RESEARCH ARTICLE Indian Journal of Animal Research, Volume 58 Issue 4: 681-687 (April 2024)

A Comparative Study of the Internal and External Quality Characteristics of Table Eggs and the Effect of Storage Periods and Layer Strain on them under Summer Conditions

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10.18805/IJAR.BF-1721

ABSTRACT

Background: Eggs are a rich source of protein and a portion of food that satisfies human demands and supplies the body with amino acids, metal elements and vitamins that are beneficial for general health. This research aimed to determine the influence of storage duration and hen breed on the internal and external quality characteristics of brown- and white-shelled eggs under different domestic storage circumstances.

Methods: A total of 240 eggs from the two species were randomly selected. They were stored at a humidity of 65% and temperatures of ±1°C for 0, 15 and 30 days. All eggs were cracked to determine the egg coefficient, egg weight, egg weight loss and air chamber depth. Egg-specific density, Haugh unit values, yolk color, the presence of flesh and blood spots, white weight, yolk weight, shell integrity, white weight percentage, percentage of shell weight, yolk weight ratio and yolk weight ratio. Shell thickness, density, cleanliness, surface area and weight relative to shell area.

Result: The Haugh unit, specific density, air chamber depth and shell thickness were all significantly (P≤0.05) affected by the length of time eggs were stored. It had a favorable influence on shell density and weight for brown and white-shell eggs, but the Huff unit values of the eggs were negatively affected the longer they were stored. This effect was more pronounced the longer the eggs were stored. Due to the difference in shell color and the extended period of storage, there was a major change in all of the components of the egg. This was caused by the storage duration.

Key words: External egg quality, Human consumption, Internal egg quality, Layers strain, Storage period.

INTRODUCTION

Table eggs are the cheapest animal protein and a full food with 75 kcal per egg. High digestibility and well-balanced amino acids make it a good human protein source (Nys and Sauveur, 2004). Changes in eating habits and rising pulse costs have led to an increase in demand for protein-rich foods such as fowl products. Given the rate of population increase and the surge in demand for chicken products such as eggs, the country must expand its supply (Chaudhari and Tingre, 2015). So, it's a basic food product eaten worldwide (Gautron *et al.*, 2022; Nys *et al.*, 2022). About 150 eggs are consumed on average by each person across the globe every single year (Nys *et al.*, 2022). The storage traits of eggs play an important role in their acceptability to consumer preferences (Sapkota *et al.*, 2020). Therefore, eggs are a low-cost, low-calorie source of high-quality protein and other nutrients (Ruxton, 2013; Zaheer, 2015). Eggs are an important food item for humans because they contain animal protein, fats, mineral salts, essential amino acids, saturated fats, yeasts and enzymes that are only available in a few foods. One egg can constitute a complete meal for the consumer, which can be obtained at all times and places (Sahar and Rahman, 2018).

Genotype and storage periods have been proven to influence egg quality traits (Anderson *et al.*, 2004; Alsobayel and Albadry, 2011). External and internal egg quality features have a genetic basis, as is well known. The qualitative, chemical, functional and microbial characteristics of table eggs are affected by environmental variables such as age of the bird, feeding, season, temperature, transportation, storage period and exposure to heat. Farm-produced eggs may be of high quality, but inefficient farm handling, storage and marketing practices may result in a decline in egg quality (Al-Obaidi *et al.*, 2011). The loss of weight owing to the evaporation of water is the single most important factor that determines whether an egg's quality is compromised on the inside or the outside during the course of storage or when it is handled (Samli *et al.*, 2005; Calik, 2013). There is rise in hydrogen power of albumin and yolk, reduced Haugh unit

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How to cite this article: Murshed, M. and Qaid, M.M. (2024). A Comparative Study of the Internal and External Quality Characteristics of Table Eggs and the Effect of Storage Periods and Layer Strain on them under Summer Conditions. Indian Journal of Animal Research. 58(4): 681-687. doi: 10.18805/IJAR.BF-1721.

