UDC 637.4.053(497.113)
doi: 10.5937/AASer2356125S

Acta Agriculturae Serbica, 28 (56), 125–130, 2023

Publisher: Faculty of Agronomy Čačak

www.afc.kg.ac.rs

The influence of rearing system and age on the phenotypic correlation of the physical properties of eggs of Banat naked neck layers

Jelena Stepić[1], Vladan Đermanović[1], Zoran Popović[1], Stefan Stepić[1], Veselin Petričević[2], Aleksandra Petrović[2], Simeon Rakonjac[3]

[1]*Faculty of Agriculture, University of Belgrade, Belgrade, Republic of Serbia*
[2]*Institute for Animal Husbandry, Autoput 16, 11080, Belgrade-Zemun, Republic of Serbia*
[3]*Faculty of Agronomy in Čačak, University of Kragujevac, Čacak, Republic of Serbia*

**Corresponding author: jecastanojlovic@gmail.com*

Received 26 September 2023; Accepted 7 November 2023

A B S T R A C T

The aim of the study was to examine the influence of the rearing system and age on the phenotypic correlation of the physical properties of the eggs of the Banat naked neck layers. In both examined systems (extensive and semi-intensive system) there were 50 Banat naked neck layers each. The egg properties were examined at three evenly distributed time intervals (40, 45 and 50 weeks of age) in the period from May to July. In order to determine the external properties of egg quality, three basic measures were observed: egg weight, egg length and egg width. Based on the measured length and width of the eggs, the egg shape index was calculated, and subsequently the volume and surface area of the eggs were determined. For each examined factor, the correlation between the mentioned characteristics was determined. The obtained results showed a significant effect of the rearing system on all examined egg properties ($P < 0.05$), while the influence of age as well as the interaction of the two examined factors had no significant effect. The highest correlation among all investigated factors was found between surface area and egg volume.

Keywords: Banat naked neck, breeding system, egg quality.

И З В О Д

Циљ ових истраживања био је да се испита утицај система гајења и узраста на фенотипску повезаност физичких особина јаја банатског голошијана. У оба испитивана система (екстензивни и полуинтензивни систем) налазило се по 50 кокоши банатског голошијана. Испитивање особина јаја вршено је у три равномерно распоређена временска интервала (40, 45. и 50. недеља узраста) у периоду од маја до јула месеца. У циљу утврђивања спољашњих особина квалитета јаја, измерене су три основне мере, и то: маса јаја, дужина јаја и ширина јаја. На основу измерене дужине и ширине јаја израчунат је индекс облика јаја, а затим су одређене запремина и површина јаја. У оквиру сваког испитиваног фактора утврђена је и корелација између наведених особина. Добијени резултати су показали да систем гајења има значајан утицај на све испитиване особине јаја ($P < 0,05$), док утицај узраста као и интеракције два испитивана фактора нису били значајни. Највећа повезаност код свих испитиваних фактора је утврђена између површине и запремине јајета.

Кључне речи: банатски голошијан, систем гајења, квалитет јаја.

1. Introduction

Banat naked neck layers originate from primitive domestic layers created by crossbreeding with foreign breeds, with the greatest influence of Naked neck or Transylvanian hens, because the property of naked neck was dominantly inherited (Milošević et al., 2013). These chickens tolerate poor feeding conditions, they are resistant to high and low external temperatures, they are very mobile and diligent in searching for food. They are characterized by tolerance to poor housing conditions; therefore, they can provide satisfactory production results in extensive conditions. The Banat naked neck is a medium-sized breed, it lays between 5 and 6 months, 120–160 eggs per year, with an average weight of about 60 g. The body weight of adult birds is 2.5 to 3.0 kg (rooster) and 2.0 to 2.5 kg (hens) (Mitrović et al., 2012). In terms of meat quality, it is second to the Astal breeds (Milošević and Perić, 2011). The original color of the feathers of the Naked Neck hens was gray. Today's feather color of this breed is very different, from black to white (Mitrović and Đekić, 2013). The Naked Neck chickens have good production capabilities both in terms of laying capacity and in terms of quantitative and qualitative slaughter values.

