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The Effect of Different Layer Genotypes Raised in The Free-range System on Egg Quality Storage at Different Temperatures

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Abstract

The aim of this study was to investigate the effect of stored eggs obtained from different layer genotypes raised in a Free-range system on egg quality at different storage temperatures. Lohmann Brown, Lohmann Sandy, and ATAK-S were used as layer genotypes in the study. The study was performed in a 3x2 factorial design with three genotypes and two storage temperatures. A total of 300 table eggs were used in the study. Egg quality analysis was carried out on 100 eggs from each genotype. Eggs were stored in refrigerator (4±2°C) and at room temperature (22±2°C) for 28 days. Egg quality was determined in 10 eggs from each group after 0, 7, 14, 21, and 28 days of storage, and the effects of temperature, genotype, and temperature x genotype interaction were determined. In the study, the effects of genotype and storage temperature on egg weight loss, Haugh unit, yolk index, and albumen pH were determined to be significant (P<0.05). However, the interaction effects of storage temperature x genotype were not statistically significant for any period of storage on egg quality characteristics such as Haugh unit and albumen pH. As a result, it was determined that eggs stored at refrigerator temperature during the research, depending on the storage conditions, preserved their quality characteristics better than those stored at room temperature. The study concluded that the eggs of the ATAK-S genotype had a lower shelf life compared to those of the Lohmann Sandy and Lohmann Brown genotypes.

Introduction

Eggs have been utilized as a dietary source for humans since ancient times, owing to their high biological value (Doğan 2008). Because it contains proteins and other nutrients in the egg structure and retains all of its biological value, it is used as an indicator for the quality of vegetable proteins (Durmuş 2014). Egg production is mostly done in conventional cages in the world as well as in our country. However, with the results obtained from studies conducted in recent years, it has been determined that chickens raised in traditional cages cannot fully meet their physiological needs and behavioural activities. (Bozkurt 2009). Since 2012, countries in the European Union have prohibited the use of conventional cage systems to produce eggs, and alternative methods have been recommended (Directive 1999). The free-range system is one of these producing methods. The need to determine the layer genotypes that will be used in the free-range system's egg production is increasing. Researchers have undertaken a lot of studies for this specific reason (Türker et al., 2017).

In our country, ATAK-S, Lohman Brown, Nick Brown layer hybrids are generally used in the free-range system. The Lohman Brown breed is a hybrid of foreign origin, established in Turkey through the utilization of the free-range farming. The Ankara Poultry Institute. developed the ATAK-S layer hybrid, which produces brown-shelled eggs (Goger et al., 2016). It is preferred in free-range systems and small family breeding production models in Turkey (Tutkun et al., 2018). In recent years, genotypes that produce eggs with pink-cream colored shells, have lower feed consumption than brown layers, and are commonly called tinted (Lohmann Sandy, Lohmann Silver, Hy-Line Pink, Hy-Line Sonia, H&N Coral) have also begun to be used.

It has been stated that the quality of the egg is at its highest as soon as it is laid. Egg quality may deteriorate depending on storage conditions. Depending on storage conditions, egg weight loss increases (Sert et al., 2011; Akpinar et al., 2015), Haugh unit and yolk index decreases (Baylan et al., 2011; Maman and Yildirim 2022; Parmak and Aygün 2023) and albumen pH increases (Aygun and Sert 2013; Maman and Yildirim 2022; Sariyel et al., 2022). Since no study on these genotypes grown in a free-range system was found in our literature research, this study was conducted to reveal the advantages or disadvantages of the egg quality characteristics of ATAK-S, our local layer genotype, compared to foreign layer hybrids.

Materials and Methods

The research was conducted in the Department of Animal Science, Faculty of Agriculture, Selcuk University. A total of 300 eggs (10 eggs x 5 periods x 3 genotypes x 2 storage temperatures= 300 eggs) obtained from 34-week-old Lohmann Brown, ATAK-S and Lohmann Sandy layer genotypes reared in free-range system houses were used. Collected eggs were stored in storage cabinets at average room temperature (22±2°C) and refrigerator (4±2°C) for 28 days. Egg quality analyses were performed at the beginning of storage, on the 7th, 14th, 21st, and 28th days of storage. Egg weight loss, specific gravity, albumen height, Haugh unit, yolk index and albumen pH were determined as egg quality analysis. The weights of the eggs were weighed and recorded before storage. Egg weights were determined with a digital scale with a sensitivity of 0.01 g, and egg weight loss was determined with the formula below.

Egg weight loss (%) = [Before storage egg weight(g) – Period egg weight (g)] / Before storage egg weight (g) x 100.

Egg specific gravity was determined according to the Archimedes principle (Wells 1968). Egg albumen height was determined with a height gauge after the egg was broken on a flat glass surface. After determining the albumen height and egg weight, the following formula was used to calculate the Haugh unit (Haugh 1937).

Haugh Unit = 100 log ($H + 7.57 – 1.7 W^{0.37}$) where H: Albumen height (mm) W: Egg weight (g).

The egg white and yolk were separated, and the yolk was placed on a flat glass surface. The yolk index was calculated according to Funk (1948) by measuring the yolk height with a digital height gauge and the yolk diameter with a digital micrometer. The albumen pH value was determined by separating the egg albumen from the yolk, mixing the thin and thick layer of the egg albumen thoroughly, and then measuring with a pH meter. The research was conducted using a randomized plots factorial design (3x2), including three layer genotypes (Lohmann Brown, Lohmann Sandy, and ATAK-S) and two storage conditions (room temperature and refrigeration). The statistical software tool MINITAB 16 was utilized to perform the analyses, while the Tukey multiple comparison test was employed to compare the groups. As a result of statistical analysis, P<0.05 value was considered statistically significant.

