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Principal component and stepwise discriminant analysis of the morphometric traits of three dual-purpose breeds of chicken

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Target Audience: Animal geneticists, poultry producers, policy makers

Abstract

Using the principal component procedure of SAS, 10 variables; body weight (BW), body length (BL), breast girth (BG), shank length (SL), thigh length (TL), comb length (CL), comb height (CH), wing length (WL), wattle length (WAL) and wattle thickness (WT) obtained from three dual-purpose chicken breeds (Shika, Kuroiler, and Sasso), variables were separated. Similarly, stepwise discriminant analsis procedure of the SAS software was employed to evaluate variables that contribute to the overall differences in breeds. Results showed three principal components (PC1, PC2 and PC3) were extracted for all the breeds and pooled data. 45.60% of total variance was accounted for by PC1, 28.17% by PC2 and 16.22% by PC3. The principal components partitioning of total variance were 50.80, 15.10 and 9.70%, 50.82, 19.90 and 14.90%, and 48.63, 14.00 and 12.67% for Shika, Kuroiler, and Sasso breeds respectively, with different factor loadings. Communalities ranged from 0.43-0.97, 0.45-0.83, 0.45-0.88 and 0.45-0.90, indicating that a good amount of variance was accounted for. Stepwise discriminant analysis indicated that seven morphometric traits, TL, SL, WAL, WL, CL, CH and BL, contributed significantly ($P<0.001$) to the separation of the birds into breeds. TL and SL, however, indicated higher discriminating power compared to others. The principal component analysis allowed for better understanding of the complex correlations among traits and reduced the number of traits along with high communalities, using only PC1, PC2 and PC3the first three PCs, without loss of information. Summary of stepwise discriminant analysis shows that lengthwise measures of long bones of the body of chickens, such as thigh and shank, are viable metrics for phenotypic differentiation of birds in the studied population.

Key Words: Principal Component, Stepwise discriminant Analysis, Morphometric traits, chickens

Description of Problem

Genetic diversity is evaluated using morphological, morphometric, biochemical and molecular characterisation methods. Molecular characterization method requires expensive technology and allows the assessment of environmental influence on traits (1). In addition, some morphological characters and morphometric traits are correlated with body weight (1, 2) therefore, morphometric traits could be used as markers in body weight improvement programmes and as body weight predictors. Traditional linear regression yields less reliable results due to multicollinearity, in characterisation and prediction under univariate assumption. On the other hand, multivariate techniques (such as principal component, multivariate regression, and canonical correlation analysis) yield more reliable prediction and classification in farm animals (3).

Morphometric traits are the quantitative description of the structure, shape, and size of an organism. The derivation of body weight from body measurements (i.e., morphometric traits) has been reported to be a practical and easy technique, especially among rural poultry breeders with lack of resources (4, 5) reported that morphometric traits such as shank length and diameter were indicators of leg development while body girth was an indicator of breast development.

Aside its use as an indicator of body weight, morphometric traits can further be used to develop breeding strategies via optimum combination of body measurements (6) to achieve maximum body weight and economic returns. Phenotypic correlation estimates between body weight and morphometric traits could guide the breeder in the choice of body size traits to incorporate into his selection index. Nigeria has an estimated 175 million highly heterogeneous chicken populations of which the local chicken accounts for more than 60 percent (7). The genetic resource base of indigenous chicken in Nigeria and other tropical countries is rich and should form the basis for genetic improvement and development of new breeds. This study is aimed at morphologically classifying breeds of chicken used in the study based on their morphometric measurements.

Materials and Methods

The data used for this study was collected from 3000 dual purpose chicken genotypes (1000 each of Shika, Kuroiler and Sasso strains) raised as experimental birds at Landmark University Teaching and Research Farm, Omu Aran, Kwara State. The Teaching and Research Farm is located at latitude 8° 8' 0" North and longitude 5° 6' 0“ East, 427m above sea level in the guinea savannah zone of Nigeria.

The traits studied were body weight, body length, breast girth, shank length, thigh length, comb length, comb height, wing Length, wattle length and height. Body weight were taken by direct measurement using digital kitchen scale in Kg, while metric variables were measured using graduated flexible tape in centimeter, as outlined by (8, 9). The obtained variables were separated to their principal components on breed basis as well as and pooled using the princomp procedure of (10). Morphometric variables were subjected to factor analysis based on principal components analysis to identify the characteristics that best suited the breed characterization. The number of factors were established based on eigenvalues which explained a minimum of 70% of accumulated variation. Those with a value < 70% were discarded, according to the (11). Also the Stepdisc procedure was employed in the discrimination of measured variable to evaluate variables that contributed to the overall differences in breeds.