Nowadays, there is a high demand on the market for meat and eggs from chickens that are not reared in an intensive way, i.e., the production of the so-called "healthy food" is of particular importance. There are two main reasons for the introduction of alternative rearing systems: the production of better and healthier products for human consumption and the provision of a higher level of well-being for animals (Rakonjac et al., 2017). The price of the products obtained in this way can be several times higher than the products obtained in the usual intensive rearing system (Vidović, 2020). From the point of view of animal welfare, advantage is given to less intensive poultry rearing systems (Amato and Castellini, 2022). However, the disadvantages are the possibility of infection diseases, parasites and predator attack (Bonnefous et al., 2022*)*.

The semi-intensive production system as an alternative to the intensive method is characterized by certain specificities. Poultry uses built facilities (poultry houses) which can be adapted or strictly intended for the category that is to be reared. Large ranges are needed where the poultry can move freely. In such conditions, the environment is not strictly controlled; semi-open facilities are frequently used without modern equipment for feeding and water supply, with no lighting system, but also without large labor requirements. On the other hand, extensive poultry production involves the free rearing of poultry in a large area such as meadows and pastures, ponds where mobile poultry houses are located with very simple (primitive) equipment. This equipment usually consists of handy feeders and waterers. In this way, poultry is not reared for the mass market.

Local breeds have significant socio-cultural and ecological relevance, and their rearing may enhance local communities and reduce the negative impact of intensive farming systems (Franzoni et al., 2021). These genotypes have several advantages: they are agile and can run fast, fly and roost in trees, and therefore they can escape predators, they are more resistant to bacterial and protozoan diseases and parasitic infestations than commercial layers, their eggs are generally preferred to those from commercial birds (Pym, 2013). This is also the way to affect the preservation of biodiversity, i.e., the preservation of some breeds and the sustainability of the environment. The main obstacle in using autochthonous breeds in poultry production is their poorer production performance compared to hybrids (Rakonjac et al., 2021). Although this way of rearing has been overcome, because it cannot provide enough eggs and meat for the market, it also has prospects.

2. Materials and methods

2.1. Trial material

The research was carried out on Banat naked neck hens according to the system of a two-factorial experiment. The effect of the rearing system, which included extensive and semi-intensive methods of rearing, was examined. For the second investigated factor, data for hens of three different ages (40, 45, and 50 weeks of age) were processed. A total of 100 hens were divided into two groups of 50 hens each at the age of 25 weeks so that they had uniform initial body weight in both tested systems. The examination of the physical properties of the eggs began after the 15th week of rearing in these systems and was done at three equal time intervals (40, 45, and 50 weeks of age) in the period from May to July.

2.2. Rearing system and nutrition

In the extensive rearing system, the hens were reared on a grassy pasture where there was an improvised wooden building with an area of 10 m^2 with a canopy built on an earth surface, where the hens could shelter from the weather. The facility contained nests with straw for laying eggs and wooden perches. Nutrition was provided *ad libitum*. In addition to the range area of 30 m^2/hens, the hens received a mixture of grains (maize and wheat in a ratio of 1:1) as a supplement to their diet. The semi-intensive system involved accommodation in a solid building with a range. The dimensions of the building used were 4 x 5 m, and the stocking density was 2.5 hens/m^2. The hens had a range area of 10 m^2/hens, most of which was covered with grass. The floor in the building was covered with a sawdust mat, which was periodically changed and added as needed. In the building, wooden boards were placed and served as perches, and nests for laying eggs were placed along the walls. Diet was limited to 100 g feed/bird/day. For feeding, a complete mixture for layers of table eggs based on corn and soybean with 16.5% crude protein was used, while water consumption was *ad libitum*. In addition to the mixture, the hens met the rest of their nutritional needs by feeding on the range. The lighting was natural, without controls, and there was no heating or cooling during the entire production cycle.

