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THE EFFECT OF THE TYPE OF ALTERNATIVE HOUSING SYSTEM, GENOTYPE AND AGE OF LAYING HENS ON EGG QUALITY

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Abstract

The present study investigated the effect of the type of alternative housing system, and genotype and age of laying hens on physical traits of egg shell and contents. It was demonstrated that alternative housing system type influenced egg weight and shape, and eggshell color and yolk color intensity. Eggs from free-range system were heavier and were characterized by more intense yolk color. No effect of alternative housing system type on albumen height, value of Haugh units (HU value) and presence of meat and blood spots was noted. Hen genotype had a significant effect on egg weight and eggshell color intensity in each of the alternative housing systems tested in this study. Hy-line Brown hens laid heavier eggs than hens of native breeds. Genotype was also observed to affect egg content traits (albumen height, HU values and presence of meat and blood spots). Independently of the type of alternative housing-system, most blood and meat spots were noted in eggs of hens laying brown-shelled eggs, i.e. R-11 and Hy-line Brown layers. Laying hen age significantly impacted on egg weight, yolk percentage, eggshell traits (color intensity, weight, thickness and strength) and egg content traits (HU value, yolk weight and color intensity, presence of meat and blood spots). Older hens laid heavier eggs with a greater yolk percentage but with thinner eggshell.

Key words: alternative housing systems, egg quality, hen genotype

According to EC Directive 1999/74/EE, in all European countries consumption eggs can be produced in cage, litter, free-range and organic housing systems. Like in many European countries, a majority of eggs marketed in Poland are produced in cage system, however, an interest in eggs from alternative non-cage housing systems (litter, free-range and organic) has been on the rise in recent years. Many studies evidenced that housing system could significantly influence egg quality traits, including egg weight and shape, eggshell color, weight, thickness, density and strength, and albumen and yolk traits (Küçükylmaz et al., 2012; Dalle Zotte et al., 2013; Rizzi et al., 2015; Batkowska and Brodacki, 2017).

In studies by Samiullah et al. (2016), heavier eggs were obtained from hens housed in cage system than in litter system while Küçükylmaz et al. (2012) and Dalle Zotte et al. (2013) showed production of heavier eggs by hens reared in free-range and litter systems. The effect of housing system on egg shape index was evidenced by Englmaierová et al. (2014) but studies of Clerici et al. (2006) and Batkowska and Brodacki (2017) did not confirm the effect of housing system on egg shape index. There is no relation between eggshell color and egg quality but consumers in different parts of the world show preferences for certain colors. According to Nedup and Phurba (2014) and Samiullah et al. (2015), the amount of pigment accumulated in the shell surface depends on housing system. Studies of Van den Brand et al. (2004), Ferrante et al. (2009), Samiullah and Chousalkar (2014), Englmaierová et al. (2014) and Batkowska and Brodacki (2017) evidenced the effect of housing system on eggshell quality traits. Results of other authors did not confirm the influence of housing system on eggshell traits (Küçükylmaz et al., 2012; Kühn et al., 2014).

Egg content quality traits are estimated on the basis of albumen traits (height and HU value) and yolk color. Kimunda et al. (2001) found that housing conditions were decisive for albumen quality. The impact of housing system on albumen quality estimated by HU value was reported by Rizzi et al. (2015). In the opinion of consumers, yolk color intensity is an important indicator of egg quality. The effect of housing system on yolk color was confirmed in many studies. More intense yolk color in eggs from free-range system than from cage system was reported by Karadas et al. (2005).

Consumers believe that the presence of meat and blood spots in egg content is a disadvantageous feature.

