Analysis of the relations between some physical indicators of market eggs

R. Gálik, Z. Poláková, Š. Boďo, M. Denker

Faculty of Engineering, Slovak University of Agriculture in Nitra, Nitra, Slovak Republic

Abstract

Gálik R., Poláková Z., Boďo Š., Denker M., 2011. **Analysis of the relations between some physical indicators of market eggs**. Res. Agr. Eng., *57 (Special Issue)*: S1–S6.

The paper discusses the relations between some physical indicators of market eggs of laying hens housed in conventional and enriched cage batteries. The measured results were evaluated by the multiple regression dependence method. They show that in the case of both the conventional as well as the enriched cages a statistically significant dependence exists between the eggshell deflection (dependent variable) and thickness, or the force needed for the eggshell destruction (independent variable). The respective P values are given in brackets ($0.002 < 0.05$; $0.03 < 0.05$; $1.16 \times 10^{-10} < 0.05$; $8.31 \times 10^{-4} < 0.05$); in the case of the conventional cage and enriched cage also a statistically significant dependence existed ($3.81 \times 10^{-91} < 0.05$; 3.86×10^{-81}; $1.27 \times 10^{-97} < 0.05$; $3.46 \times 10^{-57} < 0.05$) between the shell weight (dependent variable) and shell thickness, or egg weight (independent variable); in the conventional cage, statistical dependence also occurred between the eggshell weight and egg shape index, ($1.07 \times 10^{-6} < 0.05$), in the enriched cage this was on the verge of statistical significance ($0.062 > 0.05$); if in the conventional cage the eggshell thickness was increased by 1 mm, the shell deflection decreased by 0.08 mm, and if the force necessary for the eggshell destruction was increased by 1 N, the shell deflection decreased by 0.0003 mm; if in the conventional cage the shell thickness was increased by 1 mm, the shell weight increasee by 15.509 g and if the egg weight was increased by 1 g, the shell weight increased by 0.061 g. Our work brings further knowledge concerning the monitored characteristics and their mutual relations.

Keywords: conventional cage; enriched cage; physical indicators of market eggs

Alongside the efficient production of eggs, current rearing of laying hens also requires a gradual shift to new housing technologies, introduced by the European Union Directive 1999/74 EC, which says that as from January 1, 2012 only enriched cage systems should be used in the rearing of laying hens. In addition to new enriching elements, they have to comply with the requirement of a larger area per hen – from the current 550 cm^2 to 750 cm^2. The requirement to increase the area per hen decreases the number of hens in a battery, which results in the increase of the number of batteries – that is, the number of halls.

The results of experimental measurements of some foreign researchers, especially in the beginnings of the introduction of enriched cages, show that, as far as the quality of eggs is concerned, less favourable results were achieved by using the enriched cage technologies than those in the conventional cages (Appleby et al. 2002; Leyendecker et al. 2005). The authors mentioned reached lower values, for example, for the shell strength, egg weight, and shell weight in the enriched cages compared to the un-enriched ones. Similar results were also arrived at by Lichovníková and Zeman (2008). Walker et al. (1998) compared conventional cages with enriched cages in terms of the weight of laid eggs. They found that the average weight of eggs in the conventional cages was 63.5 g, in the enriched cages 62.9 or 63.0 g. The lower weight of eggs from the enriched cages did the authors attribute to the fact that the hens rest on the perch or in dust bath during the dim light and at night while in the conventional cage they devote to feeding.

These facts demonstrated the need to compare the individual technologies, especially from the aspect of the physical features of eggs.

MATERIAL AND METHODS

The research was conducted under laboratory conditions on the Slovak University of Agriculture premises in Nitra, equipped with a three-floor classical (un-enriched) cage technology and with a three-floor (enriched) cage technology. The given batteries were placed in one hall, which ensured identical conditions for both technologies as regards the lighting, ventilation, or the warmth of animals, which influences the quality of the animal environment (Karandušovská et al. 2009; Lendelová, Pogran 2009; Pogran et al. 2009). The classical cages housed 18 laying hens (2 hens per cage), 33 hens were housed in the comfort cages (11 hens per cage).

