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QUALITY AND CHEMICAL COMPOSITION OF EGGS AFFECTED BY REARING SYSTEM AND HEN'S AGE

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Abstract: The aim of this study was to evaluate the effect of rearing system and hen's age on quality and chemical composition of eggs. The tested rearing systems were: cage, floor and organic (30 birds Isa Brown hybrid per group). Fifteen eggs per group were collected for analyses in each of three phases of the productive cycle (32, 48 and 72 weeks hen's age). In these samples were investigated external (egg weight and egg shape index), internal (albumen height, Haugh unit and yolk colour) and chemical composition of eggs (dry matter, minerals, protein and lipids content). The general conclusion is that the egg weight and Roche values were increased, while egg shape index, albumen height and Haugh unit were decreased with hen's age. Organic eggs had higher albumen height and more Haugh units in the 48 and 64 weeks compared to the floor and cage eggs. Yolk colour of the floor and cage hens most dependent on the hen's age, on the other hand - yolk colour of organic hens most dependent on the grass availability at the outlet. Eggs from the organic rearing system had a lower dry matter, proteins and lipid content as compared to the cage system.

Keywords: Laying hens, rearing systems, egg quality, chemical composition, hen's age.

Introduction

Although producers around the world are increasingly converting their facilities to cage-free, data from the *International Egg Commission (2016)* show that the majority of laying hens (89.7%) are housed in a cage system. The main reason why the cage system of laying hens is the most widespread in the world is that it is the most economical - it provides that the price of eggs is low and that product be accessible to all segments of the population. Egg consumption in Hungary, USA

and Argentina are more than 250, in Japan more than 300 and in Mexico more than 350 eggs per person per year *(International Egg Commission, 2015).*
However, in many countries, consumers demands are more focused on quality rather than price. In research of *Pavlovski et al*. (2011) states that the number od of consumers which were willing to pay a higher price by 10% for eggs of guaranteed and controlled quality or from free-range system increased from 46% in 1981. to 71.5% in 2011. In the report of *Committee for the Common Organisation of the Agricultural Markets (2018)*, it is stated that in the EU countries 18.4% of the hens have access to an outlet (free range and organic together).
Due to all these facts, the aim of this study was to evaluate the effect of rearing system and hen's age on quality and chemical composition of eggs.

Material and methods

The study was carried out in three rearing systems: cage, floor and organic. In each system, the same genotype of laying hens (Isa Brown hybrid) was housed - 30 birds per group.
Each bird in battery system had at its disposal 750 cm² floor area. In floor and organic system the stocking density was 2.5 birds/m^2. The organic layers also had about 5 m^2 per birds available outdoor area which was covered with grass and bushes and these hens were able to supplement their diets using vegetation and small creatures living in an outlet.
Cage and the floor laying hens were fed with the same standard commercial diets whose average chemical composition is shown in Table 1. In organic system, except in the facility, the feeders and drinkers were located in the outlet. It is important to note that the diet from organic hens was complete without additions of synthetic amino acids, vitamins and minerals, with the use of more 80% organically grown components. Its chemical composition is also shown in Table 1. In all of three experimental groups feed and water were available *ad libitum.*

Table 1. The chemical composition of diet from laying hens

	Cage and floor system	**Organic system**
Chemical composition	%	%
Dry matter	88.38	89.82
Crude proteins	16.79	16.82
Crude fats	5.15	4.31
Cellulose	4.82	4.29
Ash	12.52	12.68
Ca	3.72	3.43
Total P	0.71	0.81
Na	0.17	0.18
Lysine	0.79	0.80
Methionine+cystine	0.68	0.48
Metabolisable energy, MJ	11.5 MJ	11.3 MJ

Fifteen eggs per group were collected for analyses in each of three phases of the productive cycle (32, 48 and 72 weeks hen's age). In these samples (eggs were one day old) were investigated external, internal and chemical composition of eggs.
- Egg weight was measured on an electronic scale with accuracy of 10^{-2} g.
- Egg shape index, or short-axis to long-axis length ratio (%), was determined using a special device (B.V. Apparatenfabriek van Doorn, Holland).
- Albumen height was determined tripod micrometer (AMES, USA)
- Haugh units were calculated according to following formula: HU=100log ($H+7.57-1.7M^{0.37}$) where H = albumen height, mm, M = egg weight, g.
- Egg yolk colour was determined according to Roche yolk colour fan.

