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MORPHOMETRIC AND MORPHOLOGICAL ANALYSIS OF INDIGENOUS MATABELE GOATS OF ZIMBABWE

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Abstract: This study aimed to characterize Matabele goats based on their qualitative and quantitative traits, to facilitate their genetic improvement and conservation. Data were collected from 120 goats over 12 months, comprising 20 males and 100 females using a stratified random sampling approach. Body weight and various body measurements were recorded. Five growth curve estimation models were employed to describe the growth pattern of Matabele goats. Descriptive statistics were computed for both qualitative and quantitative traits. T-tests were conducted to assess the impact of sex on morphometric measurements in different age groups. The results revealed an average body weight of 20.93 kg, with significant sex-related differences ($p < 0.05$) observed across all quantitative traits. Most goats displayed horned and bearded characteristics, while black and white coat colours were predominant. Among the growth curve models, the Gompertz model exhibited the highest R^2 value (0.992). Notably, the study found relatively low average morphometric measurements and body weight for Matabele goats, emphasizing the urgent need for genetic improvement efforts and the development of comprehensive breeding standards for this breed.

Key words: body measurements, body weight, growth models, genetic improvement

Introduction

Goats, through millennia, have been integral to human civilization, offering a plethora of valuable products, including meat, milk, and skins (*Mataveia et al., 2021*). Particularly in developing countries like Zimbabwe, goats play an indispensable role, making a substantial contribution, especially to the economically disadvantaged smallholder sector. It is noteworthy that women and youth are prominently engaged in goat rearing. These animals offer distinct advantages such as shorter generation intervals compared to cattle, prolific reproductive rates, ease of marketing, and minimal competition with humans for food resources (*Zvinorova, 2016*).

However, it is disheartening that goats are frequently viewed as subsistence animals with limited profitability (*Assan*, *2013*). Consequently, resources and attention often lean toward cattle production, leaving indigenous goat breeds underappreciated and under-supported. Many African nations, including Zimbabwe, suffer from inadequate breeding standards for indigenous goats, a dearth of well-structured small stock improvement programs, and fragmented efforts that yield meagre impacts on goat productivity and the livelihoods of farmers (*Nsoso et al., 2003; Badi et al., 2016*). Compounding these challenges is the concerning trend of uncontrolled breeding and the introduction of exotic animals and crossbreeding practices by breeders and farmers. These practices, while well-intentioned, pose a significant risk through genetic erosion (*Gizaw et al., 2011; Celik, 2019*). This, in turn, threatens to obscure vital traits, such as disease resistance inherent in indigenous livestock breeds and even pushes certain breeds toward extinction (*Khan, 2018*).

Recognizing the need for long-term intervention, morphological characterization of indigenous goats emerges as a crucial avenue for enhancing overall productivity and developing sustainable breeding strategies. This, in turn, can lead to lower-cost initiatives that ultimately elevate the livelihoods of those involved (*Fernandes et al., 2019*). Critical to genetic improvement efforts is a deep understanding of the variation in morphological and morphometric traits (*Nguluma et al., 2016*), an understanding that can be facilitated through the use of body weight and morphometric measurements. While prior phenotypic characterization studies of Matabele and Small East African goats in Zimbabwe were conducted more than a decade ago by *Sikosana (2008)*, information about these goat breeds remains scarce. Recent efforts by the Value Chain Alliance for Livestock Upgrading (*VALUE*) project in 2021 attempted to establish breed standards for Matabele and Mashona goats, albeit with a predominant focus on qualitative traits. Therefore, the primary objective of this study is to furnish comprehensive baseline information regarding the phenotypic characteristics, encompassing both qualitative and quantitative traits, of indigenous Matabele goats in Zimbabwe. In addition, this study seeks to gauge the practical utility of these traits in animal breeding and management. Furthermore, it aspires to identify the most fitting growth curve model for the indigenous Matabele goats.

