JWPR
Journal of World's Poultry Research

2021, Scienceline Publication
J. World Poult. Res. 11(3): 368-375, September 25, 2021

Research Paper, PII: S2322455X2100044-11
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DOI: https://dx.doi.org/10.36380/jwpr.2021.44

Effects of Broiler Breeders' Age on Egg Quality Characteristics and Their Correlation Coefficients

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Received: 21 July 2021
Accepted: 08 September 2021

ABSTRACT

The current study was designed to assess the effect of Ross breeder hens' age on the egg qualities and their correlations. The external and internal qualities of eggs were compared, and their correlation coefficients as influenced by the age of breeder hens were determined. A sample of 300 Ross breeder hen eggs was obtained from the Ross breeder farm with 100 eggs drawn from each laying period of ages, namely 30, 45, and 60 weeks. Measured parameters included egg weight, egg length, egg width, shell weight, and shell thickness. Data were evaluated for linear and quadratic effects using polynomial contrasts. Response surface regression analysis was applied to describe the responses of egg quality to the aging of breeder hens. The results showed that egg weight, egg length, egg width, shell weight, egg yolk, egg content, egg volume, shell percentage, albumen weight, egg shape index, and egg surface area increased over time. Haugh unit and thick albumen indicated that the eggs in all age groups were fresh and had high quality. Shell thickness was constant in all age groups. Egg weight was significantly correlated with egg length, width, yolk (length, width, weight, and height), and shell weight. In conclusion, the egg quality improved as the hens' age increased implying that age is an effective factor in improving the quality of eggs.

Keywords: Age, Broiler breeder, Egg quality, Shell quality

INTRODUCTION

An egg is a control house of nutrition for the growing embryo, and it is the source of essential amino acids and fatty acids for humans (Alkan et al., 2015). Measuring external and internal qualities offer an assurance of egg safety. At the farm level, the quality of the broiler breeder eggs is determined by egg external and internal qualities which in turn determine broiler chick weight at slaughter. Egg quality characteristics include cleanliness, freshness, egg weight, shell quality, yolk index, albumen index, Haugh unit, and chemical composition (Song et al., 2000; Roberts, 2004).

Quality depends on factors, such as time of oviposition, genotype, age, ambient temperature, and nutrition (Tumova and Gous, 2012). There are other less well-understood factors, including the effect of the breeder's age on egg quality before incubation, which may affect the embryonic life of the chick and thereafter the quality of the broiler chicks and growth potential post-hatch. A vast quantity of literature has determined the effects of breeders' age on egg quality. Yilmaz and Bozkurt (2009) and Crosara et al. (2019) reported a significant deterioration in the shell characteristics as breeder hens aged. Kontecka et al. (2012) reported that as the reproductive season of the hens progressed egg weight increased while the percentage of the white (index and Haugh unit) decreases. Understanding the relationship between egg quality at different ages of broiler breeder hens is critical in production management. It is known that poor eggshell quality influences embryo development leading to low hatchability results (Kontecka et al., 2012). Nasri et al. (2020) observed that a positive correlation exists between the number of hatchlings and shell thickness and strength.

The internal and external egg quality characteristics in broiler breeder hens are largely unknown in Botswana because most research focuses on commercial layer chickens (Duman et al., 2016), indigenous chicken eggs

(Kgwatalala et al., 2016; Manyeula et al. 2018), and guinea fowl (Manyeula et al., 2020). It has been reported that poor egg quality causes high losses in egg production and high chick mortality in a broiler breeder production (Tona et al., 2004). Due to the lack of knowledge, some farmers would spend money on chicken feeds to improve the shell quality of aged chickens with low reproductive rates. Information on egg quality would be used to educate farmers on good management practices of raising breeder chickens to produce high-quality eggs. Hence, the objectives of this study were to evaluate the effect of broiler breeder hen's age on egg quality and to determine correlations among the different egg quality parameters at different ages. It was hypothesized that the age of breeder hens would affect the external and internal quality of eggs.

