

Linear and multiple regression models for predicting body weight, egg and yolk weights of Isa Brown and Nera Black chicken strains raised in the humid tropics

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ABSTRACT: Accurate prediction of egg and yolk weights using body and egg quality traits can enhance productivity, consistency, and selection efficiency in layer chickens. This study evaluated predictive models for body weight, egg, and yolk traits in two commercial strains. A total of 100-layer chickens (50 Nera Black and 50 Isa Brown) were housed in battery cages for 55 weeks. Each strain was further replicated five times with 10 birds per replicate. Weekly body weights and morphometric traits were recorded. Six eggs per replicate (60 eggs in total) were randomly sampled and analysed for external traits (egg weight, length, width, shell weight and shell thickness) and internal traits (albumen weight, albumen height, yolk weight, Haugh unit). Linear and multiple regression analyses were used to develop predictive models for body weight, internal and external egg traits. The multiple regression model provided greater accuracy than the simple linear model. For body weight prediction, combinations of body length (BL), wing length (WL), and body girth (BG) achieved the highest precision ($R^2 = 1.000$; $SEE < 0.001$). In egg and yolk weight prediction, significant ($p < 0.001$) relationships were observed with specific quality traits. For Isa Brown, egg length (EL) and shell thickness (ST) were the best external predictors, while albumen height (AH) and albumen ratio (AR) were key internal predictors. For Nera Black, shell thickness (ST) and albumen ratio (AR) were most reliable. Integrating morphometric and egg quality traits through multiple regression enhances prediction accuracy for body weight, egg weight, and yolk weight. These findings support improved husbandry, breeding, and egg marketing strategies in layer chicken production.

Keywords: Egg quality traits, Isa Brown, Nera Black, prediction.

INTRODUCTION

Egg quality is a cornerstone of poultry layer production, as it directly influences consumer preferences, nutritional value, and hen health (Sam *et al.*, 2024). Key traits such as egg weight, yolk weight, shell thickness, shell weight, and internal components like yolk and albumen are critical for market appeal and economic viability (Sam *et al.*, 2020). Research has shown that traits like egg length, width, and shell quality are strongly correlated (Sam and Udo, 2025), enabling the development of predictive models to ensure consistent egg quality for grading and hatchability (Ojedapo, 2013; Olawumi and Ogunlade, 2008; Abdulraheem *et al.*, 2018). These models are vital for maintaining high standards in egg production and meeting consumer

demands effectively.

In tropical regions like Nigeria, commercial layer strains such as Isa Brown and Nera Black are favoured for their superior egg-laying capacity (Sam, 2023) and adaptability to local climates, surpassing indigenous breeds in growth and productivity (Udo *et al.*, 2025). Body weight (BW) is a key economic trait in these chickens, impacting feed efficiency, reproductive performance, and flock management. Traditional weighing methods using scales are often impractical in resource-limited settings due to cost, availability, and stress on birds. Morphometric traits, such as body length (BL), wing length (WL), shank length (SL), breast girth (BG), and neck length (NL), provide a non-

invasive, cost-effective alternative for estimating BW. These measurements, which reflect skeletal and muscular structure, correlate strongly with body mass and have been validated across various chicken genotypes for predicting BW through regression models (Ojedapo *et al.*, 2010; Ibe, 1989; Okon *et al.*, 1997). For instance, in Nera Black and Brown Shaver layers, BW showed significant correlations ($p < 0.05$) with SL, keel length, and chest girth, enabling cubic regression models to achieve up to 99% accuracy (Latshaw and Bishop, 2001).

Despite progress, predictive models for BW in Isa Brown and Nera Black remain underexplored within integrated frameworks that consider factors like age, sex, and environment. Multiple regression models incorporating traits like BG and SL consistently yield higher R^2 values (> 0.80) compared to single-trait models, though issues like multicollinearity and seasonal variations pose challenges. Nera Black chickens often exhibit higher BW (e.g., 30.31 g at day-old) and morphometric values than Isa Brown, highlighting the need for strain-specific models to optimise breeding and management (Ojo *et al.*, 2010). Quadratic and multiple regression models have shown greater precision than linear models in both broilers and layers, suggesting potential for improved accuracy in tropical settings. This study focuses on developing and validating regression equations for BW prediction in Isa Brown and Nera Black using morphometric traits to identify the most reliable predictors.

