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Mathematical evaluation of the relationships between some objective measurements and prices of breeding bucks and does in Nasarawa State, Nigeria

[1]*Yakubu, A., [1]Ishaya, J. O., [1]Idahor, K. O. and [2]Nwangwu, A.

[1]Department of Animal Science, Faculty of Agriculture, Nasarawa State University, Keffi, Shabu-Lafia Campus, P.M.B. 135, Lafia, Nasarawa State, Nigeria.
[2]Department of Animal Husbandry Services, Federal Ministry of Agriculture and Rural Development (FMARD), Abuja, Nigeria
***Corresponding author:** abdulmojyak@gmail.com

Target audience: Goat producers, marketers, consumers, breeders/geneticists, policy makers

Abstract

Body size is one of the most important traits in the breeding objectives and marketing of goats in sub-saharan Africa. This study aimed at determining objectively the relationships between some morphometric measurements and the prices of breeding bucks and does in Nasarawa State, north central Nigeria. Data were collected from a total of 1,012 randomly selected live adult goats of both sexes covering the three Nigerian indigenous breeds of goats [332 West African Dwarf (197 males and 135 females), 374 Red Sokoto (216 males and 158 females) and 306 Sahel goats (172 males and 134 females)]. The animals were sampled in Karu/Keffi and Akwanga/Lafia markets. The traits measured were body weight (BW), chest circumference (CC), scrotal circumference (SC) and udder circumference (UC) including the determination of the price of each animal. General linear model (GLM) was used to test the fixed effects of breed, sex and location including their interactions on the body traits. Pearson's coefficients of correlation among the various traits were computed. The prediction of price from body parameters was done using stepwise regression analysis. The univariate analysis revealed that Sahel goats had significantly (P<0.05) higher morphometric variables compared to other breeds. They also commanded (P<0.05) highest price than the other two breeds. Sex also influenced (P<0.05) all the body parameters with higher values recorded for males, while there was no effect (P>0.05) of market location on the body traits. Among the various interactions, only interaction between sex and location were significant (P<0.05) on price. Coefficients of phenotypic correlation between the traits were positive and significant (P<0.01), ranging from 0.55-0.98. Across all the three breeds, CC appeared to be the best single measurement to determine the prevailing market price of goat. The present information will be useful in determining objectively the prices of goats to the advantage of the farmers, sellers and consumers of meat including researchers who need this information to determine selection index and policy makers for decision making.

Keywords: breeding, goat, marketing, Nigeria, prediction

Description of problem

In Nigeria, goats constitute a very important part of the rural economy, with more than 95% of the rural households keeping goats (1). There are quite a number of country's reports on farm animal genetic resources (2) which illustrate the importance of farm animal genetic resources, particularly for the poor under smallholder animal production systems in Nigeria. Various mathematical/statistical models have been widely been used, amongst are cubic, quadratic and linear models which are put in place to describe quantitative association between dependent and independent variables in animal studies including those involving body size, body condition etc (3, 4).

Livestock marketing studies are essential to provide vital information on the operations and efficiency of the livestock marketing system for accurate price determination including effective research, planning and policy formulation in the livestock sector (5) The common measures of estimation of body weight has been simple correlation coefficients between body weight and morphometric measures or regression of body weight on a number of body measurements like chest girth, testicular and udder circumference (6). Therefore, goat being one of the most important livestock raised by resource-limited farmers, the morphometric measures and BW will viz-a-viz be a determinant for market price of goat. Morphological traits have been used in animals to estimate body weight. This has largely been the case in rural communities where scales are not readily available (7).

The main objective of this study was to evaluate the relationship between objective measurements and the prices of breeding goats (bucks and does) in Nasarawa State, Nigeria; thereby offering opportunity to determine holistically the market price of goats from BW and body measurements with a high degree of accuracy and build trust in goats' value chain system.