MATERIALS AND METHODS

A total of 300 eggs (i.e., 100 eggs age period) were obtained from three commercial Ross broiler breeder hens aged 30, 45, and 60 weeks, which were reared in open-sided houses at Thamaga in Botswana. Eggs were transported to the Meat Science Laboratory at Botswana University of Agriculture and Natural Resources (BUAN), Botswana where they were stored overnight at 20°C and at 70-80% relative humidity (Ross Breeders, 2018). Eggs were used to study the effects of breeder age on egg quality characteristics and their correlations. Egg quality measurements were carried out the following day in the Meat Science Laboratory.

Ethical approval

The experimental procedure employed conformed to the guideline for care and use of research animals and was approved by the Animal Research Ethics Committee of BUAN (AEC 2021-03).

Management and diets

The feed, water, light program, and other management conditions were administered to broiler breeder hens in accordance with Ross breeder guidelines and recommendations (Ross Breeders, 2018). Vaccinations and medication were carried out following the company's comprehensive health management plan. Breeders were vaccinated by spray route against Newcastle disease and infectious bronchitis at 3, 6, 13, 18, and 24 weeks of age and thereafter at intervals of 8 weeks until breeders reached the end of their production life. Vaccinations against Newcastle disease were carried out using Nobilis® ND Clone 30 and Nobilis® IB MA5, respectively. The vaccine against swollen head syndrome (SHS) was administered intramuscularly at 4, 14, and 24 weeks of age, whereas Panacur (active ingredient: Fenbendazole) was administered at 21 weeks and was repeated whenever signs of parasites were observed.

Measurement of egg quality characteristics

A total of 300 eggs corresponding to each laying period, including weeks 30, 45, and 60 (100 eggs per laying period), were randomly sampled for egg quality analysis. At each period, the eggs were individually weighed using the OXO electronic scale (Explorer EX 224, OHAUS Corp, China) sensitive to 0.001 g. Egg length (EL) and egg width (EWD) were measured using a digital Vernier caliper (NEIKO 01407A Electronic Digital Caliper, 0-6 Inches, China) sensitive to. 0.01 mm. Eggs were individually placed on a flat tile and cracked, and then egg yolk and albumen spread on the tile. Thereafter, the height of thick and thin albumen was measured using a Vernier caliper (0.01 mm). The egg yolk length (YL) and yolk width (YWD) were also measured using a Vernier caliper (0.01 mm). The egg yolk was then gently and smoothly transferred to a petri dish and weighed on an electronic food kitchen scale (0.001 g). The shell was then wiped with a paper cloth to remove adhering albumen and thereafter weighed using OXO electronic scale. The eggshell thickness (ST) was measured in three locations (broad, sharp, and equator) using a Vernier caliper (0.01 mm) and the values averaged. Egg content (EC), egg surface area (ESA), egg shape index (SI), Haugh unit (HU), egg volume (EV), shell percentage, and yolk index (YI) were calculated using the formulae given in Table 1.

Statistical analysis

Data were evaluated for linear and quadratic effects using polynomial contrasts. Response surface regression analysis (SAS, 2010) was applied to describe the responses of egg quality to the aging of breeder hens using the quadratic model of $y = ax^2 + bx + c$, where y is the response variable, a and b signify the coefficients of the quadratic equation, c refers to intercept, and x stands for different breeder hen age (weeks). Correlation coefficients for egg weight and other egg quality traits were determined at different breeder ages using the Proc Corr procedure of SAS (2010) and tested for significance at a level of 0.05 ($p \leq 0.05$).