In both rearing technologies, the laying hens were of the same hybrid (ISA Brown), the same age, and were fed with the same complete feed mixture. The egg samples intended for analyses (in the total amount of 30 pieces) were taken during the whole laying cycle (7 times in total), always 10 pieces from every floor and at the same time; the laying hens were weighed. The influence of different stabling systems on the weight of hens is dealt with in the work by Gálik et al. (2009). The following quantitative indicators of market eggs were analysed and evaluated:

Fig. 1. Instrument for the measuring of eggshell deflection

Weight of eggs and weight of eggshell (g)

To determine the weight of eggs and that of eggshell, the laboratory scales Chirana P3-200, type 397, No. 1627-85 with the 0.1 g precision (Chirana Strašnice, Prague, Czechoslovakia) was used.

Thickness of eggshell (mm)

The eggshell thickness was measured after the removal of the undershell membrane by the slot gauge, type R-4-0247 (Somet CZ, Ltd., Hradec Králové, Czech Republic) on both poles as well as on the equator of the egg. It was expressed as an average of these three values.

ITV – Index of egg shape (%)

The egg dimensions were determined with an electronic digital slide calliper. The ITV was expressed as the quotient of the egg width and length in % (Halaj 1999). It was assessed according to the following relation:

$$\text{ITV} = \frac{\text{width of egg (mm)}}{\text{length of egg (mm)}} \times 100 \qquad (\%) \qquad (1)$$

Force needed for eggshell destruction

The force needed for the eggshell destruction was determined with the egg crusher (Veit Elektronics, Ltd., Brno, Czech Republic). This portable instrument is powered by a battery. Its simple operation allows fast measuring of a large number of samples. The measured values may be read directly from the instrument display (or stored on a chip card). They may be consequently loaded into PC for further processing.

Deflection of eggshell (mm)

The eggshell deflection was determined with the instrument described in the work by Gálik et al. (2004), to which the digital gauge, type ID-N112, (Mitutoyo, Kawasaki, Japan), was added (Fig. 1). The deflection was determined on the egg equator while using a non-destructive load (500 g) on the longitudinal axis of the egg (Bainová 2004).

The results measured were processed and evaluated using suitable statistical methods (Poláková 2007). The dependence of the values of the dependent variables (deformation of eggshell in mm, or weight of eggshell in g) on several independent variables (force needed for the destruction of eggshell, or the ITV, eggshell thickness, egg weight) was assessed through a multiple regression analysis method. The model formula used is as follows:

$$y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 \quad (2)$$

where:

y – value of dependent variable

b_0 – intercept

$b_1...b_3$ – regression coefficient expressing the influence of the unit change of independent variable on the value of the monitored dependent variable

$x_1...x_3$ – value of independent variable

The calculations were done in Microsoft Excel.

RESULTS AND DISCUSSION

The aim of the analysis was to determine the functional relations between the eggs qualities, i.e.: the eggshell deflection, eggshell thickness and force needed for the eggshell destruction. Table 1 shows the results of the dependence of the dependent variable (eggshell deflection) on the independent variables (eggshell thickness and force needed for eggshell destruction). Thus, for example, in the case of the conventional cage [KK (whole)], the correlation coefficient R (0.328) shows statistical dependence; according to the determination coefficient R^2 (0.108), however, only 10.8% of the eggshell deflection variability can be explained through the regression model chosen.

In the case of the enriched cage, the correlation coefficient R has a markedly higher value (0.538), and according to the coefficient of determination,

Table 1. Results of multiple dependence between eggshell deflection and some physical indicators of market eggs

Cage	Dependent variable	Independent variable	R	R^2	P	Result	Model's equation
KK (top)	deflection	thickness force	0.117	0.014	0.616 0.568	no dependence no dependence	$y = 0.048 - 0.024x_1 - 0.0002x_2$
KK (centre)	deflection	thickness force	0.390	0.152	0.055 0.173	no dependence no dependence	$y = 0.077 - 0.09x_1 - 0.0003x_2$
KK (bottom)	deflection	thickness force	0.616	0.379	0.000 0.121	dependence no dependence	$y = 0.117 - 0.197x_1 - 0.0003x_2$
OK (top)	deflection	thickness force	0.470	0.221	0.000 0.265	dependence no dependence	$y = 0.093 - 0.133x_1 - 0.0002x_2$
OK (centre)	deflection	thickness force	0.497	0.247	0.000 0.095	dependence no dependence	$y = 0.116 - 0.189x_1 - 0.0003x_2$
OK (bottom)	deflection	thickness force	0.655	0.429	0.000 0.004	dependence dependence	$y = 0.11 - 0.168x_1 - 0.0004x_2$
KK (whole)	deflection	thickness force	0..328	0.108	0.002 0.030	dependence dependence	$y = 0.072 - 0.08x_1 - 0.0003x_2$
OK (whole)	deflection	thickness force	0..538	0.289	1.16×10^{-10} 8.31×10^{-4}	dependence dependence	$y = 0.105 - 0.158x_1 - 0.0003x_2$

