Using factor scores in multiple linear regression model for predicting the carcass weight of broiler chickens using body measurements

Uso de las puntuaciones del factor del eje principal en el modelo de regresión lineal múltiple para predecir el peso de la canal de pollos de engorde usando medidas corporales

Abdulmojeed YAKUBU ✉ [1], Kingsley Omogiade IDAHOR [1] and Ya'u Isopa AGADE [2]

[1]Animal Science Department, Faculty of Agriculture, Nasarawa State University, Keffi, Shabu-Lafia Campus, P.M.B. 135, Lafia, Nigeria and [2]Department of Animal Science, College of Agriculture, Lafia, Nasarawa State, Nigeria. E-mail: abdul_mojeedy@yahoo.com ✉ Corresponding author

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ABSTRACT

Information on the relationships among pre- and post-slaughter traits of broiler chickens is valuable to poultry farmers and researchers as it allows early selection, as well as giving a chance to make an early evaluation of the breeding programme. In this study, factor and multiple regression analysis were combined to examine the relationship between carcass weight and six body measurements (live weight, body length, breast circumference, thigh circumference, shank length and wing length) of 8-week old Arbor Acre broiler chickens in a sub-humid environment of Nigeria. In the varimax rotated factor analysis, two factors were extracted which explained 87.53% of the total variability in the body measurements of chickens. The first factor, termed Form Factor, had its loadings for body weight, body length, breast circumference and thigh circumference respectively. The second factor was characterised by shank length and wing length, and was thus referred to as Length Factor. These two factors together accounted for 84.50% of the variation in carcass weight when their scores were considered as independent variables in the fitted multiple linear regression equation.

Keywords: Broilers, body measurements, factor analysis, rotation, regression, multicollinearity.

RESUMEN

La información sobre las relaciones entre los caracteres pre-y post- sacrificio de pollos de engorde es muy valiosa para los avicultores e investigadores, debido a que permite la selección temprana, así como da la oportunidad de hacer una evaluación precoz del programa de mejoramiento. En este estudio, la metodología del factor del eje principal y el análisis de regresión múltiple se utilizaron para examinar la relación entre el peso de la canal y seis medidas corporales (peso vivo, longitud corporal, circunferencia del pecho, circunferencia del muslo, longitud de tarso y longitud del ala) de pollos de engorde Arbor Acre de 8 semanas de edad en un ambiente subhúmedo de Nigeria. En el análisis de factores rotados por varimax, se extrajeron dos factores que explicaron 87,53% de la variabilidad total de las medidas corporales de los pollos. El primer factor, denominado factor de forma, tuvo sus cargas para peso corporal, longitud corporal, circunferencia del pecho y circunferencia del muslo, respectivamente. El segundo factor se caracterizó por la longitud del tarso y la longitud del ala y fue denominado factor de longitud. Estos dos factores representaron 84,50% de la variación en el peso en canal cuando sus valores se consideraron como variables independientes en la ecuación ajustada de regresión lineal múltiple.

Palabras clave: Pollos de engorde, medidas corporales, análisis factorial, rotación, regression, multicolinearidad.

INTRODUCTION

As with all animal species, information on correlations among the pre- and post- slaughter traits is quite important in poultry breeding. This is because knowing which of the pre-slaughter trait(s) affect which of the post-slaughter trait(s) enables breeders to predict what kind of product(s) will be obtained (Mendeş *et al*., 2005; Mendeş, 2009). Size and shape (conformation) of various body parts are the major determinants of the overall size and shape of a live bird or carcass. According to Pinto *et al*. (2006), body weight at various ages and carcass characteristics are examples of variables that can indicate the usefulness of the chicken for commercial purposes.

