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MULTIVARIATE ANALYSIS FOR BODY WEIGHT AND SOME LINEAR BODY MEASUREMENTS OF NIGERIAN INDIGENOUS CHICKENS

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ABSTRACT

The use of path analysis will not only produce a regression equation for prediction of body weight but also partition correlation between two traits into direct effects of one on other and indirect effects caused by other characters which may be of importance in selection. A total number of 2641 mature cocks comprising of 1782 Yoruba ecotype and 859 Fulani ecotype were sampled from markets in Osun state, southwest Nigeria. Live weight (LW) and eight morphometric characters were measured from these birds. The biometric traits were keel length (KL), chest circumference (CC), thigh length (TL), wing length (WL), body length (BL), drum stick (DS), breast length (BrL) and shank length (SL). T-test was used to check the significance of variation in biometric traits between the two ecotypes. Correlation analysis was used to check degree of association between these traits. Regression and path analysis was also explored. There were significant differences in keel length, thigh length, wing length, body length, breast length and shank length between the two genotypes. All traits considered in Yoruba ecotype but drum stick showed significant ($p<0.05$) positive correlation with body weight whereas in Fulani ecotype all characters but chest circumference showed a significant ($p<0.05$) correlation with body weight. Body length and breast length had significant ($p<0.05$) direct effect on the body weight in Yoruba ecotype whereas significant ($p<0.05$) path coefficients were obtained for chest circumference, wing length and breast length in Fulani ecotype. Body length and breast length had the highest direct effect on body weight in Yoruba and Fulani ecotype cocks respectively. The highest indirect effect was obtained for breast length through drum stick in Fulani ecotype, while in Yoruba ecotype the highest indirect effect was obtained for body length through chest circumference. Body length and breast length can be deduced as the most important morphometric traits in determining body weight of Yoruba and Fulani ecotype cocks respectively.

Key words: Nigeria; chickens; morphometric correlation; path coefficients

INTRODUCTION

Morphometric characters have for years been used to predict body weight of animals; where different regression models are explored. These models do not only make on-farm measurement of animal weight to be less tedious but also reduce risk of hazards associated with the use of weighing scale especially in farm animals with large body size. A linear relationship between BW and shank length has been reported (Lerner, 1937). Tierce and Nordskog (1985) produced a general formula for estimation of live weight in poultry; shank length (mm) = αW (kg)^B. Although accurate estimation of productivity of indigenous strains of chicken is now a difficult task due to indiscriminate cross breeding which has taken place between them and the exotic strains (Raji *et al.*, 2009; Oluyemi, 1989). Rearing of broilers is now becoming extensively popular in the southwest Nigeria. Thus, there is need for caution in sampling indigenous strains of chicken

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for characterization. Chineke *et al.* (2002) reported that the relationship existing among body characteristics provide useful information on performance, productivity and carcass characteristics of animals and these quantitative measure of size and shapes are necessary for estimating genetic parameters in animal breeding programmes. Phenotypic correlation between traits is sum of genotypic correlation and environmental correlation. Series of traits of economic importance in farm animals show pleiotropism, a situation where same portion of DNA (gene) code for more than one protein. Proper knowledge of genotypic correlation between traits is essential for selection, thus, tandem selection may be effective when positive correlations exist between the trait selected for and other characters of interest.

Simple correlation between traits has been commonly used in the past, its suitability as a measure of degree of association between traits is moot. Yakubu and Mohamed (2012) opined that body measurements that are used to predict body weight may affect its determination directly and indirectly. Thus partitioning of correlation coefficient between two characters into direct and indirect component (path analysis) is crucial. Path analysis partitioned the correlation coefficient into direct (path coefficient) and indirect effects (effect exerted through other variables). So it provides an effective means of partitioning correlation coefficients into unidirectional path ways and alternate pathways thus permitting a critical examination of specific factors that produce a given correlation. It is a standardized partial regression analysis that deals with a closed system of variable which are linearly related. The technique of path analysis in livestock experiment has been extensively used by several researchers (Yakubu and Mohamed, 2012; Ogah *et al*., 2011; Yakubu and Salako, 2009). This study was thus carried out with the objective of establishing a detailed relationship between body weight and linear body measurements of Yoruba and Fulani ecotype cocks using path analysis.

