Principal Components as Measures of Size and Shape in Nigerian Indigenous Chickens

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Abstract

The study aimed at describing objectively the interdependence among the morphological traits of Nigerian indigenous chickens and to predict body weight from their orthogonal body shape characters using principal component factor analysis. Body weight and eight body measurements namely, comb height, comb length, beak length, body length, neck length, shank length, chest circumference, and thigh circumference were measured on 238 randomly selected adult chickens of three genetic groups. The birds were extensively managed in Nasarawa State, north central Nigeria. General linear model was used to study genotype and sex effects. Frizzled birds had higher beak length and lower neck length compared to their normal feathered and naked neck counterparts. Sexual dimorphism was observed in all the traits with higher values recorded for males. Phenotypic correlations among body weight and biometric traits were positive and highly significant ($r = 0.56$-0.91, 0.61-0.91 and 0.55-0.96; $P<0.01$ for normal feathered, naked neck and frizzled chickens respectively). In factor solution of the principal component analysis, with varimax rotation of the transformation matrix, three factors were identified in each of the genetic group (ratio of variance = 87.84, 90.60 and 89.20 for normal feathered, naked neck and frizzled chickens respectively). The first factor in each case accounted for the greatest percentage of the total variation, and was termed general size. The subsequent factors (indices of body shape) presented patterns of variation independent of general size. The principal component based regression models, which are preferable for selecting animals for optimal balance, accounted for 85, 84 and 87% of the variation in the body weight of normal feathered, naked neck and frizzled chickens respectively.

Keywords: body weight, body dimensions, chickens, multivariate analysis

Introduction

Poultry keeping is of great importance to the human race, providing the teeming populace with a vital source of animal protein and income (Gueye et al., 1998; Gondwe, 2004), and plays a key role within the context of many social events. In tropical countries, poultry production is largely based on the traditional scavenging system and chickens are the most important poultry species. Village chickens are generally birds of indigenous breeds living in symbiotic relationship with human communities (Spradbrow, 1993). Out of a total of 72,400,856 chickens in Nigeria, 86.17% are free-range (RIM, 1992), kept mainly in the rural areas.

The indigenous chickens are repositories of unique genes that could be used in other parts of the world (Adebambo, 2004). Hence, the need for their conservation. This is to keep genetic variation within and between local breeds. The future improvement and sustainability of local chicken production systems is dependent on the availability of genetic variation (Benitez, 2002). According to FAO, a global strategy involves identifying and understanding a unique genetic resource in a particular region and to develop the proper use of the associated diversity (Franklin, 1997).

Characterisation of a breed of livestock is the first approach to a sustainable use of its animal genetic resource (Lanari, 2003). The first step of the characterisation of local genetic resources falls on the knowledge of the variation of morphological traits (Delgado et al., 2001). Morphometric measurements have been found useful in contrasting size and shape of animals (Mckracken et al., 2000; Latshaw and Bishop, 2001; Afolayan et al., 2006; Ajayi et al., 2008). However, correlations between body dimensions may be different if the dimensions are treated as bivariates rather than multivariates. This is because of the interrelatedness or lack of orthogonality (collinearity) of the explanatory variables. To address this limitation, multivariate analysis of data sets such as the use of principal component factor technique becomes imperative. Principal components are a weighted linear combination of correlated variables, explaining a maximal amount of variance of the variables (Truxillo, 2003). This aids in data reduction, and breaks multicollinearity which may lead to a wrong inference.

In spite of the rich genetic resource base of Nigerian indigenous chickens, there is dearth of information on its characterization using multivariate analysis. Therefore, the present study aimed at describing objectively body shape of Nigerian native chickens using principal component factor analysis. It equally investigated the hypothesis that relationships involving body measurements and body weight may be different when orthogonal conformation traits derived from the factor analysis are used instead of the intercorrelated original traits. The results so obtained may aid in the selection and genetic improvement of the native chickens.

Materials and Methods

Location of Study

The study was carried out in the three agricultural zones of Nasarawa State, which falls within the guinea savanna zone of north central Nigeria. It is located between latitude 07^0 52’N and $08^0$56’N and longitude 07^0 25’E and $09^0$31’N respectively.

Experimental Animals

Two hundred and thirty eight adult birds comprising 125 normal feathered (38 males and 87 females), 62 naked neck (23 males and 39 females) and 51 frizzled (25 males and 26 females) Nigerian indigenous chickens were randomly sampled between January and March, 2008. The birds were reared under the traditional scavenging system.

