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Application of Principal Components Factor Analysis in Quantifying Slaughter Weight and Carcass Characteristics of F1 Crosses between Marshal Parents Stock Broilers and Nigerian Normal Feathered Local Chickens

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Abstract

Slaughter weight and seven carcass characteristics namely dressed weight, eviscerated weight, wing weight, thigh weight, breast weight, back weight and neck weight of unsexed 200 f1 crossbred chicks were measured. The study aimed at describing objectively the interdependence among carcass characteristics and to predict slaughter weight from their independent factor scores using principal components analysis. Correlations between slaughter weight and carcass characteristics were positive and highly significant except neck weight. From the factor analysis with varimax rotation of the intercorrelated characteristics, two principal components were generated from the reciprocal crossbred chicks and only one principal component from the main crossbred which accounted for 93.96 and 91.64 percent of the total variance respectively. The first principal component reciprocal (Lc × Ex) crossbred PC1, termed general form, had its loadings for thigh weight, dress weight, back weight, wing weight and breast weight, and explained 74.08 percent of the variance. Neck weight primarily determined the second principal component, PC2, which contributed to 19.88% of the generalized variance. The first only principal component for main (Ex × Lc) crossbred chicks, PC1, had its loading for breast weight, dress weight, wing weight, thigh weight and neck weight and explained 91.64 percent of the total variance. Orthogonal carcass characteristics derived from the factor analysis accounted for 97.9 percent, 95.20 percent for main (Ex × Lc) crossbred and reciprocal (Lc × Ex) crossbred chicks respectively, of the variation in slaughter weight of f1 crossbred chickens. The principal component-based prediction model is preferable to original data set-based models for selecting animals for optimal balance.

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Introduction

The correlation between slaughter weight and carcass components is very important in the prediction of slaughter live body weight of animals. Ozoje and Mgbere (2002) reported that the final body weight of animals is a real reflection of the sum total of the weight of all its component parts. Consequently, when one of the component parts changes, positively or negatively, it affects the final slaughter weight of the animal and this depends on the direction of the change. According to Olutogun *et al.* (2003) and Egena *et al*., (2014), body dimension traits have a positive relationship with body weight.

Data obtained from such a relationship can be used by animal breeders for selecting breeding stock, (Isaac *et al.,* 2011), and also in predicting body weight without resulting in animal slaughter weight.

Most of the studies on the correlation between body characteristics and body weight use univariate analysis. This is limiting because bodyweight components are interrelated both genetically and phenotypically (Akanno and Ibe, 2005; Egena *et al*., 2011). The use of multivariate analysis considers the interdependence of traits in addition to their linear relationship. Factor analysis is a multivariate analysis used for extracting a smaller number of factors or unobservable variables that best explain most of the original data variability. Many researchers have used interdependent factors scores derived from the multivariate technique of factor analysis as predictors of the total carcass, bone, muscle and fat and other traits (Karacaoren and Kadarmideen, 2008 and Ogah (2012), and also as a selection criterion for the improvement of body size (Pinto *et al*., 2006).

In the humid tropical environment, the interrelationships among carcass traits and slaughter live body weight of chickens using a multivariate approach have not been fully exploited. Hence, this study was designed to establish the relationship between carcass characteristics and slaughter weight of F1 crosses of exotic broilers and Nigerian normal-feathered chickens.

Materials and methods

Study location

The research was conducted in the Poultry Breeding Unit of the Faculty of Agriculture. Delta State University, Asaba Campus. Asaba, Delta State. Nigeria. The area lies on longitude 60˚ 44" East and Latitude 60˚ 12" North. The mean annual rainfall ranges from 1800 to 3000 millimeters and this extends from April to October.

Experimental animals and their management

Eight hundred and thirteen-day old F1 crossbred chicks were generated from the crossing between exotic boilers and Nigerian normal- feathered chickens. Two hundred out of the 813 day old F1 crossbred chicks were separated using simple random techniques into two breeding groups with two replicate each of 50 birds. The birds were placed on optimum feeding for 22 weeks with a concentrate diet containing 18% CP and metabolizable energy of 2700 kcal/kg, and they were supplied with clean drinking water *ad libitum*. The medication was administered at regular intervals. After 22 weeks of age, twenty birds per replicate were selected randomly from each replicate, for carcass weight evaluation.