Materials and Methods

Ethical clearance for this study was obtained from the Lupane State University Animal Welfare and Ethical Committee.

Study site description

The study was conducted at Lupane State University in Lupane district of Zimbabwe. Located in the Matabeleland North Province of Zimbabwe, Lupane District is nestled within the southern African landscape with geographic coordinates ranging approximately between latitude 18.9313° S and longitude 27.7985° E. This semi-arid region experiences a distinct wet and dry season, with a mean annual rainfall of around 600 to 800mm. The climate in Lupane is classified as subtropical, featuring warm to hot temperatures during the day, averaging between 25°C to 32°C in the summer months, and cooler nights, with temperatures ranging from 10°C to 20°C during the dry season. The district's landscape is characterized by rolling plains, valleys, and low hills, adorned with acacia trees, miombo woodlands, and various grass species. These environmental factors, along with Lupane's rich cultural heritage and communal farming practices, make it a significant area for livestock farming, including the rearing of indigenous Matabele goats, which are integral to the local agricultural and economic activities.

Experimental design

The study involved the collection of data from a sample of Matabele goats. A stratified random sampling approach was used for the selection of the target groups based on sex and age. A total of 120 goats were selected, comprising 20 males and 100 females. The age range considered was from zero to 48 months.

Data Collection

To assess the physical characteristics of the animals, body weight (BW) and several morphometric measurements were taken, including wither height (WH), body length (BL), chest girth (CG), rump length (RL), hip width (HW), thurl width (TW), and pin bone width (PW) (*Getahum et al., 2020*). BW was determined using a livestock weighing scale (TAL-TEC, Ptv Ltd Model 1440). WH was measured from the highest point of the withers to the ground while the animal stood on a flat platform, employing a graduated measuring rod. BL was measured as the distance from the anterior points of the shoulder to the posterior extremity of the pin bone, using a tailor's tape measure. The CG represented the circumference of the body immediately behind the shoulder and was measured with a tape measure (*Khan et al., 2018*).

The HH was measured from the highest point of the hip vertically to the ground, utilizing a measuring rod. RL was measured with a tape measure from the hip bone to the pin bone area (*Ndhlovu et al., 2017*). HW, representing the width between the two hip bones, was measured using a digital calliper, while TW, the area between the thurl bones, was also determined with a digital calliper. PW, representing the width between the two pin bones, was measured similarly with a digital calliper. To minimize variations arising from different individuals, all measurements were consistently performed by the same person, with the animals measured in the morning before grazing and watering to mitigate the effects of rumen distention (*Ndhlovu et al., 2017*). To minimize variation due to environmental factors, body weight, and linear measurements were taken in the morning before grazing and watering, aiming to reduce the potential impact of rumen distention effects.

Qualitative traits under scrutiny included coat colour (grey, white, multiple, brown, or black, either singly or in combination), hair pattern (plain or patchy), beard presence or absence, horn presence or absence, ear orientation (erect, pendulous, or horizontal), horn orientation (lateral, backward, or upward), and facial profiles (straight, concave, or convex). The *FAO (2015)* livestock descriptor tool for goats was employed for the morphological trait descriptions, primarily relying on visual assessments (*Hagan et al., 2012; Birteeb et al., 2015*).

Statistical Analysis

Five growth curve estimation models were utilized, including the Gompertz, Bertalanffy, Wood, Logistics, and Brody growth models (*Brody, 1945; Gompertz, 1825; Unal et al., 2018*). To construct the growth curves, data on the age and live body weight of the animals at various stages were collected from farm records.