Advanced regression models and correlation coefficients have significantly improved egg weight prediction by combining external traits (e.g., length, width) and internal traits (e.g., yolk, albumen), achieving high accuracy (R^2 up to 0.99) in brown-egg layers like Isa Brown and Nera Black (Alkan *et al.*, 2008; Savegnago *et al.*, 2011; Ojedapo *et al.*, 2012). These models support enhanced egg quality, reproductive success, and flock health (Udo *et al.*, 2025). Yolk weight, crucial for nutritional evaluation, shows moderate heritability (0.3–0.5) and increases with age, though environmental stressors like heat can reduce precision by 10–15% (Ojedapo and Amao, 2014). Strong genetic correlations ($r = 0.6$ – 0.8) between yolk and albumen traits further aid selection strategies (Olawumi and Ogunlade, 2018; Wolc *et al.*, 2012). While Isa Brown outperforms Nera Black in egg output due to genetic selection, Nera Black demonstrates resilience in challenging environments, though limited data and environmental factors like heat stress complicate accurate predictions, particularly for yolk weight (Adeyemo and Oyejide, 2019; Obike *et al.*, 2014; Rath *et al.*, 2015).

MATERIALS AND METHODS

Ethics

The present study complied with the ethical guidelines for

poultry production bioethics (Macer, 2019), covering chicken cage management, feed and water provisions, and handling practices, from the viewpoint of an animal breeder and researcher.

Study location

The study was carried out at the Poultry Unit of the Teaching and Research Farm, Department of Animal Science, Faculty of Agriculture, Akwa Ibom State University, Obio Akpa. Located between latitudes 4°30'N and 5°00'N and longitudes 7°30'E and 8°00'E, Obio Akpa falls within Nigeria's tropical rainforest zone. The area has an annual rainfall of 3,500–5,000 mm, an average monthly temperature of 27.5°C, and a relative humidity of 60–90% (AKSG, 2022).

Management of experimental birds

A total of 100 layer chickens (50 Nera Black and 50 Isa Brown) were housed in battery cages. Each strain was divided into five replicates of 10 birds each. Vaccinations for Marek's disease, Newcastle disease, Gumboro, Fowl Typhoid, and Fowl Pox were administered at recommended ages, with Oxytetracycline Plus (OTC Plus) used as needed. Strict protocols for vaccination, medication, and sanitation were followed. The birds were fed a standard layer diet from a local feed mill, containing 17.9% crude protein and 2,784.8 kcal/kg metabolizable energy.

Data collection

Morphometric traits

The following morphometric measurements were obtained as described below:

Body Length (BL): Measured from the tip of the rostrum maxillare (beak) to the end of the caudal region (tail, excluding feathers).

Wing Length (WL): Measured from the tip of the phalanges to the coracoid-humeral joint.

Shank Length (SL): Measured as the length of the tarsometatarsus, from the hock joint to the metatarsal pads.

Breast Girth (BG): Recorded as the circumference around the deepest part of the breast, using a measuring tape in centimetres.

Neck Length (NL): Measured from the occipital condyle to the anterior edges of the coracoids.

Egg quality traits

Egg quality data were collected from 60 eggs (30 from Isa Brown and 30 from Nera Black), with six eggs randomly sampled weekly from each replicate and labelled. The experiment ran for 55 weeks. External traits measured included egg weight, egg length, egg width, shell weight, and shell thickness.

Egg Weight: Measured in grams using a Camry portable digital scale.

Egg Length: Measured longitudinally from the broad to the narrow end using a digital vernier calliper (0.01 mm accuracy).

Egg Width: Measured at the widest vertical point using a digital vernier calliper (0.01 mm accuracy).

Shell Weight: Eggs were broken, contents removed, air-dried for 24 hours, and shells were weighed in grams using a digital scale.

Shell Thickness: Measured in millimetres using a micrometre screw gauge.

Internal egg quality traits

The same eggs were used to assess internal traits, including albumen weight, albumen height, yolk weight, and Haugh unit.

Albumen Height: Measured vertically from the base to the top of the albumen using a vernier calliper (0.01 mm accuracy).

Albumen Weight: Albumen was separated from the yolk and weighed in grams using a digital scale.

Yolk Weight: Yolks were separated and weighed in grams using a digital scale.

Haugh Unit: Calculated using the formula $HU = 100 * \log(H + 7.57 - 1.7 * W^{0.37})$, where H is albumen height and W is egg weight (Haugh, 1937).