MATERIAL AND METHODS

Study area

Data for this study were collected from markets and traditionally managed flocks in different parts of Osun state, Southwest Nigeria.

Management of Chicken

Chicken surveyed were semi-intensively managed. They roamed freely during the day when only maize or sorghum was occasionally given to them in the morning before they were allowed to scavenge for the remaining uptake. In the evening they returned home, some of them were kept in locally made cages "ago" and others without cages stayed on trees till dawn.

Data collection

Data were collected from 2641 mature cocks comprising of 1782 Yoruba ecotype and 859 Fulani ecotype. Cocks were mainly selected for this study because of their market value (local farmers rarely put hen for sale) and importance of sire in breeding program. Body weights of the birds were measured using 5 kg weighing scale. Linear body measurements were performed using a measuring tape graduated in centimetres. Measurements were done with one person throughout the duration of data collection to avoid variation between individuals. The sampling of birds in market was done at random with intervals of ten (10) days between two consecutive measurements while each household was visited once to avoid repeated measurement of the same bird. Body weight and eight (8) morphometric traits were measured for each animal. The anatomical reference points were as described earlier (Monsi, 1992; Udeh *et al*., 2011). The biometric traits were keel length (KL), chest circumference (CC), thigh length (TL), wing length (WL), body length (BL), drum stick (DS), breast length (BrL) and shank length (SL).

KL: Measured as the length of the breast bone

CC: Circumference of the pectus (hind breast)

TL: Measured as the distance between knee and end of femur bone.

WL: Measured between the caput humeri to the end of the third carpal digit.

BL: Measured between the first cervical vertebra and the pygostyle.

DS: Length from the knee joint to the hock.

BrL: Measured as the distance between the right and left glenoid cavity.

SL: Distance from the hock to the extremity of the digitus pedis.

Measurements were done according to the illustrations by FAO (2012).

Statistical Analysis

Means, standard deviation (SD) and coefficient of variation (CV) of live weight and linear body measurements were done. T-test was used to check whether significant differences occurred in the morphometric characters between the two ecotypes. Pearson correlation was explored to determine the degree of association between the variables. Compound linear regression was also performed where partial regression coefficients were standardized. The standardized linear regression coefficient (path coefficient) shows the direct effect of linear measurements (X) on live weight (Y).

$$PY.X_i = b_i \frac{SDX_i}{SDY}$$

where

$PY._{Xi}$ = path coefficient from X_i to Y (i = KL, CC, TL, WL, BL, DS, BrL, SL)

b_i = unstandardized or partial regression coefficient

SDX_i = standard deviation of linear measurements

SDY = standard deviation of live weight

The indirect effects of X_i on Y through X_j were computed as

$$IEYX_i = (rX_iX_jP)\ (PY.X_j)$$

where

$IEYX_i$ = correlation coefficient between ith and jth linear measurements

$PY.X_j$ = path coefficient that indicates the direct effect of jth linear measurement (exogenous variable) on the live weight (endogenous variable)

The model for the multiple linear regression was

$$Y = a + b_1X_1 + b_2X_2 \ldots\ldots + b_8X_8$$

Y = body weight (dependent variable)

a = intercept

b = standardized regression coefficient

X = exogenous variable (KL, CC, TL, WL, BL, DS, BrL and SL)

The significance of each path coefficient in the model was tested by t- test procedure adapted from Yakubu and Mohammed (2012)