It has also been indicated that laying hen genotype (breed) and age have a significant impact on egg quality traits. It was demonstrated that egg weight depended on laying hen genetic traits (Holt et al., 2011; Küçükylmaz et al., 2012; Rizzi and Marangon, 2012; Hammershøj and Steenfeldt, 2015; Hanusová et al., 2015; Steenfeldt and Hammershøj, 2015) and age (Ferrante et al., 2009; Simčič et al., 2009; Haunshi et al., 2010; Samiullah et al., 2016). Egg shape was documented to depend on laying hen genotype (Hanusová et al., 2015; Ajmal et al., 2016) and age (Calik, 2011; Krawczyk, 2016). According to Nedup and Phurba (2014) and Samiullah et al. (2015), the amount of pigment accumulated in the shell surface depends on breed and age of hens. Clerici et al. (2006), Zita et al. (2009) and Hanusová et al. (2015) revealed that eggshell quality was dependent mostly on genetic traits while Świątkiewicz and Koreleski (2008), Hincke (2012) and Küçükylmaz et al. (2012) reported the influence of laying hen age on eggshell strength, thickness and density. The impact of hen breed and age on albumen height and HU value was reported by Küçükylmaz et al. (2012), Hammershøj and Steefedt (2015), and Dudek and Rabsztyn (2011), respectively. Incidence of meat and blood spots is dependent on genetic traits and age of laying hens (Smith and Musgrove, 2008).

The results presented in world literature regarding the impact of housing system on egg quality usually focused on assessing the quality of eggs from different types of cages and comparing eggs from cage and free-range systems, however, there are only scant studies aimed to evaluate whether eggs from different types of alternative systems (litter, free-range and organic) differ in commercially important eggshell traits and egg content traits important for customers and processing industry. Since both commercial hybrids and native breeds are used for egg production in alternative housing systems it is justified also to establish the effect of genotype and age of hens on egg quality.

The aim of our studies was to evaluate the effect of the type of alternative housing system, and genotype and age of laying hens on physical traits of shell and content of consumption eggs.

Material and methods

The experiment conducted to achieve the aim of this study involved in total 270 hens, including 90 hens of the native breed Greenleg Partridge (Z-11), 90 Rhode Island Red (R-11) hens, included in a conservation program in Poland and 90 commercial hybrids Hy-line Brown.

At 16 weeks of age, 30 hens of each breed and 30 commercial hybrids were assigned to the following housing systems: litter (group L), free-range (group FR) and organic (group O).

The birds of group L were housed in a poultry house with windows (window area-to-floor area ratio was 1:15) in deep litter without access to a run (paddock). Indoor stocking density was 6 hens/m^2. Hens from group FR were housed in a poultry house with windows (window area-to-floor area ratio was 1:15) in deep litter with free access to grass-covered open-air run. Indoor stocking density was 6 hens/m^2, while outdoor stocking density was one laying hen per 4 m^2. Group O hens were housed according to regulations pertinent to organic rearing, i.e. EC Directive 1804/1999 and Regulation of European Economic Community (EEC) Council 2092/91. Hens of this group were housed in a poultry house with windows (window area-to-floor area ratio was 1:15) in deep litter (6 hens/m^2) with free access to grass-covered open-air run with growing trees (5 m^2/hen). The light schedule in the house was the same for all groups and comprised 16 h light and 8 h dark (16L : 8D). In autumn and winter when natural day was shorter than 16 h daylight was complemented with artificial light. In each tested housing system, bars were equipped with round feeders, drinkers and nests. In groups FR and O feeders and drinkers were available also in the run.

Birds of group L and FR were fed *ad libitum* with a concentrate layer feed (16.08% protein, 11 MJ), and group O hens (*ad libitum*) were given organic poultry feed (16.0% protein, 11 MJ). Layer feeds used in all groups did not contain color feed additives.

To evaluate quality of eggs from various housing systems, 30 eggs were randomly sampled from hens of every breed/line and commercial hybrids housed in each system. Eggs were sampled three times, i.e. at 26, 42 and 56 weeks of hen age. Immediately after collection eggs were transported to the laboratory in a portable refrigerator and stored for 1 h at a temperature of +8°C until analysis. Egg quality assessment was based on the following egg traits: weight (g), shape index (%), yolk, albumen, and shell percentage in the whole egg; eggshell traits: color intensity (%), weight (g), thickness (μm), density (mg/cm^2), breaking strength (N), physical features of egg content: albumen height (mm), value of Haugh units (HU), yolk color (scores according to a 15-point DSM scale) and presence of meat and blood spots. Egg weight was determined by weighing individually with a digital laboratory balance exact to 0.1 g. Shape index of eggs was determined as a ratio of short-to-long axis which were measured using an electronic caliper MITUTOYO Absolute Digmatic Caliper model CD-15DCX (Japan) exact to 0.01 mm. Percentage contents of egg morphological components (albumen, yolk and shell) were calculated based on their weights measured individually for each egg. Eggshell color, weight, density and thickness, HU value, yolk color according to DSM scale were measured using electronic equipment for egg quality measurements (EQM – Egg Quality Measurements, Technical Services and Supplies, UK). Eggshell strength (N) was measured using a multipurpose testing system, model BT1-FR1.OTH.D14 with measuring head 100N and software testXpert (Zwick/Roell GmbH&Co.KG, Germany).

