QUANTIFYING SIZE AND SHAPE DIFFERENCES BETWEEN MUTURU AND N'DAMA BREEDS OF CATTLE

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ABSTRACT

Body weight and eight linear body traits, namely heart girth, body and diagonal lengths, height at withers and at hip, width of loin and at pelvic bone, and depth at rear flank, were measured forthnightly on 32 Muturu bulls, 16 of which were born in the dry season (Muturu -D) and the remaining 16 in the rainy season (Muturu-R), and on 11 N'dama bulls. Correlations between all pairs of traits in all groups were high, positive and significant (r >0.093). The first two principal components derived from the correlation matrix of the linear measurements, PCI and PC2 accounted for at least 98% of total variance in all cases and were regarded as 'size' and 'shape' vectors, respectively. Whereas PC1 gave largest weight to heart girth, PC2 gave largest weight to two or more different other linear measurements in the three groups. N'dama had the best conformation, followed by Muturu -D and then Muturu - R. PC- based prediction models were more parsimonius than linear measure-based models and are considered preferable for selecting animals for "optimal" balance. Also, in addition to discriminating between the two different breeds, PC- based discriminant functions were able to discriminate among individuals within the same breed on the basis of nutritional differences. These functions are therefore recommended for classifying animals according to different macro and micro criteria.

Key Words: Body size, shape, linear measurement, parsimonious component, discriminant function

INTRODUCTION

Body size and shape (or conformation) are important traits in meat animals. Whereas the former has been largely estimated quantitatively by scale weights, the later has generally been described by visual appraisal, giving rise to subjective scores and such descriptions as blocky, rangey, compact, etc. However, various linear body traits have traditionally been assessed and recorded in many countries (Zarnecki et al., 1985), and their relationships with body size, shape and production have been investigated by previous workers.

For example, Lerner (1937) observed that shank length was a criterion of body size in broiler chickens, while Jaap and Penquite (1938) reported that the most desirable measure of body shape in chickens was the relationship between the cube root of body weight and length of shank. In cattle, while Wilson *et al.* (1969) used the product of chest depth, hook width and body length as a measure of mature size, Jeffery and Berg (1972) used weight/height ratios as indicators of cow condition. Also, in studies involving three West African breeds of cattle in Nigeria, Buvanendran *et al.* (1980) reported that under field conditions, live weight estimated using chest girth alone may be preferred to combinatons with other measurements.

More recently, the multivariate techniques of principal components and factor analysis have been found useful for analyzing data on body weight and linear body measurements of meat animals to provide quantitative measures of body size and shape (Brown *et al.*, 1973; Carpenter *et al.*, 1978; McCurley and McLaren, 1981; Zarnecki *et al.*, 1985; Zarnecki *et al.*, 1987; Ibe, 1989). Questions of optimal size and shape of beef cattle have generated controversy among cattlemen and scientists alike (Carpenter *et al.*, 1978). Moreover, a quantitative measure for animal conformation is desirable as it will enable reliable genetic parameters for this trait to be estimated and permit its inclusion in breeding programmes (Ibe, 1989). Also, the relationship between scale weight and easily measured linear body traits will be useful for predicting body weight in situations where weighing facilities are not available, as in many African farming conditions (Mani *et al.*, 1991).

The objectives of this study are, therefore, (i) to examine the nature of interdependencies among different linear body measurements in two tropical beef breeds of cattle, namely Muturu and N'dama, and their relationships with scale weight, (ii) to determine appropriate quantitative measures of body size and conformation (shape) in these breeds, and (iii) to use these quantitative measures to discriminate between them.

MATERIALS AND METHODS

Material

Thirty-two Muturu bull calves were used. Sixteen of these born during the dry season between November and January (Muturu-D) had an average weaning age of 40 days (26-62 days); the remaining sixteen born during the rainy season between April and July (Muturu -R) had an average weaning age of 69 days (56-97 days). These calves were purchased from Muturu cattle rearers around the research area, a derived savanna zone. Eleven N'dama bull calves with an average age of 140 days (86-150 days) were purchased from a commercial ranch. All calves were reared in the University Teaching and Research Farm.