Submitted: 19-10-2023 **Accepted:** 16-01-2024 **Online:** 12-02-2024

values and carbon acid dissociation (Mohiti-Asli *et al*., 2008; Monira *et al*., 2003). These variations are the result of water movement through the vitelline membrane from albumin to yolk due to the weakness of the vitelline membrane (Jones, 2007; Kralik *et al*., 2014). Fresh eggs contain the highest quality characteristics and specifications and over time they begin to deteriorate and become corrupted and are susceptible to the factors of the surrounding environment as a result of storage and exposure to heat, drought and others. In many cases, the production of eggs is greater than the ability to market them in a short time, forcing the product to be stored for the longest possible period so it can retain its specifications (Johanning *et al*., 1996). Commercial table eggs are predominantly sold in supermarkets, poultry markets and grocery shops in Saudi Arabia. Saudi families buy eggs in trays of 30 eggs, keep them in the refrigerator and consume them within two to three weeks. In the meantime, there is relatively little information available on the quality features of locally produced commercial eggs. The current study sought to assess egg quality by assessing the internal and exterior characteristics and the effect of the storage period on commercial table eggs sold in Riyadh during the summer. Consequently, the research was carried out to compare and evaluate the influence of storage duration on external and internal quality traits of brown and white-shell eggs produced by commercial farmers raised under local conditions and marketed in the Riyadh region.

MATERIALS AND METHODS

Experimental area and the eggs administration

This experiment was completed in the Animal Production Department of the College of Food and Agriculture Sciences-King Saud University, during the duration from (6/7/2022 - 6/10/2022). In this investigation, 480 brown and white shell eggs were used. Eight fresh egg dishes made up of two trays with 30 eggs each were chosen at random from the supermarket four times, at various intervals. They contained 240 brown-shelled eggs and 240 white-shelled eggs. The eggs of each species were separated into four treatments, with 30 eggs in each treatment and stored for 0, 10, 20 and 30 days at 4±1°C and 50-70% prorated humidity. The eggs of each treated collection were randomly portioned into four treatments, each replicate contained 20 eggs. The different egg treatments were individually weighed to the nearest 0.01 g. Eggs treatments that were stored for 10, 20 and 30 days were reweighed and the depth of egg air cell (AC) was measured in millimeters for each replicate utilizing a candling light and a thin plastic ruler.

Evaluation of the external adjectives of egg quality

Before being stored, each of the different egg-weighted groups were separately weighed. To determine the percentage of egg weight loss (WL), egg groups that were kept for 10, 20 and 30 days were reweighed and the candling lamp, a thin plastic ruler and the egg test equipment were utilized to measure the depth of the air chamber in millimeters for each of the eggs in duplicate. This was done for all of the eggs in each replicate. The cleanliness of the shell (CL) and the absence of any cracks or fractures in it were both factors that were evaluated. Using the inserted ruler and an egg test device were determine the depth of the air chamber using the inserted ruler and an egg test device. The egg was placed with the device from its wide end and the air chamber measured, other shell characteristics including shell thickness (ST), shell density (SD), shell surface area (SA) and shell weight (SWUSA). The specific density was determined by submerging an egg in water to determine the volume of water that was displaced and then calculating the specific density (SG), based on the equation that is presented below:

$$\text{Specific density (SG)} = \frac{\text{Egg weight in air}}{\text{Egg weight in air - Weight in water}}$$

Calculating the egg's coefficient (EI) by measuring the length and width of the egg > (width/length) * 100.

Egg surface area (SA) in cm^2 was calculated for each egg using the following equation suggested by Nordstrom and Qusterhout (1982):

$$SA = ¼\ 3{:}9782 \times \text{Egg weight } 0{:}7056$$

$$SD\ (g.cm^{-3}) = \frac{\text{Shell weight (g)}}{\text{Surface area, } cm^2 \times \text{Shell thickness, cm}}$$

According to the following equation:

$$SG = \frac{\text{Weight of air}}{\text{Difference between weight of air and water}}$$

(North and Bell, 1990)

Evaluation of traits Internal egg quality

After eggs were removed from each replication of each egg shell color and placed on a specialized glass table with a mirror on the bottom, the contents of the egg could be observed from both above and below using the mirror. Optical inspection was used to analyze the contents of the inner egg for the presence or absence of meat (MS) and blood (BS) spots, as described in the following. The Roch Color Scale (Hoover Man La Roche), which is graded to the degrees of yellow of 1-15 color gradations from extremely pale to deep yellow (North and Bell, 1990), was used to measure the degree of yolk color (YC). These color gradations range from very pale to deep yellow. The Haugh unit value was directly established by using a micrometer that is adjustable to egg weight and gives the Haugh unit value (USDA, 2000). The Haugh unit was measured using the Haw device (Haugh, 1937), which measures the height of the heavy whites at a distance of half a centimeter from the yolks. After entirely separating the yolk from the white using a specialized funnel, the yolk was placed on a scale and given its weight in grams after being thoroughly cleaned of any remaining traces of whiteness. After the albumin had been removed from the shell, it was thoroughly cleaned, allowed to dry at temperatures between 21 and 24 degrees

Celsius for twenty-four hours and then it was weighed (SW) to the nearest 0.1 g increment. Each egg with a membrane was given three separate measures of its shell thickness (ST) using a dial touch micrometer. These measurements were taken in the middle of the egg as well as on both of its sides.

