Prediction of Carcass Weight from Live Body Weight and Morpho-Biometric Traits of Male Nigerian Indigenous Chickens Using Path Coefficient Analysis

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Summary

Carcass weight has great economic importance in poultry industry and is associated with other traits. This study investigates correlations among morpho-biometric traits (body length (BL), thigh length (TL), breast girth (BL), shank length (SL) and wing length (WL), live-body weight (LBW) and carcass weight (CW) in male chickens and quantifies the direct and indirect influence of LBW and morpho-biometric traits on CW. The aforementioned traits were measured in 187 male Nigerian indigenous chickens at 20 weeks of age. Correlation and regression coefficients among the traits were obtained to determine the intensity and nature of their association while the path analysis was used to investigate effects of LBW and morpho-biometric traits on CW trait. All analyses were done by SAS 9.1.3 software. The correlation coefficients among morpho-biometric traits, LBW and CW ranged from 0.1953 to 0.9930. The highest correlation was between LBW and CW (0.9930). The results showed a positive and highly significant correlation ($P < 0.001$) between CW and all morpho-biometric traits except for SL (0.2652, $P > 0.05$). The LBW had the highest direct influence on CW followed by BG. Individual pre-selection for these traits could favour an increased CW in the future generations of this chicken type since the LBW and the BG are directly related to CW.

Key words

path analysis, biometric, selection, correlation coefficient, direct effect, regression equation

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Introduction

Nigerian indigenous chickens are genetically diverse, with a wide range of phenotypes and genotypes to choose from. They are important tools for the poultry industry because their genetic diversity allows for poultry to be raised in a variety of environments and produce a variety of products (Akpan et al., 2018). Recently, the Nigerian indigenous chicken has found its way into large-scale poultry enterprises for breeding and meat production purposes (Ojerinde, 2019). Body weight, growth rate and conformation are important components in chickens that influence the profitability and are essential objectives in selection strategies. In many studies (Ajayi et al., 2008; Yakubu and Salako, 2009; Egena et al., 2014; Tyasi et al., 2017; Adenaike et al., 2019; Udeh et al., 2021), morphological traits have been used in chickens to estimate live body weight.

The common measures of estimation of live body weight such as simple correlation coefficients between body weight and morphometric measures or regression of body weight on a variety of body measurements have been used by Ajayi et al. (2008); Ige (2014) and Nosike et al. (2018). These, on the other hand, fall short of describing the complex biological relationships that exist between body weight and morphological characteristics. Simple correlation coefficients and regression do not capture the causal effects of biologically associated variables well. Furthermore, researchers (Adenaike et al., 2015; 2018) have shown that regression procedures fail to account for multicollinearity between independent variables, resulting in skewed results. Multicollinearity occurs when the association between variables is very high, making it difficult to obtain accurate estimates of their individual regression coefficients. In this case, certain variables essentially measure the same phenomenon and provide similar data. These variables may have a negative impact on regression outcomes. As a result, path analysis has been found to be more effective in determining the direct and indirect effects of one variable on another, as well as separating the correlation coefficients of the variables into components of direct effect, indirect effect and compound path (Yakubu and Mohammed, 2012).

Path analysis is a multiple regression model extension that allows for the identification of explanatory variables which primarily affect the response variable. This study shows that using live body weight and morpho-biometric traits as prediction indices, it is possible to estimate carcass weight with a high degree of accuracy. This will help with improved animal selection for breeding purposes based on morpho-biometric traits. The aim of this study was to find direct and indirect causal relationships between carcass weight and morpho-biometric traits in male indigenous chickens, as well as to build a functional model for predicting carcass weight using various morpho-biometric traits and live body weight.

Materials and Methods

In this study, 187 male Nigerian indigenous chickens were chosen at random at the age of 20 weeks. The chickens were brooded for 4 weeks and were fed on starter diet (22% crude protein and 2800 kcal kg^{-1}) from day old to 8 weeks and grower diet (18% crude protein and 3000 kcal kg^{-1})) after 8 weeks until 20 weeks of age. The birds were raised on deep litter in the Poultry Unit of the Federal University of Agriculture's Directorate of University Farms in Abeokuta, Nigeria. Animal Care and Use Committee of the Federal University of Agriculture, Abeokuta, Nigeria approved all of the research protocols.

