DOI: 10.22620/agrisci.2024.42.008

MORPHOBIOMETRIC CHARACTERIZATION OF DONKEY RESOURCES IN KATSINA STATE

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Abstract

This study was conducted to assess the morphological characteristics of the donkey (*Equus asinus*) population in Katsina State, Nigeria. One hundred and three (103) donkeys (39 female and 64 male), randomly selected, were grouped into three age categories for this study. Data collected included: body weight and ten (10) body measurements. The statistical analysis of variance was applied for estimation the effects of sex and age on the studied parameters. Variance Inflation Factors (VIF), as a multicollinearity diagnostic tool of the independent variables, were incorporated in the regression models. The principal component analysis with a variance maximizing the orthogonal rotation was used to extract the components. The factor analysis identified four (4) principal components (PCs) of morphometric traits which explained about 70.392% of the total variance, with a PC1 accounted for 37.912%. The results showed that the body weight was correlated with HG, PG, BL, RH, SH, EL, TL and NC (ranging from 0.464 to 0.946; $p<0.01$) and body weight correlated to NL ($r = 0.402$; $p<0.05$) and HL ($r = 0.375$; $P<0.05$). The best predictors of body weight (BWT) in female and male revealed that the combination of heart girth, body length and rump height featured prominently in the prediction of BWT.

Keywords: body weight, donkeys, morphological, prediction, regression

INTRODUCTION

Donkeys are mainly used for traction, transportation of various goods and farming activities in the Northern Nigeria, however, annually the traders purchase and transport about 16 000 donkeys to the Southern part of Nigeria where both the meat and the milk are consumed (Starkey & Fielding, 2004, John et al., 2017). Rossel et al. (2008) reported that the donkey can thrive better under harsh environmental conditions, including high temperature, low rainfall and low-quality feeds as a result of certain genetic and morphological changes that occurred during its domestication. According to FAOSTAT (2014), the world population of donkeys was around 43 million, with about 38.7% found in Africa. In Nigeria, the donkey population accounts for about 800 000 (FAO, 1989) widely distributed in the Northern part of the country due to the influence of the trans-boarders trading across the Sahara (Starkey & Fielding, 2004).

Donkey breeds are globally reduced and are vulnerable to extinction (Quaresma et al., 2013). This is due to a recent increasing demand for donkey hides from China for the production of medicine which has triggered a decline in the global donkey population (FAO, 2016, Matlhola & Chen, 2020). It is observed that most of the donkey-hides trading takes place in Kano State of Northern Nigeria. The trading activities cause a loss of many qualitative breeds with highly valuable traits (John et al. 2017).

The loss should be considered as disastrous for the future and should be avoided acknowledging the donkey significance in habitat conservation and economic development (Quaresma et al., 2013).

Genetic resource conservation is a key in conserving biodiversity, especially when indigenous breeds are rapidly decreasing. A significant decline in population size might generate high inbreeding rates and depression with a high risk of breed extinction (Ahmad-Syazni et al., 2017, Khaleel et al., 2020). The loss of genetic diversity, especially in potentially unsustainable species such as donkeys, causes the simultaneous loss of essential functional traits (Navas et al., 2017) and the genetic variation have to be maintained in any given species (Ha et al., 2017; Ahmad-Syazni et al., 2017). Hassen et al. (2012), however, reported that indigenous genetic resources are faced with extinction, emphasizing the importance of conserving the identified domestic animal diversity for proper utilization.

Variations in phenotype and morphological features are the basic parameters in the species genetic diversity (Rosa et al., 2007). The parameters create the basics for comparison that is cheaper and yields positive results especially among different breeds (Lanari et al., 2003, Tolenkhomba et al., 2012). Researchers have highlighted the benefits of the comparative body morphological traits amongst different breeds as essential and as a pre-requisite for a genetic modification as well as a selective breeding database (Turke et al., 2016, John et al., 2017, Behl et al., 2017). Also, understanding the morphological and phenotypic characteristics of an animal helps in determining the history, origin and geographical distribution of the breed (Turke et al., 2016). Research on the donkey population in the region is generally limited, hence this study aimed to assess the morphological characteristics of the donkey population found in the region as to provide a useful database for selection, breeding and conservation purposes as well as to facilitate the sustainable utilization of the resources. The information obtained from this study will also assist in predicting body weight using the linear body measurements of the donkeys.

MATERIALS AND METHODS

Study Area

This study was carried out in two towns within Katsina State, Charanchi and Mai'Adua. The description of the study location was earlier given by Rotimi et al. (2023).

Data collection

Age Determination

The age of the donkeys was determined using a dentition (FAO, 2003). The donkeys were categorised into three (3) age groups: group 1 (< 5 years), group 2 (6-10 years) and group 3 (>11 years).