Statistical analysis

Statistical analysis of data collected from the experiment was performed using Regression in the Statistical Package for the Social Sciences Software (2021).

Statistical model

$Y = B + \beta_1X + e$ (1) Simple regression model.

$Y = B + \beta_1X_1 + \beta_2X_2 + \dots + \beta_kX_k + e$ (2)
Multiple regression model

Where Y = dependent variable (body weight, egg weight and yolk weights); B = the intercept; X = independent variables; β = the regression coefficient, while e = Error term or residual.

The coefficient of determination (R^2) was evaluated to assess how much each independent variable contributed to predicting the dependent variable, egg weight and yolk weight. The precision of the regression equations was determined by calculating residuals, defined as the absolute difference between the predicted egg weight from the equations and the actual weight measured using a scale. The choice of best-fitted regression model was selected using the coefficient of determination (R^2) and the Standard error of estimates (SEE). Correlations between the body weight of the pullets and various morphometric traits were also determined using the same package.

RESULTS AND DISCUSSION

Prediction of body weight of Isa Brown and Nera Black at the pullet phase

Research on predicting body weight (BW) in Isa Brown and Nera Black pullets using morphometric traits has been summarised in two key tables. Table 1 outlines the prediction equations derived from linear and multiple regression models, while Table 2 compares actual and predicted BW values. These models were evaluated based on their correlation coefficients (R^2) and standard error of estimate (SEE), which serve as critical indicators of predictive accuracy. According to Ali *et al.* (2020) and Hirokazu *et al.* (2017), a low SEE indicates a reliable model, suggesting minimal deviation between predicted and actual values. Conversely, Topal *et al.* (2023) argued that a high R^2 value, reflecting a strong correlation between variables, is a better indicator of model quality, as it shows how well the model explains the variability in BW. For Isa Brown pullets, the linear regression model using body length (BL) is expressed as $Y = -9121.705 + 586.890BL$, with an R^2 of 0.717 and an SEE of 0.416. For Nera Black pullets, the corresponding equation is $Y = -5244.653 + 360.716BL$, with an R^2 of 0.723 and SEE of 0.402. These results indicate a moderate correlation between BL and BW. The relatively high R^2 values suggest that BL accounts for a significant portion of BW variation in both strains. When wing length (WL) is used as the predictor, the linear model for Isa Brown is $Y = -4481.628 + 562.828WL$, yielding an R^2 of 0.772 and an SEE of 0.52. For Nera Black, the equation is $Y = -4299.341 + 532.577WL$, with an R^2 of 0.774 and an SEE of 0.50. These models show improved correlation compared to BL,

Table 1. Prediction of body weight of Isa Brown and Nera Black at the pullet phase.

Strains	Traits	Prediction equation	R	R ²	SEE
Isa brown	BL	$Y = -9121.705 + 586.890BL$	0.847	0.717	0.416
Nera black	BL	$Y = -5244.653 + 360.716BL$	0.850	0.723	0.402
Isa black	WL	$Y = -4481.628 + 562.828WL$	0.879	0.772	0.52
Near black	WL	$Y = -4299.341 + 532.577WL$	0.880	0.774	0.50
Isa brown	BG	$Y = -951.767 + 145.572BG$	0.970	0.958	0.05
Near brown	BG	$Y = -528.220 + 42.150BG$	0.989	0.978	0.02
Isa brown	BG, BL	$Y = -300.720 + 164.69BG + (-87.123)BL$	0.82	0.677	0.04
Near black	BG, BL	$Y = -11832.906 + (-53.156)BG + 777.349BL$	0.829	0.687	0.03
Isa brown	NL, BG, BL	$Y = 345843.148 + 978.183NL + (-968.905)BG + (-46531.574)BL$	1.000	1.000	0.0008
Nera black	NL, BG, BL	$Y = 1166978.053 + (-734.935)NL + (4269.176)BG + 165638.482BL$	1.000	1.000	0.0003

Table 2. Comparison between the actual and predicted body weight of Isa Brown and Nera Black at the pullet phase.

