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RESEARCH NOTE

# Effects of egg shell color and storage duration on the external and internal egg quality traits of ATAK-S layer hybrids

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**Abstract**

**A. Şekeroğlu, H. Gök, and M. Duman. 2016. Effects of egg shell color and storage duration on the external and internal egg quality traits. Cien. Inv. Agr. 43(2):327-335.** The present study was conducted to investigate the effects of storage duration and egg shell color on external and internal egg quality traits. Eggs were obtained from 29-week--old ATAK-S layer hybrids reared in a traditional cage system. Storage durations were set as 0, 7, 14, 21 and 28 days. Shell color was classified as dark (59.00-67.99); moderate (68.00-70.99) and light (71.00-79.99) using the ΔE values of the eggs. The storage duration significantly affected the egg weight ($P \leq 0.01$), specific gravity ($P \leq 0.01$), breaking strength ($P \leq 0.01$), shell thickness ($P \leq 0.01$), shell weight ($P \leq 0.01$), surface area ($P \leq 0.01$), albumen index ($P \leq 0.01$), yolk index ($P \leq 0.01$), Haugh unit ($P \leq 0.01$), yolk color ($P \leq 0.05$) and albumen pH ($P \leq 0.01$). The egg shell color significantly affected the specific gravity ($P \leq 0.01$), breaking strength ($P \leq 0.01$), shell thickness ($P \leq 0.01$), shell weight ($P \leq 0.01$), albumen pH ($P \leq 0.05$) and albumen blood-meat spots ($P \leq 0.05$). The current findings revealed that the eggs should be transported to consumers as soon as possible, and further studies should be performed to darken egg shell colors. It was concluded that newly laid dark colored eggs had the best quality.

**Key words:** ATAK-S, brown egg, hen, poultry, quality characteristics.

## Introduction

In the poultry industry, the developments in genetics, rearing systems, feeding and health conditions have increased the annual egg yield of hens up to 310 eggs per hen. Parallel to increasing egg production, significant improvements were observed in egg quality parameters. Therefore, the factors effecting egg quality, such as herd genotype, age, rearing system, feeding, health, egg classification, storage, transport, processing technology and marketing, should be well-designed (Abdullah *et al.*, 1993; Atasoy *et al.*, 2001). Together with the improved social and welfare levels, egg quality is also becoming a significant issue for consumers worldwide. Egg

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preference and hedonic consumption value vary from one person to another. All of the factors that influence egg preference and acceptability affect egg quality parameters. Egg shell color is among the factors influencing egg preference by consumers (Hooge, 2007). In addition to brown and white colored eggs, different tones of brown also influence consumer preferences. Biliverdin, zinc chelate and porphyrine pigments excreted from the uterus of the reproductive track colorize the egg shell. The protoporphyrin content is higher in brown eggs, and the egg shell color varies with different brown tones, ranging from dark brown to light brown based on the amount of this pigment (Kennedy and Vevers, 1973). In brown eggs, the shell color also influences the hatchability. Dark color eggs have better hatchability than light color eggs (Şekeroğlu and Duman, 2011).

Among the pigments coloring egg shells, biliverdin has an antioxidant effect, porphyrin and derivatives have photodynamic and antibacterial effects and protoporphyrin has an egg shell breakage resistance and increased thickness effects. The biliverdin content of an egg shell is an indicator of the egg's antioxidant capacity (Ishikawa *et al.*, 2010; Şekeroğlu and Duman, 2011). In commercial laying hen facilities, storage temperatures play a significant role in delivering the eggs to the consumer at peak laying freshness. Following the laying, based on storage temperature and duration, $CO_2$ and weight losses, increased albumen pH levels, decreased albumen weight and heights are observed in eggs (Yılmaz and Bozkurt, 2008).

The present study was conducted to investigate the effects of egg shell color on consumer preferences and the storage duration on the internal and external egg quality traits of ATAK-S hybrids.

## Materials and methods

### *Materials*

The eggs were obtained from ATAK-S layer hybrids housed at Poultry Research Unit of Gaziosmanpaşa University Agricultural Faculty Animal Science Department.