The qualitative characteristics of eggs were estimated using the following formula:

Weight of the egg =

Weight of the egg after storage - (Yolk weight + Shell weight)

$$\text{Yolk indicator} = \frac{\text{Yolk height (mm)}}{\text{Yolk diameter (mm)}}$$

$$\text{Yolk percentage} = \frac{\text{Yolk weight (g)}}{\text{Egg weight}} \times 100$$

$$\text{Albumin ratio} = \frac{\text{Weight of albumin (gm)}}{\text{Weight of eggs}} \times 100$$

$$\text{Yolk/albumin} = \frac{\text{Yolk weight (g)}}{\text{Weight of albums (g)}} \times 100$$

$$\text{Haugh unit} = 100 \text{ leu } (e + 7.57 - 1.7\, f - 37)$$

Statistical analysis

Using the SAS program (2005), the data were statistically analyzed to verify the presence of significant differences between the average levels of each factor and the ability to overlap between the studied traits for each strain, using the following statistical model:

$$Y_{ijk} = \mu + B_i + S_j + BS_{ij} + e_{ijk}$$

Y_{ijk} = k^{th} observation of the ith breed (B), j^{th} storage period. BS_{ij} = Interaction between breeding and storage time.

RESULTS AND DISCUSSION

The results showed that faster rates of change in trait scores were associated with longer storage periods. According to the findings of the study, egg storage duration (10, 20 and 30 days) resulted in a significant ($p \leq 0.05$) decrease in some egg parameters.

Table 1 shows significant differences in weight between brown and white-shell eggs, yolk and white and shell. Whilst, not significant changes were seen in yolk (0.43) to whiteness (0.42) and egg weight loss (0.57), (1.10), respectively. With an increase in storage time, the weight of the yolk and white and the ratio of yolk and albumin between brown eggs and white-shell eggs changed, while the weight of eggs, loss and shell weight did not change. The interaction did not affect the previously mentioned traits except for egg weight. Large eggs had more albumin than small eggs (Cunningham *et al.*, 1960; Attia, 2014). Silverides and Scott (2001) and Zeta *et al.* (2009) found statistically significant differences in these parameters between breeds and strains. Increasing storage time greatly lowers albumin and increases yolk (Akyurek and Okur, 2009).

The given percentages show statistically significant differences between eggs of all breeds held for different times, however, strain and storage period do not interact. Scott and Silversides (2000) found no significant effect of strain-storage period interaction on the studied traits, as well as an increase in yolk color grade, yolk albumin ratio and air cell depth. Shape index and shell density were unaffected by storage length (Alsobayel and Albadry, 2011; Alshaikhi *et al.*, 2021). Research indicates that storage length (10, 20 and 30 days) days) and strain genotype significantly ($p \leq 0.05$) reduce yolk weight ratio to shell weight per unit surface area and Haugh unit values (Fig 1-4). Several studies found similar storage length effects for Haugh unit values and the yolk index. Samli *et al.* (2005), Alsobayel and Albadry (2011); Khatun (2016) and Monira *et al.* (2003) measured specific density, air cell depth and shell thickness. Unlike us, other researchers found no effect of storage duration on yolk color grade, yolk albumin ratio, shell thickness, or shell surface area. Some researchers found that increasing storage duration increased shell density, thickness and weight per unit of surface area (Lee *et al.*, 2016; Alsobayel and Albadry, 2011) and decreased yolk color grade.

Brown eggs scored substantially higher ($p<0.01$) than White Lohmann eggs. According to Hassanin and Gabal (1990), this is true. Local Iraqi chickens were compared to

Table 1: Impact of strain genotype and egg storage period on brown (B) and white (W) shelled eggs on egg weight (EW), egg weight loss (EWL), yellow weight (YW), albumen weight (AW), shell weight (SW) and YW/AW ratio.

