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Egg Quality of Japanese Quail Depends on Layer Age and Storage Time

Sebastian NOWACZEWSKI, Helena KONTECKA, Andrzej ROSIŃSKI, Sebastian KOBERLING and Piotr KORONOWSKI

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The aim of the study was to analyse egg quality changes of Japanese quail during the reproductive season and after several days of storage. A significantly higher egg weight was recorded in week 9 than in week 25 and week 31 of age of birds. The egg specific gravity value of eggs also decreased with the age of quails. The smallest yolk weight and its percentage proportion in egg mass were observed in week 25. Eggs laid in weeks 9 and 25 were characterised by similar and lower ($P \leq 0.05$) white weight in comparison to those examined on the last date. The highest white proportion in egg weight was recorded during the 25th week. The value of this trait was similar or smaller on the remaining dates. Similar and lower values of the white index and Haugh units, in comparison with the first date, were determined in eggs laid on weeks 25 and 31, whereas similar and greater eggshell thickness than in the 9th week of age was recorded on the last two dates of examination. Lower ($P \leq 0.05$) egg weight was observed after 5 and 8 than after 0 (measured on the day of laying) days of storage. Likewise, smaller egg specific gravity was recorded after three consecutive periods of storage in comparison with the eggs examined on the day of laying. Eggs examined after 3, 5 and 8 days of storage, in comparison with those stored for 0 days, were characterised by lower yolk index. Significantly smaller weight and white index than after 0 days were determined in eggs stored, respectively, for 5 and 8 as well as for 3, 5 and 8 days. Similarly, smaller numbers of Haugh units were determined after 3 consecutive storage periods in comparison with the eggs examined on the day of laying. Eggs stored for 0 and 3 days were characterised by a greater eggshell weight than those examined after 5 and 8 days. The weight of Japanese quail eggs decreased significantly from day 5 onwards, whereas the egg specific gravity – from the 3rd day of storage. Yolk and white quality began to deteriorate already after 3 days of egg storage. It appears, therefore, that egg storage of Japanese quails before hatching lasting more than 3 days in the analysed conditions deteriorated the eggshell quality and internal egg traits.

Key words: Japanese quail, egg quality, age, storage time.

Sebastian NOWACZEWSKI, Helena KONTECKA, Andrzej ROSIŃSKI, Sebastian KOBERLING and Piotr KORONOWSKI, Department of Poultry Science, Poznań University of Life Sciences, Witosa 45, 61-693 Poznań, Poland.
E-mail: sebnow@jay.au.poznan.pl

Egg quality traits are influenced by many factors, including genetic and environmental ones (BEDNARCZYK 1991). In addition, the quality of laid eggs can further be affected by the age of birds. In this regard, the domestic hen is by far the best known species. It was demonstrated that with the age of layers, the weight of their eggs increased, while features characterising the white (index, Haugh units) as well as the shell (thickness, strength) deteriorated (SZCZERBIŃSKA 1997; VAN DEN BRAND *et al.* 2004; AKYUREK & OKUR 2009). However, these results are frequently equivocal and can also vary depending on the poultry species. For example, investigating eggs of Pekin ducks, KOKOSZYŃSKI *et al.* (2007) failed to confirm that their eggshell thickness changed significantly with the passage of the reproduction period.

Both external and internal egg traits can further be significantly influenced by the length of storage period prior to hatching. Together with the lengthening of the storage period, unfavourable physicochemical changes of egg content take place (JONES & MUSGROVE 2005; SAMLI *et al.* 2005). In hens, it was demonstrated that eggs stored for more than 10 days were characterised by worse white and yolk indices and lower number of Haugh units, in comparison with those examined on the day of laying (0 days of storage), (YILMAZ & BOZKURT 2009). Similar results were obtained in the case of pheasants (*Phasianus colchicus*). Comparing eggs after 1-2 and 9-10 days of storage, eggs stored for shorter periods were found to be characterised by higher values of the white and yolk indices and number of Haugh units (DEMIREL & KIRIKÇI 2009). In other investigations carried out on the rock partridge (*Alectoris graeca*), no significant differences were recorded in the white index and the number of Haugh units when egg quality was analysed after 1-2 and 9-10 days of storage (CAĞLAYAN *et al*. 2009).

