ISSN 0189-0514
J. Anim. Prod. Res. (2018) 30(1):235-244

National Animal Production Research Institute
Ahmadu Bello University
P.M.B 1096, Shika-Zaria,
Kaduna State, Nigeria.
Email:japr@napri.gov.ng Url:journals.napri.gov.ng

PREDICTION OF BODY-WEIGHT FROM BIOMETRIC TRAITS IN TWO FOUNDATION LINES OF BROILER

[*1]Adejoh-Ubani, E. O., [1]Adeyinka, I. A., [2]Orunmuyi, M. [1]Nwagu, B. I, [3]Akinsola, O. M., [1]Abeke, F. O., [1]Sekoni, A. A., [1]Otu, M. O. and [1]Olutunmogun, A. K

[1]*National Animal Production Research Institute (NAPRI), Shika, Zaria, Kaduna State, Nigeria.*
[2]*Department of Animal Science, Federal University Oye-Ekiti, Ekiti State, Nigeria*
[3]*Department of Animal Science, University of Jos, Plateau State, Nigeria*
**Corresponding Author: lizzyubani@yahoo.com +2348034536959, +2348102752648*

ABSTRACT

The research was conducted at the Poultry Breeding Unit, National Animal Production Research Institute (NAPRI), Shika, Zaria. A total of 1680 birds comprising of 1440 hens and 240 cockerels were used in 3 generations for the experiment. Mating ratio was 1 cockerel to six hens in each pen for different lines. Eggs were sorted sire wise before setting. Chicks were weighed individually at hatch, using a digital weighing balance and recording their individual body weights and wing tagged for easy identification. Weighing was done subsequently on a bi-weekly basis. Biometric traits: Neck length (NL) Back length (BL), Keel length (KL), BRL-Breast length (BRL) and Thigh (TL) length were measured with a tape rule at 8 weeks. The deep litter system of management was used to rear the birds from day old to 8 weeks of age. Stepwise multiple regression procedure was used to find the best linear combination of metric variables that best explains the live weight. The regression analysis was carried out using the SASREG procedure of the SAS (2008) Package. The correlation coefficients of body weight and the linear body measurements were also determined. From the correlation matrix, data for the principal component factor analysis were generated. All predictors had positive correlations within generations except at base generation where negative association (r = -0.010) existed between breast and thigh length. The highest prediction power (R^2 = 0.96 and 0.98 %) was obtained in the third generation for sire and dam line, respectively. Generation 1 recorded percentage variance of 41.70%, 29.60% and 20.8% respectively for PC1, PC2 and PC3. Generation 2 also had three components extracted with share variance accounting for 58.2, 29.6 and 21.0% of the total variance. Three components were also extracted in generation 3 with share variance of 71.2%, 48.9% and 22.6 % respectively. In concluding the low multicollinearity observed between body weight and body measurements implies that the prediction power obtained in this study is highly reliable for estimating body weight in settings where measuring scales are absent

Keywords: Prediction, biometric traits, broilers

INTRODUCTION

The relationship between body-weight and biometric traits is direct and positive, as reported by Okon *et al*. (1996). As such, knowledge of this relationship would help breeders organize selection in order to achieve an optimum combination of body-weight and good conformation for maximum economic returns (Adeniji and Ayorinde, 1990). The importance of evaluating interrelationships and productivity traits in poultry lies in their usefulness as predictors of characteristic like body-weight. Such applications could speed up the assessment of traits through the involvement

of simple measurement tools like ruler or tape (Chambers *et al.,* 1984). Understanding the interrelationships between body-weight and body measurements in these birds will help the farmer predict their body-weight at various ages especially in the rural areas where scales may not be available. The objective of this study was to examine the relationship among body measurements in two genetic lines of broiler chickens with a view to identifying those components that define body conformation. These could be used as selection criteria for improving meatiness in broilers.