Morphobiometric measurements

Measurements were taken on randomly sampled donkeys from the study area. Data were obtained from one hundred and three (103) donkeys (39 Jennets and 64 Jerks) for this study. Sick and pregnant donkeys were not included. The measured body parameters were as follow:

Heart girth (HG): the circumference of the body at the narrowest point just behind the shoulder perpendicular to the circumference of the body, and just in front of the hind leg perpendicular to the body axis.

Paunch girth (PG): the circumference of body at the narrow point just before the crupper perpendicular to the circumference of the body in the front of the fore leg.

Body length (BL): the distance between the point of the shoulder to the point of the hip i.e. the distance from the first thoracic vertebrae to the base of the tail.

Rump Height (RH): vertically measurment from the crupper down to the hoof.

Shoulder Height (SH): the vertical distance from the ground to the point of the withers measured vertically from the ridge between the shoulder bones to the fore hoof. This is also known as the height at wither.

Ear length (EL): the distance from the base to the zygomatic arch of the ear.

Tail length (TL): from the base of the tail to the tip.

Neck length (NL): the distance from the base of the cervical vertebra to the base of the top shoulder.

Neck circumference (NC): the circumference of the neck at the midpoint.

Head Length (HL): the distance from between the ears to the upper lip.

The measurements were recorded following the recommended FAO descriptors for animal genetic resources (FAO, 2003, Salako, 2006). The linear body measurements were taken by using measuring tapes (cm).

Estimation of body weight

Body weight (BW) was estimated using the body measurements (Pearson and Ouassat, 2000), thus;

$$\text{BW (kg)} = \frac{[\text{Heart girth (in cm)X } 2.12]\text{X } [\text{body length (in cm)X } 0.688]}{3801}$$

Body Indices

Two (2) body indices were calculated from the body measurements following the methods described by Madani et al. (2022):

Profile index (PI) = SH/BL

Where, SH = Shoulder height (cm), BL = Body length (cm)

Body index (BI) = BL/HG

Where, BL = Body length (cm), HG = Heart girth (cm)

Analysis of variance of morphometric traits

The analysis of variance (ANOVA) statistics was performed using the statistical procedure of SPSS (IBM SPSS 23.0.0), to evaluate the effects of age and sex of the donkeys on the body parameters. Significant means were separated using the Duncan Multiple Range Test.

Regression analysis

Stepwise regression was performed to find the best linear combination of independent variables that can predict the body weight. The applied models were as follows:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + \dots + b_nX_n$$

Where:

Y=Dependent variable (body weight)

a= Intercept

$b_1, b_2, b_3, \dots b_n$=Regression coefficients

$X_1, X_2, X_3, \dots X_n$ = independent variables (i.e. the body measurements).

Correlation analysis

The degree of association between body weight and body linear measurements were computed to evaluate the magnitude of relationships among the variables.

Principal component analysis

Multicollinearity occurs (Shahin and Hassan, 2000) because two or more variables measure virtually the same thing and this can lead to unreliable results from multiple regression analysis. The multicollinearity among the variables can be reduced substantially by adopting principal component analysis (PCA) procedures. The Principal component analysis is used to reduce a number of correlated variables into a smaller number of uncorrelated variables. Thereby, the first few principal components with most of the variation present in the original variables are retained (Jolliffe, 2002).

RESULTS AND DISCUSSION

The effect of age on body measurements (cm) and body weight in female donkeys are presented in Tables 1 – 3. Eleven (11) body measures of growth were evaluated. Table 1 shows significant (P<0.01) effects of age on all the parameters measured. The donkeys in age group 3 (>11 years) were significantly (P<0.01) higher than the ones in age groups 1 (<5 years) and 2 (6-10 years). This is similar to the results obtained by Nininahazwe et al. (2017). The trend shows that body measures were generally increasing as the animals matured in age. This pattern of growth based on age have been observed by Mavule et al. (2013), who reported that the body developes at a different rate at different age groups.

The effect of age on body measurements (cm) and body weight (kg) in male donkeys are presented in Table 2. There were significant (P<0.01) effects of age on the parameters measured, the donkeys in age group 3 (>11 years) were significantly (P<0.01) higher than the ones in age groups 1 (<5 years) and 2 (6-10 years). However, the trend in the male donkeys showed no significant (P>0.05) effects of age on the paunch girth and ear length.

Table 1. Effects of the age group on body measurements (cm) and body weight (kg) in female donkeys.