The birds were starved overnight and slaughtered by cutting their jugular veins the following morning. Ethical clearance for the chickens used for the experiment was done in agreement with the ethical guidelines and consideration of Delta state University, faculty of agriculture animal ethics committee on research animal.

Parameter measured

Carcass cuts traits included dress weight (DW) enviscerated weight (EW), wing weight (WW), Thigh weight (THW) Breast weight (BW), Back weight (BkW), and Neck weight (NW). Slaughter weights of the birds were also measured using a 5kg kitchen scale. A sensitive electronic salton emperor (1kg) scale was used to obtain other carcass cut data. For accurate data, the same person was used throughout to take all weight, thus eliminating errors due to personal differences.

Statistical analysis

Means, standard deviations and coefficients of variation of each variable were calculated. The correlation coefficients of live body weights and carcass traits were also computed. From the correlation matrix, data for the principal components factor analysis were determined in accordance to Everitt *et al.* (2001); principal components analysis is a system for transferring the variables in a multivariate data set $x_1, x_2, ..., x_p$, into new variables, $y_1, y_2...., y_p$ which are uncorrelated with each other and account for reducing proportions of the total variance of the original variables defined as:

$$Y_1 = a_{11}X_1 + a_{12}X_2 + ... + a_{1P}\,x\,p$$

$$Y_2 = a_2 X_1 + a_{22} X_2 + ... + a_{2P}\,x\,P$$

$$Y_p = a_{p1} X_1 + a_{p2} X_2 + ... + a_{pp}\,x\,p$$

With the coefficients being chosen so that $y_1, y_2, ..., y_p$ account for reducing proportions of the total variance of the original variables, $x_1, x_2, ... x_p$.

When evaluating, factors were rotated with verimax rotation of Kaiser (Data). The objective of the varimax rotation is to maximize the sum of the variance of aij^2 quadratic weight. The stepwise variable selection multiple regression procedure was used to obtain models for predicting live body weight from carcass traits (a) and established principal components (b)

$LBW = a+B_1 x_1 + ...B_k X_h.......$ (a)

$LBW = a+B_1 PC_1 + ... B_k P_{Ck}......$(b)

Where, LBW is the live body weight, a is the regression intercept, B_1 is the i-th partial regression coefficient of the i-th carcass traits, X_1 or the i-th principal component.The programme SPSS version 22 (2016) statistical package was used for the analysis.

Results and discussion

Slaughter weight and carcass characteristics

Table 1 shows the means and their corresponding standard errors, minimum and maximum values, and covariant percentages for all slaughter weights, dress weights, envicerated weights and carcass characteristics of the main (Ex × Lc) and reciprocal (Lc × Ex) crossbred chicks. The lowest variabilities were observed for slaughter weight, back, wing and neck weights for main crossbred (Ex × Lc) and reciprocal (Lc × Ex) crossbred chicks. The other characteristics had higher variabilities above 13 percent. This could be as a result of sire/dam breed effect from which the main (Ex ×Lc) and reciprocal (Lc × Ex) crossbred chicks resulted.

Table 1. Descriptive statistics Slaughter weight and carcass characteristics (g) of unsex F1 Crossbred Resulting from the Crossing of marshal parent strain of broiler (Ex × Ex) with Nigerian normal feathered local chickens (Lc × Ex) at 22 weeks of age.