Materials and Methods

Description of the study area

The study was conducted in four randomly selected markets within the three senatorial zones of Nasarawa State, Nigeria. However, based on close proximity, they were merged into two namely, Karu/Keffi and Akwanga/Lafia markets. The State covers an area of 27,117km2 with estimated population of 1,863,275 people (8). Nasarawa State falls within the guinea savannah agro-ecological zone and is found between latitudes 7° 52' N and 8° 56' N and longitudes 7° 25' E and 9° 37' E respectively (9)

Data Collection

Data for this study were collected through body weight and some morphometric measurements of 1,012 mature goats (males and females) covering the three Nigerian indigenous breeds of goats [332 West African Dwarf (WAD) (197 males and 135 females), 374 Red Sokoto (RS) (216 males and 158 females) and 306 Sahel (SH) goats (172 males and 134 females)] The animals were sampled as indicated below:

Breed	Sex	Location 1 (Karu/Keffi)	Location 2 (Akwanga/Lafia)
West African Dwarf	Male	77	120
	Female	61	74
Red Sokoto	Male	125	91
	Female	93	65
Sahel	Male	100	72
	Female	77	57
Total		533	479

The physical parameters measured include; body weight (BW), chest circumference (CC), scrotal circumference (SC) and udder circumference (UC). The price [P, in naira (₦)] of each animal was equally recorded.

The anatomical parts and mode of measurements are:

BW: This was taken as the live body weight. Measurement was done using a hanging scale.

CC: The circumference of the chest just behind the forelimbs. A measuring tape was used to measure CC.

SC: This was taken as the widest part of the testes, after the testes had been firmly pushed into the scrotum). A measuring tape was used to measure SC.

UC: This was taken round the udder using a measuring tape.

BW was measured in kg while other body measurements were determined in cm. Only animals having 8 permanent incisors were measured. In order to avoid between-individual variations, all measurements were taken by the same person.

Data Analysis

Data were analysed using the general linear model (GLM) procedure to test the fixed effects of breed, sex, location and their interactions on BW, CC and P. Means were separated using Least Significant Difference (LSD) and tested at 95% confidence interval. The general model employed was:

$Y_{ijk} = \mu + B_i + S_j + L_k + (BS)_{ij} + (BL)_{ik} + (SL)_{jk} + (BSL)_{ijk} + e_{ijkl}$

Y_{ijk} = individual observation

μ = overall mean

B_i = fixed effect of i^{th} breed (i= WAD, RS, SH)

S_j = fixed effect of k^{th} sex (j= *male*, female)

L_k = fixed effect of location (k = 1, 2)

$(BS)_{ij}$ = interaction effect of i^{th} breed and j^{th} sex

$(BL)_{ik}$ = interaction effect of i^{th} breed and k^{th} location

$(SL)_{jk}$ = interaction effect of j^{th} sex and k^{th} location

$(BSL)_{ijk}$ = interaction effect of i^{th} breed, j^{th} sex and k^{th} location

e_{ijkl} = random error associated with each record (normally, independently and identically distributed with zero mean and constant variance).

The Pearson's correlation coefficients were used to assess the association between BW, CC, SC, UC and P. In order to predict P from BW, CC, SC and UC, the stepwise multiple regression analysis procedure was adopted. Coefficient of determination (R^2) (to quantify the proportion of variability explained by a model), Adjusted R^2 = (1

– [(n-1) / (n-p)] (1-R^2) and RMSE (Root mean squares error) were used to assess the accuracy of the regression models. R statistical package (10) was employed in the analysis.

Results

Effect of breed on biometric traits and price of goat

Breed differences were observed in the BW, CC and price of goats. Sahel goats were significantly (P<0.05) superior to RS goats which in turn had higher values than their WAD counterparts in BW and CC. While price was higher in Sahel, there was no significant (P>0.05) difference in the values obtained for RS and WAD (15,200±150.36 versus 8,379±136.92 versus 8,463±145.88) (Table 1).

Table 1. Effect of breed on the morphometric traits and price (Means±SE) of Nigerian goats

	Breed		
Traits	West African Dwarf	Red Sokoto	Sahel
Body weight	20.36±0.16 [c]	23.09±0.15 [b]	27.72±0.17 [a]
Chest circumference	56.66±0.28[c]	60.91±0.26 [b]	69.45±0.29 [a]
Price	8,463±145.88[b]	8,379±136.92 [b]	15,200±150.36 [a]

SE=standard error

Means in the same row with different superscripts are significantly different (P<0.05)

Effect of sex on biometric traits and price of goat

Sexual dimorphism was observed in BW and CC where higher values (P<0.05) were recorded for males (24.16±0.12 versus 23.24±0.21). Male goats also attracted significantly (P<0.05) higher prices than their female counterparts (11,140±108.87 versus 10,220±126.43) (Table 2).