Performance testing, which forms the basis for breeding work is difficult to conduct in the case of slaughter value parameters. Selection towards meatiness improvement requires reliable and easy-toapply methods for estimating the performance and breeding value of poultry species (Kleczek *et al*., 2007). Body measurements and meatiness traits are inter-correlated (Shahin, 1999; Isiguzar, 2003). However, the analysis of these traits should address interdependence among the predictors (multicollinearity). The problem in the analysis of body measurements and carcass weight data is the difficulty in interpreting the influence of body measurements and determining the measurements which are most useful for predicting carcass weight (Keskin *et al*., 2007). Hence, the use of a multivariate technique called factor analysis. This helps to uncover the latent structure of a set of variables. Factor analysis reduces a large number of variables to a smaller number of factors for modelling purposes (Tabachnick and Fidell, 2001; Manly, 2005). This involves the use of factor scores for orthogonalization of predictors, thereby handling multicollinearity in such procedures as multiple regressions (Grice, 2001).

In Nigeria, the estimation of carcass weight from body measurements of chickens using factor analysis has not been exploited. The present investigation therefore, aimed at describing objectively the interrelationships existing between carcass weight and body measurements of broiler chickens and to predict carcass weight from the orthogonal traits derived from principal axis factoring. This will further aid in the selection and breeding programmes of broilers in a sub-humid tropical environment.

MATERIALS AND METHODS

Data were obtained from one hundred and twenty randomly selected unsexed 8-week old Arbor Acre broiler chickens intensively reared at the Poultry Unit of the College of Agriculture, Lafia, Nasarawa State, 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. The birds which were wing banded for identification purpose were reared on deep litter from day-old. A finisher diet containing approximately 20% crude protein and a metabolizable energy of 2900 kcal/kg was given from 5-8 weeks of age *ad libitum*. Fresh clean water was also freely available. Routine vaccination and other management practices were strictly adhered to.

Prior to slaughtering the birds at weight 8 weeks of age, the following measurements were taken: live weight (LW), body length (BL), breast circumference (BC), thigh circumference (TC), shank length (SL) and wing length (WL). The anatomical reference points were as described by Gueye *et al*. (1998) and Teguia *et al*. (2008). For carcass evaluation, the birds were slaughtered by severing the carotid arteries and jugular veins and blood drained under gravity; scalded to facilitate plucking and eviscerated. The carcasses were then divided into parts as described by (Kleczek *et al*., 2006). The weights of the thigh, breast and back were taken as the carcass weight.

Means, standard deviations and coefficients of variation of carcass weight and body measurements of birds were calculated. Pearson's correlation coefficients (r) among carcass weight and the various body measurements of birds were calculated. From the correlation matrix, data were generated for factor analysis using principal axis factoring. The determinant of the correlation matrix was used to test for multicollinearity and singularity. Anti-image correlations, Kaiser-Meyer- Olkin measures of sampling adequacy and Bartlett's Test of Sphericity (tests the null hypothesis that the original correlation matrix is an identity matrix) were computed to test the validity of the factor analysis of the data set. The appropriateness of the factor analysis was further tested using communalities and ratio of cases to variables. Cumulative proportion of variance criterion was employed in determining the number of factors to extract. Reproduced and residual correlations were used to test the validity of the number of factors extracted. The orthogonal varimax rotation was employed to enhance the interpretability of the factor loadings. Principal axis factoring is a method which tries to find the lowest number of factors which can account for the variability in the original variables that is associated with these factors (Wood *et al*., 1996; Rencher, 2002; Manly, 2005).

If the observed variables are $X_1, X_2, \ldots, X_n$, the common factors are $F_1, F_2, \ldots, F_m$ and the unique factors are $U_1, U_2, \ldots, U_n$, the variables may be expressed as linear functions of the factors:

$$X_1 = a_{11}F_1 + a_{12}F_2 + a_{13}F_3 + \ldots + a_{1m}F_m + a_1U_1$$
$$X_2 = a_{21}F_1 + a_{22}F_2 + a_{23}F_3 + \ldots + a_{2m}F_m + a_2U_2$$
$$\ldots$$
$$X_n = a_{n1}F_1 + a_{n2}F_2 + a_{n3}F_3 + \ldots + a_{nm}F_m + a_nU_n$$

Each of these equations is a regression equation; factor analysis seeks to find the coefficients

a_{11}, a_{12},…,a_{nm} which best reproduce the observed variables from the factors. The coefficients a_{11}, a_{12},…,a_{nm} are weights in the same way as regression coefficients (because the variables are standardized, the constant is zero).

