PATH COEFFICIENT ANALYSIS OF BODY WEIGHT AND MORPHOLOGICAL TRAITS OF NIGERIAN INDIGENOUS CHICKENS

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Abstract:*In this study, body weight and eight biometric traits namely, comb height, comb length, beak length, body length, neck length, shank length, chest circumference and thigh circumference of 238 adult Nigerian autochthonous chickens were subjected to multivariate analysis. The birds reared under the traditional scavenging system, were randomly selected in Nasarawa State, north central Nigeria. The investigation aimed at determining the explanatory variables that most effectively influenced the body weight of indigenous chickens of both sexes using path coefficient technique. Sex-associated differences (P<0.05) were observed in all the studied traits, with superior values recorded for males. Phenotypic correlations between body weight and body dimensions in cocks ranged from 0.55-0.97. Correspondingly, a range of 0.46-0.85 was obtained in hens. The path analysis revealed that thigh circumference had the strongest direct effect on body weight of male chickens, followed by comb height and body length (path coefficient = 0.681, 0.325 and 0.193 respectively). However, the direct effects of comb length, beak length, shank length and chest circumference on body weight were non-significant. A different trend was observed in females, where the influence of comb height on body weight was greatest, followed by thigh circumference, body length, chest circumference and shank length (path coefficient = 0.289, 0.277, 0.249, 0.246 and 0.180 respectively). Comb length, beak length and neck length did not significantly influence body weight. The optimum linear model in males included forecast indices such as thigh circumference, comb height and body length, with a determination coefficient (R^2) of 0.952 and* *determination coefficient of error of 0.048. The corresponding indices in female birds were, comb height, thigh circumference, body length, chest circumference, and shank length, with R^2 value of 0.820 and determination coefficient of error of 0.180. These models could be useful in weight estimation in the field and for selection purposes.*

INTRODUCTION

Growth is related to an increase in cell number and volume. It is a complex and highly dynamic physiological process that exists from conception until maturity. Growth in any traits is a result of the genetic potential of the individual and genetic x environment interaction (Kor *et al*., 2006). Body growth in livestock may be evaluated with body components such as live weight and body measurements (Wolanski *et al*., 2006; Saatci and Tilki, 2007). Poultry breeders need some techniques to select animals for breeding purposes. Further selection towards meatiness and egg production improvement requires reliable and easy-to-apply methods for estimating the performance and breeding value of chickens. Examining relationships between live weight and linear body measurements of birds especially in rural communities where weighing scales may not be readily available can assist in the selection of animals. However, using simple correlation coefficients between body weight and linear type traits may not explain the complex relationships in all aspects and may be inadequate in investigating the causal effects among the biologically related variables (Keskin *et al*., 2005).

A major problem of contemporary science is to understand the structure and dynamics of complex systems. In such complex systems, it can be difficult to isolate causes and effects because each component potentially can influence others through a network of direct and indirect interactions (Smith *et al*., 1997). A misspecified model therefore can generate a serious bias in the estimation of the coefficient of each independent variable (Jeonghoon, 2002). In order to address this limitation, path analysis could be more suitable. Path analysis is a subset of Structural Equation Modelling (SEM), that allows examination of a set of relationships between one or more independent variables either continuous or discrete and one or more dependent variables, either continuous or discrete (Ullman, 1996). In this wise, overall correlation between two variables is decomposed into the direct effects of one on the other, indirect effects mediated by other variables, and spurious effects due to common causes. The computed path coefficients indicate the amount of change expected in the dependent variable as a result of a unit change in the independent variable (Smith *et al*., 1997).

Rural poultry offers a wide range of genetic potential in Nigeria, as the local chickens are genetically heterogeneous with diverse phenotypes and genotypes to select from. However, there is virtually no documented evidence in literature on the relationships between their body weight and body measurements using a classical statistical tool such as path analysis. The present investigation therefore, aimed at estimating body weight from biometric traits of Nigerian indigenous chickens using path analysis with a view to yielding a more appropriate selection criterion.