Table 2. Effect of sex on the morphometric traits and price (Means±SE) of Nigerian goats

	Sex	
Traits	Female	Male
Body weight	23.24±0.21[b]	24.16±0.12[a]
Chest circumference	61.45±0.24[b]	63.24±0.21[a]
Price	10,220±126.43[b]	11,140±108.87[a]

SE=standard error

Means in the same row with different superscripts are significantly different (P<0.05)

Effect of market location on biometric traits and price of goat Location of the markets did not significantly (P>0.05) influence BW, CC and price (23.57±0.13 and 23.87±0.14 for Karu/Keffi and Akwanga/Lafia, respectively) of goat in the study area (Table 3).

Table 3. Effect of location on the morphometric traits and price (Means±SE) of Nigerian goats

	Location	
Traits	Karu/Keffi	Akwanga/Lafia
Body weight	23.57±0.13[a]	23.87±0.14[a]
Chest circumference	62.18±0.22[a]	62.50±0.23[a]
Price	10,570±114.59[a]	10,790±121.27[a]

SE=standard error

Means in the same row with the same superscripts are not significantly different (P>0.05)

Interaction effects on biometric traits and price of goat

With the exception of interaction between Sex and Location which significantly (P<0.05) affected the price of goat (Mean square =32930000), other interactions did not have significant (P>0.05) effects on BW, CC and price (Table 4).

Table 4. Analysis of variance showing the interaction effect of breed, sex and location on the morphometric traits of Nigerian goats

Source of variation	Mean squares and level of significance			
	DF	Body weight	Chest circumference	Price
Breed * Sex	2	12.99^{ns}	47.11^{ns}	15580000^{ns}
Breed * Location	2	15.48^{ns}	8.49^{ns}	10830000^{ns}
Sex * Location	1	24.66^{ns}	40.55^{ns}	32930000*
Breed * Sex * Location	2	19.66^{ns}	12.88^{ns}	9457382.94^{ns}

DF=degree of freedom; *Significant at P<0.05; ^{ns} Non-significant

Phenotypic correlations of biometric traits and price of WAD goats in Lafia/Akwanga market Coefficients of correlation (P<0.01) of CC, SC, BW and price of WAD goat ranged from 0.90-0.98 in male goats in Lafia/Akwanga market. In female goats however, the estimates (P<0.01) for CC, UC, BW and price ranged from 0.82-0.96 (Table 5). Price was most highly correlated with CC in both sexes of WAD goats (r = 0.90 and 0.82 for males and females, respectively).

Table 5. Phenotypic correlations of price and the body parameters of West African Dwarf goats in Lafia/Akwanga market*

Traits	CC	SC	UC	BW	Price
CC	-	0.98	NA	0.93	0.90
SC	NA	-	NA	0.89	0.83
UC	0.96	NA	-	NA	NA
BW	0.76	NA	0.75	-	0.85
Price	0.82	NA	0.76	0.71	-

*Significant at P<0.01 for all correlation coefficients
NA= not applicable
Upper matrix: Male goats
Lower matrix: Female goats

Phenotypic correlations of biometric traits and price of RS goats in Lafia/Akwanga market Phenotypic correlations (P<0.01) of CC, SC, BW and price of RS goats in Lafia/Akwanga market ranged from 0.91-0.94 in male goats. In female goats however, the estimates for CC, UC, BW and price ranged from 0.82-0.89 (Table 6). The relationship between price and CC was highest in both sexes (r = 0.94 and 0.89 for males and females, respectively) compared to SC (r = 0.91) and BW (r = 0.86) (males) as well as UC (r = 0.80) and BW (0.81) (females).