MATERIALS AND METHODS

The research was conducted at the Poultry Breeding Unit of Poultry Research Programme of the National Animal Production Research Institute (NAPRI) Shika, Zaria. Shika is located in the semi-arid, Northern Guinea savanna zone of Nigeria within latitude $11^{o}8$'N and $07^{o}4$'E with an elevation of 2178 feet (663.77 metres) above sea level. The average annual precipitation is 1,100mm, which spreads from late April or early May to mid- October, with a peak between June and September (wet season). The wet season is usually followed by "Harmattan", a period of cool, dry weather which lasts from mid-October to February (post rains). The mean maximum temperature varies from 27oC to 35oC depending on the season; and the mean relative humidity during Harmattan and wet season are 21 and 72 %, respectively (Ovimaps, 2014).

Birds used for the work were derived from the Dam and Sire lines foundation stock of Breeder broiler chickens of the poultry breeding unit. . A total of 1880 birds comprising of 1640 hens and 240 cockerels were used in 3 generations. Mating ratio was 1 cockerel to six hens. Eggs were picked on daily basis and identified by the sire number and taken to the hatchery. Eggs were sorted based on sire number wise before setting. Chicks were weighed individually within 24 hours of hatching using a digital weighing balance and recording their individual body-weights and wing tagged for easy identification. Weighing was done subsequently on a bi-weekly basis. Biometric traits: Neck length (NL) Back length (BL), Keel length (KL), BRL-Breast length (BRL) and Thigh (TL) length were measured with a tape rule at 8 weeksThe deep litter system of management was used to rear the birds from day old to 8 weeks of age. A starter ration containing 23% crude protein (CP) and 2800kcal ME/kg was fed *ad libitum* during the first four weeks. Thereafter, the feed was changed to broiler finisher containing 20% CP and 3000kcal ME/kg for the next four weeks of the study. Water was given ad-lib. The vaccination schedule for broilers was strictly adhered to .Growing birds were kept on restricted feeding programme, from 9 to 20 weeks of age to minimize fat accumulation and maximize egg production.

Data analysis

Stepwise multiple regression procedure was used to find the best linear combination of metric variables that best explains the live weight. The following linear multiple regression models were applied.

$$y = a + b_1 X_1 + b_2 X_2 + b_3 X_3 + \ldots\ldots b_i X_i$$

Where:

y = the dependent variable (Live weight)

a = the intercept of regression curve on y – axis and is the value of the dependent variable y when all independent variables are zero.

b_1 = the partial regression coefficient associated with respective independent variable X_1.

X_1= the independent variables (i.e. morphometric measurement) the regression assumes that the Independent variable has no measurement error, and that the errors above the regression line are equal. The regression analysis was carried out using the SASREG procedure of the SAS (2008) Package.

Principal Component Analysis Procedures

The correlation coefficients of body weight and the linear body measurements were also determined. From the correlation matrix, data for the principal component factor analysis were generated. According to Everitt *et al.* (2001), principal component analysis is a method for transforming the variables in a multivariate data set x_1, x_2, ---, xp, into new variables, y_1, y_2,---, yp which are uncorrelated with each other and account for decreasing proportions of the total variance of the original variables defined as:

$$y_1 = a_{11}\, x_1 + a_{12}\, x_2 + \text{----------} + a_{1p}x_p$$

$$y_2 = a_2\, x_1 + a_{22}\, x_2 + \text{----------} + a_{2p}x_p$$

$$y_p = a_{p1}\, x_1 + a_{p2}\, x_2 + \text{----------} + a_{pp}x_p$$

with the coefficients being chosen so that y_1, y_2, --, y_p account for decreasing proportions of the total variance of the original variables, x_1, x_2, --, x_p. In matrix form:

$$Y_1 = a'x$$

The a_{ji} are scaled such that $a_1'a_1=1$. Y_1 accounts for the maximum variability of the p variables of any linear combinations. The variance of Y_1 is λ_1. The next, principal component Y_1 is formed such that its variance, λ_2 is the maximum amount of the remaining variance and that it is orthogonal to the first principal component. That is,

$$a_i'a_2 = 0$$

Components are extracted until some stopping criteria are encountered or until principal components are formed. The weights used to create the principal components are the eigenvectors of the characteristics equation: $(R-\lambda_1 I)\, a = 0$

Where R is the correlation matrix. The λ_1 are the Eigen values, the variances of the components. The Eigen values are obtained by solving $(R-\lambda_1 I)a = 0$ for λ_1.