Statistical analysis of the obtained results was performed using Statistica 12 PL software package. The effect of housing system, breed and age of layers on the number of eggs with meat and blood spots in egg content was verified with Kruskal-Wallis non-parametric test, and the frequency of meat and blood spots was expressed as percent. The results for the effect of housing system, breed and age of layers on the other egg quality traits were subjected to multifactorial analysis of variance and determinations were made of the major effects (S – effect of housing system, B – effect of breed, A – effect of age) and of the effect of the interaction of treatments (S×B; S×A, B×A and S×B×A). Significant differences between means in the groups were estimated with Duncan's multiple range test. Differences were considered to be significant when $P<0.05$.

Results

The present studies demonstrated the effect of housing system on egg weight (Tables 1 and 4). Eggs from layers housed in organic system were characterized by a greater weight compared with eggs from litter system. The impact of the type of housing system on egg weight was particularly conspicuous in autumn and spring-summer, when hens of the studied breeds housed in free-range and organic system laid heavier eggs than layers reared in litter system. In each alternative housing system, commercial hybrid hens (Hy-line Brown) laid heavier eggs than hens of the remaining breeds. In all the systems, R11 hens laid heavier eggs than Z11 hens. It was found that egg weight increased with layer hen age ($P<0.05$).

Table 1. The effect of alternative housing system type, and hen genotype and age on egg weight, shape and percentage content of morphological egg components

Trait	Laying hen age (weeks)	Housing system											
		Litter (L)				Free-range (FR)				Organic (O)			
		Z-11	R-11	Hy-line Brown	SEM	Z-11	R-11	Hy-line Brown	SEM	Z-11	R-11	Hy-line Brown	SEM
Egg weight (g)	26	x50.68 a	x54.83 b	x55.68 b	0.45	x51.03 a	x55.01 b	x54.36 b	0.53	52.94 a	x56.22 b	59.45 c	0.67
	42	x52.61 a	y57.26 b	y57.77 b	0.46	y53.14 a	y57.97 b	y58.89 b	0.61	55.98 a	57.88	61.37 b	0.82
	56	y56.58 a	z60.38 b	z62.17 b	0.47	z56.61 a	y59.67 b	y60.07 b	0.59	57.42 a	y60.98	62.93 b	0.77
Shape index (%)	26	74.44	75.56	75.61	0.34	74.13 a	75.24	76.44 b	0.32	74.45	72.91 a	76.33 b	5.52
	42	74.97	75.65	75.92	0.36	74.02 a	75.06	76.30 b	0.32	74.37	75.31	75.01	0.42
	56	75.24	76.86	76.90	0.32	73.13 a	74.73	76.09 b	0.35	73.15	75.52	74.97	0.67
Proportions of egg elements:													
shell (%)	26	11.13 a	10.82 a	12.71 b	0.20	11.19 a	12.36 b	11.99	0.18	11.49 a	12.77 b	12.32 b	0.22
	42	10.81 a	10.53 a	12.70 b	0.18	10.97 a	12.24 b	11.71 b	0.14	10.89 a	12.76 b	12.26 b	0.28
	56	10.79 a	10.25 a	12.42 b	0.18	10.89 a	12.19 b	11.66 b	0.16	10.69 a	12.71 b	12.03 b	0.25
albumen (%)	26	59.96	x61.37 a	58.45 b	0.43	59.57	58.45	58.95	0.47	58.57	57.32 a	60.62 b	0.57
	42	58.70	y58.89	57.14	0.43	58.97	57.75	58.78	0.49	57.95	57.04	60.14	0.59
	56	57.81	y58.79	57.10	0.38	58.91	57.64	58.71	0.45	57.84	56.88	59.94	0.55
yolk (%)	26	x28.91	x27.81	x28.84	0.31	29.24	29.19	29.06	0.40	30.59 a	30.16 a	27.06 b	0.49
	42	y30.49	y30.43	30.15	0.36	30.06	30.01	29.51	0.45	31.27 a	30.19	27.80 b	0.51
	56	y31.40	y30.51	y30.48	0.29	30.20	30.16	29.63	0.36	31.35 a	30.37 a	27.83 b	0.50

