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Association of Different Body Sizes and Egg Quality Characteristics in White Leghorn Chicken Breed of South Africa

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ABSTRACT

Egg quality could influence the price of the table and hatching eggs. However, the effects of hen's live body weight on egg characteristics are poorly understood. The present study evaluated the influence of body weight (BW) on egg characteristics, such as egg width (EWD), shell weight (SW), egg length (EL), albumen weight (AW), yolk weight (YW), shell surface index (SI), albumen ratio (AR), shell ratio (SR), and yolk ratio (YR) of White Leghorn chicken. A total of 100 White Leghorn chickens at 30 weeks of age were used in the current study of which 300 eggs were collected. Live body weight was classified into three groups namely, small (≤ 195g), medium (196-220g), and large (≥ 221g). The results revealed that the White Leghorn layer's live body weight was positively influenced by the eggshell index and egg length. Additionally, the results indicated that body weight did not affect EW, SW, EWD, SR, YW, AW, AR, and YR. In conclusion, the live body weight influences egg length and shell index in the White Leghorn chicken breed.

Keywords: Chicken, Egg length, Egg weight, Egg width, Shell index

INTRODUCTION

Chickens are an important source of food and money for households, and they also play a significant role in the sociocultural life of rural communities (Qin et al., 2015; Hlokoe et al., 2023). According to Onunkwo and Okoro (2015), the chicken egg functions as the embryo's primary source of nutrition and is a biotic structure for reproduction. The egg characteristics are extremely important in poultry breeding due to their impact on future generations' production performance, as well as the quality and growth of the chicks, breeding performance, and chick performance (Jatoi et al., 2015). Key indicators of egg quality include shell color, weight, thickness, density, albumen height, yolk color, albumen pH, and viscosity (Lee et al., 2016). White Leghorn chickens are mostly used in poultry enterprises for egg production, and they are regarded as one of the highly efficient laying breeds (Ferreira et al., 2022). The egg weight is related to the body weight of a chicken (Jatoi et al., 2015). However, the egg quality is affected by the various body sizes of chickens (Jatoi et al., 2015). The production of poor egg quality results in financial misfortunes, affecting the profit margins (Jatoi et al., 2015). Previous studies have examined the influence of live body weight on the egg characteristics in other poultry species, such as Lohmann White hens (Lacin et al., 2008), Japanese Quails (Jatoi et al., 2015), and guinea fowls (Onunkwo and Okoro, 2015). However, there is a lack of literature on the influence of live body weight on the egg characteristics of the White Leghorn chicken breed. Therefore, the objective of the study was to evaluate the influence of live body weight on the egg characteristics of the White Leghorn chicken breed. The obtained results might assist the chicken farmers in knowing the right live body weight of the chickens that can produce good quality egg characteristics.

MATERIALS AND METHODS

Ethical approval

The University of Limpopo Animal Research and Ethics Committee, in South Africa approved the study (AREC/42/2023:UG).

Study area

The study was conducted at the University of Limpopo Experimental Farm, South Africa. The study area has ambient temperatures that range between 20 and 36ºC in summer (November to January) and between 5ºC and 25ºC during winter (May to July). The University of Limpopo lies at latitude 27.55 ºS and longitude 24.77 ºE. The research area experiences an average yearly rainfall of less than 400 mm (Shabalala et al., 2019). The study was conducted in September 2023.

Experimental animals, management, and experimental design

A total of 100 30-week-old White Leghorn chickens from the University of Limpopo experimental farm were employed in the investigation. The chickens were raised as explained by Alabi et al. (2012). The chickens were raised under an intensive production system. The chicken house was well-ventilated, with curtains opened during the day and closed at night to control the ventilation. The light was provided for 16 hours a day and the temperature in the chicken house ranged from 24 to 32ºC. Wood shavings were used as bedding material. For the hens to produce eggs for the study, they were fed laying mash (Driehoek Feeds, South Africa) and given unlimited access to water. The nutritional constituents of the diet were metabolizable energy (2453.60Kcalkg^{-1}), crude Protein (16%), crude fats and oils (4.3%), crude fibers (4.8%), crude ash (13.6%), calcium (4.3%), phosphorus (0.6%), sodium (0.15%), lysine (0.7%) and methionine (0.35%). The diet was balanced according to NRC (1994). To prevent the hens from catching infectious diseases, Virokill disinfectant (UK) was used to clean the chicken house seven days before the arrival of the chickens. The biosecurity was followed according to Alabi et al. (2012). Mareks' vaccine (Zoetis, South Africa) was administered to the chicks at the hatchery before delivery. Nobilis® CAV P4 (Zoetis, South Africa) vaccine was administered intramuscularly to prevent chicken anemia 6 weeks before the onset of lay. In the current investigation, a completely randomized design was employed.