Analysis of the basic chemical composition of the eggs was performed based on SRPS ISO procedures (dry matter SRPS ISO 1442/1998, mineral materials SRPS ISO 936/1999, proteins SRPS ISO 937/1992, lipids 1444/1998).
Quality of eggs data were analysed by ANOVA and LSD test (*Stat Soft Inc Statistica For Windows, Version 7.0., 2006*).

Results and discussion

Egg quality parameters are presented in Table 2 shows that the egg weight was significantly influenced by hen's age ($p \leq 0.05$) while the effect of the rearing system was not significant ($p \geq 0.05$). Generally, egg weight was increased with hen's age, which is consistent with the results published by *Zita et al. (2009)* and *Rakonjac et al. (2017)*. It is important to note that the egg weight between the 32 and 48 weeks old hens differed significantly ($p \leq 0.05$), while in the later period (48-72 weeks) there were no differences ($p \geq 0.05$). That indicated that in an early period of laying there was increasing in egg weight but in later phases of egg production egg weight remain static (*Padhi et al., 2013*). On the other hand, the effect of rearing system on egg weight was not significant, similar to the results reported by *the Mugnai et al. (2009)* and *Rakonjac et al. (2017)*. Contrary to this, *Lolli et al. (2013)* and *Kralik et al. (2013)* found higher egg weight in free range than the cage system, while *Ferrante et al. (2009)* and *Lewko and Gornowicz (2011)* found the opposite - a higher egg weight in the cage than in the rearing systems with the outlet.

Egg shape index decreased with hen's age, and eggs from 32 week age hens had higher values of the index form of eggs from the 48 and 72 week age hens. As well as the weight of the eggs, the rearing system did not affect differences in this parameter ($p \geq 0.05$). *Škrbić et al. (2011)* also found that the egg shape index value decreased with hen's age ($r = -0.15$). These results *Nikolova and Kocevski (2006)* were explained by the fact that the higher shape index of eggs from younger hens showed a presence of more eggs of rounded shape, while lower shape index of eggs from older layers showed more percentage of eggs of an

elongated shape which is typical for hens in deep age. Similar results were published and by *Zita et al. (2009)*. The rearing system did not influence differences in egg shape index, which is in agreement with the findings by *Đukić-Stojčić et al. (2009), Lewko and Gornowicz (2011), Ahhamed et al. (2014) and Dikmen et al. (2017).*

Table 2. Effect of the rearing systems and laying hen's age on egg quality parameters

Rearing systems	Hen's age		Egg weight (g)	Egg shape index	Albumen height (mm)	Haugh unit	Yolk colour (Roche)
Cage	32 week	$\bar{x}$	61.30 c	78.13 ab	7.42 ab	85.20 abc	9.07 f
		Sd	3.91	2.88	0.87	5.45	1.33
	48 week	$\bar{x}$	63.31 bc	75.93 cde	6.91 b	81.07 bc	10.60 de
		Sd	4.89	2.31	0.81	6.16	0.51
	72 week	$\bar{x}$	67.39 a	75.07 de	4.93 d	62.67 e	13.40 a
		Sd	5.75	1.71	1.04	12.08	0.51
Floor	32 week	$\bar{x}$	61.19 c	78.93 a	7.85 a	87.73 a	8.87 f
		Sd	3.15	2.63	1.12	5.97	0.92
	48 week	$\bar{x}$	66.86 ab	76.53 bcd	7.03 b	80.13 c	10.27 e
		Sd	5.78	2.90	1.26	9.09	0.96
	72 week	$\bar{x}$	67.03 a	75.93 cde	4.87 d	62.67 e	13.00 a
		Sd	5.45	2.31	1.07	10.31	0.65
Organic	32 week	$\bar{x}$	60.03 c	77.20 abc	7.62 ab	87.00 ab	11.47 bc
		Sd	4.53	2.01	0.91	6.00	0.64
	48 week	$\bar{x}$	65.54 ab	76.13 cde	8.07 a	88.07 a	11.13 cd
		Sd	5.84	1.92	1.39	8.42	0.64
	72 week	$\bar{x}$	65.63 ab	74.67 e	5.71 c	70.67 d	11.73 b
		Sd	4.44	2.64	1.03	9.62	0.46
P value							
Rearing system			0.427	0.078	0.005	0.003	≤0.001
Hen's age			≤0.001	≤0.001	≤0.001	≤0.001	≤0.001
Rearing system x Hen's age			0.421	0.846	0.159	0.240	≤0.001