Results

Egg Weight Loss

The effect of storage temperature, genotype, and storage x genotype interaction on egg weight loss is given in Table 1. The interaction effects of storage temperature x genotype on egg weight loss were found to be statistically significant at the before storage egg weights and on the 28th day of storage (P<0.05). Before storage, the highest egg weight was found in the eggs of the Lohmann Sandy genotype at 4 °C (60.27 g), and the lowest egg weight was determined in the eggs of the ATAK-S genotype (48.46 g) at 22 °C. On the 28th day of storage, the highest egg weight loss was found in eggs of the ATAK-S genotype (5.16%) stored at 23 °C, and the lowest egg weight loss was found in eggs of the Lohmann Sandy genotype (1.56%) stored at 4 °C. The effects of different storage temperatures on egg weight loss were found to be statistically significant in all periods of storage except for the before storage egg weight (P<0.05). In general, egg weight loss was found to be lower in eggs stored at 4 °C than in eggs stored at 23 °C (P<0.05). On the 28th day of storage, the weight loss in eggs stored at 4 °C was 1.67%, while the weight loss in eggs stored at 23 °C was 4.47% (P<0.05). The effects of genotype on egg weight loss were found to be statistically significant on before storage egg weights on the fourteenth and twenty-eighth days of storage (P<0.05). The before storage egg weights obtained from the ATAK-S genotype were lower than the egg weights of the other genotypes (P<0.05). However, the difference between the egg weights of the Lohmann Brown and Lohmann Sandy genotypes in terms of before storage egg weight was found to be statistically insignificant. On the fourteenth (14) day of storage, the egg weight loss of the Lohmann Brown genotype (1.61%) was higher than the egg weight loss (1.34%) of the Lohmann Sandy genotype (P<0.05), the difference between the egg weight loss of the ATAK-S genotype and the egg weight loss (1.60%) was statistically insignificant. Similarly, egg weight loss in the ATAK-S genotype was found to be higher than that of the Lohmann Sandy genotype (P<0.05). On the 28th day of storage, egg weight loss of the ATAK-S genotype (3.50%) was higher than that of the Lohmann Brown (2.89%) and Lohmann Sandy genotypes (2.82%) (P<0.05). However, the difference in egg weight loss between Lohmann Brown and Lohmann Sandy genotypes was found to be statistically insignificant.

Haugh Unit

The effect of storage temperature, genotype, and storage x genotype interaction on egg Haugh units is shown in Table 2. The interaction effects of storage temperature x genotype on egg albumen height were found to be statistically insignificant at all periods of storage. The effects of storage temperature on the egg Haugh unit were found to be statistically insignificant only in the before storage Haugh unit and were found to be statistically significant in all periods of storage (P<0.05). In general, the Haugh unit was found to be higher in eggs stored at 4 °C compared to eggs stored at 25 °C, depending on the temperature in all periods of storage (P<0.05). On the 28th day of storage, the Haugh unit was 77.96 in eggs stored at 4 °C, while the Haugh unit in eggs stored at 23 °C was 74.29 (P<0.05). The effects of genotype on the egg Haugh unit were found to be statistically significant in the before storage Haugh unit and at all periods of storage (P<0.05). In the before storage Haugh unit, on the seventh (7) and twenty-eighth (28) days of storage, Lohmann Brown genotype eggs were higher than Haugh unit (99.18), ATAK-S genotype (93.92), and Lohmann Sandy genotype eggs (94.23) (P<0.05). However, the difference between Lohmann Sandy genotype (94.23) and Haugh units (93.92) of ATAK-S genotype eggs was found to be statistically insignificant. On the fourteenth (14) and twenty-one (21) days of storage, the Haugh unit of Lohmann Brown genotype eggs (day 14: 93.20, day 21: 87.09), ATAK-S (day 14: 82.75, day 21: 76.22), and Lohmann Sandy genotype eggs derived from the Haugh unit (day 14: 87.52, day 21: 80.53) was found to be higher (P< 0.05). Similarly, the Haugh unit of Lohmann Sandy genotype eggs (14 day: 87.52, 21.day: 80.53) was found to be higher than the Haugh unit (14 day: 82.75, 21 day: 76.22) of ATAK-S genotype eggs (P<0.05). On the 28th day of storage, the Haugh unit (82.23) of the Lohmann Brown genotype eggs was found to be higher than the Haugh unit (70.48) of the ATAK-S genotype and the Haugh unit (75.68) of the Lohmann Sandy genotype eggs (P<0.05). No significant differences were found between the Haugh unit of the ATAK-S genotype (70.48) and the Haugh unit of the Lohmann Sandy genotype (75.68).

Yolk Index

The effect of storage temperature, genotype and storage x genotype interaction on egg yolk index is shown in Table 3. The interaction effects of storage temperature x genotype on egg yolk index were found to be statistically significant only on the 14 d and 28 d of storage (P<0.05). On the 14 d of storage, the highest yolk index (0.57) was observed in the eggs of the Lohmann Brown genotype stored at 4 °C, and the lowest yolk index value was observed in the eggs of the ATAK-S (0.42) genotype stored at 23 °C. On the 28th day of storage, the highest yolk index (0.47) was observed in the eggs of the Lohmann Sandy genotype stored at 4 °C, and the lowest yolk index value was observed in the eggs of the Lohmann Brown genotype (0.33) stored at 23 °C. However, the difference between the yolk index (0.40) of Lohmann Sandy genotype eggs stored at 23°C and the yolk index (0.43) of ATAK-S genotype eggs stored at 4°C was found to be statistically insignificant. The effects of temperature on the egg yolk index were found to be statistically insignificant in the before storage yolk index and were found to be statistically significant in all periods of storage (P<0.05). In general, the yolk index was found to be higher in eggs stored at 4 °C in all periods compared to eggs stored at 23 °C (P<0.05). While the yolk index was 0.46 in eggs stored at 4 °C on the 28th day of storage, the yolk index was 0.35 in eggs stored at 23 °C (P<0.05). The effects of genotype on egg yolk index were found to be statistically insignificant in the before storage yolk index and were found to be statistically significant in all periods of storage (P<0.05). On the 7 d of storage, the yolk index of the ATAK-S genotype was lower than the yolk index of the Lohmann Sandy genotype (P<0.05), it was similar to the yolk index of the Lohmann Brown genotype, and the difference in yolk index between the eggs of the Lohmann Brown and Lohmann Sandy genotypes was statistically significant. was found to be insignificant. On the 14 d of storage, the yolk index of the ATAK-S genotype was lower than the yolk index of the Lohmann Sandy genotype and Lohmann Brown genotype (P<0.05), and the difference between the yolk index value of the eggs of the Lohmann Brown and Lohmann Sandy genotypes was statistically insignificant. On the twenty-first day of storage, the yolk index of the ATAK-S genotype was lower than the yolk index of the Lohmann Sandy genotype (P<0.05), it was similar to the yolk index of the Lohmann Brown genotype, and the yolk index of the Lohmann Brown genotype eggs was found to be lower than the yolk index of the Lohmann Sandy genotype eggs. (P<0.05). On the 28th day of storage, the yolk index (0.44) of the eggs of the Lohmann Sandy genotype was higher than the egg yolk index (0.38) of the ATAK-S genotype and the yolk index (0.40) of the Lohmann Brown genotype (P<0.05). There was no statistical difference between the yolk index (0.38) and the egg yolk index (0.40) of the Lohmann Brown genotype.