The equations for the various growth models were as follows:

Gompertz: $Yi = A * \exp(-\alpha * \exp(-\beta t))$

Bertalanffy: $Yi = A * (1 - \exp(\beta t)^3)$

Wood: $Yi = A * t^\alpha * \exp(\beta t)$

Brody: $Yi = A * (1 - \alpha * \exp(\beta t))$

Logistics: $Yi = A / (1 + \alpha * \exp(\beta t))$

Where: Yi: Body weight (kg) at age t (months), A: Body weight at maturity (kg), α: Integration constant, β: Maturation rate, exp: Exponential (natural logarithm) and t: Age (months)

The Shapiro-Wilk test was employed to evaluate the normality of continuous variables using Minitab 19, while Levene's test, also through Minitab 19, assessed homogeneity of variance. Descriptive statistics were employed for the analysis of qualitative and quantitative traits using SPSS version 21 and Minitab 19, respectively. The growth curves were fitted using StaPro version 2.0 (Kyoto University, Japan). To ascertain differences in trait measurements between males and females, a T-test was conducted. The selection of the most appropriate curve was based on the R-square value. All analyses were performed at a 95% confidence interval (CI).

Results

Table 1 shows the descriptive statistics for morphometric traits and body weight of Matabele goats. The traits are body weight, chest girth, wither height, hip height, rump length, chest depth, body length, hip width, thurl width, and pin bone width. The mean, standard deviation, and coefficient of variation are presented for each trait. The results show that the Matabele goat is a relatively small goat breed with moderate to high variation in morphometric traits.

Table 1. Descriptive statistics of grouped morphometric trait data of Matabele goats

	Matabele goats		
Traits	**Mean**	**SD**	**CV%**
Weight (kg)	20.93	7.69	36.74
Chest girth (cm)	62.99	10.18	16.17
Wither height (cm)	56.57	7.47	13.22
Hip height (cm)	57.89	7.53	13.01
Rump length (cm)	17.48	2.70	15.50
Chest depth (cm)	30.55	4.98	16.32
Body length (cm)	55.01	8.44	15.35
Hip width (cm)	10.93	2.07	18.90
Thurl width (cm)	12.69	2.14	16.82
Pin bone width (cm)	7.89	1.82	23.03

Notes: CV- Coefficient of variation, SD-Standard Deviation

Within-sex means of body weight and morphometric measurements are presented in Table 2.

The study found that male Matabele goats are larger and more robust than female Matabele goats, with significant differences in body weight and morphometric measurements at all ages. Males had higher body weight, chest girth, wither height, hip height, rump length, body length, hip width, thurl width, and pin bone width than females. The exception were on hip height, thurl width at 24 months and rump length where the difference was only statistically significant at birth and 12 months of age. No comparisons were made between males and females at the ages of 36 and 48 months because no males had reached these ages in the current study. Where comparisons were made, the males had a higher PW than females across these ages (Table 2).

