Animal Science Papers and Reports vol. 27 (2009) no. 3, 227-235
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Quality of eggs from Polish native Greenleg Partridge chicken-hens maintained in organic *vs*. backyard production systems

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(Received January 15, 2009; accepted April 23, 2009)

The aim of the study was to evaluate the quality of eggs from 56-week-old hens of the native Greenleg Partridge chicken breed, maintained in three production systems and differentiated by feeding – organic (group 1), backyard (group 2) and intensive, kept indoors in a poultry house (group 3 – control).
Egg quality and eggshell traits were found to be related to the production groups. The eggs laid by hens from group 1 were characterized by the highest total weight and highest weight of yolk which had the most desirable colour. The yolks of these eggs were characterized by the lowest level of cholesterol and the lowest shell strength. with the highest level of vitamin E. In the backyard production system (group 2) eggs were characterized by the lowest total weight and yolk weight, the highest protein content of albumen, the highest vitamin A and the lowest vitamin E content of yolk as well as lower shell crushing strength compared to the control group.

KEY WORDS: backyard production system / chicken / egg quality / Greenleg Partridge chicken / organic production system

In Poland as in the whole of Europe, consumers show an increasing interest in eggs from free-range and organic production systems. Under the free-range system, the chemical composition of eggs is modified in accordance with consumers' demands to increase the colour intensity, as well as vitamin and unsaturated fatty acids content

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of yolk [Trziszka 2000, Castellini *et al*. 2006, Krawczyk and Sokołowicz 2007, Egerer and Grashorn 2008]. The literature also shows that outdoor keeping of hens has a significant effect on the physical traits of eggs, in particular shell strength and egg weight [Van den Brand *et al*. 2004, Krawczyk *et al.* 2005]. For this reason, free-range egg production has expanded markedly in many European countries. In addition to the organic production system, the most popular free-range system is the backyard system, in which hens are kept in small flocks of 30-100 birds and fed mainly cereals and ground grains. Eggs from backyard production system are cheaper than organically produced eggs and are very popular with Polish consumers [Sokołowicz *et al*. 2008]. The organic production system is expensive because it involves a strict production regimen controlled by certification authorities and sanitary and veterinary services. Backyard egg production is oriented towards farm self-supply, with surplus production sold at competitive prices compared to the organic production system. These egg-consumer preferences encouraged the authors of the present report to evaluate qualitatively the eggs from native Greenleg Partridge chicken-hens maintained in organic *vs*. backyard production system and subjected to different feeding regimens.

Material and methods

Native/local breeds of chicken, which efficiently convert feeds under free-range farming conditions are recommended for extensive egg production systems. For this reason, the study covered table eggs from 56-week-old hens of the Greenleg Partridge (Z-11) chicken breed which is included in the conservation programme. Hens were kept in three production systems: organic (group 1), backyard (group 2) and intensive, kept indoors (group 3 – control).

Laying hens from group 1 (200 birds) were kept on a certified organic farm. Throughout the year layers used free range and received farm-produced feed containing 70% cereals from the same farm as well as lupin, ground limestone, cooked potatoes and dried plants. Hens from group 2 (50 birds) were kept in the backyard system with free access to grass area (20 m^2/bird) throughout the year. Layers from this group were fed ground cereals and whole wheat and barley grain. Group 3 (control) had 60 hens kept indoors on a litter in a poultry house under controlled temperature and humidity conditions, and was fed complete layer diet *ad libitum*. Chemical composition of the diets is shown in Table 1. Samples of feed were taken from a feeding hopper (group 3) and from a large container (group 1) after thorough mixing. The sample of farm-produced feed (group 2) contained individual feed ingredients mixed at a ratio calculated according to daily intake per group.

At the hens'age of 56 weeks, 30 eggs were taken from each group over two days for analyses. Egg Quality Measurements (EQM) electronic equipment was used to determine the physical traits of egg shell and shell inner content. The egg shape index was defined as the width to length ratio measured with calipers. Shell strength (N) was determined using an Egg Crusher device (VEIT Electronics, Czech Republic).

Cholesterol level of yolk was determined colorimetrically according to Crawford [1958], modified by Ryś and Bączkowska [1965].