Explanations: within a given rearing system: a, b – values in rows with different letters differ significantly at P<0.05; within the same trait: x, y – values in columns with different letters differ significantly at P<0.05.

Table 2. The effect of alternative housing system type, and hen genotype and age on eggshell traits

Trait	Laying hen age (weeks)	Housing system											
		Litter (L)				Free-range (FR)				Organic (O)			
		Z-11	R-11	Hy-line Brown	SEM	Z-11	R-11	Hy-line Brown	SEM	Z-11	R-11	Hy-line Brown	SEM
Shell color (%)	26	x63.25 a	44.08 b	32.37 c	1.60	64.25a	43.27 b	x30.20 c	1.67	67.47 a	x45.33 b	32.10 c	2.18
	42	x67.84 a	44.92 b	32.67 c	1.86	67.90 a	44.20 b	x31.06 c	1.87	68.63 a	46.20 b	32.60 c	2.32
	56	y68.60 a	45.15 b	32.95 c	1.83	68.90 a	46.07 b	y34.79 c	1.61	68.90 a	y47.80 b	32.73 c	2.32
Shell weight (g)	26	x5.61 a	x5.91 a	x7.07 b	0.11	x5.70 a	6.77 b	x6.51 b	0.10	6.04 a	x7.06 b	7.33 b	0.15
	42	x5.68 a	6.02 a	y7.33 b	0.11	5.83 a	7.10 b	6.89 b	0.12	6.07 a	7.35 b	7.47 b	0.16
	56	y6.06 a	y6.45 a	z7.72 c	0.12	y6.14 a	7.24 b	y7.07 b	0.09	6.11 a	y7.79 b	7.54 b	0.16
Shell thickness (µm)	26	349.92 a	329.52 b	295.00 b	3.87	x311.9	307.33	322.35	3.47	323.20	x298.51	x326.10	5.37
	42	348.88	342.92	297.90	4.67	y348.6 a	320.33 b	348.33 b	5.58	313.95 a	y312.7 a	y348.1 b	5.67
	56	351.60	339.30	303.43	4.44	y350.7 a	333.0 b	351.93 b	4.02	325.60	y320.80	x318.00	4.45
Shell density (mg/cm²)	26	x74.82 a	x85.8 b	98.31 c	1.72	73.11 a	x90.6 b	x88.50 b	1.65	85.31 a	96.36 b	94.68 b	1.82
	42	y90.86 a	y76.60 b	94.48 a	1.49	77.67a	y98.01 b	y92.34 b	1.64	81.71 a	99.23 b	91.46 c	1.97
	56	z80.38 a	y73.17 b	100.14 c	1.79	76.59 a	y100.3 b	y102.7 b	1.63	81.64 a	101.67 b	90.49 c	1.82
Shell strength (N)	26	33.97	36.86	37.06	0.79	35.03	32.28	33.27	0.77	33.00	35.00	32.60	0.82
	42	32.20	36.67	36.92	0.90	34.94	31.96	32.13	0.76	30.59	31.62	32.23	0.92
	56	31.85 a	32.67	35.90 b	0.82	31.75	31.54	31.37	0.63	29.32	31.13	30.73	0.95

For explanations: see Table 1.

