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Effects of Storage Time on Ostrich Egg Quality

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ABSTRACT

Egg quality is considered as both internal egg quality that focuses on the egg content and external egg quality that focuses on the eggshell. This study investigated the effect of storage time on ostrich egg quality. A total of 15 ostrich eggs were obtained from Dibete Ostrich Multiplication Unit and subjected to five storage periods (0, 3, 6, 9, and 12 days) at room temperature (18-25^{o}C). The measured parameters were egg weight, egg length, egg width, yolk weight, albumen weight, albumen height, yolk height, shell weight, egg specific gravity (ESG), egg surface area, Haugh Unit (HU), egg shape index, albumen ratio, shell ratio, yolk ratio and weight of egg contents. Results showed that storage time did not influence egg weight for eggs stored for 0, 3, and 6 days. On the other hand, storage time significantly affected egg weight for eggs stored at 9 and 12 days. The albumin ratio for egg storage duration had no significant impact on eggs held for 0, 3, or 6 days. However, the albumen ratios of eggs held for 9 and 12 days were impacted by the storage period compared to those stored for 0, 3, and 6 days. The HU for the eggs stored for 0, 3, and 6 days was not affected by storage time. On the contrary, the HU for eggs stored for 9 and 12 days was significantly impacted by storage time as the HU decreased with the prolonged storage time, compared to those stored for 0, 3, and 6 days. The results of this study suggest that ostrich eggs should not be stored for more than 6 days at ambient temperature to avoid egg quality degradation.

Keywords: Cuticle, Egg quality, Ostrich eggs, Storage time

INTRODUCTION

An ostrich (*Struthio camelus*) is the largest and longest bird that belongs to the ratite family, *Struthionidae*. Ostrich eggs are the largest eggs measuring 15.4 cm long and 12.7 cm wide (Cooper et al., 2009), with a thick eggshell of about 1.8 cm that is very resistant to breakage (Ceylan et al., 2006). Similarly, Di Meo et al. (2003) reported the average ostrich egg length and width of 15.4 cm and 12.9 cm, respectively. However, Al-Obaidi et al. (2012) in Iraq found the ostrich egg length and width to be 16.9 cm and 12.6 cm, respectively. The weight and shell of the egg are the main external and internal quality indicators of an egg (van Niekerk, 2014). The internal egg quality focuses on the yolk and the egg white, and the external quality on the soundness of the shell. The amount of time that ostrich eggs are stored significantly affects their quality. Factors such as water activity, temperature, the gaseous environment, and environmental pollutants have an impact on storage (Ceylan et al., 2006).

Eggshells are enclosed in a cuticle, a protective layer that regulates the exchange of gases across the shell and acts as a first line of defense against microbial penetration across the eggshell (Samiullah and Roberts, 2014). Therefore, the washing of eggs is not recommended, especially for eggs from older hens with thinner shells, as it might result in damage to the cuticle leading to bacteria entering into the egg, thus risking the consumers' lives. According to Hassan et al. (2005), storage time affects egg weight loss; hence ostrich eggs should be stored at 16^{o}C for at least 7 days. The study by Sahan et al. (2003) showed that ostrich eggs must be stored at 21^{o}C or less to

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maximize hatchability, whereas Archer and Cartwright (2017) recommend storage temperatures of 13 to 18°C for no more than 10 days. Ograk and Altinel (2014) mentioned that ostrich eggs should not be stored for over 10 days while Moreki et al. (2016) stated that ostrich eggs must be stored for at least 11 days to avoid degrading the egg quality characteristics. According to Wilson et al. (1997), the date the egg is laid is a factor that determines how long ostrich eggs can be stored.

Many available published sources give estimates of the maximum storage time for ostrich eggs; however, it is difficult to find up-to-date information specifically suitable for Botswana's climate and biological conditions. Therefore, the objective of this study was to investigate the effects of five storage periods (i.e., 0, 3, 6, 9, and 12 days) on the ostrich egg quality characteristics at room temperature.

MATERIALS AND METHODS

Study site

The experiment was carried out in May 2021 in the Meat Science Laboratory at the Botswana University of Agriculture and Natural Resources (BUAN), Gaborone, Botswana.

