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DEVELOPMENT OF PREDICTIVE MODELS FOR EGG WEIGHT IN SHIKA BROWN CHICKENS USING STEPWISE REGRESSION

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ABSTRACT

Egg quality traits are essential indicators of productivity and commercial value in poultry breeding. This study evaluated egg quality characteristics of Shika Brown laying chickens and developed predictive models for egg weight (EWT) using stepwise regression. A total of 240 eggs, obtained from Shika Brown laying chickens, were analyzed for parameters including egg length (ELT), egg width (EWD), shell thickness (STK), shell weight (SWT), egg shape index (ESI), albumen weight (AWT), and yolk weight (YWT). Data were analyzed using statistical analysis procedures of Statistical Package for Social Sciences version 27.0 (IBM SPSS, 2020). Descriptive statistics and phenotypic correlations were computed to assess trait relationships. Stepwise regression analysis was employed to develop predictive models for EWT. Correlation analysis revealed significant relationships ($p < 0.01$) between EWT and external traits such as EWD ($r = 0.256$) and egg volume (EGV; $r = 0.188$), with a strong negative correlation between EWT and shell thickness index (STI; $r = -0.763$). Internal traits (albumen and yolk) showed weaker associations. The optimal predictive model was EWT = 57.271 - 19.030(STI) + 2.392(STK) + 4.080(EWD) - 0.125(ESI) - 0.155(ELT) with adjusted $R^2 = 0.888$ and RMSE = 1.813. External egg quality traits enable accurate EWT estimation, reducing reliance on direct measurement. These findings support optimized selection strategies in Shika Brown breeding programs, enhancing productivity and market value.

1. INTRODUCTION

Egg quality traits, particularly weight, are crucial in poultry breeding and commercial egg production. Egg weight affects hatchability, market value, and consumer preference (Ledvinka *et al.,* 2012). Understanding the relationship between external and internal egg traits and their predictive value for egg weight is vital for optimizing breeding programs (Tyasi *et al.,* 2024). However, traditional egg weight measurement methods are time-consuming and impractical for large-scale production. Predictive modeling offers a more efficient alternative for breeders, with statistical approaches like multiple linear regression and machine learning being explored in poultry research (Rotimi, 2023).

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Stepwise regression was chosen for its ability to identify significant predictors and eliminate less relevant variables, improving model efficiency and balancing simplicity with predictive accuracy (Hlokoe & Tyasi, 2021; Smith, 2018; Landau & Everitt, 2017). This method is particularly effective in navigating high-dimensional predictor spaces and is widely used for variable selection in regression modeling. The primary advantage of stepwise regression is that it's computationally efficient. The Shika Brown laying chicken, a popular breed in Nigeria, has not been extensively studied for egg trait prediction, particularly through integrated models. While prior studies highlight relationships between egg weight (EWT) and individual traits like egg width and shell thickness (Saroj *et al.,* 2020), a holistic model combining multiple external and internal quality traits remains unexplored. This study addresses this gap by developing a stepwise regression model to predict

EWT in Shika Brown chickens, integrating diverse egg parameters to enhance accuracy for improved selection programs. The approach iteratively selects statistically significant variables using criteria such as Residual Mean Square Error (RMSE), Akaike information criterion (AIC), Bayesian information criterion (BIC), minimizing overfitting while maintaining generalizability. Its application to egg weight prediction in poultry demonstrates a robust framework for optimizing productivity through trait-based selection (Tyasi *et al.*, 2024; Smith, 2018).

Egg weight variability poses a challenge in poultry production, affecting hatchability and marketability. Inconsistent egg sizes lead to inefficiencies in grading, packaging, and pricing, impacting profitability (Ukwu *et al.*, 2017). Although egg weight is influenced by both genetic and environmental factors, its accurate estimation remains challenging due to the dynamic nature of egg quality traits (Rotimi, 2023). Traditional egg weight measurement methods require direct weighing, which can be time-consuming and impractical for large-scale production.

Previous studies have explored the relationship between egg weight and quality traits in poultry breeds like Isa Brown (Rotimi, 2023) and Lohmann Brown chickens (Tyasi *et al.*, 2024). However, limited research has focused on the Shika Brown laying chicken, particularly in Nigeria. While individual traits such as egg width and shell thickness are strongly correlated with egg weight, a comprehensive predictive model incorporating multiple traits is necessary for greater accuracy (Saroj *et al.*, 2020). This study aims to develop a robust regression model for predicting egg weight using key external and internal quality traits.