Proximate analysis of feeds was performed by the main laboratory of the National Research Institute of Animal Production, based on AOAC [1990] procedures. Determined was crude protein of egg albumen (Kjeltec). Yolk was analysed for the content of vitamins A and E according to Polish Standard PN-EN ISO 14565 (total trans-retinol, vitamin A) and Polish Standard PN-EN ISO 6867 (α-tocopherol, vitamin E). The determinations were made with HPLC (MERCK-HITACHI) on the column LiChroCART™ 250-4 Superspher™ 100 RP-18, 4 μ, using a UV-VIS (324 nm, vitamin A) and FL detector (Ex295 nm, Em350 nm, vitamin E).

The differences among group means were verified statistically by analysis of variance using Duncan's test and the STATGRAPHIC Plus 4.0 package.

Results and discussion

The organic and farm-produced feeds (group 1 and 2, respectively) contained standard levels of crude fibre, but were significantly lower in protein and vitamin compared to the standard and to the complete diet consumed by layers from group 3 (Tab. 1).

Table 1. Results of proximate analysis and vitamin content of feeds

Feed - Group	Dry matter (%)	Crude protein (%)	Crude fibre (%)	Vit. A IU/kg	Vit. E mg/kg
Organic feed Group 1 (experimental)	90.78	13.90	4.76	<900*	27.7
Farm-produced feed Group 2 (experimental)	91.67	11.73	3.24	2164	12.6
Complete DJ diet Group 3 (control)	89.46	18.24	2.60	9476	23.7

The different housing and feeding systems had a significant effect on most of egg and shell quality traits except the shape index (Tab. 2 and 3). Egg shape is critical for the egg crushing strength, but it is a hereditary trait that is associated mainly with hen genotype and age [Solomon 1991].

The lightest eggs and yolks were found in hens from the backyard system (group 2), while both the heaviest – in the organic farm (group 1) – $P \leq 0.05$. with a statistically significant correlation between the traits (Tab. 2). Keshavarz and Nakjima [1995] confirmed the well-known relationship that in addition to hen genotype, egg weight is influenced mostly by the energy and nutritive value of feed, especially the level of protein. The fact that the feeds offered to hens from groups 1 and 2 had a low content of protein which birds were not always able to find on free range could lead to reduced egg weight in these groups. The literature reveals different results in this area.

Table 2. Results of egg quality evaluation

Item	Group 1 (organic system)	Group 2 (backyard system)	Group 3 (intensive system)	SEM
Shape index (%)	74.2±2.37	74.3±1.95	75.6±2.35	0.325
Egg weight (g)	57.3±5.60^{b}	54.1±2.66^{a}	56.5±3.82^{ab}	0.605
Yolk weight (g)	17.9±3.02^{b}	16.2±0.60^{a}	17.2±1.17^{ab}	0.271
Proportion in egg weight (%)				
albumen	59.9	60.1	59.5	
yolk	31.2	30.0	30.4	
Albumen height (mm)	4.78±1.29^{AB}	6.36±1.59^{B}	5.64±1.27^{A}	0.210
Haugh units	65.9±13.05^{aA}	80.0±10.55^{b}	74.2±9.48^{bB}	1.709
Blood spots (%)	3.3	0.0	0.0	
Meat spots (%)	0.0	0.0	0.0	
Yolk colour (La Roche)	8.5±0.99	7.9±0.83	7.8±0.93	0.133
Cholesterol content of yolk (mg/g)	12.89±0.61^{A}	13.83±0.22^{B}	13.93±0.27^{B}	0.111
Protein content of albumen (%)	10.3±0.10^{A}	11.7±0.44^{bB}	10.6±0.58^{a}	0.245
Vitamin content of yolk (mcg/g)				
A	5.8±0.50^{ab}	6.3±0.46^{b}	5.1±0.33^{a}	0.224
E	91.33±14.18^{B}	36.42±5.67^{A}	84.05±10.76^{B}	9.155

$^{aA...}$Within rows means bearing different superscripts differ significantly at: small letters – P≤0.05; capitals – P≤0.01.

