The Journal of Animal & Plant Sciences, 28(6): 2018, Page: 1602-1608
ISSN: 1018-7081

EFFECT OF AGE AND SEASON ON PRODUCTION PERFORMANCE AND EGG QUALITY OF LAYING HENS FROM DIFFERENT REARING SYSTEMS

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ABSTRACT

The aim of this study was to evaluate the effect of hen's age and season on production performance and egg quality of laying hens from three different rearing systems. The tested rearing systems were: cage, floor and organic (30 birds Isa Brown hybrid per group). Experimental period was divided into four sub-periods (4 seasons per 13 weeks) and weekly were recorded: deposition, daily produced egg mass, feed consumption, feed conversion in egg mass and mortality. Eggs were collected for analyses during the all four seasons, in all the different phases of the productive activity (summer - 24 weeks hen's age, autumn - 40 weeks hen's age, winter - 56 weeks hen's age and spring - 64 weeks hen's age). In these samples (fifteen eggs per group, eggs were one day old) were evaluated external and internal egg quality parameters: egg weight, egg shape index, albumen share, yolk share, shell share, albumen height, Haugh unit and yolk colour. Age and season, as well as the rearing system, have a significant effect on the production results and egg quality of laying hens. Generally, in summer and autumn, the most of production performances were the best in cage rearing system, while organic system was superior in spring. Egg weight and yolks share were increased, while egg shape index, albumen share, albumen height and Haugh unit were decreased with hen's age. Generally, eggs from cages and the floor had a greater weight compared to organic. Organic eggs had higher albumen height and Haugh unit score in the spring compared to the cage and floor eggs. Yolk colour of the floor and cage eggs 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.

Key words: Laying hens, egg quality, production, rearing systems, season.

INTRODUCTION

Commercial egg production in industrial systems began to expand develop rapidly in the USA after World War II, and soon after in Western Europe. It is characterized by closed facilities, artificial lighting and ventilation, a large number of highly productive hybrid hens in a limited space (in cages - batteries), the use of complete feeds (with various additives - antibiotics, stimulants, hormones, artificial colours etc.) and the use of many of the preparation for hygiene in the farms (Rakonjac *et al*., 2014). This system has become the dominant rearing system of laying hens all over the world, due to the high profitability of this type of production. Windhorst (2015) noted that in battery system produced about 90% of eggs in the world and that in countries such as Brazil, India, Iran, Mexico, Russia and Turkey almost don't have alternative production systems of laying hens. Only approximately 5.6% of the hens are reared in a non-cage rearing systems in the USA, of which about 2.9% are the organic layers.

However, in recent years, market demand is changing. The price is not the deciding factor when producers buy some food product. Many studies have confirmed that very intensive agricultural production (which includes applying a large number of chemical substances and growth promoters) may result in poorer quality of food. In some cases, these products may pose a risk to human health. Increasingly, consumers decide to buy a product that is produced in a "natural way", and for him are willing to pay a higher price. This was contributed to the perception that the products of "happy animals" are better and healthier for human consumption. In research of Pavlovski *et al*. (2011) states that the number od of consumers which were willing to pay 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. European consumers are leading in looking at things in this way, which is best illustrated by the statistic that out of a total of 380.5 million laying hens in the EU, in some of non-cage rearing systems is raised about 44% of individuals (in the floor about 26%, in the "free range", about 14% and about 4% of the birds are organic layers). (Committee for the Common Organisation of the Agricultural Markets, 2016). The number of birds that are rearing in some of non-cage rearing systems is constantly increasing, so that in the UK this percentage is already about 50% (United Kingdom Egg Statistics, 2016), while in some European countries even forbidden to keep hens in cages (Switzerland, Norway).

However, instead of the conventional egg production where the effect of environmental factors is either very low or absent due to the fact that all parameters that may adversely affect production (diet, temperature, humidity, light regimen) are controlled by the producer (Rakonjac *et al*., 2013), in alternative rearing systems this is not the case - especially in rearing systems with outlets. It is not possible to control the temperature, humidity and light intensity in the open space and individuals are under the significant effect of climatic factors and the season. Also, in addition to hens, the season has a significant effect on a grass cover, which is a very important part of this way of table eggs production. For this reason, the effect of seasons on production and egg quality of laying hens is very important in alternative rearing systems (Mugnai *et al*., 2009; Ojedapo, 2013). Also hen's age is significant factor which affecting that the quality of eggs is not constant during production cycle (Silversides and Scot 2001; Zita *et al*., 2009; Chung and Lee, 2014).