Albumen pH

The effect of storage temperature, genotype and storage x genotype interaction on egg albumen pH is shown in Table 4. The interaction effects of storage temperature x genotype on egg yolk index were found to be statistically insignificant in all periods of the experiment. The effects of temperature on egg albumen pH were found to be statistically insignificant at the day 0 of storage and were found to be statistically significant in all periods of storage (P<0.05). In general, albumen pH was found to be lower in eggs stored at 4 °C in all periods compared to eggs stored at 23 °C (P<0.05). On the 28th day of storage, the albumen pH value was 8.96 in eggs stored at 4 °C, while the albumen pH value in eggs stored at 23 °C was 9.12 (P<0.05). The effects of genotype on egg albumen pH were found to be statistically significant at 14, 21 and 28 days of storage (P<0.05). On the 14 d of storage, the albumen pH value of Lohmann Sandy genotype eggs (8.89) was lower than the albumen pH value of ATAK-S genotype eggs (8.97). On the 21d of storage, the albumen pH value of

Lohmann Sandy genotype eggs (8.93) was lower than the albumen pH value of ATAK-S genotype eggs (9.04) and the albumen pH value of Lohmann Brown genotype eggs (9.02) (P<0.05). On the 28th day of storage, the albumen pH value of ATAK-S genotype eggs (9.06) was higher than the albumen pH value of Lohmann Sandy genotype eggs (9.03) and the albumen pH value of Lohmann Brown genotype eggs (9.03) (P<0.05). The difference between the albumen pH value of eggs obtained from the Lohmann Brown genotype (9.03) and the albumen pH value of eggs obtained from the Lohmann Sandy genotype (9.03) was found to be statistically insignificant.

Discussion

Egg Weight Loss

As a result of the research, the effect of temperature on egg weight loss during storage was found to be statistically significant. This result is consistent with the studies of Gavril and Usturoi (2011), Tayeb (2012), Akter et al., (2014), Jones et al., (2018), and Kale and Aygün (2022). Jones et al., (2018) found that on the 28th day of storage, egg weight loss was 0.58% in eggs stored at 4 °C, and 4.67% in eggs stored at 23 °C. Tayeb (2012) determined the weight loss of eggs as 7.66% in eggs stored at room temperature (25-30°C) on the 27th day of storage, and as 2.93% in eggs stored in a refrigerator (5 °C). In a study by Gavril and Usturoi (2011) they found that egg weight loss was 1.99% at 4°C and 3.12% at 25°C in eggs stored at 4 °C and 25 °C. Kale and Aygün (2022) determined that the average egg weight loss at the end of the 28th day of storage was 1.53% in eggs stored at 4°C, and 5.68% in eggs stored at 23°C at the end of the 28th day of storage. Akter et al., (2014) determined that after 28 days of storage, egg weight loss in eggs stored at 4 °C was lower than in eggs stored at 28-31 °C.

As a result of the research, the effect of genotype on egg weight loss was found to be significant on the 14 and 28 days of storage. The egg weight loss of the ATAK-S genotype was found to be higher than that of the Lohmann Brown and Lohmann Sandy genotypes on the 28th day of storage. This result is compatible with the studies of Silversides et al., (2001), Tunçer (2006), Şekeroğlu et al., (2008), Bozkurt and Tekerli (2009), and Alsobayel and Albadry (2011). Alsobayel and Albadry (2011) found in their study that the white shelled egg weight was higher than the brown shelled egg weight after 20 days of storage of eggs. Silversides et al., (2001) determined that the egg weight of the ISA-Brown genotype was higher than the egg weight of the ISA-White genotype after 10 days of storage. In the study conducted by Tunçer (2006), it was determined that the egg weight of the Isa-Brown genotype was higher than the egg weight of the Babcock300 genotype after 14 days of storage.

The cuticle layer on the eggshell, synthesized by the secretory cells 1.5-2 hours before ovulation, acts as a buffer for gas and water permeability in the egg (Wyburn et al., 1973; Nys et al., 1999; Samiullah et al., 2014; Ketta and Tůmová 2016; Wilson et al., 2017). The permeability of the crust increases with the drying of the cuticle (Rodríguez-Navarro et al., 2013). During storage, egg weight loss occurs when the water vapor in the egg is removed from the egg through the pores densely located in the egg shell (Akyurek and Okur 2009). It is thought that the rate of removal of the water spring increases at higher temperatures.