KK – conventional cage; OK – enriched cage

Table 2. Results of multiple dependence between eggshell weight and some physical indicators of market eggs

Cage	Dependent variable	Independent variable	R	R^2	P	Result	Model's equation
KK (top)	eggshell weight	ITV	0.9899	0.960	0.734	no dependence	$y = -4.87 + 0.002x_1 + 16.098x_2 + 0.074x_3$
		eggshell thickness			2.30×10^{-35}	strong dependence	
		egg weight			1.51×10^{-35}	strong dependence	
KK (centre)	eggshell weight	ITV	0.966	0.932	3.64×10^{-5}	strong dependence	$y = -1.889 - 0.024x_1 + 15.82x_2 + 0.059x_3$
		eggshell thickness			1.38×10^{-34}	strong dependence	
		egg weight			3.46×10^{-29}	strong dependence	
KK (bottom)	eggshell weight	ITV	0.931	0.867	0.00071	strong dependence	$y = -0.878 - 0.0265x_1 + 15.335x_2 + 0.052x_3$
		eggshell thickness			3.63×10^{-26}	strong dependence	
		egg weight			3.08×10^{-19}	strong dependence	
OK (top)	eggshell weight	ITV	0.969	0.940	0.072	no dependence	$y = -3.096 - 0.0144x_1 + 16.042x_2 + 0.065x_3$
		eggshell thickness			1.19×10^{-35}	strong dependence	
		egg weight			7.45×10^{-22}	strong dependence	
OK (centre)	eggshell weight	ITV	0.923	0.852	0.682	no dependence	$y = -3.479 - 0.0028x_1 + 15.645x_2 + 0.059x_3$
		eggshell thickness			1.99×10^{-25}	strong dependence	
		egg weight			5.89×10^{-17}	strong dependence	
OK (bottom)	eggshell weight	ITV	0.952	0.907	0.430	no dependence	$y = -4.406 - 0.0068x_1 + 18.454x_2 + 0.062x_3$
		eggshell thickness			8.07×10^{-34}	strong dependence	
		egg weight			2.30×10^{-19}	strong dependence	
KK (whole)	eggshell weight	ITV	0.963	0.926	1.07×10^{-6}	strong dependence	$y = -2.277 - 0.0019x_1 + 15.509x_2 + 0.061x_3$
		eggshell thickness			3.81×10^{-91}	strong dependence	
		egg weight			3.86×10^{-81}	strong dependence	
OK (whole)	eggshell weight	ITV	0.953	0.908	0.062	no dependence	$y = -3.629 - 0.008x_1 + 16.784x_2 + 0.061x_3$
		eggshell thickness			1.27×10^{-97}	strong dependence	
		egg weight			3.46×10^{-57}	strong dependence	

KK – conventional cage; OK – enriched cage

through the given regression model, up to 28.9% of variability is explained by the eggshell deflection. By comparing the P values and the significance level $\alpha = 0.05$, it was determined that a statistically significant dependence exists between the deflection and eggshell thickness, as well as between the deflection and the force needed for the eggshell destruction.

The equation of the linear model of multiple dependence for KK is as follows:

$$y = 0.072 - 0.08x_1 - 0.0003x_2 \quad (3)$$

The regression coefficient for x_1 (value 0.08) reveals that: if in KK the eggshell thickness increases by 1 mm, the eggshell deflection decreases by 0.08 mm. The regression coefficient for x_2 (value 0.0003) says: if in KK the force needed for the eggshell destruction thickness increases by 1 N, the eggshell deflection decreases by 0.0003 mm. Table 2 shows multiple dependencies between the dependent variable (eggshell weight) and the independent variables: ITV (x_1), eggshell thickness (x_2) and egg weight (x_3). The correlation coefficient (for KK whole) R (0.963) shows a strong statistical dependence. The determination coefficient value (R^2) was 0.926 (92.6% of eggshell weight variability is explained by the selected regression model). By comparing the P values and the significance level $\alpha = 0.05$, it was found that a statistically significant dependence occurs between the eggshell weight and the ITV, between the eggshell weight and eggshell thickness, as well as between the eggshell weight and egg weight.