Table 3. The effect of alternative housing system type and hen genotype and age on egg content traits

Trait	Laying hen age (weeks)	Housing system											
		Litter (L)				Free-range (FR)				Organic (O)			
		Z-11	R-11	Hy-line Brown	SEM	Z-11	R-11	Hy-line Brown	SEM	Z-11	R-11	Hy-line Brown	SEM
Albumen height (mm)	26	7.33 a	7.66	8.19 b	0.14	7.21 a	7.32 a	8.21 b	0.15	7.91 a	7.23 a	8.18 b	0.18
	42	7.31 a	7.60	8.14 b	0.13	7.12 a	7.23 a	8.16 b	0.12	7.87 a	7.21 a	8.11 b	0.17
	56	7.27 a	7.49	8.04 b	0.14	6.97 a	7.11 a	8.07 b	0.15	7.74	7.08	7.99	0.22
Haugh units (HU)	26	x88.27 a	x91.97 b	x98.34 c	0.90	x86.73 a	x83.66 a	x98.95 b	1.09	88.43 a	76.63 b	89.09 a	1.28
	42	y81.17 a	y79.60 b	y86.60 a	1.27	y76.42 a	y77.43 a	x96.10 b	1.27	89.25 a	76.94 b	88.50 a	1.50
	56	y79.43	y76.69 a	y84.76 b	1.10	y75.34 a	y75.19 a	y90.6 b	1.15	88.87 a	77.29 b	88.92 a	1.54
Yolk weight (g)	26	x14.59 a	x15.21 a	x16.03 b	0.15	x14.84 a	x15.98 b	x15.77	0.21	16.95	16.94	x16.05	0.20
	42	y16.00 a	y17.35 b	y17.40 b	0.18	y15.91 a	y17.25 b	y17.31 b	0.21	17.47	17.38	16.94	0.26
	56	z17.66 a	z18.38 b	z18.93 b	0.14	z17.06 a	y17.80 b	y18.00 b	0.15	17.91	17.63	y17.41	0.22
Blood spots (%)	26	4.00	12.00	5.00	3.10	0.00	3.33	15.00	2.79	0.00	6.67	10.00	3.39
	42	0.00	12.00	8.33	3.14	0.00	23.33	31.25 b	4.78	5.26	6.67	10.00	3.84
	56	5.00	25.00	36.7	5.16	0.00	23.00	33.33 b	4.60	40.00	13.33	26.67	7.80
Meat spots (%)	26	0.00	8.00	10.00	2.79	0.00	3.33	20.00	3.10	0.00	13.33	10.00	4.28
	42	0.00	8.00	16.67	3.14	0.00	20.00	25.00	4.44	0.00	13.33	30.00	4.84
	56	0.00	10.00	30.00	4.38	0.00	33.3	20.00	4.50	10.53	20.00	46.67	7.15
Yolk color (DSM)	26	6.80	7.24	7.20	0.13	x8.45	x7.97	7.95	0.12	x10.58 a	x9.33 b	x8.40 b	0.22
	42	6.96	7.60	7.58	0.14	x8.35	x7.77	x7.69	0.13	y9.40 a	y8.13 b	y7.71 c	0.21
	56	6.55 a	7.15 b	7.67 b	0.13	y9.15 a	y9.10 a	y8.43 b	0.09	x10.80	z10.27	z10.30	0.12

For explanations: see Table 1.

The type of alternative housing system and hen breed were shown to affect shape index; statistical analysis did not confirm the effect of hen age on this quality trait (Tables 1 and 4).

Alternative system type and hen breed influenced shell percentage in the whole egg ($P<0.05$). In eggs of R-11 hens from organic and free-range system, shell percentage was higher than in eggs from litter system ($P<0.05$). The impact of layer age on shell percentage in egg was not confirmed by statistical analysis (Tables 1 and 4).

The present studies indicated that the type of alternative housing system had no effect on albumen or yolk percentage in the egg. The effect of breed on yolk percentage was confirmed by statistical analysis ($P<0.05$). In eggs from Z-11 hens housed in organic system, yolk percentage was higher than from Hy-line Brown hens. Yolk percentage increased with layer age (Table 4).