Haugh Unit

In our study, the effect of temperature on the Haugh Unit was found to be significant as a result of storing eggs obtained from different layer genotypes (Lohmann Sandy, Lohmann Brown and ATAK-S) at different temperatures (4 ℃ and 23 ℃). This result is similar to Samli et al., (2005), Bozkurt and Tekerli (2009), Baylan et al., (2011), Jin et al., (2011), Gavril and Usturoi (2011), Adamski et al., (2017), Kale and Aygün (2022). It is compatible with the studies conducted by Samli et al., (2005) conducted a study to determine the effects of storage temperature on the quality parameters of eggs obtained from Bovans White egg hens, and as a result of 10 days of storage, the Haugh unit of eggs stored at 5 °C was (76.27) compared to that of eggs stored at 21 °C. They found that the Haugh unit (53.74) of eggs stored at 29°C was higher than the Haugh unit (53.74). In a study carried out by Bozkurt and Tekerli (2009) to examine the egg quality characteristics of eggs obtained from different layer genotypes depending on storage conditions, the Haugh unit of eggs stored at 4 °C (58.11) after 5 weeks of storage was lower than the Haugh unit of eggs stored at 24 °C (58.11). 40.90) were found to be higher. Jin et al., (2011) conducted a study to determine the effect of storage temperature on egg quality. As a result of 10 days of storage, the Haugh unit of eggs stored at 5 °C was 87.63, the Haugh unit of eggs stored at 21 °C was 72.63, and the Haugh unit of eggs stored at 29 °C was 87.63. It was determined to be higher than the Haugh unit (61.85) of stored eggs. Gavril and Usturoi (2011), in their study to determine the effect of the level of environmental factors provided during egg storage on egg quality, at the end of the 28th day of storage, the Haugh unit of eggs stored at 4 °C (73.48), was lower than the Haugh unit of eggs stored at 25 °C (48.45), were found to be higher. In their study to examine the change in egg quality characteristics depending on storage conditions, Adamski et al., (2017) found that the Haugh unit of eggs stored at 4 °C (71.60) after 28 days of storage was higher than the Haugh unit (32.66) of eggs stored at 23 °C were found to be high. Kale and Aygün (2022) examined the effect of storing eggs obtained from different rearing systems at different temperatures on egg quality. According to the results obtained from the study, they determined that the Haugh unit of eggs stored at 4 °C (69.81) was higher than the Haugh unit of eggs stored at 23 °C (62.98) after 28 days of storage.

As a result of our study, the effect of genotype on the Haugh Unit was found to be significant. On the 28th day of storage, it was determined that the Haugh unit value (82.23) of Lohmann Brown genotype eggs was higher than the Haugh unit value of ATAK-S genotype eggs (70.48) and the Haugh unit value of Lohmann Sandy genotype eggs (75.68) (P<0.05), while the Lohmann Sandy genotype egg Haugh unit value (70.48) was higher than the Haugh unit value (75.68) (P<0.05). The Haugh unit of Lohmann Sandy genotype eggs is similar to the Haugh unit of ATAK-S genotype eggs. While this result is parallel to the studies of Tunçer (2006), Bozkurt and Tekerli (2009), and Şekeroğlu et al., (2008), it is incompatible with the study of Alsobayel and Albadry (2011). Tunçer (2006) examined the effect of storage on egg quality criteria in two different commercial laying hen genotypes (Babcock300 and Isa-Brown), and in the study, the effect of genotype on the Haugh unit was found to be significant. As a result of their research, Bozkurt and Tekerli (2009) found the effect of genotype on the Haugh Unit in storage in two different laying hen genotypes (Lohmann White and ISA Brown) to be significant. At 5 weeks of storage, the Haugh unit (51.96) of eggs belonging to the Lohmann White genotype was determined to be higher than the Haugh unit (47.05) of eggs belonging to the Isa Brown genotype. Şekeroğlu et al., (2008) found in their study that the effect of genotype on the Haugh unit was significant as a result of the storage of eggs obtained from ATAK and ATABEY genotypes. They found that the Haugh unit of ATABEY genotype eggs (74.40) was higher than the Haugh unit of ATAK genotype eggs (77.10) on the 20th day of storage. In a study conducted by Alsobayel and Albadry (2011), the effect of genotype on storage of eggs obtained from brown and white laying hens was found to be insignificant. On the 20th day of storage, the Haugh unit (79.48) of the eggs obtained from the brown layer genotype and the Haugh unit (79.39) of the eggs obtained from the white layer genotype were determined to be similar.

The decrease in Haugh unit occurred due to decreases in albumen height and increased egg weight loss. At high storage temperatures, denaturations in the structure of ovomucin, the egg albumen protein, occur rapidly, and the albumen height decreases due to the decrease in egg albumen density (Tunçer 2006; Quan and Benjakul 2018; Quan and Benjakul 2019). Similarly, high storage temperatures increase egg weight losses by affecting the evaporation rate of water vapor in the egg.

Yolk index

In our study, the effect of temperature on the yolk index was found to be significant in all periods of storage. This finding supports parallelism between research by Samli et al., (2005), Akyurek and Okur (2009), Bozkurt and Tekerli (2009), Gavril and Usturoi (2011), Tayeb (2012), Akpinar et al., (2015), and Jones et al., (2018). Gavril and Usturoi (2011) found the effect of temperature on the yolk index to be significant. At the end of the 28th day of storage, the yolk index (0.36) of eggs stored at 4 °C was found to be higher than the yolk index (0.28) of eggs stored at 25 °C. Jones et al., (2018) found that, after 6 weeks of storage, the yolk index of eggs stored at 4 °C (0.54) was higher than the yolk index of eggs stored at 25 °C (0.35). Bozkurt and Tekerli (2009) found that the yolk index (0.55) of eggs stored at 4 °C was higher than the yolk index (0.45) of eggs stored at 24 °C in the 5th week of storage. Akyurek and Okur (2009) found that the yolk index of eggs stored at 4°C was higher than the yolk index of eggs stored at 20°C after 14 days of storage. Samli et al., (2005) examined the effect of different storage temperatures (5 °C, 21 °C and 29 °C) and storage time on egg quality in laying hens and found the effect of temperature on the yolk index to be significant. They found that after 10 days of storage, the yolk index of eggs stored at 5 °C was higher than the yolk index of eggs stored at 21 °C and the yolk index of eggs stored at 29 °C. Tayeb (2012) found the effect of temperature on yolk index to be significant. On the 27th day of storage, the yolk index of eggs stored at 5 °C was determined to be higher than the yolk index of eggs stored at 25-30 °C.

