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ASSESSMENT OF EGG AND EGGSHELL QUALITY: INSIGHTS FROM A THREE-YEAR STUDY ON ISA BROWN HYBRID LAYERS

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Abstract: The aim of this research was to examine the influence of the year (production cycle) and laying age on the quality of eggs for consumption. Examination of certain properties of egg and shell quality was carried out over a period of three years continuously and in four evenly spaced time intervals (24, 35, 46, and 57 weeks of age). Determining the external quality of eggs included determining the weight and shape index. Examination of the internal quality of eggs included the determination of albumen height and Haugh units. At the same time, the quality of the eggshell involved the determination of the following properties: (weight, thickness, deformation, breaking force, and color of the shell). The obtained results showed that during three production cycles, the genetic progress of this hybrid was confirmed, which is primarily reflected in a statistically significantly higher ($p<0.05$) value of egg weight, egg white height, and Haugh's units in the third year compared to the first year examinations. Also, under the influence of this factor, statistically significantly higher values of weight and shell thickness and a darker shell color were determined in the third compared to the first year of research. No statistically significant differences were found for other examined parameters under the influence of this factor. In the presence of statistically significant influence ($p<0.05$), various laying ages were systematically examined for internal and external egg quality attributes alongside shell quality properties, excluding shell deformation. Egg weight increased significantly with increasing laying age, while shape index values, contrary to egg weight, decreased. The parameters of internal egg quality were worse with increasing laying age. Regarding the shell quality properties, it was found that the shell weight and thickness, similar to the egg weight, increased with the age of the layers, while the breaking force was found to be the lowest in the oldest layers. The interaction of

both tested factors did not cause a statistically significant effect on tested egg quality traits.

Key words: egg quality, laying age, shell quality, Isa Brown

Introduction

Breeding centers in the poultry industry have created easy-line hybrids characterized by annual egg production that increases year by year and is at the limit of the biological maximum of the species. The goal of the selection work is that such intensive production is accompanied by good animal health, low mortality, and as favorable a feed conversion as possible. Egg quality traits are also the focus of selection improvement and are important for producers and end consumers. Producers are particularly interested in improving shell quality characteristics, while consumer demands focus on eggs' internal quality.

The internal quality of eggs can be affected by many factors, the most important of which are age, diet, and genotype (*Tang et al., 2015*). Research by *Zita et al. (2009)* and *Kraus and Zita (2019)* confirm significant differences in egg quality characteristics under the influence of genotype and laying age. *Perić et al. (2017)* also investigated the influence of age and storage time on egg quality properties. They reported a significant decrease in the value of egg white height and Haugh units in older laying hens. *Johnston and Gous (2007)* and *Bozkurt and Thackerley (2009)* state that egg weight increases with age. In the research by *Vitorović et al. (2002)* and *Galea (2011)*, it is established that nutrition is also a factor that can influence egg and shell quality characteristics. The economic success of the production and the placement of the product on the market largely depend on the characteristics of the quality of the shell. Eggshell quality traits can be affected by age, diet, stress, disease, and rearing system *Roberts (2004)*.

Sometimes, one-sided selection and improvement of certain traits can result in weaker results for other traits, so the goal of the research was to determine genetic progress and changes in egg quality traits over the course of three years in the light line hybrid Isa Brown, which is produced in significant numbers in the Republic of Serbia, as well as the effect of hen age on external and internal egg quality characteristics as well as shell quality.

Materials and Methods

Sample material

The research was carried out on the experimental farm of the Animal Husbandry Institute in Zemun on chickens of the light line hybrid Isa Brown. During three consecutive production cycles (years 2019-2021), 2000 birds at the

age of 18 weeks were moved to a facility for exploitation, cage type. The initial body weights of layers were uniform and in accordance with the norms for the specified age. The animals originated from the same supplier, who is the general representative of the said hybrid for our country.

Diet and environmental conditions

The layers were provided with the same housing, environment, and healthcare conditions. Diet and nutrition were provided ad libitum. The hens were fed with complete mixtures for layers of table eggs, which were made according to the same recipes and which were adapted to the nutritional needs of the said hybrid: in the period of 18-30 weeks of age, a complete mixture containing 17% crude protein was used; in the period from 31-50 weeks of age a mixture with a content of 16.5% crude protein and after the 50 weeks of age a mixture with a 16% crude protein content. The light regime and lighting were controlled and in accordance with the technological recommendations of hybrids with an adequate ventilation system during the entire production cycle.

