

Multivariate principal component analysis of morphological traits in Ross 308 broiler chicken breed

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Abstract

A principal component exploration is a valuable instrument in multivariate methodology and it is very useful when characteristics are related. The objective of the study was to explore the relationship amongst morphological traits and body weight (BW) of Ross 308 chicken breed. Morphological traits were recorded on one hundred Ross 308 chicken (male = 50, female = 50) at Broiler Production division of Potchefstroom College of Agriculture, South Africa. The data was analysed using stepwise regression, Pearson's correlation and Principal Component Analysis (PCA). Correlation findings in females ranged from -0.16 to 0.51 while ranged from -0.07 to 0.56 in males. PCA results extracted only three and two components in males and females chicken, respectively, which contributed remarkable 67.78% and 57.15% of variation. The specified principal components extracted contributed excellently to describe overall structuring. Regression results revealed that use of components was more appropriate than the use of correlated morphological traits in predicting BW. The SC might be used as a key morphological trait in the selection criteria to advance BW of male chickens while SL might be used as a key trait in the case of female Ross 308 chickens.

Keywords: Body weight, Morphological characterization, Principal component analysis

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Introduction

Phenotypic characterisation of animal breeds is imperative stage in animal development program as it allows livestock keepers to recognize and choose superior lines for progression (Ngomuo et al., 2017; Dube et al., 2018; Abbas et al., 2021). In this respect, Yakubu (2011) revealed that morphological

differences within breed are of immense biological interest, both as a phenomenon, descriptive and an analytical tool. Furthermore, sexual variation in external morphology are of curiosity in recent studies of reproductive biology, descriptively and to analyse population composition. Assessment of morphological differences in animals is the first stage for classification and identification of breed to



converse local genetic resources (Sankhyan et al., 2018). The investigation of relationship and variance are commonly used in demonstrating morphological and genetic association amongst morphological traits (Patoo et al., 2016). Nonetheless, factor investigation by means of principal component exploration is useful instrument in multivariate methodology and is of practice when traits are related (Sankhyan et al., 2018).

The principal component analysis (PCA) is a procedure depending on two or more variables with main function is to outline the fundamental structure among the analysed variables (Yunusa et al., 2013). Nevertheless, there is limited literature documented in South Africa about the phenotypic characterization using morphological traits and principal component analysis technique. Thus, the objective of this study is to provide baseline evidence on sexual characterization in Ross 308 chicken breed using morphological traits and principal component analysis technique and further assess percentage contribution of various linear body measurements towards total dimensional variation of the breed. The study might ensure thriving characterization which could help in the selection and genetic improvement of the Ross 308 chicken stock.

Material and Methods

Study area

This research was done at the Broiler Production division of the Animal Production Department at Potchefstroom College of Agriculture, North West Province, South Africa. Potchefstroom College of Agriculture is situated on the premises of the Agricultural Centre of the North West Department of Agriculture and Rural Development (NWARD) along the Chris Hani Drive as 26° 42' 53'' S; 27° 05' 49'' E (Cilliers and Cilliers, 2015).

Experimental animals and management

The Ross 308 broiler chicken breed was used for the purpose of the study. The broiler house comprised of 500 chickens, however, a total of hundred birds (50 males and 50 females) were used. The flock was reared under intensive system and kept in the same house. The chickens were subjected to phase-feeding practices which were provided *ad libitum*, whereby broiler starter was fed from day 1 to day 21, broiler grower was fed from day 21 to day 28, and broiler

finisher was fed from day 28 until slaughter. The chickens were provided with clean water daily *ad libitum*. Temperature was recorded daily and regulated through controlling the ventilation of the house. Upon arrival until day 3, the chicks were given “stress-pack” through drinking water to enable them to acclimatize to the new environment and to combat stress. Moreover, the chickens were vaccinated against Gumboro and Newcastle diseases. Both these vaccines were administered through drinking water. The chickens were weighed weekly and the weight gains were recorded. Measurements of the biometric traits were conducted on week five (5), where the 130 birds were randomly sampled.

