Principal component regression of carcass traits in meat line funaab alpha chicken genotype

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Abstract

This study aimed to assess the relationship among carcass traits of meat line FUNAAB Alpha chicken genotype, to identify the components that defined bled weight in them using multivariate principal component regression. A total of 14 different carcass traits from sixty-eight birds were recorded and subjected to one-way analysis of variance to vet for sex effect. Phenotypic relationships among the carcass traits were also established to pave way for the principal component analysis. The results reveal significant effects between the traits measured. The male significantly ($P < 0.05$) had greater mean values for the traits measured. Correlations among the considered carcass traits were found to be positive and significant ranging from $r = 0.406$ (LrWt) - 0.981 (EdWt) for the female chicken; $r = 0.330$ (Head Wt) - 0.978 (BdWt) for the male chicken. The extracted components PC1 to PC7 contributed 95.66% with PC1 accounting for 68.68% of the variability in the original parameters. Communality estimates varied from 0.466 (thigh weight) to 0.983 (liver weight). In the principal component regression models, Eviscerated weight accounted for 95% of the variation observed in bled weight. The use of PC1 as a single predictor, explained 96.4% of the variability, whilst combining PC1 and PC4 showed improvements in the variance explained ($R^2 = 96.7\%$) with a lower Mallows' cp (5.31). Using the principal components scores from the chicken morphometric traits was more appropriate than using the original traits in bled weight prediction.

Introduction

Poultry production in developing countries is a fast growing sub-sector of agriculture that is quick in terms of shorter production cycles (Magothe *et al.*, 2012; Mottet and Tempio, 2017; Alabi *et al.*, 2019; Alabi *et al.*, 2020). Products from poultry are one of the most popular options available in Nigeria in reducing protein deficiency and malnutrition in the populace diet (Obasoyo *et al.*, 2005; Anyawu and Okoro, 2006; Ojedapo *et al.*, 2015). The call for the improvement and development of chicken breeds that are indigenous to Nigeria led to the development of the FUNAAB Alpha chicken breed (Broiler and dual purpose). The breed was developed at the Federal University of Agriculture, Abeokuta, Nigeria, using the Naked and Frizzled feather chicken genotype (Broiler type) having over six generations through cross breeding with some exotic lines to maximise growth and their productive performance (Adebambo *et al.*, 2018). This development has been effected for improved production without compromise to its climatic adaptation and diseases susceptibility (Saleh *et al.*, 2017).

The growth process within the indigenous chicken is a complex one that relates to increasing body cells and volume. Growth mechanisms and processes are mostly too multifaceted to be explained with univariate analysis. This can be because of the biological linkage caused by gene loci and pleiotropic effect. The principal component analysis which is a multivariate procedure could better solve the problems associated with the univariate analysis of growth and its observed traits. This is because it reduces related variables into a lesser numbers of uncorrelated variables called principal components (Kor *et al.*, 2006; Rosario *et al.*, 2008; Amao, 2018). The principal component analysis is a tool for exploratory data and is adapted for making predictive models (Acha, 2012). It has been used to describe the inter-relationship between body measurements and size in chickens (Yakubu *et al.*, 2009a; Udeh and Ogbu, 2011; Akporhwarho and Omoikhoje, 2017). In animal genetics and improvement, principal components simultaneously considers certain attributes that may be utilised for selection purposes. An important aspect is that every principal component explains a certain percentage of the total variance with the first principal component explaining the highest percentage of this variance (Pinto *et al.*, 2006). This study was aimed at analyzing the principal component regression of carcass traits of meat line FUNAAB Alpha Chicken Genotype. The outcome could aid the management and subsequent selection towards genetic improvement of the indigenous stock.

Materials And Methods

Experimental site

The study was conducted at PEARL (Program for Emerging Agricultural Research Leaders) Poultry Breeding unit of the Directorate, University Farms (DUFARMS), Federal University of Agriculture, Abeokuta (FUNAAB), Ogun State, Nigeria. The area lies in the South-western part of Nigeria, it is located within the Longitude $7^{\circ} 10^0$ N and Latitude $3^{\circ} 2^0$ E, with an average temperature of 33.7°C and relative humidity of 80% with rainfall of about 1037mm (AGROMET, FUNAAB, 2014).

