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Robust Assessment of Body Weight and Linear Body Measurements of Nigerian Normal Feather Chickens using Bayesian Inference

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ABSTRACT

Previous studies on the relationships between body weight and morphometric indices in chickens have been mainly on classical analysis with assumptions that, data have normal distribution and constant variances. A more reliable assessment of body weight and morphometric indices requires a Bayesian multiple linear regression with assumptions of unequal variances. Body weight and nine morpho-structural traits of 234 Nigerian indigenous normal-feather chickens were measured using weighing scale and measuring tape at sixteen weeks. Two different regression models (weighted and unweighted) were fitted in Winbugs software to obtain Bayesian inference for each sex. Predicted relationships between body weight and shank length, thigh length, keel length, body length, wing length and breast girth were positive and ranged from 0.272 ± 4.972 to 101.5 ± 24.56. Shank diameter, tail length and wing span had negative relationships with body weight and estimates ranged from –15.94 ± 12.31 to –4.608 ± 59.86. Goodness of fit of models was assessed using Bayesian p–value, Deviance information criterion (DIC) and graph of residuals against predicted values under each model. The Bayesian p–value (0.502) for unweighted model for male chicken was closed to 0.5 compared to its weighted counterpart (0.573). This implied that weighted model fitted relationship between body weight and morpho-structural traits in Nigerian normal-feather male chicken compared to unweighted model. The

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differences in DIC and Bayesian p–values and residuals' plot against predicted values of weighted and unweighted regression models were sufficient for us to believe that weighted models fitted body weight and morpho-structural traits data better than unweighted models.

Keywords: Bayesian, body dimension, indigenous, model

INTRODUCTION

Chicken is the most common among poultry growers in Nigeria. Many farms have started to raise local chickens at commercial level due to growing interest as providers of meat and eggs. Nigerian indigenous chickens (NIC) contain a highly conserved genetic reservoir, with high level of heterozygosity, which may serve as biological animals, and offer useful information on the suitability of animals for selection (Ajayi et al., 2012). Normal-feather chicken is among NIC that provides meat, eggs and even manure at subsistence level to rural people.

Relationship exists between body weight and linear body measurements (Ige, 2013). Linear body measurements serve as good indicator of body weight and market value of chickens apart from body weight (Ukwu et al., 2014). Hence, the increasing need to estimate the weight of chickens in order to study their growth pattern as resulted in development of different regression equations. These equations are designed to predict the live weight of animals from linear body measurements (Peters et al., 2007). Assessment of body weight and linear body measurements of chickens have been reported by several authors in literature (Alabi et al., 2012; Gueye et al., 1998; Ibe, 1989; Ibe & Ezekwe, 1994; Ige et al., 2007; Ige, 2013; Momoh & Kershima, 2008; Ukwu et al., 2014). This assessment was based on frequentist (classical) predictions where solution of a model consisted in a single value for each parameter while as Bayesian predictions are based on estimation of distribution rather than single value. Despite this shortcoming in classical prediction, no available information on use of Bayesian inferences to study relationships of body weight and linear body measurements exist. In classical predictions, formula for estimating standard error is more complicated, including the Gaussian multipliers for regressions that contain more than one explanatory variable. This complex formula can be ignored when using Bayesian methods (McCarthy, 2007).

Therefore, in this study, unweighted and weighted Bayesian regression analyses were used to predict body weight from linear body measurements in Nigerian indigenous normal feather chicken. In unweighted model, we assumed that dependent variable is normally distributed, and its variance is constant over all values of the independent variables while in weighted model, we assumed unequal variances over all values of the independent variables. This is done so that we can have robust assessment of relationship between body weight and linear body measurements in normal-feather chicken.