Accurate egg weight prediction has significant implications for poultry breeding, farm management, and the broader poultry industry. A reliable model will facilitate selection programs to improve egg weight, reduce production losses, and optimize market value. This is especially relevant for the Shika Brown laying chicken, a breed of growing commercial importance in Nigeria. Shika Brown is an egg-laying chicken breed that produces approximately 280-300 eggs within its production cycle, exhibiting excellent shell quality, high production rate, persistency, egg weight, livability, and feed conversion. This breed is well-suited to harsh tropical environments and is resistant to many economically significant diseases (Dessie and Getachew, 2016; Kallah, 1999).

Predicting egg weight allows breeders to make informed decisions about selection and culling, improving the genetic potential of the flock. Furthermore, a predictive model can reduce the need for direct weighing, saving time and labor costs. Poultry farmers can estimate egg weights without destructive sampling, preserving egg quality for sale or incubation.

The use of stepwise regression in predicting egg weight based on egg quality traits in Shika Brown laying chickens is not well-documented. Therefore, this study aims to assess the relationship between egg weight and egg quality traits, developing an accurate predictive model for the Shika Brown breed. The findings will serve as a reference for researchers, poultry geneticists, and farm managers, promoting efficient and sustainable poultry production. By adopting predictive modeling, poultry farms can enhance productivity and competitiveness in the market (Liswaniso *et al.*, 2021).

2. MATERIALS AND METHODS

Study location

The study was carried out at the Poultry Unit of the Livestock Teaching and Research Farm, Federal University, Dutsin-Ma, located in Katsina State, Nigeria. The descriptions of the location are the same as earlier given by Rotimi (2023) and Rotimi *et al.* (2021).

Experimental Birds and Management

Fleshly laid eggs from Shika Brown laying chickens were used for this study. The birds were raised under an intensive production system and managed according to standard husbandry practices (Alabi *et al.*, 2012). Biosecurity measures were strictly followed, with footbaths containing disinfectant placed at the door for sanitation before entering the chicken house. The chickens were provided with laying mash and cool drinking water *ad libitum*.

Data collection

Egg quality traits measurements

A total of 240 freshly laid eggs were collected and analyzed for both external and internal traits. Each egg was carefully cracked to avoid damaging the membranes enclosing the albumen and yolk. The shells were collected, air-dried overnight, and then weighed. External and internal egg quality parameters were measured for each individual egg.

Egg weight (EWT, g): Measured using a precision digital scale.
Egg length (ELT, cm): Determined with a Vernier caliper.

Egg width (EWD, cm): Measured with a Vernier caliper.
Shell thickness (STK, cm): Assessed using a micrometer screw gauge.
Shell weight (SWT, g): Air-dried shells weighed on a precision scale.
Egg Shape Index (ESI, %): This was calculated using the formular; ESI (%) = $\frac{EWD}{ELT}$ X 100
Shell Ratio Index (SRI, %): Calculated using the formular; $\frac{SWT}{EWT}\ X\ 100$
Egg Volume (EGV, cm³): Estimated using the formula by Narushin (2005):
EGV = (0.6057 - 0.0018EWD) X ELT X EWD^2
Shell Strength Index (SSI, %): Derived as SSI (%) = $\frac{SWT}{STK}\ X\ 100$
Shell Thickness Index (STI, %): Calculated as STI = (STK EWT) × 100
Albumen weight (AWT, g): Determined by subtracting yolk and shell weights from total egg weigh. Thus; AWT = EWT − (YWT + SWT) (Alkan *et al.*, 2013).
Yolk weight (YWT, g): Measured directly using a precision scale.
Albumen ratio (ALR). This was obtained using the formular; ALR (%) = $\frac{AWT}{EWT}$ X 100
Yolk ratio (YLR). This was evaluated using the formular; YLR (%) = $\frac{YWT}{EWT}\ X\ 100$
Yolk/albumen (YAR). This was evaluated from the formular; YAR (%) = $\frac{YWT}{AWT}\ X\ 100$
Measurements adhered to established poultry research protocols (Rotimi, 2023; Markos *et al.*, 2017; Kgwatalala *et al.*, 2013).

Data analysis

The data were analyzed using the Statistical Package for Social Sciences version 27.0 (IBM SPSS, 2020).

Descriptive statistics

All evaluated traits were summarized using descriptive statistics.

Pearson's correlation

Relationships among egg traits were assessed using Pearson's correlation coefficients.