Table 1. Formulae used to calculate some egg characteristics in the present study

Traits	Formula	References
Egg content weight (g)	Egg weight – shell weight	Alkan et al. (2015)
Shape index (%)	Egg weight / Egg length ×100	Anderson et al. (2004)
Haugh unit	100*log (albumen height+7.57-1.7*egg weight $^{0.37}$	Haugh (1937)
Egg volume (g/mm^3)	0.708 × Egg weight × 100	Carter (1975)
Egg surface area (mm^2)	3.978 × Egg weight$^{0.7056}$	Alkan et al. (2015)
Shell percentage (%)	Shell weight / Egg weight × 100	Roberts (2004)
Yolk index (%)	Yolk height / Yolk width ×100	Duman et al. (2016)

RESULTS

External parameters

There were significant linear ($p < 0.05$) trends on egg weight [y = 33.6 (± 4.51) - 0.81 (± 0.21) x; R^2 = 0.61; $p < 0.05$] and length [y = 47.2 (± 2.49) - 0.30 (± 0.11) x; R^2 = 0.42; $p < 0.05$] in response to breeder hen age (Table 2). The egg width [y = 33.7 (± 1.25) - 0.36 (± 0.06) x + 0.003 (± 0.0007) x2; R^2 = 0.51; $p < 0.05$] and shell weight [y = 8.6 (± 1.00) - 0.08 (± 0.05) x + 0.001 (± 0.0005) x2; R^2 = 0.05; $p < 0.05$] increased quadratically while shell percentage quadratically decreased at y = 84.4 (± 1.75) + 0.35 (± 0.08) x - 0.002 (± 0.0009) x2; R^2 = 0.61; $p < 0.05$ with the aging of breeder hens. However, no linear or quadratic trends ($p > 0.05$) was observed in shell thickness as the breeder hens aged.

Internal egg parameters

Albumen weight [y = 26.3 (± 3.81) + 0.12 (± 0.18) x; R^2 = 0.43 ; $p < 0.05$], egg surface area [y = 41.2 (± 3.56) – 0.66 (± 0.17) x; R^2 = 0.61; $p < 0.05$], and egg volume [y = 26.8 (± 3.60) - 0.64 (± 0.17) x; R^2 = 0.61; $p < 0.05$] linearly increased ($p < 0.05$) in response to breeder hen age while shape index decreased linearly at y = 73.0 (± 3.40) +0.20 (± 0.16) x; R^2 = 0.05 ; $p < 0.05$ (Table 3). The thin albumen [y = 5.2 (± 0.91) + 0.06 (± 0.04) x - 0.0009 (± 0.0005) x2; R^2 = 0.17; $p < 0.05$], egg contents [y = 25.5 (± 4.19) + 0.89 (± 0.20) x - 0.005 (± 0.002) x2; R^2 = 0.63; $p < 0.05$] and Haugh unit [y = 63.3 (± 1.24) + 0.24 (± 0.06) x - 0.002 (± 0.0006) x2; R^2 = 0.30; $p < 0.05$] increased quadratically with breeder hen age. However, quadratic trends were observed only on the thick albumen [y =5.2 (± 0.91) + 0.06 (± 0.04) x - 0.001 (± 0.0004) x2; R^2 = 0.17; $p < 0.05$]. There was a significant ($p < 0.05$) quadratic decrease in yolk index [y = 34.4 (± 3.30) + 0.45 (± 0.15) x - 0.005 (± 0.002) x2; R^2 = 0.04; $p < 0.05$], whereas, yolk width [y = 25.2 (± 2.00) +0.61 (± 0.09) x - 0.005 (± 0.002) x2; R^2 = 0.43; $p < 0.05$], height [y = 7.1 (± 1.07) + 0.46 (± 0.05) x -0.005 (± 0.0006) x2; R^2 = 0.33; $p < 0.05$] and weight [y = -0.72 (± 1.65) + 0.77 (± 0.07) x - 0.007 (± 0.0009) x2; R^2 = 0.64; $p < 0.05$] increased quadratically in response to breeder hens' age (Table 4).