Phenotypic correlations of biometric traits and price of SH goats in Lafia/Akwanga market Coefficients of correlation (P<0.01) of CC, SC, BW and price of SH goats in Lafia/Akwanga market ranged from 0.95-0.96 in male goats. In female goats however, the estimates for CC, UC, BW and price ranged from 0.83-0.91(Table 7). The phenotypic correlation coefficient between price and CC was highest in

Table 6. Phenotypic correlations of price and the body parameters of Red Sokoto goats in Lafia/Akwanga market*

Traits	CC	SC	UC	BW	Price
CC	-	0.92	NA	0.91	0.94
SC	NA	-	NA	0.92	0.91
UC	0.82	NA	-	NA	NA
BW	0.85	NA	0.79	-	0.86
Price	0.89	NA	0.80	0.81	-

*Significant at P<0.01 for all correlation coefficients
NA= not applicable
Upper matrix: Male goats
Lower matrix: Female goats

Table 7. Phenotypic correlations of price and the body parameters of Sahel goats in Lafia/Akwanga market*

Traits	CC	SC	UC	BW	Price
CC	-	0.95	NA	0.96	0.96
SC	NA	-	NA	0.98	0.92
UC	0.91	NA	-	NA	NA
BW	0.83	NA	0.89	-	0.89
Price	0.86	NA	0.90	0.89	-

*Significant at P<0.01 for all correlation coefficients
NA= not applicable
Upper matrix: Male goats
Lower matrix: Female goats

males (r = 0.96) while in females, price was most highly correlated with UC (r = 0.90).

Phenotypic correlations of biometric traits and price of WAD goats in Karu/Keffi market Coefficients of correlation (P<0.01) of CC, SC, BW and price of WAD goats ranged from 0.91-0.97 in male goats. In female goats however, the estimates for CC, UC, BW and price ranged from 0.71-0.89 (Table 8). The phenotypic correlation between price and CC was highest in males (r = 0.91) while in females, price was most highly correlated with BW (r = 0.78).

Table 8. Phenotypic correlations of price and the body parameters of West African Dwarf goats in Karu/Keffi market*

Traits	CC	SC	UC	BW	Price
CC	-	0.97	NA	0.91	0.91
SC	NA	-	NA	0.88	0.85
UC	0.89	NA	-	NA	NA
BW	0.71	NA	0.65	-	0.84
Price	0.72	NA	0.55	0.78	-

*Significant at P<0.01 for all correlation coefficients
NA= not applicable
Upper matrix: Male goats
Lower matrix: Female goats

Phenotypic correlations of biometric traits and price of RS goats in Karu/Keffi market Phenotypic correlations (P<0.01) of CC, SC, BW and price of goat ranged from 0.83-0.93 in male goats (Table 9). In female goats however, the estimates for CC, UC, BW and price ranged from 0.77-0.87. The phenotypic correlation between price and CC was highest in both sexes (r = 0.83 and 0.77 for both males and females, respectively).

Table 9. Phenotypic correlations of price and the body parameters of Red Sokoto goats in Karu/Keffi market*

Traits	CC	SC	UC	BW	Price
CC	-	0.93	NA	0.92	0.83
SC	NA	-	NA	0.93	0.81
UC	0.83	NA	-	NA	NA
BW	0.87	NA	0.80	-	0.78
Price	0.77	NA	0.65	0.73	-

*Significant at P<0.01 for all correlation coefficients
NA= not applicable
Upper matrix: Male goats
Lower matrix: Female goats

Phenotypic correlations of biometric traits and price of SH goats in Karu/Keffi market

Coefficients of correlation (P<0.01) of CC, SC, BW and price of goat were 0.93 in male goats. In female goats however, the estimates for CC, UC, BW and price ranged from 0.81-0.87 (Table 10). The relationship between price and CC was highest in males (r = 0.93) while in females, price was most highly associated with UC (r = 0.89).

Table 10. Phenotypic correlations of price and the body parameters of Sahel goats in Karu/Keffi market*

Traits	CC	SC	UC	BW	Price
CC	-	0.93	NA	0.93	0.93
SC	NA	-	NA	0.91	0.90
UC	0.87	NA	-	NA	NA
BW	0.81	NA	0.90	-	0.91
Price	0.81	NA	0.89	0.86	-

*Significant at P<0.01 for all correlation coefficients
NA= not applicable
Upper matrix: Male goats
Lower matrix: Female goats

Regression analysis of price and body traits of goats in Lafia/Akwanga market

In bucks, the prediction model revealed that CC is the most important single trait to predict price of WAD goat in Lafia/Akwanga market. The coefficient of determination (R^2) to assess the level of prediction was found to be very high (about 81%). Similarly, CC was the most significant single trait to predict price of does. Price could also be predicted from the combination of CC and SC (bucks), CC and BW and CC, BW and UC (does) (Table 11).