On the other hand, it is known that deteriorating egg quality, especially white and shell traits, may be one of the causes of obtaining worse hatching results. For example, thicker eggshells were found to contribute to better hatching results of broiler breeders. Moreover, these eggs were also characterised by lower embryo mortality during the middle and final periods of incubation (ROQUE & SOARES 1994). Higher embryo mortality and worse hatching results were also observed in eggs characterised by lower egg specific gravity (IPEK & SAHAN 2001). There are few publications involving complex egg quality assessment in Japanese quail in relation to the age of birds (IMAI *et al*. 1986; NARAYANANKUTTY *et al*. 1989; GONZÁLEZ 1995). There is no information on egg quality trait changes of Japanese quail during egg storage. Nevertheless, in this species research carried out on other domestic fowl were confirmed indicating that excessive egg storage before hatching can exert a negative influence on hatchability (SEKER *et al*. 2005; ROMAO *et al*. 2008; KOŻUSZEK *et al*. 2009).

The aim of this study was to analyse quality changes of Japanese quail eggs in the course of the reproduction period and following their storage for several days.

Material and Methods

The experimental material comprised eggs of Japanese quail (*Coturnix coturnix japonica*) of laying type in their first year of laying derived from a commercial farm. Up to week 6 of age, chicks were kept on rye or triticale litter in a rearing chamber of 40 m^2. There were approx. 5500 birds. During the growing period, Japanese quail were fed *ad libitum* complete diets which contained: 12.08 MJ/kg ME, 24% crude protein, 7% crude fat, 3% crude fibre and 1% calcium. Experimental birds began laying on the 7^{th} week of age, at mean body weight of 150 g, and finished egg production on the 43^{rd} week. During the entire laying period, the birds were kept in cages with a 35 birds/m^2 stocking rate with a 6:1 ratio of females to males. Adult Japanese quail were fed *ad libitum* complete diets which contained: 11.63 MJ/kg ME, 20.5% crude protein, 5% crude fat, 3% crude fibre and 3.1% calcium.

Eggs for investigations were selected randomly from eggs laid during 2 days on the 9^{th}, 25^{th} and 31^{st} weeks of age (respectively: date I, II and III). A total of 180 eggs were analysed (60 eggs were selected from about 1000 eggs at each date). Additionally, on week 11 and 33, we examined 20 eggs collected on each of these dates, stored for 0, 3, 5 and 8 days in identical conditions, i.e. at a temperature of 19°C and relative air humidity ranging between 50-55% (a total of 80 eggs was evaluated on each date). The following traits were assessed:

– Egg weight (g) with 0.01 g accuracy with the assistance of a WPS 360C type balance,

– Egg specific gravity (g/cm^3) using a set for the density determination of solids and liquids,

– Yolk weight (g) with 0.01 g accuracy with the assistance of the WPS 360C type balance,

– Yolk index (%) was calculated according to the formula:

$$\text{Yolk}_{\text{index}} = \text{yolk height (mm) x 100\%/yolk width (mm)}$$

– White weight (g) after subtracting the weight of yolk and eggshell from the egg weight,

– White index (%) was calculated according to the formula:

$$\text{White}_{\text{index}} = \text{thick white height (mm) x 100 \%/thick white width (mm)}$$

– Haugh units was calculated according to the formula:

$$HU = 100 \log (h - 1{,}7\ W^{0{,}37} + 7{,}6)$$

where:

HU – Haugh units

h – average thick white height (mm)

W – egg weight (g)

– Eggshell weight (g) after drying at the temperature of 105°C until reaching constant weight with 0.01 g accuracy with the assistance of a WPS 360C type balance,

In addition, on the 9^{th}, 25^{th} and 31^{st} weeks of age the following traits were assessed:

