

# APPLICATION OF PATH ANALYSIS METHODOLOGY IN ASSESSING THE RELATIONSHIP BETWEEN BODY WEIGHT AND BIOMETRIC TRAITS OF RED SOKOTO GOATS IN NORTHERN NIGERIA

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Original scientific paper

**Abstract:** Relationship between body weight (BW) and seven morpho-biometrical traits [withers height (WH), body length (BL), chest girth (CG), shoulder width (SW), ear length (EL), cannon circumference (CC) and neck circumference (NC)] were studied in 142 Red Sokoto goats aged 19.3-30.6 months old using path analysis. The animals were randomly selected in certain smallholders' farms located in northern Nigeria. Pair-wise correlations among body weights and linear type traits were positive and highly significant ( $r = 0.74 - 0.92$ ;  $P < 0.01$ ). The path analysis revealed that body length had the highest direct effect on body weight, closely followed by chest girth and shoulder width, respectively (path coefficient = 0.354, 0.253 and 0.214 for BL, CG and SW, respectively). The optimum linear regression model with a coefficient of determination ( $R^2$ ) value of 0.934 included forecast indices, such as body length, chest girth, shoulder width, cannon circumference and neck circumference. This regression equation could be used to predict the body weight of Red Sokoto goats in the field and for selection purposes.

**Key words:** Body weight, body dimensions, path coefficients, Red Sokoto goats, Nigeria.

## Introduction

Size and conformation are important characteristics in meat animals. Traditionally, animals are visually assessed, which is a subjective method of judgement (*Abanikannda et al., 2002; Yakubu, 2003*). In goats body growth and development, objective means (linear body measurements) for describing and evaluating body size and conformation characteristics (*Bingol et al., 2011*) would

overcome many of the problems associated with visual *evaluation* (Shrestha *et al.*, 1984). Body weight is the measurement used mostly to evaluate body development and carcass characteristics in *animals* (De Brito Ferreira *et al.*, 2000; Kuzelov *et al.*, 2011). Body size and shape measured objectively could improve selection for growth by enabling the breeder to recognize early maturing and late maturing animals of different sizes. Knowing the body weight of goats could also be exploited in adequate feeding and health care (treatment doses of antibiotics, anthelmintics, and so forth) (Slippers *et al.*, 2000). However, it is not easily measured in the field. This is due to the time and energy expended while determining it; and the non-availability of weighing scales especially in the small scale farming sector. The chief method of weighing animals without scales is to regress body weight on a certain number of body characteristics, which can be measured readily (Thiruvankandan, 2005; Abdel-Moneim, 2009; Yakubu, 2010a; Yakubu *et al.*, 2011a).

Body measurements that are used to predict body weight may affect its determination directly and indirectly. Therefore, simple correlation coefficients between response variables and predictor variables may not be appropriate to explain the complex relationships. Hence, the use of path analysis which measures a direct and indirect effect of one variable on another and also separates the correlation coefficients of the variables into components of direct effect, indirect effect and compound path (Keskin *et al.*, 2005). Path analysis is a subset of Structural Equation Modelling (SEM), the multivariate procedure, which, as defined by Ullman (1996), allows examination of a set of relationships between one or more independent variables, either continuous or discrete, and one or more dependent variables, either continuous or discrete. Path analysis model is not a substitute for regression analysis; rather it is a complementary methodology to regression analysis (Jeonghoon, 2002).

The objective of the study therefore, was to establish a comprehensive relationship between body weight and some morphological traits of Red Sokoto goats (noted for high quality skin used in the leather industry), Nigeria using path analysis. The multiple regression model so obtained could be useful in predicting body weight and also for the selection of animals for breeding purposes.

## **Materials and Methods**

### *Experimental animals and their management*

142 Red Sokoto goats of both sexes (98 males and 44 females) were randomly selected in certain smallholders' farms in villages located within Kaduna and Kano States in the northern part of Nigeria. The animals were extensively managed with little or no provision for shelter in the night. They scavenged on

kitchen wastes when available. The animals were 19.3 months - 30.6 months old (animals having 2-8 permanent incisors) as described by *Matika et al. (1992)*.

