhardt-Henrich, S. G., Harlander-Matauschek, A., Würbel, H., Toscano, M. J. 2016. Genetic selection to increase bone strength affects prevalence of keel bone damage and egg parameters in commercially housed laying hens. *Poultry Science*, vol. 95, no. 5, p. 975-984. https://doi.org/10.3382/ps/pew026

Su, G., Kjaer, J. B., Sørensen, P. 2005. Variance components and selection response for feather-pecking behavior in laying hens. *Poultry Science*, vol. 84, no. 1, p. 14-21. https://doi.org/10.1093/ps/84.1.14

Surai, P. F., Sparks, N. H. C. 2001. Designer eggs: from improvement of eggs composition to functional food. *Trends Food Science Technology*, vol. 12, no. 1, p. 7-16. https://doi.org/10.1016/s0924-2244(01)00048-6

Uitdehaag, K. A., Komen, H., Rodenburg, T. B., Kemp, B., van Arendonk, J. A. M. 2008. The novel object test as predictor of feather damage in cage-housed Rhode Island Red and White Leghorn laying hens. *Applied Animal Behaviour Science*, vol. 109, no. 2-4, p. 292-305. https://doi.org/10.1016/j.applanim.2007.03.008

Verhallen-Verhoef, E., Rijs, A. 2003. *Encyclopedia of hens*, 1. ed. REBOn productions, 336 p. ISBN 80-7234-285-1.

Wei, R., Bitgood, J. J. 1990. A new objective measurement of eggshell color. 1. A test for potential usefulness of two color measuring devices. *Poultry Science*, vol. 69, p. 1775-1780. https://doi.org/10.3382/ps.0691775

Wright, A. P., Richardson, L., Mahon, B. E., Rothenberg, R., Cole, D. J. 2016. The rise and decline in *Salmonella enterica* serovar Enteritidis outbreaks attributed to egg-containing foods in the United States, 1973–2009. *Epidemiology and Infection*, vol. 144, no. 4, p. 810-819. https://doi.org/10.1017/s0950268815001867

Yoho, D. E., Moyle, J. R., Swaffar, A. D., Bramwell, R. K., Tabler, G. T., Watkins, S. E. 2008. Effect of incubating poor quality broiler breeder hatching eggs on overall hatchability and hatch of fertile. *Avian Advice, Winter*, vol. 10, no. 4, 15 p.

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