Measured Traits

Body weight and eight (8) morphometric traits were measured on each animal. The anatomical reference points were as described by Gueye et al. (1998) and Teguia et al. (2008). The parts measured were, comb height (CH); measured as distance between the point of attachment of the comb to the head and its highest point; comb length (CL); horizontal distance from the beginning to the end of the comb; beak length (BKL), measured as distance from the rectal apterium to the maxillary nail; body length (BL), length between the tip of the Rostrum maxillare (beak) and that of the Cauda (tail, without feathers); neck length (NL), distance between the occipital condyle and the cephalic borders of the coracoids; shank length (SL), distance from the shank joint to the extremity of the Digitus pedis; chest circumference (CC), taken under the wings at the edge of the sternum and thigh circumference (TC), measured as the circumference at the widest point of the thigh. All measurements were taken by the same person to avoid between-individual variations.

Statistical Analysis

Means, standard errors and coefficients of variation of body weight and linear body measurements were calculated. General linear model (GLM) was used to analyze genetic group and sex effects. Pearson’s 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 factor analysis. 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. Principal component analysis according to Everitt et al. (2001), is a method for transforming the variables in a multivariate data set into new variables, which are uncorrelated with each other and account for decreasing proportions of the total variance of the original variables. The components themselves are merely weighted linear combinations of the original variables. The varimax criterion of the orthogonal rotation method was employed in the rotation of the factor matrix to enhance the interpretability of the principal components.

The first principal component can be expressed as follows:

$Y_1 = a_{11}X_1 + a_{21}X_2 +$ ---------------$+ a_{p1}X_p$

Or 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 combination. The variance of Y_1 is λ_1.

Next, principal component Y_2 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,

$a_1'a_2 = 0$

Components are extracted until some stopping criteria is encountered or until p components are formed. The weights used to create the principal components are the eigenvectors of the characteristic equation:

$(S-\lambda_i I)a = 0$, or

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

Where, S is the covariance matrix and R is the correlation matrix. The λ_i are the eigenvalues, the variances of the components. The eigenvalues are obtained by solving $|S-\lambda_i I| = 0$ for λ_i.

The stepwise multiple regression procedure was used to obtain models for predicting body weight from body measurements (a) and from principal component factor scores (b):

$BW = a + B_i X_i +$ -----------$+ B_k X_k$ ---------- (a)

$BW = a + B_i PC_i +$ ----------$+ B_k PC_k$ ----------- (b)

where,

BW is the body weight, a is the regression intercept, B_i is the i-th partial regression coefficient of the i-th linear body measurement, X_i or the i-th principal component (PC).

Cumulative proportion of variance criterion was employed in determining the number of principal components to extract. The overall reliability of the factor solution was tested using Chronbach's Alpha. The factor programme of SPSS (2001) statistical package was used for the principal component analysis.

Results and Discussion

Morphological Traits

The means (±SE) and coefficients of variation of body weight and biometric traits of the three genetic groups and sexes investigated are presented in Table 1. Genotype had significant ($P < 0.05$) effect on beak length and neck length only. Frizzled birds had higher beak length (2.13 versus 1.94 and 2.00cm respectively) and lower neck length (7.58 versus 8.73 and 8.20cm respectively) compared to their naked neck and normal feathered counterparts. The genetic groups appeared similar in comb height, comb length, body length, shank length, chest circumference and thigh circumference. The present values are comparable to those reported by Fayeye et al. (2006). However, Patra et al. (2002) reported that naked neck chickens have heavier body weight compared to their normal feathered counterparts. Similarly, Galal (2000) reported the superiority of naked neck and frizzled genes over normal feathered chickens in boy weight, shank length and comb length. Sex-associated ($P < 0.05$) differences were observed in all the traits measured, with superior values recorded for male birds. These apparent sex- related differences might be attributed to the usual between- sex differential hormonal effects on growth. This is consistent with the findings of Hancock et al. (1994) and Deeb and Cahaner (2001). In a related study, Baeza et al. (2001) attributed the differences between male and female ducks to sexual dimorphism.

Table 1 Means, standard errors (SE) and coefficients of variation (CV) for body weight (kg) and body measurements (cm) of Nigerian indigenous chickens according to genotype and sex.

