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EFFECT OF STORAGE TIME ON THE QUALITY OF JAPANESE QUAIL EGGS (*COTURNIX COTURNIX JAPONICA*)

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K e y w o r d s: quail, storage time, quality albumen, yolk, shell.

A b s t r a c t

Along with the storage time, in the egg content there occur changes based of which their quality and condition of egg freshness may be determined. The aim of the study was determination of the effect of 7-week storage period at a temperature of 4°C on the quality of Japanese quail eggs. The eggs were analyzed at one-week intervals to determine their morphological composition. No statistically significant differences were observed between particular dates of evaluation within the range of the egg weight and its proportional loss, which in the 7th week was 2.78%. No statistically significant differences were observed in the weight of yolk and albumen in total. The amount of albumen did not change, while the Haugh units ranged from 91.4 in the 1st week to 87.2 in the 7th week of storage. These results show that quail eggs are characterized by a long period of retaining freshness.

WPŁYW CZASU PRZECHOWYWANIA NA JAKOŚĆ JAJ PRZEPIÓRKI JAPOŃSKIEJ (*COTURNIX COTURNIX JAPONICA*)

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S ł o w a k l u c z o w e: przepiórka, czas magazynowania, jakość białka, żółtko, skorupa.

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A b s t r a k t

Wraz z upływem czasu przechowywania jaj w ich treści zachodzą zmiany, na podstawie których można określić stan świeżości oraz jakość jaj. Celem pracy było określenie wpływu 7-tygodniowego przechowywania jaj przepiórki japońskiej w temperaturze 4°C na ich jakość. Jaja analizowano w odstępach tygodniowych, określając ich skład morfologiczny. Wykazano brak statystycznie istotnych różnic między poszczególnymi terminami oceny w obrębie masy jaja oraz procentowego jej ubytku, który w 7. tyg. przechowywania wyniósł 2,78%. Nie odnotowano statystycznie istotnych różnic w masie żółtka i białka ogółem. Wysokość białka się nie zmieniała, zaś jednostki Haugha przyjmowały wartości 91,4 w 1. tygodniu do 87,2 w 7. tygodniu przechowywania. Wyniki te pokazują, że jaja przepiórcze cechuje długi okres zachowania świeżości.

Introduction

Nowadays, we can observe an increasing consumer interest in food which has a directed and desirable effect on the body, the so called functional food. Good quality of such food and its beneficial effect on human health results from the presence of bioactive substances in its composition, stimulating the desirable effect of metabolic transformations (GÓRECKA et al. 2009). Therefore, quail eggs are becoming more and more popular as they fulfill the criteria of a product with traits of functional food. Quail eggs compared to chicken eggs, contain more essential exogenous amino acids, mineral compounds and elements such as iron, phosphorus, copper and zinc. They have a high content of vitamins, especially provitamin A, thiamine, riboflavine and cyanocobalamins. Owing to their chemical composition, they are not harmful for people allergic to albumen in chicken eggs. Moreover, quail eggs are characterized by a low cholesterol content and a more beneficial ratio of PUFA/SFA than chicken eggs (SINANOGLOU et al. 2011, GENCHEV 2012).

The quality of eggs of different bird species is conditioned by many genetic and environmental factors (TRAVEL et al. 2010), among others by the origin (genotype) of birds (CZAJA and GORNOWICZ 2006, LEWKO and GORNOWICZ 2007, SALMAN and TABEEKH 2011, DUKIĆ STOJČIĆ et al. 2012, GUGOŁEK et al. 2013), their age and stage of laying period (SAHIN et al. 2004, SEKER et al. 2004, CZAJA and GORNOWICZ 2006, KRAWCZYK 2009, NOWACZEWSKI et al. 2010 a,b) feeding methods (MILES and HENRY 2004, KORÉNEKOVA et al. 2007, YALČIN et al 2009, SULEYMAN and UYGUR 2010, SANGILIMADAN et al. 2012), housing system and prevention programs (VAN DEN BRAND et al. 2004, DE RUE et al. 2008, HIDALGO et al. 2008, DUKIĆ-STOJČIĆ et al. 2009), as well as environmental conditions of rearing, such as temperature and humidity, as well as the CO_2 content in the room (SAMLI et al. 2005, RAJI et al. 2009), methods of storing eggs (DUDUSOLA 2009) and conditions of their distribution.