The equation of the linear model of multiple regression is as follows:

$$y = -2.277 - 0.0019x_1 + 15.509x_2 + 0.061x_3 \qquad (4)$$

From the regression coefficient values it follows that if the ITV increases by 1%, then the eggshell weight decreases by 0.0019 g, if the eggshell thickness increases by 1 mm, then the eggshell weight increases by 15.509 g, and if the egg weight increases by 1 g, then the eggshell weight increases by 0.061 g.

The most frequent indicators of the eggshell quality evaluation include its weight, thickness and strength. There are many works dealing with these issues and the possibility to compare the individual rearing methods, their advantages and shortcomings, which have become the objects of monitoring and comparison by many professionals in the field. The acquired overall view of these systems helps in the search for optimum distribution of the individual enriching elements, which gradualy brings the enriched cages to the level of conventional cages also from the aspect of the acquired utility. If we manage to decrease the number of non-standard eggs below the level achieved in the case of conventional cages, this system will prove to be a suitable substitution as regards its economic aspect as well as the aspect of welfare. However, the results achieved in the field are so far not unified. Thus, for example, according to Karkulín and Chmelničná (2004), the enriched cage technology positively influenced the eggshell quality. A statistically evident difference ($P < 0.05$) was recorded between the technologies; in the force needed for the eggshell destruction, a statistically highly evident difference ($P < 0.01$) existed in the eggshell thickness. The eggshell weight was not influenced by the technology. In contrast to these results, it follows from the work of Pokludová et al. (2008) that the housing technologies do not have any significant influence on the egg quality. A lower weight of eggs in the conventional cage technologies (as opposed to the enriched cage technologies and the housing on bedding) is equalised by a higher laying intensity. This was partly confirmed also by Gálik et al. (2009) who did not record any evident differences between the weight of laying hens and the weight of eggs of the hens housed in enriched or conventional batteries. In another work, however, Gálik et al. (2010) determined a statistically significant difference in the force needed for the eggshell destruction and a statistically not evident difference in the eggshell thickness and eggshell deflection between the enriched and un-enriched cage batteries. Karkulín et al. (2005) claim that there have been just a few experiments so far which could lead to concrete conclusions.

CONCLUSION

The analysis of the relations between some physical variables of consumer eggs shows that between the shell deflection (dependent variable) and the thickness of the shell, respectively the force needed to destroy the shell (independent variables), statistically significant dependence exists for the batteries of both conventional and enriched cages. If the shell thickness was increased by 0.1 mm, the deflection of the shell was reduced by 0.008 mm in the conventional cages and by 0.0158 mm in the enriched cages. If the force to destroy the shell was increased by 1 N, the deflection of the shell was reduced by 0.0003 mm in the conventional as well as in the enriched cages. Statistically significant dependence was also found between the shell mass (dependent variable) and egg shape index, shell thickness and egg weight (independent variables) in both the conventional and enriched cages. Between the shell weight and egg shape index statistical dependence close to the limit of significance was observed with the enriched cage. If the egg shape index increased by 1%, the shell weight was reduced by 0.0019 g in the conventional and by 0.008 g in the enriched cages. If the shell thickness increased by 0.1 mm, the shell mass increased by 1.550 g in the conventional and by 1.678 g in the enriched cages and if the egg mass increased by 1 g, the shell weight would increase by 0.061 g in the conventional as well as in the enriched cages. The results obtained are a contribution benefits to scientific knowledge, characteristics observed and their interrelationships.

References

Appleby M.C., Walker A.W., Nicol C.J., Lindberg A.C., Freire R., Hughes B.O., Elson H.A., 2002. Development of furnished cages for laying hens. British Poultry Science, *43*: 489–500.

Bainová M.M., 2004. New innovations in the assesment of eggshell quality – a Review. In: Proceedings of the XXII.

World's Poultry Congress. Istanbul, Turkey, WPSA Turkish Branch, 22: 8–9.