Stepwise regression analysis

To develop optimal models for estimating egg weight, stepwise regression analysis (following Rotimi, 2023) was applied by regressing egg weight against egg quality traits. The equation used is shown below;

$$Y = a + b_1X_1 + b_2X_2 + \ldots + b_nX_n$$

Where;
Y = dependent variable (EWT),
a = intercept,
$b_1, b_2 \ldots b_n$ = coefficient of regression,
$X_1, X_2 \ldots X_n$ = independent variables (egg quality traits).

The accuracies of the regression models were evaluated by coefficient of determination (R^2) along with the Residual Mean Square Error (RMSE) as the goodness-of-fit criteria. The following criteria were applied:

$$RMSE = \sqrt{\frac{SSE}{N-k-1}}$$

$$AIC = N.Ln\left(\frac{SSE}{N}\right) + 2k$$

$$BIC = N.Ln\left(\frac{SSE}{N}\right) + k.LN$$

Where;
RMSE = residual mean square error;
N= number of observations;
k= number of parameters in the regression equation (including the intercept);
AIC= Akaike information criterion;
BIC= Bayesian information criterion;
Ln = natural logarithm.

3. RESULTS AND DISCUSSION

Descriptive statistics

Table 1 presents the descriptive statistics of egg traits in Shika Brown. The average egg weight was 60.735±0.347g, lower than the 65.67±0.36 g reported for Lohmann Brown chickens (Tyasi *et al.*, 2024) and the 65.68 g recorded for Alabio duck eggs (Danang *et al.*, 2023). Other measured traits include: egg length (4.338±0.169 cm), egg width (2.927±0.018 cm), shell thickness (1.338±0.007 mm), shell weight (6.426±0.291 g), egg shape index (70.157±0.555), shell ratio index (10.598±0.445), egg volume (22.590±0.947), shell surface index (4.845±0.236), shell thickness index (2.226±0.021), albumen weight (39.698±1.368 g), yolk weight (16.373±0.916 g), albumen ratio (65.732±2.167), yolk ratio (27.179±1.554), and yolk/albumen (42.626±2.024).

Egg shell strength (4.845±0.236), a critical external trait for reducing breakage during handling and transportation, fell within an average range. Danang *et al.* (2023) and Ledvinka *et al.* (2012) emphasized that egg quality traits are influenced by internal factors (genetics, health, age, production phase) and external factors (nutrition, housing, management, microclimate).

Phenotypic correlation

The phenotypic relationships between egg weight (EWT) and external/internal egg parameters are summarized in Tables 2 and 3. For external traits (Table 2), EWT exhibited positive correlations with EWD (r = 0.256**) and EGV (r = 0.188**), while showing negative correlations with STI (r = -0.763**). Other parameters (ELT, SWT, SSI, STK, ESI, SRI) had weak or nonsignificant (NS) associations. Internal parameters (Table 3) displayed predominantly weak, nonsignificant relationships, with only AWT (r = 0.065NS) and YWT (r = 0.010NS) showing marginal positive links to EWT, contrasting with negative trends in ALR, YLR, and YAR.

These results differ from Tyasi *et al.* (2024), who reported stronger correlations in Lohmann Brown chickens, likely due to breed and age variations. Similarly, Rotimi (2023) found highly significant (P<0.01) positive associations between EWT and egg length/diameter in Isa Brown chickens, though shell thickness showed a nonsignificant negative correlation (r = -0.136). Such discrepancies highlight how correlations between EWT and egg parameters depend on breed, nutrition, and age. The overall weak relationships observed here suggest limited reliability in estimating EWT solely through these traits, emphasizing the multifactorial complexity of egg weight determination.

Notably, Pearson's correlation identifies trait relationships but not their causal contributions to EWT variability (Tadele *et al.,* 2018). While positively correlated traits may indicate pleiotropic effects (Hlokoe *et al.,* 2022), this study underscores the need for multivariate models, rather than univariate correlations, to improve prediction accuracy.

Stepwise Regression Analysis

Table 4 presents the variance inflation factor (VIF) values for the independent variables in the stepwise regression analysis of Shika Brown laying chickens. The VIF values ranged from 1.000 to 4.880, indicating no or very low multicollinearity issues among the variables, as VIF measures the degree of multicollinearity (Johnston *et al.*, 2018).