Traits	**Age group** 1 (N = 9)	2 (N = 18)	3 (N = 12)	**Overall** (N = 39)	***LOS***
Body weight	306.09 ± 31.67^{b}	474.16 ± 12.02^{a}	465.05 ± 15.62^{a}	432.57±15.07	**
Heart Girth	85.42 ± 7.70^{b}	112.24 ± 1.50^{a}	108.43 ± 2.18^{a}	104.88±2.61	**
Paunch girth	100.02 ± 3.35^{b}	122.33 ± 1.82^{a}	118.11 ± 2.82^{a}	115.88±2.00	**
Body length	92.51 ± 1.52^{b}	109.91 ± 1.72^{a}	111.50 ± 1.96^{a}	106.38±1.61	**
Rump height	97.02 ± 2.47^{b}	106.17 ± 2.15^{a}	103.63 ± 1.53^{a}	103.28±1.34	*
Shoulder height	98.13 ± 1.48^{b}	107.38 ± 1.70^{a}	105.42 ± 0.50^{a}	104.64±1.04	**
Ear length	25.50 ± 0.83^{b}	29.57 ± 1.02^{a}	26.86 ± 0.58^{ab}	27.79±0.60	**
Tail length	40.44 ± 4.29^{b}	61.66 ± 1.80^{a}	56.92 ± 1.68^{b}	55.31±1.92	**
Neck length	37.33 ± 0.97^{b}	45.28 ± 1.97^{a}	44.58 ± 1.16^{a}	43.23±1.11	**
Neck circumference	58.50 ± 2.09^{b}	68.49 ± 1.36^{a}	69.88 ± 0.95^{a}	66.61±1.10	**
Head length	42.41 ± 0.90^{b}	45.27 ± 0.83^{b}	51.33 ± 2.66^{a}	46.47±1.06	**

*N = Number of observations, *p< 0.05, **p< 0.01, ***p< 0.001, LOS = Level of significance*

Table 2. Effects of the age group on body measurements (cm) and body weight (kg) in male donkeys.

Traits	**Age group** 1 (N = 26)	2 (N = 21)	3 (N = 17)	**Overall** (N = 64)	***LOS***
Body weight	344.29 ± 10.44^{b}	461.00 ± 9.37^{a}	464.06 ± 12.49^{a}	414.40±9.52	**
Heart Girth	94.09 ± 1.95^{b}	111.63 ± 1.61^{a}	112.24 ± 2.13^{a}	104.67±1.55	**
Paunch girth	146.05±38.39	119.65±2.22	121.00±7.12	130.73±15.62	NS
Body length	95.00 ± 1.30^{b}	107.54 ± 1.24^{a}	107.55 ± 1.23^{a}	102.45±1.07	**
Rump height	95.82 ± 0.69^{b}	103.92 ± 1.07^{a}	104.06 ± 1.63^{a}	100.67±0.79	**
Shoulder height	96.63 ± 1.50^{b}	106.43 ± 1.13^{b}	103.72 ± 0.95^{b}	101.73±0.93	**
Ear length	26.09±0.43	27.59±0.83	26.61±0.55	26.72±0.36	NS
Tail length	47.76 ± 1.78^{c}	63.45 ± 1.71^{a}	54.57 ± 2.89^{b}	54.72±1.45	**
Neck length	37.06 ± 0.67^{c}	42.69 ± 1.35^{b}	47.36 ± 2.25^{a}	41.64±0.94	**
Neck circumference	62.18 ± 0.86^{b}	69.40 ± 1.03^{a}	70.29 ± 1.35^{a}	66.70±0.76	**
Head length	41.87 ± 0.56^{b}	47.71 ± 0.82^{a}	47.32 ± 0.66^{a}	45.24±0.52	**

Table 3 reveals a non-significant (P>0.05) effect of sex on all the body parameters measured. However, the males had higher body weight than the female donkeys. This result is close to the report of Nininahazwe et al. (2017) who recorded differences in the traits measured with males higher than female donkeys. However, Mustefa et al. (2020) reported that there was a sexual size dimorphism without a specific trend: females had higher body weight than males.

Table 3. Effects of sex on body measurements (cm) and body weight (kg) in donkeys.

Traits	**Sex**		**Overall (N = 103)**
	Female (N = 39)	**Male (N = 64)**	
Body weight	432.57±15.07	474.41±60.95	458.57±38.23
Heart Girth	104.88±2.61	120.15±15.65	114.37±9.77
Paunch girth	115.89±2.00	130.73±15.62	125.11±9.73
Body length	106.38±1.61	102.45±1.07	103.94±0.92
Rump height	103.28±1.34	100.67±0.79	101.66±0.72
Shoulder height	104.64±1.04	101.73±0.93	102.83±0.71
Ear length	27.80±0.60	26.72±0.36	27.13±0.32
Tail length	55.31±1.92	54.72±1.45	54.94±1.15
Neck length	43.23±1.11	41.64±0.94	42.25±0.72
Neck circumference	66.61±1.10	74.71±7.88	71.64±4.92
Head length	46.47±1.06	45.24±0.52	45.71±0.52