Sample preparation

The ostriches at Dibete Ostrich Multiplication Unit (DOMU), a government facility located about 100 km northeast of Gaborone, the capital city of Botswana, were sourced from South Africa and Zimbabwe at different ages. The DOMU is the only operational ostrich facility in the country from which we obtained the eggs for this study, as other facilities have collapsed due to myriad challenges, including the high cost of feeds, the frequent closures of the sole ostrich abattoir, lack of access to credit facilities and lack of technical extension support (Moreki et al., 2012). The ostriches found at DOMU are crosses of South African black and Zimbabwean blue. A total of 15 eggs used in this study came from multiple-age parents. DOMU is located on the periphery of Dibete village of Central District and lies within latitude 22° south and 24° south, north of Gaborone, and longitude 26° west and 28° west (Moreki et al., 2012).

Eggs were bought according to the dates they were laid on the farm and were stored at five different storage periods, including 0, 3, 6, 9, and 12 days at room temperature (20-25°C). Eggs were placed in wooden trays with their sharp ends pointing downwards and stored at room temperature before data collection in accordance with Hassan et al. (2005). In this study, eggs were not covered during storage. The windows for the room in which eggs were stored were opened during the day and closed at night, indicating that the room was naturally ventilated. At 3-day intervals, three eggs were opened and analyzed for egg quality.

Data collection

Prior to breaking eggs for egg quality determination, eggs were individually weighed using an electronic scale sensitive to 0.01 g and their weight was recorded. Egg width and length were measured using Vernier calipers sensitive to 0.01 mm. Thereafter, eggs were carefully opened using a saw to avoid mixing the internal contents, including albumen and the yolk. The contents were removed from the shell and poured into containers. Following the emptying of the shell contents into a container, the shell with membranes was washed with clean water and wiped with a paper towel. Thereafter, shell thickness and shell weight were measured using a Vernier caliper and electronic scale, respectively (Nonga et al., 2010). Shell thickness was measured only at the equator of the egg. The weight of egg contents was obtained by subtracting shell weight from egg weight.

The albumen and yolk were separated by pushing them into separate containers and weighed separately. After separating the yolk from the albumen, the height and the length of the yolk and albumen were measured using a Vernier caliper. The Haugh unit (HU), shell ratio, albumen ratio egg ratio, egg surface area, shell ratio, and egg specific gravity (ESG) were evaluated according to El-Safty and Mahrose (2009) using the formulae below.

Egg specific gravity (g/cm^2) = Egg weight/Egg volume
Egg shape index = Egg width/Egg length ∗ 100
Shell ratio (%) = Shell weight/Egg weight ∗ 100
Albumen ratio (%) = Albumen weight/Egg weight ∗ 100
Yolk ratio (%) = Yolk weight/Egg weight ∗ 100
Yolk index = Yolk weight/Yolk diameter∗ 100
Haugh unit = 100 log (H - 1.7W0.37 + 7.6)

Where, H is albumen height and W denotes the egg weight
Egg surface area= $3.9782W^{0.7056}$
Where, W is the egg weight

Statistical analysis

Data on egg quality traits were subjected to analysis of variance (ANOVA) and analyzed using Statistical Analysis System (SAS) Software (version 9.4, 2012). Duncan's Multiple Range test was used to find significant differences among the means ($p < 0.05$).

RESULTS AND DISCUSSION

Egg quality characteristics

The effects of storage time on egg quality characteristics are presented in Table 1. The egg weight for eggs stored for 0, 3, and 6 days was not affected by storage time, compared to 9 and 12 days ($p > 0.05$). However, compared to 0, 3, and 6 days, storage time had a significant impact on egg weight at 9 and 12 days ($p < 0.05$). Furthermore, the weight of eggs stored for 0 and 9 days was similar to those stored for 3, 6, and 12 days ($p > 0.05$). Eggs that were kept for 9 and 12 days had similar weights. This finding agrees with Khan et al. (2014), who reported a negative effect of storing eggs for more than 3 days on egg weight, hatchability, embryonic development, and hatchling weight in Fayoumi chickens. Similarly, Samli et al. (2005) observed that egg weight decreased with an increased storage time of up to 10 days.