Determination of egg quality properties

During each production cycle, 30 eggs were randomly sampled at the end of the 24, 35, 46, and 57 weeks of age (total of 360 eggs). The quality of fresh eggs was determined immediately after collection, representing the initial quality of table eggs. Determining the external quality of eggs included determining the weight and shape index. Examination of the internal quality of eggs included the determination of egg white height and Haugh units (HU), while the quality of the eggshell involved the determination of the following properties: (weight, thickness, deformation, breaking force, and color of the shell). The properties of egg and shell quality were determined according to the methods mentioned in the research by *Petričević et al. (2017).*

Statistical data processing

The obtained data were processed using the program package "STATISTICA" (Stat Soft Inc, 2012). The data analysis from these studies was performed based on calculated mean values and their standard deviations for all investigated properties. Testing the significance of the differences in the average values of the tested traits between the experimental groups of laying hens was performed using the appropriate variance analysis model for two factors (year and age). If the analysis of variance and the applied F-test determined an influence of the investigated factors or their combination, the group comparison was switched to an individual, whereby the degree of statistical significance of the differences between the groups was determined using the Tukey test.

Results and Discussion

The average values of the external and internal characteristics of egg quality obtained during the test are shown in Table 1. A statistically significant influence ($p<0.05$) of the tested year on egg weight, egg white height, and Haugh's unit value was determined. Significantly higher values were found for the mentioned properties during the third year of the test compared to the first year. The egg shape index, which represents the ratio between egg width and length, did not differ under the influence of this factor. The second examined factor (laying age) had a statistically significant effect on all external and internal egg quality properties. Egg weight increased significantly ($p<0.05$) with increasing laying age, so at 57 and 46 weeks, a significantly higher weight was recorded compared to the 24th week. Contrary to egg weight with increasing laying age, a significant decrease in shape index was found (values in the 24 and 35 weeks were significantly higher compared to the 57 weeks). The best internal egg quality was recorded in the youngest laying age. Significant differences ($p<0.05$) in the 24 weeks compared to the 46 and 57 weeks were confirmed for the height of the egg white and Haugh's units. The interaction of both examined factors had no significant effect on eggs' external and internal qualities for consumption.

Egg weight is an important parameter that substantially affects the overall quality of eggs and the production economy (*Dikmen et al., 2017*). Higher egg weight values were found in the second and third year of testing compared to the first year. Also, *Škrbić et al. (2006)* found a significant increase in egg weight under the influence of the year of examination, which is probably the result of selection work aimed at increasing the genetic potential of hens. With increasing layer age in our study, egg weight increased while the value of Haugh units decreased, which was established by *Samiullah et al. (2014)* and *Vlčkova et al. (2018)*. In contrast to the previously mentioned studies, *Zemkova et al. (2007)*, in hens aged from 39 to 75 weeks, did not find significant differences in egg weight with increasing age. Examining the influence of genotype and age on egg quality traits such as egg weight and shape index, *Petričević et al. (2017)* determined that the genotype did not influence both investigated traits, while statistical significance was confirmed in the influence of age only on the egg shape index. The values for the egg shape index decreased with age (at 35 weeks, it was 78.08%, and at 65 weeks, 76.27%). *Ledvinka et al. (2012)* and *Kraus and Zita (2019)* affirm that a progressive increase in age is consistently linked to a significant decline in the egg shape index. *Rakonjac et al. (2018)* have found a decrease in egg shape index with the growing age of reared layers in different rearing systems. The height of the albumen and Haugh units significantly decreased with the age of the layer, which is in accordance with the results of *Rizzi and Chiericato (2005)* and *Škrbić et al. (2011)*.

Table 1. External and internal quality of eggs

Factor	Year	Age (weeks)	Egg quality properties							
			Weight, g		Index, %		Albumen height, 0.1 mm		HU	
			$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Year	2019-I		60.26[b]	4.93	78.35	2.39	81.98[b]	14.49	89.12[b]	7.90
	2020-II		64.54[a]	5.09	78.55	2.02	83.26[b]	12.51	89.19[b]	7.41
	2021-III		64.33[a]	5.61	78.57	2.29	92.64[a]	14.30	94.25[a]	7.13
Age		24	58.61[b]	4.59	79.05[a]	1.99	95.21[a]	12.30	96.60[a]	5.65
		35	63.86[ab]	5.30	79.04[a]	1.87	87.17[ab]	12.47	91.62[ab]	6.51
		46	64.08[a]	4.87	78.12[ab]	2.52	79.97[b]	13.81	87.38[b]	7.67
		57	65.29[a]	5.07	77.77[b]	2.25	81.94[b]	14.79	88.10[b]	7.85
Year x Age	2019-I	24	55.37	3.80	79.47	2.06	93.03	13.82	96.03	6.42
		35	60.98	3.96	78.97	1.85	83.63	12.12	90.07	6.29
		46	62.14	3.98	77.77	2.40	71.20	9.87	82.60	6.07
		57	62.56	4.39	77.20	2.58	80.07	13.18	87.77	6.52
	2020-II	24	60.83	4.09	79.04	2.17	91.07	9.22	94.15	4.26
		35	65.15	4.86	78.93	1.76	87.83	13.03	91.70	7.53
		46	65.10	5.34	78.17	2.23	80.10	12.04	87.47	7.06
		57	66.69	4.24	78.1	1.83	74.8	8.47	83.93	6.01
	2021-III	24	59.94	3.93	78.61	1.69	101.54	10.97	99.57	4.68
		35	65.46	5.84	79.23	2.03	90.03	11.76	93.10	5.40
		46	64.99	4.74	78.43	2.91	88.60	13.64	92.07	6.89
		57	66.62	5.49	78.00	2.26	90.97	16.89	92.60	8.47
Two-factor analysis of variance (p value)										
Year			p<0.05		n.s		p<0.05		p<0.05	
Age			p<0.05		p<0.05		p<0.05		p<0.05	
Year x Age			n.s		n.s		n.s		n.s	