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

where

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

S^2 = mean square of residual obtained from ANOVA

Coefficient of determination (R^2) was computed according to the method of Yakubu and Salako (2009):

$$R^2 = P^2Y.X_1 + P^2Y.X_2 + P^2Y.X_3 + P^2Y.X_4 + P^2Y.X_5 + P^2Y.X_6 + P^2Y.X_7 + P^2Y.X_8 + 2rX_1X_2PY.X_1PY.X_2 + 2rX_1X_3PY.X_1PY.X_3 + 2rX_1X_4PY.X_1PY.X_4 + 2rX_1X_5PY.X_1PY.X_5 + 2rX_1X_6PY.X_1PY.X_6 + 2rX_1X_7PY.X_1PY.X_7 + 2rX_1X_8PY.X_1PY.X_8 + 2rX_2X_3PY.X_2PY.X_3 + 2rX_2X_4PY.X_2PY.X_4 + 2rX_2X_5PY.X_2PY.X_5 + 2rX_2X_6PY.X_2PY.X_6 + 2rX_2X_7PY.X_2PY.X_7 + 2rX_2X_8PY.X_2PY.X_8 + 2rX_3X_4PY.X_3PY.X_4 + 2rX_3X_5PY.X_3PY.X_5 + 2rX_3X_6PY.X_3PY.X_6 + 2rX_3X_7PY.X_3PY.X_7 + 2rX_3X_8PY.X_3PY.X_8 + 2rX_4X_5PY.X_4PY.X_5 + 2rX_4X_6PY.X_4PY.X_6 + 2rX_4X_7PY.X_4PY.X_7 + 2rX_4X_8PY.X_4PY.X_8 + 2rX_5X_6PY.X_5PY.X_6 + 2rX_5X_7PY.X_5PY.X_7 + 2rX_5X_8PY.X_5PY.X_8 + 2rX_6X_7PY.X_6PY.X_7 + 2rX_6X_8PY.X_6PY.X_8 + 2rX_7X_8PY.X_7PY.X_8$$

where

$P^2Y.X_1$ = direct effects of predictor variables (= KL, CC, TL, WL, BL, DS, BrL, SL) in contributing to the variation of Y (body weight).

$2rX_iX_j\ (PY.X_i)(PY.X_j)$ = combined effects of explanatory predictor variable (= KL, CC, TL, WL, BL, DS, BrL, SL) in contributing to the variation of Y (body weight).

RESULTS AND DISCUSSION

Description of body weight and linear body measurements

Description of live weight and linear body measurements showing means, standard deviation (SD) and coefficient of variation (CV) for mature indigenous chicken of Nigeria is presented in Table 1. The range for average weight between Yoruba and Fulani ecotype cocks was 0.1g. Mean body weight obtained in this study for both ecotypes were similar to 1.37 ± 0.004 kg as reported for mature Nigerian cock by Yakubu and Salako (2009). Yakubu *et al*. (2009) in another related study reported lesser live weight (1.26 ± 0.004 kg) for frizzle feathered and naked neck fowl. Though sex of these birds was unspecified, the lesser weight obtained could have resulted from either sexual dimorphism or the stage of growth rather than from the major genes. Because of susceptibility of frizzle feathered and naked neck birds to cold, there are more proclivities of sampling them immature. There were significant differences in keel length, thigh length, wing length, body length, breast length and shank length between the two genotypes investigated. Fulani ecotype cocks had higher means for all significant traits. CV ranged between 13.35 % - 69.88 % in Yoruba ecotype and 8.99 % - 26.58 % in Fulani ecotype. Large variability obtained in this study indicated that these traits are still largely unselected for; therefore, they may largely respond to selection. Yakubu *et al.* (2009) reported CV of 24.26 % for live weight of adult cock. Traits that are related to bone development tend to be less variable because of large genetic influence, in spite of this; CV of 69.88 % was obtained for drum stick length of Yoruba ecotype cocks.