Correlation coefficients at different ages

There were significant correlations between egg weight and other egg quality traits at different breeder ages except for shell thickness and thin albumen (Table 5). Egg weight was positively correlated with egg length, egg width, yolk (length, width, weight, and height), and shell weight at different breeder ages. Thick albumin and egg weight correlated negatively at all ages. However, at 30 weeks the correlation was not significant ($p > 0.05$) but significant ($p < 0.05$) at 45 and 60 weeks of age (Table 5). Shell thickness was negative but not significantly correlated to egg weight at weeks 30 and 45, however, at week 60 a non-significant positive correlation coefficient was observed between egg weight and breeder hen age.

Table 2. Effect of Ross breeder hen age on the external egg parameters

Parameters	Age (week)				p value	
	30	45	60	SE	Linear	Quadratic
Egg weight (g)	54.1	61.6	67.2	0.43	< 0001	0.08
Egg length (mm)	54.8	57.7	59.6	0.23	< 0001	0.24
Egg width (mm)	41.8	43.9	44.7	0.11	< 0001	< 0001
Shell weight (g)	6.5	6.4	6.9	0.09	0.0007	0.03
Shell thickness (mm)	0.74	0.73	0.74	0.01	0.83	0.16
Shell percentage (%)	9.8	9.6	9.3	0.40	< 0001	0.02

SE: Standard error of the mean

Table 4. Effects of breeder age on yolk parameters of eggs in broiler breeder hens

Parameters	Age in weeks				p value	
	30	45	60	SE	Linear	Quadratic
Yolk index	43.13	43.94	42.37	0.31	0.08	0.002
Yolk width	38.70	41.79	42.44	0.19	< 0001	< 0001
Yolk height	16.64	18.33	17.96	0.10	< 0001	< 0001
Yolk weight	16.25	20.16	21.02	0.16	< 0001	< 0001

SE: Standard error of the mean

Table 3. Effect of age on internal egg quality in Ross breeder hens

Parameters	Age (week)				p value	
	30	45	60	SE	Linear	Quadratic
Albumen weight (g)	31.3	34.9	39.2	0.36	< 0001	0.44
Thin albumen (mm)	2.6	2.8	2.7	0.04	0.006	0.01
Thick albumen (mm)	6.1	5.8	5.1	0.08	< 0001	0.04
Shape index (%)	76.4	76.2	74.8	0.32	0.0006	0.12
Egg surface area (mm^2)	58.0	63.9	68.3	0.36	< 0001	0.06
Egg contents (g)	47.6	55.1	60.1	0.34	< 0001	0.02
Egg volume ($g/mm^{3)}$	43.1	49.1	53.6	0.34	< 0001	0.08
Haugh unit	68.8	70.2	70.9	0.11	< 0001	0.0001

SE: Standard error of the mean

Table 5. Correlation coefficients between egg weight and other egg quality traits at different ages of broiler breeder hens

Traits	30 weeks	45 weeks	60 weeks
Egg length	0.54^{*}	0.70^{*}	0.60^{*}
Egg width	0.70^{*}	0.64^{*}	0.69^{*}
Yolk length	0.33^{*}	0.18^{*}	0.47^{*}
Yolk width	0.27^{*}	0.23^{*}	0.41^{*}
Yolk weight	0.37^{*}	0.56^{*}	0.40^{*}
Yolk height	0.27^{*}	0.39^{*}	0.31^{*}
Thick albumin	-0.01^{ns}	-0.24^{*}	-0.31^{*}
Thin albumin	-0.08^{ns}	-0.06^{ns}	-0.16^{ns}
Shell weight	0.45^{*}	0.36^{*}	0.43^{*}
Shell thickness	-0.29^{ns}	-0.05^{ns}	0.11^{ns}

^{ns}: Not statistically significant at $p < 0.05$ level of significance, *: Statistically significant at $p < 0.05$ level of significance

DISCUSSION

External egg parameters

Egg weight is an important phenotypic trait that influences egg quality and fitness of broiler breeder hens. It is known that egg weight increases with the breeder hen age (Kontecka et al., 2012). This increase in egg weight is related to the increase in weight of the yolk and albumin with a higher proportion of yolk than the proportion of albumin in the egg. This explains the reason for which egg weight (EWT), egg length, and EWD increased linearly with breeder hen age in the current study. These results are in line with several investigators who reported that EWT, EL, and EWD increase as broiler breeder hens grow older (Luquetti et al., 2004; Abudabos 2010; Traldi et al., 2011). Similarly, Alsobayel (2013) observed that EWT of Cobb breeder was the lowest at 30-35 weeks and the highest at 40-45 weeks of age.