Traits measured

The body weight was recorded and six morphological parameters were taken for every broiler chicken. The morphological traits were taken following the normal biometrical procedures reported by Yakubu (2011) and Tyasi et al. (2017). The live weight of broiler chickens was measured individually using a sensitive weighing balance. The morphological traits were taken with the use of a measuring tape graduated in centimeters (cm). Biometric traits were taken according to the method described by Tyasi et al. (2017). The traits were measured as follows:

The body weight (BW) was recorded with the use of a sensitive weighing balance with a capacity of three decimal digits. Body length (BL) was measured with a measuring tape stretched from bird's nasal opening, along its neck and back, to the tip of its pygostyle. Body girth (BG) was taken when a measuring tape is looped round the region of the breast under the wing. Wing length (WL) was measured as the distance from the humerus-coracoid junction to the distal tip of the phalange digits. Shank length (SL) was measured as the length of the tars-metatarsus from the hock joint to the metatarsal pad. Shank circumference (SC) was measured as the circumference of the middle shank. All the linear body measurements were taken using tape by the same person in order to avoid individual variations in measurements.

Statistical analysis

The descriptive statistics including mean, standard error, and coefficient of variance (CV) of BW and independent variables were calculated using statistical package of social sciences (SPSS, 2019) in both sexes. Correlations among body weight and morphological parameters were also calculated.



Results

Boxplot (Figure 1) depicts the summary of body weight (BW) distribution of Ross 308 female and male chickens. The results showed a significant ($p < 0.001$) difference between both chicken genders. Male chickens had a higher BW than females. The female boxplot, showed minimum values of less than 1.5 kg, first quartile, and a median above 1.5 kg, whereas third quartile had a maximum of 2 kg, respectively. Meanwhile, boxplot of male BW displayed a minimum values greater than 1.5 kg, first quartile, median greater than 1.5 kg, and the maximum greater than 2 kg. Summary of boxplot suggests that the data regarding BW in female and male Ross 308 chickens sexes were well distributed without outliers.

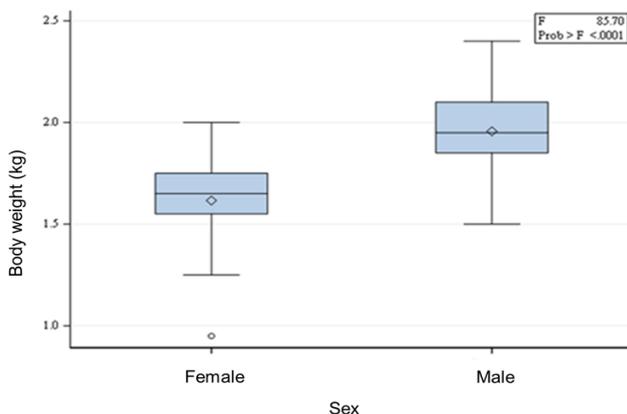


Figure-1: Boxplot depicting the median, minimum, maximum, 25th and 75th percentile values of Ross 308 female and male body weights.

Table-1: Descriptive statistics for body weight and morphological traits of Ross 308 male and female broiler chickens.

TRAITS	Male (n = 50)		Female (n = 50)	
	MEAN ± SE	CV (%)	MEAN ± SE	CV (%)
BW (kg)	1.95 ± 0.02	8.81	1.62 ± 0.03	1.05
WL (mm)	86.36 ± 0.50	4.13	82.28 ± 0.62	5.28
BKL (mm)	17.12 ± 0.21	8.64	17.12 ± 0.16	6.74
SL (mm)	85.70 ± 0.45	3.70	78.52 ± 0.58	5.24
BG (mm)	408.42 ± 2.65	4.58	376.94 ± 4.33	8.13
BL (mm)	281.10 ± 2.76	6.93	252.50 ± 2.24	6.27
SC (mm)	48.42 ± 0.07	5.13	42.72 ± 0.46	7.63

BW: body weight, WL: wing length, BKL: beak length, SL: shank length, BG: body girth, BL: body length, SC: shank circumference, SE: standard error, and CV: coefficient of variance.

