Research Note: The nutritional value of eggs from native Polish Crested chickens and commercial hybrids that have been stored in various conditions

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ABSTRACT The aim of the study was to compare the nutritive value of eggs from Polish Crested chickens (**PCr**) to that of eggs from commercial hybrid Hy-Line Brown (**HLB**) and to examine the effect of storage conditions on physical quality parameters. In total, 135 PCr (9 pens) and 75 (5 pens) HLB chickens were kept on litter and fed commercial feed. At laying peak (36 wk), all eggs (n = 66/ genotype) were collected on the same day and divided into 3 groups (n = 20): group I was assessed on the day after laying; group II was analyzed after 28 d of storage in a fridge; group III, after 28 d in storeroom conditions of 19.5 to 20.5°C. For group I, vitamin A and E content (n = 3 samples) and fatty acid (**FA**) profiles (n = 6 samples) were determined. For all groups, the physical quality parameters of the eggs were assessed. The vitamin E content was higher ($P < 0.05$) for PCr than HLB. The PUFA n-6 FA content was higher and the amount of MUFA was lower ($P < 0.05$) for PCr when compared to HLB. All physical parameters changed after storage, with more negative changes recorded for group III than for group II. Concerning egg weight, albumen height, Haugh unit score and the pH of the yolk and albumen, interaction between genotype and storage conditions ($P < 0.001 - P < 0.05$) was demonstrated. The lightest eggs with the lowest albumen height and the highest pH were recorded from PCr in group III. The lowest Haugh unit score was recorded from HLB eggs stored in the same conditions. Moreover, the eggs of PCr were characterized by a higher ($P < 0.001$) yolk content and yolk color ($P < 0.05$), whereas the weight of the yolk and content of albumen were lower ($P < 0.001$) for HLB. Eggs from PCr that are stored in appropriate conditions could possibly be offered as a niche product.

Key words: indigenous chicken, quality of egg, fatty acid profile, egg storage

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INTRODUCTION

In recent years, interest in table eggs produced by extensive farming methods has been steadily increasing. For this type of production, local breeds of chickens are recommended (Sokołowicz et al., 2019; Marelli et al., 2020; Ianni et al., 2021; Lordelo et al., 2020). One such breed is the Polish Crested Chicken (**PCr**), which are kept by the University of Agriculture in Krakow. This is a typical Central European indigenous breed of laying chicken, known for a specific phenotypic feature, namely a bouffant crest of feathers on the top of the head. During the laying period, hens produce about 170 eggs which have a cream-colored shell.

The eggs produced by indigenous breeds are better suited to the expectations of modern consumers, who desire original products from rarer breeds of chickens. To date, no attempt has been made to compare the nutritive value of eggs from PCr chickens with those produced by commercial hybrids.

The freshness of eggs is one of the most important quality characteristics demanded by consumers. Overproduction at peak laying period is common in small-scale farming, which means eggs are stored in warehouses for several days. This justifies the evaluation of egg quality parameters from this production period after they have been stored in various conditions.

We hypothesise that eggs from PCr chickens match the quality of eggs produced by commercial hybrids in terms of many of their nutritional and physical characteristics, irrespective of storage conditions.

The objective of this study was 1) to compare vitamin and fatty acid composition and the internal physical quality parameters of eggs from PCr chickens to those of commercial hybrids kept under the same management

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conditions; and 2) to examine the effect of storage conditions on physical quality parameters of eggs collected during the peak egg production period.

MATERIALS AND METHODS

Experimental Birds and Management

The study was carried out on eggs from PCr (CP−11 strain) and Hy−Line Brown hybrids (**HLB**). A total of 135 PCr and 75 HLB chickens were kept on litter at the Research and Education Centre of the Faculty of Animal Sciences of the Agricultural University in Krakow, Poland. There were 9 pens for PCr and 5 pens for HLB chickens (2.0 × 2.5 m; stocking density: *3 birds/m*^{2}), which were connected with runs (stocking density*: 1.25 bird/m*^{2}). Housing, lighting and feeding conditions were in accordance with welfare standards for laying hens. A commercial, granulated, layer-breeder mixture based on wheat, corn, wheat bran, soybean oil, and post-extraction soybean and sunflower meal, was fed to the chickens. The chemical composition of the mixture was 14.9% crude protein, 5.1% crude fat, 4.6% crude fibre, 0.47% of available P and 3.93% Ca. The fatty acid (**FA**) composition of the mixture is given in Table 1.