Table 2. Body weight and morphometric measurement within sexes

Trait	Age (m)	Males	Females	P-value
Body weight (kg)	B	2.49 ± 0.56	1.87 ± 0.41	0.001
	12	18.08 ± 2.57	14.72 ± 2.02	0.001
	24	25.90 ± 4.91	18.64 ± 3.08	0.008
	36	….	27.18 ± 2.65	….
	48	…	31.36 ± 2.49	….
Chest girth (cm)	B	35.26 ± 2.83	32.40 ± 1.92	0.001
	12	48.69 ± 4.09	46.27 ± 2.41	0.044
	24	55.77 ± 3.35	50.42 ± 4.03	0.005
	36	…….	61.59 ± 1.67	...
	48	……	62.42 ± 2.61	….
Withers height (cm)	B	32.23 ± 4.67	28.48 ± 1.74	0.001
	12	53.94 ± 4.91	50.95 ± 7.72	0.041
	24	59.07 ± 3.96	55.34 ± 3.70	0.050
	36	….	59.93 ± 1.19	….
	48	….	64.06 ± 1.35	….
Hip height (cm)	B	32.96 ± 2.12	30.87 ± 1.88	0.001
	12	55.36 ± 5.06	50.59 ± 7.72	0.019
	24	60.46 ± 4.43	56.88 ± 2.73	0.092
	36	….	61.06 ± 1.18	…
	48	….	65.07 ± 1.52	…
Rump length (cm)	B	8.89 ± 0.40	8.18 ± 0.85	0.001
	12	17.19 ± 1.90	15.87 ± 2.84	0.050
	24	19.14 ± 2.12	17.53 ± 1.50	0.103
	36	….	18.93 ± 0.55	….
	48	….	20.77 ± 0.75	….
Body length (cm)	B	30.02 ± 4.83	27.01± 1.30	0.008
	12	53.44 ± 3.77	47.76 ± 8.70	0.005
	24	59.79 ± 4.53	53.28 ± 5.63	0.010
	36	….	58.86 ± 1.01	…
	48	….	62.78 ± 0.33	
Trait	**Age (m)**	**Males**	**Females**	**p-value**
Hip width (cm)	B	5.07 ± 0.804	4.52 ± 0.34	0.004
	12	10.21 ± 1.39	9.32 ± 1.45	0.050
	24	11.73 ± 0.89	10.68 ± 0.73	0.037
	36	….	13.30 ± 1.09	….
	48	….	13.99 ± 2.48	….
Thurl width (cm)	B	6.69 ± 0.50	6.47 ± 0.22	0.005
	12	12.25 ± 1.47	11.05 ± 1.58	0.016
	24	14.89 ± 2.22	12.73 ± 0.67	0.099
	36	….	13.12 ± 0.42	….
	48	….	15.25 ± 0.61	….
Pin bone width (cm)	B	3.93 ± 0.83	3.41 ± 0.35	0.009
	12	7.75 ± 0.94	6.60 ± 0.72	0.001
	24	8.84 ± 0.65	7.86 ± 103	0.012
	36	….	8.20 ± 0.31	….
	48		10.27 ± 0.54	….

Notes: B- at birth; gender values are represented as mean ± SD

Interestingly, morphological results showed that most of the goats were horned (85.4%), and a few percentages (14.6) were polled. Most of the goats under investigation had lateral horns (47.6%), followed by those with upward (26.2%) and backward orientations (11.7%). Another interesting feature in goats is the presence of beards. In the present study, most of the goats had no beards (69.9%), and a few percentages had beards (30.1%). The main hair patterns observed in the studied goats were the patchy type and plain type. The patchy type dominated (70.9) and the plain type (29.1%). There was an unequal representation of the different colours observed in the study. The different colours observed include brown, white, fawn, black, and various combinations of these (multiple). The combination of black and white dominated the herd (27.2%), and white, white, and brown combinations dominated 13.6% of the population. The brown and black colours were equally (8.7%) distributed among the Matabele goats. The fawn and multiple had the least equal distribution of 5.8%. The facial profiles that characterized the Matabele goats were straight and concave types. The convex type was not observed in the study population. The straight facial profiles dominated (97.2%). The concave type was observed in males entirely.

The study found that the Gompertz growth model had the highest coefficient of determination (R2 value), followed by Bertalanffy, Brody, Logistics, and Wood. This indicates that the Gompertz model was the most accurate model for predicting the growth of Matabele goats. The Gompertz model also estimated the highest asymptotic weight (maturity weight; A), followed by Bertalanffy, Brody, Logistics, and Wood. This suggests that Matabele goats reach their maximum weight at around 25.3 kg under this study conditions. The study also found that Matabele goats mature at different rates, with the Gompertz model estimating the slowest maturation rate (0.152) and the Logistics model estimating the fastest maturation rate (0.489). Overall, the study found that the Gompertz growth model is the most accurate model for predicting the growth of Matabele goats. Matabele goats reach their maximum weight at around 25.3 kg and mature at different rates. These results are further presented graphically in Figure 1.

Table 3. Equations of the five growth models and their R-square values

Model	**A**	**A**	**B**	**R-square value**
Wood	17.550	0.772	0.015	0.655
Von Bertalanffy	27.093	0.512	0.104	0.991
Brody	35.607	0.811	0.035	0.947
Logistics	20.321	13.579	0.489	0.894
Gompertz	25.330	2.342	0.152	0.992

Notes: where A is the mature weight (asymptotic weight); B is the maturation index (growth rate), and α is the integration constant.