	EW (g)	EWL (g)	YW (g)	AW (g)	SW (g)	YW/AW (g)
Genotype (G)	**	NS	**	**	**	NS
B	61.41^{a}	0.57	16.59^{a}	38.42^{a}	5.87^{a}	0.43
W	56.63^{b}	1.10	15.31^{b}	34.72^{b}	5.48^{b}	0.42
Storage period (SP; d)	NS	**	**	**	NS	**
0	58.99	0.00	14.76^{c}	38.66^{a}	5.62	0.38
10	58.86	0.26	16.23^{b}	35.53^{b}	5.59	0.43
20	59.21	0.87	16.86^{a}	35.51^{b}	5.72	0.48
30	60.19	1.12	17.21^{a}	34.42^{c}	5.86	0.55
G*SP	NS	NS	NS	**	NS	NS
SEM	±0.126	±0.318	±0.092	±0.333	±0.037	±0.007

NS: Non-significant. Means in the same column with different superscripts differ significantly (P<0.05). **Highly significant (P<0.01).

Table 2: Impact of strain genotype and storage period egg weight (EW), shell thickness (ST), egg surface area (SA), shell density (SD), specific gravity (SG), air cell depth (AC) and shape index (SI) of both species.

	EW (g)	ST (mm×10)	SA $(cm)^2$	SD $(g/cm)^3$	SG	AC (mm)	SI
Genotype (G)	NS	NS	**	**	**	**	**
B	61.41	3.39	72.20^a	2.07^a	1.07^b	3.62^b	78.41^a
W	56.63	3.95	67.47^b	2.04^b	1.08^a	3.10^a	76.05^b
Storage period (SP; d)	NS	NS	NS	NS	**	**	**
0	58.99	3.90	70.63	2.01	1.09^a	2.63^a	78.08^a
10	58.86	3.96	68.98	2.02	1.08^b	2.20^b	76.51^b
20	59.21	3.95	68.88	2.10	1.07^c	4.25^c	77.10^{ab}
30	59.42	3.94	68.79	2.25	1.06^c	4.34	77.98^{ab}
G* SP	NS	NS	NS	NS	NS	NS	NS
SEM	±0.007	±0.002	±0.393	±0.081	±0.001	0.035	±0.002

White (W) and Brown (B). Means in the same column with different superscripts differ significantly (P<0.05).
NS: Non-significant. ** Highly significant (P<0.01).

Table 3: Impact of genotype and storage period on blood (BS) and meat (MS) spots percent, shell cleanliness (CL), broken and yolk color grades (YC) of both species.

	BS	MS	YC	CL	Broken
Genotype (G)	**	**	**	NS	**
B	0.34^a	0.21^a	6.91^a	0.01	0.02
W	0.01^b	0.08^b	5.07^b	0.05	0.11
Storage period (SP; d)	**	NS	NS	NS	**
0	0.27^a	0.20	5.77^c	0.07	0.05
10	0.15^{ab}	0.06	5.98^b	0.03	0.08
20	0.12^b	0.17	6.22^a	0.00	0.07
30	0.9^b	0.23	6.43^a	0.000	0.05
G*SP	NS	NS	**	NS	NS
SEM	±0.025	±0.026	±0.026	±0.013	±0.019

White (W), Brown (B). Means in the same column with different superscripts differ significantly (P<0.05).
**Highly significant (P<0.01), NS: Non-significant.

imported breeds and those researched utilizing multiple breeds (Monira *et al.*, 2003; Zita, 2009; Murshed *et al.*, 2023). When stored for 0, 10, 20 and 30 days, egg weight reduced considerably (Table 2). Meijerhof (1994) showed no significant influence of storage time on egg weight. Storage has a substantial effect on white and brown shell eggs in terms of egg weight loss, yolk weight, white weight and shell weight. Other than egg weight reduction, the storage period affected all the other features. The interaction did not affect all attributes.

Table 3 indicates significant differences between white and brown shell eggs in yolk color (YC), shell integrity (BR), meat and blood stains (MS, BS) and shell cleanliness. We found that storage increased blood spots in the yolk color, but it did not affect the rest of the characteristics, as the interaction model predicted that the significant effects of the HU unit and yolk color did not affect the shell. This contradicted (Samil *et al.,* 2005), who observed no significant strain-storage duration interaction on egg weight. Many researchers say the mean HUF is 0.173 (Stadelman and Cotterill, 1995). The investigation found a significant effect (P<0.01) of the HOF measurement unit for strains (71,40) (75,30) brown and white. Issa Brown (83) measured HU, which was equivalent to White Livorno, University of Baghdad (Al-Nedawi, 2006). White leghorn's value is the same as before (Monira *et al.*, 2003; Scott and Silversides, 2000). In earlier research, longer storage periods considerably reduced Hof units in different breeds (Akyurek and Okur, 2009). Interaction between strain and storage duration significantly impacted the HU unit (P<0.01). The storage dropped gradually in the Haugh unit with extended storage time (P<0.05) (Alsobayel and Albadry, 2011).