From all the above, the aim of this study was to evaluate the effect of hen's age and season on production performance and egg quality of laying hens from three different rearing systems: cage, floor and organic.

MATERIALS AND METHODS

The effect hen's age and season on production and egg quality was observed on 90 hens of Isa Brown hybrid. The tested rearing systems were: cage, floor and organic (30 birds per group). Hens 18 weeks of age were housed in a facility. Monitoring of production performances started from 21 weeks of age when the birds had full laying intensity.

Conventional battery-cages providing 750 cm² of floor space per bird. Hens from floor system had 4000 cm² per bird spaces availability. Wood shavings were used as litter cover. In facility was set perches and nests. As the floor hens, the organic layers also had 4000 cm² per bird spaces availability, but and about 5 m^2 per birds available outdoor area. Outlet in most of their part was covered with grass and bushes, and birds were able to supplement their diets using vegetation and small creatures (worms, insects etc.) living on free range.

Cage and the floor laying hens were fed *ad libitum* with 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 most 80% organically grown components. Its chemical composition is also shown in Table 1. In all of three experimental groups water was 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

The production cycle was divided into four sub-periods - 4 seasons per 13 weeks - summer

(June, July, August), autumn (Septermber, October, November), winter (December, January, February) and spring (March, April, May) so the experiment lasted one year (52 weeks). During the experimental period weekly were recorded: deposition, daily produced egg mass, feed consumption, feed conversion in egg mass and mortality.

Eggs were collected for analyses during the all four seasons, in all the different phases of the productive activity (summer - 24 weeks hens age, autumn - 40 weeks hens age, winter - 56 weeks hens age and spring - 64 weeks hens age). In these samples (fifteen eggs per group, eggs were one day old) were investigated external and internal egg quality parameters: egg weight, egg shape index, albumen share, yolk share, shell share, albumen height, Haugh unit and yolk colour.

Table 2 shows the average air temperatures by seasons, as well as the highest and lowest temperature values recorded during the meteorological measurement.

Production performances data were analysed by non-parametric Wilcoxon test (except mortality where was shown only mean). Quality of eggs data were analysed by ANOVA and LSD test (Stat Soft Inc Statistica For Windows, Version 7.0., 2006).

Table 2. Air temperature by season.

	Summer (June, July, August)	Autumn (Septermber, October, November)	Winter (December, January, February)	Spring (March, April, May)
Average daily temperature (◦C)	21.6	13.0	4.8	12.2
Maximum recorded temperature (◦C)	38.2	33.3	16.3	25.6
Minimum recorded temperature (◦C)	6.1	-2.4	-12.4	-3.2

Table 3. Effect of the season and rearing systems on production performances of laying hens.

Season	Rearing system	Deposition (%)	Egg mass (g egg hen day^{-1})	Feed consumption (g day^{-1})	Conversion (g feed for g eggs)	Mortality (%)
	Cage	87.28 a	51.37 bc	113.38 a	2.24 b	3
Summer	Floor	86.79 ab	50.35 c	124.15 bc	2.48 c	0
	Organic	84.24 b	47.66 d	114.08 a	2.40 bc	0
	Cage	89.08 a	57.03 a	114.38 a	2.01 a	0
Autumn	Floor	83.81 b	53.05 b	131.92 d	2.49 cd	3
	Organic	84.77 b	52.48 bc	136.77 d	2.61 d	3
	Cage	77.45 c	52.11 bc	119.15 b	2.30 bc	0
Winter	Floor	76.05 cd	50.48 bcd	124.08 bc	2.47 bc	3
	Organic	78.56 c	49.05 cd	124.72 bc	2.59 d	3
	Cage	64.41 e	44.12 e	124.69 bc	2.84 e	0
Spring	Floor	64.23 e	43.36 e	124.74 bc	2.91 e	0
	Organic	72.58 d	46.87 d	128.85 cd	2.85 e	0

a-e: Values within columns with different superscripts are significantly different (P<0.05)

RESULTS

Table 3 shows that the deposition was decreased with hen's age. In the summer and autumn, the maximum deposition was in the cage system (p>0.05). During the winter, there was no difference in the deposition between all three systems (p≥0.05), while in organic system was recorded best results compared with the cage and floor systems in the spring (p>0.05).