2.3. Determination of physical properties of egg quality

To determine the external properties of egg quality, all eggs laid 3 days in a row (40, 45 and 50 week of age) in the period from May to July were collected from both investigated rearing systems. In order to determine the physical properties of egg quality, three basic measures were observed/recorded, namely: egg weight, egg length and egg width. Based on the measured egg length and width, the egg shape index was calculated. In addition to the egg shape index, the egg volume and surface were determined. The formula was used to determine the volume: V = (π/6) x LW2 (V – volume, π – 3.1415926, L – length, W – width). In order to determine the surface, the geometric diameter was first calculated: Gd = (LW2)1/3 (Gd – geometric diameter, L – length, W – width). After determination of the geometric diameter, the surface was calculated using the formula: P = πGd2 (P – surface, π – 3.1415926, Gd – geometric diameter) (Đermanović, 2016).

2.4. Statistical data processing

The obtained data were processed using the program package "STATISTICA" (Stat Soft Inc, 2012). The analysis of the obtained data was performed on the basis of calculated mean values and their standard deviations. Testing the significance of the differences of the average values of the tested traits between the experimental groups of hens was performed using the appropriate variance analysis model for two factors (rearing system and age). In addition to the variance analysis, a correlation was established between egg quality traits in each rearing system and in each of the mentioned ages.

3. Results and discussions

The effects of the rearing system and the age of the hens on the physical properties of the examined eggs are shown in Table 1.

The obtained results indicate a significant effect ($P < 0.05$) of the rearing system on all investigated traits. The mean values of egg weight, length, width, shape index, surface and volume were significantly higher in hens reared in the semi-intensive system compared to the extensive system. The different ages of the laying hens as well as the interaction of the examined factors did not have a significant effect on the examined traits ($P > 0.05$).

Table 1.
Physical properties of the examined eggs

Factor	Rearing system	Age	Investigated traits											
			Weight, g		Length, mm		Width, mm		Index, %		Surface, mm^2		Volume, mm^3	
			$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Rearing system	Semi intensive		59.66^a	3.77	57.06^a	2.39	43.03^a	0.97	75.53^a	3.30	6967.8^a	319.4	55370.9^a	3835.3
	Extensive		54.05^b	4.00	55.92^b	2.10	41.55^b	1.12	74.39^b	2.91	6564.0^b	326.8	50630.2^b	3809.1
Age		Week 40	57.53	4.49	56.57	2.21	42.53	1.24	75.26	2.94	6821.9	373.3	53656.8	4430.9
		Week 45	57.06	4.78	56.45	2.34	42.35	1.26	75.11	3.12	6774.9	380.6	53106.8	4485.5
		Week 55	57.01	4.97	56.66	2.44	42.29	1.30	74.75	3.42	6778.2	384.7	53145.9	4544.9
Rearing system x Age	Semi intensive	Week 40	60.19	3.54	57.18	2.27	43.18	1.01	75.61	2.97	7011.2	331.2	55892.1	3994.3
		Week 45	59.35	3.47	57.03	2.23	42.94	0.96	75.40	3.40	6944.6	282.9	55084.9	3397.9
		Week 55	59.52	4.20	56.99	2.66	43.00	0.94	75.60	3.48	6955.9	343.7	55236.1	4112.4
	Extensive	Week 40	54.12	3.04	55.78	1.88	41.68	0.98	74.80	2.85	6578.9	270.5	50788.3	3133.1
		Week 45	54.17	4.66	55.72	2.29	41.61	1.20	74.74	2.72	6560.7	381.4	50608.2	4462.4
		Week 55	53.87	3.99	56.24	2.07	41.40	1.14	73.70	3.05	6555.4	311.5	50526.0	3624.0
ANOVA (p value)														
Rearing system			0.000		0.000		0.000		0.000		0.000		0.000	
Age			0.550		0.632		0.147		0.256		0.461		0.474	
Rearing system x Age			0.603		0.388		0.491		0.149		0.808		0.776	

a-b The average values in each row without common marks are significantly different at the level of 5%