MATERIALS AND METHODS

Location of study

The study was carried out in the three agricultural zones of Nasarawa State, which falls within the guinea savanna zone of north central Nigeria. The State is located between latitude 07^0 52'N and $08^0$56'N and longitude 07^0 25'E and $09^0$31'N respectively.

Experimental animals

Two hundred and thirty eight adult birds comprising 86 male and 152 female Nigerian indigenous chickens were randomly sampled between January and March, 2009. The birds were reared under the traditional scavenging system.

Measured traits

Body weight and eight (8) morphometric traits were measured on each animal. The anatomical reference points were in accordance with standard zoometrical procedures (Gueye *et al*., 1998; Teguia *et al*., 2008). The parts measured were, comb height (CH); measured from its base at the crest of the head to the tip of the tallest cusp on the comb; comb length (CL); horizontal distance from the beginning to the end of the comb; beak length (BKL), measured as distance from the rectal apterium to the maxillary nail; body length (BL), length between the tip of the *Rostrum maxillare* (beak) and that of the Cauda (tail, without feathers); neck length (NL), distance between the occipital condyle and the cephalic borders of the coracoids; shank length (SL), distance from the shank joint to the extremity of the *Digitus pedi*s; chest circumference (CC), taken behind the wings, through the anterior border of breast-bone crest and the central thoracic vertebra and thigh circumference (TC), measured as the circumference at the widest point of the thigh. All measurements were taken by the same person to avoid between-individual variations.

Statistical analysis

Means, standard deviations (SD) and coefficients of variation (CV) of body weight and linear type traits were computed. Pairwise correlations among body weight and morphometric characters were also determined. Standardized partial regression coefficients called path coefficients (beta weights) were calculated. This was to allow direct comparison of values to reflect the relative importance of independent variables to explain variation in the dependent variable. The path coefficient from an explanatory variable (X) to a response variable (Y) as described by Mendes *et al*. (2005) is shown below:

$$P_{Y.Xi} = b_i \frac{S_{Xi}}{S_Y}$$

where,

$P_{Y.Xi}$ = path coefficient from X_i to Y (i= CH, CL, BKL, BL, NL, SL, CC,TC)

b_i = partial regression coefficient

S_{Xi} = standard deviation of X_i

S_Y = standard deviation of Y

The significance of each path coefficient in the multiple linear regression model was tested by t-statistic.

The indirect effects of X_i on Y through X_j were calculated as follows:

$$IE_{YXi} = r_{XiXj}P_{Y.Xj}$$

where,

IE_{YXi} = the direct effect of X_i via X_j on Y

r_{XiXj} = correlation coefficient between ith and jth independent variables

$P_{Y.Xj}$ = path coefficient that indicates the direct effect of jth independent (exogenous) variable on the dependent (endogenous) variable

Coefficient of determination (R^2) was partitioned into its components using path analysis as follows:

$$R^2 = P^2_{Y.X1} + P^2_{Y.X2} + P^2_{Y.X3} + P^2_{Y.X4} + P^2_{Y.X5} + P^2_{Y.X6} + P^2_{Y.X7} + P^2_{Y.X8}$$
$$2r_{X1X2}P_{Y.X1}P_{Y.X2} + 2r_{X1X3}P_{Y.X1}P_{Y.X3} + 2r_{X1X4}P_{Y.X1}P_{Y.X4} + 2r_{X1X5}P_{Y.X1}P_{Y.X5} +2r_{X1X6}P_{Y.X1}P_{Y.X6}+ 2r_{X1X7}P_{Y.X1}P_{Y.X7} + 2r_{X1X8}P_{Y.X1}P_{Y.X8} + 2r_{X2X3}P_{Y.X2}P_{Y.X3} + 2r_{X2X4}P_{Y.X2}P_{Y.X4} + 2r_{X2X5}P_{Y.X2}P_{Y.X5} + 2r_{X2X6}P_{Y.X2}P_{Y.X6} + 2r_{X2X7}P_{Y.X2}P_{Y.X7} + 2r_{X2X8}P_{Y.X2}P_{Y.X8} + 2r_{X3X4}P_{Y.X3}P_{Y.X4} + 2r_{X3X5}P_{Y.X3}P_{Y.X5} + 2r_{X3X6}P_{Y.X3}P_{Y.X6} + 2r_{X3X7}P_{Y.X3}P_{Y.X7}+2r_{X3X8}P_{Y.X3}P_{Y.X8} +2r_{X4X5}P_{Y.X4}P_{Y.X5} +2r_{X4X6}P_{Y.X4}P_{Y.X6} +2r_{X4X7}P_{Y.X4}P_{Y.X7} + 2r_{X4X8}P_{Y.X4}P_{Y.X8} + 2r_{X5X6}P_{Y.X5}P_{Y.X6} + 2r_{X5X7}P_{Y.X5}P_{Y.X7} + 2r_{X5X8}P_{Y.X5}P_{Y.X8} + 2r_{X6X7}P_{Y.X6}P_{Y.X7} + 2r_{X6X8}P_{Y.X6}P_{Y.X8} + 2r_{X7X8}P_{Y.X7}P_{Y.X8}$$