The male donkeys in this study had a higher heart and paunch girth than the female donkeys Purzyc et al., 2007 reported specific physiological and biochemical processes in male donkeys making them stronger in comparison with female counterparts. However, this result is different from the one reported by Mustefa et al. (2020): female donkeys were higher. On the other hand, the female donkeys had higher shoulder and rump heights than the male donkeys. This is in contrast to the observations of Mustefa et al. (2020) who reported that male donkeys had higher shoulder and rump heights than the female counterparts. They alluded the differences to be due to the foetus load which pulled their belly down in pregnancy. This difference in the reports shows that pregnant female donkeys were not included in this study. Nicks et al. (2006) reported that the shoulder height is the main parameter for the measure of size of animals. The average values obtained in this study are close to those reported by Madani et al. (2022). However, the result is lower than the findings of other authors; Kefena (2011) on Ethiopian donkey; Aroua et al. (2020) on Tunisian donkey; Mustefa et al. (2020) on Egyptian donkey.

Correlation

Tables 4 and 5 present the phenotypic associations between the morphometric variables by sex. The body weight was correlated with HG, PG, BL, RH, SH, EL, TL and NC (r = 0.946 to 0.464; P<0.01) and body weight correlated with NL and HL (r = 0.402 and 0.375; *P*>0.05, respectively). The highest correlation value was recorded between body weight and HG (r = 0.946; P<0.01).

In the male donkeys, the correlations between body weight and body measurements were highly significant and positive in magnitude with all the body measurements (r = 0.380 to 0.950; P<0.01) except PG (r = 0.078NS). Similar to the female donkeys, the highest correlation value was recorded between body weight and HG. It was observed that there was none of the body measurements with negative correlation values. This trend is similar to the reports by Ayad et al. (2019); John et al. (2017); Sobotková & Jiskrová (2015); Yilmaz

& Ertugrul (2011) who also recorded positive correlation values. Assan (2015) also observed similar trend in three genotypes of pigs. This trend implies that a significant progress could be achieved in the improvement of body weight by selecting for these traits in donkeys. Many researchers observed a strong correlation among body measurements and asserted that body weight can be estimated using these traits (Abdel-Moneim, 2009; Adeyinka and Muhammed, 2006). However, negative correlation values were observed by other researchers in adult donkeys (John & Iyiola-Tunji, 2019; Folch & Jordana, 1997).

Table 4. Phenotypic correlation coefficients between morphometric traits of female donkeys.

	EBW	HG	PG	BL	RH	SH	EL	TL	NL	NC
HG	.946**	--								
PG	.832**	.758**	--							
BL	.905**	.723**	.789**	--						
RH	.646**	.675**	.629**	.472**	--					
SH	.664**	.604**	.644**	.604**	.738**	--				
EL	.464**	.503**	.469**	.309	.554**	.641**	--			
TL	.830**	.859**	.701**	.666**	.638**	.517**	.526**	--		
NL	.402*	.384*	.426**	.381*	.064	.105	.168	.585**	--	
NC	.795**	.691**	.758**	.782**	.577**	.698**	.508**	.734**	.426**	--
HL	.375*	.304	.224	.423**	.231	.102	-.096	.287	.306	.378*

HG = Heart girth, PG = Paunch girth, BL = Body length, RH = Rump height, SH = Shoulder height, EL = Ear length, TL = Tail length, NL = Neck length, NC = Neck circumference and HL = Head length.
**Correlation is significant at the 0.01 level (2-tailed),
*Correlation is significant at the 0.05 level (2-tailed).

Table 5. Phenotypic correlation coefficients between morphometric traits of male donkeys.

	EBW	HG	PG	BL	RH	SH	EL	TL	NL	NC
HG	.952**	--								
PG	.078	.029	--							
BL	.902**	.732**	.150	--						
RH	.799**	.784**	.055	.665**	--					
SH	.713**	.651**	.015	.689**	.565**	--				
EL	.380**	.377**	.021	.309*	.333**	.468**	--			
TL	.656**	.621**	.054	.585**	.581**	.486**	.245	--		
NL	.621**	.561**	-.125	.575**	.489**	.324**	.278*	.409**	--	
NC	.760**	.699**	.018	.710**	.556**	.465**	.168	.564**	.526**	--
HL	.732**	.674**	.002	.684**	.758**	.638**	.423**	.575**	.498**	.491**

Body Indices

Table 6 shows the profile and body indices of both female and male donkeys. Results show no significant (P>0.05) effects of sex on these indices. Madani et al. (2022) also reported no significant difference among the sexes on these indices. The profile and body indices in this study showed that the donkeys included in this study were medial linear in the profile index and small in the body index. (PI< 1 and BI < 0.80). The donkeys sampled for this study can be classified as medial-linear. This is similar to the observations of Madani et al. (2022). The profile index and body index made it possible to distinguish the brevilinear, medial-linear and longitudinal conformations.