Eggs collection

A total of 300 eggs were randomly collected from 100 White Leghorn chickens for 3 weeks to measure the physical egg quality traits. A total of 100 eggs per week were randomly selected from the chickens. The eggs were collected in the morning and evening. The collected eggs were taken to the laboratory at room temperature to measure the external and internal egg quality traits.

Measurements of external egg quality and internal egg quality

The external egg characteristics measured from the chickens at different body weights included egg weight (g), egg length (cm), egg width (cm), and shell weight (g). External egg characteristics were measured according to Kgwatalala et al. (2013). Other external egg characteristics such as shell index (%) and shell ratio (%) were computed as described by Markos et al. (2017). The yolk weight (g) and albumen weight (g) were measured as the internal egg characteristics. The procedure introduced by Kgwatalala et al. (2013) was followed to measure the internal egg characteristics. The formulas provided by Ashraf et al. (2016) were used to compute additional internal egg characteristics, such as albumen ratio and yolk ratio. The following formulas were used in this study.

Albumen weight (g) = egg weight – (yolk weight + shell weight)

$$\text{Albumen ratio (\%)} = \frac{\text{Albumen weight}}{\text{Egg weight}} \text{x100}$$

$$\text{Yolk ratio (\%)} = \frac{\text{Yolk weight}}{\text{Egg weight}} \text{x 100}$$

$$\text{Shape index (\%)} = \frac{\text{Egg width}}{\text{Eeg length}} \text{x 100}$$

$$\text{Shell ratio (\%)} = \frac{\text{Shell weight}}{\text{Egg weight}} \text{x 100}$$

Measurements of chicken body weight

The BW of 100 chickens was measured using an electronic weighing scale (Medidata®, USA) with a precision of 0.01 g. The chickens were weighed individually on the weighing scale, and the body weights were classified into three namely, small (≤ 195g), medium (196-220g), and large (≥ 221g).

Statistical analysis

For the analysis of data, Statistical Package for Social Sciences IBM SPSS, version 28.0 was employed. For each trait, descriptive statistics were calculated. The association between measured characteristics was examined using Pearson's correlation. The influence of live body weight on egg characteristics was determined using a general linear model (GLM). The least significant difference (LSD) was used for the separation of means. The p-value at 0.05

shows a significant difference. The effect of body weight was computed using the model below (Jatoi et al., 2015):

$Y_{ij} = \mu + S_i + e_{ij}$

Where Y_{ij} is the j^{th} observation in the i^{th} body weight group, μ is the overall mean, S_i is the fixed effect of the i^{th} body weight group and e_{ij} is residual error.

RESULTS

Descriptive statistics

Table 1 displays the summary of the live body weight and egg characteristics. As can be seen, the live body weight of the White Leghorn chickens ranged from 119 g to 259 g. The coefficient of variation ranged from 0.50% to 15.85%.

Correlation matrix

The associations between live body weight and egg characteristics are displayed in Table 2. The findings showed that live body weight had a negatively high remarkable relationship ($p < 0.01$) with yolk weight and positively significantly correlation with albumen ratio ($p < 0.05$). The results also revealed that live body weight had no significant association with egg weight, shell weight, egg width, egg length, shell index, albumen weight, shell ratio, and yolk ratio ($p > 0.05$). Table 2 also showed that egg weight was associated with almost all the traits except with shell index.

Effect of live body weight on egg characteristics

Table 3 shows the findings of the influence of body weight on internal and external egg characteristics. The outcomes displayed that live body weight affected egg length and shell index ($p < 0.05$). The chickens with medium live body weight had the highest egg length, while the chickens with small live body weight had the lowest egg length. The findings further indicated that the shell surface index (SI) of the chickens with small, medium, and large body weight groups was significantly different ($p < 0.05$). The small body weight group had the highest SI, while the medium body weight group had the lowest SI. The outcomes also displayed that live body weight had no effect on egg weight, egg width, shell ratio, shell weight, albumen weight, yolk weight, albumen ratio, and yolk ratio ($p > 0.05$).