Trait	Normal feathered bird (n=125)		Naked neck bird (n=62)		Frizzled bird (n=51)		Male chicken (n = 86)		Female chicken (n = 152)	
	Mean (±SE)	CV	Mean (±SE)	CV	Mean (±SE)	CV	Mean (±SE)	CV	Mean (±SE)	CV
Body weight	1.25± 0.02[a]	21.60	1.26±0.03[a]	21.43	1.26±0.04[a]	24.60	1.37±0.04[a]	24.26	1.19±0.02[b]	17.65
Com height	1.64±0.09[a]	60.36	1.65±0.12[a]	55.49	1.57±0.15[a]	69.43	2.17±0.12[a]	52.53	1.32±0.06[b]	56.06
Comb length	3.22±0.16[a]	54.04	3.09±0.21[a]	52.75	3.11±0.24[a]	54.98	3.97±0.22[a]	52.01	2.70±0.10[b]	45.56
Beak length	2.00±0.03[b]	14.00	1.94±0.04[b]	14.95	2.13±0.04[a]	12.21	2.12±0.04[a]	16.98	1.95±0.02[b]	11.28
Body length	27.27±0.27[a]	10.85	27.50±0.36[a]	10.18	27.23±0.46[a]	12.16	28.67±0.40[a]	13.01	26.56±0.17[b]	8.09
Neck length	8.20±0.17[a]	22.80	8.73±0.20[a]	18.10	7.58±0.27[b]	25.59	8.90±0.24[a]	24.61	7.81±0.12[b]	19.21
Shank length	6.36±0.07[a]	12.89	6.44±0.12[a]	14.44	6.42±0.11[a]	11.84	6.65±0.12[a]	16.69	6.25±0.05[b]	9.28
Chest circumference	26.21±0.29[a]	12.37	26.04±0.39[a]	11.90	26.79±0.50[a]	13.29	27.42±0.44[a]	14.88	25.65±0.20[b]	9.79
Thigh circumference	7.66±0.19[a]	28.20	7.74±0.27[a]	27.52	7.86±0.33[a]	29.90	8.78±0.28[a]	24.09	7.13±0.13[b]	17.65

Means in the same row bearing the same superscripts do not differ significantly (P>0.05).

Bivariate Correlations

Coefficients of correlation of body weight and body measurements of the three genetic groups are presented in Table 2. Highly significant ($P < 0.01$) association existed among body weight and zoometrical traits of the birds. The coefficients ranged from 0.56-0.91, 0.61-0.91 and 0.55-0.96 for normal feathered, naked neck and frizzled chickens respectively. Among the body shape characters, the highest correlation was found between comb height and comb length ($r = 0.95$) in normal feathered, body length and chest circumference ($r = 0.96$) in naked neck and comb height and comb length ($r = 0.94$) in frizzled chickens respectively. The estimates of correlation in the present study are comparable to those reported by earlier workers (Gueye et al., 1998; Yang et al., 2006). The strong relationship existing between body weight and body measurements may be useful as selection criterion, since positive correlations of traits suggest that the traits are under the same gene action (Pleiotropy). This, therefore, provides a basis for the genetic manipulation and improvement of the native stock.

Principal Component Matrix

Anti – image correlations computed showed that partial correlations were low, indicating that true factors existed in the data. This was buttressed 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 (0.87, 0.89 and 0.83 for normal feathered, naked neck and frizzled chickens respectively). The overall significance of the correlation matrices tested with Bartlett's Test of Sphericity for the body measurements of normal feathered (chi-square =1100.86; $P < 0.01$), naked neck (chi-square =595.44; $P < 0.01$) and frizzled birds (chi square =457.41; $P < 0.01$) provided support for the validity of the factor analysis of the data sets. The communalities, which represent the proportion of the variance in the original variables that is accounted for by the factor solution ranged from 0.759-0.967, 0.849-0.991 and 0.831-0.944 for the three genetic groups respectively. This further lent credence to the appropriateness of the principal component factor analysis. The ratio of cases to variables (26 to 1 far exceeded the minimum of 5 to 1 standard) was also met as sample size requirement. The Chronbach's Alpha (0.75, 0.75 and 0.77 for normal feathered, naked neck and frizzled chickens respectively) revealed the reliability of the factor solution.

Principal component analysis revealed three discernable patterns of variation in the three genetic groups (Table 3). In normal feathered birds, the first principal component (PCI) accounted for

Table 2 Phenotypic correlations among body weight and linear type traits of Nigerian local chickens[1/].