Table 6. Least square means (±SE) of body indices in male and female donkeys.

Indices	Sex	N	Mean	Standard error
Profile Index (PI)	Female	39	0.989	0.012
	Male	64	0.995	0.008
	Overall	103	0.993	0.007
Body Index (BI)	Female	39	1.036	0.027
	Male	64	0.986	0.012
	Overall	103	0.997	0.016

Regression Analyses

Table 7 presents the regression analyses for body weight prediction in females and male donkeys. The predictors predicted the body weights of female and male donkeys with a high degree of accuracies (R^2 = 89.5 – 99.8% and 90.7 – 99.8%: p<0.001, respectively). The prediction of body weight based on sex showed that the combinations of HG, BL and RH were the best predictors of body weight (BWT) in female donkeys (R = 99.8%), while the best predictors of body weight in males were HG, BL, RH and NL (R^2 = 99.8%). The heart girth, body length and rump height featured prominently in the prediction of body weight of both female and male donkeys. This is in agreement with the reports of other researchers (John and Iyiola-Tunji, 2019; Pearson and Oussat, 1996), who affirmed that a prediction equation involving more than one variable yields a higher degree of prediction than the one involving only one variable.

Table 7: Prediction regression models for body weight in donkeys by sex.

Sex	Model	Equation	R^2(%)
Female	1	-139.484 +5.455HG***	89.5
	2	-397.282 +3.525HG +4.326BL***	99.7
	3	-419.009 +3.411HG +4.334BL +0.317RH**	99.8
Male	1	-197.224 +5.844HG***	90.7
	2	-393.603 +3.857HG +3.946BL***	99.8
	3	-412.957 +3.734HG +3.891BL +.377RH***	99.8
	4	-410.257 +3.697HG +3.824BL +0.365RH +0.222NL*	99.8
Both	1	13.039 +3.896HG***	99.1
	2	-394.189 +3.870HG +3.946BL***	100.0

HG = Heart girth, BL = Body length, RH = Rump height NL = Neck length, *P<0.05, ***P<0.001

Table 8 shows the result of the variance inflation factors (VIF) analysis. The VIF values obtained in this study were generally low (1.000–3.390). The range VIF result obtained in this study indicates an absence of a multi-collinearity issue among the predictor variables (Johnston et al., 2018). The VIF indicates the degree of multicollinearity (Rotimi et al., 2023). The VIF can be estimated using the following formula:

$$VIF = \frac{1}{1 - R^2}$$

Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Tests were used to check the suitability and adequacy of the data used for this study. The KMO value was 0.79, which is close to 1, and Bartlett's test of sphericity was significant (0.000).

Several authors had used the principal component analysis in different livestock and poultry: Yakubu and Ayoade (2009) in crossbred rabbits; Oseni and Ajayi (2014) in heterogeneous rabbits; Ajayi *et al.* (2017) on chickens, Ogah *et al*. (2009) in muscovy ducks;

Yakubu *et al.* (2022a) in helmeted Guinea fowl and Yakubu *et al*. (2022b) in pigs.

Table 8. Variance inflation factors (VIF).

Sex	Model	Variables			
Female	-	**HG**	**BL**	**RH**	**NL**
	1	1.000	-	-	-
	2	2.095	2.095	-	-
	3	2.481	1.275	2.399	-
Male	**-**	**HG**	**BL**	**RH**	**NL**
	1	1.000	-	-	-
	2	2.151	2.151	-	-
	3	3.271	2.256	2.726	-
	4	3.390	2.445	2.729	1.597
Both	-	**HG**	**BL**		
	1	1.000	-	-	-
	2	1.005	1.005	-	-

Table 9 presents the eigenvalues and the variance contributions for the principal components analysis (Johnson & Wichem, 2001) of the morphometric body measurements of donkeys. The eigenvalues of PCs 1 to 4 were above 1, and the percentage of the variance explained by the components 1 to 4 accounted for 70% of the total variance. Therefore, component 1 to 4 will be retained, while other components are less important. Furthermore, in Table 9, the component matrix and the rotation component matrix indicate that, the higher the absolute values in each of the loadings in each component, the more important the values are. In PC1, the eigenvalues are 3.791 and accounted for 37.91% of the total variance, while PCs 2, 3 and 4 contributed 11.34%, 11.00% and 10.13, respectively. The important variables under each PCs are the following: for PC1, BL (0.845); RH (0.817); SH (0.793) and TL (0.792) which describes the body conformation of the donkey population. In PC2 the key variables and their eigenvectors are: NC (0.813); EL (-0.558); HL (0.278) and SH (-0.223) which describe the neck and the head region. PC3 shows the following key variables and their eigenvector loadings: HG (0.892); NL (-0.385); HL (-0.231) and NC (0.128) describes the heart girth region, while in PC4, PG (0.956); NL (-0.326); HL (-0.092) and HG (0.076). These listed variables and eigenvectors highlight the important variables under each PC.