Generally speaking, 40 week age hens produced the highest egg mass daily. The reason for this is the high deposition associated with a high average egg weight in this period. During the summer and autumn, the cage layers were produced more egg mass per day compared to organic hens (p>0.05). During the summer and floor layers had a higher value of this parameters compared to organic (p>0.05). There was no difference in this parameter (p≥0.05) between the studied rearing systems in the winter, while in the spring period the organic hens due to the higher deposition produced more egg mass compared to the other two groups (p>0.05).

Floor reared hens had at least the oscillations of the daily feed consumption, and only in the autumn they consumed significantly more feed compared to the other three seasons (p>0.05). Organic layers consumed much more feed in the autumn compared to the summer (p>0.05), but less than in the winter and the spring (p>0.05).

On the other hand, cage hens consumed significantly (p>0.05) less feed in the first (summer, autumn) than in the second half of the production cycle (winter, spring).

As well as feed consumption, the feed conversion into the egg mass was most constant in floor rearing system, and only in the last quarter of production cycle (spring) was recorded significantly lower conversion compared to the previous three (p>0.05). In organic system, this parameter is continuously decreasing with age, while in the cage system the best results recorded in the autumn, then in the summer, while in winter and spring was realized the worst conversion of feed into the egg mass. During the autumn and winter cage hens had better feed conversion compared to organic, while compared to the floor - they were superior only in summer (p>0.05). In the last quarter - spring, there was no difference between the studied rearing systems (p>0.05).

Cage hens had mortality of 3%, while the other two groups had mortality of 6%.

Egg quality parameters are presented in Table 4.

Table 4 shows that the egg weight was significantly influenced by rearing system, age of hens and their interactions. Generally, egg weight was increased with hen's age. Also, the eggs from organic rearing system had significantly lower weight compared to eggs from the other two systems (p>0.05).

Shape index decreased with hen's age, and eggs from 24 week age hens had higher values of the index form of eggs from the 56 and 64 week age hens. Significant difference in the values of this parameter between the floor and the organic production system was recorded only at 40 week age hens (p>0.05), while in all other cases the rearing system did not affect differences in egg shape index (p≥0.05).

The share of egg albumen and yolk was significantly affected by the age and the applied rearing systems, and also their interaction (p>0.05), whereas none of the investigated factors did not significantly effect on the egg shell share (p≥0.05).

Rearing system had not a significant effect on the albumen height (p≥0.05), while the effect of age was significant (p>0.05) and albumen height was decreasing with hen's age.

Haugh unit was decreased throughout the experimental period, due to the decreasing albumen height with hen's age. Generally, organic eggs had more Haugh units compared to the other two groups, which is confirmed in the 56 (compared to cage eggs) and 64 week (compared to the cage and floor eggs) (p>0.05).

Table 4. Effect of the season and rearing systems of laying hens on egg quality.

Season (age of hens)	Rearing system	Egg weight (g)	Egg shape index	Albumen share (%)	Yolk share (%)	Shell share (%)	Albumen height (mm)	Haugh unit	Yolk colour (Roche)
Summer 24 week	Cage	58.75d	79.00a	60.63c	26.47d	12.90	7.35abc	85.33ab	8.93d
	Floor	58.21d	79.07a	62.27b	23.84e	13.90	7.91a	88.87a	7.87e
	Organic	53.61e	78.40a	63.86a	23.03e	13.11	7.74abc	89.47a	11.13b
Autumn 40 week	Cage	63.09bc	76.67ab	59.95cde	27.66bc	12.39	6.79bcde	79.40bcd	10.07c
	Floor	66.37ab	78.53a	61.18bc	26.68cd	12.14	7.80ab	82.13bc	9.33cd
	Organic	61.57cd	75.80b	60.33cd	27.07cd	12.59	7.05bcd	82.47bc	11.87a
Winter 56 week	Cage	68.64a	76.13b	59.06de	28.30b	12.65	5.95ef	71.73 f	11.87a
	Floor	68.89a	76.27b	60.08cde	27.45bcd	12.47	6.15ef	74.87def	11.93a
	Organic	58.77d	75.73b	58.51e	28.42ab	13.07	6.27def	77.60de	9.93c
Spring 64 week	Cage	68.86a	76.27b	57.93e	29.50a	12.57	5.90f	71.20f	11.93a
	Floor	69.43a	76.60b	60.27cd	27.30bcd	12.43	5.93f	70.93f	12.27a
	Organic	63.92b	76.20b	58.86de	27.67bc	13.47	6.65bde	78.60cd	11.67ab
p value									
Season (age of hens)		>0.001	>0.001	>0.001	>0.001	0.077	>0.001	>0.001	>0.001
Rearing system		>0.001	0.057	>0.001	>0.001	0.337	0.116	0,006	>0.001
Season (age of hens) x Rearing system		0.048	0.534	0.020	0.002	0.454	0.796	0.727	>0.001