Table 4. The effect of alternative housing system type, breed and hen age on egg quality

Trait	Effect							SEM
	S	B	A	S×B	S×A	B×A	S×B×A	
Egg weight (g)	*	*	*	NS	NS	NS	NS	0.22
Shape index (%)	*	*	NS	NS	NS	NS	NS	0.13
Percentage in egg:								
shell (%)	*	*	NS	*	NS	NS	NS	0.06
albumen (%)	NS	NS	NS	*	NS	NS	NS	0.16
yolk (%)	NS	*	*	*	*	NS	NS	0.14
Eggshell traits								
shell color (%)	*	*	*	NS	NS	NS	NS	0.63
shell weight (g)	*	*	*	*	NS	NS	NS	0.04
shell thickness (µm)	*	*	*	*	NS	NS	*	1.65
shell density (mg/cm^2)	*	*	NS	*	*	*	*	0.59
shell strength (N)	*	NS	*	*	NS	NS	NS	0.28
Egg content traits								
albumen height (mm)	NS	*	NS	*	NS	NS	NS	0.05
Haugh units (HU)	NS	*	*	*	*	NS	NS	0.44
yolk weight (g)	*	*	*	*	*	NS	NS	0.07
blood spots (%)	NS	*	*	*	NS	NS	NS	1.48
meat spots (%)	NS	*	NS	NS	NS	NS	NS	1.43
yolk color (DSM)	*	*	*	*	*	*	NS	0.06

Explanations: B – breed, A – hen age, S – rearing system, * statistically significant effect ($P<0.05$); NS – no statistically significant effect ($P>0.05$).

The results of our studies regarding the impact of housing system type on eggshell quality were diversified. The type of alternative housing system, genotype and hen age were shown to influence eggshell color, weight and thickness but hen age had no impact on eggshell density while hen breed had no effect on eggshell strength (Tables 2 and 4).

The present studies evidenced that the type of alternative housing system did not have any effect on HU value or albumen height ($P>0.05$) (Table 4). However, HU value and albumen height did depend on hen breed (P<0.05). Also the effect of layer age on HU value was confirmed (Table 3).

Our studies proved the influence of the type of alternative housing system, breed and hen age on yolk weight (P<0.05) (Table 4). Hy-line Brown hens laid eggs with the heaviest yolk when reared in litter system (Tables 3 and 4).

No effect of the alternative system type on percentage content of meat and blood spots was seen. These traits were determined by layer breed. The present studies demonstrated that yolk color from hens of the studied breeds housed in organic and free-range systems was more intense than from litter system. Also layer hen breed and age significantly influenced yolk color intensity (Tables 3 and 4).

Discussion

A greater weight of eggs from free-range and organic systems can be associated with access to open-air run, where hens could supplement their diet. According to Borowiec et al. (2001) green runs inhabited by soil invertebrates, including earthworms are rich in nutrients and can be an additional source of protein for hens. Also roughage, including green forage consumed in the run can supply additional nutrients to hens (Hammershøj and Steenfeldt, 2005; Steenfeldt et al., 2007; Steenfeldt and Hammershøj, 2009). Scientific reports on the analysis of the effect of housing system on egg weight yielded diverse results. Studies of Stanley et al. (2013), Kühn et al. (2014) and Onbasilar et al. (2015) did not show any effect of rearing system on egg weight, while Küçükylmaz et al. (2012) did evidence that weight of eggs from hens of brown breeds reared in organic system was higher than from conventional cage system while eggs from hens of white breeds housed in organic and conventional systems had similar weight. Also studies of Dalle Zotte et al. (2013) documented that eggs from organic system were characterized by higher weight than from litter system.

The fact that hens of commercial breed lay heavier eggs is the result of selection in breeding flocks of laying hen while hens of native breeds, in conformity with the genetic resources conservation program, are reared in small populations in which selection for greater egg weight is not performed. The effect of breed on egg weight was shown also by other authors. Hammershøj and Steenfeldt (2015) and Steenfeldt and Hammershøj (2015) investigated quality of eggs from Lohmann Silver and New Hampshire hens reared in organic system and revealed that hen genotype had a significant effect on all egg traits and supplementation of bird diet with roughage significantly influenced weight and size of laid eggs. Hanusová et al. (2015) investigated quality of eggs from Orávka and Rhode Island Red hens and indicated that egg weight depended on hen breed. Orávka hens laid heavier eggs (60.96±0.56 g) than Rhode Island Red hens (57.60 ± 0.76 g). Rizzi and Marangon (2012) examined eggs from two commercial hybrids Hy-line Brown and Hy-line White and two local breeds, i.e. Ermellinata di Rovigo and Robusta maculata and found that eggs from Hy-line Brown were larger than from Hy-line White (62.9 and 60.4 g, respectively).