MATERIALS AND METHODS

Location of Study, Experimental Birds and their Management

The research was carried out in Alabata, Abeokuta, Ogun State, 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^{o}C in June to 27.1^{o}C in December with average relative humidity of 80%, while the vegetative site represents an inter–phase between the tropical rainforest and the derived savannah. Fertile eggs of Nigerian indigenous chicken were collected from the Poultry Breeding Unit of Federal University of Agriculture, Abeokuta and hatched at the hatchery of the Unit. Two hundred and thirty-four chicks (95 males and 139 females) were collected from the hatchery at day–old and raised up to sixteen weeks of age. The chicks managed under intensive system and fed commercial feed purchased from market and water supplied *ad libitum*. The diet fed from day-old to 8th weeks had 2800 kcal of ME/kg of diet with 22% CP. Also, the diet fed from 9th to 16th weeks had 3000 kcal of ME/kg of diet with 20% CP.

Data Collection

Body weight and nine linear body measurements of 234 Nigerian Indigenous normal feather chickens were individually measured using a 5kg weighing instrument with sensitivity of 0.01 g and a measuring tape. Reference points for body measurement were according to standard descriptor (Sørensen, 2010). The parts measured were body length (BOL), measured as the distance between the tip of the beak and the longest toe without the nail; wing length (WIL), taken as the distance between the tip of the phalanges and the coracoids-humerus joint; wing span (WIS), measured as the distance between the left wing tip to the right wing tip across the back of the chicken; shank length (SHL), taken as the distance from the hock joint to the tarsometatarsus; thigh length (THL) measured as the distance between the hock joint and the pelvic joint; breast girth (BOG), measured as the circumference of the breast around the deepest region of the breast and keel length (KEL), taken as the distance between the anterior and posterior ends of the keel, shank diameter (SHD) measured as the circumference of the shank at the middle region and tail length (TAL) measured as the length from the tip of a central rectrix to the point where it emerged from the skin.

Statistical Analysis

Bayesian analysis of variance was carried out to estimate means and standard errors of body weight and linear body measurements for both sexes. The 95% Highest Density Interval and Bayes factor values were used as critical to determine significant difference between the sexes using R software. In order to carry out robust Bayesian regression analysis, two different regression models (weighted and unweighted) were fitted in Winbugs software to obtain Bayesian inference for each sex. The unweighted model assumes body weight must be normally distributed, and the variance of the body weight must be constant over all values of the linear body measurements while weighted model assumes unequal variances over all values of the linear body measurements. The general model is given below:

Y_{ij} = b0 + b1*SHL + b2*SHD + b3*THL + b4*KEL + b5*BOL + b6*TAL + b7*WIL+ b8 * WIS + b9 * BOG + e_{ij}

Prior distributions for regression coefficients in the model above are listed below:

tau ~ dgamma (0.01, 0.01)
b0 ~ dnorm (0.0, 0.0001)
b1 ~ dnorm (0.0, 0.0001)
b2 ~ dnorm (0.0, 0.0001)
b3 ~ dnorm (0.0, 0.0001)
b4 ~ dnorm (0.0, 0.0001)
b5 ~ dnorm (0.0, 0.0001)
b6 ~ dnorm (0.0, 0.0001)
b7 ~ dnorm (0.0, 0.0001)
b8 ~ dnorm (0.0, 0.0001)
b9 ~ dnorm (0.0, 0.0001)

where tau is precision, which is inverse of variance of the model, b0 is intercept, b1 is shank length regression coefficient, b2 is shank diameter regression coefficient, b3 is thigh length regression coefficient, b4 is keel length regression coefficient, b5 is body length regression coefficient, b6 is tail length regression coefficient, b7 is wing length regression coefficient, b8 is wing span regression coefficient; b9 is breast girth regression coefficient for linear body measurements and Y_i is body weight. A posterior analysis was executed with 51,000 observations generated for the simulation, with a burn in of 5000 and a refresh of 100 in WinBUGS version 1.4.3 (Spiegelhalter et al., 2003) package. Posterior predictive check with a Bayesian p–value to assess the adequacy of the model for the dataset was included in the code. The code for setting up this model in WinBUGS is available on demand from the authors.