The eggs produced in the semi-intensive rearing system had significantly higher ($P \leq 0.05$) weights compared with extensively produced eggs. The results of Ferrante et al. (2009) and Rakonjac et al. (2018) also showed that different rearing systems can cause significant differences in egg quality properties, and reported higher egg weight in indoor-reared laying hens compared to organic eggs. On the other hand, Sokołowicz et al. (2018b) and Dikmen et al. (2017) reported that eggs produced in a free-range system had a higher weight compared to indoor produced eggs. Contrary to these results, a number of researchers have shown that the rearing system does not necessarily affect egg weight. Basmacioglu and Egrul (2005) reported no significant differences in egg weight in Isa Brown layers reared in cage and floor systems; similar results were determined by Zemkova et al. (2007) for the same genotype in cages, enriched cages, floor and free range systems. Consistent results reporting no effect of the rearing system on egg weight were also published by Sokołowicz et al. (2018a) and Rakonjac et al. (2019). The results obtained for egg weight in the present study correspond with the results of Petričević et al. (2017), who indicate absence of significant differences ($P \geq 0.05$) in egg weight depending on the age of the hens. On the other hand, some authors found that the egg weight increased with the aging of the laying hens (Škrbić et al., 2011; Rakonjac et al., 2019). An explanation for these differences can be provided by the research published by Padhi et al. (2013), who found that egg weight increased only at the beginning of the production cycle while it remained unchanged in later phases. Hens at the age of 14 months reach their maximum egg weight and from then on the egg weight starts to decrease slightly (Milošević and Perić, 2011). In addition to genotype, nutrition and age, egg weight is also influenced by the intensity of laying. Castellini et al. (2006) determined that the total egg weight was negatively correlated with the intensity of laying. Different authors reported that eggs produced in free range systems had higher weight than eggs produced on the floor or in a cage. Some of them believe that the differences in weight between the eggs produced in the free range system and those produced in closed facilities were due to the different air temperature. According to Krawczyk (2009), the use of the free range rearing system increased egg weight. Also, there are studies in which lower egg weight was determined in birds reared in systems that included free range (Minelli et al., 2007). These studies suggest that rearing system is not necessarily of decisive importance for egg weight.

Eggs from the semi intensive rearing system had a higher egg shape index compared to extensively produced eggs ($P \leq 0.05$), which is in agreement with the results by Kralik et al. (2013), who reported that free range rearing decreased egg shape index. Conversely, Dikmen et al. (2017), Rakonjac et al. (2018) and Sokołowicz et al. (2019) did not find a significant effect ($P \geq 0.05$) of the rearing system on this trait. The age of the hens had no significant effect on egg shape index ($P \geq 0.05$), which is consistent with the results of Škrbić et al. (2011) for Banat naked neck and Sokołowicz et al. (2019) for Araucana and Green-legged

Partridge breeds. The results of the authors who found the opposite, i.e., a significant effect of hen age on egg shape index (Ledvinka et al., 2012; Rakonjac et al., 2018), can be explained by the following: in these studies they used hybrids whose egg elongation decreased with aging, which in this experiment was not the case. Also, these discrepancies may be partially attributed to the longer time period of trait testing in previous studies, as opposed to the testing period in this study.

The following tables show the correlation coefficient between the tested traits in both production systems and for all three ages (Tables 2, 3, 4, 5 and 6).

Table 2.
Correlation coefficient in the semi-intensive system

Traits	Weight	Length	Width	Index	Surface
Length, mm	0.774				
Width, mm	0.682	0.761			
Shape index, %	0.015	-0.198	0.483		
Surface, mm^2	-0.025	-0.286	-0.640	-0.521	
Volume mm^3	0.151	-0.112	-0.479	-0.506	0.980

Table 3.
Correlation coefficient in the extensive system

Traits	Weight	Length	Width	Index	Surface
Length, mm	0.627				
Width, mm	0.749	0.292			
Shape index, %	-0.087	-0.755	0.404		
Surface, mm^2	0.864	0.717	0.875	-0.087	
Volume mm^3	0.866	0.717	0.875	-0.087	0.999

The correlation coefficient varied from 0 to ±1; if the value was closer to one, the connection is stronger. Also, it is considered that the correlation is weak up to r = 0.3, medium at r = 0.5 and strong above r = 0.7 (Petrović and Pantelić, 2015).

