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Changes in the quality of table eggs depending on storage method and time

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The aim of the research was to determine the changes occurring in table eggs depending on storage time at room temperature and in refrigeration conditions. The experimental material consisted of 75 eggs, which were randomly divided into five groups of 15. The first group (the control) comprised fresh eggs, which were tested on the day they were collected. The remaining 60 eggs were divided into two groups (30 eggs in each) and stored under different conditions for a period of 28 days. Eggs from the first group (I) were stored at room temperature, which was about 20°C with 50% humidity. Eggs from the second group (II) were placed in cold storage at 4°C and about 30% humidity. After 14 and 28 days of storage, the physicochemical properties of the eggs were analysed: the height of the air space, egg density, egg weight loss, albumen and shell quality, and yolk colour. The results indicate that the storage method had a significant (P≤0.05) effect on most of the egg quality traits analysed. Eggs stored at 4°C were of good quality and were classified as EXTRA class eggs even after 28 days. Eggs stored at 20°C were eliminated as Class A eggs as early as day 14, and on day 28 their quality disqualified them as fit for consumption. To sum up, food eggs should be refrigerated before being sold to the consumer to prevent premature ageing and thus deterioration of quality.

KEY WORDS: eggs / temperature/ storage time / egg quality

The egg is a product of animal origin that has all the desired nutrients in the right proportions, as well as high digestibility [4]. It is one of the oldest food products [12, 17], considered a low-energy food with many vitamins and minerals [29].

The egg has a characteristic layered structure which has a protective function, preventing the migration of microorganisms to the interior of the egg while at the same time allowing the diffusion of matter and energy between the cell and the internal and external environment [26].

From the moment the egg is laid, metabolic processes begin in its interior. Natural ageing of the egg is a fundamental problem that leads to biophysical and chemical

changes in its contents [20, 28]. As a consequence of these changes, the natural protective capacity of the egg is lost, and thus more microorganisms penetrate its interior. As a result, the eggs spoil faster. How quickly microorganisms penetrate the egg and the degree of deterioration of its quality depend on the hygienic condition of the egg and the surrounding environment. Changes in egg quality have been shown to be associated with the temperature and length of storage [2, 18]. These factors primarily affect the number of Haugh units, the pH of the albumen, and the size of the air space, which are the most important quality indicators [22]. According to Olivier and Olivier [19], changes in the yolk and albumen resulting from ageing of the egg lead to changes in its taste.

The most intensive processes occurring inside the egg concern the loss of water and gases. The evaporation of water leads to a reduction in the volume of the albumen, resulting in an increase in the size of the air space, while the release of dissolved carbon dioxide leads to alkalization of the albumen. The pH of the albumen increases from 8.2 to even 9.5 during advanced ageing of the egg. As a consequence, the thick albumen changes from a gelatinous, stable form into a thin liquid form. The height of the albumen decreases, resulting in a decrease in the number of Haugh units, which for fresh eggs should range from 72 to 110 [27]. During egg ageing, an increase in yolk volume and weakening of its structure may be observed as well, which leads to independent breakage of the vitelline membrane [13, 15] due to the penetration of water from the white to the yolk. Another important factor that leads to spoilage of eggs is the increase in the number of pathogenic bacteria in the contents, which occurs after 12-30 days of storage. Bacteria produce various lipolytic or proteolytic enzymes, whose activity depends on pH and temperature [29].

Many means of storing eggs have been developed to prolong their shelf-life. According to Giampietro-Ganeco et al. [9], packaging in a modified atmosphere preserves the high quality of eggs up to 28 days. However, the basic and at the same time the easiest method is refrigeration [10]. According to Feddern et al. [7], eggs kept at room temperature should be consumed within two weeks, while refrigerated eggs retain good quality up to eight weeks. According to Commission Regulation 589/2008 of 23 June 2008 [21] on marketing standards for eggs, eggs ‘should in general not be refrigerated before sale to the final consumer’. This is explained by the possibility of condensation when the eggs are later placed at room temperature, which may be conducive to the growth of bacteria on the shell. According to the regulation, the shelf-life of the egg after laying is 28 days. However, it should be emphasized that eggs in retail outlets are usually stored at ambient temperatures of up to 20-25°C, which highly accelerates their ageing process. Thus it is very likely that the consumer will buy eggs that are about two weeks old, still suitable for consumption, but of much poorer quality.

The aim of the research was to determine changes occurring in table eggs depending on storage time at room temperature and in refrigeration conditions.

Material and methods

The experimental material comprised table eggs from Lohmann Brown laying hens kept in a battery system. The eggs (75) were collected at the peak of laying (about the 16th week), marked, and submitted for analysis in the Egg Quality Assessment Laboratory of the Department of Poultry Science, University of Warmia and Mazury in Olsztyn.