RESULTS AND DISCUSSION

Table 1 shows the means, standard errors and Bayes factor of body weight and linear body measurements of Nigerian indigenous normal-feather chicken at sixteen weeks. Based on Bayes factor values and 95% HDI (HDI tables not shown), male chicken had credibly better body weight and body measurements than female chickens. Kass and Raftery (1995) suggested that if Bayes factor value was less than 3 it was not worth mentioning, while Bayes factor value from 3 up to 20 are positive evidence for significant difference. Bayes factor value from 20 up to 150 is strong evidence, and more than 150 are very strong evidence for the significant difference. Hence, multiple linear regressions were carried out for female and male separately in order to avoid interference of sex effect as confounding factor in the analysis. Multiple linear regressions were used to test for the nature of relationship between body weight and linear body measurements. Table 2 showed unweighted multiple regressions relating body weight to linear body measurements

Table 1
Effect of sex on body weight and linear body measurements of Nigerian normal feather male chickens using Bayesian inference

Variable	Sex	Mean ± SE	N	Bayes Factor
Body weight	Female	1404.554± 16.359	138	4.371 X 10^{24}
	Male	1805.927 ± 16.434	95	
Shank length	Female	9.987 ± 0.057	138	3.251 X 10^{14}
	Male	11.040 ± 0.058	95	
Shank diameter	Female	4.907 ± 0.018	138	1.513 X 10^{16}
	Male	5.277 ± 0.018	95	
Thigh length	Female	15.409 ± 0.086	138	6.109 X 10^{15}
	Male	17.053 ± 0.087	95	
Keel length	Female	11.657 ± 0.052	138	8.224 X 10^{10}
	Male	12.493 ± 0.053	95	
Body length	Female	61.059 ± 0.302	138	1.415 X 10^{23}
	Male	68.292 ± 0.305	95	
Tail length	Female	18.403 ± 0.170	138	7.261 X 10^{3}
	Male	20.010 ± 0.171	95	
Wing length	Female	23.651 ± 0.114	138	8.248 X 10^{13}
	Male	25.679 ± 0.114	95	
Wing span	Female	81.449 ± 0.356	138	1.748 X 10^{14}
	Male	87.820 ± 0.355	95	
Breast girth	Female	29.7267 ± 0.130	138	3.925 X 10^{15}
	Male	32.162 ± 0.131	95	

SE = standard error, N = sample size

Table 2
Unweighted multiple regression relating body weight to linear body measurements of Nigerian normal feather male chickens

Parameters	Reg. coeff.	sd	MC error	95% credible interval
Intercept	–162.9	96.89	3.327	–349 to 24.19
Shank length	101.5	24.56	1.459	56.84 to 154.8
Shank diameter	–4.608	59.86	3.642	–120.4 to 116
Thigh length	10.74	17.21	1.019	–24.31 to 46.3
Keel length	60.87	27.82	1.726	2.888 to 116.2
Body length	5.619	4.38	0.2603	–3.004 to 14.42
Tail length	–6.126	6.999	0.3112	–19.73 to 7.788
Wing length	–15.94	12.31	0.76	–40.97 to 9.371
Wing span	0.272	4.972	0.3207	–9.805 to 10.19
Breast girth	1.861	11.89	0.7494	–22.13 to 24.93
bpvalue	0.5021	0.5	0.002502	0 to 1
tau	$3.30(10^{-5})$	$5.15(10^{-6})$	$9.83(10^{-8})$	2.37 to $4.38(10^{-5})$

Reg. coeff = Regression coefficient, sd = standard deviation, MC = Monte Carlo, bpvalue = Bayesian p–value, tau = precision of Nigerian normal feather male chickens. Predicted relationship between body weight and some of the linear body measurements (SHL, THL, KEL, BOL, WIL and BOG) were positive and ranged from 0.272 ± 4.972 to 101.5 ± 24.56. The SHD, TAL and WIS had negative relationships with body weight with estimates ranging from –15.94 ± 12.31 to –4.608 ± 59.86. These positive regression coefficients obtained between body weight and aforementioned body dimensions were in tandem with reports of Olowofeso (2009) and Ojedapo et al. (2012) in their studies with chickens. However, different results were obtained when weighted multiple regression was used. This might not be unconnected with assumption of unequal variance in weighted multiple regression. Hence, when using classical analysis or unweighted multiple regression in fitting linear body measurements of chickens, independent and homoscedasticity assumptions should be tested.