The established correlation coefficients in different rearing systems show that egg weight is strongly related to egg length and width. Egg width is associated with a moderately strong negative correlation with egg surface area and egg volume. The shape index is negatively correlated with egg surface and volume, while the strongest positive correlation was recorded between surface and volume.

Table 4.
Correlation coefficient at 40 weeks of age

Traits	Weight	Length	Width	Index	Surface
Length, mm	0.775				
Width, mm	0.765	0.885			
Shape index, %	0.390	0.229	0.653		
Surface, mm^2	-0.182	-0.518	-0.696	-0.537	
Volume mm^3	-0.008	-0.357	-0.546	-0.476	0.981

Table 5.
Correlation coefficient at 45 weeks of age

Traits	Weight	Length	Width	Index	Surface
Length, mm	0.694				
Width, mm	0.828	0.372			
Shape index, %	-0.098	-0.739	0.349		
Surface, mm^2	0.926	0.757	0.887	-0.121	
Volume mm^3	0.927	0.758	0.887	-0.122	0.999

Table 6.
Correlation coefficient at 50 weeks of age

Traits	Weight	Length	Width	Index	Surface
Length, mm	0.638				
Width, mm	0.790	0.290			
Shape index, %	-0.073	-0.756	0.405		
Surface, mm^2	0.899	0.721	0.872	-0.094	
Volume mm^3	0.899	0.722	0.870	-0.096	0.999

At 40 weeks of age, egg weight was positively related to egg length and width (Table 4). However, there was a negative correlation of weight, length and width with the surface and volume of eggs. There was a moderate to strong positive correlation between almost all observed egg quality properties at 45 weeks (Table 5). The only property that stands out is the egg shape index, whose correlation with all properties, except width, is negative. Comparing all ages, the egg shape index showed the greatest variation between 40 and 50 weeks of age of hens. At 40 weeks of age, there was a positive correlation between the egg shape index and the length, while at 50 weeks of age, with the increase in laying age, a significant decrease in the egg shape index was observed in the negative direction in relation to egg length. This indicates that, as egg length increases, the egg shape index decreases. These results are consistent with the results of Nikolova and

Kočevski (2006), who also report that the egg shape index decreases with laying age, given that hens at a later age are more likely to lay a higher percentage of elongated eggs. The egg shape index is a property that represents the ratio of egg width and length, expressed in percentages, and can also be expressed as a coefficient value (without a unit of measurement). The obtained result indicates whether the egg is elongated and narrow (lower index value) or short and wide (higher index value). This property is important for designing egg packaging, but also for designing production equipment in facilities. Ledvinka et al. (2012) confirmed that the egg shape index, apart from the rearing system, is significantly influenced by the age and genotype of the laying hens. This index is also important for eggs intended for breeding, i.e. for incubation.

4. Conclusions

Based on the results of the examination of the influence of the production system and age on the phenotypic correlation between the physical properties of the eggs of the Banat Naked neck, it was determined that:

- The semi-intensive system of egg production shows significantly better results in terms of egg weight, length, width, shape index, surface and volume compared to the extensive system.
- The age of hens and the interaction of the examined factors had no significant effect on all the examined egg properties.
- The strongest correlation between the physical properties of eggs was determined between surface area and volume.

Acknowledgment

This study was funded by the Ministry of Science, Technological Development and Innovation of Republic of Serbia, No. 451-03-47/2023-01/200022; No. 451-03-47/2023-01/200088 and No. 451-03-47/2023-01/200116.

References

Amato, G.M., Castellini, C. (2022). Adaptability challenges for organic broiler chickens: a commentary. *Animals*, 12(11), 1354.