Fig 1 indicates no significant differences in the breed (brown and white) for shell weight per unit of surface area (SWUSA). While in significant differences between white and brown shell eggs in HU units (Fig 2). The results showed that there were statistically significant differences between storage duration (0, 10, 20 and 30 days) on shell weight per unit of surface area (SWUSA) and HU units (Fig 3, 4). The results in Fig 5 and 6 showed a significant significance between storage duration (0, 10, 20, 30 days) on egg yolk weight loss (YW) and albumin weight (AW). There were no

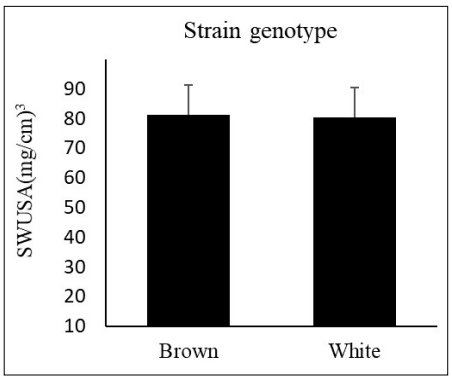

Fig 1: Effect of Strain on shell weight per unit of surface area (SWUSA) of brown (B) and white (W) shell eggs. Non-significant different.

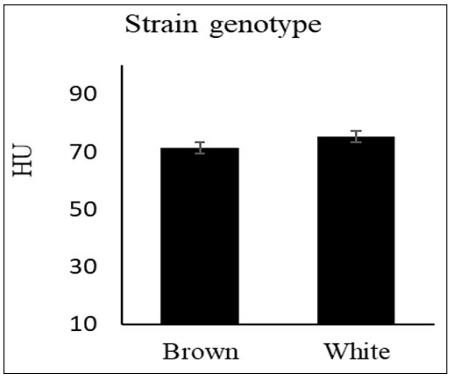

Fig 2: Effect of genotype on Haugh unit values (HU), of brown (B) and white (W) shell eggs.

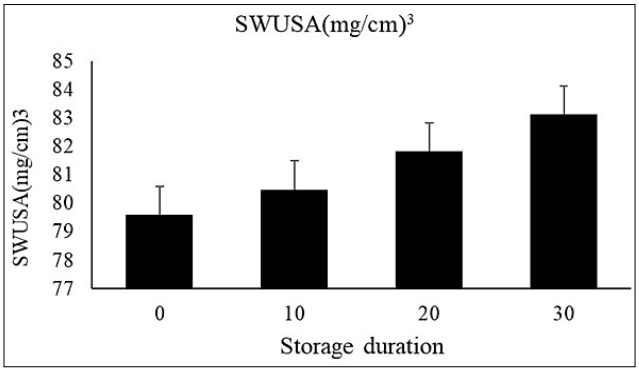

Fig 3: Effect of egg storage duration (0, 10, 20 and 30 days), on shell weight per unit of surface area (SWUSA), of brown (B) and white (W) shell eggs marketed in Riyadh region.

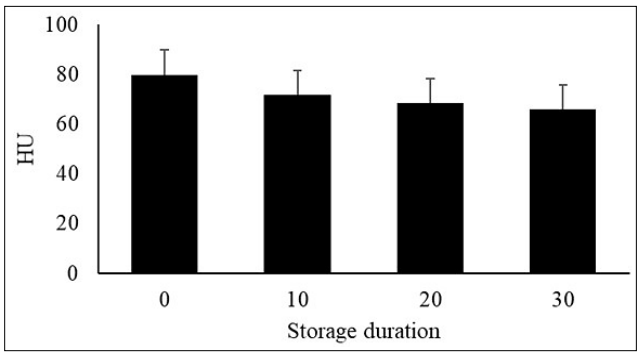

Fig 4: Effect of egg storage duration (0, 10, 20 and 30 days), on Haugh unit values (HU), of brown (B) and white (W) shell eggs marketed in Riyadh region.