Table 1. Fatty acid profile of lipids in the commercial layer−breeder mixture and egg yolks (% of total fatty acids−FA) (n = 6 samples/ genotype; mean ± SEM) from Polish Crested chickens (PCr) and Hy−Line Brown (HLB) commercial hybrids.

Item	Mixture	PCr	HLB	SEM
C12:0	0.01	−	−	−
C14:0	0.19	$0.30^a \pm 0.01$	$0.30^a \pm 0.01$	0.01
C16:0	15.24	$25.78^a \pm 0.60$	$26.39^a \pm 0.30$	0.33
C18:0	2.42	$10.09^a \pm 0.11$	$9.33^a \pm 0.23$	0.17
C20:0	0.28	$0.02^a \pm 0.001$	$0.02^a \pm 0.001$	0.001
C22:0	0.21	$0.06^a \pm 0.001$	$0.07^a \pm 0.001$	0.002
C16:1	0.42	$3.50^a \pm 0.18$	$3.81^a \pm 0.13$	0.12
C18:1 n−9	29.47	$47.83^a \pm 0.79$	$45.73^b \pm 0.45$	0.55
C22:1	0.04	−	−	−
C18:2 n−6	46.68	$8.71^a \pm 0.63$	$10.88^b \pm 0.41$	0.51
C18:3 n−6 gamma	0.01	$0.10^a \pm 0.01$	$0.09^a \pm 0.01$	0.01
C18:3 n−3	4.91	$0.50^a \pm 0.05$	$0.65^a \pm 0.05$	0.05
C20:4 n−6	0.01	$2.28^a \pm 0.14$	$2.00^a \pm 0.01$	0.09
C20:5 n−3	0.06	$0.01^a \pm 0.001$	$0.01^a \pm 0.001$	0.001
C22:6 n−3	0.03	$0.81^a \pm 0.05$	$0.72^a \pm 0.03$	0.03
∑ SFA	18.37	$36.11^a \pm 0.24$	$36.25^a \pm 0.52$	0.39
∑ UFA	81.63	$63.88^a \pm 0.24$	$63.75^a \pm 0.52$	0.27
∑ MUFA	29.93	$49.54^a \pm 0.45$	$51.34^b \pm 0.68$	0.49
∑ PUFA n−6	46.69	$12.96^a \pm 0.41$	$11.09^b \pm 0.69$	0.49
∑ PUFA n−3	5.00	$1.38^a \pm 0.05$	$1.32^a \pm 0.08$	0.04
∑PUFA n−6/n−3	9.33	$9.39^a \pm 0.22$	$8.40^a \pm 0.12$	0.21
AI	0.20	$0.42^a \pm 0.01$	$0.43^a \pm 0.01$	0.01
TI	0.33	$1.02^a \pm 0.02$	$1.02^a \pm 0.01$	0.01
h	81.17	$60.24^a \pm 0.68$	$60.07^a \pm 0.37$	0.36
H	15.43	$26.08^a \pm 0.62$	$26.69^a \pm 0.31$	0.34
h/H	5.26	$2.32^a \pm 0.08$	$2.25^a \pm 0.04$	0.04

Abbreviations: AI, Atherogenic index (C12:0 + 4 × C14:0 + C16:0) / (MUFA + PUFA); FA, fatty acids; h/H, Hypocholesterolemic /hypercholesterolemic index = (C18:1 + C18:2 + C18:3 + C20:4 + C20:5 + C22:6)/ (C14:0 + C16:0); MUFA, monounsaturated; PUFA, polyunsaturated; SFA, saturated; UFA, unsaturated; TI, Thrombogenic index = (C14:0 + C16:0 + C18:0)/ [(0.5 × ∑ MUFA) + (0.5 × ∑ n−6) + (3 × ∑ n−3) + (∑ n−3)/ ∑n-6)].