In our study, the effect of genotype on yolk index was found to be significant in all periods of storage. Nevertheless, this result is parallel to the studies of Bozkurt and Tekerli (2009), and (Keener et al., 2006), it is opposition to those of Şekeroğlu et al., (2008). As a result of their research, Bozkurt and Tekerli (2009) found that the effect of genotype on the yolk index in storage in two different laying hen genotypes (Lohmann White and ISA Brown) was significant. They found that the yolk index of the Lohmann White genotype (0.48) was lower than the yolk index of the ISA Brown genotype (0.50) in eggs stored for 5 weeks. In a study conducted by Keener et al., (2006), the effects of genotype on yolk index were found to be significant as a result of storage of two different chicken genotypes (Hyline White 36 and Bovans White). The yolk index (0.45) of the Bovans White genotype was determined to be higher than the yolk index of the Hyline White-36 genotype in 7-week-old stored eggs. Şekeroğlu et al., (2008) found that the effect of genotype on the yolk index as a result of storage of eggs obtained from ATAK and ATABEY chickens was insignificant. After 20 days of storage, the yolk index (0.40) of ATABEY genotype eggs and the yolk index (0.40) of ATAK genotype eggs were determined to be similar.

As a result of the decrease in the amount of albumen and deterioration in its structure during storage, the yolk loses its spherical appearance and acquires a round and loose appearance, causing the yolk diameter to increase (Silversides and Budgell 2004). As the vitelline membrane in the egg albumen loses its elasticity, it ruptures and the egg albumen and yolk mix (Avan and Alişarlı 2002). Deterioration in the structure of the vitelline membrane causes the yolk height to decrease and the yolk diameter to increase. Accordingly, decreases occur in the yolk index (Kale and Aygün 2022).

Albumen pH

In our study, the effect of temperature on albumen pH was found to be important in all periods of storage. This result is in parallel with those of Jin et al., (2011), Chung and Lee (2014), Lee et al., (2016), Adamski et al., (2017) and Feddern et al., (2017). Jin et al., (2011) found that after 10 days of storage, the albumen pH value of eggs stored at 5 °C (8.76) was lower than the albumen pH value of eggs stored at 21 °C (9.50) and the albumen pH value of eggs stored at 29 °C (9.71). Chung and Lee (2014) found that the albumen pH value (8.72) of eggs stored at 4 °C on the 28th day of storage was lower than the albumen pH value (9.03) of eggs stored at 23 °C. In a study conducted by Lee et al., (2016), on the 30th day of storage, the albumen pH value of eggs stored at 2°C (8.03) was compared with the albumen height value of eggs stored at 12°C (8.68) and the albumen pH value of eggs stored at 25°C (8.68). As a result of 28 days of storage, Adamski et al., (2017) found that the albumen pH value of eggs stored at 4 °C (8.26) was lower than that of eggs stored at 23 °C (8.54). Furthermore, Feddern et al., (2017) found that the albumen pH value of eggs stored at 5°C (8.63) on the 28th day of storage was higher than the albumen pH value of eggs stored at 20-30°C (9.30).

In our study, the effect of genotype on albumen pH was found to be significant on the 14th, 21st and 28th days of storage. On the 28th day of storage, the albumen pH value of ATAK-S genotype eggs (9.06) was higher than the albumen pH value of Lohmann Sandy genotype eggs (9.03) and the albumen pH value of Lohmann Brown genotype eggs (9.03). The albumen pH value of Lohmann Brown genotype eggs and the albumen pH value of Lohmann Sandy genotype eggs were found to be similar. While this result is parallel to those of Silversides and Budgell (2004) and Şekeroğlu et al., (2008), it is incompatible with the study conducted by Feddern et al., (2017). In their study by Silversides and Budgell (2004), the effect of genotype on albumen pH was found to be significant as a result of storage of eggs obtained from Brown Leghorn, ISA Brown, Babcock genotypes.

After 10 days of storage, the albumen pH value of the Brown Leghorn genotype (8.84) was determined to be higher than the Bobcook genotype albumen pH value (8.70) and the albumen pH value of the ISA Brown genotype (8.67), and the difference between ISA Brown and Babcock genotype eggs was found to be statistically significant. Şekeroğlu et al., (2008) found that the effect of genotype on albumin pH was significant as a result of storage of eggs obtained from ATAK and ATABEY genotypes. After 20 days of storage, the albumen pH value of ATAK genotype eggs (7.62) was higher than that of ATABEY genotype eggs (7.54). As a result of storage of eggs obtained from white and brown layer genotypes, the effect of genotype on albumen pH was found to be insignificant by Feddern et al., (2017). After 28 days of storage, the albumen pH value of eggs obtained from brown genotypes (8.94) was determined to be similar to the albumen pH value of eggs obtained from white genotypes (8.98).

During storage, the ovomucin-lysozyme complex breaks down and helps increase the pH of the eggs (Akter et al., 2014). High storage temperatures cause rapid removal of water and CO_2 from the egg albumen through the pores in the eggshell, resulting in greater increases in albumen pH (Avan and Alişarlı 2002; Yılmaz and Bozkurt 2008).

Conclusions

The genotype x storage temperature interaction effect did not generally significantly affect egg quality characteristics during storage. It has been observed that the quality characteristics of eggs stored under refrigerator conditions during storage are better than those stored under room conditions. During storage, the quality characteristics of eggs obtained from the ATAK-S genotype were observed to be in worse condition than the eggs of the Lohmann Brown and Lohmann Sandy genotypes. Refrigerator should be preferred for storing table eggs. It should be taken into consideration that genotype has a significant impact on the storage of table eggs.

Author Contributions:

Conceptualization, C.B. and A.A.; methodology, C.B. and A.A.; validation, C.B. and A.A; formal analysis, C.B., and A.A.; investigation, C.B. and A.A.; data curation, C.B., A.A. and F.İ.; writing—original draft preparation, C.B. and A.A.; writing—review and editing, C.B., and A.A.; supervision, C.B., A.A.; project administration, A.A.; funding acquisition, A.A. All authors have read and agreed to the published version of the manuscript.