Good shell quality must be maintained throughout all the reproductive life of breeder hens since it influences embryonic development (Crosara et al., 2019). However, in the current study, as the breeder hens aged, SWT increased quadratically due to an increase in the egg content resulting in weak shell strength. It is known that shell weight and shell strength are negatively correlated (Tumova et al., 2014). Strong shell strength protects the egg from bacteria ingression. Vast literature supports the current results (Abudabos, 2010; Tumova et al., 2014;

Abudabos et al., 2017). Shell thickness (ST) is one of the most important external quality parameters that affect shell breaking strength (Tumova et al., 2014). In the current study, it was observed that ST was not affected by age of breeder hens suggesting that mineralization was constant. However, shell strength decreased with age because hens at an advanced age have low calcium reserves. Lack of linear and quadratic trends on ST could be due to the supplementation of calcium in the diet hence better shell quality across the ages. Similarly, van den Brand et al. (2004) reported no significant difference of ST across the age. Contrary to the current results, Padhi et al. (2013) reported higher ST at 52 and 72 weeks of age, compared to lower age. The current results imply that breeder age did not affect ST, indicating that shell quality was not affected. This could be attributed to the breeder hens being offered calcium supplements at the farm.

Internal parameters

The increased linear trends observed in albumen weight, SI, ESA, and SP with breeder hens' age could be attributable to EWT and body weight. These results compare favorably with those of Rath et al. (2015) and Carter (1975). Also, Manyeula et al. (2018) reported an increase in ESA with an increased body weight of indigenous Tswana hens. Similarly, Moreki et al. (2011) observed that ESA increased over time from 36 to 60 weeks of age in Ross broiler breeder hens. In the current study, a linear decrease of SI in response to breeder hens' age indicated that the young hens were likely to produce round eggs and older hens (60 weeks) normal-shaped eggs that were good for the setting. Egg shape index is the ratio of EWT to EL and is an important criterion for determining egg quality. Altuntaş and Şekeroğlu (2008) found that sharp, normal (standard), and round eggs have SI values of <72, 72-76, and >76, respectively. Similar results were reported by Roberts (2004) and Kontecka et al. (2012). Additionally, Nikolova and Kocevski (2006) found SI values of 76.16% and 74.20% in younger (45 weeks) and older (> 45 weeks) hens, respectively. Egg weight is influenced by breeder hen's age and this explains why thin albumen weight and EC quadratically increased with breeder hen's age (Suk and Park, 2001). It has been reported that HU is used to measure the quality of albumen (Rizzi and Chiericato, 2005) and freshness of eggs, thus high-quality eggs have thicker whites (Charvatova and Tumova, 2010). The study by Carrazzoni de Menezes et al. (2012) reported that the HU of fresh eggs decreases with age. The quadratic increase of HU in response to breeder hen age in the present study could be due to good storage time and indicated that the egg was fresh (USDA, 2000). Indeed, Barbosa (2003) confirmed that good storage time and temperature caused an increase in HU and EWT. The present results are consistent with Alkan et al. (2015) who reported increased HU with increased egg weight. A decreased quadratic trend observed in thick albumen in response to breeder hen ages indicates that young chickens (30 weeks) have better thick albumen than the older flock (60 weeks).