There were also differences between Italian native breeds (56.5 and 54.4 g). Smaller egg weight and greater yolk percentage in eggs from native hens (Robusta maculata and Ermellinata of Rovigo) compared with commercial breeds was also reported by Simčič et al. (2009) in Styrian hens. The effect of layer hen genotype and age on egg weight was also observed by Holt et al. (2011) and Tůmová et al. (2017).

In the present studies, eggs from litter system were characterized by a higher shape index than eggs from free-range and organic systems. Also Dalle Zotte et al. (2013) demonstrated the effect of rearing system on egg shape index but, like in our studies, they did not note any differences in shape index between eggs from free-range system and organic system. In our studies, shape index of eggs from Hy-line Brown hens was the highest while the lowest from Z-11 hens. Küçükylmaz et al. (2012) indicated that eggs from hens with white plumage housed in organic system were characterized by a higher shape index than the eggs from conventional system whereas eggs from hens of brown breeds from organic and conventional system had similar shape index. The effect of breed on egg shape index was also reported by Shaker et al. (2016). Sarica and Erensayin (2009) proposed classification which assumed that eggs with normal elliptic shape possessed shape index at the level 72–76%, eggs with a lower value of shape index than 72% were characterized as sharp in shape and those with shape index greater that 76% as round. Taking classification of eggs as suggested by those authors, eggs from all rearing systems and all hen breeds examined in the present studies can be classified as having normal (standard) shape. Typical elliptic egg shape can be considered as a beneficial trait since it reduces breaking losses during transport, because, as suggested by Nedomová et al. (2009) shape index influences eggshell strength.

In the present studies, there was a tendency towards laying eggs with less intense shell color in free-range and organic systems than in litter system which corresponds with the opinion of Samiullah et al. (2015) who reported that pigment accumulation depended on the rearing system, among other things. High variability and progressive reduction of shell color intensity are common problems with marketing eggs from free-range system. Roberts and Chousalkar (2013) observed reduction of shell color intensity in eggs from hens reared in free-range system which was improved after transferring hens to cages. In our studies, in every rearing system, shell color depended on hen breed and age. Also studies of Nedup and Phurba (2014) demonstrated dependence of eggshell color on breed and its intensity on hen age. Results of assessment of the impact of rearing system on eggshell traits are inconsistent. Like in the present studies, Pavlovski et al. (2001) showed that eggs from litter system had a thicker shell while the shell in eggs from free-range system was thinner. Also studies of Ferrante et al. (2009) and Dalle Zotte et al. (2013) on quality of eggs from organic, litter and cage systems evidenced the impact of rearing system on eggshell thickness. On the other hand, Kühn et al. (2014) while investigating quality of eggs from litter and free-range system observed no effect of rearing system on eggshell weight or thickness. Küçükylmaz et al. (2012) also did not observe an impact of housing system on eggshell thickness. Mertens et al. (2006) investigated how rearing system (cage, aviary, free-range) influenced egg quality and found the highest eggshell strength in the case of aviary rearing and the lowest in free-range system however, studies of Hidalgo et al. (2008) did not show differences in shell strength between eggs from different rearing systems. Samiullah et al. (2014) comparing eggs from cage and free-range system observed more shell defects and worse shell strength in eggs from free-range system.

The present studies documented the impact of the type of alternative rearing system and layer hen breed and age on yolk percentage in the egg. Likewise, Küçükylmaz et al. (2012) and Rizzi et al. (2006) noted that yolk percentage in eggs from organic system was higher than from cage system. A greater yolk percentage in eggs from organic system can be connected with supplementation of laying hen diet on the run where they could additionally consume green forage and invertebrates (Rizzi et al., 2006).