Experimental birds

68 birds comprising of 44 males and 24 females randomly selected from the meat line of the improved indigenous chicken, FUNAAB Alpha was used in the experiment. They were generated through artificial insemination at PEARL Farm, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria.

Feeds and feeding

Feeding was *ad libitum*; the chicks were on a starter diet that supplied 24% crude protein and 2900Kcal/KgME metabolizable energy from 0 - 4 weeks old and a finisher diet that supplied 23% crude protein and 3000Kcal/KgME metabolizable energy from 5 - 8 weeks. Clean water was given *ad libitum* throughout the experimental period.

Data collection: The birds were fasted for 12 hours and slaughtered by severance of the carotid arteries and jugular veins, the blood was drained under gravity and scalded to facilitate plucking and evisceration. The carcass were divided into parts as described by Kleczek et al. (2006). Data were collected on the following traits using a 0.1g sensitive scale: bled weight, de-feathered weight, eviscerated weight, breast weight, thigh weight, back weight, shank weight, wing weight, neck weight, head weight, drum stick weight, liver weight, whole gizzard weight, empty gizzard weight.

Statistical analysis: Means, standard errors and coefficient of variation of carcass traits of each sex was obtained using the descriptive statistic of S.A.S (Version 9.1). One-way analysis of variance was used to test for sex effect on the carcass parameters. Pearson correlation coefficients amongst the carcass traits was calculated for both sex and the matrix was the major data required to generate the principal components. Principal component analysis is a method that transforms variables in a multivariate data set $x_1, x_2, \dots, x_p$ into new ones, $y_1, y_2, \dots, y_p$ which are uncorrelated and account for decreasing proportions in the total variance of the original variables defined as:

$$y_1 = a_{11} x_1 + a_{12} x_2 + \dots + a_{1p} x_p$$

$$y_2 = a_{21} x_1 + a_{22} x_2 + \dots + a_{2p} x_p$$

$$y_p = a_{p1} x_1 + a_{p2} x_2 + \dots + a_{pp} x_p \text{ (Adenaike et al., 2015).}$$

The varimax rotation maximized the sum of variances of the a_{ij}^2 quadratic weight, whilst the stepwise multiple regression procedure was used to obtain models for the prediction of bled weight from the carcass traits (i) and from the established principal components (ii).

$$BdWt = a + B_i x_i + \dots + B_k x_k \quad (a)$$

$$BdWt = a + B_i PC_i + \dots + B_k PC_k \quad (b)$$

Where; BdWt is Bled weight,

a is regression intercept,

B_i is the i th regression coefficient of the i th linear bled weight measurement,

X_i is the i th principal component.

The components were extracted until certain stopping criteria were encountered or when the p components were formed. The weights used for the formulation of the principal components were the eigenvectors of the characteristic equation:

$$(R - \lambda I) a = 0$$

Where R is the correlation matrix,

The λ are the eigenvalues (variances of the components).

Cumulative proportion variance were employed to determine the number of principal components for extraction. The means, correlation and regression procedures of S.A.S 9.1 statistical package was used for the principal component regression (Adenaike et al., 2015). Mallow's C_p was used to select maximal accurate subsets of predictor variables in the stepwise regression (Lieberman and Morris, 2008).

Results

The means, standard error and coefficients of variation for the carcass traits of meat line of FUNAAB Alpha chicken genotype at 8 weeks of age are presented in Table 1. The results reveals significant effects amongst the traits measured. The male significantly ($P < 0.05$) had greater mean values for the traits measured; from bled weight of 1174 ± 20.49 compared to the female with 1030 ± 29.5 to liver weight 23.69 ± 0.56 and female 20.58 ± 0.68 .

