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Morphological characterisation of three indigenous Mozambican cattle populations

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Abstract

Information on phenotypic and morphometric variation is important in the characterisation of indigenous cattle breeds. The objective of this study was to assess the morphological variation of the indigenous Angone, Landim, and Tete cattle populations of Mozambique, kept under traditional management systems. These cattle are farmed mainly for meat and draught power, although they can produce some milk, especially the Landim. Data were collected through a survey of twenty-three villages in Maputo, Gaza, Inhambane (southern Mozambique), and Tete (central Mozambique) provinces. A total of 614 heads of adult animals including 140 Angone, 292 Landim, and 182 Tete were sampled. The collected qualitative and quantitative data were examined using SPSS version 16. The dominant coat pattern was even (no spotting) (59.5 %), with black being the most common coat colour (51.5 %), followed by light brown (26.5 %). The three cattle populations showed morphological differentiation based on size, body weight, and horn shape. Landim males and females were significantly ($p<0.05$) heavier than their Tete and Angone counterparts. Across populations, the majority of cattle (95.2 %) had horns, and 66.9 % of these horns were curved. Individual assignment using discriminant function analysis revealed that 73.0 % of Landim, 77.4 % of Angone, and 59.9 % of Tete cattle were correctly assigned to their respective populations. Results from this study indicate a considerable phenotypic variation of Mozambican indigenous cattle and will assist in future improvement and conservation programs.

Keywords: body measurements, livestock, morphometric qualitative traits, smallholder

1 Introduction

Livestock plays an essential role in the social, economic and cultural stability of rural households. It contributes significantly to livelihoods by providing meat, milk, draught power, and transport (INE, 2006; MASA, 2011) and is also used for cultural purposes and to improve social status (Morgado, 2000; Swanepoel *et al*., 2010). The majority of Mozambique's cattle population of 2.02 million heads consists of indigenous breeds that are distributed across the country (FAO, 2019a), of which 85 % are owned by smallholder farmers (MASA, 2011). Three native cattle breeds are recognized in Mozambique, namely the Landim, Tete, and Angone (Alberro, 1983; Kotze *et al*., 2000; Bessa *et al*., 2009). Indigenous Mozambican cattle are characterised by their superior adaptability traits including disease resistance, heat tolerance, walking ability, and ability to use poor-quality feed resources (Maciel, *et al*., 2013; Matjuda *et al*., 2014; Nyamushamba *et al*., 2017). These cattle breeds thrive on very little human input compared to exotic ones. A major advantage of their adaptive traits is that they are useful for the development of climate-smart cattle production, particularly in smallholder farming systems, which are characterised by low-cost inputs (Meissner *et al*., 2013a; 2013b). Indigenous breeds are thus preferable for resource-poor smallholder farmers who cannot afford the high demanding exotic cattle breeds (Maciel *et al*., 2001; MASA, 2011).

Despite their socio-economic importance, indigenous cattle genetic resources are in an advanced state of dilution and/or extinction (Bessa *et al*., 2009; FAO, 2015), due to several factors. Nyamushamba *et al*. (2017), noted that these

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factors include indiscriminate crossbreeding, breed substitution, and social and environmental disasters. Indigenous populations of cattle in Mozambique experienced a serious genetic bottleneck owing to a civil war that lasted 15 years (1977-1992), which reduced the national herd by approximately 80 %. After this period, there was an introgression due to the livestock re-stocking program, where several breeds of cattle were imported, with emphasis on Nguni cattle from Zimbabwe and South Africa (Bessa *et al.*, 2009; Maciel *et al.*, 2013). Another force that may have shaped the genetic diversity of indigenous cattle in Mozambique is their crossbreeding with exotic breeds for improvement purposes, especially in smallholder production systems.

Loss of genetic diversity in native livestock breeds is a major concern worldwide. It is estimated that 7 % of known livestock breeds have already become extinct and another 24 % are at different stages of risk (FAO, 2019b). Among mammal species, cattle are one of those with the largest number of extinct breeds reported worldwide (FAO, 2015). Because of this, the Food and Agriculture Organization of the United Nations (FAO) has highlighted the importance of characterising all Animal Genetic Resources (AnGR) to determine the current genetic status within and among indigenous livestock populations (FAO, 2011).

