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Research Article

Phenotypic Characterisation of the Bapedi Sheep

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Abstract: Bapedi sheep are at risk of extinction, which necessitates thorough documentation to inform and drive effective conservation efforts. We aimed to characterize Bapedi Sheep phenotypic characteristics using 231 Bapedi sheep (≥1 year of age) from Limpopo and Gauteng Provinces. The Bapedi Sheep were grazed on natural pasture and the data was collected during the autumn season. Qualitative and quantitative phenotypic characteristics were collected through visual observation, weighing belt, and measuring tape respectively. The data were analyzed and both the Bapedi rams and ewes had no beards and toggles. A high proportion (88%) of Bapedi rams used were polled. The Bapedi sheep had fat straight tails while their body weight (BW) was positively correlated to the age, body condition score (BCS), body length (BL), body depth (BD), body height (BH), heart girth circumference (HGC) and rump width (RW). There was a strong positive correlation (0.944) between the HGC and BW in Bapedi sheep. Additionally, the HGC of the Bapedi sheep was positively correlated to the age, BCS, BL, BD, BH, BW, RW, and testicular circumference (TC). Subsequently, Bapedi sheep were characterized as multi-colored with white bodies and brown heads being more dominant.

Keywords: Animal Genetic Resource (AnGR), Indigenous Sheep, Linear Body Measurements, Qualitative Traits

Introduction

The Bapedi sheep are an integral contributor to food, heritage, and genetic biodiversity in Southern Africa (Nyamushamba *et al.*, 2016). They are a valuable source of genetic material since they are adapted to local harsh environmental conditions, nutritional fluctuations, and resistance to diseases and parasites (Soma *et al.*, 2012). Genetically adapted breeds such as Bapedi sheep can provide genes needed for improving the performance and health of commercial breeds (Zonabend König *et al.*, 2016). However, they are perceived as inferior. As a result, they are being poorly managed and are currently at risk of extinction (Mafolo *et al.*, 2020). Due to the increasing human population and the standard of living, most farmers improve their farming practices by crossbreeding and replacing their flocks with exotic breeds (Leroy *et al.*, 2016). However, the entire herd of those few specialized breeds can be wiped out in the case of a disease outbreak, leaving consumers hungry and the country's economy in shambles (Letsoalo, 2017). In East Africa, there was a severe drought in 2008 and 2009. Exotic breeds, such as the Dorper, were nearly wiped out; however, Indigenous breeds, such as the Red Maasai, survived better (Zonabend König *et al.*, 2016). Zonabend König *et al.* (2017) also reported a higher survival rate of indigenous sheep breeds (Red Maasai) compared to exotic breeds (Dorper) and crossbreds at the International Livestock Research Institute ranch in (Nairobi) Kenya. Thus arises the need for the conservation and sustainable use of Indigenous Animal Genetic Resources (AnGRs) as they are hardy compared to exotic animals (Ramukhithi *et al.*, 2019). Conservation of such indigenous genetic resources can help slow down the loss of diversity and reduce extinction while preserving AnGRs for future use (Tamminen, 2015). In the quest for the conservation of AnGRs, it is essential to describe the characteristics of the breeds (Leroy *et al.*, 2016). This is crucial in describing and differentiating the breed from other breeds and strains (Hassan *et al.*, 2021). Phenotypic characterization also serves as one of the guidelines for genetically improving the low productivity of the breed to satisfy the increasing demand (Michael *et al.*, 2016). In addition, it provides information on whether the animals are suitable for selection, as some of them affect

the reproductive performance of the animal (Galina & Geffroy, 2023). Phenotypic characterization is divided into qualitative and quantitative characteristics. Most of the qualitative characteristics are very important for the adaptation and survival of the animal (Ramukhithi, 2016). At the same time, the quantitative characteristics differ depending on age, gender, and other environmental factors (Mzimela *et al.*, 2022). Few studies have been conducted to study the qualitative and semen characteristics of Bapedi sheep (Mafolo *et al.*, 2020; Maqhashu *et al.*, 2024). However, there is limited information on the quantitative phenotypic characteristics of Bapedi sheep and the interaction between qualitative and quantitative characteristics. Therefore, further investigation on Bapedi sheep phenotypic characterization is warranted for effective conservation efforts.