Measurement of Traits

Body measurements were taken for all the chickens prior to slaughter. The standard zoometrical procedures for anatomical reference points of chickens were followed as recommended by FAO (2012). The morpho-biometric traits included: live body weight (LBW), body length (BL) as distance from the tip of the beak, through the body trunk to the tail; breast girth (BG) as circumference of the breast region; wing length (WL) as length of the wing from the scapula joints to the last digit of the wing; shank length (SL) as length of the tarso-metatarsus from the hock joint to the metatarsal pad; keel length (KL) as length of the meta-sternum, thigh length (TL) as length from shinbone femur joint to the shinbone tarsus joint. After collecting the morpho-biometric traits, the chickens were not fed and in the morning of the following day, they were slaughtered. Measurements were done using a tape rule except the live body and carcass weights (CW) which were measured using a sensitive weighing balance.

Data Analysis

Normality of data distribution and equality of variances were checked before means, standard deviations and coefficients of variation of carcass weight and morpho-biometric traits were calculated. Pairwise correlations among the morpho-biometric traits and carcass weight were also determined. Full model and stepwise of regression were used to predict CW from morpho-biometric traits. Path coefficients were calculated to allow direct comparison of values to reflect the relative importance of morpho-biometric traits in explaining variation in the carcass weight. All analyses were carried out using Statistical Analysis Software (SAS, 2003).

The path coefficient from an explanatory variable (X) to a response variable (Y) as described by Mendes et al. (2005) was calculated with the following equations:

$$P_{Y.Xi} = b_i S_{Xi}/S_Y$$

where:

$P_{Y.Xi}$ = path coefficient from X_i to Y (i= LBW, BL, BG, SL, TL, WL)

b_i = partial regression coefficient,

S_{Xi} = standard deviation of Xi

S_Y = standard deviation of Y.

The following multiple linear regression model was adopted:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + \ + b_5X_5 + b_6X_6 + e$$

where:

Y = endogenous variable (carcass weight), a = intercept, b's = regression coefficients, X's = exogenous variables (LBW, BL, BG, SL, TL, WL) e = error term. The significance of each path coefficient in the statistical model was tested by t-test using the following model:

$$t_j = \frac{b_j - \beta_j}{\sqrt{var(bj)}} \sim t\alpha\ (n\text{-}p\text{-}1);\ j = 1, 2, \text{----------------}, p$$

where var(bj) = the diagonal member of matrix $S^2(X'X)^{-1}$

S^2 = mean square of residual obtained from ANOVA. The indirect effect of Xi on Y through Xj was calculated as follows:

$$IE_{YXi} = r_{XiXj} PY_{.Xj}$$

where:

IE_{YXi}= the direct effect of X_i via X_j on Y, r_{XiXj} = correlation coefficient between i^{th} and j^{th} independent variables, $P_{Y.Xj}$ = path coefficient that indicates the direct effect of j^{th} independent variable on the dependent variable.

Results

Morpho-Biometric Traits and Carcass Weight

Descriptive statistics of the carcass weight and morpho-biometric traits of Nigerian indigenous male chickens are shown in Table 1. The mean of carcass weight (CW) was 1.63 kg while that of live body weight (LBW) was 1.74 kg. The mean of morpho-biometric traits ranged from 8.58 cm (shank length, SL) to 42.06 cm (body length, BL). The highest coefficient of variation was observed in carcass weight (15.34) followed by live body weight (15.52) while shank length had the lowest coefficient of variation (3.59).