The first step was assessment of the quality of fresh eggs, which was performed on 15 eggs immediately after collection. The remaining 60 eggs were divided into two groups (30 in each) and stored under different conditions for 28 days. Eggs from the first group (I) were stored at room temperature, which was about 20°C with 50% humidity. Eggs from the second group (II) were refrigerated at 4°C and about 30% humidity.

On the 1st, 14th and 28th days of the experiment, the physicochemical properties of the eggs were tested to assess changes indicative of ageing. The eggs were weighed individually to determine weight losses and the air space was measured. The density of the eggs was measured using an Axis Hydro AD densitometer (Gdansk, Poland). Then the eggs were broken and the quality of the albumen was assessed, based on its height and the weight of the egg, and expressed using Haugh units [11]. The yolk colour was specified using the 15-point DSM scale. Next, the yolk was separated from the white and weighed in order to determine the percentage share of each part of the egg. Shell thickness was expressed as the mean of measurements on three parts of the egg (the blunt and narrow ends and the short axis), made with a micrometer. The strength of the shell was determined using an Egg Force Reader (ORKA Food Technology).

The results were statistically analysed by one-way analysis of variance in Statistica 13.0 software, at a significance level of $P \leq 0.05$ [23]. The significance of differences between means was determined using Duncan's test.

Results and discussion

The physicochemical characteristics of eggs stored at room temperature are shown in Table 1. Most of the features analysed deteriorated significantly with storage time. There was a significant ($P = 0.001$) increase in the height of the air space (4.47 vs. 2.07 mm) after just 14 days of storage. After 28 days, the height of the air space had increased to 6.4 mm. The height of the air space is the basic measure of egg freshness [1]. According to the Commission Regulation (EC) on marketing standards for eggs [21], the height of the air space of Class A eggs must not exceed 6 mm. It follows that 28-day-old eggs stored at room temperature should not be sold to the consumer as a high quality product. This is confirmed by the results of a study by Calik [2], which showed that the height of the air space in eggs stored at 24°C may reach 8.9 mm by day 21.

Table 1
Quality of chicken eggs depending on storage time at room temperature (20° C)

Trait	Day			SEM	P
	1	14	28		
Height of air space (mm)	2.07^{c}	4.47^{b}	6.40^{a}	0.313	0.001
Egg weight loss (g)	0^{c}	1.96^{b}	4.13^{a}	0.264	0.001
Egg density (g/cm^3)	1.08^{a}	1.05^{b}	1.01^{c}	0.004	0.001
Shell strength (kg/cm^2)	3.60	3.59	3.53	0.114	0.068
Shell thickness (mm)	0.353	0.358	0.339	0.004	0.066
Egg yolk percentage (%)	25.0^{b}	25.4^{b}	29.1^{a}	0.451	0.001
Egg albumen percentage (%)	65.7^{a}	64.5^{a}	60.7^{b}	0.502	0.001
Egg shell percentage (%)	9.38^{b}	10.09^{a}	10.21^{a}	0.119	0.007
Haugh units	86.3^{a}	31.2^{b}	28.7^{b}	4.214	0.001
pH of albumen	8.64^{b}	9.45^{a}	9.45^{a}	0.061	0.001
Yolk colour (pts)	8.67^{a}	7.80^{b}	8.27^{a}	0.106	0.002

a, b, c – values with different superscripts differ significantly at P≤0.05

Changes taking place in the egg during storage can be monitored by determining the loss of egg weight and its density. In our study, a significant (P = 0.001) decrease in egg weight was noted: 1.96 g by day 14 and as much as 4.13 g by day 28. Similar results have been obtained by other authors [8]. Loss of egg weight may be caused by an increase in pore area and permeability, as a result of drying out of the cuticle and shell membrane in stored eggs [6]. In our research, no significant changes in the thickness and strength of the shell were found depending on storage time, but the eggs kept at room temperature had a significantly (P = 0.007) higher percentage share of shell (10.09% vs. 9.38%) after 14 days. After 28 days, the percentage of shell in the egg was 10.21% and was nearly 9% higher than in fresh eggs. At the same time, a significantly (P = 0.001) larger share of yolk and significantly (P = 0.001) smaller share of albumen (by about 7%) were found in comparison to fresh eggs and those stored for 14 days. According to Świerczewska [25], shell quality is closely correlated with the

density of the egg. Śmiechowska and Podgórniak [24] state that eggs whose density is lower than 1.021 g/cm^3 should be classified as a product on the verge of spoilage. In our study, egg density decreased significantly (P = 0.001) with the storage time, with the oldest eggs having a density of 1.011 g/cm^3. Therefore, these results also suggest that eggs stored at room temperature for 28 days should be considered unfit for human consumption.