where,

$P^2_{Y.Xi}$ = direct effects of explanatory variables (CH, CL, BKL, BL, NL, SL, CC, TC) in contributing to the variation of Y (body weight).

$2r_{XiXj}(P_{Y.Xi})(P_{Y.Xj})$ = combined effects of explanatory variables (CH, CL, BKL, BL, NL, SL, C, TC) in contributing to the variation of (body weight).

SPSS (2001) statistical package was employed in the analysis.

RESULTS AND DISCUSSION

Body weight and morphological characters

The means (±SE) and coefficients of variation of body weight and biometric traits of the Nigerian adult indigenous chickens based on sex are presented in Table 1. Sex-influenced ($P < 0.05$) differences were observed in all the traits measured, with superior values recorded for cocks. These apparent sex-associated differences might be attributed to the usual between- sex differential hormonal effects on growth. This is consistent with the findings of Deeb and Cahaner (2001) and Zaky and Amin (2007). In a related study, Baeza *et al.* (2001) attributed the differences between male and female ducks to sexual dimorphism. The average live weight values obtained in the present study are comparable to documented evidence in literature (Sonaiya, 2003), showing that the native chickens of the study area are of the normal class (moderate weight). This probably suggests low indiscriminate miscegenation, geographical overlap and intermixing of local genes with exotic lines.

Pairwise correlations

Phenotypic correlations of body weight and linear body measurements of the chickens of both sexes are presented in Table 2. In cocks, highly significant ($P < 0.01$) association existed among body weight and zoometrical traits. The coefficients of correlation ranged from 0.545-0.968. Correspondingly in hens, the coefficients ranged from 0.456-0.848. The estimates of correlation in the present study are comparable to those reported by earlier workers (Gueye *et al*., 1998; Yang *et al*., 2006; Mancha *et al*., 2008). The strong relationship existing between body weight and body measurements may be useful as selection criterion, thereby providing a basis for the genetic manipulation and improvement of the native stock.

Path coefficients of explanatory variables

Path coefficients of the independent variables are presented in Table 3. Path analysis permits the partitioning of correlation coefficient into component parts (Topal and Esenbuga, 2001; Woods *et al*., 2003). The first component is the path coefficient (beta weight) that measures the direct effect of the predictor variable on the response variable. The second component estimates the indirect effect of the predictor variable on the response variable through other predictor variables (Pfeiffer and Morris, 1994).

In cocks (Table 3), the path analysis revealed that thigh circumference had the highest direct effect on body weight (path coefficient = 0.681; P<0.01). This implies that one unit change in standard deviation of thigh circumference results in 0.681 unit change in standard deviation of body weight. The direct effects of comb height (0.325; P<0.01) and body length (0.193; P<0.05) though low, were positive and significant. The direct effects of shank length and chest circumference were positive, but non-significant (0.005 and 0.047; P>0.01 respectively). These traits were realized indirectly via thigh circumference. The direct contributions of comb length and beak length to body weight were negative and non-significant (-0.126 and -0.024; P>0.01 respectively); while the direct effect of neck length, though significant, was negative (-0.124; P<0.01). Conversely, in hens (Table 4), the highest direct positive contribution to body weight was made by comb height, closely followed by thigh circumference, body length, chest circumference and shank length (path coefficient = 0.289, 0.277, 0.249, 0.246 and 0.180; P<0.01 respectively). The direct effects of comb length, beak length and neck length on body weight were however, negative and non-significant (path coefficient = -0.159, -0.002 and -0.020 respectively). Mendes *et al*. (2005) used path analysis to quantify the association between body weight and body measures of American Bronze Turkeys. In a related study, Wu *et al.* (2008), showed the relationship between body weight and body dimensions of rabbits using path analysis.