The eggs were obtained in a single day from 1800 ATAK-S hybrids for use in the experiments. The hens were 29-weeks–old and reared in a traditional cage system with 7 hens in each case. Eggs were selected by almost equal weight by weighing the eggs with a precise balance (±0.01 g). The shell color parameters of L* a* b* (CIE-LAB) were measured with a Minolta Chroma Meter (CR-300, Konica Minolta Co. Ltd., Osaka, Japan), (L*: Brightness, a*: Redness, b*: Yellowness). By using L*, a* and b* values, the shell color (ΔE) was calculated with the formula $\Delta E = (L^2+a^2+b^2)^{1/2}$ (Ingram *et al.*, 2008). Based on the ΔE values, the eggs were classified into three groups of dark-, moderate- and light-colored (Table 1). Then, the classified eggs were stored in an incubation chamber at 10 °C and 60% to 80% relative humidity.

In the egg quality analyses at 0, 7, 14, 21 and 28$^{th}$ days, 30 eggs from the dark-, moderate- and light-colored groups (90 eggs for each storage duration; 450 eggs in total) were broken, and the quality parameters were analyzed.

**Table 1.** Egg shell color (ΔE ) groups and average egg weights.

| ΔE color groups | Average ΔE | Average L* | Average a* | Average b* | Weight G |
|---|---|---|---|---|---|
| Dark (59.00-67.99) | 65.94 | 58.84 | 14.10 | 25.90 | 60.06 |
| Moderate (68.00-70.99) | 69.46 | 62.52 | 12.99 | 27.01 | 60.06 |
| Light (71.00-79.99) | 72.45 | 66.19 | 11.74 | 26.69 | 60.13 |

*Methods*

Egg weight, shape index, specific gravity, shell breaking strength, shell thickness, shell weight, egg surface area and shell color were considered the external quality traits. Egg weights were measured with a precise balance (±0.01 g). Egg length and widths were measured with a digital caliper, and the shape index was calculated as the width-to-length ratio. Common salt solutions were used to measure the specific gravity. Shell breaking strength was measured using a strength measurement device developed by Rauch, and the results were expressed in $kg \cdot cm^{-3}$. Following the removal of the shell membranes, the shell thickness was measured over the bumped, medium and pointed sections of the broken shells with a micrometer (± 1/100 mm). Then, the average of the three measurements constituted the egg shell thickness. The shell weight was calculated with the following formula, and the egg shell surface area (A) was calculated with the following formula specified by Nordstorm and Ousterhout (1982).

Shell Weight (g) = ((2.0341 × Egg Weight (g))-(2.1014 × Egg Weight(g)))/ Egg Specific Gravity ($g\ cm^{-3}$)

$A = 3.9782 \times \text{Egg weight}^{0.7056}$

A specifically designed mirrored glass table was used to measure the eggs' internal quality traits. Albumen index, yolk index, Haugh unit, yolk color, albumen pH, blood and meat spots were considered the internal quality traits. Thick albumen height and yolk height were measured with a tripod micrometer (± 1/100 mm). Albumen length, width and yolk diameter were measured with Vernier calipers (Efil and Sarıca, 1997). Albumen and yolk indexes were measured with the following formulas:

Albumen Index = (Thick albumen height (mm) / Average albumen length and width (mm)) × 100

Yolk Index = (Yolk height (mm)/ Yolk Diameter (mm)) × 100

Egg weight and albumen height were used to calculate the Haugh units according to the following formula:

$\text{Haugh unit} = 100 \log (H + 7.57 - 1.7\ G^{0.37})$

where H is the albumen height (mm), and G is the egg weight (g).

A Roche color circle with 15 sections was used to identify the yolk color. Albumen pH was measured with a pH meter (Sartoriious PP15, AG Weender Landstrasse 94-108, Goettingen, Germany). The ratio of eggs with blood and meat spots was determined using a glass table equipped with an inclined mirror underneath; blood and meat spots were assessed together. Blood-meat spots over the albumen and yolk were separately assessed as either existent – non-existent.