Table I: Means, standard errors and coefficients of variation of carcass traits of meat line of FUNAAB Alpha chicken genotype at 8 weeks of age.

Traits	No	Female		No	Male	
		Mean $\pm$ S.E	CV%		Mean $\pm$ S.E	CV%
Bdwt	24	1029.79 $\pm$ 29.5 ^b	14.30	44	1173.60 $\pm$ 20.46 ^a	11.56
DfdWt	24	996.48 $\pm$ 31.79 ^b	15.63	44	1117.23 $\pm$ 20.58 ^a	12.22
EdWt	24	814.88 $\pm$ 27.34 ^b	16.44	44	923.35 $\pm$ 18.58 ^a	13.34
BtWt	24	189.73 $\pm$ 9.03 ^b	23.31	44	211.93 $\pm$ 6.4 ^a	20.04
TWt	24	117.91 $\pm$ 5.89 ^b	24.46	44	133.88 $\pm$ 2.65 ^a	13.13
BaWt	24	142.84 $\pm$ 5.35 ^b	18.36	44	162.26 $\pm$ 3.66 ^a	14.96
ShkWt	24	50.09 $\pm$ 1.78 ^b	17.37	44	59.48 $\pm$ 1.34 ^a	15
WingWt	24	104.65 $\pm$ 2.6 ^b	12.23	44	119.03 $\pm$ 2.27 ^a	12.63
NkWt	24	59.14 $\pm$ 2.02 ^b	16.74	44	64.93 $\pm$ 1.42 ^a	14.54
HeadWt	24	36.96 $\pm$ 1.02 ^b	13.53	44	42.28 $\pm$ 0.8 ^a	12.56
DkWt	24	111.83 $\pm$ 3.85 ^b	16.88	44	130.41 $\pm$ 3.05 ^a	15.5
WGdWt	24	45.36 $\pm$ 1.71 ^b	18.52	44	52.39 $\pm$ 1.23 ^a	15.59
EGdWt	24	32.31 $\pm$ 0.9 ^b	13.68	44	35.60 $\pm$ 0.97 ^a	18.15
LrWt	24	20.58 $\pm$ 0.65 ^b	15.45	44	23.69 $\pm$ 0.56 ^a	15.28
a, b Means along the same row with different superscripts are significantly different (P<0.05)						

Bdwt= Bled weight, DfdWt = Defeathered weight, EdWt = Eviscerated weight, BtWt = Breast weight, TWt= Thigh weight,

BaWt - Back weight, ShkWt= Shank weight, WingWt=Wing weight, NkWt = Neck weight, HeadWt= Head weight, DkWt = Drum stick weight, WGdWt - Whole gizzard weight, EGdWt = Empty gizzard weight, LrWt = Liver weight,

The correlation coefficients among the carcass traits of meat line FUNAAB Alpha Chicken are shown in Table 2: The results revealed that the observed values varied between $r = 0.406$ (Liver Weight) and $r = 0.981$ (Eviscerated weight) for the female chicken; $r = 0.330$ (Head weight) and $r = 0.978$ (Bled weight) for the male chicken. There are very high positive significant correlations between the bled weight, de-feathered weight, eviscerated weight, breast weight, thigh weight, back weight, shank weight, wing weight, neck weight and drumstick weight. However, whole gizzard weight, empty gizzard weight and liver weight relationship with other variables had no significant correlation.

Table 2
Correlation coefficient among carcass traits of meat line FUNAAB Alpha Chicken Genotype.