Table 1. Body weight and egg characteristics of the White Leghorn chicken breed

Traits	Minimum	Maximum	Mean	SD	CV (%)
Body weight (g)	119	259	211.42	22.13	10.46
Egg weight (g)	48.60	66.84	58.24	3.98	15.85
Egg length (mm)	53.53	63.26	56.95	1.82	3.32
Yolk weight (g)	11.05	23.41	17.94	1.69	2.86
Shell weight (g)	6.33	10.26	7.82	0.77	0.59
Egg width (mm)	40.13	45.28	43.07	1.02	1.04
Albumen weight (g)	23.47	41.68	32.48	3.28	10.73
Shape index (%)	66.04	81.84	75.69	2.70	7.28
Shell ratio (%)	10.87	17.36	13.74	1.25	1.57
Albumen ratio (%)	48.29	68.65	55.70	3.03	9.19
Yolk ratio (%)	18.90	38.26	30.86	2.71	7.33

SD: Standard deviation, CV: Coefficient of variation

Table 2. Correlation between the body weight and egg characteristics of White Leghorn chicken breed

Traits	BW	EW	EL	YW	SW	EWD	ST	AW	SI	SR	AR	YR
BW												
EW	0.13^{ns}											
EL	0.11^{ns}	0.66**										
YW	-0.71**	0.44*	0.29^{ns}									
SW	0.00^{ns}	0.55**	0.35*	0.27^{ns}								
EWD	0.02^{ns}	0.73**	0.19^{ns}	0.44*	0.43*							
AW	0.19^{ns}	0.86**	0.57**	-0.05^{ns}	0.30*	0.55**	0.04^{ns}					
SI	-0.08^{ns}	-0.10^{ns}	-0.76**	0.03^{ns}	-0.02^{ns}	0.49*	0.29^{ns}	-0.13^{ns}				
SR	-0.04^{ns}	0.36*	0.03^{ns}	0.19^{ns}	0.95**	0.40*	0.41*	0.12^{ns}	0.24^{ns}			
AR	0.32*	0.34*	0.23^{ns}	-0.63**	-0.14^{ns}	0.12^{ns}	-0.10^{ns}	0.77**	-0.11^{ns}	-0.24^{ns}		
YR	-0.18^{ns}	-0.31*	-0.20^{ns}	0.72**	-0.13^{ns}	-0.10^{ns}	0.00^{ns}	-0.71**	0.10^{ns}	-0.07^{ns}	-0.93**	1.00

BW: Body weight, EW: Egg weight, EL: Egg length, YW: Yolk weight, SW: Shell weight, EWD: Egg width, AW: Albumen weight, SI: Shell surface index, SR: Shell ratio, AR: Albumen ratio, YR: Yolk ratio, ns: Not significant ($p > 0.05$) *Significant ($p < 0.05$) and **Significant ($p < 0.01$)

Table 3. Effect of live body weight on external and internal egg characteristics of White Leghorn chicken breed

Traits	Small, ≤ 195g (Mean ± SD)	Medium, 196-220g (Mean ± SD)	Large, ≥ 221g (Mean ± SD)
Egg weight (g)	56.84 ± 3.82^{a}	58.73 ± 4.07^{a}	58.35 ± 3.84^{a}
Egg length (mm)	56.09 ± 1.37^{b}	57.31 ± 1.82^{a}	56.92 ± 1.94^{ab}
Shell weight (g)	7.73 ± 0.62^{a}	7.85 ± 0.86^{a}	7.84 ± 0.71^{a}
Egg width (mm)	43.08 ± 1.31^{a}	43.09 ± 0.90^{a}	43.01 ± 1.02^{a}
Shell surface index (%)	76.84 ± 3.00^{a}	75.25 ± 2.42^{b}	75.62 ± 2.80^{ab}
Shell ratio (%)	13.78 ± 1.10^{a}	13.69 ± 1.38^{a}	13.77 ± 1.15^{a}
Yolk weight (g)	17.55 ± 1.41^{a}	18.33 ± 1.53^{a}	17.53 ± 1.99^{a}
Albumen weight (g)	31.55 ± 3.31^{a}	32.55 ± 3.15^{a}	32.97 ± 3.43^{a}
Albumen ratio (%)	55.42 ± 3.29^{a}	55.35 ± 2.61^{a}	56.44 ± 3.45^{a}
Yolk ratio (%)	30.95 ± 2.53^{a}	31.27 ± 2.33^{a}	30.09 ± 3.28^{a}

SD: Standard deviation, ^{ab} means in the same row with different superscript letters are significantly different ($p < 0.05$).