Table 3. Results of shell quality evaluation

Item	Group 1 (organic system)	Group 2 (backyard system)	Group 3 (intensive system)	SEM
Colour (pts)	61.7±4.77^{b}	63.7±3.15^{bB}	57.7±6.12^{aA}	0.782
Weight (g)	5.08±0.85^{A}	5.35±0.47^{AB}	5.71±0.43^{B}	0.091
Density (mg/cm^2)	67.8±11.2^{A}	73.3±7.75^{AB}	78.1±5.6^{B}	1.297
Thickness (μm)	308±33.0^{A}	320±27.9^{AB}	338±21.2^{B}	4.180
Strength (N)	20.57±7.35^{a}	26.51±12.56^{a}	30.17±9.63^{b}	1.559
Shell content of egg (%)	8.9	9.9	10.1	
Calcium content (g/kg)	383±1.00	387±3.23	386±4.51	1.109

$^{aA...}$Within rows means bearing different superscripts differ significantly at: small letters – P≤0.05; capitals – P≤0.01.

Sekeroglu *et al*. [2008] reported slightly lower, and Van Ben Brand [2004] and Rossi [2007] significantly higher weight of eggs from free-range hens. However, in all these studies the hens were fed complete diets.

In all the groups the coefficient of correlation estimated between egg weight and yolk weight was positive and consistent with the literature (Tab. 4) being in accordance with Suk and Park [2001] and Hartman and Wilhelmson [2001]. A characteristic trait of the native Greenleg Partridge hens is high yolk content of egg [Krawczyk and Sokołowicz 2007] as a result of which the yolk percentage in this study remained unchanged despite the significant differences in egg and yolk weight resulting from the application of the experimental factor.

Table 4. Correlation coefficients between egg quality traits

Correlation	Group 1 (organic system)	Group 2 (backyard system)	SEM
Egg weight × yolk weight	0.8171*	0.5609*	0.6088*
Shell thickness × shell strength	0.1533	0.6475*	0.4797*
Shell density × shell strength	0.508	0.5547*	0.3844

* $P \leq 0.05$.

Eggs from group 2 received the best scores for freshness (albumen height and Haugh units), corroborating the results of similar studies by Kosmidou *et al*. [2007] and Sekeroglu *et al*. [2008]. Meanwhile, Rossi [2007] obtained lower Haugh units for the eggs of hens kept under organic production systems compared to caged layers. The discrepancy between the present results obtained for this trait is supported by Bell *et al.* [2001], who studied more than ten American hypermarkets. They found that egg freshness is related mainly to the time of storage and to a small extent to shell colour, and not to egg weight, housing system or region of a country.

The eggs from groups 2 and 3 had no blood or meat spots, and those from group 1 were characterized by a low proportion of these defects (3.3%). The eggs evaluated except those from group 1 had no blood and meat spots. The eggs of Greenleg Partridge hens are characterized by light cream shell colour [Conservation Programme…], and the absence of blood and meat spots in their yolks is in accordance with Decuypere and Baerdemaeker [2006], who found this trait to be characteristic of brown-shelled eggs. Likewise, Flock *et al.* [2001] reported that the number of blood and meat spots is greater in brown than in white eggs and their frequency can be reduced under stress-free production conditions.

The yolks of eggs from three groups had good colour, ranging from 7.8 to 8.5 points in La Roche scale, showing that the trait in question can be considerably improved when hens are given access to green outdoor areas. Despite the lack of a significant correlation in this respect, it should be noted that farm-produced feeds given to layers from groups 1 and 2 did not contain any staining agents used in the standard diet for control hens. Free-range layers consumed plants that were a source of xanthophylls for egg yolk. Hughes and Dun [1983] showed that in this housing system, layers consume about 30-35 g more dry matter in the form of grasses and herbs, whereas Van den Brand *et al.* [2004] and Horsted *et al*. [2006] observed that plants consumed on free-range have a beneficial effect on yolk colour.

Hens from the organic system laid eggs with the lowest cholesterol content per g of yolk and the lowest crude protein content of albumen, showing significant differences with the other groups. Unlike other compounds, the cholesterol content of egg yolk remains stable and is modified to a small extent by environment and feeding [Sparks 2006]. Our earlier study showed that Greenleg Partridge hens have a lower level of cholesterol per g of yolk compared to layers of other breeds and varieties [Krawczyk *et al*. 2005]. The results presented here may indicate that this specific trait of the Polish native chicken can also be changed by environmental factors.

The yolks of eggs from the organic and backyard systems showed a higher level of vitamin A compared to the yolks of eggs from the intensive system. While the yolks of eggs from group 1 hens had the highest level of vitamin E (91.33 mcg/g) and those of eggs from group 3 had a level of 84.05 mcg/g, in the group of backyard hens the content was only 36.42 mcg/g. The vitamin content of eggs depends on the vitamin content of feed [Melluzzi *et al*. 2000; Leeson and Caston 2003]. In the present study, diets offered to group 1 and 2 of layers contained several-fold less vitamins than the control diet. Thus, it can be assumed that food consumed additionally on free range (plants and invertebrates) was a source of vitamins.