For the consumer, especially significant are such quality traits of the egg as its size (weight) and freshness, to which testify, above all, height of thick albumen, size of its surface area after breaking out and values of Haugh units, as well as the size of the air cell (ROBERTS 2004, DUDUSOLA 2009, GENCHEV 2012). In the formation of egg quality, a significant role is played by, among others, time and conditions of their storage, as eggs undergo the biological process of aging, which is initiated at the time of laying them. Intensity of changes occurring in the egg content during its storage is determined to a high degree by mechanical damage as well as the effect of external factors on eggs, such as temperature, humidity and sunlight. Eggs stored at a lower temperature, retain their freshness longer through inhibiting development of microflora. Storage temperature has a significant effect on the egg weight, albumen height, value of Haugh units, yolk index and size of the air cell (SAMLI et al. 2005, PIOTROWSKA 2010).

Owing to their specific structure and content of biologically active compounds, eggs belong to the most durable materials of animal origin (ROBERTS 2004). The basic structural element protecting the egg content against microbiological contamination is the shell along with outer and inner membranes and strong alkaline pH of the albumen, in which occur proteins of an antibacterial activity, ie. lysozyme, conalbumin and avidin (GOŁĄB and WAWRAS 2005, WĘSIERSKA 2006).

In order to retain good quality traits and complete usability as food, various forms of storage and conservation of eggs are used. Refrigeration is of greatest importance as it allows to maintain a high quality of eggs, while slowing down the ageing processes and reducing microflora development (JONES et al. 2004). Conducting measurements of physical and chemical changes occurring in the egg during the storage time allows to determine level of freshness, and thus its quality and culinary and technological value (CZARNIECKA-SKUBINA 2012). The aim of the research was determination of the effect of 7-week storage time on the quality of Japanese quail eggs, with a special consideration of traits, which the consumers and producers of eggs are interested in.

Materials and Methods

The research was carried out in the Department of Animal Science, Establishment of Poultry Breeding, of the Faculty of Animal Breeding and Biology, of the University of Science and Technology in Bydgoszcz, Poland. The experimental material included table eggs of Japanese quail, from the peak of the first laying period in birds. The eggs were obtained from layers in their 17. week of life, in their 10. week of laying. The flock had a population of 2000 birds.

The study included 210 eggs collected on the same day. The eggs were stored for between 1 and 7 weeks in a cooler at a temperature of 4°C. After 24 hours from laying, all eggs were weighed individually with the use of scales RADWAG WPS 360 C. In order to evaluate the effect of storage time on quality, in each week of storage 30 eggs were designated for the evaluation of the egg content.

The egg weight (g) was determined on a scales RADWAG WPS 360 C. Next, the egg content was broken out, and with the use of QCD system (TSS), the height of thick albumen and yolk (mm) was measured. With the use of a digital caliper, the yolk diameter was determined along chalaza lines, as well as the diameter of thick albumen (mm). The height of thick albumen (H) and the egg weight (W) allowed for calculating Haugh units according to the formula (WILLIAMS 1992): $HU=100 \lg (H + 7.7\text{-}1.7 W^{0,37})$. With the use of a pipette, two albumen fractions were separated from the egg content: a thick and a thin one. The yolk and then the thick albumen were weighed on scales WPS 360 C.

The eggshell after breaking out the content, was dried for an hour at a temperature 105°C in a laboratory dryer, type SUP 100 M. Next, on scales Medicat 160, shell weight [g/cm^3] was evaluated, while an electronic micrometer screw gauge was used to measure its thickness [mm]. Shell density was determined after separating a sample of about 1- to 2-grams with the use of a set for determining density of solids with the use of scales program, WPS 360 C. Distilled water, of a temperature of 17°C, was used as a standard liquid for determining shell density. Weight of thin albumen was calculated from the difference between the egg weight and the weight of yolk, thick albumen and shell. Proportional content of the yolk, thick albumen and thin albumen, as well as the shell was compared to the egg weight.

The evaluation of traits indicating the egg freshness did not include study of the depth of the air cell because of the pigmentation of eggshells, specific for this bird species. It is consistent with methodical assumptions of the studies carried out on quail eggs by other authors (DUDUSOLA 2009, DUKIĆ-STOJČIĆ et al. 2009, RAJI et al. 2009, NOWACZEWSKI et al. 2010a, NOWACZEWSKI et al. 2010b, SANGILIMADAN et al. 2012, JIN et al. 2011, SALMAN and TABEEKH 2011, GENCHEV 2012, LUKÁŠ et al. 2013).