Correlations among Morpho-Biometric Traits and Carcass Weight

Pairwise correlations among morpho-biometric traits, live body and carcass weights of Nigerian indigenous male chickens are shown in Table 2. The correlation coefficients among the traits ranged from 0.1953 to 0.9930. The highest correlation coefficient was between live body and carcass weights (0.9930). The results showed a positive and highly significant correlation ($P < 0.001$) between carcass weight and all morpho-biometric traits except for shank length (0.2652, $P > 0.05$). No significant difference ($P > 0.05$) was observed between shank length and other traits measured in this study.

Direct and Indirect Effects

Correlation coefficients among CW, LBW and morpho-biometric traits, direct and indirect effects of male Nigerian indigenous male chickens are presented in Table 3. The results showed significant direct effect of the live body weight ($P < 0.001$), BG, TL and WL ($P < 0.05$) on CW while SL did not have significant direct effects on CW ($P > 0.05$). LBW (1.1645) made most contribution on CW, followed by BG (0.0057). The LBW showed the highest indirect effect (1.1313) on CW through BL.

Table 1. Descriptive statistics of carcass weight and morpho-biometric traits of indigenous Nigerian chickens

Traits	Mean	Standard deviation	Coefficient Variation	Minimum	Maximum
CW (kg)	1.63	0.25	15.34	1.23	2.19
LBW (kg)	1.74	0.27	15.52	1.32	2.30
SL (cm)	8.58	0.31	3.61	7.70	9.30
BL (cm)	42.06	3.46	8.23	36.90	48.40
BG (cm)	21.74	1.64	7.55	18.70	25.30
TL (cm)	14.48	0.72	4.97	13.10	15.40
WL (cm)	20.48	1.68	8.20	18.10	23.70

Note: CW = carcass weight, LBW = live body weight, SL = shank length, BL = body length, BG = body girth, TL = thigh length, WL = wing length

Table 2. Pairwise correlations among morpho-biometric traits, live body and carcass weights

Traits	CW	LBW	SL	BL	BG	TL
LBW	0.9930***					
SL	0.2652	0.2883				
BL	0.9583***	0.9714***	0.2754			
BG	0.8281***	0.8095***	0.3576	0.7838***		
TL	0.8766***	0.9042***	0.1953	0.8647***	0.6492***	
WL	0.8292***	0.8607***	0.1956	0.8318***	0.5348**	0.8743***

Note: CW = carcass weight, LBW = live body weight, SL = shank length, BL = body length, BG = body girth, TL = thigh length, WL = wing length. ** = $P < 0.01$, *** = $P < 0.001$

Table 3. Direct and indirect effects of morpho-biometric traits on carcass weight

	Correlation coeff.	Direct	Indirect effect on CW						
	with CW	effect on CW	LBW	SL	BL	BG	TL	WL	Total
LBW	0.9930	1.1645***		-0.0092	-0.0101	0.0046	-0.0315	-0.0063	-0.0524
SL	0.2652	-0.0318	0.3358		-0.0029	0.0020	-0.0068	-0.0014	0.3267
BL	0.9583	-0.0104*	1.1313	-0.0087		0.0045	-0.0301	-0.0061	1.0908
BG	0.8281	0.0057*	0.9426	-0.0114	-0.0081		-0.0226	-0.0039	0.8966
TL	0.8766	-0.0348*	1.0529	-0.0062	-0.0090	0.0037		-0.0064	1.0351
WL	0.8292	-0.0073*	1.0023	-0.0062	-0.0086	0.0030	-0.0304		0.9600

Note: CW = carcass weight, LBW = live body weight, SL = shank length, BL = body length, BG = body girth, TL = thigh length, WL = wing length

Table 4. Preliminary and optimum regression models for estimation of carcass weight from morpho-biometric traits

Model	Regression equation	R^2 (%)	MSE	AIC
Preliminary	CW=0.8399+1.1645LBW-0.0318SL-0.0104BL+0.0057BG-0.0348TL-0.0073WL	99.16	0.00065	-169.68
Optimal	CW=0.8399+1.1645LBW-0.0104BL+0.0057BG-0.0348TL-0.0073WL	99.19	0.00066	-168.59

Establishment of Regression Equations

The preliminary and optimum regression equations with standard error of means, akaike information criterion and coefficient of determination obtained from simple regression between carcass weight and morpho-biometric traits of male Nigerian indigenous chickens are presented in Table 4. The coefficient of determination (R^2) for optimum model (99.19%) was higher than preliminary model (99.16%). However, higher value of Mean square errors (0.00066) was estimated in optimum model compared to preliminary model (0.00065).