Coefficients of determination and establishment of preliminary regression equations

The direct and combined effects of morphometric traits on the variation of body weight are presented in Table 5. In cocks, the highest direct contribution to the variation in body weight was made by thigh circumference (R^2 = 0.464). Combined effects of thigh circumference and comb height were the highest among the variable pairs (R^2 = 0.380). The sum of determination coefficients of any independent variable and two independent variables' interaction in the present study was: $\sum d$= 0.962. According to path analysis principle, the sum of determination coefficients plus the determination coefficient of error is 1 (Wu *et al*., 2008). In the present study therefore, the determination coefficient of error was $1-\sum d$= 0.038. The preliminary multiple regression equation for male chickens was:

$$Y= 0.086+ 0.095CH- 0.020CL- 0.023BKL+ 0.017BL- 0.019NL+ 0.001SL+ 0.004CC + 0.087TC$$

In hens however, the highest single contribution to the variation in body weight was by comb height, closely followed by thigh circumference, body length and chest circumference (R^2 = 0.084, 0.077, 0.062 and 0.061 respectively). The combination of comb height and thigh circumference was highest (R^2 = 0.115). The sum of determination coefficients was 0.822 while the determination coefficient of error was 0.178. The preliminary linear model for female chickens was:

$$Y=-0.685+0.083CH-0.028CL-0.002BKL+0.025BL-0.003NL+0.006SL+ 0.021CC + 0.037TC$$

Deletion of less significant variables in the estimation of body weight

The path coefficients of comb length, beak length, shank length and chest circumference in males were statistically non-significant while the effect of neck length, though significant, was negatively impacted as revealed by the t-test. These traits were realized considerably and indirectly via thigh circumference. Thus, they were expunged from the regression model to obtain a much more simplified equation. However, in females, comb length, beak length and neck length were removed from the regression equation.

Establishment of optimum regression models for the prediction of body weight in indigenous chickens

After the deletion of five of the predictor variables (CL, BKL, SL, CC and NL) in cocks, the path coefficients for the remaining three exogenous variables [thigh circumference (TC), comb height (CH) and body length (BL)] were calculated again. The path coefficients obtained in this wise were: 0.656, 0.177 and 0.173 for TC, BL and CH respectively, and were found to be highly significant (P<0.01). The direct effects of TC, BL and CH in contributing to the variation in body weight were: R^2 = 0.430, 0.031 and 0.030 respectively. The combined effects gave R^2 value of 0.461 (TC&CH= 0.195, TC&BL= 0.215 and CH&BL= 0.051). The optimum multiple regression model for cocks was:

Y= 0.070+ 0.084TC+ 0.051CH+0.016BL

The sum of determination coefficient was 0.952 while the determination coefficient of error was 0.048. In female chickens, the new path coefficients obtained were: 0.150, 0.284, 0.180, 0.219 and 0.237 for CH, BL, SL, CC and TC respectively. The direct effects accounted for 0.24 of the variation in body weight while the combined effects contributed to 0.58 of the observed variation. The optimum linear model was:

Y= -0.727+ 0.043CH+ 0.028BL+0.066SL+0.019CC+0.031TC

The sum of determination in this case was 0.820 while the determination coefficient of error was 0.180.

The present findings further highlight the significance of body measurements in body weight estimation. These are consistent with the reports of earlier workers (Peters *et al*., 2006; Yang *et al*., 2006; Ajayi *et al*., 2008; Teguai *et al*., 2008).