Results and Discussion

Principal component analysis pooled for all breeds is presented in Table 1 three principal components (PC1, PC2 and PC3) were extracted in this table, 45.60% of total variance was accounted for by PC1, 28.17% by

PC2 and 16.22% by PC3. Communalities ranged from 0.43-0.97.

The first component (PC1) gave loadings of Body weight, Breast girth and Body length as the principal variable, PC2 retained high loadings for wing length and PC3 for wattle length respectively in the pooled analysis.

Table 2 shows the Principal Component (PC) analysis for the Shika breed where PC partitioning of total variance were 50.80%, 15.10% and 9.70% respectively, while Communalities ranged 0.45-0.83.

In this breed, PC1 gave loadings of Body weight, Shank Length, Thigh Length and Body Length, PC2 loaded Comb length and Thigh Length and PC3 showed loadings of Wattle length.

Table 3 shows PC partitioning In the Kuroiler breed partitioning of total variation were 50.82, 19.90 and 14.90% respectively and Communalities ranged from 0.45-0.88.

Also for the Kuroiler, PC1 loadings were wing length, Body weight, Thigh Length and Body Length; PC2 gave loadings of Wattle length and PC3 loaded for Wing Length.

Total variation were partitioned as 48.63%, 14.00% and 12.67% in Table 3 for the Sasso breed. Communalities ranged from 0.45-0.90.

The Sasso breed showed loadings of Body weight , Breast girth, Wattle height and Body Length in PC1, Wing length and Shank Length in PC2 and Wattle height in PC3.

All these indicated that a good amount of variance was accounted for by the component solution. Similar high communalities have been reported by (12) in Nigerian indigenous chickens raised under extensive management system and in different breeds of broiler chickens (13, 2).

The extraction of three components differed from those of (14) where they extracted two components from three genotypes of Nigerian indigenous chickens; however, the proportions of variance that PC1 and PC2 accounted for in their work (42.53% and 31.40) were similar to 45.60% and 28.17% obtained in this study. Worthy of note is that the morphological traits that contributed to the variability of the three principal components were different and no commonality were obtained in the pooled dataset, but existed within the breeds. The numbers of traits that contributed significantly to the variability observed in each component were low compared to those obtained by (14). Our results also differed from the reports of four PC in helmeted Guinea fowl (15) but agreed with the results of (16) who worked on phenotypic characterization of the indigenous chickens in the northwest of Algeria.

The present findings are consistent with the reports in literature, in which general size is reported as the main factor of variation and thus constitutive of the first axis of PCA in chickens, rabbits, or turkeys (17, 2, 12). The principal component analysis allowed for better understanding of the complex correlations among the traits and reduced the number of traits, using only the three first PCs (without loss of information.

Table 1: Eigenvalues, total variance plus factor loading and communalities for ten linear body measurements pooled for three dual-purpose chicken breeds

Variables	PC1	PC2	PC3	Communality
Body weight (kg)	**0.87**	0.54	-0.10	0.85
Comb length (cm)	-0.26	0.21	0.06	0.80
Comb height (cm)	-0.11	0.53	-0.06	0.93
Breast girth (cm)	**0.91**	0.30	0.46	0.76
Wing Length (cm)	0.21	**0.72**	-0.05	0.56
Wattle length (cm)	0.50	-0.06	**0.85**	0.50
Wattle height (cm)	0.05	0.07	0.61	0.97
Shank length (cm)	0.54	0.70	-0.10	0.83
Thigh length (cm)	0.57	0.80	0.01	0.43
Body Length (cm)	**0.76**	-0.12	0.62	0.65
Eigenvalue	4.56	2.31	1.33	
Percentage of variance	0.46	0.28	0.16	

Table 2: Eigenvalues and share of total variance along with factor loading and communalities for ten linear body measurements pooled for Shika breed.

Variables	PC1	PC2	PC3	Communality
Body weight (kg)	**0.76**	-0.32	0.43	0.59
Comb length (cm)	-0.04	**0.80**	-0.41	0.45
Comb height (cm)	0.37	0.12	0.29	0.76
Breast girth (cm)	0.81	0.19	-0.22	0.79
Wing Length (cm)	0.15	0.35	0.28	0.83
Wattle length (cm)	0.09	0.25	**0.78**	0.62
Wattle height (cm)	0.54	0.03	-0.04	0.61
Shank length (cm)	**0.92**	0.55	0.05	0.77
Thigh length (cm)	**0.86**	**0.91**	-0.07	0.80
Body Length (cm)	**0.75**	-0.02	-0.53	0.77
Eigen value	3.86	1.45	0.93	
Percentage of variance	0.51	0.15	0.09	

Table 3: Eigenvalues and share of total variance along with factor loading and communalities for ten linear body measurements pooled for Kuroiler breed.