Table 9. Variance contributions and communalities of each components extracted.

Traits	PC1	PC2	PC3	PC4	Communalities
Heart girth	0.070	0.083	0.892	-0.076	0.812
Paunch girth	0.071	0.028	-0.064	0.956	0.923
Body length	0.845	0.017	-0.057	0.070	0.723
Rump height	0.817	0.002	0.127	0.068	0.688
Shoulder height	0.793	-0.223	0.121	0.059	0.697
Ear length	0.575	-0.558	0.118	0.040	0.657
Tail length	0.792	0.146	0.055	0.008	0.652
Neck length	0.592	0.041	-0.385	-0.326	0.607
Neck circumference	0.170	0.813	0.128	0.042	0.708
Head length	0.658	0.278	-0.231	-0.092	0.572
Eigenvalues	3.791	1.134	1.100	1.014	-
Variance (%) contribution	37.912	11.340	11.002	10.138	-
Cumulative variance (%)	37.912	49.252	60.254	70.392	-

CONCLUSION

Four PCs adequately described the entire morphobiometric variables of the donkey population and contributed 70.392% to the total variances in the measured variables. The first PCs included body length, rump height, shoulder height, and tail length and PC2 key variables are neck circumference, ear length, head length and shoulder height. The key variables in PC3 are heart girth, neck length, head length neck circumference, while the key variables in PC4 are: paunch girth, neck length, head length, heart girth. The selection efforts can be concentrated on these traits for the genetic improvement of the morphostructural traits in the donkey population in Katsina state.

REFERENCES

Abdel-Moneim, A. Y. (2009). Use of live body measurements for prediction of body and carcass cuts weights in three Egyptian breeds of sheep. Egyptian. *Journal of Sheep and Goat Science*, 2, 17-32.

Adeyinka, I.A., & Mohammed, I.D. (2006). Relationship of liveweight and linear body measurement in two breeds of goat of Northern Nigeria. *Journal of Animal Veterinary Advances*. 5, 891-893.

Ahmad-Syazni, K., Khaleel, A.G., Norshida, I., Connie, K., Nguang, S., & Ha, H. C. (2017). Population Structure of Swamp Eel *Monopterus albus* in East Coast of Peninsular Malaysia Inferred from 16S Mitochondrial DNA. *World Applied Sciences Journal*, 35(8), 1392-1399.

Ajayi, B. A., Ladokun, A. O., Afolayan, J.L., Akeno, E. R., John, C., & Ayeni, A. A. (2017). Multivariate analysis of body measurements of improved Nigerian indigenous chicken in the derived savanna zone of Nigeria. *Uniosun Journal of Agriculture and Renewable Resources*, 1, 100-105.

Aroua, M., Bayrem, J., Hatem, O.H., Khaldi, S., Ben-Said, S., Baccouche, R., & Mahouachi, M. (2020). Genetic characterization of Tunisian donkey with DNA microsatellites. *Indian Journal of Animal Sciences*, 89, 966- 969.

Assan, N. (2015). Prospects for utilization of the relationship between zoometrical measurements and performance traits for poultry and livestock genetic improvement in developing countries. *Scientific Journal of Animal Science,* 4(11), 124-132.

Ayad, A., Aissanou, S., Amis, K., Latreche, A., & Iguer-Ouada, Y. (2019). Morphological characteristics of donkeys (*Equus asinus*) in Kabylie area, Algeria. *Slovakia Journal of Animal Science*, 52(2), 53–62.

Behl, R., Niranjan, S.K., Behl, J., & Vijh, R.K. (2017). Comparison of three types of Indian donkey populations based on morphometric characteristics. *Journal of Livestock Biodiversity,* 7(1), 17-21.

DoF. (2018). Feedback: Donkeys for Africa *“Status of the Skin Trade”*. Available online: www.donkeysforafrica.org/dfa_june18_flipfile/mobile/index.html#p=2 .

FAO, (2003). Food and Agriculture Organization (FAO). F.A.O Statistical data base webside. Food and Agriculture Organization, Rome, Italy. (FAOStats: https://apps.fao.org)

FAO, (2016). Food and Agriculture Organization. https://www.fao.org/faostat/en/#home .

FAOSTAT, (2014). Live animals (data). https://www.fao.org/faostat/en/#data/QA.

Folch, P., & Jordana, J. (1997). Characterization, reference ranges and the influence of gender on morphological parameters of the endangered Catalonian donkey breed. *J Equine Vet Sci*., 17, 102-111.