The collected numerical data has been developed statistically with the use of STATISTICA PL (Statistika 2002), by ANOVA module. Mean values (x) of the studied traits and their variation coefficients (v) have been calculated. The significance of differences between the storage time of eggs have been verified by Sheffe test.

Results and Discussion

Basic indicators of physical and chemical changes occurring in the ageing process are the losses and diffusion of water and gases in the egg content, which cause, among other things, decrease in the egg volume and extension of the air cell, and thus decrease in the weight of the whole egg. While analyzing the mean egg weight (Table 1) it was found that seven weeks of storage did not significantly affect the variation of this trait. However, the proportional loss in the egg weight during storage increased with every week and was from 1.13% in the 2nd week to 2.78% in the 7th week of storage. Significant differences were observed between the first two weeks and the last one, which testified to the highest proportional weight loss in the final period of storage.

Table 1

Characteristics of the structure of quail eggs and their shells in successive weeks of storage

Storage Time (weeks)		Egg				Eggshell			
		weight [g]		weight loss		weight		thickness [mm]	density [g cm^{-3}]
		fresh egg	at the test time	[g]	[%]	[g]	[%]		
I	x	12.1^a	12.1^a	–	–	0.90^a	7.4^a	0.211^a	1.568^a
	v	5.8	5.8	–	–	13.3	10.8	9.6	9.3
II	x	11.8^a	11.7^a	0.13^b	1.13^b	1.00^a	8.6^a	0.245^a	1.541^a
	v	6.8	6.8	46.1	43.4	10.0	8.1	16.7	13.4
III	x	11.8^a	11.6^a	0.18^a	1.46^b	0.96^a	8.3^a	0.217^a	1.593^a
	v	5.9	5.2	55.6	54.8	7.3	6.0	4.2	11.2
IV	x	11.6^a	11.4^a	0.24^a	2.09^{ab}	0.88^a	7.8^a	0.208^a	1.549^a
	v	4.3	3.5	20.8	20.6	13.6	12.8	8.2	5.2
V	x	11.1^a	10.8^a	0.28^a	2.49^{ab}	0.86^a	7.9^a	0.217^a	1.348^a
	v	5.4	5.6	28.6	27.7	10.5	10.1	13.4	12.9
VI	x	11.9^a	11.6^a	0.31^a	2.65^{ab}	0.97^a	8.4^a	0.221^a	1.440^a
	v	9.2	10.3	35.5	38.6	8.2	10.7	18.6	9.2
VII	x	11.3^a	10.9^a	0.31^a	2.78^a	0.97^a	8.9^a	0.206^a	1.352^a
	v	7.1	7.3	19.4	19.1	7.2	5.6	7.8	14.1
Total	x	11.6	11.4	0.22	1.89	0.93	8.2	0.216	1.474
	v	6.9	7.0	59.1	58.7	10.8	11.0	12.0	12.3

$^{a,\,b}$ – mean values of the traits in columns in particular weeks of storage denoted by different letters differ significantly (P = 0.05)

x – standard value

v – coefficient of variation

Worse results were obtained by Moraes et al. (2009), in whose research, the weight loss in eggs stored at a temperature 7.5°C was on the 20th storage day 3.4%. It was probably the result of a higher by 3.5°C storage temperature, compared to the temperature of storing eggs in the author's own research.

During storage of quail eggs at a temperature of 13°C and humidity of 75–80% AYGUN and SERT (2013) observed egg weight loss of 1.72% after 7 days and 2.73% after 14 days. On the other hand, NOWACZEWSKI et al. (2010a), while comparing traits of fresh quail eggs with the ones stored for 3, 5 and 8 days (at a temperature of 19°C and relative moisture 50–55%), found that the egg weight decreased significantly from day 5 of storage. From other studies of this author (NOWACZEWSKI et al. 2010b), however, it follows that apart from thermal and moisture conditions, also the egg size has an influence on the weight losses in quail eggs during storage.

DUDUSOLA (2009), while using various storage techniques with quail eggs (at a room temperature, in a refrigerator, immersing in groundnut oil, storing in black polythene bag), observed the highest losses in the egg weight, both fresh ones and those stored for 4, 7, 14 and 21 days in the egg group kept at a room temperature, and the lowest in eggs subjected to several seconds of immersing in oil. AYGUN and SERT (2013) showed statistically significant differences in egg weight loss after sprinkling quail eggs from the control group with a 15% solution of propolis. A decrease in evaporation of water from 1.80% to 1.37% after the first week of storage, and from 2.74% to 2.28% was observed. CANER and YÜCEER (2015) showed that hen egg weight loss during a 6-week storage at a temperature of 24°C can be limited by covering the egg surface with shellac and zein. The authors recorded lower egg weight loss – 5.72% and 4.58% respectively – as compared to eggs not covered with any substance. Thus, from the quoted research it follows that apart from temperature and humidity, and their weight, also method of storage has an effect on the weight loss in eggs.