Factor scores were considered as independent variables for predicting the carcass weight of birds using the following multiple regression model:

$$CW = a + b_1FS_1 + b_2FS_2 + ... + b_kFS_k + e$$

Where,
CW = carcass weight
A = regression constant.
b's = regression coefficients
FS's = factor scores
e = random error term

The significance of the regression coefficients was tested with a t-statistic while the goodness-of-fit of the regression was assessed using the coefficient of determination (R^2) and adjusted R^2. SPSS statistical package program was used to analyze the data (Anonymous 2001).

RESULTS AND DISCUSSION

The means, standard deviations and coefficients of variation of body measurements (live weight, body length, breast circumference, thigh circumference, shank length and wing length) and carcass weight are presented in Table 1. Variability was higher in thigh circumference. This might not be unconnected with the high influence of environment on these traits.

Table 1. Descriptive statistics of body measurements and carcass weight of Arbor Acre broiler chickens intensively reared at the Poultry Unit of the College of Agriculture, Lafia, Nasarawa State, North Central Nigeria.

Traits	Mean	SD	CV
Live weight (kg)	1.76	0.26	14.77
Body length (cm)	36.74	3.89	10.59
Breast circumference (cm)	32.15	4.74	14.74
Thigh circumference (cm)	11.36	2.60	22.89
Shank length (cm)	8.62	1.17	13.57
Wing length (cm)	18.58	2.25	12.11
Carcass weight (kg)	1.27	0.19	14.96

SD: Standard deviation; CV: Coefficient of variation (%)

Pairwise correlations among carcass weight and body measurements of birds are presented in Table 2. Carcass weight was positively and highly correlated with the pre-slaughter traits investigated (r= 0.70-0.91; $p<0.01$). The correlation coefficients between the body measurements ranged from moderate (r = 0.48) to high (r = 0.86) values ($p<0.01$). Similar findings in other breeds/strains of chickens have been reported (Musa *et al*., 2006; Yang *et al*., 2006; Ojedapo *et al*., 2008). In a related study, Wolanski *et al*. (2006) reported that the relationship existing between hatch weight, hatch body length, hatch shank length and carcass weight was high and significant. The high association observed indicates that carcass weight can be predicted from body measurements.

The determinant of the correlation matrix (0.001) was greater than 0.00001 while 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. The present value of 0.80 was found to be sufficiently high for all the body traits. The overall significance of the correlation matrix tested with Bartlett's Test of Sphericity for the body measurements of birds (Chi-square = 776.90; $p< 0.01$). The value of Bartlett test implied that the factor analysis is applicable to 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 0.753-0.987. This further lent

Table 2. Phenotypic correlations (Pearson's correlations) between body measurements and carcass weight of Arbor Acre broiler chickens intensively reared at the Poultry Unit of the College of Agriculture, Lafia, Nasarawa State, North Central Nigeria **.

Traits	BL	BC	TC	SL	WL	CW
LW	0.85	0.80	0.71	0.79	0.70	0.91
BL	-	0.70	0.65	0.62	0.48	0.73
BC	-	-	0.86	0.72	0.55	0.80
TC	-	-	-	0.70	0.69	0.71
SL	-	-	-	-	0.78	0.79
WL	-	-	-	-	-	0.70

LW: Live weight (kg), BL: Body length (cm), BC: Breast circumference (cm), TC: Thigh circumference (cm), SL: Shank length (cm), WL: Wing length (cm) and CW: Carcass weight (kg)
** Significant at $p<0.01$ for all correlation coefficients.

credence to the appropriateness of the factor analysis. The ratio of cases to variables (17.3 to 1 far exceeded the minimum of 5 to 1 standard) was met as sample size requirement while estimates of the residual correlation matrix were low enough.