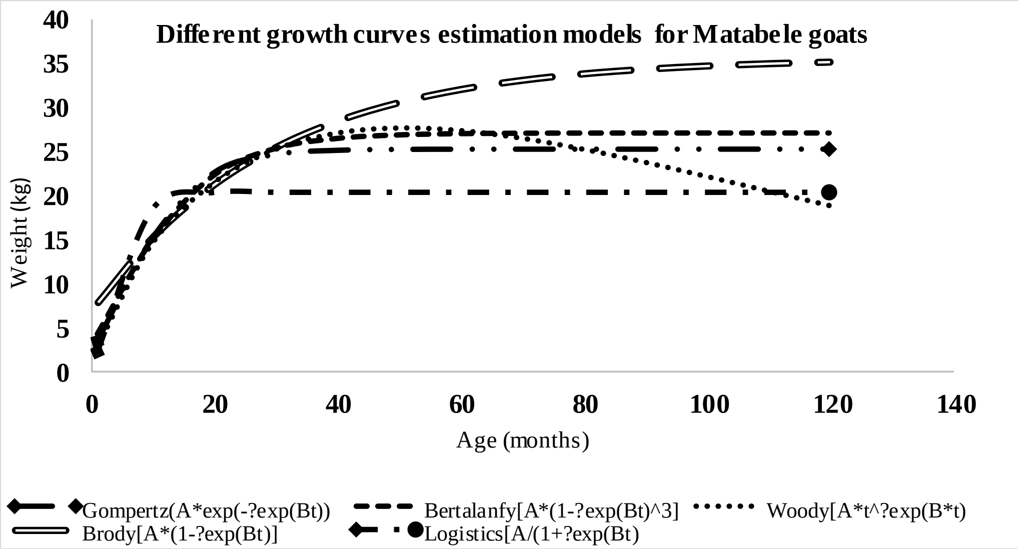

Figure 1. The growth curves of Indigenous goats from different non-linear equations

Discussion

In the current study, the mean BW of the combined sexes was much lower than those reported by *Ndhlovu et al. (2017)* for the same goat type. The study's findings suggest that males are better adapted to growth and development than females and that this may be due to differences in hormonal profiles or other biological factors (*Ojedapo et al., 2007*). A similar scenario was also observed in other body measurements such as CG, CD, RL, WH, HH, HW, and TW. Moreover, the BW and other body measurements were lower than those reported by *Getahum et al. (2020)* in Ethiopian goats and *Diba (2017)* in Nigerian indigenous goats. The difference can be attributed to genetic and environmental variations that can exist within these goat breeds or types (*Toro et al., 2011*). In addition to the source variances discussed above, the average age of a particular population can affect its average body weight and body measurements. In the present study, the average was 19 months. This might be a cause of the difference observed from other studies because younger animals tend to weigh less than mature animals.

The results of the study revealed that sex is an important source of variation in live BW and linear body measurements. A similar observation was made by *Tyasi et al. (2021)*. Most of the linear body measurements were significantly different between the sexes. This indicates that sexual dimorphism was observed in most of the quantitative traits. All quantitative traits were consistently higher in male goats than in female goats. These results are in line with observations made by *Bedada et al. (2019), Monau et al. (2018) and Getahum et al. (2020)* working with different goats. According to *Ndhlovu et al. (2017),* this is a result of intersex differential in hormonal response causing sexual dimorphism. The different hormone profiles in bucks and does invariably translate to differential growth rates. Testosterone is the most important male sex hormone, culpable with most of the male attributes and masculinity.