During the evaluation, factors were rotated with Varimax rotation of Kaiser (Kaiser, 1958). The aim of the Varimax rotation is to maximize the sum of variances of a_{ij}^2 quadratic weight. Anti-image correlations, Kaiser – Meyer Olkin measures of sampling adequacy and Bartlett's Test of Sphericity were computed to test the validity of the factor analysis of the data sets. The appropriateness of the factor analysis was further tested using communalities and ratio of cases to variables (Snedecor and Cochran, 1989).

RESULTS AND DISCUSSION

Table 1 outlines the prediction of body weight from biometric traits of broiler male and female lines at different generations. Generation 3 had the highest prediction estimates (R^2=0.98 and 0.99) in the female line when BRL, BL, KL and TL were combined. The male line had prediction power of 96% and 97% respectively when NL, BL, KL, BRL and TL were combined.. Generation two had the lowest prediction power (R^2=0.73 and 0.75; 0.75 and 0.76) in male and female lines respectively, when NL, BL, KL, BRL, TL and another time when all the three components were combined together respectively. High prediction power (R^2=0.73 and 0.81 and 0.83and 0.88) was also observed for the base generation and generation one for both male and female lines respectively. The high and positive R^2 range (0.73 – 0.98 %) obtained in this study at different generations implies that increase in the growth rate of any of the components will correspondingly increase live weight gain and vice versa. The study also indicated that with these stains of chickens, body weight of birds could easily be predicted from any of the body measurements. The regression model fitted explains the data well especially in the dam line across generations. High estimates of coefficient of determination obtained from this study might be attributed to low environmental influence such as ability to manage heat stress, housing quality, choice of statistical techniques and management etc. This agrees with the report of Yalcin *et al*. (2007) who reported high R^2 for bodyweight of broiler

in fall than in summer. This effect is substantially greater in BW from four weeks of age to seven weeks of age. Peters *et al*. (2006) in chickens and Teguia *et al*. (2008) in ducks obtained high R^2 of 87 and 91 % respectively. However, high estimates of prediction power obtained in this study might be due to multicollinearity effects. The use of interdependent explanatory variables should be treated with caution, since multicollinearity has been shown to be associated with unstable estimates of regression coefficients (Ibe, 1989; Malau-Aduli *et al*., 2004) rendering the estimation of unique effects of these predictors impossible. However, Yakubu *et al*., (2010a) reported that sexual dimorphism in body weight and other body linear measurements favoured females than males in chickens which lines up with the trend obtained in this study.

In the Sire line (Table 2), the generalized variance estimates for the first generation were 33.20, 31.40 and 22.70 % respectively for PC1, PC2 and PC3. The communality ranged from 0.37-0.77. Traits loadings were BL, KL with BRL, NL, TL with KL across the three components. The Kaiser–Meyer–Olkin (KMO) the sampling adequacy estimate were 0.811 and chi square value of 2218.009; ($P<0.05$) was obtained for Bartlett's Test of Sphericity. Generation 2 also had three components extracted with share variance accounting for 41.70, 29.60 and 20.80 % of the total variance. The communality ranged from 0.25-0.48. The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy estimate were 0.792 and chi square value of 3617.029 ($P<0.05$) was obtained for Bartlett's Test of Sphericity. Loadings indicated were NL, BL, KL and BL and KL for the three components respectively. Three components were also extracted in generation three with share variance of 48.20, 38.90 and 10.60. The communality ranged from 0.35-0.72. The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy estimate were 0.891 and chi square value of 4615.119; $P<0.05$) was obtained for Bartlett's Test of Sphericity.