Comprehensive studies were conducted on aspects related to the health, nutrition and production systems of indigenous Mozambican cattle breeds (Catalão & Syrstad, 1990; Otto *et al.*, 2000; Maciel *et al.*, 2013). However, little effort has been made to identify, characterise and conserve the genetic diversity of these livestock species, and there is little information available on their genetic characteristics (Maciel *et al.*, 2004). Consequently, the implementation of rational and effective conservation and utilisation strategies for these genetic resources is difficult (FAO, 2012). Thus, this study aimed to describe the quantitative and qualitative morphological characteristics of the three major indigenous Mozambican cattle breeds, as the first step towards their genetic characterisation.

2 Materials and methods

The University of Pretoria Ethics Committee (ECO25-18) and the Institutional Committee of bioethics in Health of the Eduardo Mondlane University (CIBS FM&HCM/18/2018) have approved the research. Sampling was conducted in Maputo, Gaza, Inhambane, and Tete provinces of Mozambique, which represent five of the ten agroecological regions of the country. Mozambique has a tropical humid climate with two distinct seasons, dry winter and wet summer. The average annual precipitation is approximately 1200 mm and occurs mostly during the summer months of November to April. The average temperature ranges from 24 °C to 40 °C in summer (October to April) and from 18 °C to 23 °C in winter (May to September) (INE, 2015). The vegetation is characterised by Miombo and Mopane forests with a herbaceous layer of grasses including mainly Setaria sp., Themeda triandra, Urochloa sp., Panicum maximum, Digitaria sp. and Cenchrus sp. (Timberlake & Jordão, 1985). Based on livestock availability and road accessibility, three districts per province were identified and using purposeful sampling techniques two rural areas were chosen in each district. Cattle sampled for the study were Landim (n = 292) from Magude, Namaacha, Chibuto, Chokwé, Guija, Vilankulo, Zavala, and Inharrime districts, Tete (n = 182) from Marara and Changara districts, and Angone (n = 140) from Angonia district (King *et al.*, 2021). A total of 132 males and 482 females of adult (4 pairs of permanent incisors) cattle were randomly selected from the identified populations (Table S1, supplementary material). Cows in late pregnancy were excluded from the sampling. Quantitative, as well as qualitative, data collection, was done according to the FAO guide for phenotypic characterisation of AnGR (FAO, 2012). Qualitative traits recorded included coat colour (CC), sex, coat pattern (CP), horn presence (HP), horn shape (HS), horn orientation (HO), and ear orientation (EO). Quantitative traits such as heart girth (HG), muzzle circumference (MC), body length (BL), horn length (HL), top line length (TL), height at withers (WH), height at rump (RH), rump width (RW), hock circumference (HC), and body weight (BW) were taken using a tape measure.

Data analyses were performed with SPSS software v16.0 (Statistical Package for the Social Science). Initially, descriptive statistics were performed to test for statistical differences between the three cattle populations. Frequency distributions were determined for classes of qualitative traits and the Chi-square test was performed to assess any statistical significance. Quantitative traits were subjected to an analysis of variance to test for statistically significant differences between cattle populations, using the GLM (General Linear Model) approach. Comparisons of means between cattle populations were performed using the least significant differences (LSD) method at a 5 % level of significance. In addition, stepwise discriminant analysis and canonical discriminant analysis were used to identify any highly discriminant variables and their level of differences. In this study, the 10 quantitative variables were introduced in a stepwise fashion as independent variables in the discriminant function analysis. The relative importance of these functions in differentiating the three populations was assessed by F-to-remove statistics, under default settings. The discriminating ability of these functions was indicated as the percentage of assignment of individuals to their populations of origin. Genetic distance was evaluated by SPSS hierarchical cluster analysis, from which a dendrogram was constructed showing the relationship between the three populations under study.