The summary of BW and morphological traits (WL, BKL, SL, BG, BL and SC) is displayed in Table 1. The average numeric value of BW was higher in male (1.95 ± 0.02 kg) than in female Ross 308 chicken (1.62 ± 0.03 kg). Descriptive statistics of morphological parameters showed that males had higher average numerical values for all parameters, excluding BKL (17.12 ± 0.21 mm). The CV was computed by dividing the average with standard deviation and the results revealed a range of 3.70 - 8.81% in males and 1.05 - 8.13% in females.

Table-2: Correlation matrix of body weight and morphological traits, females below diagonal and males above diagonal.

TRAIT S	BW	WL	BKL	SL	BG	BL	SC
BW (kg)		0.33*	0.15 ^{ns}	0.33*	0.40**	0.55**	0.56**
WL (mm)	0.48**		0.19 ^{ns}	0.22 ^{ns}	0.07 ^{ns}	0.42**	0.37**
BKL (mm)	0.39**	0.31*		0.13 ^{ns}	0.07 ^{ns}	0.08 ^{ns}	-0.08 ^{ns}
SL (mm)	0.51**	0.51**	0.18 ^{ns}		0.15 ^{ns}	0.13 ^{ns}	0.36**
BG (mm)	0.39**	0.24 ^{ns}	0.23 ^{ns}	0.25 ^{ns}		0.08 ^{ns}	0.09 ^{ns}
BL (mm)	0.11 ^{ns}	0.22 ^{ns}	-0.14 ^{ns}	0.27 ^{ns}	-0.16 ^{ns}		0.41**
SC (mm)	0.47**	0.19 ^{ns}	0.20 ^{ns}	0.26 ^{ns}	0.12 ^{ns}	-0.11 ^{ns}	

BW: body weight, WL: wing length, BKL: beak length, SL: shank length, BG: body girth, BL: body length, SC: shank circumference, ns: not significant, * significant ($p < 0.05$) and ** significant ($p < 0.01$).

Person's correlation was used to evaluate associations between BW and morphological parameters of Ross 308 chicken breed for both genders (Table 2). The findings above are sloping line display association results of male Ross 308 chicken breed. These results showed a positive highly significant of BW with BG (0.40, $p < 0.01$), BL (0.55, $p < 0.01$) and SC (0.56, $p < 0.01$) but did not significantly correlate with BKL (0.15). The results further showed that SC had a positive high correlation with BL (0.41, $p < 0.01$), SL (0.36, $p < 0.01$) and WL (0.36, $p < 0.01$). However, morphological traits correlation findings of female below sloping line showed BW showed a positive high correlation with all morphological parameters, except with BL (0.11). Furthermore, WL revealed a positive significant correlation with BW (0.33, $p < 0.01$), BKL (0.31, $p < 0.05$) and (0.51, $p < 0.01$).



The predicted factor loading extracted by factor analysis, Eigen-values and variation explained by each factor are presented in Table 3. PCA results extracted only three and two components in males and females chicken, respectively. Moreover, another criterion for determination of number of component is scree plot that could be used to decide the actual number of component to be retained for analysis. Scree plot can depict various components and the component having Eigen-value up to the bent of the elbow are usually considered. Extracted three components in case of male Ross 308 chickens accounted 67.78% of the variance. The first component explained 37.42% of variance and was presented by high loading for BW, WL, SL, BL and SC. The second factor was accounted 15.61% of variance and had high positive loading for BKL and BG, while had high negative significant with SC. Third component had high negative loading for BG and high positive with WL and BKL and explained by 14.75% of variance. In female Ross 308 chickens extracted two principal components contributed 57.15% of the variance in the data, while the first component was enough to explain about 38.03% of the total variance amongst the seven measures predicted. The first component was denoted by remarkable high positive loading for almost all traits, except BL. The second component accounted 19.12% of variation and was denoted by high positive

remarkable loadings for BL. The communality estimate for male Ross 308 chickens ranged from 0.21 for BKL to 0.84 for BW. In female the communality ranged from 0.37 (SC) to 0.73 (BW). The communality after extraction gives the common variance that is shared between variable.