In the Dam line (Table 3), the result of the Principal Component (PC) from all generations used in this study showed that three components were extracted from the original five biometric traits of the sire and dam selected lines. The generalized variance for the first generation in dam line selected were 21.09, 17.22 and 15.77 %, respectively, for PC1, PC2 and PC3. The communality ranged from 0.37-0.97. Traits loadings were BL, KL with BRL, NL, TL with KL across the three components.

The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy estimate were 0.724 and chi square value of 1604.221; ($P<0.05$) was obtained for Bartlett's Test of Sphericity. Generation 2 also had three components extracted with share variance accounting for 28.41, 27.26 and 10.64 % of the total variance. The communality ranged from 0.49-0.95. The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy estimate were 0.681 and chi square value of 1972.029 ($P<0.05$) was obtained for Bartlett's Test of Sphericity. Loadings indicated were NL, BL, KL and BL and KL for the three components respectively.

Table 1: Stepwise Multiple Regression of Body weight on Body Measurements at Different Generation using Backward Elimination

Traits Original body measurements as explanatory variables Base Generation	**Models**	**R^2**
Male line	BWT=8259.11+115.91NL+127.34BL-82.317KL+80.48BRL – 109.42TL	0.73
	BWT=629.24+206.02PC1+178.36PC2+106.5PC3	0.76
Female line	BWT=9267.12+150.94NL+103.40BL-162.10KL+69.58TL	0.81
	BWT=709.21+266.01PC1+118PC2+101PC3	0.83
Generation one		
Male line	BWT=11259.11+150.91NL+223.34BL-62.317KL+150.48BRL – 129.42TL	0.83
	BWT=709.21+209.68PC1+101.23PC2+97.9PC3	0.88
Female line	BWT=11260.93+117.94NL+98.45BL-67.17KL+79.51TL	0.88
	BWT=689.29+261.01PC1+108PC2+164PC3	0.91
Generation Two		
Male line	BWT= 6475.23+ 94.91NL + 93.34BL - 162.317KL +0.48BRL – 29.42TL	0.73
	BWT=819.22+304.01PC1+208.42PC2+168.20PC3	0.75
Female line	BWT=7260.00+100.94NL+83.40BL-62.17KL+29.51TL	0.75
Generation Three	BWT=711.29+178.01PC1+156.72PC2+106.24PC3	0.76
Male line	BWT=12099.46+67.14NL+142.08BL+116.41KL +221.84BRL – 22.62TL	0.96
	BWT=709.21+266.01PC1+118PC2+101PC3	0.97
Female line	BWT=12478.45+ 443.49BL+90.09KL +212.90BRL – 88.95TL	0.98
	BWT=802.26+237.23PC1+206.17PC2+104.34PC3	0.99

BWT= Body weights, NL=Neck length, BL= Body length, KL=Keel length, BRL= Breast length, TL=thigh length

TABLE 2 EIGEN VALUES AND SHARE OF TOTAL VARIANCE ALONG WITH FACTOR LOADINGS AND COMMUNALITIES OF MORPHOMETRIC TRAITS OF SIRE LINE.