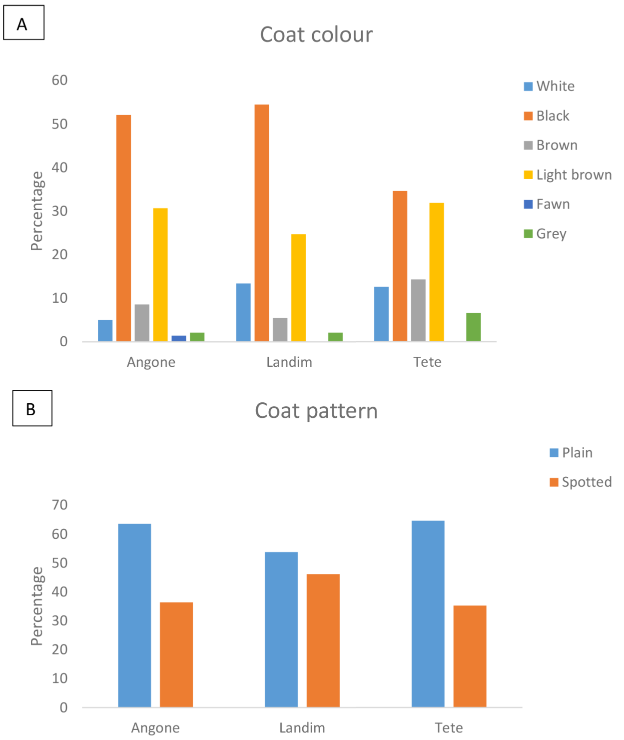

Fig. 1: *Distribution of coat colour (A) and coat pattern (B) in three indigenous Mozambican cattle populations.*

3 Results

The distribution of coat colour and patterns varied among the three populations (Fig. 1). The majority of cattle in each population had plain (non-spotted) coat patterns (Fig. 1B). Black was the dominant coat colour in all three populations (Fig. 1A). However, the Landim population presented a higher percentage of black coat colour compared to Angone and Tete (Table 1). Other coat colours observed were light brown, white, dark brown, grey, and fawn, with fawn being found only in the Angone population (Fig. 1AB).

Substantial variation among the three populations was also observed in the distribution of horn presence, horn shape, horn and ear orientation (Table 1). Nearly all animals (>90 %) were horned, of which most horns were curved and upward oriented. More than 70 % of Angone cattle had straight horns; however, most of the Landim (>80 %) and Tete (>70 %) cattle had curved horns. Horns with upward, forward, or lateral orientation were observed in all the studied populations. Most animals in the three populations had laterally oriented ears, with very few drooping ears being found only in the Angone. The distribution of classes of qualitative traits by sex is shown in Table 1. There were no significant differences between sexes in the parameters studied except for horn shape and horn orientation.

Tables 2 and 3 present within sex comparisons of means for the morphological variables and body weight among the three Mozambican cattle populations. Females of the three populations differed significantly ($p < 0.05$) in all measurements, except muzzle circumference. Landim cows had significantly ($p < 0.05$) higher measurements in all parameters, compared to the other two populations.

Angone males were significantly ($p < 0.05$) lighter and generally smaller than those of the other two populations. Landim and Tete males were similar in most body measurements and differed significantly ($p < 0.05$) for only three (horn length, body length, and height at rump) characteristics.

Out of 10 variables subjected to the stepwise discriminant analysis, six (BL, HL, RW, WH, RH, and TL) showed significant ($p < 0.001$) discriminatory power (Table 4). MC, HG, HC and BW were excluded from the analysis as they did not meet the minimum partial F to enter of 3.84 (default settings).

To assess the performance of the discriminant function in discriminating the three cattle populations, the percentage of misclassification for each population (Table 5), was estimated. Thus, approximately 70 % of individuals were correctly allocated to their source population. More than 70 % of Angone and Landim cattle were correctly assigned to their respective source populations. The Tete population had poorer differentiation, as 23,6 % of the individuals were allocated to the Angone and another 16.5 % to Landim cattle populations.

The Mahalanobis distances between the three cattle populations are shown in Table S2 (supplementary material). The greatest distance was observed between Landim and Angone (6.45) and the smallest distance between Landim and Tete (1.28).

The relatedness among the populations was also studied by cluster analysis based on body measurements. The three populations under study formed two main clusters as shown in the dendrogram (Fig. S1, supplementary material). The first cluster is composed exclusively of Landim cattle while the second comprises the two remaining populations of indigenous cattle (Angone and Tete).