Stepwise regression exploration was conducted to fit best models for prediction of body weights in case of male and female Ross 308 chickens (Table 4). Results revealed that in case of male shank circumference alone accounted 31% of variation in body weight and inclusion of body length improved it to 43%. Furthermore, inclusion of body girth and shank length improved the accuracy to 55%. In females, contribution of shank length alone accounted 26% of variation in body weight and inclusion of wing length improved the accuracy to 33%, while shank circumference and beak length did not make remarkable difference in improving accuracy. Meanwhile, inclusions of body girth in the model improve the accuracy to 52%. In male Ross 308 chickens, the use of PC 1 as a single predictor explained 71% of total variability while inclusion of PC 2 did not make a remarkable contribution in the model. Lastly, inclusion of PC 3 improved accuracy of the model to 75%. In females, the use of PC 1 alone explained 73% of total variability while inclusion of PC 2 in the model was not remarkable.

Table-3: Eigen-values, share of total variance along with loading and communalities of the morphometric traits of male and female Ross 308 chickens.

	Males			Communality	Females		Communality
	PC1	PC2	PC3		PC1	PC2	
BW	0.84	0.07	-0.21	0.75	0.85	-0.04	0.73
WL	0.64	-0.06	0.45	0.61	0.73	0.27	0.61
BKL	0.21	0.76	0.54	0.91	0.54	-0.39	0.45
SL	0.53	0.18	-0.11	0.32	0.73	0.35	0.66
BG	0.37	0.51	-0.66	0.83	0.51	-0.36	0.40
BL	0.71	-0.24	0.21	0.60	0.15	0.88	0.79
SC	0.74	-0.40	-0.10	0.71	0.53	-0.28	0.37
Eigen-value	2.62	1.09	1.03		2.66	1.34	
% of total variance	37.42	15.61	14.75		38.03	19.12	

BW: body weight, WL: wing length, BKL: beak length, SL: shank length, BG: body girth, BL: body length, SC: shank circumference, PC1: principal component 1, PC2: principal component 2 and PC3: principal component 3.



Table-4: Best fitted regression models with stepwise regression analysis on original morphometric traits and principal components in Ross 308 chicken breed

Estimators	Models	R ²	MS E	F-value
Male				
Original morphometric traits as estimates				
SC	BW = 0.09 + 0.04SC	0.31	0.14	21.46**
SC and BL	BW = -0.33 + 0.03SC + 0.00BL	0.43	0.13	17.70**
SC, BL and BG	BW = -1.47 + 0.03 + SC + 0.00BL + 0.00BG	0.54	0.12	18.01**
SC, BL BG and SL	BW = -1.82 + 0.02SC + 0.00BL + 0.00BG + 0.01SL	0.55	0.12	13.84**
SC, BL, BG, SL and WL	BW = -1.84 + 0.02SC + 0.00BL + 0.00BG + 0.01SL + 0.00WL	0.55	0.12	10.83**
Principal component as estimates				
PC1	BW = 1.96 + 0.14PC1	0.71	0.09	115.08**
PC1 and PC2	BW = 1.96 + 0.14PC1 + 0.01PC2	0.71	0.09	57.55**
PC1, PC2 and PC3	BW = 1.96 + 0.14PC1 + 0.01PC2 - 0.04PC3	0.75	0.09	47.03**
Female				
Original morphometric traits as estimates				
SL	BW = -0.29 + 0.02SL	0.26	0.17	17.23**
SL and WL	BW = -0.84 + 0.12SL + 0.01WL	0.33	0.16	11.80**
SL, WL and SC	BW = -1.35 + 0.01SL + 0.01WL + 0.02SC	0.45	0.15	12.37**
SL, WL, SC and BKL	BW = -1.65 + 0.01SL + 0.01WL + 0.02SC + 0.03BKL	0.48	0.15	10.54**
SL, WL, SC, BKL and BG	BW = -1.82 + 0.01SL + 0.01WL + 0.02SC + 0.03BKL + 0.00BG	0.52	0.14	9.50**
Principal component as estimates				
PC1	BW = 1.62 + 0.17PC1	0.73	0.10	126.67**
PC1 and PC2	BW = 1.62 + 0.17PC1 - 0.01PC2	0.73	0.10	62.52**