Multicollinearity inflates the variance of the independent variables, potentially making predictor variables statistically insignificant when they should be significant (Rotimi *et al*., 2023). Table 5 shows the stepwise regression analysis for estimating egg weight in Shika Brown laying chickens. The stepwise regression technique was applied to develop optimal regression models for predicting egg weight, with goodness-of-fit criteria (R^2, RMSE, AIC, and BIC) used to select the best models. Five models were derived, all showing statistical significance ($p < 0.01$). The first model included STI, explaining 58.20% of the variability in egg weight, with high RMSE, AIC, and BIC (3.47969, 600.52, and 601.49, respectively). The second model added STK, explaining 87.50% of the variation. The third model included EWD, explaining 87.90%, while the fourth model added ESI, explaining 88.60%. The fifth model, which included ELT, explained 88.80% of the variation, with lower RMSE (1.81308), AIC (291.53), and BIC (286.52). R^2 increased as more independent variables were added, suggesting that R^2 alone is insufficient to assess model accuracy (Abdelaziz *et al.*, 2020). The study used VIF to evaluate multicollinearity and only included variables with VIF less than 10.

RMSE measures the accuracy of predictions by assessing the average difference between predicted and actual egg weights. It allows comparison of model performance to identify the most accurate model. The stepwise regression procedure identified the best-fit model for estimating egg weight in Shika Brown laying chickens, using external traits (ELT, EWD, STK, SWT, ESI, SRI, EGV, SSI, STI) and internal traits (AWT, YWT, ALR, YLR, YAR) as independent variables. The best model was evaluated using R^2, RMSE, AIC, and BIC. The results showed that STI alone explained the least variation ($R^2 = 0.582$), but had the highest RMSE, AIC, and BIC (3.47969, 600.52, and 601.49, respectively).

The stepwise regression analysis showed that STI alone contributed least to egg weight variability, with the highest RMSE, AIC, and BIC, making it unsuitable for prediction. The fifth model, which included STI, STK, EWD, ESI, and ELT, explained the most variation (88.80%), with the lowest RMSE, AIC, and BIC, making it the best model for predicting egg weight. This implies that egg weight in Shika Brown laying chickens can be more accurately predicted by including more egg traits. The study confirms that improving egg traits such as STI, STK, EWD, ESI, and ELT leads to better egg weight prediction in Shika Brown laying chickens.

This study supports findings by Hlokoe and Tyasi (2021) on Potchefstroom Koekoek chickens and Tyasi *et al.* (2024) on Lohmann Brown chickens, who recommended using more egg traits for accurate egg weight prediction. Rotimi (2023) also found that traits like EL, ED, SW, AW, and YW can predict egg weight in Isa Brown laying hens with high accuracy. Egg traits are reliable predictors of egg weight in chickens (Liswaniso *et al.*, 2021).

The stepwise regression analysis identified STI, STK, EWD, ESI, and ELT as the most significant predictors of egg weight, with an adjusted R^2 of 0.888. These findings align with previous studies on Lohmann Brown chickens (Tyasi *et al.*, 2024), but show slightly lower correlation values, possibly due to breed and environmental differences. The strong negative correlation between STI and EWT (-0.763) suggests that eggs with thinner shells tend to weigh more, a pattern also found in Isa Brown hens (Rotimi, 2023).

These results have practical implications for poultry breeding programs. By selecting traits like EWD and STK, breeders can optimize egg weight without directly measuring it, improving efficiency in large-scale operations. However, the study's limitation to a single breed and environmental setting may affect the generalizability of the model. Future research should explore multi-breed comparisons and incorporate environmental factors like temperature and humidity.

4. CONCLUSION

This study evaluated egg quality traits in Shika Brown laying chickens and developed regression models for EWT prediction. External traits, particularly EWD ($r = 0.256$) and STI ($r = -0.763$), showed significant correlations with EWT, while internal traits (AWT, YWT) exhibited weaker associations. However, albumen ratio (ALR) and yolk ratio (YLR) demonstrated strong intercorrelations ($r = 0.980$ and $r = 0.989$, respectively). The optimal model (EWT = 57.271 - 19.030(STI) + 32.392(STK) + 4.080(EWD) - 0.125(ESI) - 0.155(ELT)) achieved an adjusted R^2 of 0.888 and RMSE of 1.813, confirming that combining external traits provides robust EWT prediction.

5. CONFLICT OF INTEREST

All authors have declared that there is no conflict of interest regarding the publication of this article.