Basmacioglu, H., Ergul, M. (2005). Research on the Factors Affecting Cholesterol Content and Some Other Characteristics of Eggs in Laying Hens. *Turkish Journal of Veterinary Science*, 29, 157-164.

Bonnefous, C., Collin, A., Guilloteau, L.A., Guesdon, V., Filliat, C., Réhault-Godbert, S., Rodenburg, T.B., Tuyttens, F.A.M., Warin, L., Steenfeldt, S., Baldinger, L., Re, M., Ponzio, R., Zuliani, A., Venezia, P., Väre, M., Parrott, P., Walley, K., Niemi, J.K., Leterrier, C. (2022). Welfare issues and potential solutions for laying hens in free range and organic production systems: A review based on literature and interviews. *Frontiers in Veterinary Science*, 9.

Castellini, C., Perella, F., Mugnai, C., Dal Bosco, A. (2006). Welfare, productivity and qualitative traits of egg in laying hens reared under different rearing systems. Poster at: XII European Poultry Conference, 10-14 September, 2006, Verona, Italy.

Dikmen, B.Y., Ipek, A., Şahan, Ü., Sözcü, A., Baycan, S.C. (2017). Impact of different housing systems and age of layers on egg quality characteristics. *Turkish Journal of Veterinary and Animal Science*, 41, 77-84.

Đermanović, V. (2016). Praktikum iz živinarstva. Univerzitet u Beogradu. Poljoprivredni fakultet.

Ferrante, V., Lolli, S., Vezzoli, G., Cavalchini, L.G. (2009). Effects of two different rearing systems (organic and barn) on production performance, animal welfare traits and egg quality characteristics in laying hens. *Italian Journal of Animal Science*, 8, 165-174

Franzoni, A., Gariglio, M., Castillo, A., Soglia, D., Sartore, S., Buccioni, A., Mannelli, F., Cassandro, M., Cendron, F., Castellini, C., et al. (2021). Overview of Native Chicken Breeds in Italy: Small Scale Production and Marketing. *Animals*, 11, 629.

Kralik, Z., Radišić, Ţ., Grčević, M., Kralik, G. (2013). Comparison of table eggs quality originating from hens kept in different housing systems. Proceedings of XV European Symposium on the Quality of Eggs and Egg Products and XXI European Symposium on the Quality of Poultry Meat / Petracci, Massimiliano (ed). - Bergamo: The Italian Branch of The World´s Poultry Science Association, 2013, 1-5.

Krawczyk, J. (2009). Quality of eggs from Polish native Greenleg Partridge chicken-hens maintained in organic vs. backyard production systems. *Animal Science Papers and Reports*, 27(3), 227-235.

Ledvinka, Z., Tumová, E., Englmaierová, M., Podsedníček, M. (2012). Egg quality of three laying hen genotypes kept in conventional cages and on litter. *Archiv fur Gefluegelkunde*, 76(1), 38-43

Milošević, N., Perić, L. (2011). Tehnologija živinarske proizvodnje. Udžbenik. Univerzitet u Novom Sadu. Poljoprivredni fakultet.

Milošević, N., Perić, L., Đukić Stojčić, M., Trivunović, S., Rodić, V., Bjedov, S. (2013): Autochthonous hen breeds in the Republic of Serbia – Banat naked neck and Sombor Crested. *World's Poultry Science Journal*, 69, 153 – 162.

Minelli, G., Sirri, E., Folegatti, A., Melluzzi, A., Franchini, A. (2007). Egg quality traits of laying hens reared in organic and conventional systems. *Italian Journal of Animal Science*, 6 (SUPPL. 1), 728-730.

Mitrović, S., Bogosavljevć-Bošković, S., Đermanović, V., Perić, L., Jokić, Ž., Pandurević, T. (2012). Poluintenzivni tov golovrate kokoši, organska proizvodnja živinskog mesa. 17. Savetovanje o biotehnologiji sa međunarodnim učešćem, Čačak, 6-7 April, Zbornik radova, 17(19), 304-309.