The effects of the egg shell color and storage duration on the internal and external egg quality traits were assessed using analysis of variance (ANOVA) performed with SPSS 17.0. Duncan's multiple range tests were used to compare the means. Because the data pertaining to blood and meat spots were classified as either existent or non-existent, a nonparametric Kruskal-Wallis H test was used for these data.

## Results and discussion

*External egg quality traits*

The effects of the egg shell color and storage duration on the external egg quality traits of egg weight, shape index, specific gravity, breaking strength, shell thickness, shell weight, egg surface area and shell color were investigated (Table 2).

While the effects of storage duration on egg weight, specific gravity, breaking strength, shell thickness, shell weight, shell surface area and shell color were found to be significant ($P \leq 0.01$), the effects on the shape index were found to be insignificant ($P > 0.05$). Egg shell color had a significant effect

**Table 2.** Effects of storage duration and egg shell color on external egg quality traits.

| | | Egg Weight | Shape Index | Specific Gravity | Breaking Strength | Shell Thickness | Shell Weight | Surface Area | Shell Color (E) |
|---|---|---|---|---|---|---|---|---|---|
| External egg quality traits | | | | | | | | | |
| Storage duration, days | Initial | 60.39 c | 77.29 | 1.087 d | 2.17 a | 33.88 a | 6.14 d | 71.82 c | 68.68 a |
| | 7 | 59.67 bc | 77.57 | 1.083 c | 2.78 b | 34.99 b | 5.59 c | 71.20 bc | 72.23 bc |
| | 14 | 59.24 ab | 77.88 | 1.076 b | 2.69 b | 34.99 b | 4.83 b | 70.84 ab | 72.38 c |
| | 21 | 59.22 ab | 78.56 | 1.077 b | 2.63 b | 35.99 c | 4.97 b | 70.85 ab | 73.59 d |
| | 28 | 58.60 a | 77.08 | 1.072 a | 2.64 b | 34.64 b | 4.35 a | 70.31 a | 71.69 b |
| Egg shell color | Light | 59.56 | 77.89 | 1.078 a | 2.42 a | 34.36 a | 5.11 a | 71.12 | 73.62 c |
| | Moderate | 59.34 | 77.50 | 1.079 b | 2.53 a | 34.84 a | 5.20 ab | 70.93 | 71.81 b |
| | Dark | 59.43 | 77.66 | 1.080 b | 2.79 b | 35.51 b | 5.28 b | 70.82 | 69.66 a |
| Source of variation P values | | | | | | | | | |
| Storage duration | | ** | NS | ** | ** | ** | ** | ** | ** |
| Egg shell color | | NS | NS | ** | ** | ** | * | NS | ** |
| Interaction | | NS | NS | ** | NS | NS | NS | NS | ** |

Within each column, means followed by different letters are significantly different. (*P≤0.05; *P≤0.01). NS: Not significant.

on specific gravity (P≤0.01), breaking strength (P≤0.01), shell thickness (P≤0.01), shell weight (P≤0.05) and shell color (P≤0.01). The effects of the egg shell color on the shape index and egg surface area were not significant (P>0.05). The interactions between the storage durations and the egg shell color were found to be significant regarding the egg's specific gravity and shell color characteristics (P≤0.01) and insignificant regarding the other external egg quality traits (P>0.05).

The present findings agree with the findings of Scott and Silversides (2000), Yılmaz and Bozkurt (2008), Oliveira *et al*. (2009) and Raji *et al*. (2009), indicating decreasing egg weights with increasing storage durations. However, despite the decreasing egg weights, there are various other researchers reporting insignificant effects of storage durations on egg weights (Şamlı *et al*., 2005; Şekeroğlu *et al*., 2008; Akyürek and Okur, 2009; Alsobayel and Albadry, 2011; Okur and Şamlı, 2013), and the current findings agree with the findings of Demirel and Kırıkçı (2009), indicating that the duration of storage did not have any effect on egg weight.