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References:

Adamski, M., Kuzniacka, J., Czarnecki, R., Kucharska-Gaca, J., Kowalska, E. 2017. Variation in Egg Quality Traits Depending on Storage Conditions. Pol. J. Natl. Sci, *32*: 39-47.

Akpinar, G. C., Canogullari, S., Baylan, M., Alasahan, S., Aygun, A. 2015. The Use of Propolis Extract for the Storage of Quail Eggs. Journal of Applied Poultry Research, *24*(4): 427-435.

Akter, Y., Kasim, A., Omar, H., Sazili, A. Q. 2014. Effect of Storage Time and Temperature on the Quality Characteristics of Chicken Eggs. Journal of Food, Agriculture & Environment, *12*(3&4): 87-92.

Akyurek, H., Okur, A. A. 2009. Effect of Storage Time, Temperature and Hen Age on Egg Quality in Free-Range Layer Hens. Journal of Animal and Veterinary Advances, *8*(10): 1953-1958.

Alsobayel, A., Albadry, M. 2011. Effect of Storage Period and Strain of Layer on Internal and External Quality Characteristics of Eggs Marketed in Riyadh Area. Journal of the Saudi Society of Agricultural Sciences, *10*(1): 41-45.

Avan, T., Alişarlı, M. 2002. Muhafaza Şartlarının Yumurtanın Fiziksel, Kimyasal Ve Mikrobiyolojik Kalitesi Üzerine Etkisi. Yüzüncü Yıl Üniversitesi Veteriner Fakültesi Dergisi, *13*: 98-107.

Aygun, A., Sert, D. 2013. Effects of Vacuum Packing on Eggshell Microbial Activity and Egg Quality in Table Eggs under Different Storage Temperatures. Journal of the Science of Food and Agriculture, *93*(7): 1626-1632.

Baylan, M., Canogullari, S., Ayasan, T., Copur, G. 2011. Effects of Dietary Selenium Source, Storage Time, and Temperature on the Quality of Quail Eggs. Biological Trace Element Research, *143*(2): 957-964.

Bozkurt, Z. 2009. Kafes Ve Alternatif Sistemlerde Yumurtacıtavukların Refahı. Kocatepe Veteriner Dergisi, *2*(1): 59-67.

Bozkurt, Z., Tekerli, M. 2009. The Effects of Hen Age, Genotype, Period and Temperature of Storage on Egg Quality. Kafkas Üniversitesi Veteriner Fakültesi Dergisi, *15*(4): 517-524.

Chung, S. H., Lee, K.-W. 2014. Effect of Hen Age, Storage Duration and Temperature on Egg Quality in Laying Hens. International Journal of Poultry Science, *13*(11): 634.

Directive, E. 1999. Council Directive 99/74/Ec of 19 July 1999 Laying Down Minimum Standards for the Protection of Laying Hens. Official journal of the European Communities, *203*: 53-57.

Doğan, H. 2008. Adana 'Da Satışa Sunulan Yumurtalarda Sunuş Çeşitliliği Ve Kalite Değişimi Üzerine Bir Çalışma. Çukurova Üniversitesi Fen Bilimleri Enstitüsü Zootekni Anabilim Dalı Yüksek Lisans Tezi, *54*.

Durmuş, İ. 2014. Yumurta Kalite Özelliklerinin Kuluçka Sonuçlarına Etkisi. Akademik Ziraat Dergisi, *3*(2): 95-99.

Feddern, V., Prá, M. C. D., Mores, R., Nicoloso, R. d. S., Coldebella, A., Abreu, P. G. d. 2017. Egg Quality Assessment at Different Storage Conditions, Seasons and Laying Hen Strains. Ciência e Agrotecnologia, *41*: 322-333.

Funk, E. 1948. The Relation of the Yolk Index Determined in Natural Position to the Yolk Index as Determined after Separating the Yolk from the Albumen. Poultry Science, *27*(3): 367.

Gavril, R., Usturoi, M. 2011. Effects of Temperature and Storage Time on Hen Eggs Quality. Lucrări Ştiinţifice, Seria Zootehnie, *56*: 259-264.

Goger, H., Demirtas, S. E., Yurtogullari, S. 2016. A Selection Study for Improving Eggshell Colour in Two Parent Lines of Laying Hens and Their Hybrids. Italian Journal of Animal Science, *15*(3): 390-395.

Haugh, R. 1937. The Haugh Unit for Measuring Egg Quality. United States egg and poultry magazine, *43*: 522-555.

Jin, Y., Lee, K., Lee, W., Han, Y. 2011. Effects of Storage Temperature and Time on the Quality of Eggs from Laying Hens at Peak Production. Asian-Australasian Journal of Animal Sciences, *24*(2): 279-284.

Jones, D., Ward, G., Regmi, P., Karcher, D. 2018. Impact of Egg Handling and Conditions During Extended Storage on Egg Quality. Poultry science, *97*(2): 716-723.

Kale, B., Aygün, A. 2022. Farklı Yetiştirme Sistemlerinden Elde Edilen Yumurtaların Farklı Sıcaklıklarda Depolanmasının Yumurta Kalitesi Üzerine Etkisi. Osmaniye Korkut Ata Üniversitesi Fen Bilimleri Enstitüsü Dergisi, *5*(3): 1550-1566.

Keener, K., McAvoy, K., Foegeding, J., Curtis, P., Anderson, K., Osborne, J. 2006. Effect of Testing Temperature on Internal Egg Quality Measurements. Poultry science, *85*(3): 550-555.

Ketta, M., Tůmová, E. 2016. Eggshell Structure, Measurements, and Quality-Affecting Factors in Laying Hens: A Review. Czech Journal of Animal Science, *61*(7): 299-309.

Lee, M. H., Cho, E. J., Choi, E. S., Sohn, S. H. 2016. The Effect of Storage Period and Temperature on Egg Quality in Commercial Eggs. 한국가금학회지, *43*(1): 31-38.

Maman, A. H., Yildirim, I. 2022. The Effect of Short Periods of Incubation During Egg Storage (Spides) on Internal Egg Quality, Hatchability and Chick Quality of Long Stored Old Layer Breeder Eggs. European Poultry Science/Archiv für Geflügelkunde(353).