Table 1: *Distribution of external characteristics of three Mozambican cattle populations.*

	Angone (%)		*Landim (%)*		*Tete (%)*		*Overall (%)*	
Parameter	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*
Coat colour pattern								
Plain	65.7	58.5	52.8	57.4	64.5	66.7	59.1	59.8
Patchy	34.3	41.5	47.2	42.6	35.5	33.3	40.9	40.2
Coat colour								
White	6.1	2.4	15.2	6.6	12.5	13.3	12.4	6.8
Black	47.5	63.4	53.2	59.0	32.2	46.7	45.4	57.6
Dark Brown	10.1	4.9	4.3	9.8	15.1	10.0	8.9	8.3
Light Brown	34.3	22.0	24.7	24.6	33.6	23.3	29.5	23.5
Fawn	0.0	4.9						1.5
Grey	2.0	2.4	2.6	0.0	6.6	6.7	3.7	2.3
Horn presence								
Present	97.0	100.0	91.3	95.1	96.7	93.3	94.2	96.2
Absent	3.0	0.0	8.7	4.9	3.3	6.7	5.8	3.8
Horn shape	***		*		**		***	
Straight	59.4	95.1	5.2	13.8	14.3	39.3	19.6	45.7
Curved	40.6	4.9	92.9	86.2	85.7	60.7	79.5	54.3
Lyre-shape			1.9	0.0			0.9	
Horn orientation					*		***	
Lateral	41.7	61.0	9.0	19.0	10.2	28.6	16.3	34.6
Upward	52.1	36.6	61.6	53.4	66.0	60.7	61	49.6
Downward			0.9	0.0	1.4	0.0	0.9	
Forward	6.2	2.4	27.5	25.9	22.4	10.7	21.4	15
Other			0.9	1.7			0.4	0.8
Ear orientation								
Erect	45.8	14.6	8.7	9.8	9.2	16.7	16.4	12.9
Lateral	52.1	82.9	91.3	90.2	90.8	83.3	83.2	86.4
Drooping	2.1	2.4					0.4	0.8

$^{*}p < 0.05$; $^{**}p < 0.001$; $^{***} < 0.0001$; F = female; M = male.

Table 2: *Adult female body measurements of three indigenous Mozambican cattle populations.*

	Angone		*Landim*		*Tete*		*Overall*	
Parameter	*Mean (± SE)*	*CV*	*Mean (± SE)*	*CV*	*Mean (± SE)*	*CV*	*Average (± SE)*	*CV*
Muzzle circumference (cm)	$39.6^{a} \pm 0.3$	6.1	$42.2^{b} \pm 0.2$	8.6	$40.2^{a} \pm 0.2$	4.9	40.7 ± 0.1	7.7
Horn length (cm)	$17.3^{a} \pm 1.1$	38.3	$30.0^{b} \pm 0.7$	42.1	$24.7^{c} \pm 0.9$	37.6	24.0 ± 0.5	45.3
Top line (cm)	$158.4^{a} \pm 1.3$	7.7	$167.6^{b} \pm 0.9$	8.7	$163.2^{c} \pm 1.0$	6.2	163.1 ± 0.6	8.1
Body length (cm)	$116.3^{a} \pm 1.1$	7.4	$134.2^{b} \pm 0.7$	9.7	$123.6^{c} \pm 0.9$	6.3	124.7 ± 0.5	10.2
Height at withers (cm)	$116.8^{a} \pm 0.8$	7.9	$123.4^{b} \pm 0.5$	7.0	$119.5^{c} \pm 0.7$	4.7	119.9 ± 0.4	6.9
Heart girth (cm)	$147.9^{a} \pm 1.2$	10.6	$161.3^{b} \pm 0.8$	7.7	$152.6^{c} \pm 1.0$	4.9	153.9 ± 0.6	8.4
Rump width (cm)	$37.2^{a} \pm 0.3$	7.2	$40.6^{b} \pm 0.2$	6.2	$39.2^{c} \pm 0.2$	5.5	39.0 ± 0.1	7.0
Height at rump (cm)	$113.9^{a} \pm 0.6$	4.3	$124.0^{b} \pm 0.4$	5.5	$119.7^{c} \pm 0.5$	4.2	119.2 ± 0.3	5.9
Hock circumference (cm)	$32.1^{a} \pm 0.3$	9.4	$34.6^{b} \pm 0.2$	8.4	$33.3^{c} \pm 0.2$	7.8	33.3 ± 0.1	8.9
Body weight (kg)	$243.3^{a} \pm 5.5$	17.5	$310.0^{b} \pm 3.5$	21.6	$265.7^{c}c \pm 4.4$	12.8	273.0 ± 2.6	21.3

SE: Standard error; CV: coefficient of variation; Means that have different superscripts in the same row differ statistically ($p < 0.05$).