Traits	BdWt	DfdWt	EdWt	BtWt	TWt	BaWt	ShkWt	WingWt	NkWt	HeadWt	DkWt	WGdWt	EGdWt	LrWt
Bdwt		0.956 ***	0.978 ***	0.870 ***	0.852 ***	0.818 ***	0.768 ***	0.938 ***	0.569 ***	0.757 ***	0.909 ***	0.516 ***	0.608 ***	0.484 ***
DfdWt	0.958 ***		0.958 ***	0.871 ***	0.842 ***	0.814 ***	0.720 ***	0.917 ***	0.492 ***	0.693 ***	0.869 ***	0.640 ***	0.606 ***	0.546 ***
EdWt	0.961 ***	0.981 ***		0.900 ***	0.885 ***	0.813 ***	0.761 ***	0.953 *	0.518 ***	0.730 ***	0.914 ***	0.484 ***	0.561 ***	0.465 **
BtWt	0.828 ***	0.874 ***	0.900 ***		0.854 ***	0.690 ***	0.571 ***	0.858 ***	0.289 ***	0.557 ***	0.804 ***	0.430 **	0.488 ***	0.447 **
TWt	0.694 ***	0.713 ***	0.766 ***	0.759 ***		0.729 ***	0.593 ***	0.837 ***	0.424 **	0.495 ***	0.853 ***	0.361 *	0.395 **	0.419 **
BaWt	0.930 ***	0.924 ***	0.918 ***	0.783 ***	0.652 ***		0.546 ***	0.776 ***	0.488 ***	0.575 ***	0.726 ***	0.398 **	0.503 ***	0.407 **
ShkWt	0.778 ***	0.779 ***	0.787 ***	0.621 ***	0.579 **	0.700 ***		0.729 ***	0.564 ***	0.707 ***	0.698 ***	0.514 ***	0.519 ***	0.382 **
WingWt	0.697 ***	0.807 ***	0.802 ***	0.684 ***	0.606 **	0.624 ***	0.722 ***		0.461 **	0.714 ***	0.843 ***	0.374 **	0.464 **	0.454 **
NkWt	0.761 ***	0.714 ***	0.714 ***	0.534 **	0.571 **	0.744 ***	0.563 **	0.495 **		0.506 ***	0.546 ***	0.176 ***	0.241 ***	0.265 ***
HeadWt	0.550 **	0.590 **	0.536 **	0.361 **	0.057 **	0.489 *	0.502 **	0.553 **	0.292 **		0.626 ***	0.389 **	0.484 ***	0.330 *
DkWt	0.951 ***	0.958 ***	0.971 ***	0.847 ***	0.711 ***	0.887 ***	0.777 ***	0.805 ***	0.711 ***	0.633 ***		0.504 ***	0.535 ***	0.479 ***
WGdWt	0.410 *	0.382 *	0.328 *	0.17 *	0.151 *	0.274 *	0.339 *	0.36 *	0.387 *	0.357 *	0.381 *		0.864 ***	0.215 ***
EGdWt	0.332 *	0.298 *	0.24 *	0.062 *	0.031 *	0.221 *	0.231 *	0.271 *	0.337 *	0.301 *	0.277 *	0.799 ***		0.189 ***
LrWt	0.439 *	0.457 *	0.417 *	0.356 *	0.418 *	0.406 *	0.459 *	0.473 *	0.292 *	0.276 *	0.395 *	0.173 *	0.045 *	
* (P<0.05), ** (P<0.01), *** (P<0.001), Female (lower diagonal), Male (upper diagonal)														

The scree plot is shown in Fig. 1. The scree plot is a criterion for selecting the actual number of components which would be retained for further analysis. The components having eigenvalue up to the bent of elbow in scree plot are generally considered (Dalal et al., 2020). Only the first two components have eigenvalues greater than 1. This accounts for 78% of the total variance. However, there is a small drop between components 2, 3 and 4. Components 5 through 14 appeared at the bottom of the plot. Component 1 to 7 accounts for 95.66% of the total variance.

The eigenvalues and shares of variance along with the rotated factor loading and communalities for the carcass traits of the meat line of FUNAAB Alpha Chicken Genotype at 8 weeks old are presented in Table 3. The communalities represents the estimates of variance for each variable accounted by the components. This ranged from 0.113 - 0.983 in the traits. The eigenvalues showed the number of variances out of the total variance explained by each factors. Seven principal components PC1 to PC7 was extracted. PC1 to PC7 contributed 95.66% while PC1 accounted for 68.68% of the total variance. Furthermore, the varimax rotation method of principal component analysis indicated that the carcass traits that contributed significantly to PC1 were bled weight, eviscerated weight, drumstick weight and wing weight, while PC2 displayed that whole gizzard

weight and empty gizzard contributed to the total variance. The communalities obtained for some traits were at high range. The highest was from liver weight while the lowest was from bled weight.