Council Directive 1999/74/EC. Laying down minimum requirements for minimum protection of laying hens. Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1999:203:0053:0057:EN:PDF

Gálik R., Karas I., Švenková J., Žitná M., 2004. Vývoj zariadenia na meranie pevnosti škrupiny vajec (Development of a device for measuring eggshell solidity). Acta Technologica Agriculturae, *7*: 11–14.

Gálik R., Poláková Z., Boďo Š., 2009. Vplyv rôznych technologických systémov ustajnenia na hmotnosť nosníc a produkovaných vajec (The influence of different stabling systems at the weight of hens and their eggs production). In: International Science Conference "Technika v podmienkach trvalo udržateľného rozvoja", May 20–22, 2009. Plavnica: 13–18.

Gálik R., Švenková J., Poláková Z., Boďo Š., 2010. Vplyv niektorých technologických systémov ustajnenia nosníc na vybrané ukazovatele kvality škrupiny vajec (Effect of technological systems for layng hens housing on selected indicators of eggshell quality). Acta Technologica Agriculturae, *13*: 1–5.

Halaj M., 1999. Posudzovanie vlastností a kvality konzumných vajec (Assessment of performance and quality of table eggs. In: Weis J., Halaj M., CHmelničná Ľ., Kopecký J., Chov hydiny (Poultry). Nitra, SAU in Nitra: 61–71.

Karandušovská I., Pogran Š., Knížatová M., 2009. Posudzovanie produkcie škodlivín v objektoch pre chov dojníc a hydiny (Assessment of production of pollutants in buildings for dairy and poultry). 1st Ed. Nitra, SPU in Nitra: 170.

Karkulín D., Chmeliničná Ľ. 2004. Vplyv rozdielnych klietkových technológií na kvalitu škrupiny konzumných vajec (Influence of different cage technologies on shell quality of market eggs). In: Možnosti a perspektívy zvyšovania produkcie v chove hydiny a malých hospodárskych zvierat. Nitra, SAU in Nitra: 27–32.

Karkulín D., Gálik R., Švenková J., Šesták M., 2005. Kvalita škrupiny konzumných vajec nosníc ustajnených v rozdielnych technológiách (Eggshell quality of table eggs from laying hens housed in different cage technologies). In: First International Scientific Poultry Days Section 3: Table Eggs Production. Nitra, SAU in Nitra: 14–17.

Lendelová J., Pogran Š., 2009. Technika prostredia a možnosti redukovania vplyvu klimatických extrémov v ustajňovacích objektoch (Environ technique and reduction possibility of climatic extrems effect in stables). Technika v technológiách agrosektora 2009 (CD-ROM). Nitra, SPU in Nitra: 137–142.

Leyendecker M., Leyendecker M., Hamann H., Hartung J., Kamphues J., Neumann U., Sürie C., Distl O., 2005. Keeping laying hens in furnished cages and an aviary housing system enhances their bone stability. British Poultry Science, *46*: 536–544.

Lichovníková M., Zeman L., 2008. Effect of housing system on the calcium requirement of laying hens and on eggshell quality. Czech Journal of Animal Science, *53*: 162–168.

Pogran Š., Šottník J., Karandušovská I., Knížatová M., Orság J., Mihina Š., 2009. Sledovanie rozdielov koncentrácií amoniaku počas zimného a letného chovu v ustajnení brojlerov (Monitoring of differences of ammonia concentrations during winter and summer feeding in broiler housing). Acta Technologica Agriculturae, *12*: 26–28.

Pokludová M., Hrouz J., Klecker D., 2008. Influence of particular technological systems on selected qualitative parameters of eggs. Available at www.old.af.mendelu.cz/mendelnet2003/obsahy/zoo/pokludova.pdf (accessed October 23, 2008).

Poláková Z., 2007. Návody na cvičenia z bioštatistiky (Instructions for Exercises in Biostatistics). Nitra, SAU in Nitra: 1–84.

Walker A.W., Walker A.W., Tucker S.A., Elson H.A., 1998. An economic analysis of a modified, enriched cage egg production system. British Poultry Science, Sp*39*: S14–15.

Received for publication December 8, 2010
Accepted after corrections May 25, 2011

Corresponding author:

doc. Ing. Roman Gálik, Ph.D., Slovak University of Agriculture in Nitra, Faculty of Engineering,
Department of Production Engineering, Tr. A. Hlinku 2, 949 76, Nitra, Slovak Republic
phone: + 421 376 414 307, e-mail: Roman.Galik@uniag.sk