Means in the same row with different superscripts are different (^{a,b} $-P < 0.05$).

Eggs, Storage Conditions, and Physical Quality Parameters

A total of 66 eggs/genotype were collected on the same day during the peak period of production (at 36 wk). Egg weight had to match the mean for the given genotype of each breed: 49.3 g and 66.1 g for PCr and HLB, respectively. The eggs (n = 60 / genotype) were randomly divided into 3 groups of 20 eggs each: group I consisted of eggs assessed one day after laying; group II was eggs stored for 28 d in a fridge (4−6°C and RH 60−65%); and group III was eggs stored in a storeroom (19.5−20.5°C and 32−35% RH). Internal egg quality assessment was performed using Egg Quality Measurements Electronic Equipment (Technical Services and Supplies Ltd., Dunnington, York, UK). The color of the yolk was measured using the DSM scale with the Yolk Colorimeter Apparatus. The pH value of the albumen and yolk was measured using a CyberScan 110 (Eutech Instruments Pte Ltd, Singapore) pH meter with a Hamilton glass electrode. The pH meter was calibrated using 3 calibration buffers (pH 4.0, pH 7.0 and pH 10.0). On the first day of the experiment and after 28 d of storage, the height of the air cell in the eggs was measured. Measurements were conducted in an ovoscope (Ovolux, Masalles, Spain).

Vitamin A and E Content and the Fatty Acid Profile of Yolk

The determination of vitamins A (total trans-retinol) and E (α-tocopherol) content in the yolks (n = 3 / genotype) were performed in duplicate by *HPLC* analysis using Merck−Hitachi (MERCK−HITACHI, Tokyo, Japan) equipment with UV detection (324 nm, vitamin A) and fluorescent detection (Ex295 nm/Em350 nm, vitamin E). A reverse phase LiChroCART 250−4 Superspher 100 RP−18 column was used for chromatographic separation.

The fatty acid (**FA**) profile of the mixture used in feeding and in the yolks (n = 6/ genotype) were analyzed in duplicate using gas chromatography by determining the acids as methyl esters. Determination of individual FAs were performed using a gas chromatograph (SHIMADU GC−2010 Plus, Shimadzu Kyoto, Japan) equipped with a Rtx2330 capillary column (105 m × 0.32 mm × 0.20 μm). Detailed information on the methodology of vitamin and FA determination was given by Sokołowicz et al. (2019).

The health lipid indexes were calculated: atherogenic (**AI**, C12:0 + 4 × C14:0 + C16:0)/ (MUFA + PUFA); thrombogenic (**TI**, C14:0 + C16:0 + C18:0)/ [(0.5 × ∑ MUFA) + (0.5 × ∑ n-6) + (3 × ∑ n-3) + (∑ n-3)/ ∑n-6)]; and hypocholesterolemic /hypercholesterolemic (**h/H**, C18:1 + C18:2 + C18:3 + C20:4 + C20:5 + C22:6)/ (C14:0 + C16:0).

Statistical Analysis

The data were examined using the Shapiro−Wilk test for normal distribution and using the Levene test for

homogeneity of the variances. The significance of differences in vitamin content between the genotypes was determined using the Mann−Whitney U test and for FA profiling, by the Student's t test. For physical egg quality parameters data, the two-way ANOVA was conducted according to the following linear model: $Yijk = \mu + Gi + Sj + (G \times S)ij + \varepsilon ijk$, where Yijk = values of variable; μ = overall mean; Gi = effect of genotype; Sj = effect of storage treatment; G × S = interaction of genotype × storage treatment; εijk = residual random error. The significance of the differences between the groups' means was estimated using Duncan's multiple−rank test. Values were expressed as mean and SEM. Differences were considered significant at the level of $P < 0.05$. The statistical analysis was processed using the Statistica version 6.0 (TIBCO Software Inc., Palo Alto, CA).