Reconstituted powdered milk was fed twice daily (morning and evening) at the rate of 700-800 ml per calf per day to the Muturu calves for a period of about 40 days. Calves of both breeds also had daily access to fresh green fodder consisting mainly of guinea grass *(Panicum maximum)* and giant star grass *(Cynodon dactylon)*. In addition, a 16% crude protein concentrate ration, comprising maize (39%), palm kernel meal (27%), undelinted cotton seed cake (4%), dry brewer's spent grain (28%) and bone meal (2%), was fed to the calves at the rate of 400-800 g per calf per day, depending on the calf's body weight. This feeding regimen was maintained until the calves were approximately 9 months old when brewer's spent grain was substituted for the 16% crude protein concentrate rations. Calves were thenceforth maintained only on the spent grain and normal grazing until the termination of the experiment. Routine deworming and spraying programmes of the farm were carried out.

Calves were weighed every forthnight between 07.15h and 08.30h before morning feeding/grazing. The following linear body measurements were also taken on each animal after weighing: height at withers (HW), heart girth (HG), body length (BL), height at hips (HH), width of loin (WL), width at pelvic bone (WPB), diagonal length (DL) and depth at rear flank (DRF).

Statistical Analysis

The correlation matrix of body weight (BW) and the linear body measurements were determined in each of the three experimental groups of cattle, namely Muturu-D, Muturu-R and N'dama.

A principal components analysis was run on a subset of the overall correlation matrix corresponding to the linear measurements in each group. The technique, fully described by Anderson (1958), Morrison (1967) and Draper and Smith (1981), involves computation of eigenvectors and eigenvalues of the correlation matrix. Whereas the former are principal component weights, the latter represent the generalized variance explained by each principal component (PC). The i-th PC, considering a p-variate system, may be represented, following Ibe (1989), as in (1).

$$PC_i = a_{ij} X_j + a_{i2} X_2 + \ldots\ldots\ldots\ldots + a_{ip} x_p \ldots. (1)$$

where a_{ij} is the j-th component of the coefficient vector of the linear transformation, and X_j is the j-th original variable (linear body measurement).

The stepwise variable selection multiple regression approach was used to obtain models for predicting live body weight from linear body measurements (2) and from established principal components (3).

$$BW = a + \beta_1 x_1 + ... + \beta_k x_k .... (2)$$

$$BW = a + \beta_i PC_i + ... + \beta_k PC_k ....(3)$$

where Bw is the body weight, a is the regression intercept, β_i is the i -th partial regression coefficient of the i - th linear body measurement, x_i or the i - th principal component, PC_i.

A simple linear regression model (4) was fitted to the PC-age data to determine how each PC was changing with age.

$$PC_i = a + \beta A_i \quad ....(4)$$

where a is the intercept, B is the regression slope and A_i is the i-th age. Correlations between the principal components and between each of them and the linear body traits were also determined.

Discriminant analyses, using the linear body measurements and established PCs, were performed. This technique determines k-1 new orthogonal variables, D_i originating from the measured traits by linear transformaton (Hyankova *et al.,* 1985). It was used here to discriminate among the three groups of animals. The i-th discrminant function is of the form in (5).

$$D_i = d_{i1}z_1 + d_{i2} z_2 + ... + d_{ij} z_j ..... (5)$$

where z_j s are standardized values of the original variables and d_{ij} 's are the standardized classification function coefficients.

All analyses were done using the Statgraphics Statistical Graphics System Software for personal computers (STSC, 1987).

RESULTS

Correlations

Correlations between BW and each of the linear body traits and between the latter themselves in all groups were high, positive and significant (r>0.93); P<.001). In all groups, while correlations between the first derived principal component, PC1 and BW and between the former and each of the linear body measurements were high, positive and significant (average r>0.96; P<.001), those between the second principal component, PC2 and the aforementioned traits were high, negative and significant (average r = -0.96; P<.001). Also, a high, negative and significant correlation (r = -0.999 to - 0.952; P<.001) between PC1 and PC2 in all groups was obtained.