The present findings agree with the results of previous researchers, indicating insignificant impacts of the storage duration on the shape index (Yılmaz and Bozkurt, 2008; Akyürek and Okur, 2009; Demirel and Kırıkçı, 2009; Raji *et al*., 2009; Alsobayel and Albadry, 2011).

The findings of egg specific gravity, which is closely related to the egg shell quality, are similar to results reported by Şamlı *et al.* (2005), Şekeroğlu *et al*. (2008), Akyürek and Okur (2009), and Alsobayel and Albadry (2011). Higher breaking strength values at the end of the storage period than the initial values agree with the findings of Yılmaz and Bozkurt (2008).

Yılmaz and Bozkurt (2008) and Demirel and Kırıkçı (2009) investigated the effects of storage durations on egg shell quality and reported similar results with the present study and indicated increasing shell thicknesses with increasing storage durations. Alsobayel and Albadry (2011) reported significant effects of storage durations on shell thickness and, contrary to previous studies, reported decreasing shell thicknesses with increasing storage durations. In contrast, some researchers reported that the storage duration did not have any significant impacts on shell thickness (Şamlı *et al*., 2005; Okur and Şamlı, 2013; Englmaierová and Tůmová, 2009).

The current findings were similar to findings of Şamlı *et al.* (2005), Jin *et al.* (2011), Englmaierová and Tůmová (2009), and Okur and Şamlı (2013), indicating that there was an effect of storage duration on shell weight.

Decreasing egg surface areas were observed with increasing storage durations. These findings were similar to results of Scott and Silversides (2000), Englmaierová and Tůmová (2009), Oliveira *et al.* (2009), and Raji *et al.* (2009).

The current findings were found to be similar with the results of Shafey *et al.* (2005) and Kożuszek *et al.* (2009), indicating unchanged egg weights with darkening shell colors; however, this was not concurrent with the findings of Aygun (2014) who reported increasing egg weights with darkening shell colors.

Kożuszek *et al.* (2009) reported increasing shape index values with darkening shell colors. The inconsistency in the literature was because hen eggs were used in this study but pheasant eggs were used in Kożuszek *et al.* (2009).

Increasing specific gravity values were observed with darkening shell colors. These findings comply with the results of Kożuszek *et al.* (2009); however, Ingram *et al.* (2008) reported decreasing specific gravity values with darkening shell colors.

Increasing breaking strength values were observed with darkening shell colors. Similar to this study, Aygun (2014) reported increasing breaking strength values with darkening shell colors.

Increasing shell thickness was observed in this study with darkening shell colors. The present findings comply with the results of Ingram *et al.* (2008), Kożuszek *et al.* (2009), and Şekeroğlu and Duman (2011), indicating increasing shell thicknesses with darkening shell colors.

Increasing shell weights were observed with darkening shell colors of the present study. The eggs with dark shell colors had the highest shell weights. However, Shafey *et al.* (2005) and Kożuszek *et al.* (2009) indicated that shell color did not have a significant effects on shell weight.

Despite the insignificant differences the egg surface areas of different color tones, decreasing surface areas were observed with darkening shell colors. Kożuszek *et al.* (2009) also reported similar findings to this study.

*Internal egg quality traits*

The effects of egg shell color and storage duration on internal egg quality traits are provided in Table 3. While the effect of storage duration on albumen index ($P \leq 0.01$), yolk index ($P \leq 0.01$), Haugh unit ($P \leq 0.01$), albumen pH ($P \leq 0.01$) and yolk color ($P \leq 0.05$) were found to be significant. The effects of egg shell color and storage duration on the blood-meat spot ratio of albumen and yolk were not found to be significant. While the effect of egg shell color on albumen pH and the albumen blood-meat ratio were found to be significant ($P \leq 0.05$), effects on the other internal egg quality traits were not found to be significant ($P > 0.05$).

Effects of storage duration on albumen index were found to be significant, and decreasing index values were observed with increasing storage durations. Current findings were similar to results of Şekeroğlu *et al.* (2008), Yılmaz and Bozkurt (2008), Akyürek and Okur (2009), Demirel and Kırıkçı (2009), Khan *et al.* (2013) and Raji *et al.* (2009).