Peculiar morphological characteristics of Matabele goats include a mixture of coat colour patterns and the presence of horns and beards. A greater percentage of these goats have horns, no beards, and various coat colours. This was similar to findings by several authors on various indigenous breeds (*Ahmed et al., 2015; Alubele et al., 2015; Mukete et al., 2016*). *Castanheira et al. (2010)* asserted that coat colour is also useful in protecting deep tissue against excess exposure to solar shortwave radiation in tropical zones; hence, goats develop this as a form of protection. Moreover, this might be because farmers could unintentionally select these traits as an environmental adaptation mechanism for thermoregulation, cultural purposes, and protection from predators. This is also true with horn presence which can be used as a defense mechanism against predators (*Monau, 2018*).

Most of the goats in this study had pendulous ear orientations. This has been a defining characteristic of Matabele goats throughout the decades (*Mhlanga, 1999*). However, this cannot be the sole indicator that a goat is a Matabele goat type. Other factors such as body posture and horns can be incorporated to describe these goats (*VALUE, 2021*). The predominant mixed coat colour could be advantageous during the country's common seasonal temperature fluctuations. The presence of beards is thought to be associated with superior reproductive characteristics such as high conception, prolificacy, and fertility rates (*Monau et al., 2018*). However, no research has been done to scientifically ascertain this association. Therefore, research is required to determine the true impact of these qualitative traits on Matabele goats' adaptation, performance, and overall productivity. Morphological characteristics are important in defining goat type and breed. Breeding societies rely on these traits to register breeds. Any animal that diverges greatly from the expected morphology might not be considered for registration (*Zimbabwe Herd Book - ZHB, 2019*).

In general, all non-linear models demonstrated good capacities of fitting for describing the growth kinetics of goats. However, in the current study, the Gompertz and von Bertalafny functions had the best fit. *Teleken et al. (2017)* found a similar result in chickens; the Gompertz model fitted the chicken growth curve better than other models. The von Bertalanffy model was found to be a good choice for fitting the gain of body weight for the bulls in cattle (*Brown, 1992*). *Silva et al. (2011)* evaluated five non-linear models for the gain of weight for cows of different biological types and found that Richards' and Brody's models were the most appropriate for Nelore cows. *Beltran et al. (1992)* evaluated the growth patterns of two lines of Angus cows using Brody and Richards' models and concluded that both models provided good results.

Out of the five models evaluated, the Brody model showed a higher asymptotic weight, that is, the maturity weight (A) for the Matabele goats, followed by the von Bertalanffy model, Gompertz, Logistics, and Wood models. However, following the results of this study, it was proven that the Gompertz function had the best fit. In this study, the maturity weight estimation from the Gompertz growth model was estimated to be 25.33kg. However, it should be noted that this figure was influenced by the lower average age of the animals in this study. The average weight can change with the incorporation of older and mature populations. The growth curves represent the growth pattern of that particular population data set; hence the existence of difference is expected Wood showed that after the asymptotic weight, there is a decrease in the weight. This antagonistic behaviour has been reported by other authors (*Coyne et al., 2015*) in pigs and sheep (*Hossein-Zadeh, 2017*). The trend can be explained by the loss of feeding ability and loss of muscles as animals age, hence a decrease in body weight (*Adeyinka and Mohammad, 2016; Bathaei and Leroy, 2016*). The growth rate or maturation index (B) of Matabele, as estimated by the stated models, shows that it ranges from a low value of 0.015kg to 0.489kg per month. The Gompertz growth model, which fits best, estimates this value at 0.152 kg per month. A lower maturation index indicates a slow growth rate (*Ceron et al., 2020; Ali et al., 2020; Sharif et al., 2021*). This translates to the fact that Matabele goats have slow growth, which might indicate a lack of genetic improvement compared to other breeds. A gap remains to estimate the growth curves of other indigenous goats so that a comparative study can be done to assert differences in the growth rate with growth equations so that proper interventions can be taken.