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

Both studied factors and their interactions had significant effect on the yolk colour. Generally speaking, Roche value increased in floor and cage system with the hen's age. On the other hand, eggs from organic laying hens had palest yolk colour in the winter compared to other three seasons (p>0.05).

DISCUSSION

In the according to the technological normative (Isa Brown - General Managment Guide, 2016), the deposition was decreased with hen's age. The highest deposition in the cage system (p>0.05) in our experiment was expected according to Anderson (2010) and Dvorak *et al*. (2010). Mugnai *et al*. (2009) found a significant effect of season and rearing system on deposition. It is interesting that their results by the seasons were very similar to ours - higher deposition cage hens in the summer and autumn, while in the winter and spring the differences were small and there were none - even though their experiment began in the winter and our in the summer. Higher deposition of organic birds in the spring can be explained by the better environmental conditions, and the use of the outlet, which was contributed to the decreasing in the deposition in this rearing system was smaller compared to the cage and floor.

Also, Mugnai *et al*. (2009) found that the cage layers were produced more egg mass per day compared to organic hens during the summer and autumn.

Organic layers consumed less feed in the summer when the grass cover as a supplement to the diet was of the best quality. Feed consummation dramatically increased during the autumn, when the grass cover was almost completely spent. Such high food consumption also contributed to the low air temperature. If we observe the differences between the rearing systems, it is clearly contemplated that the cage and organic hens consumed significantly less feed compared to the floor hens at the first period. Feed consumption in organic layers was increased dramatically in the autumn, and it is equalized with the floor hens, while the cage hens had lowest feed consumption in this period. Floor hens had spent more energy for the movement of the cage, and Tumova and Ebeid (2003) suggested that the floor hens required 10% more feed than cage for this reason. Reason for less food consumption in organic system during the summer was that the layers have enough grass and various insects, worms etc. available at the outlet, which has settled the part of their nutritional needs (Henry (2002) avoided that this percentage can be high as 20%). It is interesting that there was no significant difference between any of three rearing systems in the second half of the production cycle, which is in accordance with results published by Rizzi *et al*. (2007) and Mugnai *et al*. (2009).

According to our results, also Mugnai *et al*. (2009) did not establish a difference in the feed conversion in the spring period between cage and organic plus layers, while in the other three season cage hens were superior compared to organic plus hens. Better feed conversion in the cage system compared to the alternative rearing systems reported in their researches and Senčić and Butko (2006) and Lolli *et al*. (2013).

The higher mortality in the systems with outlet compared to the cage system except us determined and Senčić and Butko (2006) and Anderson (2010), while Gerzilov *et al*. (2012) found higher mortality at the floor system compared to cage system.

As we expected, egg weight was increased with age of hens (Curtis *et al*., 2005; Rizzi and Cassandro, 2009; Zita *et al*., 2009). Also, the eggs from organic rearing system had significantly lower weight compared to eggs from the other two systems. The explanation for this can be found in the results published by Koreleski and Świątkiewicz (2009) - organic hens were increased average eggs weight with the addition of synthetic methionine in feed. This confirms the results of our research - that limited level of methionine in feed of organic laying hens may, inter alia, resulted in a decrease of the average eggs weight. Eggs from organic rearing system achieved especially low egg weight in the autumn (40 weeks of age), probably due to lack of food at the outlet, and they were not able to compensate one third lower level of methionine and cystine in organic feed (0.48%) compared to conventional feed (0.68%). Also, Elwinger *et al*. (2008) state that meets the needs of methionine in the diet of organic birds is the biggest challenge in this production. And Zemkova *et al*. (2007) found a significant interaction rearing system x genotype on egg weight. It is interesting that in studies of these authors individual factors are not significantly affected by the egg weight.