Principal Components

Principal component weights derived from the correlation matrix of the eight linear body measurements in the three groups studies are given in Table 1. In all cases, the first two components, PC1 and PC2 accounted for at least 98% of total variance. As a result, only these two components were considered. The first PC consists of all positive coefficients and is regarded as the 'size' vector, whereas PC2, consisting of both positive and negative coefficients, is the 'shape ' vector (Brown *et al.,* 1973; Carpenter *et al.,* 1978; McCurley and McLaren, 1981; Zarrnecki et al., 1985; Zarnecki *et al.,* 1987; Ibe, 1989). In all groups, the largest coefficient in PC1 was for HG, followed by DL and BL, in that order. In Muturu-D, PC2 essentially contrasts individuals with small heart girth and shallowness at rear flank with those having pronounced back and diagonal lengths and height at withers and at hips. In N'dama, the contrast is between individuals having pronounced height at withers and at hips and those poor in the other linear body measurements.

Linear prediction models

Models for predicting body weight from linear body measurements and from the established principal components are given in Tables 2 and 3, respectively. Whereas five of the eight linear body traits, namely HG, WL, WPB, DL and DRF, explained over 98% of the variation in body weight in Muturu -D, only four (HG, WL, HH and BL) and three (HW, WL and WPB) expalined same amount of variation in body weight in Muturu-D, only four (HG, WL, HH and BL) and three (HW, WL and WPB) explained same amount of variation in Muturu - R and N'dama, respectively. All regressions were significant (P<.001). With the exception of WL which appeared in prediction models for the three groups, HG in models for the two Muturu groups, and WPB in models for Muturu-D and N'dama, the models used different linear measurements to predict body weight.

Both PCI and PC2 were required to predict BW in Muturu-D, whereas only PCI was required in Muturu-R and in N'dama. Each principal component model accounted for about 97% of the total variation and was significant ($P < .001$).

Change of body size and shape indices with age

Regressions of PCI and PC2 individually on age for all groups are presented in Tables 4 and 5, respectively. Table 4 shows that, although N'dama had the largest body size index at birth and at subsequent ages compared with two Muturu groups, the positive rate of change in the index with age was not statistically different ($P > .05$) among the three (average = 7.29). On the other hand, the rate of change in shape index was negative, with N'dama showing the smallest change (0.68) compared with 3.99 and 4.53 for Muturu-D and Muturu-R respectively.

At the ages considered, N'dama had the best conformation, followed by Muturu-D and then Muturu-R. Ibe (1989) had reported that larger PC2 values were indicative of better conformation. Each of the linear regression models accounted for between 80 and 97% of total variation and was significant ($P < .001$).

Discriminant analysis

Results of the discriminant analyses using both linear body measurements and derived principal components are presented in Table 6. The discriminant function derived from the linear measurements provides good discrimination between N'dama and the two Muturu groups but could not discriminate between the latter (see group centroids in Table 6). The function correctly classified 65.6, 67.7 and 98.9% of N'dama, Muturu-D and Muturu-R individuals, respectively.

On the other hand, the function derived from the two principal components provides good discrimination among the three groups (See group centroids in Table 6). More importantly, the PC-based discriminant function provided 99.4 to 100% correct classification of individuals belonging to the three groups.

DISCUSSION

The high correlations between body weight and all the linear body measurements indicate a definite association of the latter with body growth. Similar high correlations have been reported in temperate breeds of cattle by Jeffery and Berg (1972) and by Carpenter *et al.* (1978), and in three West African breeds, namely White Fulani, Sokoto Gudali and N'dama, by Buvanendran *et al.* (1980). As a result of such high correlations, it is possible to predict growth of the whole body from parts thereof. This is useful in farm situations where scales are not available, as indicated earlier. Even where scales are available, it is recognised that scale weight does not adequately distinguish difference in body composition of animals and is greatly influenced by fluctuations in gut fill (Carpenter *et al.*, 1978; Ibe, 1989). Dalton (1981) estimates that 10-25% of actual weight in cattle and sheep could be accounted for by gut fill. Fitzhugh *et al.* (1967) also observed that while weights of mature cows vary considerably during the production cycle, depending on seasonal changes in nutrient sources and physiological status, especilly pregnancy and lactation, linear body measurements of these animals vary little throughout the production cycle.