Mitrović, S., Đekić V. (2013). Organska živinarska proizvodnja. monografsko delo. Univerzitet u Beogradu, Poljoprivredni fakultet.

Nikolova, N., Kocevski, D. (2006). Forming egg shape index as influenced by ambient temperatures and age of hens. *Biotechnology in Animal Husbandry*, 22(1-2), 119-125.

Petrović, M., Pantelić, V., (2015). Savremena selekcija domaćih životinja. Institut za stočarstvo, Beograd-Zemun.

Petričević, V., Škrbić, Z., Lukić M., Petričević, M., Dosković, V., Rakonjac, S., Marinković, M. (2017). Effect of genotype and age of laying hens on the quality of eggs and egg shells. *Scientific papers: Series D, Animal Science*, 60, 166-170.

Padhi, M.K., Chatterjee, R.N., Haunshi, S., Rajkumar, U. (2013). Effect of age on egg quality in chicken. *Indian Journal of Poultry Science*, 48(1), 122-125.

Pym, R. (2013). Poultry genetics and breeding in developing countries. Poultry Development Review.

Rakonjac, S., Bogosavljević-Bošković, S., Škrbić, Z., Perić, L., Dosković, V., Petrović, M.D., Petričević, V. (2017). The effect of the rearing system, genotype and laying hens age on the egg weight and share of main parts of eggs. *Acta Agriculturae Serbica*, 22(44), 185-192.

Rakonjac, S., Petrović, M.D., Bogosavljević-Bošković, S., Škrbić, Z., Perić, L., Dosković, V., Petričević, V. (2018). Effect of age and season on production performance and egg quality of laying hens from different rearing systems. *The Journal of Animal and Plant Sciences*, 28(6), 1602-1608.

Rakonjac, S., Bogosavljević-Bošković, S., Škrbić, Z., Lukić, M., Dosković, V., Petričević, V., Petrović, M.D. (2019). Egg characteristics of New Hampshire laying hens from floor and organic rearing systems. *Acta Agriculturae Serbica*, 24(48), 87-95.

Rakonjac, S., Dosković, V., Bogosavljević-Bošković, S., Škrbić, Z., Lukić, M., Petričević, V., Petrović D.M. (2021). Production Performance and Egg Quality of Laying Hens as Influenced by Genotype and Rearing System. *Brazilian Journal of Poultry Science*, 23(2), 001-008.

Sokołowicz, Z., Krawczyk., J, Dykiel, M. (2018a). Effect of alternative housing system and hen genotype on egg quality characteristics. *Emirates Journal of Food and Agriculture*, 30(8), 695-703.

Sokołowicz, Z., Krawczyk, J., Dykiel, M. (2018b). The effect of the type of alternative housing system, genotype and age of laying hens on egg quality. *Annals of Animal Science*,18(2), 541-555.

Sokołowicz, Z., Dykiel, M., Krawczyk, J., Augustyńska-Prejsnar, A. (2019). Effect of layer genotype on physical characteristics and nutritive value of organic eggs. *CyTA - Journal of Food*, 17(1), 11-19.

Škrbić, Z., Pavlovski, Z., Lukić, M., Vitorović, D., Petričević, V., Stojanović, LJ. (2011). Changes of egg quality properties with the age of layer hens in traditional and conventional production. *Biotechnology in Animal Husbandry*, 27(3), 659-667.

Vidović, B. (2020). Bolesti živine. Praktikum. Univerzitet u Novom Sadu. Poljoprivredni fakultet.

Vračar, S., Mitrović, S., Đurđević, Z. (1995). The influence of growth and layers genotypes on the external and quality propertites. *Biotechnology in Animal Husbandry*, 11(3-6), 307-314.

Zemkova, L., Simeonova, J., Lichovnikova, M., Somerlikova, K. (2007). The effects of housing systems and age of hens on the weight and cholesterol concentration of the egg. *Czech Journal of Animal Science*, 52(4), 110-115.