Albumen quality depends on the quality of the thick albumen, which can be determined by measuring its height and calculating the number of Haugh units. The number of Haugh units for fresh eggs should be between 72 and 110 [6]. In our study, storing eggs at room temperature resulted in significant (P = 0.001) deterioration of albumen quality after just 14 days, as the number of Haugh units decreased from 86.3 to 31.2, and by the 28th day to 28.6. These changes are caused by the loss of carbon dioxide from the egg and the significant (P = 0.001) increase observed in the pH of the albumen, whose thick fraction becomes looser and loses strength. As a consequence, the albumen becomes watery and homogeneous, which is reflected in the drop in the number of Haugh units. The loss of carbon dioxide from the egg depends on the ambient temperature. It is faster at higher temperatures and continues until equilibrium between the egg white and ambient air is reached [5].

According to consumers, one of the most important characteristics distinguishing egg quality is the yolk colour. In our study, no clear influence of storage time on changes in yolk colour was found. The statistical analysis showed that eggs stored for 14 days had statistically significantly (P = 0.002) the lightest yolk colour. It should be emphasized, however, that this is a trait that is easily controlled, as it largely depends on how the laying hens are fed.

Table 2 presents the physicochemical characteristics of refrigerated eggs. The results indicate that refrigeration significantly slowed down the unfavourable changes occurring in the egg.

Although refrigeration time significantly (P = 0.004) increased the size of the air space in eggs stored for 14 and 28 days, it was still less than a millimetre higher than in fresh eggs (3.00 and 2.87 mm vs. 07 mm). This meant that all eggs analysed qualified as a class EXTRA product [21]. For comparison, the air space in the eggs stored at room temperature was 2.4 mm higher than in fresh eggs after just 14 days, and after 28 days it disqualified the eggs as Class A eggs [24]. Similar dependencies were obtained in the assessment of other egg quality traits.

Our research showed that refrigeration of eggs significantly (P = 0.001) reduces egg weight loss, which even after 28 days of storage did not exceed 1 g. The albumen quality, expressed in Haugh units, was significantly reduced (P = 0.001), but the values obtained on days 14 and 28 were similar and, importantly, still indicative of high quality (77.1 and 76.0, respectively). These results are comparable to those obtained by Jones et al. [14] and more favourable than those reported by Kokoszyński et al. [16], in which the loss of weight of refrigerated eggs decreased by about 1.5% after

Table 2
Quality of chicken eggs depending on storage time in refrigerated conditions (4°C)

Trait	Day			SEM	P
	1	14	28		
Height of air space (mm)	2.07^{b}	3.00^{a}	2.87^{a}	0.104	0.004
Egg weight loss (g)	0^{a}	0.376^{b}	0.803^{b}	0.611	0.001
Egg density (g/cm^3)	1.08^{a}	1.073^{b}	1.067^{c}	0.001	0.001
Shell strength (kg/cm^2)	3.60	3.97	3.92	0.092	0.199
Shell thickness (mm)	0.353	0.341	0.360	0.003	0.162
Egg yolk percentage (%)	25.0^{b}	26.2^{a}	26.4^{a}	0.242	0.032
Egg albumen percentage (%)	65.7^{a}	64.6^{ab}	63.7^{b}	0.288	0.017
Egg shell percentage (%)	9.38^{b}	9.21^{b}	9.92^{a}	0.101	0.008
Haugh units	86.3^{a}	77.1^{b}	76.0^{b}	1.023	0.001
pH of albumen	8.64^{b}	8.92^{b}	9.05^{a}	0.250	0.001
Yolk colour (pts)	8.67^{b}	8.60^{b}	9.00^{a}	0.799	0.001

a, b, c – values with different superscripts differ significantly at P≤0.05

just 21 days, and the number of Haugh units dropped from 75.7 on the first day of storage to 69.6 on the 21st day.

According to Calik [2], the means of storing eggs also affects the acidity of the albumen, as the pH of the albumen of eggs stored at 21°C increased much faster than in eggs stored at 6°C. Our research confirmed the positive effect of a low storage temperature on albumen pH, which increased significantly (P = 0.001) in comparison with fresh eggs only after 28 days of storage.

In the refrigerated eggs, no influence of storage time on shell quality was observed. Both the thickness of the shell and its strength were comparable in fresh eggs and those stored for 14 or 28 days. However, the storage time did affect the proportions of individual egg components. In comparison with day-old eggs, a significant (P = 0.032) increase in the share of yolk and a significant (P = 0.017) decrease in that of albumen were observed in eggs stored for 14 days and 28 days. This correlation was also

observed by Calik [2] and by Campo et al. [3], who showed that exchange of water and gases takes place between the albumen and yolk during storage of eggs, which weakens the vitelline membrane. Water permeates the yolk, thereby increasing its weight.

The results of the study indicate that storage time significantly ($P \leq 0.05$) influenced the increase in the size of the air space, loss of egg weight, deterioration of albumen quality, and changes in the proportions of albumen and yolk in the egg. Eggs stored at 4°C were of good quality and were classified as class EXTRA even after 28 days. Eggs stored at 20°C were eliminated as Class A eggs by the 14th day, and by the 28th day they were unfit for consumption. In summary, before being sold to the consumer, eggs should be refrigerated to prevent premature ageing and thus deterioration in quality.

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