– Egg shape index (%) on the basis of measurements of the egg length and width using slide calipers, with 0.02 mm accuracy,

– Content (%) of the yolk, white and eggshell in the egg mass,

– Eggshell thickness (μm) together with shell membranes at the equatorial part of the egg using a micrometre screw,

– Shell water vapour conductance determined on an extra 15 eggs in each examination period according to the method developed by AR *et al.* (1974) and calculated according to the formula:

$$P = \frac{mg\ H_2O}{day \times torr}$$

where:

P – water vapour permeability through the eggshell,

mg H_2O/day – mean daily egg weight loss in the form of water vapour,

torr = 23,756 – value read from Tables – pressure of saturated water vapour at a temperature of 25°C (ACHMATOWICZ 1954)

Statistical calculations were conducted with the assistance of the SAS® v. 9.1 package. Mean values ($\bar{x}$) as well as the standard errors of the means (SEM) were calculated for all traits. Differences

Table 1

Japanese quail's eggs quality in different weeks of age

Trait		Week of age 9	25	31	Mean 9-31
Egg weight (g)	$\bar{x}$	11.33 a	10.91 b	11.09 ab	11.11
	SEM	0.080	0.100	0.091	
Egg shape index (%)	$\bar{x}$	79.0 a	79.6 a	79.1 a	79.2
	SEM	0.376	0.360	0.386	
Egg specific gravity (g/cm^3)	$\bar{x}$	1.059 a	1.052 b	1.046 c	1,052
	SEM	0.002	0.001	0.001	
Yolk weight (g)	$\bar{x}$	3.50 a	3.25 b	3.42 a	3.39
	SEM	0.044	0.043	0.045	
Yolk content (%)	$\bar{x}$	30.97 a	29.75 b	30.88 a	30.53
	SEM	0.274	0.233	0.240	
Yolk index (%)	$\bar{x}$	49.18 a	48.60 ab	47.67 b	48.48
	SEM	0.397	0.432	0.354	
White weight (g)	$\bar{x}$	6.90 a	6.78 a	7.44 b	7.04
	SEM	0.065	0.080	0.066	
White content (%)	$\bar{x}$	61.10 a	62.11 b	61.07 a	61.43
	SEM	0.285	0.246	0.235	
White index (%)	$\bar{x}$	9.91 a	8.26 b	8.28 b	8.82
	SEM	0.245	0.201	0.183	
Haugh units (points)	$\bar{x}$	86.15 a	82.51 b	82.36 b	83.67
	SEM	0.474	0.384	0.358	
Eggshell weight (g)	$\bar{x}$	0.89 a	0.88 a	0.89 a	0.89
	SEM	0.010	0.009	0.011	
Eggshell content (%)	$\bar{x}$	7.92 a	8.14 a	8.04 a	8.03
	SEM	0.079	0.074	0.082	
Eggshell thickness (μm)	$\bar{x}$	197.2 a	203.9 b	200.7 ab	200.6
	SEM	0.002	0.002	0.002	
Shell water vapour conductance (mg H_2O/day * torr)	$\bar{x}$	1.55 a	1.60 a	1.97 a	1.71
	SEM	0.101	0.165	0.261	

Mean values designated in rows with different letters differ significantly at the level $P \leq 0.05$.

between age (weeks) of birds with regard to the egg traits were determined employing the one-way analysis of variance (ANOVA). Differences between storage times with regard to the egg traits were determined using a two-way analysis of variance (ANOVA).

For all traits, the significance of differences between weeks of age and storage times was verified using Fisher's test.