Correlation between traits

Matrix of correlation between body measurements of Yoruba and Fulani ecotypes cock is presented in Table 2. Correlation is a measure of degree of association between two variables; it does not produce cause and effects. All traits considered in Yoruba ecotype but drum stick showed significant ($p<0.05$) positive correlation with body weight. The low correlation of drum stick with all other parameters in Yoruba ecotype (0.11-0.18) could have resulted from

Table 1: Description of body weight and linear body measurements

Traits	Yoruba ecotype Mean ± SE	SD	CV	Fulani ecotype Mean ± SE	SD	CV
LW (kg)	1.48 ± 0.03	0.42	28.38	1.58 ± 0.05	0.42	26.58
KL (cm)	11.98 ± 2.83[b]	2.83	23.62	15.50 ± 0.49[a]	4.00	25.81
CC (cm)	25.86 ± 0.29	3.59	13.88	26.80 ± 0.42	2.41	8.99
TL (cm)	11.07 ± 0.15[b]	1.90	17.16	11.71 ± 0.24[a]	1.98	16.91
WL (cm)	14.91 ± 0.16[b]	1.99	13.35	16.66 ± 0.26[a]	2.17	13.03
BL (cm)	31.43 ± 0.39[b]	4.79	15.24	33.22 ± 0.48[a]	3.96	11.92
DS (cm)	11.82 ± 0.67	8.26	69.88	12.27 ± 0.25	2.03	16.54
BrL (cm)	10.62 ± 0.13[b]	1.62	15.25	11.42 ± 0.23[a]	1.85	16.20
SL (cm)	9.04 ± 0.12[b]	1.49	16.48	10.24 ± 0.23[a]	1.89	18.46

[ab]Means along same row with different superscripts are significantly different ($p<0.05$)
SE: Standard error for means
SD: Standard deviation
CV: Coefficient of variation

Table 2: Simple correlation analysis of body weight and linear body measurements

Traits	LW	KL	CC	TL	WL	BL	DS	BrL	SL
LW (kg)		0.42	0.13[ns]	0.45	-0.27	0.51	0.42	0.72	0.30
KL (cm)	0.22		0.23[ns]	-0.27	0.55	-0.29	0.12[ns]	-0.37	0.20
CC (cm)	0.49	0.10[ns]		0.06[ns]	0.36	-0.03ns	0.16[ns]	-0.04[ns]	0.24
TL (cm)	0.37	0.10[ns]	0.22		-0.23[ns]	0.33	0.44	0.37	0.28
WL (cm)	0.41	0.05[ns]	0.66	0.14[ns]		-0.09[ns]	0.36	0.01[ns]	0.50
BL (cm)	0.83	0.17	0.66	0.35	0.62		0.43	0.50	0.35
DS (cm)	0.15[ns]	0.11[ns]	0.14[ns]	0.17	0.18	0.15[ns]		0.52	0.80
BrL (cm)	0.34	0.15[ns]	0.06[ns]	0.24	-0.09[ns]	0.23	-0.08[ns]		0.53
SL (cm)	0.28	0.01[ns]	0.22	0.22	0.23	0.27	0.13[ns]	0.08[ns]	

Upper diagonal: Fulani ecotype
Lower diagonal: Yoruba ecotype
Correlation coefficients with superscript (ns) are not significant ($p>0.05$)

large variability (69.88 %) obtained for the trait. All characters but chest circumference showed a significant ($p<0.05$) correlation with body weight in Fulani ecotype birds. There was a significant ($p<0.05$) negative correlation of live weight with wing length (-0.27). This is critical to animal welfare because selection for larger body weight might hamper flapping ability of these birds. Correlation between body parameters obtained in this study was lower than what was reported by Yakubu and Salako (2009), though many of traits considered in the aforementioned study were not included in this finding.

Path coefficient

Path coefficients of the linear body measurements (independent variable) of Yoruba ecotype cocks are presented in Table 3. Path analysis permits the partitioning of correlation coefficient into component parts (Marjanovic-Jeromela *et al.*, 2008; Yakubu, 2010). Body length and breast length had significant ($p<0.05$) direct effect on the body weight. Body length had the highest significant ($p<0.01$) path coefficient as indicated by the t-test. Body length had both highest significant ($p<0.001$) correlation with body weight and path coefficient. This was due to the low indirect effects of other variables on body length.