In accordance with our results, Škrbić *et al*. (2011) also found that with age, the egg shape index value decreased (r = - 0.15), and similar results were published by Zita *et al*. (2009). Significant difference in egg shape index between the floor and the organic rearing system in our experiment was recorded only at 40 week age hens, while in all other cases the rearing system did not influence differences in egg shape index, which is in agreement with the findings by Lewko and Gornowicz (2011) and Ahammed *et al*. (2014).

The general conclusion about the share of egg albumen and yolk was that the proportion of yolk tended to be greater and the proportion of albumen smaller in smaller eggs than in larger eggs (Curtis *et al*., 2005). The same authors, in accordance with our results, did not confirm the significant effect of age of hens on a shell share.

In accordance with our results, a significant effect of the season and the hen's age on albumen height determined and Ojedapo (2013).

Haugh unit was decreased throughout the experimental period, due to the decreasing albumen height with hen's age. These results are consistent with the findings by Rizzi and Chiericato (2005) and Škrbić *et al*. (2011), who found that Haugh unit decreases with hen's age. Results that the organic eggs had more Haugh units compared to the other two groups are consistent with the findings of several authors who point out that access to the outlet increases the Haugh units in eggs (Minelli *et al*., 2007; Mugnai *et al*., 2009; Djukic-Stojčić *et al*., 2009).

Both studied factors and their interactions had a significant effect on the yolk colour.

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). For this reason, during the winter their yolk was palest, while in other seasons their yolk colour intensity was proportional to the input grass with outlet. Intensive yolk colour in hens reared at the outlet in the season when he is well covered with grass is in accordance with the results Mugnai *et al*. (2009) and Kralik *et al*. (2013), while the decreasing Roche value in the organic eggs in winter due to less input of carotenoids from the grass was expected according to results Minelli *et al*. (2007) and Kucukyilmaz *et al*. (2012).

Conclusion: Based on the results of these investigations it can be concluded that hen's age and season, as well as the rearing system have a significant effect on the production results and egg quality of laying hens. Generally, in summer and autumn, the most of production performances were the best in cage rearing system, while organic system was superior in spring. Egg weight and yolks share were increased, while egg shape index, albumen share, albumen height and Haugh unit were decreased with hen's age. Generally, eggs from cages and the floor had a greater weight compared to organic. Organic eggs had higher albumen height and Haugh unit score in the spring compared to the cage and floor 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.

Acknowledgement: This study was financed from funds of the Ministry of Education, Science and Technological Development of the Republic of Serbia, project No. TR-31033.

REFERENCES

Ahammed, M., B.J.Chae, J. Lohakare, B. Keohavong, M.H. Lee, S.J. Lee, D.M. Kim, J.Y. Lee and S.J. Ohh (2014). Comparison of Aviary, Barn and Conventional Cage Raising of Chickens on Laying Performance and Egg Quality. Asian-Australas J. Anim. Sci. 27 (8): *1196-1203.*

Anderson, K.A. (2010). Range egg production, is it better than in cages? MPF Convention, March 16-18, 2010.

Committee for the Common Organisation of the Agricultural Markets (2016). EU Market Situation for Eggs.

Chung, S.H. and K.V. Lee (2014). Effect of Hen Age, Storage Duration and Temperature on Egg Quality in Laying Hens. Int. J. Poult. Sci. 13 (11): 634-636.

Curtis, P.A., L.K. Kerth and K.E. Anderson (2005). Quality and compositional characteristics of layer hens as affected by bird age. XIth European Symposium on the Quality of Eggs and Egg Products Doorwerth, The Netherlands, 23-26 May 2005: 214-219.

Dvorak, P., P. Suchy, E. Starkova and A. Dolezalova (2010). Variation in egg yolk colour in different systems of rearing laying hens. Acta Vet. Brno 79: 13-19.

Đukić-Stojčić, M., L. Perić, S. Bjedov and N. Milošević (2009). The quality of table eggs produced in different housing system. Biotech. Anim. Husbandry 25 (5-6): 1103-1108.

Gerzilov, V., V. Datkova, S. Mihaylova and N. Bozakova (2012). Effect of poultry housing system on egg production. Bulg. J. of Agric. Sci. 18 (6): 953-957.

Elwinger, K., M. Tufvesson, G. Lagerkvist and R. Tauson (2008). Feeding layers of different genotypes in organic feed environments. Br. Poult. Sci. 49: 654- 665.

Henry, R. (2002). Organic Poultry – Eggs. Maritime Certified Organic Growers - Organic Profiles, March 2002.

Isa Brown – General Menagment Guide (2016).