Decreasing yolk index values were observed with increasing storage durations. Şamlı *et al.* (2005) also reported similar findings to the current study.

Haugh units decreased with increasing storage durations of the present study. Jones and Musgrove (2005), Şamlı *et al.* (2005), Şekeroğlu *et al.* (2008), Yılmaz and Bozkurt (2008), Akyürek and Okur (2009), Demirel and Kırıkçı (2009), Raji *et al.* (2011),

**Table 3.** Effects of storage duration and egg shell color on internal egg quality traits.

| | | Albumen Index | Yolk Index | Haugh Unit | Yolk Color | Albumen pH | Albumen Blood-Meat Spots | Yolk Blood-Meat Spots |
|---|---|---|---|---|---|---|---|---|
| Internal egg quality traits | | | | | | | | |
| Storage duration, days | Initial | 11.63 e | 44.47 d | 94.56 d | 11.29 b | 8.62 a | 0.08 | 0.14 |
| | 7 | 9.68 d | 43.73 cd | 87.64 c | 10.96 a | 9.15 b | 0.04 | 0.12 |
| | 14 | 8.79 c | 43.07 c | 84.41 b | 10.98 a | 9.11 c | 0.10 | 0.08 |
| | 21 | 8.16 b | 41.26 b | 82.89 b | 11.04 a | 9.28 d | 0.10 | 0.04 |
| | 28 | 7.13 a | 40.26 a | 78.47 a | 11.09 a | 9.28 d | 0.06 | 0.12 |
| Egg shell color | Light | 9.11 | 42.57 | 85.93 | 10.99 | 9.09 b | 0.04 a | 0.06 |
| | Moderate | 9.07 | 42.63 | 85.48 | 11.09 | 9.09 b | 0.06 a | 0.14 |
| | Dark | 9.19 | 42.65 | 85.89 | 11.13 | 9.06 a | 0.12 b | 0.10 |
| Storage duration | | ** | ** | ** | * | ** | NS | NS |
| Egg shell color | | NS | NS | NS | NS | * | * | NS |
| Interaction | | NS | NS | NS | NS | NS | NS | NS |

Within each column, means followed by different letters are significantly different. (*P≤0.05; *P≤0.01). NS: Not significant.

Alsobayel and Albadry (2011), Khan *et al.* (2013), and Okur and Şamlı (2013) carried out experiments on internal egg quality traits and reported similar findings with the present study. Contrary to those studies, Jin *et al.* (2011) reported insignificant effects of storage durations on the Haugh unit.

Yolk colors decreased with increasing storage durations. These findings comply with the results of Yılmaz and Bozkurt (2008), Akyürek and Okur (2009) and Jin *et al.* (2011). However, Şekeroğlu *et al.* (2008) reported increasing yolk colors with increasing storage durations. On the other hand, Alsobayel and Albadry (2011) indicated an insignificant effect of storage duration on yolk color.

The effect of storage duration on the albumen pH values was found to be significant in this study, and increasing pH values were observed with increasing storage durations. Şamlı *et al.* (2005), Şekeroğlu *et al.* (2008), Akyürek and Okur (2009) and Jin *et al.* (2011) carried out similar studies and reported significant effects of storage durations on albumen pH and observed increasing pH values with increasing storage durations. Okur and Şamlı (2013) also reported significant effects of storage durations on albumen pH values, but they reported decreasing pH values with increasing storage durations.

In the present study, the effect of the storage duration on the albumen blood-meat spot ratios was found to be insignificant. Alsobayel and Albadry (2011) also reported an insignificant effect of the storage duration on meat spots but a significant effect on blood spots.

The effect of the storage duration on the yolk blood-meat spot ratio was also found to be insignificant. Similarly, Alsobayel and Albadry (2011) reported an insignificant effect of the storage duration on yolk meat spots but it significantly affected blood spots.

Despite the numerical increases in the yolk index values, albumen index and yolk index, the different color tones were not significantly different.