Results

Table 1 presents results regarding egg quality of Japanese quail at different ages. Egg weight was found to be by 0.33 g greater on the 9th (date I) than on the 25th (date II) and 31st (data III) week of age. No significant differences were found in the shape index between eggs derived from individual examined dates. With the age of birds, the value of egg specific gravity decreased significantly (by about 0.006 g/cm^3 on the examined dates). Both the smallest weight and percentage proportion of the yolk in the egg mass were determined during the 25th week of age. The recorded differences were significant and, in comparison with the remaining dates, amounted to, respectively, 0.21 g and 1.18 percentage points. In comparison with the first date, smaller yolk index values were observed in eggs laid on the 31st week. Eggs laid in weeks 9 and 25 were characterised by similar and significantly smaller white weight (on average by 0.60 g) in comparison with those examined on the last date. On the other hand, the highest proportion of the white in the egg mass was recorded on week 25. The value of this trait was found to be similar and smaller on the remaining dates. In comparison with the first date, similar and smaller white index value and Haugh units were observed in eggs laid during the 25th and 31st weeks of life. These differences were confirmed statistically and amounted to 1.64 percentage points and 3.72 points. In comparison with week 9, the eggshell was similar and thicker on the last two dates of examination ($\bar{x}$ = 202.3 vs. 197.2 μm). Eggs laid on the selected dates did not differ with regard to the weight of the eggshell, its percentage proportion in the egg weight and water vapour conductance.

Table 2 presents the quality of Japanese quail eggs (together for week 11 and 33) following dif-

Table 2

Japanese quail's eggs quality after different time of storage

Trait		Storege time (days)			
		0	3	5	8
Egg weight (g)	$\bar{x}$	11.37 a	11.26 ab	11.01 b	11.00 b
	SEM	0.116	0.128	0.134	0.174
Egg specific gravity (g/cm^3)	$\bar{x}$	1.065 a	1.044 b	1.042 b	1.039 b
	SEM	0.002	0.004	0.003	0.002
Yolk weight (g)	$\bar{x}$	3.39 a	3.43 a	3.42 a	3.39 a
	SEM	0.051	0.051	0.054	0.067
Yolk index (%)	$\bar{x}$	50.13 a	47.11 b	45.90 b	42.74 c
	SEM	0.467	0.442	0.385	0.589
White weight (g)	$\bar{x}$	7.05 a	6.89 ab	6.71 b	6.70 b
	SEM	0.080	0.091	0.089	0.113
White index (%)	$\bar{x}$	8.84 a	7.87 b	7.00 c	6.34 c
	SEM	0.238	0.261	0.235	0.212
Haugh units (points)	$\bar{x}$	84.13 a	82.09 b	79.93 c	78.40 d
	SEM	0.461	0.470	0.453	0.484
Eggshell weight (g)	$\bar{x}$	0.93 a	0.93 a	0.88 b	0.90 b
	SEM	0.010	0.014	0.017	0.016

Mean values designated in rows with different letters differ significantly at the level $P \leq 0.05$.

ferent periods of storage. In comparison with 0 days of storage (measurements taken on the day of laying), the weight of eggs after 5 and 8 days of storage was lower. The recorded difference was statistically significant and amounted to about 0.32 g. Similarly, lower egg specific gravity, in comparison with the eggs examined on the day of laying, by approximately 0.023 g/cm^3 was observed after the 3 consecutive periods of storage. The duration of storage did not affect the yolk weight. On the other hand, eggs examined after 3, 5 and 8 days – in comparison with the eggs stored for 0 days – were characterised by a significantly lower yolk index by 3.02, 4.23 and 7.39 percentage points, respectively. It should be mentioned that values of this trait for eggs analysed after 3 and 5 days of storage were similar and, on average, amounted to 46.5%. Significantly lower weight and white index (by about 0.35 g and 1.77 percentage points) than after 0 days of storage were determined in the eggs stored, respectively, for 5 and 8 days as well as after 3, 5 and 8 days. Also the number of Haugh units was on average lower by 4 points after three consecutive periods of storage when compared with the eggs assessed on the day of laying. Eggs stored for 0 and 3 days were characterised by greater shell weight in comparison with those stored for 5 and 8 days. The difference was statistically significant and, on average, amounted to 0.04 g.