CONCLUSION

Phenotypic correlations between linear type traits and body weight of Nigerian indigenous chickens ranged from moderate to high values in both sexes. However, in male chickens, path analysis revealed that thigh circumference had the highest direct effect on body weight, followed by comb height and body length respectively. The direct effects of comb length, beak length, shank length and chest circumference were non-significant, as they were influenced greatly by thigh circumference. In female chickens, the direct effects of comb height, thigh circumference, body length, chest circumference and shank length on body weight were positive and significant. The effects of comb length and beak length were however negative and non-significant while neck length negatively and significantly impacted on body weight. The optimum regression equation in males included forecast indices such as thigh circumference, comb height and body length. Correspondingly, in female chickens, comb height, thigh circumference, body length, chest circumference and shank length were included in the optimum multiple regression model. These equations could serve as a useful practical tool for livestock farmers, researchers and rural development workers for weight estimation in the field and for selection purposes.

Table 1: Descriptive statistics of body weight (kg) and zoometrical traits (cm) of Nigerian indigenous chickens based on sex.

Variable	Male animals (n=86)		Female animals(n=152)	
	Mean(±SE)	CV	Mean(±SE)	CV
BW	1.37 ± 0.04^{a}	24.26	1.19 ± 0.02^{b}	17.65
CH	2.17 ± 0.12^{a}	52.53	1.32 ± 0.06^{b}	56.06
CL	3.97 ± 0.22^{a}	52.01	2.70 ± 0.10^{b}	45.56
BKL	2.12 ± 0.04^{a}	16.98	1.95 ± 0.02^{b}	11.28
BL	28.67 ± 0.40^{a}	13.01	26.56 ± 0.17^{b}	8.09
NL	8.90 ± 0.24^{a}	24.61	7.81 ± 0.12^{b}	19.21
SL	6.65 ± 0.12^{a}	16.69	6.25 ± 0.05^{b}	9.28
CC	27.42 ± 0.44^{a}	14.88	25.65 ± 0.20^{b}	9.79
TC	8.78 ± 0.28^{a}	24.09	7.13 ± 0.13^{b}	17.65

Means in the same row bearing different superscript differ significantly (P<0.05
SE: Standard error of mean.
CV: Coefficient of variation.

Table 2: Pearson's coefficients of correlation between body weight and linear body measurements of Nigerian native chickens

Traits	BW	CH	CL	BKL	BL	NL	SL	CC	TC
BW	-	0.882	0.820	0.545	0.928	0.750	0.813	0.861	0.968
CH	0.733	-	0.961	0.559	0.828	0.744	0.795	0.777	0.858
CL	0.684	0.891	-	0.547	0.798	0.724	0.791	0.758	0.799
BKL	0.456	0.393	0.435	-	0.595	0.605	0.548	0.609	0.567
BL	0.848	0.752	0.678	0.400	-	0.792	0.835	0.943	0.928
NL	0.495	0.591	0.467	0.026^{NS}	0.588	-	0.755	0.759	0.803
SL	0.694	0.540	0.516	0.400	0.629	0.404	-	0.802	0.820
CC	0.706	0.461	0.533	0.610	0.669	0.220	0.530	-	0.853
TC	0.801	0.720	0.731	0.332	0.805	0.523	0.582	0.557	-

Upper diagonal: Male chickens
Lower diagonal: Female chickens
NS: Not significant

Table 3: Direct and indirect effects of conformation traits on body weight of male Chickens

Traits	Correlation coefficient with body weight	Direct effect	Indirect effect							
			CH	CL	BKL	BL	NL	SL	CC	TC
CH	0.882	0.325**	-	-0.121	-0.013	0.160	-0.092	0.004	0.037	0.584
CL	0.820	-0.126	0.312	-	-0.013	0.154	-0.090	0.004	0.036	0.544
BKL	0.545	-0.024	0.182	-0.069	-	0.324	-0.075	0.003	0.029	0.386
BL	0.928	0.193*	0.269	-0.101	-0.014	-	-0.098	0.004	0.044	0.632
NL	0.750	-0.124**	0.242	-0.091	-0.015	0.153	-	0.004	0.036	0.547
SL	0.813	0.005	0.258	-0.010	-0.013	0.161	-0.094	-	0.038	0.558
CC	0.861	0.047	0.253	-0.096	-0.015	0.182	-0.094	0.004	-	0.580
TC	0.968	0.681**	0.279	-0.101	-0.014	0.179	-0.010	0.004	0.040	-