Traits	Mean ± SE	Min	Max	CV%
LW	1.91±0.11	1.46	2.04	13.62
DW	1.81±0.13	1.32	1.97	15.47
EW	1.70±0.12	1.22	1.89	16.47
WW	0.34±0.20	0.26	0.38	14.71
THW	0.33±0.24	0.24	0.38	15.15
BW	0.22±0.02	0.15	0.26	18.18
BKW	0.21±0.02	0.16	0.24	14.29
NW	0.09±0.007	0.07	0.11	22.22
Lc × Ex				
LW	3.16±0.23	0.51	2.25	78.48
DW	2.96±0.23	0.52	2.03	76.35
EW	2.60±0.25	0.56	1.76	77.31
WW	0.60±0.06	0.13	0.42	93.33
YHW	0.79±0.08	0.17	0.52	78.48
BW	0.57±0.11	0.25	0.28	82.46
BKW	0.50±0.09	0.20	0.25	98.00
NW	0.16±0.01	0.02	0.13	50.00

SW = Slaughter weight; DW = Dress weight; EW = Enviscerated weight; WW = wing weight; THW = thigh weight; BW = Breast weight; BKW = Back weight and NW = Neck weight.

This means that in the main crosses the expected crossbreeding effects, as well as sire influence, were suppressed by the overpowering maternal influence in the resulting chicks. The average bodyweight of the F1from main crossbred at 22 weeks of age was 1.91kg as against 3.16kg in the reciprocal (Lc × Ex) crossbred chicks, which were comparable to those of Ayorinde (1991) obtained for exotic guinea fowls reared in Nigeria. Although the values recorded in this present study were lower than what Ogah (2012) and Dahouda *et al.* (2009) obtained from indigenous and exotic guinea fowl.

Table 2. Pearson's correlation matrix among carcass characteristics and live weight of main Ex × Lc crossbred (lower matrix) reciprocal Lc × Ex crossbred (upper matrix).

Traits	LW	DW	EW	WW	THW	BW	BW2	NW
SW		0.99**	0.91*	0.85	0.97**	0.87	0.74	0.06
DW	0.99**		0.91*	0.84	0.96*	0.86	0.74	0.06
EW	0.99**	0.98**		0.78	0.96*	0.88	0.68	0.24
WW	0.97**	0.97**	0.98**		0.91*	0.57	0.28	0.32
THW	0.93*	0.96**	0.98**	0.97**		0.85	0.82	0.19
BW	0.94*	0.97**	0.98**	0.97**	0.99**		0.91*	0.14
BKW	0.97**	0.97**	0.98**	0.99**	0.97**	0.96**		0.49
NW	0.78	0.71	0.68	0.69	0.53	0.56	0.72	

* Significant (P<0.05); ** highly significant (P<0.01); SW = Slaughter weight, DW = Dress weight; EW = Enviscerated weight; WW = wing weight; THW = thigh weight; BW2 = Breast weight; BKW = Back weight and NW = Neck weight.

The variation might be genetic or breed effect. The carcass weight value, thigh, wing and breast weights obtained in this study were similar to what Bochno *et al.* (1999) recorded in broilers.

Bivariate correlation

Pearson's coefficient of the correlation matrix for slaughter weight and carcass characteristics of the F1 crossbred chickens resulting from the crossing of Marshal Parent strains of broilers and Nigerians normal- feathered local chicken are presented in Table 2. All the carcass characteristics except neck weight showed positive and significant correlations with slaughter weight. Moreover, the highest correlation was observed between wing weight and breast weight, between live weight and dress weight and live weight and enviscerated weight in main Ex × Lc, crossbred (lower matrix). Similar observations have been reported by Raji *et al.* (2009), Alkan *et al.* (2010) and Ogah (2012) for different strains of Japanese quails and guinea fowl. The major areas where higher muscle deposition is found in the body of birds are the breast and the thigh, hence their high correlation with live weight. This observation indicates that selection for any of these carcass characteristics will lead to an improvement in the other. For the f1 reciprocal (Lc × Ex) crossbred chicks, relationships between most of the carcass characteristics were positive but not significant. Only envicerated weight and thigh weight showed positive and significant (P<0.05) correlation (upper matix).

Principal components matix

Table 3 presents the results of the factor analysis in the two strains of chickens. Two and one common factors (Varimax rotated independent factor) were identified in both reciprocal (Lc × Ex) and main (Ex × Lc) crossbred strains of chicks which corresponded to 93.96% and 91.64% of the total variability of the original eight variables in the reciprocal (Lc × Ex) and main (Ex × Lc) crossbreds, respectively. The first factor (PC1) (general form) was full of high positive loadings on most carcass characteristics except neck weight in the reciprocal (Lc × Ex) (0.14) and NW in main (Ex × Lc) (0.73). The first factor 'general form' accounted for 74.08% of the variance in reciprocal (Lc × Ex) and 91.64% in main (Ex×Lc) crossbred chickens.