Discussion

The mean values of the traits in current study were consistent with the findings of Udeh et al. (2021) but differed with ± findings of Vincent et al. (2015) who reported lower values of body weight (1.32 ± 0.01 kg), body length (30 ± 2.32cm) and shank length (7.38 ± 0.09 cm). The variation might be due to long-time selection for LBW in the chickens used in this study as well as difference in environment. However, coefficient of determination observed in this study is lower than that of Udeh et al. (2021) who reported CV of 24.85, 8.34, 11.28 and 9.47 for body weight, body length, shank length and thigh length, respectively. The low coefficient of variations observed for all traits might not be unconnected to artificial selection being practised in this flock.

The results of correlation in this study are similar to other reports (Ukwu et al., 2014; Nosike et al., 2018; Udeh et al., 2021). Among the seven morphometric traits reported by Nosike et al. (2018), only the correlation coefficient between shank length and breast length was not significantly different. Body measurement traits play important role in the prediction of live body and carcass weights in chickens as observed by Ganiyu et al. (2016) and Nosike et al. (2018). However, the correlation coefficients do not provide how much each morpho-biometric traits contribute to carcass weight of a chicken. Therefore, it is important to use path analysis to investigate the direct and indirect effects of each morpho-biometric trait on carcass weight of male Nigerian indigenous chickens.

Body length and breast girth contributions on carcass weight in this study were indirectly similar to the reports of Ogah et al. (2009) who worked on Muscovy duck where body length had indirect effect on body weight. This implies that carcass weight could be predicted using live body weight and body length. Apart from body length, live body weight with high indirect effects (1.0529, 1.0023, 0.9426) via thigh length or wing length or breast girth respectively, could be used to predict carcass weight. Hence, these path analysis findings might be used for selection of the chickens to improve carcass weight. The total indirect effect of body length on carcass weight was highest realized largely through live body weight. Generally, the direct effect of each morpho-biometric trait was lower than the total indirect effects on carcass weight. However, this is different in live body weight where the direct effect (1.1645) is greater than total indirect effect (-0.0524). Our results shared similarity with findings of Cankaya and Abaci (2012), who reported that direct effect of body length in German Fawn x Hair crossbred kids was lower than indirect effect.

The highest single contribution to the variation in carcass weight was by live body weight followed by breast girth (1.1645, 0.0057) with R^2 = 0.9919. However, there are limited studies on relationship between carcass weight and morpho-biometric traits of chickens which makes it difficult to compare results. The path coefficients of live body weight, breast girth, thigh and wing lengths were statistically significant, while the shank length was not statistically significant on the carcass weight of Nigerian indigenous chickens. Shank length which was not significant on the carcass weight was removed from the regression model. The removal of shank length caused slight changes in the value of the coefficient of determination (R^2) but reduction in the value of akaike information criterion (AIC). The slight changes in the value of R^2 are expected since it is sensitive to number of independent variables in a regression model while reduction in AIC indicates better model. The optimum regression equation for the prediction of carcass weight from morpho-biometric traits and live body weight excluding shank length is therefore recommended.

Conclusion

Correlation coefficients for live body weight and morpho-biometric traits studied were highly significant with carcass weight (except for shank length) in male Nigerian indigenous chickens. Live body weight had the highest direct impact on carcass weight, while body length had the highest overall indirect effect on carcass weight, according to path analysis study. This study's derived equation may be a valuable practical method for livestock farmers, researchers, and rural development workers to estimate carcass weight in the field and for selection purposes. The carcass weight of Nigerian indigenous chickens will be improved by selecting and refining these traits.

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