Table 3: *Adult male body measurements of three indigenous Mozambican cattle populations.*

	Angone		*Landim*		*Tete*		*Overall*	
Parameter	*Mean (± SE)*	*CV*	*Mean (± SE)*	*CV*	*Mean (± SE)*	*CV*	*Average (± SE)*	*CV*
Muzzle circumference (cm)	$41.3^a \pm 0.6$	6.4	$45.2^b \pm 0.5$	9.0	$44.3^b \pm 0.7$	7.8	43.6 ± 0.3	8.9
Horn length (cm)	$16.0^a \pm 1.6$	37.8	$31.1^b \pm 1.3$	35.9	$20.8^c \pm 1.8$	55.3	22.6 ± 0.9	49.8
Top line (cm)	$161.0^a \pm 2.5$	7.1	$173.6^b \pm 2.1$	9.2	$169.1^b \pm 2.9$	11.8	167.9 ± 1.4	9.9
Body length (cm)	$114.7^a \pm 1.7$	5.9	$137.9^b \pm 1.4$	8.1	$128.6^c \pm 2.0$	11.1	127.1 ± 1.0	11.5
Height at withers (cm)	$124.8^a \pm 1.5$	6.0	$132.1^b \pm 1.2$	8.4	$129.5^b \pm 1.7$	5.7	128.8 ± 0.8	7.5
Heart girth (cm)	$148.5^a \pm 2.6$	13.4	$166.6^b \pm 2.2$	8.9	$160.1^b \pm 3.1$	10.0	158.4 ± 1.5	11.6
Rump width (cm)	$38.3^a \pm 0.5$	6.8	$42.4^b \pm 0.5$	8.7	$41.7^b \pm 0.6$	9.4	40.8 ± 0.3	9.4
Height at rump (cm)	$119.2^a \pm 1.1$	5.3	$128.3^b \pm 0.9$	5.8	$125.1^c \pm 1.2$	4.7	124.2 ± 0.6	6.2
Hock circumference (cm)	$34.1^a \pm 0.5$	7.7	$36.4^b \pm 0.5$	9.2	$35.8^b \pm 0.5$	7.4	35.4 ± 0.3	8.7
Body weight (kg)	$256.9^a \pm 11.1$	18.9	$346.2^b \pm 9.2$	24.0	$316.4^b \pm 13.0$	22.4	306.5 ± 6.5	25.8

SE: Standard error; CV: coefficient of variation; Means that have different superscripts in the same row differ statistically ($p < 0.05$).

Table 4: *Stepwise selection of different traits in the Landim, Angone, and Tete cattle populations.*

Step	*Trait*	*F-value*	*p-value*	*Wilks' Lambda*
1	BL	252.364	***	0.600
2	HL	166.188	***	0.532
3	RW	125.551	***	0.500
4	WH	103.877	***	0.475
5	RH	100.181	***	0.428
6	TL	88.645	***	0.413

BL: Body length; HL: Horn length; RH: Height at rump; WH: Height at withers; RW: Rump width; TL: Top line; *** $p < 0.001$.

Table 5: *Percentage (%) of individual cattle (mis-)assigned to the respective populations.*

Source population	*Angone*	*Landim*	*Tete*
Angone (N=137)	77.3	1.5	21.2
Landim (N=281)	6.0	73.0	21.0
Tete (N=182)	23.6	16.5	59.9
Priors	0.333	0.333	0.333

The canonical analysis performed on the quantitative variables identified two statistically significant canonical functions ($p < 0.01$) that explained 97.4 % and 2.6 % of the total variation, respectively (Table S3, supplementary material). The combination of variables that best discriminates the three cattle populations is canonical function 1. BL and RH were strongly correlated to function 1 while WH was more associated with function 2.

Fig. 2 shows the spatial distribution of the three populations in the current study, as determined by canonical discriminant functions. Function1 differentiated Landim from Angone cattle populations, with limited overlapping. Some individuals belonging to the Tete population were detected as outliers in the Angone and Landim populations.