### *Traits measured*

Body weight and seven morpho-biometrical characters were taken on each animal in the morning before they were released for grazing. The body parts measured were, withers height (WH), measured as the distance between the most dorsal point of withers and the ground; body length (BL), measured diagonally from the lateral tuberosity on scapula to pinbone; chest girth (CG), measured as the body circumference just behind the forelegs; shoulder width (SW), measured as the distance between the process on the left shoulder blade and that on the right shoulder blade; ear length (EL), distance from the point of attachment of the ear to its tip; cannon circumference (CC), measured as the smallest circumference of the foreleg and neck circumference (NC), taken as the distance round the mid region of the neck. Body weight (BW) was measured in kg using a hanging scale. The height measurement (cm) was done using a graduated measuring stick. The length and circumference measurements (cm) were effected using a tape rule while the width measurement was done using a calibrated wooden caliper. All the measurements were carried out by the same person in order to avoid between-individual variations.

### *Statistical analysis*

Means, standard deviations and coefficients of variation of the body weight and linear body measurements of animals adjusted for age and sex effects were computed. Bivariate correlations among body weight and morphometric characters were also determined. Standardized partial regression coefficients called path coefficients (beta weights) were calculated. This was to allow direct comparison of values to reflect the relative importance of independent variables to explain variation in the dependent variable (*Seker and Serin, 2004*). The multiple linear regression model adopted was:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + \text{-----} + b_pX_p$$

where,

Y = dependent or endogenous variable (body weight)

a = intercept

b = regression coefficients

X = independent or exogenous variables (WH, BL, CG, SW, EL, CC, NC)

The significance of each path coefficient in the statistical model was tested by t-test using the following model:

$$t_j = \frac{b_j - \beta_j}{\sqrt{\text{var}(b_j)}} \sim t_{\alpha (n-p-1)}; \quad j = 1, 2, \dots, p$$

where,

$\text{var}(b_j)$  = the diagonal member of matrix  $S^2 (X'X)^{-1}$

$S^2$  = mean square of residual obtained from ANOVA

According to *Ulukan et al.* (2003), indirect effects of independent variables play an important role on the dependent variable. The indirect effect of  $X_i$  ( $IE_{YX_i}$ ) via  $X$  on  $Y$  can be calculated following the procedure adopted by *Keskin et al.* (2005):

$$IE_{YX_i} = r_{x_{ik}} P_{YX_k}$$

where ,

$r_{x_{ik}}$  = correlation coefficient between  $X_i$  and  $X_k$  variable.

$P_{YX_k}$  = path coefficient of  $X_k$  variable.

SPSS (2001) statistical package was employed in the analysis.

## Results and Discussion

### *Morphometric traits*

Table 1 shows the descriptive statistics of body weight and zoometrical traits of Red Sokoto goats. Body weight (kg), withers height, body length, chest girth, shoulder width, ear length, cannon circumference and neck circumference (cm) averaged 22.32, 62.34, 51.63, 69.81, 14.24, 14.52, 9.83 and 30.61, respectively. The animals were found to be taller than long. The present values on withers height and chest girth are consistent with the report of *Kawu et al.* (2006), and also confirm the large body size and leggy nature of Red Sokoto goats (*Yakubu et al.*, 2011b). The high variability in the body weight might not be unconnected with great environmental influence such as temperature and nutrition on this variable. This variation therefore, could serve as a basis for the genetic improvement of body weight.

**Table 1. Mean, Standard Deviation (SD) and Coefficient of Variation (CV) of body weight (kg) and morphometric (cm) traits of Red Sokoto goats**

Traits	No	Mean	Standard deviation	Coefficient of variation
Body weight	142	22.32	4.35	19.50
Withers height	142	62.34	6.04	9.69
Body length	142	51.63	4.84	9.37
Chest girth	142	69.81	6.65	9.53
Shoulder width	142	14.24	1.74	12.23
Ear length	142	14.52	1.79	12.33
Cannon circumference	142	9.83	1.01	10.27
Neck circumference	142	30.61	2.93	9.57