Strains	Traits	Actual weight (g)	Predicted weight (g)
Isa brown	BL	1369.53	1368.54
Nera black	BL	1277.81	1275.21
Isa black	WL	1369.53	1368.71
Near black	WL	1277.81	1276.42
Isa brown	BG	1369.53	1368.52
Near brown	BG	1277.81	1276.45
Isa brown	BG, BL	1369.53	1369.21
Near black	BG, BL	1277.81	1277.92
Isa brown	NL, BG, BL	1369.53	1369.53
Nera black	NL, BG, BL	1277.81	1277.81

with R² values indicating that WL explains a greater proportion of BW variation. The SEE values are also relatively low and similar between the two strains, suggesting comparable predictive precision. However, the slightly higher R² for Nera Black indicates a marginally better fit for WL in this strain, though the difference is minimal. Breast girth (BG) emerged as the most effective single predictor of BW in both strains. For Isa Brown, the linear model based on BG achieved an R² of 0.958 and an SEE of 0.05, indicating near-perfect prediction with very low SEE. For Nera Black, the model yielded an R² of 0.978 and an SEE of 0.02, reflecting exceptional accuracy and minimal deviation. These high R² values demonstrate that BG accounts for nearly all BW variability, and the extremely low SEE values confirm the models' precision, aligning with the findings of Ali *et al.* (2020) and Hirokazu *et al.* (2017) on the importance of low SEE. The superior performance of BG-based models over those using BL or WL underscores BG's reliability as a morphometric trait for BW estimation. While linear models provide valuable insights, multiple regression models incorporating multiple morphometric traits were also evaluated, as shown in Table 1. These models generally outperformed single-trait

linear models by combining predictors like BL, WL, and BG, resulting in more precise BW predictions, as evidenced in Table 2. The high R² and low SEE of these multiple regression models align with Topal *et al.* (2023), who emphasized the importance of high R² for robust models. The findings highlight the potential of morphometric traits, particularly BG, for non-invasive BW estimation, offering practical applications for poultry management by enabling accurate growth assessments without costly equipment. However, Multiple regression models surpassed linear models in predicting body weight for Isa Brown and Nera Black pullets, offering superior accuracy, as shown in Table 2. For Isa Brown, the equation $Y = 345843.148 + 978.183NL + (-968.905)BL + (-46531.574)BG$ yielded an R² of 1.000 and a standard error of estimate (SEE) of 0.0008. For Nera Black, $Y = 1166978.053 + (-734.935)NL + (-4269.176)BL + 165638.482BG$ achieved an R² of 1.000 and an SEE of 0.0003. These near-perfect R² values and extremely low SEEs demonstrate the exceptional precision of multiple regression in estimating body weight in both strains. The strong correlation between body weight (BW) and morphometric traits in Isa Brown and Nera Black chickens aligns with Yahaya *et al.* (2012), who

Table 3. Prediction of egg weight and yolk weight using linear and multiple regression model.

Strain	Traits	Prediction equation	R	R ²	SEE
External trait					
Isa brown	EL	Y = 58.414+0.003EL	0.946	0.894***	0.0070
Nera black	EL	Y=86.487+(-0.429)EL	0.327	0.107	0.0267
Isa brown	EWD	Y=102.890+(-1.000)EWD	1.000	1.000***	0.0000
Nera black	EWD	Y=42.486+0.429EWD			
Isa brown	ST	Y=59.139+(-0.929)ST	0.929	0.862***	0.0080
Nera black	ST	Y=62.700+(0.500)ST			
Isa brown	EL, ST	Y=58.783+0.002EL+(-0.498)ST	1.000	1.000***	0.000
Nera black	SW, ST	Y=74.980+(-2.00)Sw +1.480ST	1.000	1.000***	0.000
Internal traits					
Isa brown	AW	Y=4.440+0.429AW	0.327	0.107	0.021
Nera black	AW	Y=54.360+(-1.00)AW	0.500	0.250	0.024
Isa brown	AH	Y=25.164+(-1.286)Ah	0.982	0.964***	0.0053
Nera black	AH	Y=19.540+(0.00)AH	0.929	0.862***	0.0282
Isa brown	AH, AR	Y=25.164+(-1.200)AH+(-0.40)AR	1.000	1.000***	0.000
Nera black	AH, AR	Y=18.980+(0.00)AH+1.00(AR)	1.000	1.000***	0.000

***p<0.001 (highly significant), R²=Coefficient of determination, EL, egg length; EWD, egg width; ST, shell thickness; SEE, standard error estimate; AH, albumen height; AW, albumen weight; AH, albumen height; AR, Albumen ratio.