Trait	BW	CH	CL	BKL	BL	NL	SL	CC	TC
Normal Feathered birds									
BW	-	0.84	0.80	0.56	0.91	0.67	0.77	0.81	0.91
CH	-	-	0.95	0.54	0.83	0.70	0.70	0.68	0.83
CL	-	-	-	0.55	0.79	0.65	0.71	0.70	0.82
BKL	-	-	-	-	0.57	0.40	0.51	0.63	0.53
BL	--	-	-	-	-	0.73	0.78	0.85	0.90
NL	-	-	-	-	-	-	0.65	0.56	0.71
SL	-	-	-	-	-	-	-	0.72	0.77
CC	-	-	-	-	-	-	-	-	0.75
Naked Neck birds									
BW	-	0.82	0.76	0.61	0.89	0.63	0.85	0.91	0.87
CH	-	-	0.93	0.61	0.82	0.70	0.79	0.83	0.82
CL	-	-	-	0.58	0.82	0.68	0.75	0.83	0.80
BKL	-	-	-	-	0.56	0.50	0.55	0.58	0.53
BL	-	-	-	-	-	0.70	0.83	0.96	0.87
NL	-	-	-	-	-	-	0.77	0.65	0.70
SL	-	-	-	-	-	-	-	0.85	0.78
CC	-	-	-	-	-	-	-	-	0.87
Frizzled birds									
BW	-	0.85	0.81	0.55	0.91	0.77	0.75	0.73	0.96
CH	-	-	0.94	0.60	0.81	0.77	0.69	0.54	0.84
CL	-	-	-	0.62	0.74	0.70	0.70	0.57	0.79
BKL	-	-	-	-	0.68	0.69	0.63	0.74	0.56
BL	-	-	-	-	-	0.81	0.74	0.77	0.91
NL	-	-	-	-	-	-	0.56	0.63	0.81
SL	-	-	-	-	-	-	-	0.59	0.74
CC	-	-	-	-	-	-	-	-	0.65

[1/] Significant at $P<0.01$ for all correlation coefficients; BW= Body weight, CH= Comb height, CL= Comb length, BKL= Beak length, BL= Body length, NL= Neck length, SL= Shank length, CC= Chest circumference, TC= Thigh circumference

73.94% of observed variation (eigenvalue = 5.92) and was related to overall body size, as indicated by the eigenvectors (factor-variate correlations) of all the eight body measurements. The second component (PC2) contributed to 8.57% of observed morphometric variation (eigenvalue = 0.69). The variables most associated with PC2 were comb height and comb length, hence PC2 could be termed “comb measurements”. The third component (PC3) accounted for an additional 5.33% of the total variation (eigenvalue = 0.43) and had its loading for beak length. In naked neck birds, PC1 which explained 77.66% of the generalized variance, was determined by comb height, comb length, body length, shank length, chest circumference and thigh circumference. PC2 was primarily determined by neck length, contributing to 7.45% of the variation while PC3 was influenced greatly by beak length with an additional 5.49% contribution to the total variation. Measurements most highly correlated with PCI (74.68% of the total variation) in frizzled chickens were comb height, comb length, body length, neck length and thigh circumference. PC2 was characterized by beak length and chest circumference, explaining 8.94% of the variance, while PC3 was primarily determined by shank length making up an additional 5.58% of the generalized variance.

While PC1 contrasted large or small in terms of general body size, subsequent factors presented patterns of variation independent of size (shape components). The present findings are consistent

Table 3 Eigenvalues and share of total variance along with factor loadings after rotation and communalities of the biometric traits of chickens.