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Table 1. Descriptive statistics for egg weight, external and internal egg quality traits of the Shika Brown chicken breed

Traits	N	Mean (±SE)	CV %.	Min.	Max.
External traits					
EWT (g)	240	60.735±0.347	8.847	30.000	75.400
ELT (cm)	240	4.338±0.169	60.490	2.900	44.600
EWD (cm)	240	2.927±0.018	9.447	0.100	4.000
STK (cm)	240	1.338±0.007	8.514	0.800	1.900
SWT (g)	240	6.426±0.291	70.233	3.300	55.500
ESI (%)	240	70.157±0.555	12.253	2.560	100.000
SRI	240	10.598±0.445	65.079	5.820	85.160
EGV (cm^3)	240	22.590±0.947	64.916	0.020	240.960
SSI	240	4.845±0.236	75.426	2.790	44.310
STI	240	2.226±0.021	14.907	1.310	5.000
Internal traits					
AWT (g)	240	39.698±1.368	53.395	27.400	356.900
YWT (g)	240	16.373±0.916	86.715	4.500	172.000
ALR	240	65.732±2.167	51.075	41.710	558.530
YLR	240	27.179±1.554	88.602	7.940	315.020
YAR	240	42.626±2.024	73.568	4.340	416.470

SE = Standard error, CV% = Coefficient of variation (%), EWT = Egg weight, ELT = Egg length, EWD = Egg width, STK = Shell thickness, SWT = Shell weight, ESI = Egg shape index, SRI =Shell ratio index, EGV = Egg volume, SSI = Shell surface index, STI = Shell thickness index, AWT = Albumen weight, YWT = Yolk weight, ALR = Albumen ratio, YLR = Yolk ratio, YAR = Yolk/albumen

Table 2. Correlation coefficients between egg weight and external egg quality traits of the Shika Brown chicken breed

	EWT	ELT	EWD	STK	SWT	ESI	SRI	EGV	SSI	STI
ELT	0.126	--								
EWD	0.256**	0.036	--							
STK	-0.103	-0.009	0.105	--						
SWT	0.118	0.010	0.032	-0.045	--					
ESI	-0.093	-0.517**	0.682**	0.155*	-0.013	--				
SRI	-0.031	-0.006	-0.003	-0.024	0.987**	-0.002	--			
EGV	0.188**	0.975**	0.247**	0.022	0.019	-0.358**	-0.006	--		
SSI	0.124	0.010	0.019	-0.141*	0.995**	-0.028	0.981**	0.014	--	
STI	-0.763**	-0.082	-0.096	0.665**	-0.092	0.155*	0.038	-0.102	-0.154*	--

**Correlation is significant ($p < 0.01$), *Correlation is significant ($p < 0.05$). EWT = Egg weight, ELT = Egg length, EWD = Egg width, STK = Shell thickness, SWT = Shell weight, ESI, SRI =Shell ratio index, EGV = Egg volume, SSI = Shell surface index, STI = Shell thickness index.

Table 3. Correlation coefficients between egg weight and internal egg quality traits of the Shika Brown chicken breed

	EWT	AWT	YWT	ALR	YLR	YAR
AWT	0.065	--				
YWT	0.010	0.031	--			
ALR	-0.125	0.980**	0.029	--		
YLR	-0.104	0.022	0.989**	0.044	--	
YAR	-0.020	-0.083	0.977**	-0.080	0.980**	--

**Correlation is significant ($p < 0.01$), *Correlation is significant ($p < 0.05$). EWT = Egg weight, AWT = Albumen weight, YWT = Yolk weight, ALR = Albumen ratio, YLR = Yolk ratio, YAR = Yolk/albumen.

Table 4. Variance inflation factors (VIF) of the Stepwise regression models in Shika Brown laying chicken

Model	VIF				
	STI	STK	EWD	ESI	ELT
1	1.000	-	-	-	-
2	1.794	1.794	-	-	-
3	1.888	1.892	1.064	-	-
4	2.088	1.925	2.167	2.097	-
5	2.184	1.933	3.690	4.880	2.353

VIF = Variance inflation factors, ELT = Egg length, EWD = Egg width, STK = Shell thickness, ESI, STI = Shell thickness index.

Table 5. Stepwise regression analysis for prediction of EW in Shika Brown laying chicken

Model	Equation	R^2	RMSE	AIC	BIC	Sig.
1	88.244-12.360STI	0.582**	3.47969	600.52	601.49	0.000
2	59.859 -20.174STI+34.207STK	0.875**	1.90267	311.75	309.57	0.000
3	56.791-19.868STI+33.303STK+1.230EWD	0.879**	1.87763	306.39	303.36	0.000
4	56.722-19.279STI+32.603STK+2.895EWD-0.074ESI	0.886**	1.82893	294.72	290.65	0.000
5	57.271-19.030STI+32.392STK+4.080EWD-.125ESI-0.155ELT	0.888**	1.81308	291.53*	286.52	0.000

R^2 = Coefficient of determination, RMSE = Residual Mean Square Error, AIC = Akaike information criterion, BIC = Bayesian Information Criterion, ELT = Egg length, EWD = Egg width, STK = Shell thickness, ESI, STI = Shell thickness index

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