The effect of the egg shell color on the Haugh unit was not found to be significant. However, Aygun (2014) reported decreasing Haugh units and Kożuszek *et al.* (2009) reported increasing Haugh units with darkening shell colors.

Although shell color did not have any significant effects on yolk color, increasing yolk color values were observed with darkening shell colors. Aygun

(2014) reported that egg shell color did not have any significant effects on egg yolk color.

The effect of egg shell color on albumen pH was found to be significant, and decreasing pH values were observed with darkening shell colors. However, Kożuszek *et al.* (2009) reported increasing albumen pH values with darkening shell colors.

Effects of the egg shell color on albumen blood-meat spots were found to be significant in this study, and an increasing number of blood-meat spots were observed with darkening shell colors. The egg shell color did not have a significant effect on the yolk blood-meat spots.

Egg quality is the most significant factor affecting the consumer preferences. There are several pre- and post-laying factors effecting egg quality. A newly laid egg has the highest quality; however, each day until the delivery of the egg to the consumers results in decreases in egg quality traits. The present study was conducted to investigate the effects of storage duration and egg shell color on the external and internal egg quality traits.

Considering the current results, it can be stated that the storage duration negatively impacts egg quality. Decreasing egg weights with increasing storage durations result in economic loss. Additionally, the decrease in external quality traits, such as specific gravity, and internal egg quality traits, such as albumen index, yolk index, Haugh unit and increasing albumen pH levels, indicated continuously decreasing quality with increasing storage duration. Thus, eggs should be delivered to the consumer as soon as possible after laying.

The effect of the egg shell colors on the egg quality traits was observed in this study. Increasing specific gravity, breaking strength and shell thickness and decreasing albumen pH levels with darkening shell colors were considered significant changes with regard to egg quality. However, increasing albumen blood-meat spots with darkening shell colors were considered a negative consequence in regard to egg quality. In addition, the shell color did not have negative effect on the other quality traits. Excluding blood-meat spots, darkening shell color either had a positive effect or did not have a significant effect on the other quality traits. Thus, further studies are recommended to darken the brown shell color of laying hens. Finally, it was concluded that newly laid dark color eggs had the highest quality.

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## Resumen

**A. Şekeroğlu, H. Gök y M. Duman. 2016. Efecto del color de la cáscara del huevo y el tiempo de conservación sobre las características de cualidad externas e internas del huevo. Cien. Inv. Agr. 43(2):327-335.** El presente estudio evaluó los efectos del tiempo de conservación y el color de la cáscara del huevo en las características de calidad externas e internas del huevo. El material lo constituyeron huevos obtenidos de ATAK-S híbridos de gallinas de postura de 29 semanas de edad, criadas en sistemas de jaula tradicional. El tiempo de duración fue definido como inicial (0), 7, 14, 21 y 28 días. El color de la cáscara fue clasificado como oscuro (59.00-67.99); moderado (68.00-70.99) y claro (71.00-79.99), usando el ΔE valores de huevos. El tiempo de conservación tuvo un afecto significativo en el peso del huevo (P≤0.01), la gravedad específica (P≤0.01), la resistencia a la ruptura (P≤0.01), el grosor de la cáscara (P≤0.01), el peso de la cáscara (P≤0.01), el área de superficie (P≤0.01), el índice de albumen (P≤0.01), el índice de yema (P≤0.01), la unidad Haugh (P≤0.01), el color de la yema (P≤0.05) y el pH del albumen (P≤0.01). El color de la cáscara originó un efecto significativo en la gravedad específica (P≤0.01), la resistencia a la ruptura (P≤0.01), el grosor de la cáscara (P≤0.01), el peso de la cáscara (P≤0.01), el pH del albumen (P≤0.05), manchas de sangre y de carne en el albumen (P≤0.05). Los resultados indican que los huevos deberían ser transportados a los consumidores en forma rápida. Se sugiere realizar estudios adicionales para oscurecer la cáscara de los huevos, ya que se concluye que los huevos ligeramente oscurecidos tienen la mayor calidad.

**Palabras clave:** ATAK-S, aves de postura, huevos marrón, características de calidad, gallinas.

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