n.s - not significant, p>0.05

a, b Mean values in each column without common marks are significantly different at the 5% level

The shell quality of the examined eggs is shown in Table 2. The year and age of the laying hen influenced the eggshell weight. Statistically significantly higher values (p<0.05) of shell weight were found in the third compared to the first year of the study, while with increasing laying age, similar to changes in egg weight, a significant increase in shell weight was also confirmed (significantly higher values (p<0.05) determined in the 46 and 57 weeks compared to the 24 weeks). Both examined factors had no significant effect on shell deformation as an indirect parameter of eggshell quality. The parameter that shows the most negligible cause of eggshell breakage did not differ significantly under the influence of the examined year, but significant (p<0.05) differences occurred

between the first three test periods and the fourth, more precisely, the lowest breaking force was found in the oldest layers. Shell color, as an important parameter due to the affinity of end consumers, was under a statistically significant influence ($p<0.05$) of both examined factors. In the third year of the test, a significantly darker color of the shell was recorded compared to the first two years, while at the age of 46 weeks, the color was significantly lighter compared to the other test periods. The interaction of different years of testing and laying age did not cause a statistically significant effect on eggshell quality properties.

Table 2. Eggshell quality

Factor	Year	Age (weeks)	Eggshell properties									
			Weight, g		Thickness, 0.01 mm		Deformation, μm		Breaking force, kg		Colour	
			$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Year	2019-I		8.28^{b}	0.81	34.72^{b}	4.05	19.38	2.80	4.86	1.03	3.48^{b}	0.59
	2020-II		8.64^{ab}	0.99	34.78^{b}	2.31	19.74	2.71	5.03	0.92	3.44^{b}	0.59
	2021-III		8.91^{a}	0.97	36.26^{a}	3.36	19.64	2.73	4.93	0.81	3.71^{a}	0.54
Age		24	7.98^{b}	0.86	33.74^{bc}	3.05	20.07	3.36	4.92^{b}	1.04	3.62^{a}	0.62
		35	8.69^{ab}	0.83	36.16^{a}	2.76	19.29	2.47	5.13^{ab}	0.76	3.60^{a}	0.58
		46	8.85^{a}	1.01	35.36^{ab}	2.37	19.39	2.41	5.24^{a}	0.85	3.37^{b}	0.61
		57	8.88^{a}	0.86	35.67^{ab}	4.54	19.63	2.65	4.48^{c}	0.87	3.59^{a}	0.52
Year x Age	2019-I	24	7.86	0.83	34.50	3.84	19.73	4.01	4.72	1.31	3.40	0.67
		35	8.53	0.68	36.13	2.73	18.63	2.03	5.14	0.81	3.53	0.63
		46	8.27	0.79	35.00	2.39	19.23	2.05	5.18	0.67	3.47	0.51
		57	8.48	0.79	33.23	5.92	19.93	2.59	4.41	1.05	3.53	0.57
	2020-II	24	7.74	0.82	33.67	2.48	20.26	3.06	4.85	0.94	3.59	0.50
		35	8.80	0.98	34.90	1.99	19.13	1.89	5.23	0.80	3.60	0.50
		46	9.01	0.92	35.63	2.20	19.73	2.80	5.48	0.95	3.07	0.69
		57	8.93	0.73	34.80	2.27	19.90	3.00	4.55	0.73	3.50	0.51
	2021-III	24	8.35	0.83	33.00	2.45	20.25	2.95	5.21	0.70	3.89	0.57
		35	8.74	0.80	37.43	2.94	20.10	3.16	5.00	0.66	3.67	0.61
		46	9.29	1.04	35.43	2.53	19.20	2.35	5.05	0.88	3.57	0.50
		57	9.22	0.90	38.97	2.22	19.07	2.33	4.49	0.84	3.73	0.45
Two-factor analysis of variance (p value)												
Year			p<0.05		p<0.05		n.s		n.s		p<0.05	
Age			p<0.05		p<0.05		n.s		p<0.05		p<0.05	
Year x Age			n.s		n.s		n.s		n.s		n.s	

n.s - not significant, p>0.05

a, b, c Mean values in each column without common marks are significantly different at the 5% level