However, due to observed multicollinearity (indicated by high pairwise correlations of the predictor variables and small eigenvalue of the correlation matrix), use of these linear measures to predict body weight/growth is considered statistically unsound as unstable estimates may results (Ibe, 1989), leading to unreliable predictions. Gill (1986) also stated that least squares estimates of parameters are known to be highly erratic if two or more X-variables are related in such a way that multicollinearity causes near-singularity of the X'Xmatrix. These observations justify the use of indices of the linear measurements, referred to as principal components, for prediction, since they are orthogonal to each other.

Over 98% of total variation in the system of the eight linear body measures was explained by general body size differences, represented by PCI. This probably accounts for the high positive correlation among all body parts and between PCI and body weight. Carpenter *et al.* (1978) reported a high correlation of 0.93 between cow weight and PCI from their data and observed that the first two principal components contained 90% of the information provided by their original four variables. On the other hand, less than 2% of total variance was explained by shape differences, represented by PC2, Body shapes do not always indicate a positive relationship among linear body measures, hence their negative correlations with PC2. Also, the high negative correlation between body size and shape indices (PCI and PC2, respectively) indicates that the two are different and that body shape or conformation decreases with increasing body size. Increase in the body size of an animal could be due to excessive fat deposition in different parts of the body which could result in poor body shape. Brown *et al* (1973) recognized the importance of "optimal" balance in cattle, since those which represent real extremes in some body measures may be less desirable from the standpoint of fitness. They also stated that since body weight, size or shape may be reached in different ways by animals, selection for a given performance trait need not be accompanied by an increased uniformity in body shape.

Results indicate that body size was influenced most by heart girth, irrespective of breed and season of birth. Zarnecki *et al.* (1987) similarly reported that the size vector, PC1 derived from their data gave the largest weight to heart girth for 12 and 18 month old heifers and 12-month old bulls. The implication is that a breeder or cattleman could have fairly good idea of body sizes of his animals by simply measuring their heart girths. Thys and Hardouin (1991) recognized heart girth as the most precise and easy to apply of the linear body measurements for predicting body weight in sheep. Their prediction models with heart girth only explained 86.5 and 90.8% of total variation of body weight in rams and ewes, respectively. Buvanendran *et al.* (1980) observed that chest girth accounted for 86-96% of total variation in body weight in three West African breeds of cattle, and therefore recommended the use of this body measurement alone to predict live-weight under field conditions.

For body shape, body and diagonal lengths contributed most in Muturu-D, whereas in Muturu-R, in addition to these length measurements, heights at withers and at hips were important. In N'dama, the most important measures contributing to shape are heights at withers and at hips. These results confirm the observation by Brown *et al.* (1973) that body shape may be reached in different ways and indicate that shape of animals is not as easy to quantify as body size. Different linear body measures may be required to do this in different breeds and under different circumstances, for example, feeding.

Although both linear measure-based and PC-based models for predicting body weight differed with breed and with seasonal- changes within breed, the latter were more parsimonious and are considered preferable for purposes of selection for "optimal" balance, since they combine both body size and shape components into a composite index for prediction. The better conformation of Muturu bulls born during the dry season compared with those born during the rainy season when feed was more abundant indicates that feed restriction, as occurs during the dry season, may improve the shape of animals, although it adversely affects body size. This is in consonance with the result that body size and body shape are highly negatively correlated. A similar effect of feeding restriction has been reported in broilers by Ibe (1990)

Discriminant functions derived from both linear measurements and principal components confirm that the two breeds, Muturu and N'dama are different, as expected. However, the PC-based function was able to detect differences due to non-animal factors, such as nutrition among individuals of the same breed. PC-based functions are therefore expected to provide more precise discrimination among groups, thereby facilitating better classification of individuals according to different macro and micro criteria, such as breed, strain, variety, health status, nutrient status, et cetera.