Discussion

Both age of birds and egg storage time can significantly influence egg quality traits. The mean egg weight of experimental Japanese quail in this experiment was about 1 g smaller than that reported by SAHIN *et al*. (2007) but similar to the results obtained by SEZER (2007). By analysing egg weight changes according to age of the experimental birds, it was found that the value of this trait in week 25 was smaller than in week 9. Different results were reported by GONZÁLEZ (1995) who found similar and significantly higher weight of eggs laid in weeks 12, 17, 21, 25 and 30 than in week 8 of life (10.72 against 9.67). On the other hand, IPEK *et al*. (2004) reported a significant increase of egg weight together with age of Japanese quail. They found that in periods: 7-10; 11-14; 15-18 and 19-22 weeks of age, it amounted to: 9.22; 10.98; 11.97 and 12.35 g, respectively. Similar trends for increased egg weight together with the passage of the laying period were reported in hens by BRAND *et al*. (2004) and TONA *et al*. (2001), although the latter researchers observed a gradual decrease in egg weights beyond week 52. It is difficult to explain why, in our study, the mean egg weight decreased on the 25th week of age. It is also well known that many factors (i.e. stock density, nutrition, environmental conditions, etc.), including age of birds, can be the cause of these changes. On the other hand, all quails were fed with the same complete diet, so this factor does not seem to be significant. However, the middle and the final period of quail reproduction took place during a hot season of the year (summer months). SAKURAI after SHANAWAY (1994) reported that quail eggs weight was reduced when birds were exposed to high ambient temperature (26-28^{o}C). It is worth emphasizing that TSERVENI-GOUSI (1987) also observed a lower quail egg weight in weeks 23 and 27 in comparison to weeks 15 and 19. The differences were statistically significant and amounted to about 1.25 g. But the author did not explain the obtained results.

In our experiments, the shape of eggs laid by Japanese quails was not affected by the age of the birds, although it was demonstrated that with increasing bird age the specific gravity of the examined eggs declined. GONZÁLEZ (1995) reported a significant decrease of the egg shape index of Japanese quail by approximately 1.57 percentage points in the period between 8 and 17 weeks of age. Afterwards, the value of this character stabilised and amounted, on average, to 77.1% up to the 39th week of age. As in our study, the same researcher reported certain tendencies regarding changes of egg specific gravity together with the age of birds. The value of this trait in weeks 8, 25 and 30 amounted to: 1.072; 1.066 and 1.066 g/cm^3, respectively. On the other hand, KOKOSZYŃSKI *et al*. (2007) found in Pekin ducks a higher egg shape index towards the end of the reproduction period rather than at its beginning (75.0 against 72.8%).

For yolk quality, it was found that the highest index occurred at the beginning of the laying period (9th week of age). However, the mean value for the entire reproductive period for the yolk index was 2.9 percentage points lower in comparison with those reported by GONZÁLEZ (1995) for Japanese quail in the period from week 8 to 21 of age. On the other hand, NAGARAJAN *et al*. (1991) demonstrated a higher value for the yolk index in Japanese quail eggs laid in the 18th, 22nd, and 26th weeks than in week 10 of age. Similar results in Japanese quail were obtained by NARAYANANKUTTY *et al*. (1989). However, in experiments conducted on laying hens AKYUREK & OKUR (2009) reported, in accordance with our results, a higher yolk index at the beginning of the laying season, i.e. in week 22 than in week 50. On the other hand, in the case of ducks, no significant changes in the yolk index were observed during the entire reproduction period (KOKOSZYŃSKI *et al*. 2007).

The white index value as well as Haugh units were the highest at the beginning of the laying period. The mean results for the entire reproductive period regarding white index were 4.0 percentage points lower in comparison with those reported by GONZÁLEZ (1995) for Japanese quail (8 to 21 week of age). NAGARAJAN *et al*. (1991) demonstrated higher values of white index in Japanese quail eggs laid during the 18th, 22nd, and 26th week rather than in week 10. In experiments conducted on laying hens, AKYUREK and OKUR (2009) reported higher values of white index and Haugh units at the beginning of the laying season, i.e. in week 22 than in week 50 of age. On the other hand, KOKOSZYŃSKI *et al*. (2007) reported that duck eggs laid at the beginning of the laying season were characterised by a significantly higher (by 10.6 points) number of Haugh units in comparison with eggs laid at the end of the reproductive period.

