Bayesian principal component analysis of Nigerian indigenous normal feather chickens' body linear measurements

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Abstract

The indigenous chicken is a store house of unique genes that could be used in other parts of the world for improving other breeds. This study was carried out using bayesian principal component analysis and aimed objectively at determining the effect of sex on Nigerian indigenous normal feather chickens' body dimension, describing their body shape, and predicting their body weights from body measurements using orthogonal conformation traits derived from the principal components score. The parameters measured at 16 weeks of age were body weight, body length, breast girth, thigh length, shank length, shank diameter, keel length, wing length, wing span, and tail length on 233 randomly selected adult chickens. Sexual dimorphism was observed in all the traits with higher values recorded for males. Bayesian correlations among body weight and biometric traits were positive ($r = 0.09$ to 0.651 and 0.017 to 0.579 in male and female chickens respectively). The descriptive statistics showed that the mean body weight was 1.8085 ± 0.263 kg for males and 1.403 ± 0.226 kg for females. The first two principal components (PCs) were extracted for the males, both PCs components account for 72.21%. For the females, three PCs were extracted and they account for 77%. The first PC in each case accounted for the greatest percentage of the total variation. The use of orthogonal body shape characteristics derived from components' scores was more appropriate than the use of original traits in body weight prediction as multi-collinearity problems were eliminated. This led to simultaneous analysis of these body measurements rather than on individual basis. These components could be used as selection criteria for improving body weight of indigenous Nigerian chickens.

Keywords: Body weight, Body dimensions, Chickens, Orthogonal and biometric traits

Introduction

Nigerian indigenous chickens provide significant amount of animal protein as well as source of income to meet domestic demands of farmers in rural communities of Nigeria (Ige, 2014). They are usually self-reliant and hardy, capable of withstanding the abuses of harsh climate, minimal management, and inadequate nutrition (Horst, 1989). Egena *et al.* (2014) reported that the indigenous chickens remain the largest source of poultry meat and eggs despite the increase in the growth of the poultry industry in Nigeria. The indigenous

chicken is a store house of unique genes that could be used in other parts of the world for improving other breeds (Adebambo, 2004). Hence, the need for their conservation in order to keep genetic variation within and between local breeds (Yakubu *et al.*, 2009). Benitez (2002) explained that the future improvement and sustainability of local chicken production systems depends on the availability of genetic variation.

Body linear measurements are traits of economic importance as they are the visible proof of growth in chicken. It is very important to have knowledge of the

variation of body linear measurements in indigenous chickens as such measurements have been discovered to be very useful in comparing body size and shape of this breed (Latshaw and Bishop, 2001). Body linear measurements can be used as an indirect method of predicting body weight (Ige, 2014). In spite of the rich genetic resource base of Nigerian indigenous chickens, there is dearth of information on its characterization using bayesian analysis.

Bayesian analysis synthesizes two sources of information about the unknown parameters of interest. The first of these is the sample data, expressed formally by the likelihood function and the second is the prior distribution, which represents additional information that is available to the investigator (John, 2009). The bayesian approach gives more intuitive and meaningful inferences and the ability to tackle more complex problems. In classical framework of the frequentists, it is always assumed that the data are normally distributed which is not always true in some cases while bayesian inferences can be computed exactly, even in highly complex situations (John, 2009).

The principal components are a weighted linear combination of correlated variables, explaining a maximal amount of variance of the variables (Truxillo, 2003). It is a statistical method for reducing a complex system of correlations into one of smaller dimensions through the extraction of a few unobservable latent variables, called principal components (Tabachnick and Fidell, 2001). This helps in data reduction, and eliminates multi-collinearity which may lead to a wrong inference. Component scores derived from such multivariate analysis could be nearly uncorrelated or orthogonal and could therefore be used for prediction (Abdulmojeed *et al.*, 2012).

Although a lot of studies have been conducted on the body linear measurements and body weight of the Nigerian normal feather indigenous chicken, the published work that applied the bayesian approach in indigenous chickens is scanty. It then becomes laudable that bayesian statistics be applied in present studies to describe the body shape, and predict body weights from body measurements of Nigerian normal feather indigenous chicken using orthogonal conformation traits derived from the principal components score.