No statistical difference was observed for the egg shape index (ESI) of eggs stored for 0, 3, and 6 days, compared to eggs stored at 9 and 12 days ($p > 0.05$). The present results are consistent with Nedomova and Buchar (2013), who reported that ostrich ESI ranges between 74.48% and 89.72%. The ESI for eggs stored for 9 and 12 days in the present study were significantly affected by storage time, compared to those stored for 0, 3, and 6 days ($p < 0.05$). Eggs stored for 9 and 12 days had greater ESI compared to eggs stored for 0, 3, and 6 days which was in agreement with Tabidi (2011). The ESI values in this study increased with prolonged storage. On the contrary, Tilki and Saatci (2004) found that the ESI of partridge eggs was not affected by storage from 0 to 35 days. The differences in the results of this study and that of Tilki and Saatci (2004) could be attributable to species differences.

According to Table 1, eggs stored for 3 and 6 days had greater shell weight compared to other treatments ($p < 0.05$). Shell weight for eggs stored at 0, 9, and 12 days was not statistically different but differed from the shell weight of eggs stored for 3 and 6 days ($p > 0.05$). The shell weight of eggs stored for days 0, 3, and 6 significantly differed from those stored for days 9 and 12 ($p < 0.05$). These results are inconsistent with Juergens and Bessei (2016), who observed that prolonged storage time of up to 28 days decreases shell weight. The average shell weight in the present study was 0.223 kg which is higher than the result reported by Moreki et al. (2016) who found the shell weight of ostrich eggs from multiple aged ostriches to range from 0.1750 to 0.1707 kg. The fluctuation in shell weight across the storage periods in this study may be attributable to the quality of water at DOMU in Botswana. Water supplied to birds at DOMU came from different sources due to water shortage at the farm. Balnave and Yoselewitz (1987) stated that eggshell quality could be negatively impacted over time by the water with high electrolyte concentrations (saline drinking water). This is because elevated levels of sodium interfere with calcium utilization, an important mineral in shell and bone formation.

The surface area (ESA) of the eggs stored for 0, 3, and 6 days was not affected by storage time, whereas the ESA of the eggs stored at 9 and 12 days was significantly affected by storage time (Table 1). The average ESA in the present study was 606.36 cm^2, which was higher than the value (506.41 ± 2.36) reported by Brassó and Komlósi (2021). The difference in the results may be due to the ostrich sub-species and nutrition.

The storage time had no effect on the HU for the eggs held for 0, 3, and 6 days, compared to eggs stored for 9 and 12 days ($p < 0.05$). In contrast, the storage period had a significant effect on the HU for eggs stored for 9 and 12 days as opposed to those stored for 0, 3, and 6 days because the HU decreased with increased storage time ($p > 0.05$). The mean HU value in this study was 118.20, which is less than the value of 131.16 reported by Moreki et al. (2016) in ostrich eggs. According to Pleti et al. (2009), the HU above 100 shows a good quality ostrich egg. Khan et al. (2014) explained that HU decreases with increased storage time due to the loss of water from the egg.

The albumen ratio for eggs stored for 0, 3, and 6 days was not ($p > 0.05$) affected by storage time and was higher ($p < 0.05$) compared to eggs stored for 9 and 12 days (Table 1). This is because prolonged storage results in more water moving from the albumen to the yolk. The current result agrees with Lapão et al. (1999) who observed that the albumen ratio in the ostrich egg decreases with storage time. In the study by Demirel and Kirikci (2009), it was observed that the HU, albumen index, and yolk index decreased with increased storage time due to the loss of water from the egg. Khan et al. (2014) also attributed the decrease in the albumen ratio to the movement of water from the albumen into the egg yolk. According to Lapão et al. (1999), the decrease in the albumen ratio may be due to an increase in the albumen pH, which can be solved by providing the ostrich with low-pH drinking water. In addition, Balnave et al. (2000) stated that the albumen ratio is negatively affected by increased protein dietary and amino acids content. It is further argued by Ekweozor et al. (2002) that the ingestion of crude oil has a negative effect on the albumen ratio.

The yolk ratio was not affected by storage time ($p > 0.05$). This finding is inconsistent with Khan et al. (2013; 2014), who found that albumen index, albumen weight, yolk index, yolk weight, and HU all decreased after extended storage values in Fayoumi and Rhode Island Red eggs. Similarly, Tabidi (2011) reported that the yolk index decreases with storage. However, this result contradicts the finding of Khan et al. (2014), who reported that the yolk ratio is directly proportional to the storage time and that the yolk ratio increases with increased storage time due to egg water loss.