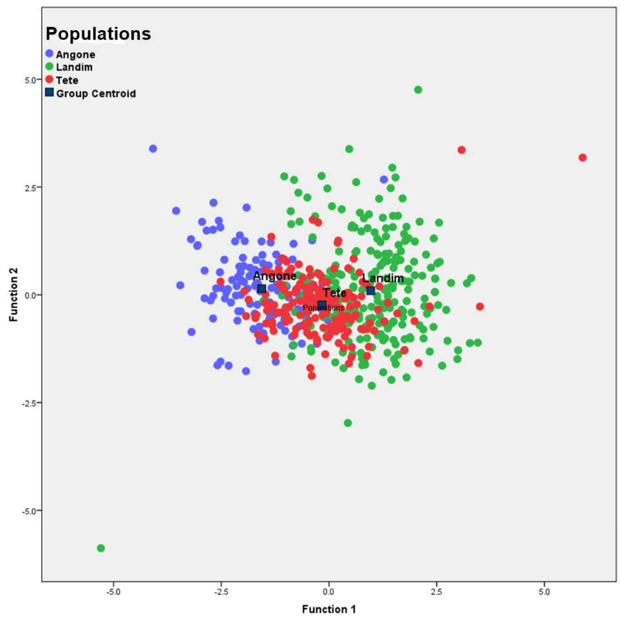

Fig. 2: *Canonical analysis for individual body measurements in three cattle populations.*

4 Discussion

Morphological variation among cattle breeds may be a result of distinctions between their genetic make-up, geographical distributions, agroecological conditions, or production systems (Desta *et al.*, 2011; Mekonne & Meseret, 2020). Physical characteristics of a breed such as coat colour, body size, and shape of horns assist in the definition of the breed and the setting of breed standards (McManus *et al.*, 2010). The current study attempted to describe the morphological features of three indigenous Mozambican cattle populations. Our findings showed substantial morphological variation among these populations, which can further be utilised for the design of rational breed improvement, conservation, and utilisation strategies.

Results indicated a wide range of coat colours, with black being the predominant one. In a previous study, Kotze *et al.* (2000) also reported high coat colour variability for relatively small sampling groups of the same breeds. The observed wide variation in coat colours among Mozambican cattle breeds might be an adaptation mechanism to the different local environments, as postulated by Yougbaré *et al.* (2020) in cattle from Burkina Faso and Mani *et al.* (2014), in Niger's goat populations. Mixed coat colour works as camouflage and cattle with such coat patterns better defend themselves from predators and insect bites (Hagan *et al.*, 2012; Kojima *et al.*, 2019). For instance, Saini *et al.* (2017) reported lower trypanosome infections in white and brownish-red-coloured animals compared to black-coloured ones. Black-coated cattle seem to have lower food intake as these animals have higher body temperatures. Therefore, the predominance of black colour may be an adaptive response of these animals to withstand food shortages (Baenyi *et al.*, 2020).

In Tanzania, Chasama (2013), found more black-coated animals in the district of Ukweru where cattle are tethered under trees than in the Bunda district where cattle graze openly and extensively. Black-coated cattle are thought to be more adapted to seasonal cold weather, as the dark pigment they have helps them to absorb heat and warm them up faster than light-coated Kenyan Borana cattle (Abdurehman, 2019).

Horn shape and size are important characteristics and help cattle to graze in thickets as well as in struggles for dominance and hierarchy, especially in bulls (Kugonza *et al.*, 2011; Hirwa *et al.*, 2017). The horns of Angone cattle were short to medium (16 cm) and mainly straight and laterally oriented. This finding is in agreement with Kotze *et al.* (2000) who observed that Angone cattle had short horns, suggesting that this breed originated from the East African Zebu, which has short horns (Otto *et al.*, 2000). Most Landim (57.5 %) and Tete (63.4 %) cattle had upward-oriented horns, which is similar to Eritrean Arado (60 %), Ethiopian Begait (62.2 %), and Ethiopian Malle (63.3 %) cattle (Gebrul *et al.*, 2017; Goitom *et al.*, 2019; Getaneh *et al.*, 2020). The observed phenotypic similarity may be due to shared ancestry as well as selective pressures.