Kontecka et al. (2012) reported that increased egg weight with age is due to the increasing weight of the yolk rather than white. This explains why yolk parameters quadratically increased with breeder hen age. Similar results were reported by Vieira and Moran (1998) and Padhi et al. (2013) who found increased yolk parameters with hen age. The proportion of yolk is positively related to egg size which is influenced by hen age (Rizzi and Chiericato, 2005; Johnston and Gous, 2007) supporting the results of the current study. Yolk index determines fresh and good quality eggs. Eggs with YI value ranging between 0.42 and 0.40 reflects good quality egg (Sharp and Powell, 1930). The YI values in this study were within the range of 0.40-0.42 implying that as hens get older the quality of eggs also improves. Thus, age could be a factor that determines the quality of broiler breeder hen eggs.

Correlation coefficients at different ages

The EWT showed a strong, positive significant correlation with EL, EWD, and YL in all weeks signifying that selection for EWT will automatically lead to improvement in EL and EWD regardless of the hen's age. Previous studies by Apuno et al. (2011), Manyeula et al. (2020), Obike and Azu (2012), Tebesi et al. (2012), and Alkan et al. (2015) also revealed positive strong significant correlations between the EWT and EL. These results were expected because EL and EWD are important factors determining egg weight. The significant positive correlation between EWT and YL, YWD, Yolk weight (YWT), and YH could be attributable to the fact that egg yolk occupies egg width area, hence contributing to heavier egg (egg weight). The YWT constitutes the yolk portion which may have influenced YWD and YL. However, the strong positive and significant correlations between EWT and YWT in all investigated weeks in the current study are consistent with those reported by Padhi and Rajkumar (2013) and Alkan et al. (2015). This indicates that grading heavy eggs for hatching will lead to a great improvement in yolk parameters which is a source of energy and lipids for the development of the embryo. Speaker (1998) confirmed that energy and lipids for embryo development are stored in the yolk sac. The thick albumen height was negatively correlated to EWT at weeks 45 and 60 implying that an increase in EWT corresponds to a decrease in albumen height. However, this result was not expected since albumen is a very important component contributing to EWT. The present result contradicts reports by Ukwu et al. (2017) and Abdalla (2018). The differences found between results may be partially attributable to differences in strains/lines, nutrition, and environment. The regression analysis between the age and shell weight found a negative quadratic trend suggesting that the younger hens had heavier shells, compared to older hens. Such results were expected since the younger breeder hens (30 weeks) have more calcium reserves compared to breeder hens aged 45-80 weeks in a study by Suk and Park (2001). Similarly, Abdalla (2018) reported a positive significant association between egg weight and shell weight. Roberts (2004) states that the eggshell thickness is affected by nutrition, stress, disease, and production system. However, the correlation between shell thickness and egg weight was not significant at all breeder hen ages (Table 5), suggesting that mineralization was not affected by the aging of the breeder hens. This could be due to the addition of supplementation of minerals in their diets. These findings are in consonance with Aryee et al. (2020) who found a non-significant correlation between egg weight and shell weight.

CONCLUSION

The findings of the study period led to the conclusion that Ross breeder hens' age determines internal and external quality traits. Also, egg quality is affected by egg weight as indicated by positive correlation values. The present results suggest that the selection of breeder eggs according to breeder age will simultaneously lead to improvement in other egg quality parameters.

DECLARATIONS

Acknowledgments

The authors sincerely acknowledge Ross Breeders Botswana for donating eggs used in this study. Moreover, the authors express their gratitude to the Botswana University of Agriculture and Natural Resources for granting the use of laboratory facilities for analysis.

Competing interests

The authors declare no conflict of interest.

Authors' contributions

Dr. F. Manyeula conceptualized this study and together with Mr. G. Sempule carried out the investigation. Drs Manyeula and B. Sebolai and Mr. Sempule were responsible for data curation. Drs Manyeula, Sebolai, and JC Moreki wrote, edited, and reviewed the manuscript. Dr. Moreki also served as the corresponding author and together with Dr. Manyeula worked on the suggestions made by the reviewers.

Ethical considerations

Prior to submission, the authors checked ethical issues including plagiarism, consent to publish, misconduct, data fabrication, and double publication.

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