	PC1	PC2	PC3	Communality
Normal feathered bird				
Comb height	0.408	0.848	0.285	0.967
Comb length	0.379	0.834	0.327	0.946
Beak length	0.191	0.253	0.904	0.918
Body length	0.726	0.503	0.362	0.911
Neck length	0.707	0.508	0.013	0.759
Shank length	0.782	0.315	0.314	0.809
Chest circumference	0.670	0.275	0.573	0.853
Thigh circumference	0.641	0.608	0.290	0.865
Eigenvalues	5.92	0.69	0.43	
% of total variance	73.94	8.57	5.33	
Naked neck bird				
Comb height	0.788	0.351	0.359	0.873
Comb length	0.809	0.304	0.26	0.853
Beak length	0.300	0.204	0.927	0.911
Body length	0.861	0.354	0.224	0.916
Neck length	0.390	0.880	0.219	0.974
Shank length	0.677	0.581	0.231	0.849
Chest circumference	0.888	0.283	0.254	0.933
Thigh circumference	0.821	0.375	0.208	0.858
Eigenvalues	0.788	0.351	0.359	0.873
% of total variance	0.809	0.304	0.26	0.853
Frizzled bird				
Comb height	0.855	0.229	0.391	0.936
Comb length	0.776	0.245	0.460	0.874
Beak length	0.298	0.817	0.275	0.831
Body length	0.679	0.566	0.323	0.885
Neck length	0.787	0.540	-0.002	0.912
Shank length	0.380	0.377	0.811	0.944
Chest circumference	0.288	0.855	0.240	0.871
Thigh circumference	0.791	0.365	0.351	0.882
Eigenvalues	5.98	0.72	0.45	
% of total variance	74.68	8.94	5.58	

with those reported by McCracken et al. (2000) in musk ducks and ruminants (Yakubu, 2009; Yakubu et al., 2009) where PC1 was termed overall body size. Similarly, Shahin and Hassan (2000) and Kashiwamura et al. (2001) reported that the first factor accounted for the largest variance in rabbits and horses respectively. The three principal components obtained for each of the genetic group in the present study could be important in evaluating animals for breeding and selection purposes. Since the correlation between principal components is zero, the selection of animals for any principal component will not cause correlated response in terms of other principal components (Pinto et al., 2006). This is buttressed by the report of Yamaki et al. (2006) who used principal component analysis to identify independent and informative variables thereby eliminating redundant information for the purpose of reducing costs of quails' genetic programmes.

Principal Component Factor Scores

The principal component factor score coefficients of normal feathered, naked neck and frizzled chickens are presented in Table 4. These factor scores could be used instead of the original interdependent linear type traits in estimating the body weight of chickens.

Prediction of Body Weight of Chickens from Interdependent Body Measurements and Their Independent Principal Component Factor Scores

The interdependent original body dimensions and their independent principal component factor scores were used to predict body weight of chickens (Table 5). The results of the stepwise multiple regression analysis in normal feathered birds revealed that body length alone accounted for 83% of the variation in body weight. The inclusion of thigh circumference in the model increased the proportion of the explained variance to 87%. The accuracy of the model was further improved (R^2= 89%) when comb height and chest circumference were added to the equation. In naked neck birds, chest circumference alone contributed to 83% of the variation in body weight. The best prediction equation (R^2 = 0.87) was however obtained with a combination of chest circumference, thigh circumference and shank length. The highest single contributor (R^2 = 0.91) to the variation in body weight of frizzled chickens was thigh circumference. However, the proportion of the explained variance progressively increased to 0.96 when chest circumference, comb height and beak length were added to the model. The present findings are consistent with the submissions of Peters et al. (2006) in chickens and Teguia et al. (2008) in ducks.

To increase the meat yield and egg production of chickens requires the genetic improvement of body weight. Proper measurement of this variable, which is often hard in villages due to lack of weighing scales, is a requisite for achieving this goal. Hence, the use of more easily measurable linear body measurements, which are more relevant for on-farm within herd use. However, 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. This justifies the use of indices of the morphological traits, referred to as principal components, for prediction. These principal components are orthogonal to each other and are more reliable in weight estimation. In the present study, the use of PC1 as a single predictor, explained 42, 65 and 56% of the total variability in body weight in normal feathered, naked neck and frizzled birds respectively. However, a combination of PC1, PC2 and PC3 gave a considerable improvement in the amount of variance explained (R^2 = 0.85, 0.84 and 0.87 for normal feathered,

Table 4 Principal Component factor score coefficients for the prediction of the body weight of chickens.