Our experiments failed to indicate that age of Japanese quail exerted any influence on eggshell weight and its percentage proportion in the egg mass. On the other hand, its slightly greater thickness was recorded during weeks 25 and 31. GONZÁLEZ (1995) reported very variable results regarding the eggshell thickness during different laying periods of Japanese quail. The mean value of this trait ($\bar{x}$ = 0.197 mm) was, however, similar to that obtained in our investigations for 9-week old quails. Although it is well known that in hens eggshell quality deteriorates with age, nevertheless there are too many genetic (breed, time the egg remains in the shell gland etc.) as well as environmental (in particular – feeding) factors affecting this trait to draw unequivocal conclusions.

Storage time induced a non-significant decline in egg weight and specific gravity - when compared with fresh eggs (0 days of storage), these indices decreased after 5 and 8 days and after 3, 5 and 8 days, respectively. On the other hand, AKYUREK & OKUR (2009) in the case of 22-week old free-range hens failed to find significant changes in the weight of eggs examined after 0, 3, 7, 10 and 14 days of storage. However, they reported smaller specific gravity of the examined eggs after 10 and 14 than after 0 and 3 days of storage (1.073 against 1.093 g/cm^3). Similarly, SAMLI *et al*. (2005) did not record changes in the weight of hen eggs stored at a temperature of 21^{o}C, although egg specific gravity decreased significantly together with the passage of time (from 1.086 to 1.074 g/cm^3). As the eggs of Japanese quail grew older, egg yolk and white quality deteriorated as evidenced by lower index values of both of these morphological elements as well as by the number of Haugh units. Experiments carried out on hens revealed a less rapid deterioration of yolk quality with the passage of storage time (AKYUREK & OKUR 2009). On the other hand, in the case of the white index and number of Haugh units, much lower values of these traits were demonstrated after 7, 10 and 14 days of storage than in fresh eggs and the difference amounted to 4.8 % and 23.6 points, respectively. In experiments on rock partridges, TILKI & SAATCI (2004) reported deterioration of white quality when eggs were stored for 7 and 14 days, although on both of the above dates similar values for Haugh units were recorded ($\bar{x}$ = 81.7 points). DEMIREL and KIRIKÇI (2009) did not notice a significant deterioration of white quality in pheasant eggs stored for 1-8 days.

In our investigations, the shell weight of Japanese quail eggs was observed to decrease only after 5 and 8 days of storage. In experiments on hens carried out by AKYUREK and OKUR (2009), no impact of egg storage time on mean eggshell weight was confirmed, despite the fact that experimental eggs were stored at relatively extreme temperatures, i.e. 4 and 20^{o}C. Also ÇAĞLAYAN *et al*. (2009) failed to record a significant influence of storage time (from 1 to 14 days) on eggshell weight of the rock partridge, although in another experiment SAMLI *et al*. (2005) observed a decrease of the eggshell weight of the hens eggs (from 7.8 to 6.4 g) during a period of 0 to 10 day storage.

The highest proportions of white and the simultaneous lowest proportions of yolk in Japanese quail eggs were recorded in the 25th week of age. It should be emphasized that poorer yolk than on the 9th week of age (lower index) and white quality (lower index and number of Haugh units) was determined in eggs laid on weeks 25 and 31. This confirmed the hypothesis that the content quality of Japanese quail eggs deteriorated with the age of experimental birds.

The weight of Japanese quail eggs decreased significantly from day 5 onwards, whereas the egg specific gravity – from the 3rd day of storage. Yolk and white quality began to deteriorate already after 3 days of egg storage. It appears, therefore, that egg storage of Japanese quail before hatching lasting more than 3 days in the analysed conditions deteriorated the eggshell quality and internal egg traits. In order to obtain more unequivocal results and draw more clear-cut conclusions, it is necessary to conduct further investigations into the problems associated with the storage of Japanese quail eggs and changes in their quality in combination with hatchability results.

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