Ha, H. C., Nguang, S. I., Zarizal, S., Komilus, C. F., Norshida, I., & Ahmad-Syazni, K. (2017). Genetic diversity of Kampung chicken (*Gallus gallus domesticus*) from selected areas in East Coast Peninsular Malaysia inferred from partial control region of mitochondrial DNA. *Malaysian Journal of Applied Biology*, 46(1), 63–70.

Hassen, H., Baum, M., Rischkowsky, B., & Tibbo, M. (2012). Phenotypic characterization of Ethiopian indigenous goat populations. *African Journal of Biotechnology*, 11(73), 13838-13846.

IBM SPSS. (2015). IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.

John, P. A., Akpa, G.N., & Iyiola-Tunji, A. O. (2017). Characterization of weaner donkeys in North West Nigeria using morphometric traits. *Nigerian Journal of Animal Science.* 19(1), 36-49.

Johnson, R. A., & Wichem, D.W. (2001). *Applied Multivariate Statistical Analysis*, 4th edition.

Johnston, R., Jones, K., & Manley, D. (2018). Confounding and collinearity in regression analysis: a cautionary tale and an alternative procedure, illustrated by studies of British voting behaviour. *Qual Quant.*, 52(4), 1957- 1976. https://doi.org/10.1007/s11135-017-0584-6

Jolliffe, I. T. (2002). Principal Component Analysis. 2nd Ed., Springer-Verlag, New York, USA.

Kefena, E., Beja-Pereira, A., Han, J. L. and Haile, A., Mohammed, Y. K., & Dessie, T. (2011). Eco-geographical structuring and morphological diversities in Ethiopian donkey populations. *Livestock Science*, 141, 232–241 https://doi.org/10.1016/j.livsci.2011.06.011

Khaleel, A. G., Lawal, L.A. Mudassir, N., Hassan, A. M., Abdu, M. I., Salisu, N., & Kamarudin, A. S. (2020). Morphometric Characterization of Donkeys (*Equus asinus*) in D/Kudu Kano State for Selective Breeding and Genetic Conservation. *Journal of Agrobiotechnology*, 11(2), 12-21.

Lanari, M. K., Taddeo, H., Domingo, E., Centeno, M.P., & Gallo, L. (2003). Phenotypic differentiation of exterior traits in local criollo goat population in patagonic (Argentina). *Arch. Tierz Dummerstort*, (46), 347-356.

Ljubodrag, S., Vladimir, D., Predrag, S., Nada, L., Ivica, R., Ante, I., & Zoran, S. (2015). Morphological, biochemical and hematological characterization of endangered Balkan donkey breed. *Acta Veterinaria.* 65(1), 125–136.

Madani, L., Djaout, A., Hayaoui, H., Djliel, F., AmeurAmeur, A., & Gaouar, S. B. S. (2022). Morphobiometric characterization of donkey resources in the extreme west of Algeria. *Genetics and Biodiversity Journal*, 6 (1): 167-180. https://doi.org/10.46325/gabj.v6i1.208

Matlhola, D. M., & Chen, R. (2020). Telecoupling of the Trade of Donkey-Hides between Botswana and China: Challenges and Opportunities. *Sustainability*, 12(5), 1730

Mavule, B.S., Muchenji, V., Bezuidenhout, C.C., & Kunene, N.W. (2013). Morphological structure of Zulu sheep based on principal component analysis of body measurements. *Small Ruminant Research*, 111, 23-30.

Moreira, C. G., Menezes, M. L., Nunes, T. R. Mota, T.P., Balieiro, J. C. C., Oliveira, C. A. A., & Brandi, R. A. (2019). Biometric parameters of adult and growing Pêga donkeys. *Revista Brasileira de Zootecnia*, 48:e20180297. https://doi.org/10.1590/rbz4820180297

Mustefa, A., Assefa, A., Misganaw, M., Getachew, F., Abegaz, S., Hailu, A., & Emshaw, Y. (2020). Phenotypic characterization of donkeys in Benishangul Gumuz National Regional State. *Online J. Anim. Feed Res.*, 10 (1), 25-35.

Navas, F. J., Jordana, J., León, J.M., Barba, C., & Delgado, J. V. (2017). A model to infer the demographic structure evolution of endangered donkey populations. *Animal*, 11(12), 2129–2138.

Nicks, B., Delfontaine, B., Canart, B., Vanderbruggen, J., & Vandenheede, M. (2006). Caractéristiques morphologiques des juments de Trait belge. *Ann. Méd. Vét.,* 150, 247-251.

Nininahazwe, P. C., Sow, A., Roamba, R. C., Kalandi, M., Ahmed, H. D., Ouédraogo, G. A., & Sawadogo, G. J. (2017). West African donkey's liveweight estimation using body measurements. *Veterinary World*, 10(10), 1221-1226.