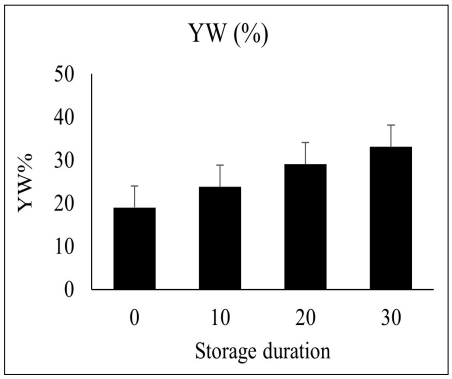

Fig 5: Impact of egg storage duration (0, 10, 20 and 30 days) on egg yolk weight loss (YW).

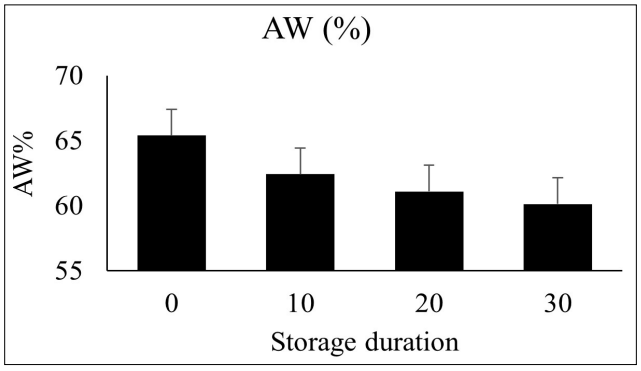

Fig 6: Impact of egg storage duration (0, 10, 20 and 30 days) on albumin weight (AW).

significant variations between brown and white-shell eggs in egg weight, weight loss, weight percentage and shell weight percentage (Fig 7, 8 and 9). It is significant differences with increased storage time by 0-10 and 20-30 days. The figures' traits are unaffected by interference (G*S). Several researchers (Scott and Silversides, 2000; Silversides and Scott, 2001; Hermiz *et al*., 2012) demonstrated a statistically significant link between egg weight and components. Genetic factors like breed, environmental changes during herd raising, chicken age, food, egg size and heat stress may cause these variances. Poor farm handling, marketing routes and storage practices also affect egg quality. The study found that storage length, strain and temperature greatly affect table egg quality. Storage of brown and white eggs at 5±2°C and 50-75% relative humidity for 30 days maintains internal quality and safety for human consumption. Eggs should be stored in their carton to protect their fragile shell, avoid refrigeration drying and prevent smells until

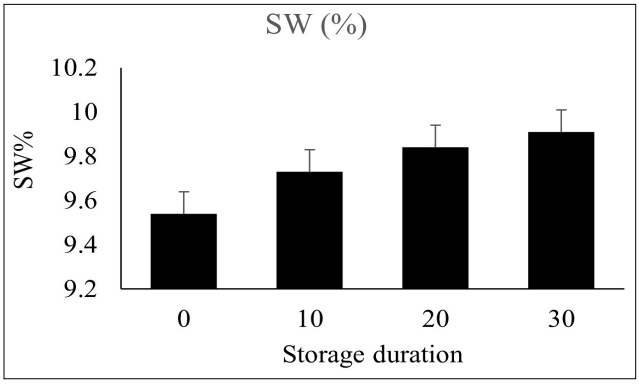

Fig 7: Impact of egg storage duration (0, 10, 20 and 30 days) on shell weight percentage (SW).

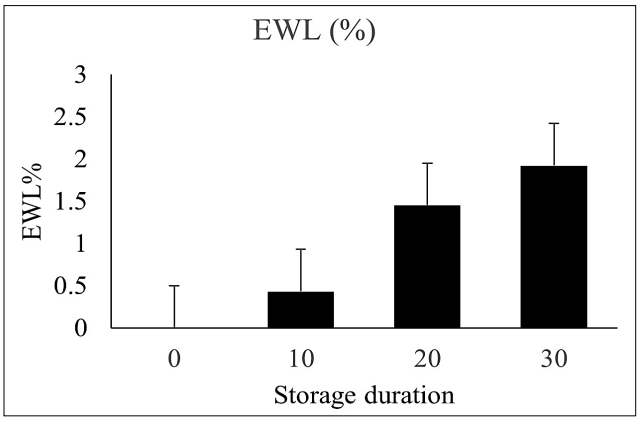

Fig 8: Impact of egg storage duration (0, 10, 20 and 30 days) on egg weight loss (EWL).