### *Pair-wise correlations*

Bivariate correlations displaying the relationship among body weight and linear body measurements of Red Sokoto goats are shown in Table 2. Body weight was positively and highly correlated with all the biometric measurements. However, the highest correlation was observed between body weight and body length, closely followed by body weight and chest girth ( $r=0.92$  and  $0.91$ ;  $P<0.01$ ). The lowest correlation was observed between body weight and ear length ( $r=0.74$ ;  $P<0.01$ ). Similar findings have been reported in certain goat breeds (*Thiruvankadan, 2005; Ojedapo et al., 2007*). Since the morpho-biometrical traits had high correlations with body weight, these linear based measures could be used for selection purposes to improve meat production. They could also be used to predict live weight in the field when scales are not readily available especially in villages or smallholder farms.

**Table 2. Pair-wise correlations among body weight and body measurements of Red Sokoto goats.\*\***

	BW	WH	BL	CG	SW	EL	CC	NC
BW	-	0.85	0.92	0.91	0.86	0.74	0.80	0.77
WH	-	-	0.84	0.90	0.75	0.74	0.62	0.65
BL	-	-	-	0.89	0.80	0.78	0.72	0.67
CG	-	-	-	-	0.79	0.75	0.69	0.67
SW	-	-	-	-	-	0.74	0.71	0.65
EL	-	-	-	-	-	-	0.59	0.56
CC	-	-	-	-	-	-	-	0.80

\*\* Significant at  $P<0.01$

### *Analysis of variance of the regression*

The analysis of variance for the regression model of Red Sokoto goats is shown in Table 3. The  $F_{\text{calculated}}$  was significant, indicating reliance on the prediction of body weight from morphometric traits of the goats.

**Table 3. Analysis of Variance (ANOVA) for regression**

Variation source	Sum of square	Degree of freedom	Mean of square	F
Regression	2496.93	7	356.70	284.73**
Residual	167.87	134	1.25	
Total	2664.80	141		

\*\*Significant at  $P < 0.01$

### *Path coefficients of body dimensions*

Path coefficient (PC) or direct effect of withers height on body weight, though positive (PC=0.063) was statistically non-significant as revealed by the t-test. Therefore, it could be inferred that the correlation between withers height and body weight was largely due to indirect effects via body length and chest girth (Table 4). Body length had the highest positive influence on body weight (PC=0.354). None of the indirect effects was as high as the direct effect. The path coefficients of chest girth and shoulder width were also positive and significant (PC=0.253 and 0.214 respectively). However, the direct effect of the two variables on body weight was influenced by body length. Ear length had a negative effect on body weight, although this effect was significant. The indirect effects were considerably high via body length, chest girth and shoulder width. Cannon circumference and neck circumference both have positive and significant relationship with body weight. However, their indirect effects mostly via body length were also considerable. Simple correlations measure all associations between two variables whether influenced directly or indirectly. However, path analysis provides a more precise determination by separating the correlation coefficients into components of direct and indirect effect. This was emphasized in the study of *Keskin et al. (2005)* and *Yakubu (2011)* where path analysis was used to partition traits affecting milk yield of goats into direct and indirect effect. Using path coefficients, *Wu et al. (2008)* showed how chest girth and body length directly and greatly influenced the body weight of Saibei rabbits.

**Table 4. Direct and indirect effect of linear type traits on body weight of Red Sokoto goats**

Traits	Correlation coefficient with body weight	Direct effect	Indirect effect						
			WH	BL	CG	SW	EL	CC	NC
WH	0.85	0.063	-	0.297	0.227	0.161	-0.061	0.083	0.082
BL	0.92	0.354	0.052	-	0.225	0.171	-0.065	0.096	0.085
CG	0.91	0.253	0.057	0.315	-	0.169	-0.062	0.092	0.085
SW	0.86	0.214	0.047	0.283	0.200	-	-0.061	0.095	0.082
EL	0.74	-0.083	0.047	0.276	0.190	0.158	-	0.079	0.071
CC	0.80	0.134	0.039	0.255	0.175	0.152	-0.049	-	0.102
NC	0.77	0.127	0.041	0.237	0.170	0.139	-0.046	0.107	-