Table 3
Eigenvalues and shares of total variance along with rotated factor loading and communalities for carcass traits of meat line of FUNAAB Alpha Chicken Genotype at 8 weeks of age.

Traits	PC1	PC2	PC3	PC4	PC5	PC6	PC7	Communalities
Bled weight	0.317	-0.032	-0.001	-0.064	-0.028	0.082	-0.009	0.113
Defeathered weight	0.314	-0.052	-0.088	0.009	-0.024	0.128	-0.02	0.126
Eviscerated weight	0.316	-0.106	-0.099	-0.076	-0.091	0.007	0.004	0.135
Breast weight	0.275	-0.197	-0.423	0.02	-0.124	0.056	0.293	0.398
Thigh weight	0.26	-0.299	-0.32	-0.061	0.291	-0.341	0.044	0.466
Back weight	0.282	-0.104	-0.031	-0.147	0.071	0.568	-0.642	0.853
Shank weight	0.274	0.065	0.278	0.011	-0.099	-0.646	-0.531	0.866
Wing weight	0.295	-0.08	-0.032	0.088	-0.263	-0.134	0.073	0.195
Neck weight	0.218	-0.077	0.562	-0.48	0.481	0.055	0.307	0.928
Head weight	0.245	0.157	0.417	0.046	-0.619	0.133	0.24	0.719
Drumstick weight	0.306	-0.055	0.038	-0.051	-0.004	-0.041	0.227	0.154
Whole Gizzard weight	0.199	0.616	0.145	0.078	0.247	-0.163	0.08	0.540
Empty Gizzard weight	0.194	0.638	0.187	-0.039	0.107	0.171	-0.002	0.522
Liver weight	0.195	-0.123	0.272	0.845	0.344	0.146	0.051	0.983
Eigenvalue	9.614	1.305	0.712	0.681	0.546	0.332	0.199	
% Of Variation	68.6	9.3	5	4.8	3.9	2.3	1.4	95.3
Cumulative % of Variation	68.6	77.9	82.9	87.7	91.6	93.9	95.3	

The original inter-dependent carcass traits and the independent principal components (orthogonal) was used to determine bled weight of the chicken. This is seen in Table IV. Eviscerated weight accounts for 95% of variation observed in bled weight while inclusion of empty gizzard weight showed the same proportion of the explained variance, but with a lower Mallow's cp (17.11) compared to (26.73) in the first model. The model's accuracy was further improved $R^2 = 96\%$ when neck weight was added to the equation. The best prediction equation ($R^2 = 96.3\%$) was however obtained with a combination of eviscerated weight, neck weight, empty gizzard weight and liver weight. The highest single contributor ($R^2 = 95\%$) to the variation in bled weight of meat line FUNAAB Alpha chickens was eviscerated weight. In this present study, PC1 as a single predictor explains 96.4% of the total variability in bled weight of meat line FUNAAB Alpha chickens. However, a combination of PC1 and PC4 shows an improvement in the total variance explained ($R^2 = 96.7\%$) with a lower Mallow's cp (5.31)

Table 4
Stepwise multiple regression of carcass traits of meat line of FUNAAB Alpha Chicken Genotype at 8 weeks of age.