Nys, Y., Hincke, M., Arias, J., Garcia-Ruiz, J., Solomon, S. 1999. Avian Eggshell Mineralization. Poultry and Avian Biology Reviews, *10*(3): 143-166.

Parmak, Z. A., Aygün, A. 2023. Effects of Different Viol Types on Egg Qualities in Table Eggs at Different Storage Temperatures. Poultry Studies, *20*(1): 19-24.

Quan, T. H., Benjakul, S. 2018. Quality, Protease Inhibitor and Gelling Property of Duck Egg Albumen as Affected by Storage Conditions. Journal of food science and technology, *55*(2): 513-522.

Quan, T. H., Benjakul, S. 2019. Duck Egg Albumen: Physicochemical and Functional Properties as Affected by Storage and Processing. Journal of food science and technology, *56*(3): 1104-1115.

Rodríguez-Navarro, A. B., Domínguez-Gasca, N., Muñoz, A., Ortega-Huertas, M. 2013. Change in the Chicken Eggshell Cuticle with Hen Age and Egg Freshness. Poultry science, *92*(11): 3026-3035.

Samiullah, S., Roberts, J., Chousalkar, K. 2014. Effect of Production System and Flock Age on Egg Quality and Total Bacterial Load in Commercial Laying Hens. Journal of Applied Poultry Research, *23*(1): 59-70.

Samli, H., Agma, A., Senkoylu, N. 2005. Effects of Storage Time and Temperature on Egg Quality in Old Laying Hens. Journal of Applied Poultry Research, *14*(3): 548-553.

Sariyel, V., Aygun, A., Coklar, H., Narinc, D., Akbulut, M. 2022. Effects of Prestorage Application of Gum Arabic Coating on the Quality of Table Eggs During Storage. Kafkas Üniversitesi Veteriner Fakültesi Dergisi, *28*(3): 363-370.

Sert, D., Aygun, A., Demir, M. K. 2011. Effects of Ultrasonic Treatment and Storage Temperature on Egg Quality. Poultry science, *90*(4): 869-875.

Silversides, F., Budgell, K. 2004. The Relationships among Measures of Egg Albumen Height, Ph, and Whipping Volume. Poultry science, *83*(10): 1619-1623.

Silversides, F., Scott, TA. 2001. Effect of Storage and Layer Age on Quality of Eggs from Two Lines of Hens. Poultry science, *80*(8): 1240-1245.

Şekeroğlu, A., Sarıca, M., Demir, E., Ulutaş, Z., Tilki, M., Saatçi, M. 2008. The Effects of Housing System and Storage Length on the Quality of Eggs Produced by Two Lines of Laying Hens. Archiv Fur Geflugelkunde, *72*(3): 106-109.

Tayeb, I. T. 2012. Effects of Storage Temperature and Length on Egg Quality Parameters of Laying Hen. Journal of Animal Scientist, *1*(2): 32-36.

Tunçer, P. (2006). İki Farklı Ticari Yumurtacı Tavuk Genotip'ine Ait Yumurtalarda Kalite Kriterlerinin Depolama Süresine Göre Değişimi Afyon Kocatepe Üniversitesi, Sağlık Bilimleri Enstitüsü].

Tutkun, M., Denli, M., Demirel, R. 2018. Productivity and Egg Quality of Two Commercial Layer Hybrids Kept in Free-Range System. Turkish Journal of Agriculture-Food Science and Technology, *6*(10): 1444-1447.

Türker, İ., Alkan, S., Akçay, S. 2017. Comparison of Domestic and Foreign Commercial Brown Layer Hens in Terms of Yield Characteristics in Freerange Raising System. Turkish Journal of Agriculture-Food Science and Technology, *5*(7): 814-821.

Wells, R. (1968). A Study of the Hen's Egg. British Egg Marketing Board Symposium, Edinburgh,

Wilson, P. W., Suther, C. S., Bain, M. M., Icken, W., Jones, A., Quinlan-Pluck, F., Olori, V., Gautron, J., Dunn, I. C. 2017. Understanding Avian Egg Cuticle Formation in the Oviduct: A Study of Its Origin and Deposition. Biology of Reproduction, *97*(1): 39-49.

Wyburn, G., Johnston, H., Draper, M., Davidson, M. F. 1973. The Ultrastructure of the Shell Forming Region of the Oviduct and the Development of the Shell of Gallus Domesticus. Quarterly Journal of Experimental Physiology and Cognate Medical Sciences: Translation and Integration, *58*(2): 143-151.

Yılmaz, A., Bozkurt, Z. 2008. Ana Yaşı, Depolama Süresi Ve Streç Filmle Paketlemenin Sofralık Yumurtaların Iç Ve Dış Kalite Özelliklerine Etkisi. Lalahan Hayvancılık Araştırma Enstitüsü Dergisi, *48*: 81-91.

Table 1. Effect of storage temperature, genotype and storage x genotype interaction on egg weight loss

Treatment		Before storage egg weight (g)	Egg weight loss (%)			
			7 d	14 d	21 d	28 d
Storage temperature (°C)	23	54.38	1.33[a]	2.31[a]	3.17[a]	4.47[a]
	4	55.82	0.27[b]	0.72[b]	1.17[b]	1.67[b]
	SEM	0.636	0.036	0.051	0.054	0.074
	P-value	0.114	0.000	0.000	0.000	0.000
Genotype	LS	58.80[a]	0.75	1.34[b]	2.05	2.82[b]
	A	50.04[b]	0.83	1.60[a]	2.20	3.50[a]
	LB	56.46[a]	0.82	1.61[a]	2.25	2.89[b]
	SEM	0.779	0.044	0.063	0.066	0.090
	P-value	0.000	0.336	0.005	0.072	0.000
Storage temperature (°C) x Genotype	23 x LS	57.32[ab]	1.25	2.06	3.01	4.08[b]
	23 x A	48.46[d]	1.37	2.44	3.13	5.16[a]
	23 x LB	57.34[ab]	1.37	2.43	3.37	4.16[b]
	4 x LS	60.27[a]	0.24	0.63	1.08	1.56[c]
	4 x A	51.61[cd]	0.29	0.75	1.28	1.84[c]
	4 x LB	55.57[bc]	0.28	0.79	1.14	1.61[c]
	SEM	1.101	0.062	0.089	0.094	0.128
	P-value	0.045	0.794	0.291	0.120	0.004