Table 4: Direct and indirect effects of conformation traits on body weight of female chickens

Traits	Correlation coefficient with body weight	Direct effect	Indirect effect							
			CH	CL	BKL	BL	NL	SL	CC	TC
CH	0.733	0.289**	-	-0.141	-0.001	0.187	-0.012	0.097	0.113	0.199
CL	0.684	-0.159	0.257	-	-0.001	0.169	-0.009	0.093	0.131	0.202
BKL	0.456	-0.002	0.114	-0.069	-	0.100	-0.001	0.072	0.150	0.092
BL	0.848	0.249**	0.217	-0.108	-0.001	-	-0.012	0.113	0.165	0.223
NL	0.495	-0.020	0.171	-0.074	-0.000	0.146	-	0.073	0.054	0.145
SL	0.694	0.180**	0.156	-0.082	-0.001	0.157	-0.008	-	0.130	0.161
CC	0.706	0.246**	0.133	-0.085	-0.001	0.167	-0.004	0.095	-	0.154
TC	0.801	0.277**	0.208	-0.116	-0.001	0.200	-0.010	0.105	0.137	-

Indigenous chickens, body weight, biometric traits, correlation, path analysis.

Table 5: Direct and combined effects of the independent variables contributing to the variation of body weight of male and female chickens

Traits	Coefficient of determination (R^2)	
	Male birds	**Female birds**
Direct effects		
$P^2_{Y.X1}$	0.106	0.084
$P^2_{Y.X2}$	0.016	0.025
$P^2_{Y.X3}$	0.001	0.000
$P^2_{Y.X4}$	0.037	0.062
$P^2_{Y.X5}$	0.015	0.000
$P^2_{Y.X6}$	0.000	0.032
$P^2_{Y.X7}$	0.002	0.061
$P^2_{Y.X8}$	0.464	0.077
Combined effects		
X1 (CH) and X2 (CL)	-0.079	-0.082
X1 (CH) and X3 (BKL)	-0.009	-0.001
X 1 (CH) and X4 (BL)	0.104	0.108
X 1(CH) and X 5 (NL)	-0.060	-0.007
X 1 (CH) and X 6(SL)	0.003	0.056
X 1 (CH) and X 7 (CC)	0.024	0.066
X1 (CH) and X8 (TC)	0.380	0.115
X 2 (CL) and X3 (BKL)	0.003	0.000
X 2 (CL) and X4 (BL)	-0.039	-0.054
X 2 (CL) and X 5 (NL)	0.023	0.003
X 2 (CL) and X 6 (SL)	-0.001	-0.030
X 2 (CL) and X 7(CC)	-0.009	-0.042
X2 (CL) and X8 (TC)	-0.137	-0.064
X 3 (BKL) and X 4 (BL)	-0.006	-0.000
X 3 (BKL) and X 5 (NL)	0.004	0.000
X 3 (BKL) and X 6 (SL)	-0.000	-0.000
X 3 (BKL) and X 7 (CC)	-0.001	-0.001
X3 (BKL) and X8 (TC)	-0.019	-0.000
X 4 (BL) and X 5 (NL)	-0.038	-0.006
X 4 (BL) and X 6 (SL)	0.002	0.056
X 4 (BL) and X 7 (CC)	0.017	0.082
X4 (BL) and X8 (TC)	0.244	0.111
X5 (NL) and X 6 (SL)	-0.001	-0.003
X 5 (NL) and X 7 (CC)	-0.009	-0.002
X5 (NL) and X8 (TC)	-0.136	-0.006
X 6 (SL) and X 7 (CC)	0.000	0.047
X6 (SL) and X8 (TC)	0.006	0.058
X7 (CC) and X8 (TC)	0.055	0.076
Sum total	**0.962**	**0.822**

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