Among body dimensions that had positive regression coefficient estimates in unweighted multiple regression, only BOG and TAL estimates changed to negative values (Table 3).

Table 3
Weighted multiple regression relating body weight to linear body measurements of Nigerian normal feather male chickens

Parameters	Reg. coeff.	sd	MC error	95% credible interval
Intercept	5.255	19.06	1.287	–32.32 to 18.66
Shank length	0.08307	1.029	0.06921	–2.23 to 0.7437
Shank diameter	0.3074	2.159	0.1457	–3.827 to 7.781
Thigh length	0.1064	0.6493	0.04397	–0.5162 to 2.43
Keel length	0.2202	1.019	0.06928	–0.7413 to 4.639
Body length	0.006364	0.1477	0.009577	–0.1521 to 0.3172
Tail length	–0.00844	0.1013	0.004861	–0.1968 to 0.07519
Wing length	–0.08284	1.151	0.07846	–0.7844 to 1.613
Wing span	–0.02699	0.2511	0.01705	–0.805 to 0.2936
Breast girth	–0.01974	0.2281	0.0151	–0.7115 to 0.2404
bpvalue	0.5726	0.4947	0.003373	0 to 1
tau	172.2	88.79	5.759	0.01597 to 282.9

Reg. coeff = Regression coefficient, sd = standard deviation, MC = Monte Carlo, bpvalue = Bayesian p–value, tau = precision

The unweighted multiple regression function fitted for body weight and linear body measurements in Nigerian normal feather female chicken is shown in Table 4.

Apart from TAL, WIS and BOG, all other body dimensions had positive regression coefficients in a range of 2.68 ± 3.463 to 55.2 ± 22.64. Meanwhile, regression coefficients of body dimensions in weighted regression were positive values except in TAL (Table 5).

These results obtained for weighted regression was in agreement with the studies of Adeleke et al. (2004) and Ganiyu et al.

Table 4
Unweighted multiple regression relating body weight to linear body measurements of Nigerian normal feather female chickens

Parameter	Reg. coeff.	sd	MC error	97.5% Credible interval
Intercept	–152.5	100.6	3.641	–346 to 43.74
Shank length	55.2	22.64	1.271	11.15 to 99.93
Shank diameter	18.61	53.59	3.164	–88.38 to 122.3
Thigh length	17.44	14.83	0.8413	–11.43 to 47.04
Keel length	37.66	22.41	1.333	–6.259 to 84.16
Body length	12.45	4.894	0.2947	3.399 to 23.52
Tail length	–6.162	8.011	0.3835	–21.75 to 8.965
Wing length	–5.81	9.03	0.5095	–25.17 to 10.59
Wing span	2.68	3.463	0.2069	–4.284 to 9.247
Breast girth	–17.41	10.25	0.6243	–37.27 to 1.718
tau	$3.0(10^{-5})$	$3.8(10^{-6})$	$5.37(10^{-8})$	2.30 to $3.79(10^{-5})$
bpvalue	0.4331	0.4955	0.002466	0 to 1

Reg. coeff = Regression coefficient, sd = standard deviation, MC = Monte Carlo, bpvalue = Bayesian p–value, tau = precision

Table 5
Weighted multiple regression relating body weight to linear body measurements of Nigerian normal feather female chickens