a-f: Values within columns with different superscripts are significantly different (P≤0.05)

Haugh unit was decreased throughout the experimental period, due to the decreasing albumen height with hen's age. A significant effect of the age of hens on albumen height determined also *Ojedapo (2013)*. Our results that Haugh unit decreases with hen's age ($p \leq 0.05$) are consistent with the findings by *Škrbić et al. (2011)* and *Padhi et al. (2013)*. Effect of rearing systems on Haugh units was not significant in the 32 weeks ($p \geq 0.05$), but eggs from organic rearing system had more Haugh units in the 48 and 64 weeks compared to the floor and cage ($p \leq 0.05$). There are a numerous reasons why the organic eggs have a more Haugh units compared to eggs from the floor and the cage system: less stress in the oviduct tract

(*Castellini et al., 2006*), effect of the higher concentration of ammonia in cage and floor systems that enhances the albumen pH affecting thus its consistency (*Minelli et al., 2007*), the high vitamin C content in albumen influenced intake fresh grass from outlet (*Mugnai et al., 2009*).

Both studied factors and their interactions had a significant effect on the yolk colour ($p \leq 0.05$). Generally, Roche values increased in floor and cage system with the hen's age. On the other hand, the yolk colour of organic eggs was relatively constant throughout the entire experimental period. Increasing Roche value with the hen's age in our experiment is in accordance to research *Rizzi and Chiericato (2005)* and *Škrbić et al. (2011)*. Both groups - cage and floor consumed constant amount synthetic carotenoids in feed throughout the entire production cycle, and increasing intensity of yolk colour was a result of their greater synthesis in the body with hen's age. On the other hand, in organic laying hens, the intensity of yolks colour was much more dependent on season and availability of grass at the outlet (no synthetic colours in their feed).

Organic hens had available a significant amount of grass rich in carotenoids in an outlet in week 32, which caused a higher Roche values compared with a floor and cage laying hens ($p \leq 0.05$). At week 48, grass amount at the outlet was reduced, which caused that there were no significant differences between Roche values in all three investigated rearing systems ($p \geq 0.05$). Finally, at week 72, all the amount of the grass at the outlet was spent, and the floor and the cage produced eggs had a significant higher Roche values then organic ($p \leq 0.05$) - organic hens no longer had grass available as an additional source of carotenoids, while the floor and the cage hens received synthetic carotenoids through feed.

Table 3. Effect of the rearing systems and laying hen's age on the chemical composition of eggs