Table 3. Eigen values and shares of total variance along with rotated factors loading and communalities for live weight of f1 Ex × Lc crosses and f1 reciprocal Lc × Ex crosses of crosses between Marshal parent strain of boiler and Nigerian normal feather local chickens.

	Lc × Ex			Ex × Lc	
Traits	Pc1	Pc2	Communality	Pc1	Communality
DW	0.97	0.16	0.97	0.99	0.99
EW	0.97	-0.04	0.94	0.99	0.99
WW	0.87	-0.33	0.88	0.99	0.98
THW	0.99	-0.07	0.99	0.97	0.94
BW	0.88	0.37	0.91	0.97	0.95
BKW	0.68	-0.70	0.95	0.99	0.98
NW	0.14	0.93	0.89	0.73	0.53
Eigen values	5.93	1.59		7.33	
% of variance	74.08	19.88	93.96	91.64	91.64
Cumulative % variance	74.08	93.95		91.64	

SW = Slaughter weight; DW = Dress weight; EW = Enviscerated weight; WW = wing weight; THW = thigh weight; BW = Breast weight; BKW = Back weight and NW = Neck weight.

The coefficients associated with the first factor THW dominated heavily in the reciprocal (Lc × Ex) crossbred chicks, while BW2 dominated heavily in the one factor of the main (Ex × Lc) crossbred chicks, respectively. These are indicators of slaughter live weight. The second factor in the reciprocal (Lc × Ex) crossbred chicks (NW) was also dominated heavily with high positive loading on all carcass characteristics other than BW2 (-0.70) which was the lowest. The result obtained in this present study is in accordance with those reported by Shahin *et aI.*, (1993). Shahin and Hassan (2000) and Yakubu and Ayoade (2009) in quantifying size, and morphological indices of domestic rabbits that the first factor (general form) explained the highest percentage of the total variance.

Table 4. Component score coefficient matrix for carcass characteristics of f1 reciprocal Lc × Ex and main Ex × Lc crosses of Marshal parent strains of broiler and Nigerian normal -feathered local chickens at 22 weeks of age.

	Lc × Ex component		Ex × Lc component
Traits	1	2	1
DW	0.16	0.04	0.14
EW	0.17	-0.08	0.14
WW	0.17	-0.26	0.14
THW	0.18	-0.10	0.13
BW	0.13	0.17	0.13
BKW	0.08	0.39	0.14
NW	0.08	-0.59	0.10

DW = Dress weight; EW = Enviscerated weight; WW = wing weight; THW = thigh weight; BW = Breast weight; BKW = Back weight and NW = Neck weight.

The communalities for the various carcass characteristics are presented in Table 3. The large commonalities (0.88 – 0.99) and (0.53 – 0.99) observed in reciprocal (Lc × Ex) and main (Ex × Lc) crossbreds respectively indicate that a larger number of variance has been accounted for by the factor solution. For thigh (THW) and wing weights (WW) in reciprocal (Lc × Ex) and main (Ex × Lc) crossbred, it means that about 99% of its variance was taken care of by the two principal components.

Table 5. Stepwise multiple regression of live weight on the original carcass characteristic and their principal component of f1 main Ex x Lc crossbred at 22 weeks of age.