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Table 1 PRINCIPAL COMPONENT WEIGHTS FOR THE VARIOUS LINEAR BODY MEASUREMENTS

Measurement[b]	Muturu-D[a] PC1	Muturu-D[a] PC2	Muturu-R PC1	Muturu-R PC2	N'dama PC1	N'dama PC2
HW	.294	.078	.300	.331	.315	.650
HG	.571	-.429	.584	-.670	.582	-.211
HH	.306	.082	.302	.334	.313	.591
WL	.108	-.118	.133	-.126	.141	-.194
WPB	.198	-.286	.221	-.053	.206	-.238
BL	.422	.516	.397	.317	.396	-.181
DL	.432	.436	.410	.394	.404	-.200
DRF	.279	-.501	.293	-.234	.287	-.130
Cum.%of total Variance	98.50	99.13	98.69	99.12	97.60	98.43

a PC1 = first principal component; PC2 = second principal component

b. HW = height at withers; HG = heart girth; HH = height at hips WL = width of loin; WPB = width at pelvic bone; BL-body length; DL = diagonal length; DRF = depth at rear flank.

Table 2. MODELS FOR PREDICTING BODY WEIGHT FROM LINEAR BODY MEASUREMENTS

Group	Model[a]	R^2(%)	S.E.
Muturu-D	BW = -94.46 + 1.13HG + 1.41WL + 1.10WPB + 1.09DRF - 0.58DL	98.3	4.360
Muturu-R	BW = -87.27 + 1.08HG-0.81HH + 3.08WL + 0.81BL	98.2	4.666
N'dama	BW = -255.66 + 2.25HW + 4.52WL + 1.84WPB	98.3	5.779

a See Table 1 for meanings of trait abbreviations

Table 3 MODELS FOR PREDICTING BODY WEIGHT FROM PRINCIPAL COMPONENTS

Group	Model[a]	R^2(%)	S.E.
Muturu-D	BW = - 138.22 + 2.18PC1 + 2.00PC2	97.2	5.541
Muturu-R	BW = - 134.08 + 1.12PC1	96.8	6.193
N'dama	BW = - 264.65 + 1.73PC1	97.0	7.617

a BW = body weight; PC1 and PC2 = lst and 2nd principal component, respectively.

Table 4 REGRESSION OF FIRST PRINCIPAL COMPONENT (PC1) ON AGE

Group	Model	R^2(%)	S.E.
Muturu-D	PC1 = 115.81 + 7.16 Age	95.7	6.276
Muturu-R	PC1 = 118.36 + 7.47 Age	96.9	5.401
N'dama	PC1 = 143.98 + 7.25 Age	94.0	6.118

TABLE 5 REGRESSION OF SECOND PRINCIPAL COMPONENT (PC2) ON AGE

Group	Model	R^2(%)	S.E.
Muturu-D	PC2 = -57.29-3.99 Age	94.8	3.877
Muturu-R	PC2 = -67.11-4.53 Age	96.6	3.399
N'dama	PC2 = -13.14-0.68 Age	80.5	1.117

TABLE 6 FIRST DISCRIMINANT FUNCTION, USING LINEAR BODY MEASUREMENTS AND PRINCIPAL COMPONENTS

Function[a]	Rel. %	Groups Centroids 1	2	3	%Correct Classification 1	2	3
D_l = -2.51HW + 1.56HG -3.02HH-0.14WL -0.02WPB + 1.99BL + 1.74DL + 0.11DRF	98.23	1.36	1.01	-4.19	65.6	67.7	98.9
D_p = +2.82PC1 + 2.92PC2	99.96	-2.84	-4.97	13.89	100.0	99.4	100.0

a D and D are lst discriminant function based on linear body measurements and on principal components, respectively. See Tables 1 and 3 for meanings of trait abbreviations.