Rearing systems	Hen's age		Dry matter (%)	Minerals (%)	Protein (%)	Lipids (%)
Cage	32 week	$\bar{x}$	25.08 a	0.91 ab	12.70 a	9.82 ab
		Sd	1.37	0.07	0.53	1.46
	48 week	$\bar{x}$	24.27 abc	0.88 c	12.23 bc	9.45 abc
		Sd	0.37	0.04	0.29	0.44
	72 week	$\bar{x}$	24.67 ab	0.92 a	12.38 ab	10.02 a
		Sd	0.71	0.03	0.19	0.76
Floor	32 week	$\bar{x}$	23.75 bc	0.85 d	12.33 ab	8.61 c
		Sd	1.11	0.10	0.70	0.79
	48 week	$\bar{x}$	24.29 abc	0.88 c	12.11 bc	9.54 abc
		Sd	1.21	0.06	0.51	1.07
	72 week	$\bar{x}$	24.63 ab	0.90 abc	12.23 bc	9.83 ab
		Sd	1.62	0.04	0.43	1.69
Organic	32 week	$\bar{x}$	23.40 c	0.85 d	12.13 bc	8.62 c
		Sd	0.60	0.06	0.26	0.68
	48 week	$\bar{x}$	23.41 c	0.91 ab	11.82 c	9.12 abc
		Sd	1.17	0.04	0.39	1.32
	72 week	$\bar{x}$	23.82 bc	0.89 bc	12.31 ab	8.94 bc
		Sd	0.64	0.12	0.44	0.59
P value						
Rearing system			≤0.001	≤0.001	0.015	0.014
Hen's age			0.378	≤0.001	0.020	0.134
Rearing system x Hen's age			0.312	≤0.001	0.460	0.313

a-d: Values within columns with different superscripts are significantly different (P≤0.05)

Table 3 shows that the eggs from the organic rearing system had a lower dry matter content as compared to the other two systems (P≤0.05). The results similar to these are given by *Matt et al. (2009)*, which found the higher content of dry matter in cage eggs compared to organic.

Ash content was significantly influenced by studied factors and their interactions (P≤0.05). These results are in agreement with the results published by *Zhu et al. (2015)*, which found a significant difference in the content of a large number of minerals in eggs between the cage and the free-range layers.

Cage produced eggs had a higher content of protein and lipids compared to the organic eggs (P≤0.05). A significant effect of the rearing system on the content of protein and lipids in eggs was determined by numerous authors. *Mat et al. (2009)* obtained the similar results in their research, the cage eggs had higher

protein and lipids content compared to free range eggs. Also, *Pavlovski et al. (2011)* determined higher protein content, and *Radu-Rusu et al. (2014)* higher lipids content in cage eggs compared to free range.

Conclusion

Based on the results of these investigations it can be concluded that the rearing system and hen's age had a significant effect on egg shape index, albumen height, Haugh unit and yolk colour, while egg weight was influenced only by the hen's age. The interaction of the observed factors significantly influenced yolk colour. On the other hand, the rearing system had a significant effect in all four parameters of the chemical composition of eggs, while the significant effect of the hen's age on these parameters was established for mineral and lipids content. Rearing system x hen's age interaction significantly influenced only the mineral content in eggs.

Kvalitet i hemijski sastav jaja uzrokovan sistemom gajenja i starošću kokoši nosilja

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Rezime

Cilj ovog rada je bio da se ispita uticaj sistema gajenja i starosti na kvalitet i hemijski sastav jaja kokoši nosilja. Ispitivani sistemi gajenja su bili: kavezni, podni i organski (30 jedinki Isa Brown hibrida po grupi). Petnaest jaja po grupi je sakupljeno u tri faze proizvodnog ciklusa (32, 48 i 72 nedelje starosti nosilja). Na ovim uzorcima su ispitivani parametri spoljašnjeg (masa i indeks oblika) i unutrašnjeg kvaliteta jaja (visina belanca, Hogove jedinice i boja žumanca) kao i osnovni hemijski sastav jaja (sadržaj suve materije, minerala, proteina i masti). Generalno se može zaključiti da su se masa jaja i intenzitet obojenosti žumanca povećavali, a indeks oblika, visna belanca i Hogove jednice smanjivale sa starošću nosilja. Organska jaja su imala veću visinu belanca i više Hogovih jedinica u 48. i 64. nedelji u poređenju sa jajima proizvedenim u podnom i kaveznom sistemu. Boja žumanca je kod podno i kavezno gajenih jedniki najviše zavisla od starosti nosilja, dok je sa druge strane kod organskih kokoši boja žumanca najviše zavisila od dostupnosti trave na ispustu. Organsaka jaja su imala manji sadržaj suve materije, proteina i masti u poređenju sa jajima iz kaveznog sistema gajenja.

Ključne reči: kokoši nosilje, sistem gajenja, kvalitet jaja, hemijski sastav, starost.

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