Trait	Normal feathered bird			Naked neck bird			Frizzled bird		
	PC1	PC2	PC3	PC1	PC2	PC3	PC1	PC2	PC3
Comb height	-0.391	0.718	-0.065	0.218	-0.121	0.085	0.417	-0.304	0.061
Com length	-0.434	0.714	0.002	0.290	-0.215	0.040	0.289	-0.278	0.240
Beak length	-0.367	-0.088	0.956	-0.325	-0.134	1.178	-0.288	0.590	0.010
Body length	0.334	-0.096	-0.005	0.337	-0.140	-0.147	0.147	0.143	-0.070
Neck length	0.451	0.029	-0.426	-0.496	1.195	-0.088	0.480	0.188	-0.742
Shank length	0.610	-0.400	-0.033	-0.010	0.418	-0.116	-0.377	-0.091	1.117
Chest circumference	0.391	-0.424	0.343	0.406	-0.298	-0.095	-0.290	0.646	-0.064
Thigh circumference	0.148	0.155	-0.087	0.293	-0.065	-0.158	0.322	-0.122	-0.020

Table 5 Stepwise multiple regression of body weight on original body measurements and on their principal component (PC) factor scores in chickens.

Model	Explanatory variable (predictors)	Intercept	Regression coefficient	Standard error	R^2
Normal feathered birds					
(i)	Original body measurements as explanatory variables				
1	Body length	-1.02	0.03	0.00	0.83
2	Body length	-0.43	0.05	0.01	0.87
	Thigh circumference		0.06	0.01	
3	Body length	-0.26	0.04	0.01	0.88
	Thigh circumference		0.05	0.01	
	Comb height		0.04	0.02	
4	Body length	0.24	0.03	0.01	0.89
	Thigh circumference		0.05	0.01	
	Comb height		0.05	0.02	
	Chest circumference		0.01	0.01	
(ii)	Orthogonal traits as Explanatory variables				
1	PC1	1.25	0.17	0.02	0.42
2	PC1	1.25	0.17	0.01	0.72
	PC2		0.15	0.01	
3	PC1	1.25	0.17	0.01	0.85
	PC2		0.15	0.01	
	PC3		0.10	0.01	
Naked neck birds					
(i)	Original body measurements as explanatory variables				
1	Chest circumference	-0.77	0.08	0.01	0.83
2	Chest circumference	-0.47	0.06	0.01	0.85
	Thigh circumference		0.04	0.01	
3	Chest circumference	-0.50	0.04	0.01	0.87
	Thigh circumference		0.03	0.01	
	Shank length		0.07	0.03	
(ii)	Orthogonal traits as explanatory variables				
1	PC1	1.26	0.22	0.02	0.65
2	PC1	1.26	0.22	0.02	0.75
	PC3		0.08	0.02	
3	PC1	1.26	0.22	0.01	0.84
	PC2		0.08	0.01	
	PC3		0.08	0.01	
Frizzled birds					
(i)	Original body measurements as explanatory variables				
1	Thigh circumference	0.28	0.13	0.01	0.91
2	Thigh circumference	-0.05	0.11	0.01	0.94
	Chest circumference		0.02	0.00	
3	Thigh circumference	0.02	0.09	0.01	0.95
	Chest circumference		0.02	0.00	
	Comb height		0.05	0.02	
4	Thigh circumference	0.24	0.08	0.01	0.96
	Chest circumference		0.03	0.00	
	Comb height		0.08	0.02	
	Beak length		-0.24	0.05	
(ii)	Orthogonal traits as explanatory variables				
1	PC1	1.26	0.23	0.03	0.56
2	PC1	1.26	0.23	0.02	0.73
	PC2		0.13	0.02	
3	PC1	1.26	0.23	0.02	0.87
	PC2		0.13	0.02	
	PC3		0.12	0.02	

naked neck and frizzled chickens respectively). Similarly, Shahin and Hassan (2000) derived regression equations for estimating live weight of rabbits using independent factor scores. In another related study, McCracken et al. (2000) obtained a single linear model involving principal component scores and capture methods and sex of musk ducks; while Keskin et al. (2007) used factor scores derived from ten body measurements to predict the carcass weight of sheep.

Conclusions

The principal component analysis technique explored the interdependence in the original eight morphometric traits (comb height, comb length, beak length, body length, neck length, shank length, chest circumference and thigh circumference) of normal feathered, naked neck and frizzled chickens. This led to an objective simultaneous analysis of these body measurements rather than on individual basis. The resultant three principal components in each genetic group could aid in selection and breeding programmes of the native birds. The use of independent orthogonal indices (PC1, PC2 and PC3) was more appropriate than the use of the original interrelated linear type traits for predicting the body weight of chickens. This is because multicollinearity of two or more interdependent original body measurements could lead to unstable regression coefficients, hence erroneous inference.

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Manuscript received 10 September 2009, accepted 30 October 2009