Korelenski, J. and S. Światkiewicz (2009). Laying performance and nitrogen balance in hens fed organic diets with different energy and methionine levels. J. Anim. Feed Sci. 18: 305–312.

Kralik, Z., Ž. Radišić, M. Grčević and G. Kralik (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.

Kucukyilmaz, K., M. Bozkurt, E.N. Herken, M. Cinar, A.U. Cath, E. Bintas and F. Coven (2012). Effects of rearing systems on performance, egg characteristics and immune response in two layer hen genotype. Asian-Australas J Anim Sci. 25 (4). 559-568.

Lewko, L. and E. Gornowicz (2011). Effect of housing system on egg quality in laying hens. Ann. Anim. Sci. 11 (4): 607-616.

Lolli, A., C.Hidalgo, C.Alampresse, V. Ferrante and M. Rossi (2013). Layer performances, eggshell characteristics and bone strength in three different housing systems. Biotech. Anim. Husbandry 29 (4): 591-606.

Minelli, G., E.Sirri, A. Folegatti, A. Melluzzi and A. Franchini (2007). Egg quality traits of laying hens reared in organic and conventional systems. Ital. J. of Anim. Sci. 6 (SUPPL. 1): 728-730.

Mugnai, C., A. Dal Bosco and C. Castellini (2009). Effect of rearing system and season on the performance and egg characteristics of Ancona laying hens. Ital. J. of Anim. Sci 88: 175-188.

Ojedapo, L.O. (2013). Effect of Age and Season on Egg Quality Traits of Isa Brown Layer Strain Reared in Derived Savanna Zone of Nigeria. T.J.S.T. 3 (7): 48-60.

Pavlovski, Z., Z. Škrbić and M. Lukić (2011). Free systems of rearing of chickens and layer hens: quality of meat and eggs. International 56th Meat Industry Conference, Tara, June 12-15th, 2011: 160-166.

Rakonjac, S., S.Bogosavljević-Bošković, V. Dosković and M.D. Petrović (2013). Mortality of laying hens and broilers under different rearing systems. 23rd International symposium „New Technologies in Contemporary Animal Production“, 19-21 June 2013, Novi Sad (Serbia) – Proceeding: 195-197.

Rakonjac, S., S. Bogosavljević-Bošković, Z. Pavlovski, Z. Škrbić, V. Dosković, M.D. Petrović and V. Petričević (2014). Laying hen rearing systems: a review of major production results and egg quality traits. Worlds. Poult. Sci. J. 70 (1): 93-104.

Rizzi, C. and G.M. Chiericato (2005). Organic farming production. Effect of age on the productive yield and egg quality of hens of two commercial hybrid lines and two local breeds. Ital. J. of Anim. Sci. 4 (SUPPL. 3): 160-162.

Rizzi, C., A.Marangon and G.M. Chiericato (2007). Effect of Genotype on Slaughtering Performance and Meat Physical and Sensory Characteristics of Organic Laying Hens. Poult Sci. 86: 128–135.

Rizzi, C. and M. Cassandro (2009). Quality of eggs of hybrid and Italian hens reared under organic production system. Proceedings of the 19th (XIX) European Poultry Symposium on Quality of Poultry Meat, XIII European Symposium on the Quality of Eggs and Egg Products. 21-25 June 2009, Turku, Finland: unpaginated.

Senčić, Đ. and D. Butko (2006). Proizvodnja nesilica i kvaliteta kokošijih jaja iz slobodnog i kaveznog sustava držanja. Poljoprivreda, 12 (2): 1-5.

Silversides, F.G. and T.A. Scott (2001). Effect of storage and layer age on quality of eggs from two lines of hens. Poult Sci. 80: 1240–1245.

Stat Soft Inc Statistica For Windows, Version 7.0. (2006). Computer program manual Tulsa.

Tumova, E. and T. Ebeid (2003). Effect of housing system on performance and egg quality characteristics in laying hens. SAB 34 (2): 73-80.

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

United Kingdom Egg Statistics (2016). A National Statistics Publication.

Windhorst, H.V. (2015). Housing Systems in Laying Hen Husbandry. IEC 2015 Business Conference, Lisbon, April 12 -14, 2015: Presentation.

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

Zita, L., E.Tumova and L. Štolc (2009). Effects of Genotype, Age and Their Interaction on Egg Quality in Brown-Egg Laying Hens. Acta Vet. Brno 78: 85–91.