Regression analysis of price and body traits of goats in Karu/Keffi market

The regression model also revealed CC as the most important single trait to predict price of WAD bucks in Karu/Keffi market. The R^2 was very high (about 80%). However, BW was the most significant single trait to predict price of does (R^2= about 60%). Price could also be predicted from the combination of CC and SC (bucks), BW and CC and BW, CC and UC (does) (Table 12). The regression model equally revealed CC as the most important single trait to predict price of RS bucks in Karu/Keffi market. The R^2 was high (about 69%). Similarly, CC

Table 11. Prediction of prices of goats in Lafia/Akwanga market from their body parameters using stepwise multiple regression models

Model	Significance	R^2	Adjusted R^2	RMSE
West African Dwarf				
Male				
Price = -4059.63 + 220.90CC	P<0.01	0.808	0.806	783.58
Price = -10079.32 + 570.20CC + -920.11SC	P<0.01	0.881	0.879	619.86
Female				
Price = -2957.90 + 199.20CC	P<0.01	0.671	0.666	911.79
Price = -3027.80 + 159.50CC + 112.90BW	P<0.01	0.691	0.682	889.68
Price = -5252.76 + 275.17CC + 126.80BW + -296.00UC	P<0.01	0.710	0.697	868.13
Red Sokoto				
Male				
Price = -29143.57 + 614.99CC	P<0.01	0.889	0.888	805.63
Price = -23249.31 + 438.52CC + 222.15SC	P<0.01	0.903	0.900	758.79
Female				
Price = -20497.97 + 472.26CC	P<0.01	0.792	0.788	908.25
Sahel				
Male				
Price = -46189.94 + 884.06CC	P<0.01	0.913	0.911	987.12
Price = -57698.62 + 1208.40CC + -395.86BW	P<0.01	0.923	0.921	931.61
Price = -48885.00 + 1064.58CC + -1102.99BW + 800.74SC	P<0.01	0.952	0.950	740.12
Female				
Price = -11041.91 + 1000.69UC	P<0.01	0.818	0.815	1418.23
Price = -15448.63 + 587.80UC + 555.98BW	P<0.01	0.855	0.849	1279.60

Table 12. Prediction of prices of goats in Karu/Keffi market from their body parameters using stepwise multiple regression models

Model	Significance	R^2	Adjusted R^2	RMSE
West African Dwarf				
Male				
Price = -4557.53 + 230.06CC	P<0.01	0.801	0.798	831.85
Price = -8045.75 + 437.94CC + -555.85SC	P<0.01	0.836	0.832	758.45
Female				
Price = -372.001 + 424.71BW	P<0.01	0.602	0.595	1044.62
Price = -2537.87 + 295.53BW + 86.23CC	P<0.01	0.656	0.644	980.24
Red Sokoto				
Male				
Price = -32084.20 + 667.61CC	P<0.01	0.689	0.686	1561.45
Price = -25193.75 + 467.76CC + 242.23SC	P<0.01	0.699	0.694	1540.89
Female				
Price = -17870.80 + 428.51CC	P<0.01	0.595	0.591	908.25
Sahel				
Male				
Price = -45976.28 + 880.37CC	P<0.01	0.855	0.854	1297.97
Price = -33279.79 + 566.22CC + 350.411SC	P<0.01	0.868	0.865	1245.99
Female				
Price = -11366.034 + 1016.79UC	P<0.01	0.790	0.787	1555.48
Price = -14409.058 + 667.18UC + 446.93BW	P<0.01	0.813	0.808	1476.81

was the most significant single trait to predict the price of does (R^2= about 70%). Price could also be predicted from the combination of CC and SC (bucks). The regression model also revealed CC as the most important single trait to predict price of SH bucks in Karu/Keffi market with R^2 value of about 86%. However, UC was the most significant single trait to predict the price of does (R^2= about 79%). Price could also be predicted from the combination of CC and SC (bucks), UC and BW (does).