After varimax rotation of the factor axes, two factors were extracted which accounted for 87.53% of the total variance of the original six variables (Table 3). Factor pattern coefficients of the rotated factors show the relative contribution of each trait to a particular factor. The first factor, which explained 77.19% of the generalized variance was characterized by high positive loadings (factor-variate correlations) on live weight, body length, breast circumference and thigh circumference. This factor was thus termed Form Factor. The variables that were more associated with the second factor were shank length and wing length, contributing to 10.34% of the variation. Thus, this factor was referred to as Length Factor.

Factor score coefficients derived from the body measurements of chickens are presented in Table 4. 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; Yakubu, 2009) rendering the estimation of unique effects of these predictors impossible. This justifies the use of factor scores for prediction. These factors are orthogonal to each other and are more reliable in weight estimation. The two factors selected were found to have significant ($p<0.01$) positive linear relationship with carcass weight (Table 5). In other words, carcass weight will be expected to increase as the values of factor 1 and 2 scores increase. A combination of these two independent factors explained 84.50% of the total variability in carcass weight. Similarly, Shahin (2000) and Shahin and Hassan (2000) derived regression equations for estimating live weight of ducklings and rabbits respectively using independent factor scores. Keskin *et al*. (2007) also used factor scores derived from ten body measurements to predict the carcass weight of sheep.

Table 3. Explained variation associated with rotated factors along with factor loadings and communalities for the body measurements of Arbor Acre broiler chickens intensively reared at the Poultry Unit of the College of Agriculture, Lafia, Nasarawa State, North Central Nigeria.

Variables	Factor 1	Factor 2	Commu-nality
Live weight (kg)	0.889	0.444	0.987
Body length (cm)	0.760	0.260	0.646
Breast circumference (cm)	0.858	0.311	0.832
Thigh circumference (cm)	0.750	0.457	0.771
Shank length (cm)	0.602	0.624	0.753
Wing length (cm)	0.314	0.942	0.986
Eigenvalue	4.63	0.62	
Percentage variance	77.19	10.34	
Description	Form	Length	

CONCLUSION

The factor analysis aided in summarizing and explaining the correlations and covariances among the original six body measurements of chickens: live weight, body length, breast circumference, thigh circumference, shank length and wing length. These interdependent body traits were reduced to two factors which were mutually orthogonal, thereby eliminating multicollinearity problems among the variables. Their factor scores fitted in a linear multiple regression model revealed that these two factors accounted for 84.50% of the variation in carcass weight of chickens. This is an indication that factor scores of pre-slaughter traits could be successfully used to predict post-slaughter trait such as carcass weight, which could aid in selection and breeding programmes of broiler chickens.

Table 4. Factor scores for the prediction of carcass weight of Arbor Acre broiler chickens intensively reared at the Poultry Unit of the College of Agriculture, Lafia, Nasarawa State, North Central Nigeria.

Traits	Factor 1	Factor 2
Live weight (kg)	1.356	- 0.404
Body length (cm)	- 0.213	0.043
Breast circumference (cm)	0.180	0.092
Thigh circumference (cm)	0.071	- 0.184
Shank length (cm)	- 0.110	- 0.008
Wing length (cm)	- 0.588	1.285

Table 5. Multiple regression model for the prediction of carcass weight of Arbor Acre broiler chickens intensively reared at the Poultry Unit of the College of Agriculture, Lafia, Nasarawa State, North Central Nigeria.

Predictor	Coefficient	Standard error	t-value	Probability
Factor 1	0.145	0.007	21.072	<0.01
Factor 2	0.094	0.007	13.631	<0.01

Constant = 1.271, R^2 = 84.50%, Adjusted R^2 = 84.20%

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