Similar tendencies concerning the formation of egg weight and its losses during storage with various methods (in a refrigerator at 5°C, at a room temperature of 21°C, as well as at a high temperature of 29°C), were observed by SAMLI et al. (2005) in chicken eggs, stored for 2, 5 and 10 days. From these studies it follows that in case of eggs stored in a refrigerator, at a temperature 5°C, no significant differences were found in the egg weight. However, along with an increase in temperature and storage time, losses in the egg weight significantly increased from 0.32 g (2nd day) to 0.65 g and 1.30 g, respectively on the 5th and 10th day of storage (temperature 21°C) and from 0.42 to 1.03 and 1.94 g (temperature 29°C).

Mineral compounds in the eggshell provide a long-term stability and mechanical resistance to deformation. It was confirmed in the results of the author's own research, which indicated that long-term storage of Japanese quail eggs at low temperatures had no visible effect ($P < 0.05$) on the shell weight, its thickness and density (Table 1). Different conclusions concerning the formation of the shell weight during storage of quail eggs were formulated by NOWACZEWSKI et al. (2010 a) who found that shell weight decreased. These authors observed the lowest shell weight after 5 and 8 weeks of egg storage. These values significantly differed from the ones found in fresh eggs and those kept for 3 days. On the other hand, BAYLAN et al. (2011) proved that storage temperature to a slight degree affects shell thickness. However, quoted authors observed differences in the shell weight. During 45-day storage time at a temperature 4°C, a loss of approximately 0.14 g was observed, while at a temperature of 20°C, the weight loss was 0.20 g.

Egg albumen as a component of the highest weight in the structure of eggs is characterized by the most intensive physical and chemical changes, and processes occurring during the storage time. At first, there occurs a loss of water through evaporation via pores in the eggshell and via permeable membranes. The author's own research did not indicate any statistically significant differences within the weight of thick and thin albumen in total (Table 2). However, the weight of thick albumen decreased along with the extension of the eggs' storage time from 2.6 g to 1.6 g, although these differences were mostly not confirmed statistically, apart from the value of this trait in eggs stored for 7 weeks. Different results were indicated by

Table 2

Traits of the yolk and albumen in quail eggs in successive weeks of storage

Storage Time (weeks)		Weight [g]				Diameter [mm]		Height [mm]		Haugh units [HU]
		yolk	albumen			yolk	thick albumen	yolk	thick albumen	
			thick	thin	total					
I	x	3.6[a]	2.6[a]	5.0[a]	7.6[a]	25.8[a]	48.0[a]	12.3[a]	4.9[a]	91.4[a]
	v	5.6	19.2	16.0	6.6	5.4	10.2	6.5	16.3	5.3
II	x	3.3[a]	2.6[a]	4.8[a]	7.4[a]	24.9[ab]	42.3[ab]	11.4[a]	5.1[a]	92.6[a]
	v	9.1	23.1	16.7	6.8	4.8	10.4	6.1	13.7	4.2
III	x	3.4[a]	2.5[a]	4.7[a]	7.2[a]	24.1[ab]	40.3[b]	12.2[a]	4.8[a]	91.1[a]
	v	8.8	20.0	10.6	5.6	2.1	4.2	4.9	6.3	1.8
IV	x	3.4[a]	2.4[a]	4.7[a]	7.1[a]	24.1[ab]	38.7[b]	11.8[a]	4.4[a]	89.0[a]
	v	11.8	29.2	14.9	4.2	4.1	7.0	9.3	9.1	2.8
V	x	3.3[a]	1.9[a]	4.8[a]	6.7[a]	23.1[b]	36.1[b]	12.1[a]	4.1[a]	87.9[a]
	v	11.8	15.8	10.4	6.0	5.6	4.4	2.5	30.0	6.1
VI	x	3.7[a]	2.0[a]	5.0[a]	7.0[a]	23.4[b]	37.0[b]	11.8[a]	4.1[a]	87.2[a]
	v	10.8	15.0	16.0	11.4	5.1	7.3	5.1	7.3	1.8
VII	x	3.3[a]	1.6[b]	5.0[a]	6.6[a]	23.0[b]	36.5[b]	11.5[a]	4.0[a]	87.2[a]
	v	9.1	12.5	14.0	9.1	4.3	4.4	5.2	12.5	3.6
Total	x	3.4	2.2	4.9	7.1	23.9	39.5	11.9	4.4	89.2
	v	8.8	27.3	14.3	8.5	5.9	12.2	5.9	15.9	4.4