reported high correlation coefficients for BW and morphometric traits in Hubbard strains, though their estimates exceeded those in this study. Adebambo *et al.* (2006) noted that breast girth (BG) is a reliable predictor of BW across poultry species, consistent with the close relationship observed between BW and BG in both strains. Udeh and Ogbu (2011) found that BG (R² = 96%) and body length (BL) (R² = 92%) were the best predictors of BW in Arbor Acre broilers. Similarly, Ubani *et al.* (2011) reported that BG and BL had the highest R² values among morphometric traits in layer strains. Regression analyses confirm that BG and BL are the most effective predictors of BW in Isa Brown and Nera Black, with all linear body parameters yielding R² values above 50%, indicating their potential for BW prediction. However, BG ranked highest, followed by BL, in predictive accuracy. Multiple regression models, incorporating BL, BG, and shank length (SL), achieved superior accuracy (R² up to 99%), as shown by Egena *et al.* (2014). Fayeye *et al.* (2014) reported strong correlations (coefficients >0.8) between BW and BL, BG, and SL, reinforcing their predictive potential. These morphometric measurements enable non-invasive BW estimation, enhancing farm management by reducing reliance on costly electronic scales, particularly in developing regions. The use of morphometric traits, especially BG, offers a cost-effective method for BW prediction, as confirmed by Molabe *et al.* (2025), benefiting small-scale farmers. This approach optimises feed efficiency by allowing tailored feed rations, reducing production costs and environmental impact. However,

Fayeye *et al.* (2014) noted a negative correlation between BW and wing length (WL) in some ecotypes, warranting further research. Nosike *et al.* (2020) highlighted that while single-trait predictions are simpler, multiple regression models combining BL, BG, and SL improve accuracy, emphasising the need for standardised measurement protocols to ensure reliable BW estimation in poultry farming.

Prediction of egg weight and yolk weight using linear and multiple regression models

Regression models to predict egg and yolk weights for Isa Brown and Nera Black chickens were developed, with results presented in Table 3. Table 4 compared actual and predicted egg and yolk weights for Isa Brown, showing nearly identical values, confirming accurate predictions using external and internal egg traits. Multiple regression models outperformed simple ones. For Isa Brown, models Y=58.783+0.002EL+(-0.498)ST (external) and Y=25.164+(-1.200)AH+(-0.40)AR (internal), and for Nera Black, Y=74.980+(-2.00)SW+1.480ST (external) and Y=18.980+(0.00)AH+1.00AR (internal), best predicted egg and yolk weights with low standard errors of estimate (SEE). The close match between actual and predicted weights highlights the models' precision. These results align with Ali *et al.* (2020) and Hirokazu *et al.* (2017), who emphasise low SEE for model suitability, and Topal *et al.* (2003), who note high R² and low SEE for better fit. This confirms egg

Table 4. Comparison between the actual and predicted egg weight and yolk weight of Isa brown and Nera black.

Strains	Traits	Actual weight (g)	Predicted Wt(g)
External trait			
Isa brown	EL	58.56	58.55
Nera black	EL	62.34	62.33
Isa brown	EWD	58.56	58.55
Nera black	EWD	62.34	62.33
Isa brown	ST	58.56	58.55
Nera black	ST	62.34	62.33
Isa brown	EL	58.56	58.56
Nera black	ST	62.34	62.34
Internal trait			
Isa brown	AW	18.34	18.34
Nera black	AW	19.54	19.54
Isa brown	AH	18.34	18.34
Nera black	AH	19.54	19.54
Isa brown	AH, AR	18.34	18.34
Nera black	AH, AR	19.54	19.54

EL, egg length; EWD, egg width; ST, shell thickness; SEE, standard error estimate; AH, albumen height; AW, albumen weight.

and yolk weights can be accurately predicted using egg length, shell thickness, albumen height, and albumen ratio, enhancing poultry management.

Conclusion

The study underscores the value of morphometric traits, especially body girth (BG), for non-invasive body weight (BW) estimation, providing practical benefits for poultry management by enabling accurate growth monitoring without expensive tools. Multiple regression models outperformed linear models in predicting body weight for Isa Brown and Nera Black pullets, delivering greater accuracy. Both simple and multiple regression analyses effectively estimated egg and yolk weights using individual or paired external and internal egg traits. This suggests that egg and yolk weights can be precisely predicted from these measurements, supporting advancements in chicken egg production, husbandry, and marketing. Specifically, multiple regression models using two traits (egg length (EL) and shell thickness) for external traits, and albumen height (AH) and albumen ratio (AR) for internal traits, yielded the most accurate predictions for egg and yolk weights, respectively.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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