The integration constant (α) shows the animal's birth weight. The Wood estimated the Matabele goat's birth weight at 0.772kg, the von Bertalanffy puts it at 0.512kg, Brody estimates it at 0.811, Logistics at 13.579kg, and the Gompertz at 2.342kg. Wood, Bertalanffy, and Brody underestimated the birth weight of these goats when compared to the actual weights observed. The Logistics function overestimated the birth weight of the Matabele goats. Gompertz gave a closer estimate of the birth weight to the actual observed values. Consequently, the Gompertz model had the most accurate estimation of the initial and mature weights of the goats. Therefore, the Gompertz equation showed the highest reliability and is the most suitable equation for describing the growth of Matabele goats.

It should be noted, however, that these growth models or non-linear equations rely on the data present at a particular time. Therefore, they are specific to the situation and may not present generic information that can be applied to every population (*Kaplan and Gurcan, 2018; Ceron et al., 2020*). This follows that proper use of the curves and estimates generated from these equations needs a proper evaluation of the environment and the population in question.

Conclusion

The findings of this study provide valuable insights into the morphometric measurements and characteristics of Matabele goats, shedding light on the diversity within this indigenous breed. The notable coefficient of variation, particularly when considering both sexes, underscores the substantial variation in morphometric traits among these goats. These variations can be primarily attributed to the animal's genetic makeup and the environmental conditions to which they are exposed. Furthermore, the study highlights the significant influence of sex and age on quantitative traits. Males consistently exhibited larger body measurements compared to females, and these measurements increased with age, emphasizing the importance of considering these factors in assessing and managing goat populations. The morphological characteristics of Matabele goats, including the presence or absence of horns, the presence or absence of beards, various coat colours, facial profiles (concave or straight), and hair patterns (smooth or patchy), were found to be diverse within this breed. These traits contribute to the unique identity of Matabele goats and may have practical implications for their adaptation, performance, and overall productivity. Regarding growth modelling, the Gompertz function emerged as the most suitable model for describing the growth curve of Matabele goats. This model provides valuable insights into the growth patterns of this indigenous breed and can serve as a valuable tool for future research and breeding programs. In summary, this study enhances our understanding of the morphometric diversity and growth characteristics of Matabele goats. These findings contribute to the knowledge base necessary for the sustainable utilization and conservation of indigenous goat breeds like the Matabele, which play a crucial role in the livelihoods of many communities.

Morfometrijska i morfološka analiza autohtonih Matabele koza u Zimbabveu

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Rezime

Istraživanje je imalo za cilj da opiše Matabele koze na osnovu njihovih kvalitativnih i kvantitativnih osobina, kako bi se olakšalo njihovo genetsko poboljšanje i očuvanje. Podaci su prikupljeni od 120 koza tokom 12 meseci, uključujući 20 muških i 100 ženskih grla korišćenjem stratifikovanog slučajnog pristupa uzorkovanja. Evidentirane su telesna težina i različite telesne mere. Pet modela za procenu krive rasta korišćeno je da se opiše obrazac rasta Matabele koza. Deskriptivna statistika je izračunata i za kvalitativne i za kvantitativne osobine. Sprovedeni su T-testovi da bi se procenio uticaj pola na morfometrijska merenja u različitim starosnim grupama. Rezultati su otkrili prosečnu telesnu masu od 20,93 kg, sa značajnim razlikama između polova ($p< 0,05$) uočenim u svim kvantitativnim osobinama. Većina koza je imala rogate i bradate karakteristike, dok su preovladavale jedinke crno-bele dlake. Među modelima krive rasta, Gompertz model je pokazao najveću vrednost R2 (0,992). Takođe, studija je otkrila relativno niske prosečne morfometrijske mere i telesnu masu kod koza Matabele rase, naglašavajući hitnu potrebu za naporima za genetsko poboljšanje i razvoj sveobuhvatnih standarda uzgoja za ovu rasu.

Ključne reči: telesne mere, telesna masa, modeli rasta, genetsko poboljšanje

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