Path coefficient of the linear body measurements (independent variables) in Fulani ecotype cocks are presented in Table 4. Significant ($p<0.05$) path coefficients were obtained for chest circumference, wing length and breast length. Breast length had the highest direct effect on body weight (Path coefficient = 0.62; $p<0.01$). This infers that a unit change in standard deviation of body weight results in 0.62 units change in standard deviation of breast length.

Coefficient of determination

The coefficient of determination where direct and combined effects of linear measurements on body weight were determined is presented in Table 5. For Yoruba ecotype, the highest direct contribution to variation in body weight was made by body length ($R^2 = 0.824$). Very low combined effects were obtained between all variable pairs. Direct coefficient of determinant of 0.00, 0.01, 0.00, 0.02, 0.00, 0.01 and 0.00 were obtained for keel length, chest circumference, thigh length, wing length, drum stick, breast length and shank length respectively. The low R^2 for all these traits indicate the importance of body length as a predictor variable for body weight of Yoruba ecotype cock. The preliminary regression equation where all traits were considered in Yoruba ecotype was:

$$BW = -1.09 + 0.06KL - 0.07CC + 0.03TL - 0.12WL + 0.91BL + 0.03DS + 0.10BrL + 0.06SL$$

Table 3: Direct and indirect effect of linear body measurements on live weight of Yoruba ecotype cock

Traits	Correlation of linear measurements with live weight	Direct effect	Indirect effect								Total
			KL	CC	TL	WL	BL	DS	BrL	SL	
KL (cm)	0.221	0.06	-	-0.01	0.00	-0.01	0.15	0.00	0.02	0.00	0.16
CC (cm)	0.485	-0.07	0.01	-	0.01	-0.08	0.60	0.00	0.01	0.01	0.56
TL (cm)	0.365	-0.03	0.01	-0.02	-	-0.02	0.32	0.01	0.02	0.01	0.34
WL (cm)	0.408	-0.12^{*}	0.00	-0.05	0.00	-	0.56	0.01	-0.01	0.01	0.53
BL (cm)	0.825	0.91^{**}	0.01	-0.05	0.01	-0.07	-	0.00	0.02	0.02	-0.06
DS (cm)	0.145^{ns}	0.03	0.01	-0.01	0.01	-0.02	0.13	-	-0.01	0.01	0.12
BrL (cm)	0.336	0.10^{*}	0.01	0.00	0.01	0.01	0.21	-0.00	-	0.01	0.24
SL (cm)	0.283	0.06	0.00	-0.02	0.01	-0.03	0.25	0.00	0.01	-	0.23

Table 4: Direct and indirect effect of linear body measurements on live weight of Fulani ecotype cock

Traits	Correlation of linear measurements with live weight	Direct effect	Indirect effect								Total
			KL	CC	TL	WL	BL	DS	BrL	SL	
KL (cm)	-0.416	-0.02	-	0.07	-0.001	-0.20	-0.03	0.03	-0.23	-0.03	-0.40
CC (cm)	0.134	0.29^{**}	0.00	-	0.00	-0.13	0.00	0.04	-0.02	-0.04	-0.15
TL (cm)	0.447	0.01	0.00	0.02	-	0.09	0.04	0.11	0.23	-0.04	0.44
WL (cm)	-0.268	-0.37^{**}	-0.01	0.10	-0.001	-	-0.01	0.09	0.00	-0.07	0.10
BL (cm)	0.507	0.11	0.00	-0.01	0.00	0.03	-	0.10	0.31	-0.05	0.39
DS (cm)	0.418	0.24	0.00	0.05	0.00	-0.13	0.05	-	0.33	-0.12	0.17
BrL (cm)	0.712	0.62^{**}	0.01	-0.011	0.00	0.00	0.06	0.13	-	-0.08	0.10
SL (cm)	0.303	-0.14	0.00	0.07	0.00	-0.19	0.04	0.19	0.33	-	0.45