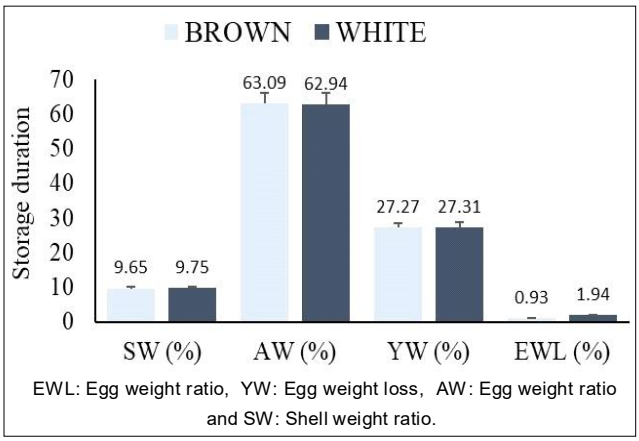

Fig 9: Impact of storage duration on egg weight percentage, egg weight loss, egg weight percentage and shell weight percentage.

35 days. Salmonella and other bacteria can be killed by cooking eggs to 160°F. Pasteurized eggs eliminate disease transmission.

CONCLUSION

In conclusion, storage period, strain and temperature all have a significant impact on the quality of table eggs. Additionally, brown and white eggs held at 35°C and 50-75% relative humidity maintain quality and are acceptable for human consumption until 30 days. Keep eggs in their cartons to safeguard their fragile shell, avoid refrigerator drying and prevent smells. Never exceed 35 days. To destroy salmonella and other pathogens, boil eggs to 160°F. Pasteurized eggs prevent disease.

ACKNOWLEDGEMENT

The authors sincerely acknowledge the Researchers Supporting Project for funding this work number (RSPD2023R1081) at King Saud University, Riyadh, Saudi Arabia.

Conflict of interest

The authors declare that they have no conflicts of interest.

REFERENCES

Akyurek, H. and 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.

Al-Nedawi, A.M. (2006). Genetic evaluation of White Leghorn chicken according to some of egg production traits (Doctoral dissertation, Thesis). Agriculture College University of Baghdad. (In Arabic).

Al-Obaidi, F.A., Al-Shadeedi, S.M., Al-Dalawi, R.H., Center, A.S.H.R. (2011). Quality, chemical and microbial characteristics of table eggs at retail stores in Baghdad. International Journal of Poultry Science. 10(5): 381-385.

Alshaikhi, A.M., Abdullatif, A.A., Badwi, M.A., Alsobayel, A.A. (2021). Effects of storage period, marketing channels and season on Internal and external quality of commercial table eggs marketed in Riyadh City (Saudi Arabia). Brazilian Journal of Poultry Science. 23. https://doi.org/10.1590/1806-9061-2020-1334.

Alsobayel, A.A., Albadry, M.A. (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.

Anderson, K.E. anderson, J.B., Tharrington, P.A., Curtis, T. Jones. (2004). Shell characteristics of eggs from historic strains of single comb white leghorn chickens and the relationship of egg shape to shell strength. J. Poultry Sci. 3(1): 17-18.

Attia, Y.A., Al-Harthi, M.A., Shiboob, M.M. (2014). Evaluation of quality and nutrient contents of table eggs from different sources in the retail market. Italian Journal of Animal Science. 13(2): 3294. DOI: 10.4081/ijas.2014.3294.

Calik, J. (2013). Changes in quality traits of eggs from yellowlegs partridge (z) over dot-33) laying hens depending on storage conditions of eggs. Zywnosc-nauka Technologia Jakosc. 20(2): 73-79.

Chaudhari, D.J. and Tingre, A.S. (2015). Forecasting eggs production in India. Indian Journal of Animal Research. 49(3): 367-372. doi: 10.5958/0976-0555.2015.00143.0.

Cunningham, F.E., Cotterill, O.J., Funk, E.M. (1960). The effect of season and age of bird: 1. On egg size, quality and yield. Poultry Science. 39(2): 289-299.

Gautron, J., Dombre, C., Nau, F., Feidt, C. and Guillier, L. (2022). Production factors affecting the quality of chicken table eggs and egg products in Europe. Animal. 16: 100425.

Haugh, R.R. (1937). The haugh unit for measuring egg quality. United States Egg and Poultry Magazine. 43: 522-555.

Hassanin, N. and Gabal, M.A. (1990). Biological and chemical characterization of metabolites of Fusarium moniliforme isolates. Veterinary and Human Toxicology. 32(6): 536-540.