Variables	PC1	PC2	PC3	Communality
Body weight (kg)	-0.26	0.43	0.09	0.86
Comb length (cm)	-0.47	0.10	-0.04	0.45
Comb height (cm)	-0.23	0.04	0.45	0.67
Breast girth (cm)	**0.85**	-0.12	0.21	0.56
Wing Length (cm)	0.06	0.43	**0.73**	0.73
Wattle length (cm)	**0.81**	**0.74**	0.40	0.88
Wattle height (cm)	0.27	0.42	-0.38	0.72
Shank length (cm)	-0.21	0.46	-0.25	0.75
Thigh length (cm)	**0.75**	0.43	0.49	0.66
Body Length (cm)	**0.94**	0.13	-0.37	0.58
Eigen value	4.32	1.89	1.34	
Percentage of variance	0.51	0.20	0.15	

Table 4: Eigenvalues and share of total variance along with factor loading and communalities for ten linear body measurements pooled for Sasso breed.

Variables	PC1	PC2	PC3	Communality
Body weight (kg)	**0.70**	0.00	0.00	0.55
Comb length (cm)	0.04	-0.27	-0.02	0.67
Comb height (cm)	0.51	-0.15	0.37	0.87
Breast girth (cm)	**0.74**	-0.03	0.37	0.58
Wing Length (cm)	-0.11	**0.70**	-0.09	0.75
Wattle length (cm)	0.05	-0.36	0.59	0.72
Wattle height (cm)	**0.83**	0.37	**0.74**	0.83
Shank length (cm)	0.56	**0.77**	0.13	0.90
Thigh length (cm)	-0.25	0.30	0.54	0.45
Body Length (cm)	**0.93**	-0.47	-0.13	0.54
Eigenvalue	3.89	1.12	0.76	
Percentage of variance	0.49	0.14	0.13	

Table 5 presents the stepwise discriminant analysis results. It indicates that seven of the ten morphometric traits: Thigh length, Shank length, Wattle length, Wing Length, Comb length, Comb height and Body Length contributed significantly ($P<0.001$) to the separation of the birds into breeds. Thigh length and Shank length however indicated higher discriminating power compared to others. The highly significant discriminating power of the entered variables implies that consistent measurements of these traits should enhance separation into distinct breeds. Without exception, all discriminating variables were measures of length and are environmentally independent, thus indicating inherent size. Non sensitivity of the five of the six discriminating variables to the prevailing environmental factors substantiated further the reliability and suitability of such traits in separation to types.

The preceding observations were consistent with the reports of (18) on Muscovy ducks, but differed in certain respects from the work of (9) who reported body weight, body width, body length and wing length as the most discriminating variables for ducks sampled in the rain forest, Guinea savanna and dry savanna; while foot length, neck length, thigh circumference and body length were the most discriminating variables for Muscovy ducks sampled in rain forest and Guinea savanna (1). This disparity might be due to differences in species sampled, sample size, location etc.

By comparing the F-value and the P-value statistics for each significant explanatory variable, we can conclude that 'Thigh Length' has the highest amount of significant discriminative potential, while 'Body Length' has the least significant discriminative power in differentiating the chicken populations sampled. The traits Thigh Length and Shank Length which determines height above ground level may be an adaptive feature for temperature control in the tropic and scavenging ability.

Table 5: Summary of the Step-wise discriminant analysis of morphometric traits of three dual purpose chicken breeds.

Step	Variables	No Variables In	Partial R-Square	Model R-Square	Wilks' Lambda	C(p)	F Value	Pr > F
1	Thigh length (cm)	1	0.388	0.388	0.61	1490.54	1901.5	<.0001
2	Shank length (cm)	2	0.1559	0.5439	0.45	349.484	1024.64	<.0001
3	Wattle length (cm)	3	0.0339	0.5778	0.27	102.931	240.61	<.0001
4	Wing Length (cm)	4	0.0056	0.5834	0.35	63.9446	40.2	<.0001
5	Comb length (cm)	5	0.0042	0.5876	0.26	34.993	30.65	<.0001
6	Comb height (cm)	6	0.0033	0.5909	0.31	12.9485	24	<.0001
7	Body length (cm)	7	0.0008	0.5917	0.26	8.8133	6.13	0.0133

Conclusion and Applications

1. The results obtained with principal component analysis of PC1, PC2 and PC3 in the pooled and individual breeds table allowed for better understanding of the complex correlations among the traits and reduced the number of traits along with high communalities, using, without loss of information. This goes to show that multivariate analysis of morphometric traits is a suitable tool for breed differentiation.
2. Also stepwise discriminant analysis showed that lengthwise measures of Long bones of the chickens such as thigh and shank length are viable metrics for phenotypic differentiation of birds in the studied population.

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