Materials and Methods

The research was carried out at the Poultry Breeding Unit of the Federal University of Agriculture, Abeokuta, (FUNAAB) located on latitude 7°10' N in Odeda Local Government Area, Ogun State, in South-Western Nigeria. The ambient temperature during the period ranged from 26.9°C to 27.1°C with average relative humidity of 80%, while the vegetative site was an inter-phase between the tropical rainforest and the derived savannah (AGROMET, FUNAAB, 2016).

Experimental animals and their management

Two hundred and thirty-three Nigerian normal feather indigenous chickens generated from a hatchery in Abeokuta were used for the study. The chicks were raised for sixteen weeks and fed *ad libitum* on chicks mash with metabolisable energy of 2600 kcal/kg and crude protein of 23% for 8 weeks while grower mash with metabolisable energy of 2450 kcal/kg and crude protein of 16% was given from 9 to 16 weeks. All the necessary vaccines were administered at the appropriate ages. Chickens were wing-banded at 1 day old. Body weights and body linear measurements of the birds were recorded at 16 weeks of age.

Traits measurement

Data collected from the birds included body weight and linear body measurements. Body weights were measured using sensitive scale with sensitivity of 0.01g while body linear measurements were measured with a tape rule calibrated in centimetres. The reference points and procedure for body measurement were as prescribed by Fayeye *et al.* (2006), Ige *et al.* (2006) and Gueye *et al.* (1998). The body linear measurements were; Shank length (SHL) measured as the length of the tarso-metatarsus from the hock joint to the metatarsal pad, Shank diameter (SHD) measured as the diameter of the tarso-metatarsus just below the spur, Thigh length (THL) measured as the length between the mid region of coax (hip bone) and that of the Genu (knee). The Keel length (KEL) was measured as the total length of the sternum, Body length (BOL) measured as distance from the tip of the beak, through the body trunk to the tail. The Tail Length (TAL) was measured as the total length of the tail feather, Wing length (WIL) measured as the length of the wing from the scapula joint to the last digit of the wing. The Wing span (WIS) was measured as the distance between the tip of one wing and the tip of the other wing when spread out, and Breast girth (BRG) measured as the circumference of the breast region.

Statistical Analysis

Means, standard errors and coefficients of variation of body weight and body linear measurements were calculated. One way analysis of variance was used to test the effect of sex on the parameters using the model;

$$Y_{ij} = \mu + S_i + e_{ij}$$

Where Y is the observational data, μ is the population mean, S_i accounts for the effect

of sex on Y, and e_{ij} is the residual error.

Bayesian coefficients of correlation (r) among body weight and the various morphometric traits were estimated. From the correlation matrix, data were generated for the principal component analysis. The first principal component was expressed as follows:

$$PC1 = a_{11}X_1 + a_{21}X_2 + \dots + a_{p1}X_p$$

The a_{ji} was scaled such that $a_1'a_1 = 1$.

The PC1 accounts for the maximum variability of the p variables of any linear combination. The variance of Y1 is λ_1 .

Next, principal component PC2 was 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, $a_1'a_2 = 0$

The weights used to create the principal components are the eigenvectors of the characteristic equation: $(S - \lambda I)a = 0$, or $(R - \lambda I)a = 0$

Where, S is the covariance matrix and R is the correlation matrix.

The λ_i were the Eigen values, the variances of the components. The Eigen values were obtained by solving $|S - \lambda I| = 0$ for λ_i . The Bayesian stepwise multiple regression procedure was used to obtain models for predicting body weight from principal component factor scores:

$$BW = a + B_iPC_i + \dots + B_kPCK$$

where, BW was the body weight, a was the regression intercept, B_i was the i^{th} partial regression coefficient of the i^{th} linear body measurement, PC_i was the i^{th} principal component (PC). Cumulative proportion of variance criterion was then employed in determining the number of principal components to extract. The R software was used to host the WinBUGS software to run the principal component analysis.

Results and discussion

Morphological traits

The analysis of variance of the effect of sex on body weight and body linear measurements showed that sex had very highly significant effects. The descriptive statistics, means, standard error, minimum, maximum and coefficient of variation estimate of body weight and linear body measurements of the indigenous chicken by sex at 16 weeks of age are presented in Table 1. Male birds had higher values for all linear body measurements compared to their female counterparts (Table 1). This is not in line with what was recorded by Egena *et al.* (2014), as they observed non significant effect for sex. The inconsistency may be due to the effect of environment as the study was conducted at a different geographical location. However, the apparent sex-related differences might be attributed to the usual between- sex differential hormonal effects on growth which tend to make male chickens aggressive and therefore eat more feed than the female counterparts and consequently have effect on growth. This is consistent with the findings of Hancock *et al.* (1994), Deeb and Cahaner (2001), Peters *et al.* (2006), Yakubu *et al.* (2009) and Ajayi *et al.* (2012).