RESULTS AND DISSCUSION

The Vitamin A and E Content and FA Profile of Yolk − PCr vs. HLB

In the present study, the content of vitamin A in eggs was similar for chickens of both genotype and was 3.37 μg/g ± 0.23 and 4.80 μg/g ± 0.14 for PCr and HLB respectively. However, vitamin E content in eggs from PCr (79.20 μg/g ± 4.20) chickens was higher ($P < 0.05$) by about 9.0 μg/g per yolk in comparison to HLB (69.77 μg/g ± 3.04). This corresponds with the findings of Ariza et al. (2021), where a high amount of vitamin E was detected in eggs from native Spanish breeds compared to Leghorns. Vitamin E is considered to be the most important antioxidant for preventing lipid peroxidation. Therefore, this is a favorable feature of eggs from PCr chickens as high antioxidant content could improve egg quality during storage.

The yolk FA profile and the values of the health lipid indexes are listed in Table 1. PCr chicken eggs characteristically had a higher ($P < 0.05$) amount of oleic acid (by 2.10 %) but had less ($P < 0.05$) linoleic acid (by 2.17 %) in comparison to HLB. Additionally, PCr eggs contained 1.80 % less MUFA ($P < 0.05$) but more 1.87 % PUFA n−6 ($P < 0.05$) compared to HLB chickens; however, this had no effect on differences in the n−6 / n−3 PUFA ratio between PCr and HLB eggs. In contrast, Sirri et al. (2018), Sokołowicz et al. (2019), and Marelli et al. (2020) reported a lower n−6 / n−3 PUFA ratio in eggs from native chickens than those of commercial hybrids. Furthermore, Ariza et al. (2021) observed a higher amount of PUFA in the eggs of native chickens compared to Leghorns. However, analysis of the FA profile of native breeds compared to commercial hybrid carried out by Ianni et al. (2021) showed no differences in PUFA content. The findings of present study correspond with those of Lordelo et al. (2020), which showed no FA differences between the eggs of native breeds and commercial hybrids, despite the fact that the native breeds are in small scale farms compared to hybrids, which are intensively farmed in cage. The differences in n−6 PUFA revealed in the present study may be due to differences in lipid metabolism between the chicken genotypes. Boschetti et al. (2016) showed differences in FADS1 and FADS2 gene expression and desaturating δ−5 and δ−6 enzyme activity, which was associated with differing FA profiles in chicken breast meat.

It is noteworthy that the AI and TI index values determined in this study were similar for eggs of both genotypes. Thus, consumption of PCr eggs is associated with the same risk of cardiovascular diseases as HLB.

Effect of Genotype and Storage Conditions on the Inner Physical Quality Parameters of Eggs − PCr vs. HLB

The effect of genotype and storage conditions on the inner physical quality parameters of PCr and HLB eggs are shown in Table 2. All physical parameters of the eggs changed after 28 d of storage; more dynamic negative changes were recorded for group III than group II. Egg weight, albumen height, the Haugh unit score and pH of yolk and albumen values were affected by two-way interaction between genotype and storage conditions ($P < 0.001 - P < 0.05$). The lightest eggs with the lowest albumen height and the highest pH were noted for PCr eggs stored at room temperature (group III). The lowest Haugh unit score, which did not meet acceptable standards for good−quality table eggs, was recorded in HLB eggs stored in these conditions. It is possible that the storage−dependent differences in albumen dynamic changes between genotypes may result from differences in ovomucin content and/ or lysozyme activity. In Krawczyk and Sokołowicz's study (2015), eggs from native breeds stored in various conditions were more susceptible to unfavorable changes in weight and albumen freshness parameters than HLB eggs. As confirmed by Vlčková et al. (2019), the higher egg weight loss noted for PCr compared to HLB may results from the relatively larger surface area in relation to volume in small eggs which causes more rapid water loss. Another contributing factor may also be shell thickness and the density of the pores in shells between breeds/ strains of laying hens (Lewko et al., 2020).