#### *Establishment of a preliminary regression equation*

From simple correlations among body weight and linear body measurements, the following equation with a coefficient of determination ( $R^2$ ) value of 0.937 was obtained:

$$Y = -24.572 + 0.045WH + 0.319BL + 0.165CG + 0.533SW - 0.201EL + 0.576CC + 0.188NC.$$

#### *Deletion of less significant variables from the regression model*

Although the simple correlation between body weight and withers height was high ( $r = 0.85$ ), its direct effect on body weight was non-significant. Thus, withers height was deleted from the regression model. Ear length had a significant effect on body weight. However, this influence was negatively impacted. It was therefore on this basis expunged from the subsequent multiple linear regression equation. This is similar to the findings of *Malau-Aduli et al. (2004)* where redundant variables were excluded in the final regression model.

#### *Establishment of optimum multiple linear regression model*

After the deletion of withers height and ear length from the regression model, a much more simplified model was obtained.

$$Y = -24.356 + 0.299BL + 0.184CG + 0.481SW + 0.550CC + 0.200NC.$$

The coefficient of determination ( $R^2$ ) in this case was 0.934 which was only slightly below 0.937 obtained in the earlier regression model. Thus, the deletion of withers height and ear length had no distinct effect on the accuracy or

robustness of the optimum regression model. The present findings have further lent credence to the use of body measurements for the prediction of body weight (Yakubu, 2010b; Sowande *et al.*, 2010; Sebolai *et al.*, 2011). In related studies, Mendes *et al.* (2005) and Yakubu and Salako (2009) used path analysis to quantify the association between body weight and body measures of American Bronze turkeys. In another study, Afolayan *et al.* (2007) reported that chest girth was the most important variable in the prediction of body weight.

## Conclusion

Simple phenotypic correlations revealed that body weight was positively and highly correlated with withers height, body length, chest girth, shoulder width, ear length, cannon circumference and neck circumference. Path analysis however indicated that body length had the highest direct effect on body weight, chronologically followed by chest girth and shoulder width, respectively. Cannon circumference and neck circumference also had positive and significant direct effects on body weight. Although withers height was highly correlated with body weight, its direct effect was non-significant as revealed by t- test. It was realized mostly via body length and chest girth. Ear length had significant negative direct effect on body weight. Therefore, the body weight of Red Sokoto goats could be estimated with a high degree of accuracy in the field using forecast indices such as body length, chest girth, shoulder width, cannon circumference and neck circumference. Animals could also be selected on the basis of these morphometric traits to improve meat production.

## Primena metodologije analize putanje u proceni odnosa između telesne mase i biometrijskih osobina koza rase crveni sokoto u severnoj Nigeriji

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### Rezime

Odnos između telesne mase (BW) i sedam morfo-biometrijskih osobina [visina grebena (WH), dužina tela (BL), obim grudi (CG), visina plećke (SW), dužina uveta (EL), obim cevanice (CC) i obim vrata (NC)] je ispitivan na uzorku od 142 koze rase crveni sokoto, u uzrastu od 19.3-30.6 meseci, korišćenjem analize putanje/pravca. Grla su odabrana metodom slučajnog uzorka na farmama malih proizvođača koje se nalaze u severnoj Nigeriji. Korelacije parova između telesnih masa i lineranih osobina tipa su bile pozitivne i visoko signifikantne ( $r = 0.74 -$



0.92;  $P < 0.01$ ). Analiza pravca je otkrila da je dužina tela imala najveći direktni uticaj na telesnu masu, zatim obim grudi i širina plećke, respektivno (koeficijent pravca/putanje = 0.354, 0.253 i 0.214 za BL, CG i SW, respektivno). Optimalni linerani regresioni model sa koeficijentom determinacije ( $R^2$ ) od 0.934 uključivao je i indikatore prognoze, kao što su dužina tela, obim grudi, širina plećke, obim cevanice i obim vrata. Ova regresiona jednačina bi mogla da se koristi za predviđanje telesne mase koza rase crveni sokoto na terenu, u aktivnostima vezanim za selekciju.

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