The quality properties of the shell are particularly influential for economic reasons. A significantly heavier, thicker, and darker shell was found in the third compared to the first year of testing, which confirms the changes under the influence of the year. *Ketta and Tumova (2016)* consider that the main factors

determining eggshell quality are oviposition time, age, genotype, and rearing system. In their research, *Suk and Park (2001)* have found a significant increase in shell weight with increasing age of the layer, which agrees with the results obtained in our research. Consumer demands are to obtain fresh eggs with satisfactory shell quality properties (*Pavlovski et al., 2002*). The shell must be clean and without cracks. The colour of the shell is also important due to consumer demands, so it is considered crucial that this property be uniform. Thus, the importance of its examination increases. Examining the effect of laying age on eggshell colour, *Zita et al. (2009)* concluded that the colour of the shell becomes lighter with increasing age, which is in agreement with our results up to 46 weeks of age.

Conclusion

The obtained results showed that during the three annual production cycles of the test, the genetic progress of the egg quality properties of the Isa Brown laying hen was confirmed, which is primarily reflected in a higher egg weight, egg white height value, and Haugh's units in the third compared to the first year of the test. During the investigation of the effect of the mentioned factor, statistically significantly higher shell weight and thickness values were determined. Under the influence of laying age, it was found that egg weight increased significantly with increasing laying age, while the shape index values decreased. The parameters of internal egg quality were worse with increasing laying age. Regarding shell quality properties, it was established that the eggshell weight and thickness increased with the age of the litter, while the lowest value was found for the breaking force in the oldest layers.

Based on the results of the examination of the influence of the year and the age of laying on the properties of egg and shell quality, we can conclude that the examined hybrid gives satisfactory results that are in accordance with its norms and that are improved from year to year. Egg quality properties should also be the focus of selection work in the following period, especially in older laying hens.

Procena kvaliteta jaja i ljuske: Uvidi iz trogodišnjeg istraživanja na ISA Brown nosiljama

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Rezime

Cilj ovog istraživanja bio je da se ispita uticaj godine (proizvodnog ciklusa) i uzrasta nosilja na kvalitet jaja za konzum. Ispitivanje određenih osobina kvaliteta

jaja i ljuske vršeno je u periodu od tri godine u kontinuitetu i u četiri ravnomerno raspoređena vremenska intervala (24., 35., 46. i 57. nedelja uzrasta). Utvrđivanje spoljašnjeg kvaliteta jaja obuhvatilo je utvrđivanje mase i indeksa oblika jaja. Ispitivanje unutrašnjeg kvaliteta jaja obuhvatilo je utvrđivanje visine belanca i Haugh-ovih jedinica. Dok je kvalitet ljuske jaja podrazumevao određivanje sledećih osobina: (masa, debljina, deformacija, sile loma i boje ljuske). Dobijeni rezultati su pokazali da je u toku tri proizvodna ciklusa potvrđen genetski progres ovog hibrida koji se pre svega ogleda u statistički značajno većoj ($p<0,05$) vrednosti mase jaja, visine belanca i Haugh-ovih jedinica u trećoj u odnosu na prvu godinu ispitivanja. Takođe su pod uticajem ovog faktora utvrđene statistički značajno veće vrednosti mase i debljine ljuske kao i tamnija boja ljuske u trećoj u odnosu na prvu godnu istraživanja. Za ostale ispitivane parametre pod uticajem ovog faktora nije utvrđeno postojanje statistički značajnih razlika. Pod statistički značajnim uticajem ($p<0,05$) različitog uzrasta nosilja bile su sve ispitivane osobine unutrašnjeg i spoljašnjeg kvaliteta jaja kao i osobine kvaliteta ljuske, izuzev deformacije ljuske. Masa jaja se značajno povećavala sa povećanjem starosti nosilja dok su se vrednosti indeksa oblika, suprotno masi jaja, smanjivale. Parametri unutrašnjeg kvaliteta jaja su bili lošiji sa povećanjem uzrasta nosilja. Kod osobina kvaliteta ljuske ustanovljeno je da su se masa i debljina ljuske, slično masi jaja, povećavale sa povećanjem starosti nosilja dok je za silu loma utvrđena najmanja vrednost kod najstarijih nosilja. Interakcija oba ispitivana faktora nije uslovila statistički signifikantan efekat na sve ispitivane osobine kvaliteta jaja.

Ključne reči: kvalitet jaja, starost nosilja, kvalitet ljuske, Isa Brown

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