Albumen quality measured by HU value for fresh eggs should reach higher values than 60 HU. In our studies, HU value remained at the level exceeding 74 HU. Thus, it can be concluded that all eggs were characterized by good albumen quality. Chodová et al. (2013) and Rizzi et al. (2015) indicated that HU value of eggs from litter and free-range systems was lower than in eggs from cage system. Küçükylmaz et al. (2012) revealed no effect of rearing system on albumen height in eggs from hens of white breeds while in eggs from hens of brown breeds, albumen height and HU value were higher compared with conventional system.

The present studies evidenced the effect of the type of alternative rearing system, and laying hen breed and age on yolk weight. Also studies of Rizzi and Marangon (2012) corroborated the influence of breed on yolk size. Hens of native Italian breeds laid eggs with heavier yolks (16.2 g) than commercial hybrids, while hen breeds with white plumage laid eggs with larger yolk than breeds with brown plumage (15.8 and 15.5 g, respectively). Van den Brand et al. (2004) indicated that quality traits of eggs from free-range system were characterized by wider variability than those from cage system for a majority of the measured parameters and noted that it was more difficult to maintain constant egg quality throughout the whole laying period when free-range system was used. It was confirmed also by our studies in which a majority of the examined egg quality traits showed a greater variability in free-range and organic systems compared with litter system.

The present investigations did not confirm the effect of the type of alternative rearing system on occurrence of meat and blood spots whereas studies of Hidalgo et al. (2008) showed a lower incidence of meat spots in eggs from free-range system compared with cage, litter and organic systems.

More intense yolk color observed in our studies in eggs from free-range and organic systems at the beginning and end of the laying period should not be linked with hen age but rather with their access to the run where they could feed on green forage in autumn (26th week) and spring (56th week). Hammershøj and Steefedt (2005) estimated the intake of green forage by laying hens on the run at 60–170 g/hen/day. It is rich in carotenoids which produce a beneficial effect on yolk color. Research of Karadas et al. (2005) also documented that eggs from free-range hens contained higher levels of carotenoids in yolk than eggs from hens reared without access to a range. In our studies yolk color intensity from organic system was higher than from litter system. Survey of yolk color in eggs produced in different housing systems marketed in Spain and Portugal revealed that eggs from an alternative system were paler and their color was more variable (Martínez-Alesón and Hamelin, 2014). Analogically, in Terčič et al. (2012) studies, hens from organic rearing system laid eggs with paler yolk than those kept in cages. Different results were obtained in our studies, i.e. yolk color was more intense in eggs from free-range and organic systems than from litter system which probably resulted from the fact that in our studies all hens were fed color additive-free feeds. In the present studies, eggs from hens reared in organic system were characterized by more intense yolk color which could have resulted from their access to a bigger run more abundant in green forage than on an organic farm. Van Ruth et al. (2011) found different carotenoid profile in eggs from organic housing system compared with eggs from free-range and litter systems and hypothesized that it probably resulted from the ban on using synthetic carotenoids in organic husbandry. Our present studies evidenced that in winter (42nd week) eggs from free-range and organic systems were characterized by less intense yolk color which can be explained by a shorter time spent by laying hens on the run and harsh climatic conditions which made impossible for hens to feed on green forage on the run.

Conclusions

The present studies indicated that:

– Eggs from tested alternative rearing systems differed in egg weight and shape and yolk color intensity. More intense yolk color in eggs from free-range and organic systems vs eggs from litter system indicate that housing system with access to a green run is beneficial for this trait.

– The type of alternative housing system was observed to have no effect on albumen height, HU value and on the presence of meat and blood spots in egg contents, therefore, it is not possible to conclusively identify the type of alternative system which yields eggs of the best quality.

– It was demonstrated that genotype influenced egg weight and egg contents traits (albumen height, HU value and the presence of meat and blood spots). In all the systems under study, Hy-line Brown and R11 hens laid heavier eggs than Z11 hens. More eggs with meat and blood spots were laid by R11 compared to Z11 hens.

– In all studied alternative rearing systems, laying hen age significantly influenced egg weight, yolk percentage, eggshell traits (color intensity, weight, thickness and strength) and egg contents traits (HU value, yolk weight and color intensity, and presence of meat and blood spots).

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