Parameter	Reg. coeff.	sd	MC error	97.50% Credible interval
Intercept	3.727	2.409	0.1623	–3.124 to 5.376
Shank length	0.03244	0.07272	0.004708	–0.1234 to 0.08932
Shank diameter	0.1414	0.183	0.01218	–0.06368 to 0.2343
Thigh length	0.01093	0.0567	0.003721	–0.03733 to 0.05468
Keel length	0.05681	0.1897	0.01288	–0.1431 to 0.1258
Body length	0.01651	0.03406	0.00229	–0.01351 to 0.0824
Tail length	$-3.67(10^{-5})$	0.01819	0.00112	–0.01331 to 0.0248
Wing length	0.01736	0.04831	0.003209	–0.02702 to 0.1342
Wing span	0.002782	0.01702	0.001141	–0.01108 to 0.02338
Breast girth	$5.19(10^{-4})$	0.1047	0.007116	–0.02948 to 0.1135
bpvalue	0.4852	0.4998	0.006023	0 to 1
tau	74.37	21.1	1.295	1.22 to 100.3

Reg. coeff = Regression coefficient, sd = standard deviation, MC = Monte Carlo, bpvalue = Bayesian p–value, tau = precision

(2016). Adeleke et al. (2004) reported the estimation of body weight of crossbred egg–type chickens from linear body measurements while Ganiyu et al. (2016) reported regression coefficients of linear body measurements for only BOL, KEL, SHL, THL and WL in Anak White broiler chickens. The 95% credible interval for the estimates suggested that only for SHL and KEL were positive relationships between the body weight and body dimension.

The Monte Carlo (MC) errors measure the variation of the mean of the regression coefficients due to sample simulation. Lower MC errors in all the models compared to corresponding estimated standard deviation implied that estimated regression coefficients were estimated with high precision regardless of violation of regression assumption. However, estimated precision (tau) values (172.20, 74.37) for male and female chickens respectively under weighted regression model were higher than estimated tau (3.30×10^{-5}**)** for unweighted regression model in both sexes. This indicated better estimation accuracy of coefficient parameters under weighted models over unweighted models.

Goodness of fit of our models was assessed using Bayesian p–value, Deviance information criterion (DIC) and graph of residuals against predicted values under each model. A fitting model with a Bayesian p–value near 0.5 and value close to 0 or close to 1 suggests doubtful fit of the model (Marc, 2010). The Bayesian p–value (0.502) for unweighted regression model for male chicken was closed to 0.5 compared to its weighted counterpart (0.573). This implied that weighted regression model fitted relationship between body weight and linear body measurements in Nigerian normal feather male chicken compared to unweighted regression model. However, a different result was obtained in female chicken. Weighted multiple regression Bayesian p–value (0.4852) was closed to 0.5 compared to unweighted Bayesian p–value (0.433).

Using DIC value, Ioannis (2009) stated that the lower the DIC value, the better the fitted model. Unweighted regression model for male chicken had higher DIC value (1260.120) compared to weighted regression model (–235.002). Similar results was obtained in female chicken, with DIC value (1840.760) for unweighted regression model higher than DIC value (–201.184) for weighted regression.

Figures 1 and 3 showed the plot of residuals against the predicted values of body weight using unweighted regression model for male and female chickens respectively. The scatter plot of the residuals scattered around zero line. This implied that the variances were heteroscedastic (i.e. variances of the error terms are not equal). This implied that the estimates of the regression parameters and its standard deviation estimates were potentially biased.

Graph of residuals against predicted values of body weight of male and female chickens in weighted regression model is shown in Figures 2 and 4 respectively. It showed that the variances were homoscedastic (i.e. variances of the error terms are equal) because the residuals roughly form a horizontal band around the zero line. Hence, there is no sign of a violation of the independent and homoscedasticity assumption under weighted regression models for both male and female chickens.