Model	Predictors	Models	C(p)	R2 %
Original carcass traits as predictors				
1	EdWt	BdWt = 149.33 + 1.10EdWt	26.73	95
2	EdWt, EGdWt	BdWt = 113.65 + 1.05EdWt + 2.45EGdWt	17.11	95
3	EdWt, NkWt, EGdWt	BdWt = 78.80 + 0.97EdWt + 1.56NkWt + 2.47EGdWt	8.61	96
4	EdWt, NkWt, EGdWt, LrWt	BdWt = 52.90 + 0.93EdWt + 1.53 NkWt + 2.53EGdWt + 2.64LrWt	5.48	96.3
Principal components as predictors				
1	PC1	BdWt = 1122.85 + 48.85PC1	9.05	96.4
2	PC1, PC4	BdWt = 1122.85 + 48.85PC1 - 9.89PC4	5.31	96.7

Discussion And Conclusion

Diverse factors which includes genetics, age, live weight and sex affects meat yield, composition and quality (Khan *et al.*, 2018). The present results showed sex associated differences in the carcass traits measured, with higher values found in the male FUNAAB Alpha chicken genotype. The apparent sex-related differences could be attributed to the average sex differential hormonal effects on the growth (Yakubu *et al.*, 2009a), and sexual dimorphism (Baeza *et al.*, 2001) of chicken. According to Van der Heide *et al.* (2016), genes for important economic traits may be differently expressed in males and females. The average bled weights observed in this study are lower compared to that of Akanno *et al.* (2007); Udeh and Ogbu (2011), who reported 1.88kg (Arbor Acre), 1.81kg (Ross) and 1.65kg (Marshal), this however could be due to the differences in the strain of birds used.

The positive relationship amongst bled weight and the carcass traits reveals that the weight can be predicted from the carcass traits in these chickens. Similar observations were made by Ajayi *et al.* (2008); Akporhwarho and Omoikhoje (2017). This asserts that the morphological traits are interrelated and indicate high predictability among the variables. Similar findings were reported by Udeh and Ogbu (2011), who opined that the correlation values revealed the pattern amongst the variables. Positive correlations of these traits suggest also that the traits are under the same gene action (pleiotropy) while selection for a trait might lead to a correlated response for the other traits (Yakubu *et al.*, 2009a; Adenaike *et al.*, 2015).

The PC approach reduced the fourteen variables into seven components for better description of carcass traits of FUNAAB Alpha chicken. PC1 had high loadings on bled weight, de-feathered weight, eviscerated weight and drumstick weight, this is largely associated with body size and accounts for 68% of the variations amongst the traits. Whole gizzard weight and empty gizzard weight were the major contributors to PC2, which can be associated with internal traits. Other PCs had low contributions to the total variation in the carcass traits. However, these PCs could be vital in evaluation of animals for breeding and selection purposes and these can be a criteria for improvement in the body weights of indigenous chickens (Ajayi *et al.*, 2012; Egena *et al.*, 2014; Vilakazi *et al.*, 2020). In this study, using PC1 as a single predictor explains 96.4% of the total variability in the carcass traits. This is lesser than the findings of Ajayi *et al.* (2012); Egena *et al.* (2014), who reported PC1 explaining 68.2 % of the variability in the body weights of indigenous Nigerian chickens. Combining PC1 and PC4 led to 0.3% ($R^2 = 96.7\%$) improvement in the variance explained in the chicken trait with a lesser Mallow's cp. The accuracy of the model improved greatly as the principal components were included as predictors of bled weight, whilst the variability in the interdependent variables used in weight estimation between sexes support the dimorphism expressed in the descriptive analysis. Principal component regression was seen to be applicable in this study in predicting the bled weight using orthogonal variable traits.

Declarations

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Authors Contribution: Wheto, M. was involved in conceptualisation, investigation, data collection and manuscript writing; Chima, N.G. was involved in the investigation, data collection and manuscript writing; Ojoawo, H.T. was involved in the data collection; Adeleke, M.A. was involved in investigation and data analysis; Peters, S.O. was involved in manuscript write up and corrections; Yakubu, A. was involved in data analysis and manuscript write up, Adebambo, A.O. was involved in investigation and correction of the manuscript, Adebambo, O.A. was involved in correction of manuscript and overall supervision.

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Figures

Figure 1
Scree plot of eigenvalues