	Base Generation				Generation One				Generation Two				Generation Three			
	PC1	PC2	PC3	Communality	PC1	PC2	PC3	Communality	PC1	PC2	PC3	Communality	PC1	PC2	PC3	Communality
BRL	0.77*	0.33	0.26	0.68	-0.06	0.56*	0.22	0.38	0.58*	-0.04	0.22	0.32	0.69*	-0.03	0.06	0.35
NL	0.27	0.26	0.14	0.37	0.54*	-0.14	0.29	0.25	0.89*	0.65*	0.06	0.51	0.86*	0.62*	-0.05	0.60
KL	0.19	0.27	0.64*	0.77	0.49*	-0.02	0.50	0.48	0.68*	-0.04	0.24	0.43	-0.30	-0.40	0.38	0.72
BL	0.14	0.81*	-0.01	0.47	-0.26	0.48*	0.13	0.30	0.17		0.62*	0.56	0.03	0.09	0.68*	0.68
TL	0.60*	0.11	0.25	0.41	0.67*	0.51*	0.09	0.32	0.18	0.09	-0.36	0.75	0.89*	0.79*	0.06	0.68
Eigen value	3.32	3.14	2.27		4.17	2.96	2.08		5.82	2.96	2.10		4.82	3.89	1.06	
%variance	33.2	31.4	22.7		41.7	29.6	20.8		58.2	29.6	21.0		48.2	38.9	10.6	

NL-Neck length, BL-Back length, KL-Keel length, BRL-Breast length, TL-Thigh length,

The Kaiser–Meyer–Olkin (Gen 1) = 0.811 and chi square value of 2218.009; (P<0.05). The Kaiser–Meyer–Olkin (Gen 2) measure of sampling adequacy = 0.792 and chi square value of 3617.029 (P<0.001). The Kaiser–Meyer–Olkin (Gen 3) = 0.891 and chi square value of 4615.119; P<0.05)

Three components were also extracted in generation three with share variance of 22.06, 18.56 and 13.00. The communality ranged from 0.32-0.93. The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy estimate were 0.878 and chi square value of 4071.083; P<0.05) was obtained for Bartlett's Test of Sphericity.

The values obtained from factor analysis with varimax rotation of the inter-correlated traits in broiler lines across generations at eight weeks agree with reports in literature (Yakubu and Ayoade 2009 and Moses *et al*., 2011). This was supported by Kaiser-Meyer- Olkin measure of sampling adequacy studied from the diagonal of partial correlation, revealing the proportion of the variance in the body measurements caused by the underlying factor. This was found to be sufficiently high for all the morphometric traits across the generations (0.681, 0.724, 0.835 and 0.878) respectively. The overall significance of correlation matrix was tested with Barlett's Test of sphericity for body dimensions across the generations (chi square = 1972.029, 1604.221, 3943.76 and 4071.08; P < 0.001) and which provided enough support for the validity of the factor analysis of the data set.

The communalities, which represent the proportion of the variance in the original variables that is accounted for by the factor solution, ranged from 0.37-0.77, 0.25-0.48, 0.32-0.75 and 0.35-0.72 respectively across the generations. This further lends credence to the appropriateness of the factor analysis. The use of PC1 as a singular indices explained a total variance of 33.2, 41.7, 58.2 and 71.2 % respectively. The factor pattern coefficients were used to assess the relative contributions of the various body measurements in determining the numerical value of the corresponding factor (principal component). These coefficients show the relative contribution of each trait to a particular principal component (factor) for the broiler lines. The body parts associated with PC1 are by themselves rather good estimators of general size. The large communalities observed for the four lines of broiler at different generations indicate that a large number of variance has been accounted for by the factor solution. PC1 had the highest loadings and variance on body measurement traits in this study. PC1 could be described as the generalized form for broilers (Salako, 2006). In a principal component analysis of body measurements of broilers, Yakubu *et al.,* (2009b) reported that PC1 had high positive loadings on body weight, breast circumference and thigh length of Arbor Acre and termed PC1 "form factor". Mendes (2011) reported that PC1 had the highest correlation with shank length, breast circumference and bodyweight of Ross 308 broilers. Yakubu *et al.,* (2009a) reported that the first principal component accounted for the largest variance in the morphological traits of three Nigerian chicken genotypes. Ogah *et al.* (2009) presented data that showed PC1 accounting for the largest variance in the body measurements of ducks with high positive loadings on body width, bill width, shank length, body length, head length and neck length. Pinto *et al.,* (2006) used Principal component analysis to analyze performance and carcass traits measured in a population of *Gallus gallus*. The authors reported that the five first principal components explained 93.30% of the total variation and the first component explained 66.00%. They called the first component generalized weight because the largest eigen vectors were associated with bodyweight at 35 and 42 days of age, liver, breast, wing and thigh weights. According to Mendes (2009), the first principal component provides an adequate summary of the data in most cases.