Ogah, D. M., Alaga, A. A., & Momoh, M. O. (2009). Principal component factor Analysis of the morphostructural traits of Muscovy duck. *International Journal of Poultry Science*, 8 (11), 1100-1103.

Oseni, S. O., & Ajayi, B. A. (2014). Morphological characterisation and principal component analysis of body dimensions of adult Heterogeneous rabbits. *Journal of Applied Agricultural Research*, 6(1), 145-153.

Pearson, R. A., & Ouassat, M. (1996). Estimation of the live weight and body condition of working donkeys in Morocco. *Vet. Record*, 138(10), 229-233.

Pearson, R. A., & Ouassat, M. A. (2000). Guide to Live Weight Estimation and Body Condition Scoring of Donkeys. Centre for Tropical Veterinary Medicine, University, Edinburgh.

Purzyc, H,, Kobryn, H,, Komosa, M., & Bojarski, J. (2007). Ocena eksterieru konia huculskiego na podstawie wybranych wskaźników morfometrycznych (część I 1). Evaluation of horse exterior based on chosen morphometric indices (part I) [In Czech]. *Acta Scientarum Polonorum–Medicina Veterinaria*, 6, 47-64.

Quaresma, M., Martins, A. M. F., Rodrigues, J. B., Colaço, J., & Payan-Carreira, R. (2013). Pedigree and herd characterization of a donkey breed vulnerable to extinction. *Animal*, 8(03), 354–359.

Rosa, A. R. D., Amato, C., & Zumbo, A. (2007). Morphological traits of the "Pantesco" donkey. *Italian Journal of Animal Science*, 6(sup1), 646-646.

Rossel, S., Marshall, F., Peters, J., Pilgram, T., Adams, M. D., & O'Connor, D. (2008). Domestication of the donkey: Timing, processes, and indicators. *Proceedings of the National Academy of Sciences*, 105, 3715–3720.

Rotimi, E. A., Aruwayo, A., Garba, M. G., & Lamido, M. (2023). Prediction of live body weights in dromedary camels (*Camelus dromedarius*) from morphometric body measurements. *FUDMA Journal of Agriculture and Agricultural Technology*, 9(3). 63-69. https://doi.org/10.33003/jaat.2023.0903.10 .

Salako, A. E. (2006). Application of morphological indices in the Assessment of Type and Function in Sheep. *International morphology*, (24), 13-18.

Shahin, K. A., & Hassan, N. S. (2000). Sources of shared variability among body shape characters at marketing age in New Zealand White and Egyptian rabbit breeds. *Ann Zootech*, 49(5), 435–445.

Sobotková, E., & Jiskrová, I. (2015). Characteristics of morphological parameters of donkeys in the Czech Republic. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, 63(1), 419–424.

Starkey, P., & Fielding, D. (2004). *Donkeys, people and development*. A resource book of the Animal Traction Network for Eastern and Southern Africa (ATNESA). ACP-EU Technical Centre for Agricultural and Rural Cooperation (CTA), Wageningen, Netherlands.

Tolenkhomba, T. C., Konsam, D.S., Singh, S., Prava, M., Singh, D.Y., Ali, A. M., & Motina, E. (2012). Factor analysis of body measurements of local cows of Manipur India. *International Multidisciplinary Research Journal*, (2), 77-82

Turke, S., Faisal, A., Jawad, A., & Elmoslemany, A. (2016). Morphological Characteristics of Hassawi Donkey, Eastern Province, Saudi Arabia. *Journal for Veterinary Sciences*, 49(2), 178-183.

Yakubu, A., & Ayoade, J. A. (2009). Application of principal component analysis in quantifying size and morphological indices of domestic rabbits. *International Journal of Morphology*, 27(4), 1013-1017.

Yakubu, A., Durven, G. L., & Hagan, J. (2022b). Multivariate analysis of body weight, morphometric and thermos-physiological traits in indigenous pigs under tropical conditions. *Genetics and Biodiversity Journal*, 6 (1), 91-104. https://doi.org/10.46325/gabj.v6il.202 .

Yakubu, A., Jegede, P., Wheto, M., Shoyombo, A.J., Adebambo, A. O., & Popoola, M. A. (2022a). Multivariate characterisation of morphobiometric traits of indigenous helmeted Guinea fowl (*Numida meleagris*) in Nigeria. *PLoS ONE*, 17(6), e0261048. https://doi.org/10.1371/journal.pone.0261048 .

Yilmaz, O. (2011). Ertugrul, M; Some Morphological Traits of donkeys raised in Igdir, Turkey, Arastirma. Makalesi. Research article. *Igdir University Journal of Institute of Science and Technology*, 1(2), 113-116.