DISCUSSION

Egg quality contributes to the improved economic price of hatching and table eggs, and the characteristics that define egg quality typically have a genetic basis (Bekele et al., 2022). Pearson's correlation was first used to evaluate the association between live body weight and egg characteristics of the White Leghorn chicken breed. The correlation outcomes displayed that body weight had a negatively high remarkable association with yolk weight, a positive statistical correlation with albumen ratio, and a non-significant correlation with egg weight, egg length, shell weight, egg width, albumen weight, shell surface index, shell ratio, and yolk ratio. According to the study that was conducted by Ojo et al. (2011) in the Japanese quail, it was found that body weight had a positive remarkable relationship with egg length and a negative statistically significant association with egg index. The findings of Ayorinde and Toye (2021) showed that body weight had a negative remarkable correlation with shell thickness and a non-significant association with egg weight. The correlation results imply that increasing the body weight might decrease yolk weight and increase the albumen ratio in White Leghorn chickens. According to Hlokoe et al. (2022), correlated traits are assumed to be controlled by the same genes. However, the results of the current study did not clearly indicate which egg characteristics are directly influenced by body weight, as the correlations only show associations between traits. Therefore, a general linear model was subsequently used to assess the influence of body weight on egg characteristics in the White Leghorn chicken breed. The results indicated that live body weight significantly influenced egg length and shell index. Specifically, chickens with medium live body weight produced eggs with the greatest length, while those with small live body weight produced eggs with the shortest length. The findings further indicated that the SI of the small, medium, and large body weight groups was significantly different. The small body weight group had the highest SI, while the medium body weight group had the lowest SI. The results also indicated that egg weight, shell weight, egg width, shell ratio, albumen ratio, yolk weight, albumen weight, and yolk ratio were not affected by body weight.

The study that was conducted by Lacin et al. (2008) in the Lohmann laying hens reported that shell index was significantly affected by body weight, but body weight had a non-significant effect on yolk ratio which is in line with the current study results. Furthermore, Lacin et al. (2008) reported that the albumen ratio was influenced by body weight, which is not in line with the current study since in the current study body weight had a non-significant effect on the albumen ratio, so the variations may be due to breed differences. Jatoi et al. (2015) in four closed-bred flocks of Japanese quails showed that body weight had a significant effect on yolk ratio which is not in line with the current study. The study also found that body weight had a significant influence on shell weight, egg weight, and shell thickness. Chickens of small and large body weights have higher egg length and shell index than medium ones. The chickens with small, medium, and large body weights perform the same in the following traits egg weight, shell weight, shell ratio, egg width, albumen weight, yolk weight, yolk ratio, and albumen ratio.

CONCLUSION

The study concluded that the live body weight had a negatively high remarkable relationship with yolk weight and positively correlated with albumen ratio. The findings also indicated that egg weight was associated with almost all the traits except the shell index. The current study indicated that body weight affected some external egg characteristics, namely egg length and shell index. Further studies need to be conducted on the effect of body weight on egg characteristics using more sample size of White Leghorn chickens.

DECLARATIONS

Funding

No available funding was received for the study.

Availability of data and materials

The data is available on request from the corresponding author.

Competing interests

There is no conflict of interest declared by the author.

Ethical considerations

All the authors avoided data fabrication, plagiarism, falsification, misconduct, and double submission/publication and have given consent to publish this article.

Authors' contributions

The initial idea of the study was by Thobela Louis Tyasi and Lindiwe Johannah Sathekge. All the authors contributed to the design of the study. The first draft of the manuscript was written by Lindiwe Johannah Sathekge and Victoria Rankotsane Hlokoe. The manuscript was revised by Thobela Louis Tyasi. The final manuscript was read and approved by all authors.

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