[a-d] Differences between groups indicated with different letters in the same column are statistically significant ($P<0.05$). LS: Lohmann Sandy genotype, A: ATAK-S genotype, LB: Lohmann Brown genotype, SEM: Standard error of mean

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Table 2. Effect of storage temperature, genotype and storage x genotype interaction on Haugh unit

Treatment		Before storage Haugh Unit	Haugh Unit			
			7 d	14 d	21 d	28 d
Storage temperature (°C)	23	94.72	88.98^{b}	84.43^{b}	79.81^{b}	74.29^{b}
	4	96.83	93.61^{a}	91.21^{a}	82.75^{a}	77.96^{a}
	SEM	1.210	0.891	1.110	0.995	1.231
	P-value	0.221	0.001	0.000	0.041	0.039
Genotype	LS	94.23^{b}	90.72^{b}	87.52^{b}	80.53^{b}	75.68^{b}
	A	93.92^{b}	87.76^{b}	82.75^{c}	76.22^{c}	70.48^{b}
	LB	99.18^{a}	95.42^{a}	93.20^{a}	87.09^{a}	82.23^{a}
	SEM	1.481	1.090	1.358	1.218	1.507
	P-value	0.022	0.000	0.000	0.000	0.000
Storage temperature (°C) x Genotype	23 x LS	93.20	87.99	84.07	79.21	73.82
	23 x A	91.75	85.70	78.60	74.77	70.66
	23 x LB	99.20	93.26	90.63	85.47	78.40
	4 x LS	95.26	93.44	90.97	81.85	77.53
	4 x A	96.08	89.82	86.89	77.67	70.29
	4 x LB	99.15	97.58	95.77	88.72	86.06
	SEM	2.094	1.542	1.920	1.721	2.130
	P-value	0.590	0.895	0.720	0.984	0.188

[a-c] Differences between groups indicated with different letters in the same column are statistically significant (P<0.05). LS: Lohmann Sandy genotype, A: ATAK-S genotype, LB: Lohmann Brown genotype, SEM: Standard error of mean

Table 3. Effect of storage temperature, genotype and storage x genotype interaction on yolk index

Treatment		Before storage yolk index	Yolk index			
			7 d	14 d	21 d	28 d
Storage temperature (°C)	23	0.55	0.50^{b}	0.44^{b}	0.40^{b}	0.35^{b}
	4	0.57	0.55^{a}	0.54^{a}	0.50^{a}	0.46^{a}
	SEM	0.0068	0.0053	0.0045	0.0050	0.0063
	P-value	0.094	0.000	0.000	0.000	0.000
Genotype	LS	0.57	0.54^{a}	0.51^{a}	0.49^{a}	0.44^{a}
	A	0.55	0.51^{b}	0.46^{b}	0.43^{b}	0.38^{b}
	LB	0.56	0.53^{ab}	0.50^{a}	0.44^{b}	0.40^{b}
	SEM	0.0083	0.0065	0.0055	0.0061	0.0077
	P-value	0.420	0.002	0.000	0.000	0.000
Storage temperature (°C) x Genotype	23 x LS	0.56	0.52	0.45^{c}	0.44	0.40^{b}
	23 x A	0.54	0.48	0.42^{d}	0.38	0.34^{c}
	23 x LB	0.57	0.50	0.44^{cd}	0.39	0.33^{c}
	4 x LS	0.58	0.57	0.56^{a}	0.53	0.47^{a}
	4 x A	0.57	0.53	0.50^{b}	0.48	0.43^{ab}
	4 x LB	0.56	0.55	0.57^{a}	0.49	0.46^{a}
	SEM	0.0116	0.0092	0.0465	0.0087	0.0109
	P-value	0.127	0.846	0.041	0.913	0.017

[a-d] Differences between groups indicated with different letters in the same column are statistically significant ($P<0.05$). LS: Lohmann Sandy genotype, A: ATAK-S genotype, LB: Lohmann Brown genotype, SEM: Standard error of mean

Table 4. Effect of storage temperature, genotype and storage x genotype interaction on albumen pH

Treatment		Before storage albumen pH	Albumen pH			
			7 d	14 d	21 d	28 d
Storage temperature (°C)	23	8.57	8.98^{a}	9.02^{a}	9.07^{a}	9.12^{a}
	4	8.60	8.80^{b}	8.84^{b}	8.92^{b}	8.96^{b}
	SEM	0.044	0.020	0.014	0.010	0.008
	P-value	0.663	0.000	0.000	0.000	0.000
Genotype	LS	8.52	8.85	8.89^{b}	8.93^{b}	9.03^{b}
	A	8.68	8.91	8.97^{a}	9.04^{a}	9.06^{a}
	LB	8.56	8.91	8.94^{ab}	9.02^{a}	9.03^{b}
	SEM	0.054	0.024	0.018	0.012	0.010
	P-value	0.097	0.178	0.010	0.000	0.024
Storage temperature (°C) x Genotype	23 x LS	8.54	8.91	8.95	8.97	9.12
	23 x A	8.69	9.01	9.08	9.12	9.14
	23 x LB	8.49	9.01	9.04	9.10	9.11
	4 x LS	8.50	8.80	8.83	8.86	8.93
	4 x A	8.67	8.80	8.85	8.96	8.98
	4 x LB	8.63	8.81	8.85	8.94	8.95
	SEM	0.076	0.035	0.025	0.017	0.014
	P-value	0.435	0.346	0.077	0.504	0.433

[a-b] Differences between groups indicated with different letters in the same column are statistically significant (P<0.05). LS: Lohmann Sandy genotype, A: ATAK-S genotype, LB: Lohmann Brown genotype, SEM: Standard error of mean