Table 3 Eigen values and Share of Total Variance along with Factor Loadings and Communalities of Morphometric Traits of Dam Line

	Generation One				Generation Two				Generation Three			
Traits	PC1	PC2	PC3	Communality	PC1	PC2	PC3	Communality	PC1	PC2	PC3	Communality
BRL	0.87*	0.34	0.46	0.60	0.74*	0.15	-0.22	0.62	0.34	0.69*	0.11	0.48
NL	0.37	0.46*	0.74*	0.37	0.70*	0.2	0.14	0.55	0.27	0.63	-0.16	0.5
KL	-0.14	0.67*	-0.01	0.47	0.64*	0.11	0.27	0.49	0.30	0.48*	0.17	0.32
BL	0.98*	0.00	0.06	0.97	0.25	0.94*	0.05	0.95	0.95*	0.10	0.04	0.93
TL	0.07	0.61*	0.06	0.38	0.11	0.10	0.94	0.90	0.20	0.34	0.61	0.53
Eigenvalue	2.54	1.80	1.07		4.68	1.00	0.96		2.74	1.56	1.07	
%variance	21.09	17.22	15.77		28.41	27.26	10.64		22.06	18.56	13.00	

NL-Neck length, BL-Back length, KL-Keel length, BRL-Breast length, TL-Thigh length,

The Kaiser–Meyer–Olkin (Gen 1) measure of sampling adequacy =0.724 and chi square value of 1604.221; (P<0.05). The Kaiser–Meyer–Olkin (Gen 2) = 0.681 and chi square value of 1972.029 (P<0.05). The Kaiser–Meyer–Olkin (Gen 3) = 0.878 and chi square value of 4071.083 (P<0.05)

CONCLUSION

All predictors had positive correlations within generations except at base generation where negative association (r = -0.010) existed between breast and thigh length. The highest prediction power (R^2 = 0.96 and 0.98 %) was obtained in the third generation for sire and dam line, respectively. The high and positive R^2 range (0.73 – 0.98 %) obtained in this study at different generations implies that increase in the growth rate of any of the components will correspondingly increase live weight gain and vice versa. The study also indicated that with these stains of chickens, body weight of birds could easily be predicted from any of the body measurements. Low multicollinearity observed between body-weight and body measurements implies that the prediction power obtained in this study is highly reliable for estimating body-weight in settings where measuring scales are absent.

REFERENCES

Adeniji, F.O. and Ayorinde, K.L. (1990). Prediction of body weight of broilers at different ages from some linear body measurements. *Nigerian Journal of Animal Production,* 17: 43- 47.

Chambers, J.R., Gavora, J.S. and Fortin, A. (1984). Genetic changes in meat-type chickens in the last twenty years. *Canadian Journal of Animal Science,* 21: 563-569.

Everitt, B. S., Landau, S. and Leese, M. (2001). *Cluster Analysis.* 4thedn. Arnold Publisher, London.

Hruby, M., Hamre, M.L. and Coon, N. (1996). Non-linear and linear functions in body protein growth. *Journal of Applied Poultry Research,* 5:109-115.

Ibe, S.N. (1989). Measurement of size and conformation in commercial broilers .*Journal* of *Animal Genetics,* 106: 461-469.