Discussion

Goat is a multi- functional animal and plays a significant role in the economy and nutrition of landless, small and marginal farmers (11). Breed differences may be due to the genetic potential of West African Dwarf, Red Sokoto and Sahel goats. The differences observed in the prices of male and female goats may be as a result of the purpose each sex was needed for and the bargaining power of the buyer. It may also be attributed to the bigger body dimensions of the male animals. It has been reported that a large body size as an indicator of good growth rate, is equally an important trait when marketing animals (12, 13).

The present findings indicate the separate rankings of the two sexes under the two locations investigated. Sex and location interaction indicates that the price of male and female goats is different in Lafia/Akwanga and Karu/Keffi markets, respectively. The amount that a farmer or marketer fixes for a male goat in the first market may be different from the value of a similar male goat in the second market and vice versa. There is dearth of information on Sex and location interaction effect on the price of goats.

The high correlation coefficients obtained in the present study indicate the level of interdependence of CC, SC, BW and price of WAD and RS goats in both markets. The strong relationship existing between body weight and body measurements may be useful as selection criterion. This, therefore, provides a basis for the genetic manipulation and improvement of the indigenous stock especially in the rural areas where resources for a large scale breeding programme are scarce. Similarly, positive association of body parameters with the price of goats suggests that any of these traits can be used to determine the market worth of goats. The estimates of correlation in the present study are comparable to those reported by earlier workers (14). The strong association of CC with other traits especially BW is consistent with the submission of Lorato *et al*. (15) where CC had the highest correlation with body weight at various ages and in both sexes compared with other parameters.

There is currently a global effort by The Goat Trust not only on marketing of goats but more important on developing a standardised transparent system of goat pricing that is reasonable and acceptable to farmers and traders both. Based on such pricing standardization, farmers, traders and the final consumers will be able to objectively assess the animals and have actual value for their livestock products. Nowadays, small ruminant fattening activities are being promoted under the smallholder farmers to enhance meat supply. However, there is difficulty in animal marketing in relation to price setting. The market price is usually set by subjective measurements (i.e. visual judgment and loin-eye-area palpation) (11). Estimating the market price based on live weight is quite important in reducing the bargaining practices. Due to lack of weighing scale in the remote rural areas and most goat markets, it is almost impossible to obtain any accurate measurement of this very important trait. The present study revealed the significance of CC in determining not

only the BW but the price of goats. Any unit increase in this variable, buyers would be willing to pay premium. Abegaz and Awgichew (16) reported that increasing the genetic potential for meat production of a goat breed requires selection for increased size and live-weight; and that mathematical equations involving linear measures like CC are useful under these situations. According to them, such equations can be used to change linear measurements into weight estimates. The practical implication of the present study this is that farmers and marketers could use the readily available tapes to determine the actual worth of their birds considering the high correlation between BW, CC, SC and UC including the price of goats. This will ultimately lead to more gains to the goat farmers and marketers while the consumers will also go home with a level of satisfaction of not being cheated. The researchers on the other could use these to derive economic values which will be fitted in the subsequent selection index.

Conclusion and application

1. Sahel goats had higher values in BW, CC and price than RS goats which in turn was superior to WAD counterparts in BW and CC only.
2. There was sexual dimorphism in all the traits measured with male goats having higher values.
3. Sex and Location interaction effect was significant on price, an indication of separate pricing of the male and female goats in the two markets investigated.
4. Positive relationships amongst BW, CC, SC, UC and price are indications that the prices of goats can be predicted from any of the measurements.
5. However, CC appeared to be the best single trait to determine objectively the market price of goat. This measurement is easy to carry out with the use of a tape, thereby enabling farmers, marketers and consumers to have values for their goats.
6. Linear tapes incorporating especially CC could be developed for goats in the study markets thereby enabling farmers, marketers and consumers to have values for their WAD, RS and SH goats.
7. Objective determination of price will also afford geneticists the opportunity to derive economic value for selection index while policy makers could exploit it to make meaningful decisions geared towards increased goat production in the study areas

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