The males were significantly heavier (1808.5 ± 263.3)g than the females (1403 ± 226)g. The result of coefficient of variation indicated that there was more variability in body weight when compared to other traits studied in both sexes. Among the males, wing length had the least variability while shank diameter had the least variability among the females. This implies that rapid response to selection can be expected from body weight when compared to linear body measurements.

Bayesian bi-variate correlations

Table 2 shows the Bayesian pair wise correlation coefficients of body weight and

body measurements of both male and female indigenous chicken. The correlation coefficients ranged from 0.09 to 0.651 and 0.017 to 0.579 in male and female chicken respectively. Relationships among all the body measurements were positive. Shank length had the highest correlation with body weight for male chicken while body length had the highest correlation with body weight in female chickens. The Monte Carlo error, the standard deviations were very small for all the correlations, which indicated that the size of the Gibbs chain was sufficient to estimate reliable posterior means. The bayesian bivariate correlation showed low correlation among the body measurements when compared with previous authors who applied the classical method of correlation. Yakubu *et al.* (2009) and Egena *et al.* (2014), observed the highest correlation between body weight and body length. While this is in disagreement with the present study, the difference may be due to the fact bayesian approach applies probabilistic method of analysis with the synthesis of prior distribution with the likelihood to give a more reliable posterior distribution and also, it can also be attributed to the fact that non-informative prior was used while running the analysis.

Principal component matrix

Table 3 shows the Eigen values, percentage of the total variance along with the rotated component matrix of the body measurements of both sexes. The Eigen values showed the amount of variance out of the total variance explained by each of the components. The principal component analysis revealed only two PCs with Eigen values greater than 1 for the males and three PCs with Eigen values greater than 1 for the females. The first two PCs for male accounted for 56.69% of observed variance. In female, the first three PCs (with Eigen

Table 1: Descriptive statistics of body weight (g) and linear body measurements (cm) of Nigerian indigenous chicken by sex at week 16 of age

Traits	Male (n=95)			Female (n=138)			CV (%)
	Mean $\pm$ SD	Minimum	Maximum	Mean $\pm$ SD	Minimum	Maximum	
BOW	1808.5 $\pm$ 263.3	1095	2558	1402.02 $\pm$ 226	789	1991.	16.13
SHL	11.053 $\pm$ 0.934	9	13	9.978 $\pm$ 0.822	8.1	13	8.24
SHD	5.278 $\pm$ 0.299	4.5	6.5	4.905 $\pm$ 0.273	4	6.2	5.57
THL	17.068 $\pm$ 1.283	13.5	19	15.398 $\pm$ 1.296	11	15	8.41
KEL	12.494 $\pm$ 0.821	11	14	11.649 $\pm$ 0.777	10	14	6.67
BOL	68.332 $\pm$ 5.233	55	78	61.025 $\pm$ 3.969	50	73	6.5
TAL	20.046 $\pm$ 2.724	13	27	18.381 $\pm$ 2.439	12	25	13.27
WIL	25.702 $\pm$ 1.494	22.9	30	23.637 $\pm$ 1.843	16	27	7.8
WIS	87.888 $\pm$ 4.729	75	96	81.406 $\pm$ 5.657	70	94	6.95
BRG	32.186 $\pm$ 2.191	27	36.7	29.708 $\pm$ 1.725	26	35	5.81

Top diagonal = Males, Lower diagonal = Females

WGT = Body weight, SHL = Shank length, SHD = Shank diameter, THL = Thigh length, KEL = Keel length, BOL = Body length, TAL = Tail Length, WIL = Wing length, WIS = Wing span, BRG = Breast girth.