Table 1 The effects of storage time on ostrich egg quality characteristics

Trait	Storage time (days)					Grand mean	Standard error of the mean
	0	3	6	9	12		
EWT, (g)	1284.00^{ab}	1346.00^{a}	1346.00^{a}	1089.67^{bc}	1050.00^{c}	1223.13	51.73
SI, (%)	74.60^{c}	74.40^{c}	74.10^{c}	78.00^{b}	81.30^{a}	76.30	0.98
SW, (g)	214.67^{bc}	234.67^{a}	238.00^{a}	208.00^{c}	224.00^{bc}	223.87	7.29
ECwt, (g)	0.170^{c}	0.173^{bc}	0.177^{bc}	0.190^{ab}	0.197^{a}	0.181	0.0063
ESA, (cm^2)	620.98^{ab}	641.92^{a}	641.89^{a}	552.98^{c}	574.01^{bc}	606.36	18.08
HU	129.02^{a}	131.11^{a}	131.09^{a}	100.0^{b}	99.79^{b}	118.20	0.79
ARE	55.33^{b}	54.63^{B}	53.94^{b}	44.93^{a}	42.57^{a}	50.28	1.67
YKR	23.96^{a}	29.25^{a}	30.40^{a}	29.75^{a}	28.51^{a}	28.37	3.04
ESG, (g/cm^3)	1.31^{ab}	1.29^{ab}	1.28^{b}	1.39^{a}	1.32^{ab}	1.32	0.32
SR	16.71^{b}	17.44^{bc}	17.68^{abc}	19.20^{ab}	19.55^{a}	18.11	0.59

^{abc} Means within a row that do not share common superscripts differ significantly (P<0.05). EWT: Egg weight; SI: Egg shape index; SW: Shell weight; ESA: Egg surface area; HU: Haugh unit; SR: Shell ratio; ESG: Egg specific gravity; AR: Albumen ratio; YKR: Yolk ratio; ECWT: Weight of egg contents.

Storage time did not affect the ESG of ostrich eggs stored for 0, 3, and 6 days. However, the storage time significantly affected the eggs that had been kept for 9 and 12 days since ESG increased with longer storage (P<0.05). The average ESG value of 1.32 g/cm^3 in the current study is consistent with the values obtained by Koutinhouin et al. (2014) and Moreki et al. (2016), who reported the ESG values of 1.13±0.006 g/cm^3 and 1.16±0.007 g/cm^3, respectively for ostrich eggs. However, Keffen and Jarvis (1984) found that the average ESG of ostrich eggs was 2.0 ± 0.84 g/cm^3. The differences in ESG values in these studies may be due to the age of birds, nutrition, and climatic conditions.

The shell ratio increased ($p < 0.05$) with prolonged storage (Table 1). The shell ratio for eggs stored for 12 days was significantly ($p < 0.05$) higher than those of eggs stored for 0 and 3 days. However, the shell ratios for storage periods 6, 9, and 12 were similar ($p > 0.05$). In addition, the shell ratio for eggs stored for 0, 3, 6, and 9 was not significantly different ($p > 0.05$) from each other. The average shell ratio in this study was 18.11%. This result is closer to the average shell ratio of 19.8% obtained by Hoffman and McMillin (2009) in ostrich eggs. The difference in shell ratios could be attributable to the age of the hen, genotype, calcium deposition, and strain of the bird (Ketta and Tůmová, 2016).

CONCLUSION

Based on the Haugh unit values, which indicate the freshness of the egg, ostrich eggs can only be stored for up to six days at room temperature without significantly losing quality.

DECLARATIONS

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Authors' contributions

This study was planned by John Cassius Moreki, who also conducted a review of the relevant literature, wrote and amended the paper, edited it, and then submitted it to the journal for consideration. Denise Florence Mosarwa collected data, surveyed the literature, and drafted the manuscript. Joshua Makore assisted with statistical design and data analysis, while Nicholas Mosweu participated in the practical part of the experiment. All authors checked and confirmed the final draft of the manuscript.

Competing interests

The authors confirm no conflict of interest.

Ethical considerations

The authors have examined ethical issues, including redundancy, plagiarism, misconduct, consent to publish, data fabrication, and double publication.

Availability of data and materials

The dataset of this study is available by the relevant authors upon request.

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