Malau-Aduli, A.E., O.−Aziz, M. A.−Kojina, T.−Niibayashi, T.−Oshima, K.−Komatsu, M. (2004). Fixing collinearity instability using principal component and ridge regression analyses in the relationship between body measurements and body weight in Japanese Black cattle. *Journal of Animal and Veterinary Advances,* 3(12): 856-863.

Mendes, M. (2009). Multiple linear regression models based on principal component scores to predict slaughter weight of broilers. *Archiv Fur Geflugelkunde*. 73(2): 139-144.

Mendes,M. (2011). Multivariate multiple regression analysis based on principal component scores to study relationship between some pre- and post- slaughter traits of broilers. *Journal of Agricultural Science* (*Tarim Bilimleri Dergisi*.) 17:77-83.

Moses, O., Yakubu, A., Peters, S.O., Ozoje, M.O., Adebambo, O.A. and Imumorin, I.G. (2011). Application of multivariate principal component analysis to morphological characterization of indigenous goats in Southern Nigeria. *Acta Agriculture Slovenia,* 98:2-4.

Ogah, D.M., Alaga, A.A. and Momoh, M.O. (2009). Principal component factor analysis of the morphology structural traits of Muscovy duck. *International Journal of Poultry Science,* 8(11): 1100-1103.

Okon, B., Ogar, I.B. and Mgbere, O.O. (1996). Interrelationship of live body measurements of broiler chickens in a humid tropical environment. *Nigerian Journal of Animal Production,* 24(1): 7-12.

Peters, S.O., Adeleke, M.A., Ozoje, M.O., Adebambo, O.A. and Ikeobi, C.O.N. (2006). Bio-prediction of live weight from linear body

measurement traits among pure and crossbred chicken. *Journal of Poultry Science,* 4: 1-6.

Pinto, L.F.B., Packer, I.U., De Melo, C.M.R., Ledur, M.C. and Coutinho, L.L. (2006). Principal components analysis applied to performance and carcass traits in the chicken. *Animal Resources,* 55: 419-25.

SAS. (2008). Statistical Analysis Systems, Computer Software, Version 9.2. SAS Institute Inc., Cary, Northern California, USA. Page 170.

Salako, A. E. (2006). Principal component factor analysis of the morph structure of immature Uda sheep. *International Journal of Morphology* 24 (4): 571-574.

Snedecor, G.W. and Cochran, W.G. (1989). Statistical Methods, 8th Edition, Iowa State University Press. ISBN 978-0-8138-1561-9.Pp 255.

Teguia, A., Ngandjou, H.M., Defang, H. and Tchoumboue, J. (2008). Study of the live body weight and body characteristics of the African Muscovy duck (*Caraina moschata*). *Tropical Animal Health Production,* 40(1): 5-10.

Yakubu, A., Kuje, D. and Okpeku, M. (2009a). Principal components as measure of size and shape in Nigerian indigenous chickens. *Thai Journal of Agricultural Science,* 42(3):167-176.

Yakubu, A., Idahor, K.O. and Agade, Y.I. (2009b). Using factor scores in multiple linear regression models for predicting the carcass weight of broiler chickens using body measurements. *Revista UDO Agricola,* 9(4): 963-967.

Yakubu, A. and Ayoade, J.A. (2009c). Application of principal component factor analysis in quantifying size and morphological indices of domestic rabbits. *International Journal of Morphology,* 27: 1013–1017.

Yakubu, A., Salako, A.E., Imumorin, I.G. (2010a). Multivariate analysis of spatial patterns of morphological traits in West African Dwarf goats in three agro-ecological zones of Nigeria. *Journal of Applied Animal Resources,* 38: 257–260.

Yalçin, S., Çabuk, M., Bruggeman, V., Babacaonoglu, E., Buyse, J., Decuypere, E. and Siegel, P.B. (2008) Acclimation to heat during incubation: 3. Body weight, cloacal temperatures and blood acid-base balance in broilers exposed to daily high temperatures. *Poultry Science,* 87:2671-2677.