[a, b] – mean values of the traits in columns in particular weeks of storage denoted by different letters differ significantly ($P = 0.05$).
x – standard value
v – coefficient of variation

NOWACZEWSKI et al. (2010 a). The authors found statistically confirmed differences in the albumen weight already after 3 days of storing quail eggs. In their studies on hen eggs SCOTT and SILVERSIDES (2000) observed statistical differences in the weight of albumen after the 5th and 10th day of storage, respectively 1 g and 1.49 g.

Following the loss of water and carbon dioxide from the egg albumen there occurs thinning of its thick fraction, which is characteristic of the advanced ageing process in the egg. In the author's own research, no significant differences were indicated in the height of thick albumen (Table 2). Values of Haugh units were from 91.4 in the 1st week to 87.2 in the 7th week of storage, which may testify to retaining freshness in eggs. From the studies of other authors (DUDUSOLA 2009, NOWACZEWSKI et al. 2010b). It follows that worse results are obtained while storing eggs at higher temperatures. This is also confirmed by the research carried out on chicken eggs by SAMLI et al. (2005), in which they observed a significant deterioration of the albumen quality along with an increase in temperature and time of egg storage. Quoted authors observed a decrease in the value of HU from 91.4 to 76.3 at a temperature 5°C for 10 days of storage, while at a temperature 21°C and 29°C HU values decreased to 53.7 and 40.6 respectively. Lower albumen quality in eggs stored at higher temperature than in the refrigerator, at a temperature 15.5°C, is confirmed in the studies also carried out on chicken eggs by MILES and HENRY (2004).

NOWACZEWSKI et al. (2010b) during a one-week storage of quail eggs at a temperature 15°C, observed a decrease in Haugh units by 6.5, compared to the initial state, being 86 HU. On the other hand, DUDUSOLA (2009), while using various methods of storing quail eggs, found the highest values of Haugh units (62.1 to 58.4) in eggs kept in a refrigerator and the lowest (53.8 to 57.4) in the group of eggs stored at a room temperature. HU values in eggs stored with all four methods (at a room temperature, in a refrigerator, immersing in groundnut oil, storing in black polythene bag) decreased along with an extension of storage time. Only statistically confirmed differences between 4-day and 7-day egg storage at a room temperature and in the refrigerator were not indicated.

The final protective barrier in the layer structure of the egg is vitelline membrane, which gives shape to the yolk and maintains diffusive balance between albumen and yolk. During long-term egg storage, water from the albumen may diffuse through vitelline membrane to the yolk, increasing its volume. In the author's own research, no statistically significant differences were indicated in the yolk weight between successive evaluation dates. This is confirmed by the research of NOWACZEWSKI et al. (2010 a), in which it was also proved that time of storing quail eggs did not affect the yolk weight. From other studies of this author (NOWACZEWSKI et al. 2010 b), it follows that apart from the duration of storage time, also the egg size has an effect on the proportional share of yolk. Quoted authors observed that in case of storing eggs both for 3 and 5 days, quail eggs of a higher weight (> 12.51 g) were characterized by a higher proportion of yolk, by approximately: 2.3 and 1.5%, respectively, than lighter eggs (to 10.50 g and from 10.51 –11.50 g). However, according to MORAES et al. (2009), duration of storage time does not significantly affect the proportional share of the egg yolk.

Conclusion and Applications

1. Analysis of changes occurring in quail eggs during 7-week storage indicated lack of significant differences between particular dates of evaluation in the egg weight. Significant differences in the proportional weight losses were observed only between the first three and the last week of egg storage.

2. During the 7-week period included in the studies, no statistically significant differences were observed in the weight of yolk and thick and thin albumen in total. Invariable height of thick albumen and high values of Haugh units during the whole storing period testified to the retention of high albumen quality in eggs.

3. These results allow to state that quail eggs are characterized by a relatively long period of retaining freshness, and their 7-week storage does not affect quality deterioration, and consequently their culinary and technological value.

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