Table 5: Direct and combined effects of the biometric traits

Traits	Coefficient of Determinant R^2 Yoruba Ecotype	Fulani Ecotype
Direct effects		
P^2LW. KL	0.0006	0.0004
P^2LW. CC	0.0125	0.0824
P^2LW. TL	0.0004	0.0001
P^2LW. WL	0.0184	0.1441
P^2LW. BL	0.8217	0.0117
P^2LW. DS	0.0004	0.0581
P^2LW. BrL	0.0106	0.3883
P^2LW. SL	0.0008	0.0188
Combined effects		
KL and CC	0.0007	0.0004
KL and TL	0.0005	0.0002
KL and WL	0.0009	0.0093
KL and BL	0.0212	0.0003
KL and DS	0.0004	0.0006
KL and BrL	0.0006	0.0141
KL and SL	0.0007	0.0004
CC and TL	0.0003	0.0003
CC and WL	0.0091	-0.0825
CC and BL	-0.0826	-0.0003
CC and DS	0.0004	0.0213
CC and BrL	0.0002	-0.0115
CC and SL	0.0005	-0.0184
TL and WL	0.0003	0.0003
TL and BL	0.0241	0.0003
TL and DS	0.0006	0.0007
TL and BrL	0.0004	0.0002
TL and SL	0.0002	0.0014
WL and BL	-0.1413	0.0131
WL and DS	0.0007	0.0582
WL and BrL	0.0004	-0.0026
WL and SL	0.0008	0.0483
BL and DS	0.0084	0.0214
BL and BrL	0.0427	0.0664
BL and SL	0.0342	-0.0132
DS and BrL	0.0003	0.1622
DS and SL	0.0006	-0.0641
BrL and SL	0.0001	-0.0914
Sum total	0.7908	0.8393

In Fulani ecotype cock nevertheless, the highest lone contribution to body weight was by breast length, closely followed by wing length, chest circumference and drum stick (R^2 = 0.39, 0.14, 0.08 and 0.06 respectively). Combined effects of drum stick and breast length (R^2 = 0.16) was highest among the variable pairs. The pilot regression equation where all traits were considered in Fulani ecotype was:

BW= -0.48 - 0.02KL + 0.29CC + 0.01TL - 0.37WL + 0.12BL + 0.24DS + 0.62BrL + 0.14SL

Deletion of less significant predictor variable in the estimation of body weight

In Yoruba ecotype, the path coefficient of keel length, chest circumference, thigh length, drum stick and shank length were statistically insignificant (p>0.05). The path coefficient of wing length though significant (p<0.05) negatively influenced the body weight. This informed the inclusion of only body length and breast length as the predictor variables for body weight. After the deletion of six less important independent variables (KL, CC, TL, WL, DS and SL), the path coefficients for body length and breast length were 0.82 and 0.15 respectively. The new regression equation was:

BW= -1.21 + 0.82BL + 0.15BrL

In Fulani ecotype, the path coefficients of chest circumference, breast length and wing length were statistically significant (p<0.05) as indicated by t-test. Wing length was primarily expunged from the equation because of its negative influence on body weight. The decision to include it in the analysis was prompted by its relatively large direct effect (R^2 = 0.14). After the deletion of less significant predictor variables, the regression equation was:

BW= -0.09 + 0.30CC + 0.74BrL - 0.38WG

CONCLUSION

Apart from body length, other linear measurements considered in this study had low correlation, though significant, with body weight in Yoruba ecotype birds. In Fulani ecotype, breast length had the highest correlation with body weight. Path analysis indicated that body length and breast length have the highest direct effect on body weight in Yoruba and Fulani ecotype cocks, respectively. The direct effects of body length and breast length on body weight in Yoruba ecotype were positive and significant whereas negative significant direct effect was obtained for wing length. In Fulani ecotype, path coefficients of chest circumference, wing length and breast length were significant but wing length had negative influence on body weight. The highest indirect effect was obtained for breast length through drum stick in Fulani ecotype while in Yoruba ecotype, highest indirect effect was obtained for body length through chest circumference. It was concluded that body length and breast length were the most important morphometric traits in determining body weight of Yoruba and Fulani ecotype cocks.

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