Variables	Model	R^2 (%)	S.E
	Body measurements		
DW	LW = 0.27+0.91	9.79	0.03
DW,EW	LW = 0.27+0.91-0.84	9.89	0.03
DW,EW, WW	LW=0.27 + 0.91 – 0.84 – 0.07	9.89	0.03
DW, EW, WW, THW,	LW=0.27 + 0.91 – 0.84 – 0.07 – 0.34	9.89	0.03
DW, EW, WW, THW, BW	LW = 0.27 + 0.91 – 0.84 – 0.07 – 0.34 – 0.34	9.89	0.03
DW, EW,WW, THW, BW, BW2	LW =0.27 + 0.91 – 0.84 – 0.07 – 0.34 – 0.34 – 0.01	9.89	0.03
DW, EW WW THW BW BW2 NW	LW=0.27 + 0.91 – 0.84 – 0.07 – 0.34 – 0.01 + 0.15	9.89	0.03
	Orthogonal trait		
PC	LW = 1.91+0.25PC1	97.9	0.04

The PC1 and PC2 reciprocal (Lc × Ex), as well as the only PC1 main (Ex × Lc) crossbred, could be used for comparison and evaluation of animals. As long as the correlation between principal components is zero, the selection of animals for any principal component will not cause a correlated response in terms of other principal components (Pinto *et al.* 2006).

Prediction of slaughter live weight of crossbred chicks from interdependent carcass characteristics and their independent principal components

The interdependent carcass characteristics and their independent factor scores were used to predict slaughter weight of the crossbred chickens (Table 5 and 6). Dressed weight alone explained about 10% and 9% in main (Ex × Lc) and reciprocal (Lc × Ex) crossbred respectively of the variation in slaughter weight. When all the variables (envicerated weight, dressed weight, wing weight, thigh, weight, back weight, breast weight and neck weight) were added to the model, it accounted for 10% of the variability in live slaughter weight in both main (Ex × Lc) and reciprocal crossbred respectively. These results mean that live slaughter weight can be predicted with a fair degree of accuracy from carcass characteristics. Similar findings have been reported by other researchers (Wu *et al.*, 2008, Teguia *et al.*, 2008; Yakubu *et al.*, 2009). However, the use of the original seven carcass characteristics to predict slaughter live weight should be handled with care as a result of multicollinearity, which has been observed to be associated with unstable regression estimates (Ibe, 1989), thereby, leading to unreliable predictions. This is because the indices of the carcass characteristics, referred to as principal components for predictions, are orthogonal to each other.

Table 6. Stepwise multiple regression of live weight on the original carcass characteristic and their principal component of f1 reciprocal Lc × Ex crossbred at 22 weeks of age.

Variables	Model	R^2 (%)	S.E
	Body measurements		
DW	LW = 0.26 + 0.98	9.04	0.04
DW,EW	LW=0.26+0.98+0.00	9.95	0.05
DW,EW, WW	LW=0.26+0.98+0.00+0.05	9.95	0.04
DW, EW, WW, THW,	LW=0.26+0.98+0.00+0.05+0.13	9.95	0.04
DW, EW, WW, THW, BW	LW = 0.26+0.98+0.00+0.05+0.13+0.06	9.95	0.04
DW, EW,WW, THW, BW, BW2	LW =0.26+0.98+0.00+0.05+0.13+0.06+0.00	9.95	0.04
DW, EW WW THW BW BW2 NW	LW=0.26+0.98+0.00+0.05+0.13+0.06+0.00+0.01	9.95	0.04
	Orthogonal trait		
PC	LW = 3.16+0.05PC1+0.15 PC2	95.20	0.13

In this wise, when only PC1 main (Ex × Lc) crossbred was used to predict slaughter live weight, the coefficient of determination (R^2) was 98%; when PC1 and PC2 reciprocal were used together, it amounted to 95% of the total variation in live slaughter weight. All these regression models were significant at $P<0.05$.

Conclusion

The present principal components study provided a way for an objective description of the interdependence in the original seven carcass characteristics (dressed weight, eviscerated weight, wing weight, thigh weight, breast weight, back weight and neck weight) of f1 crossbred of chicken resulting from the crossing of an exotic broiler chicken and the Nigerian normal feathered chicken. The use of orthogonal carcass traits (PC1 and PC2 reciprocal and PC1 main crossbred) derived from principal component factor solution may be more reliable in predicting slaughter live body weight compared to the use of the original intercorrelated carcass characteristics. The reason is as a result of multicollinearity of an interdependent explanatory variable that may lead to erroneous inferences when the seven original carcass characteristics are used as predictors.

Conflict of Interest

The author declares that there is no conflict of interest.

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