Body weight and morphological measurement values obtained in the current study are lower compared to those obtained in earlier studies on the same breeds. Catalão & Syrstad (1990), for example, reported an average body weight of 384–416 kg for mature female Landim cattle. Tomo (1997) reported an average hearth girth of 157.8 cm for bulls and 148.1 cm for cows of the Angone breed, indicating that animals of this breed some two decades ago were somewhat bigger than the present ones (present hearth girth of 148.49 cm in male and 147.93 cm in female). The size reduction could be a result of inbreeding within the population and/or deteriorating environmental conditions and decreasing feed resources as reported by Genzebu *et al.* (2012) in the Ethiopian Arado cattle breed and by Nguluma *et al.* (2016) in the Tanzanian SAE goats. Indigenous cattle in Southern Africa have been naturally selected to adapt to the food shortage that is prevalent in the region (Nyamushamba *et al.*, 2017). For example, to cope with drought and forage seasonality these animals are small to medium-sized, which makes them less demanding in terms of maintenance requirements (Bester *et al.*, 2003; Matjuda *et al.*, 2014).

Variations in morphometric measurements between cattle breeds may be caused by differences in genetics, climate, management systems, or feed quality (Ftiwi & Tamir, 2015). These variations may be useful for distinguishing different breeds (Gatesy & Arctander, 2000), evaluating breeding goals (Zechner *et al.*, 2001), and comparing feeding and production systems. Discriminant analysis revealed that 6 of the 10 body measurements were significant in distinguishing between the three populations of cattle. Body length and Height at withers were among the most discriminating traits for the three populations, in agreement with a previous study by Pundir *et al.* (2015) in Indian indigenous cattle. Thus, the six morphometric variables are sufficiently informative and can be reliably used to assign individual cattle to one of the three populations.

Multivariate analysis of morphological traits has been found to reliably discriminate populations of cattle (Pundir *et al.*, 2015), goats (Mdladla *et al.*, 2017), sheep (Wagari *et al.*, 2020), and horses (Rezende *et al.*, 2021). Assessment of the relationship among the three cattle populations using canonical discriminant functions (Function 1 and 2) revealed little differentiation between Angone and Tete. On the other hand, Landim cattle were generally assigned to a distinct cluster, with little overlapping. The proportion of individuals correctly allocated to their source population indicates the level of differentiation of that population. Canonical discriminant analysis assigned approximately 70 % of the individuals to their populations of origin. This study is in agreement with previous reports where the correct classification ranged from 62.6 % to 96.55 % for indigenous cattle populations (Yakubu *et al.*, 2010; Chencha *et al.*, 2013; Pundir *et al.*, 2015). Hirbo *et al.* (2006) postulated that high misclassification rates could indicate high gene flow or low assignment power due to the small number of variables used in the analysis. The classification errors also depend on the method and variables used in the analysis (Yakubu *et al.*, 2012; Correa *et al.*, 2013).

Tete cattle had the greatest percentage of individuals miss-assigned to other populations, with the majority (23.6 %) of these being wrongly assigned to Angone. The reason for this high misclassification between Angone and Tete breeds may be attributed to crossbreeding, as these are the predominant breeds in the central province of Tete. The high number of Tete individuals being miss-assigned to Landim (16.5 %) cattle show a relatively low morphometric differentiation between these cattle suggesting shared genetic identities. These results corroborate with those from a population structure analysis study, using microsatellite markers, reported by Madilindi *et al.* (2019).

5 Conclusions

The present study has shown substantial phenotypic heterogeneity in qualitative traits of Mozambican indigenous cattle populations. The coat colour, as well as the shape and orientation of the horn, showed variation in the three populations, indicating a lack of strong selection in these traits. Significant differences were observed for most of the morphometric traits, suggesting differences in size between the three studied cattle populations. The three cattle populations are best differentiated by measuring body length. The assessed morphological characteristics, together with genetic information, could be a valuable tool for the design of breed improvement programs, conservation, and utilisation of genetic resources of indigenous cattle.

Supplement

The supplement related to this article is available online on the same landing page at: https://doi:10.17170/kobra-202212057192 .

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Conflict of interest

The authors declare that they have no conflict of interest.

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