Hermiz, H.N., Abas, K.A., Al-Khatib, T.R., Amin, S.M., Ahmed, A.M., Hamad, D.A., Denha, H.P. (2012). Effect of strain and storage period on egg quality characteristics of local Iraqi laying hens. Research Opinions in Animal and Veterinary Sciences. 6: 1344-1348.

Johanning, E., Biagini, R., Hull, D., Morey, P., Jarvis, B., Landsbergis, P. (1996). Health and immunologv study following exposure to toxigenic fungi (*Stachybotrys chartarum*) in a water-damaged office environment. International Archives of Occupational and Environmental Health. 68(4): 207-218.

Jones, D.R. (2007). Egg functionality and quality during long-term storage. International Journal of Poultry Science. 6(3): 157-162.

Khatun, H., Rashid, M.A., Faruque, S., Islam, M.N. and Ali, M.Y. (2016). Study on egg quality characteristics of three commercial layer strains under different storage conditions. International Journal of Animal Resources. 1(2): 63-70.

Kralik, Z., Kralik, G., Grèević, M., Galović, D. (2014). Effect of storage period on the quality of table eggs. Acta Agraria Kaposvariensis. 18(1): 200-206.

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. Korean Journal of Poultry Science. 43(1): 31-38.

Meijerhof, R. (1994). Theoretical and empirical studies on temperature and moisture loss of hatching eggs during the pre-incubation period. Ph.D., Dissertation, University of Wageningen, The Netherlands.

Mohiti-Asli, M., Shariatmadari, F., Lotfollahian, H., Mazuji, M.T. (2008). Effects of supplementing layer hen diets with selenium and vitamin E on egg quality, lipid oxidation and fatty acid composition during storage. Canadian Journal of Animal Science. 88(3): 475-483.

Monira, K.N., Salahudeen, M., Miah, G. (2003). Effect of breed and holding time on egg quality characteristics of chicken. Int. J. Poultry Sci. 2(4): 261-263.

Murshed, M., Qaid, M.M. and Gatasheh, M.K. (2023). The effect of storage periods on the internal and external quality characteristics of white and brown-shell table eggs in Saudi Arabia. Indian Journal of Animal Research. doi: 10.18 805/IJAR.BF-1611.

Nordstrom, J.O., Ousterhout, L. E. (1982). Estimation of shell weight and shell thickness from egg specific gravity and egg weight. Poultry Science. 61(10): 1991-1995.

North, M.O., Bell, D.D. (1990). Commercial Chicken Production Manual (No. Ed. 4). Van Nostrand Reinhold.

Nys, Y. and Sauveur, B. (2004). Nutritional Value of Eggs. INRAE Productions Animales. 17(5): 385-393.

Nys, Y., Gautron, J., Rodriguez-Navarro, A.B. and Hincke, M. (2022). Mechanisms and Hormonal Regulation of Shell Formation: Supply of Ionic and Organic Precursors, Shell Mineralization. In Sturkie's Avian Physiology. Academic Press. (pp. 833-879).

Ruxton, C. (2013). Value of eggs during pregnancy and early childhood. Nursing Standard. 27(24): 41-50.

Sahar, A. and Rahman, U. (2018). Contribution of Animal Origin Foods in the Human Diet. In Animal Sourced Foods for Developing Economies. CRC Press. (pp. 21-41).

Samli, H.E., 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.

Sapkota, S., Kolakshyapati, M.R., Devkota, N.R., Gorkhali, N.A., Bhattarai, N. (2020). Evaluation of external and internal egg quality traits of indigenous sakini chicken in different generations of selection. Int. J. Agric. For. 10(2): 41-48.

SAS, (2005). SAS/STAT User's Guide for Personal Computers. Release, 8.2. SAS Institute, Inc., Cary, NC, USA.

Scott, T.A. and Silversides, F.G. (2000). The effect of storage and strain of hen on egg quality. Poultry Science. 79(12): 1725-1729.

Silversides, F.G. and Scott, A.T. (2001). Effect of storage and layer age on quality of eggs from two lines of hens. Poultry Science. 80(8): 1240-1245.

USDA, (2000). United States Standards, Grades and Weight Classes for Shell Eggs. AMS, 56.210.

Zaheer, K. (2015). An updated review on chicken eggs: Production, consumption, management aspects and nutritional benefits to human health. Food and Nutrition Sciences. 6(13): 1208-1220.

Zita, L., Tùmová, E., Štolc, L. (2009). Effects of genotype, age and their interaction on egg quality in brown-egg laying hens. Acta Veterinaria Brno. 78(1): 85-91.