Table2: Bayesian correlation coefficients between live body weight and body measurements of Nigerian indigenous normal feather chicken

Traits	BOW	SHL	SHD	THL	KEL	BOL	TAL	WIL	WIS	BRG
BOW	1	0.373	0.3043	0.2324	0.2324	0.3315	0.0909	0.2212	0.3088	0.2525
SHL	0.208	1	0.6509	0.5924	0.6239	0.4275	0.1395	0.5909	0.4345	0.6512
SHD	0.2451	0.5675	1	0.5164	0.6381	0.4456	0.1981	0.5888	0.3023	0.6479
THL	0.2025	0.3992	0.533	1	0.5876	0.3237	0.5003	0.5707	0.4542	0.5144
KEL	0.2361	0.4862	0.5333	0.5797	1	0.6119	0.5264	0.5988	0.6312	0.6201
BOL	0.2546	0.1208	0.2125	0.3576	0.3143	1	0.3776	0.2675	0.4815	0.2909
TAL	0.1062	0.3308	0.01763	0.5204	0.3714	0.2929	1	0.2682	0.2067	0.4600
WIL	0.1217	0.5002	0.3791	0.3858	0.4208	0.0128	0.3619	1	0.5733	0.643
WIS	0.1835	0.3653	0.2192	0.265	0.2854	0.1396	0.351	0.3584	1	0.5693
BRG	0.1589	0.4996	0.4093	0.4068	0.5540	0.5137	0.2109	0.2109	0.2796	1

Top diagonal = Males, Lower diagonal = Females

values greater than 1) accounted for 58.06% of the total variation.

Table 3 also shows the principal component factor score coefficients of male and female

normal feather chickens. These factor scores could be used instead of the original interdependent linear type traits in estimating the body weight of chickens.

Table 3: Principal components score coefficients for the prediction of the body weight, Eigen values and percentage of total variance of body measurements of Nigerian indigenous chicken by sex using the classical inference

Parameter	PC1 <i>Males</i>	PC2	PC1 <i>Females</i>	PC2	PC3
Shank length	-0.361	0.238	-0.344	0.348	-0.144
Shank diameter	-0.338	0.266	-0.309	0.162	0.622
Thigh length	-0.316	-0.103	-0.349	-0.203	0.368
Keel length	-0.368	-0.081	-0.396	-0.142	0.172
Body length	-0.342	-0.351	-0.338	-0.44	0.079
Tail length	-0.199	-0.770	-0.327	-0.143	-0.489
Wing length	-0.319	0.258	-0.191	0.625	0.019
Wing span	-0.361	-0.049	-0.388	0.322	-0.283
Breast girth	-0.361	0.264	-0.315	-0.289	-0.319
Eigen value	4.045	1.056	2.8714	1.308	1.047
% of total variance	44.95%	11.74%	31.90%	14.53%	11.63%

Table 4 shows the results obtained after running the principal component analysis on WINBUGS with 50,000 iteration and the first 5,000 samples discarded as burn in. Bayesian analyses allowed the estimation of the marginal posterior densities of the parameters, and with these densities it was possible to visualize the errors in the estimates of these parameters, making them more accurate (Gianola *et al.*, 1994). The percentage each of the extracted principal

components account for, standard deviations, Monte Carlo errors, credible interval, and the respective means of the variance of each of the components are also shown on table 4. The first two PCs were extracted for the male counterpart since they both have eigen values greater than 1 and both PCs account for 72.21%. For the female counterpart, three PCs were extracted as they have eigen values greater than 1. The three PCs altogether accounts for 77%.

Table 4: Bayesian Principal Components model for Nigerian normal feather indigenous chicken

Parameter	WinBUGS node	Mean	% of total variance	Sd	MC error	Credible interval		Burn in	Sample
						2.5%	97.5%		
MALES									
Variance	PC1	8977.0	58.41%	1331.0	6.566	6732.0	11920.0	5000	45001
	PC2	2121.0	13.80%	315.7	1.565	1592.0	2827.0	5000	45001
Precision	Tau _{eps}	89.09		360.7	23.14	0.09358	1040.0	5000	45001
FEMALES									
Variance	PC1	7697.0	59.92%	944.2	3.947	6079.0	9750.0	5000	45001
	PC2	1173.0	9.13%	143.7	0.7411	925.0	1486.0	5000	45001
	PC3	1021.0	7.95%	125.4	0.7234	804.5	1294.0	5000	45001
Precision	Tau _{eps}	145.0		298.3	19.43	0.0602	1074.0	5000	45001