The eggs of hens from groups 1 and 2 had a significantly darker colour of shells which were thinner and required lower crushing strength compared to those from the control group (Tab. 3). Eggs with the lightest shells were laid by organically maintained hens (group 1), showing highly significant differences compared to the eggs from the control group. No significant differences were identified between the groups in the shell weight content of total egg weight and in shell calcium content. Studies by Belyavin [1987] and Scholtyssek [1988] suggest that eggshell colour correlates mostly with hen genotype, while earlier study by Cywa-Benko and Krawczyk [2004] revealed that the trait is affected by nutrition and light. Scott and Silversides [2000] found a relationship between shell colour intensity and shell thickness, which is in accordance with our findings.

Shell strength is one of the most important indicators of egg quality. Differences in shell thickness are determined by both genetic and non-genetic factors, the latter including the age of layers and feeding [Rodrigez-Navarro *et al.* 2002, Van der Brand *et al*. 2004, Decuypere and Baerdemaeker 2006, Dobrzański *et al.* 2007]. Shell strength was found to decrease with age, most probably due to decreasing dietary availability of dietary calcium and phosphorus to layers and changes in shell structure (Rodrigez-Navarro *et al.* 2002). The present results as well as those of Petersen [1977], Flock [1990], Solomon [1991] and Dobrzański *et al*. [2007] indicate that shell strength can be modified by feeding. Reduced shell strength and increased shell deformation with increased ambient temperature were observed by Al-Saffar and Rose [2002]. Free-range hens are exposed to the direct effect of climate, and the possibility of supplementing the diet with necessary nutrients is determined by free range quality [Van den Brand *et al.* 2004]. Most often this means that the intake of protein, calcium, magnesium and phosphorus is insufficient. In this study backyard layers laid eggs with thinner and less dense shells compared to the control group, but not every group showed a significant correlation between these traits and shell strength (Tab. 4), as reported also by Roland and Bryant [2000].

In summing up the results of this study, quality traits of eggs and shells from layers maintained under organic, backyard and intensive (indoors) conditions of a poultry house were found to be different. The eggs of hens from the organic farming system were characterized by the highest total weight, the highest weight of yolk, (with the most desirable colour), the lowest cholesterol level of yolk, the lowest level of vitamins A and E, as well as the lowest shell strength. In the backyard system, the eggs were characterized by the lowest total weight, the lowest yolk weight, the highest protein content of albumen, the highest vitamin A and the lowest vitamin E content of yolk and lower shell crushing strength compared to the control group.

As a result of this study it was found that the organic production system of Greenleg Partridge hens has a favourable effect on most quality traits of eggs by increasing their nutritive value.

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Józefa Krawczyk

Jakość jaj kur polskiej rodzimej rasy zielononóżka kuropatwiana utrzymywanych w ekologicznym i przyzagrodowym systemie chowu

S t r e s z c z e n i e

Celem badań była ocena jakości jaj pozyskiwanych od 56-tygodniowych kur rodzimej rasy zielononóżka kuropatwiana, utrzymywanych w trzech różnych systemach chowu, z zastosowaniem zróżnicowanego żywienia. Kury utrzymywano w chowie ekologicznym (*organic*, grupa 1), przyzagrodowym (*backyard*, grupa 2) i intensywnym, w zamkniętym kurniku (*intensive*, grupa 3 – kontrolna).

Stwierdzono duże różnice między grupami pod względem jakości jaj i ich skorup. Jaja kur utrzymywanych w gospodarstwie ekologicznym (grupa 1) charakteryzowały się największą masą całkowitą i największą masą żółtek, które zarazem były najlepiej wybarwione. Żółtka tych jaj cechował najniższy poziom cholesterolu i witamin A i E, ale najniższa także wytrzymałość skorup. W przyzagrodowym systemie chowu (grupa 2) pozyskiwano jaja o najniższej masie całkowitej i najniższej masie żółtka, największej zawartości białka w białku jaja i witaminy A w żółtku, ale najmniejszej ilości witaminy E i niższej w porównaniu z grupą kontrolną wytrzymałości skorup na zgniatanie.