Regarding genotype as an individual factor, the weight of the yolks and the content of the albumen were lower by 13.0% and by 7.3% ($P < 0.001$) respectively in PCr eggs in comparison to HLB eggs. However, the proportion of yolk in the eggs of the PCr chickens was 15% greater ($P < 0.001$), and the yolks were more intense in color ($P < 0.05$). Other studies also noted differences in some physical parameters of eggs from local breeds and commercial hybrids that had been managed in the same conditions (Sirri et al., 2018; Sokołowicz et al., 2019; Ianni et al., 2021). The higher content of yolk in PCr eggs may affects the taste with presumably positive implications for consumer acceptability. The more intense yolk color that may results from differences in pigment absorption, transport, and rate of deposition between yolks of differing genotypes was also considered beneficial.

Table 2. Effect of genotype, storage conditions and their interaction on internal physical quality parameters of eggs (n = 60/ genotype; mean ± SEM) from Polish Crested chickens (PCr) and Hy−Line Brown (HLB) commercial hybrids.

Characteristic	Item	Weight of egg (g)	Albumen height (mm)	Haugh unit score	Weight of yolk (g)	Content of yolk in egg (%)	Content of albumen in egg (%)	Yolk colour (DSM)	pH of yolk	pH of albumen	Air cell height (mm)
Genotype (G)	PCr	$48.0^{A}\pm0.37$	$7.4^{A}\pm0.28$	$88.0^{A}\pm1.46$	$14.0^{A}\pm0.14$	$29.2^{A}\pm0.28$	$58.7^{A}\pm0.29$	$8.2^{a}\pm0.12$	$6.3^{A}\pm0.03$	$9.3^{A}\pm0.07$	$5.2^{A}\pm0.40$
	HLB	$64.9^{B}\pm0.50$	$8.3^{B}\pm0.33$	$87.3^{A}\pm2.00$	$16.1^{B}\pm0.17$	$24.8^{B}\pm0.23$	$63.2^{B}\pm0.25$	$7.9^{b}\pm0.11$	$6.3^{A}\pm0.02$	$9.3^{A}\pm0.06$	$5.4^{A}\pm0.43$
	SEM	0.80	0.22	1.23	0.14	0.27	0.28	0.08	0.02	0.05	0.29
Storage conditions (S)	Group I	$56.5^{a}\pm1.14$	$10.3^{a}\pm0.23$	$100.9^{a}\pm0.90$	$14.5^{a}\pm0.19$	$25.8^{a}\pm0.37$	$62.2^{a}\pm0.38$	$7.8^{a}\pm0.08$	$6.1^{a}\pm0.02$	$8.8^{a}\pm0.03$	$1.4^{a}\pm0.05$
	Group II	$57.9^{b}\pm1.49$	$7.4^{b}\pm0.20$	$86.2^{b}\pm1.09$	$15.4^{b}\pm0.23$	$26.9^{b}\pm0.45$	$61.4^{b}\pm0.45$	$8.2^{b}\pm0.16$	$6.3^{b}\pm0.01$	$9.3^{b}\pm0.04$	$5.2^{b}\pm0.07$
	Group III	$54.3^{c}\pm1.55$	$5.3^{c}\pm0.15$	$72.3^{c}\pm1.41$	$15.4^{b}\pm0.30$	$28.8^{c}\pm0.47$	$58.9^{c}\pm0.50$	$8.3^{b}\pm0.19$	$6.7^{c}\pm0.01$	$9.9^{c}\pm0.05$	$9.4^{c}\pm0.13$
PCr	Group I	$49.2^{a}\pm0.44$	$9.6^{a}\pm0.30$	$99.7^{a}\pm1.26$	$13.7^{a}\pm0.21$	$27.9^{a}\pm0.35$	$60.1^{a}\pm0.33$	$8.0^{a}\pm0.11$	$6.1^{a}\pm0.02$	$8.8^{a}\pm0.05$	$1.3^{a}\pm0.06$
	Group II	$49.3^{a}\pm0.48$	$6.7^{b}\pm0.22$	$84.8^{b}\pm1.47$	$14.4^{b}\pm0.19$	$29.3^{b}\pm0.38$	$59.1^{a}\pm0.36$	$8.5^{a}\pm0.23$	$6.3^{b}\pm0.02$	$9.3^{b}\pm0.07$	$5.2^{b}\pm0.11$
	Group III	$45.3^{b}\pm0.61$	$5.1^{c}\pm0.17$	$75.6^{c}\pm1.20$	$14.1^{b}\pm0.32$	$31.1^{c}\pm0.48$	$56.5^{b}\pm0.51$	$8.4^{a}\pm0.31$	$6.5^{c}\pm0.02$	$10.1^{c}\pm0.07$	$9.1^{c}\pm0.15$
HLB	Group I	$64.7^{a}\pm0.53$	$11.1^{a}\pm0.29$	$102.4^{a}\pm1.25$	$15.3^{a}\pm0.20$	$23.6^{ac}\pm0.25$	$64.5^{a}\pm0.27$	$7.6^{a}\pm0.12$	$6.1^{a}\pm0.02$	$8.8^{a}\pm0.04$	$1.5^{a}\pm0.08$
	Group II	$66.6^{b}\pm1.03$	$8.1^{b}\pm0.27$	$87.6^{b}\pm1.59$	$16.4^{b}\pm0.31$	$24.6^{c}\pm0.31$	$63.7^{a}\pm0.36$	$8.0^{b}\pm0.21$	$6.3^{b}\pm0.02$	$9.3^{b}\pm0.05$	$5.3^{b}\pm0.09$
	Group III	$63.4^{a}\pm0.93$	$5.4^{c}\pm0.25$	$69.0^{c}\pm2.35$	$16.8^{b}\pm0.30$	$26.5^{b}\pm0.37$	$61.3^{b}\pm0.37$	$8.2^{b}\pm0.21$	$6.4^{c}\pm0.01$	$9.8^{c}\pm0.08$	$9.7^{c}\pm0.21$
P−value											
G		<0.001	<0.001	0.770	<0.001	<0.001	<0.001	0.039	0.436	0.206	0.081
S		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.023	<0.001	<0.001	<0.001
G × S		0.013	0.049	0.003	0.094	0.779	0.854	0.722	0.006	0.003	0.167