The result of the classical principal component analysis presented that the first two components of the nine principal components were selected for males and the first three components for females were

selected as independent variables for multiple regression model because the extracted components have eigen values greater than 1. This is because Eigen values represent variances and that the value each

Table 5: Bayesian multiple regression (stepwise) of live body weight (kg) on orthogonal traits of Nigerian indigenous normal feather chicken

Step	Predictor	Regression coefficient	Sd	MC error	2.5%	median	97.5%
Males98/							
1	Intercept	-148.4	101.9	3.415	-347.3	-148.0	48.12
	PC1	-20.97	1.109	0.03715	-23.13	-20.97	-18.83
2	Intercept	-158.8	100.5	3.412	-354.6	-159.1	39.06
	PC1	-23.78	2.713	0.1496	-28.8	-23.8	-18.27
	PC2	9.094	7.958	0.4302	-6.647	9.169	24.15
Females							
1	Intercept	-127.9	100.4	3.878	-322.5	-128.1	68.74
	PC1	-17.63	1.168	0.0451	-19.88	-17.63	-15.33
2	Intercept	-135.3	100.9	3.841	-329.5	-136.4	67.68
	PC1	-17.89	1.185	0.045	-20.19	-17.91	-15.52
	PC2	-8.508	6.823	0.053	-21.89	-8.534	4.951
3	Intercept	-163.5	97.1	3.84	-357.8	-163.1	21.85
	PC1	-26.9	3.388	0.2118	-34.44	-26.81	-20.19
	PC2	0.556	7.433	0.1971	-13.91	0.5241	15.27
	PC3	28.84	10.35	0.6402	8.238	28.71	50.91

standardized variable contribute to principal component extraction is 1, a component with the Eigen value less than 1 is not as important (Tabachnick and Fidell, 2001; Keskin *et al.*, 2007). The selected two components for male explained 56.69% total variance in the classical inference but 72.21% total variance in the bayesian inference. Also, the selected three components for female explain 58.06% total variance in the classical framework but 77% total variance in the bayesian inference.

In the bayesian inference, in relation to the Monte Carlo error, the standard deviations were very small for all variance components, which indicated that the size of the Gibbs chain was sufficient to estimate reliable posterior means.

The main challenge encountered in the Bayesian principal component regression analysis is the inability of WINBUGS to automatically rank the principal components in order of magnitude.

Prediction of body weight of chickens from their independent principal components scores

The stepwise multiple regression analysis in both sexes is shown in Table 5. From the result body weight can be predicted using the regression equation stated below. The independent principal component scores were used to predict body weight of chickens from the WinBUGS.

The equations below show how the values of each of the principal components can be calculated;

For males:

$$PC1 = 10.85(SHL) + 5.851(SHD) + 16.67(THL) + 13.15(KEL) + 68.41(BOL) + 23.16(TAL) + 24.88(WIL) + 87.13(WIS) + 32.11(BRG)$$

$$PC2 = 11.43(SHL) + 6.085(SHD) + 17.55(THL) + 14.1(KEL) + 71.09(BOL) +$$

$$23.31(TAL) + 25.89(WIL) + 89.41(WIS) + 32.35(BRG)$$

$$\text{Male: body weight} = -158.8 + [-23.78(PC1)] + [9.094(PC2)]$$

For females:

$$PC1 = 9.432(SHL) + 5.033(SHD) + 16.6(THL) + 14.18(KEL) + 58.16(BOL) + 19.96(TAL) + 23.42(WIL) + 81.53(WIS) + 29.86(BRG)$$

$$PC2 = 10.7(SHL) + 5.111(SHD) + 17.05(THL) + 14.23(KEL) + 65.17(BOL) + 18.99(TAL) + 25.39(WIL) + 88.97(WIS) + 32.37(BRG)$$

$$PC3 = 9.195(SHL) + 4.587(SHD) + 14.04(THL) + 11.12(KEL) + 56.9(BOL) + 16.93(TAL) + 20.62(WIL) + 74.76(WIS) + 29.16(BRG)$$

$$\text{Female: body weight} = -163.5 + [-26.9(PC1)] + [0.556(PC2)] + [28.84(PC3)]$$

Conclusion

The variability in independent variable used in weight estimation between sexes supported the dimorphism expressed in descriptive analysis. The male chickens were heavier than the females. The use of orthogonal body shape characteristics derived from components' scores would be more appropriated than the use of original traits in body weight prediction.

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