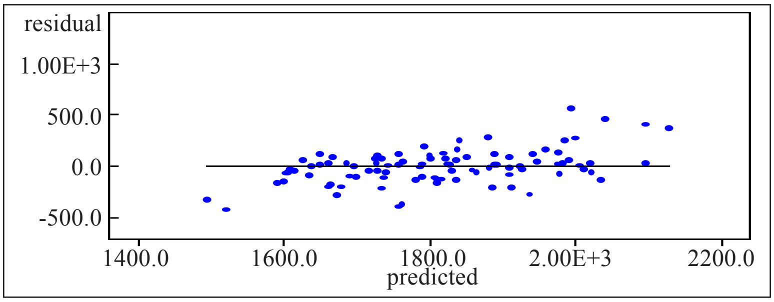

Figure 1. A plot of residual against predicted values of body weight of Nigerian normal feather male chickens using unweighted regression model

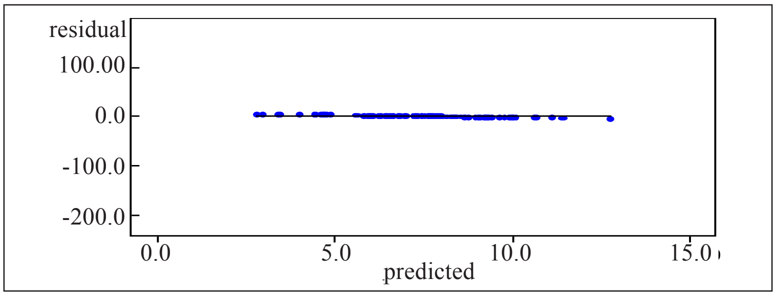

Figure 2. A plot of residual against predicted values of body weight of Nigerian normal feather male chickens using weighted regression model

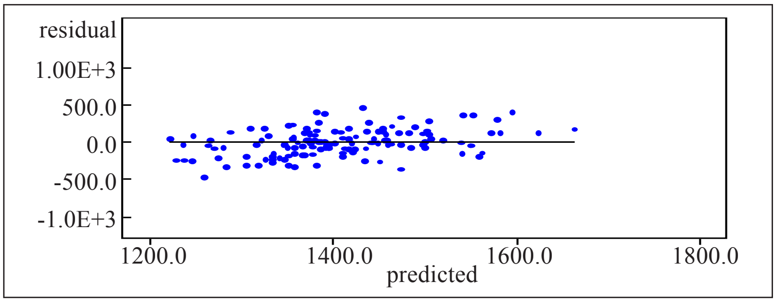

Figure 3. A plot of residual against predicted values of body weight of Nigerian normal feather female chickens using unweighted regression model

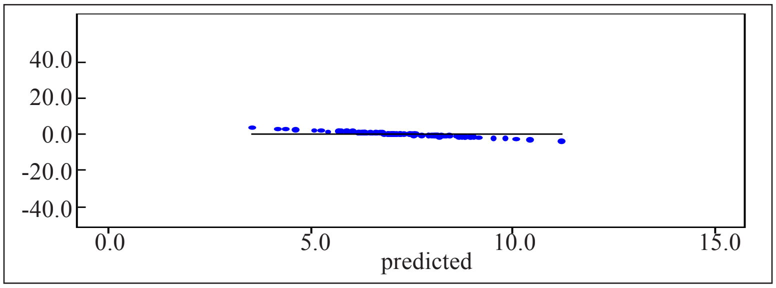

Figure 4. A plot of residual against predicted values of body weight of Nigerian normal feather female chickens using weighted regression model

CONCLUSION

The differences in DIC and Bayesian p–values and plot of residuals against predicted values of weighted and unweighted multiple regression models were sufficient for us to believe that weighted multiple regression models fitted body weight and linear body measurements data better than unweighted multiple regression models. Bayesian weighted multiple regression model is therefore recommended when fitting linear body measurements of chickens especially if prior knowledge of the parameters is available. In addition, when using unweighted linear regression in fitting linear body measurements of chickens, independent and homoscedasticity assumptions should be tested and reported in order to avoid biasness and misleading.

Conflict of Interest

The authors declare that they have no conflict of interest.

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