Means in the same column with different superscripts are different (^{a,b}− $P < 0.05$; ^{A,B} −$P < 0.001$) −for genotype PCr and HLB.
Means in the same column with different superscripts are different ($^{a\text{-}c}$−$P < 0.05$) − for groups I, II and III.
Group I−analysis on day after laying; Group II−storage for 28 days in fridge (temperature: 4−6°C).
Group III−storage for 28 days in storeroom (temperature: 19.5−20.5°C).

In the present study, egg storage conditions affected the weight of yolk, the content of yolk and albumen, yolk color (DSM) and the height of the air cell. For eggs stored at room temperature (group III), there was a 3.0% ($P < 0.05$) increase in yolk content and a 3.3% ($P < 0.05$) decrease in albumen compared to eggs analyzed 1 d after laying (group I). These changes probably occur as a result of gaseous exchange between the egg content and the external environment, and the migration of water through the vitelline membrane to the yolk. The pattern of these changes is similar to those identified in a previous study (Krawczyk and Sokołowicz, 2015). These processes probably also explain the increased air cell in both PCr and HLB eggs, which was about 7.0 times higher ($P < 0.05$) for eggs stored at room temperature (group III) than for those assessed on the day after laying (group I). In class A eggs, the air cell height must not exceed 6 mm. As PCr and HLB eggs stored for 28 d at room temperature exceed these limits, they should not be stored under such conditions for retail sale. The obtained results confirm that it is correct to keep eggs in cool conditions, preferably in refrigerators. In comparison to eggs analyzed on day after laying (group I), the storage dependent (group II and group III), increased egg yolk color may be due to oxidative processes. The occurrence of oxidative processes is catalyzed by iron; the oxidation of iron from bivalent to trivalent form produces a red−brownish color. Additionally, yolk mottling is a frequently observed result of prolonged egg storage.

Thus, it may be suggested that the nutritive value and internal quality parameters of eggs from PCr chickens match the standards of commercial egg production when kept in appropriate storage conditions. This study should be understood as a preliminary approach and future research should be conducted before the introduction of these eggs to the market as niche product.

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DISCLOSURES

The authors declare that there is no conflict of interest in this research.

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