BW: body weight, WL: wing length, BKL: beak length, SL: shank length, BG: body girth, BL: body length, SC: shank circumference, ns: not significant, ** significant ($p < 0.01$), PC1: principal component 1, PC2: principal component 2 and PC3: principal component 3

Discussion

The availability of laptop software's for data exploration in the arena of animal farming leads to rapid growth in the use of principal component examination procedures (Tyasi et al., 2020). In the present study, the collected data revealed that male Ross 308 chickens had higher mean numeric values (BW, 1.95; WL, 86.36; SL, 85.70; BG, 408.42; BL, 281.10 and SC, 48.42) of than females, except BKL (17.12) that was equal in both sexes. These findings are in agreement with the report of Yakubu and Ari (2018), who revealed that body weight, body length, chest circumference, shank length, wingspan, thigh length of male chickens were found to be higher in males than in females Kuroiler and indigenous Fulani chickens in Nigeria. Our mean numeric findings were higher than those reported by Tyasi et al. (2020) in Hy-Line Silver Brown commercial layer chickens, being 1.41 kg for BW. The values for BW, BL, BG, WL, and SL were also superior to the values reported by Egena et al. (2014) in Indigenous Nigerian chickens raised under extensive management system. This variation might be due to breed differences and

environmental conditions. This research firstly examined the correlation between BW and various morphological traits such as WL, BKL, SL, BG, BL, and SC of Ross 308 chickens with the use of Pearson's correlation in both genders. Results of male Ross 308 chickens displayed that WL, SL, BG, BL and SC had a highly positive significant correlation with BW. These findings are in agreement with the report of Amao (2018) on Nigerian indigenous chickens reared intensively under Southern Guinea Savanna. The ultimate results of this research displayed that BW might be improved by improving WL, SL, BG, BL and SC. Therefore, WL, SL, BG, BL and SC may be well incorporated in the selection criteria at times of mating to advance BW of male Ross 308 chickens. In female Ross 308 chickens, findings indicated that BW is had a highly positive significant correlation with WL, BKL, SL, BG and SC. These results indicate that, by improving WL, BKL, SL, BG and SC might as well improve the BW of female Ross 308 chickens. Therefore, WL, SL, BG, and SC may be employed in the selection criterion at times of mating of Ross 308 chickens to improve BW. Furthermore, our study showed that



WL, SL, BG and SC might be used to improve BW in both sexes. Tyasi et al. (2017) revealed that morphological correlations only assist to specify the degree of correlation without determining the exact cause influence amongst parameters and without specifying which traits a highly associated than others. Hence, the employment of principal component analysis and stepwise regression analysis to investigate which morphological traits are closely related and what percentage contribute to predict BW from morphological traits. The principal component analysis only extracted three components in case of male Ross 308 chickens with 67.78% of the variance, while female Ross 308 chicken extracted two significant components which were well enough to account for 57.15% of the variance in the data. Our regression findings revealed that in case of male Ross 308 chickens, SC alone accounted 31% of variation predicting BW, while in case of female chicken, SL accounted 36% of variation alone in predicting BW from biometric traits. Therefore, SC in male Ross 308 chicken may be used as the key morphological traits in predicting BW, while SL might be incorporated and used as the focal trait in Ross 308 female chickens to predicting BW. Moreover, this study showed that SC is the key trait for predicting BW in male Ross 308 chicken and might be well used in the selection criteria at times of mating to improve BW while SL might be useful in case improving female Ross 308 chicken breed.

Conclusion

The principal component extracted contributes effectively to explain overall structuring and shape of Ross 308 chicken breed. The positive and remarkable association amongst different morphological traits also makes them agreeable for analysis. Regression exploration recommended that use of PCA was more useful than the use of original correlated variable in estimating body weights. The SC might be used as a key morphological trait in the selection criteria to advance BW of male chickens while SL might be used as a key trait in the case of female Ross 308 chickens.

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Contribution of Authors

Bila L: Planned the research, performed data collection, wrote and approved the final manuscript.

Tyasi TL: Oversaw the experiment, performed data analysis, edited and approved the final manuscript.