Materials and Methods

Study Area

The study was conducted at four national conservation farms: the Agricultural Research Council in Gauteng Province, Tompi Seleka College, Towoomba Research Station, and Mara Research Station, all in Limpopo Province. Limpopo Province is situated at 2352" 21.2' south, 2943" 52.8' east, while Gauteng Province is situated at 25" 55' south, 28" 12' east in South Africa (Mafolo *et al.*, 2020; Aminisarteshnizi, 2023). Gauteng Province is characterized by hot summers (21.2-27°C) and mild winters (8-20°C) (Chokoe *et al.*, 2020). Limpopo Province is characterized by hot summers (22-30°C) and mild winters (9.8-20 °C) (Chokoe *et al.*, 2020). Both provinces have an average annual rainfall of 400-750 mm per annum (Chokoe *et al.*, 2020).

Management of the Experimental Animals

A total of 231 Bapedi sheep (≥1 year of age), which consisted of 35 rams and 196 ewes, were used in the current study. The animals were housed in group camps based on gender and were grazed on natural pasture. Where necessary, they were supplemented with lucerne and provided with water and *ad libitum*. Data was collected during autumn (March-May) while they were in good condition. A randomized complete block design was used to block all the other potential environmental and management factors that may cause variations (Harbur *et al.*, 2023). During data collection, all the experimental animals were confined in secured holding pens. Data was collected from 08h00 in the morning until around 10h00 to allow the animals to graze afterward. The sheep were handled with care and in an unforced position to allow them to be comfortable while assessing. Phenotypic characteristics were observed and recorded into two categories: qualitative and quantitative characteristics. Qualitative characteristics such as the condition of the coat cover, head, horns, ears, neck, chest, testis, hindquarters, legs, tail, shoulder, torso, udder, and teat appearance were visually observed (Akpa *et al.*, 2013). The Body Condition Score (BCS) was determined based on a scale of 1 (very thin) to 5 (obese) (Chun *et al.*, 2012). Quantitative data, including linear body measurements, were taken in a standing position with heads raised, and the movement of the animals was restricted (Akpa *et al.*, 2012). The quantitative characteristics were measured (cm) using a flexible tape measure (Empisal EMT-001), and Body Weight (BW) was measured (kg) using a weighing belt (Akpa *et al.*, 2012).

Statistical Analysis

The data were analyzed using the Statistical Analysis System (SAS, 2019) version 9.4. The study used descriptive statistics whereby qualitative characteristics were expressed as frequencies and percentages, and quantitative characteristics were expressed as means and standard error (mean ± se). Pearson's correlation was used to determine the relationship among phenotypic characteristics.

Results

Qualitative Characteristics of the Bapedi Sheep

Table (1) shows the qualitative phenotypic characterization of Bapedi sheep (general appearance, age, tail, and coat cover). Both Bapedi rams (97%) and ewes (75%) had satisfactory BCS; some were fat, and a few were very thin. There were no Bapedi sheep that were obese. A relative number of ewes (30%) and rams (31%) were 4 years old, whereas 28% of ewes and 26% of rams were above 5 years old. Most ewes (98%) and rams (86%) had straight tails. Most rams (91%) and ewes (*7%) did not have any ticks. There was an average proportion of ewes (69%) and rams (49%) with average coat cover conditions. Additionally, ewes (27%) and rams (51%) had shiny coat covers. Most rams (97%) and ewes (88%) had medium fiber coats. Most ewes (93%) and rams (97%) had a combination of two colors on their body; white color was dominating in Bapedi ewes (88%) and rams (97%). Most Bapedi ewes (92%) and rams (94%) had a brown head, while some Bapedi ewes (5%) and rams (6%) had a white head. There were traces of Bapedi ewes (4%) that had blackheads; however, no traces of blackheads were recorded in Bapedi rams. A high proportion of the Bapedi ewes (80%) and rams (91%) had a brown head and white body.

Table (2) Shows the skin parameters of Bapedi sheep. Most ewes (46%) had average skin sizes, whereas most rams (60%) had big and loose skin sizes. Most rams (63%) had thick skin, whereas an average number of Bapedi ewes (47%) had average skin. Most of Bapedi ewes (95%) and rams (80%) had no neck and chest folds. A high proportion of ewes (89%) and rams (66%) were red on the hairless skin part; however, there were traces of black color on the skin color of Bapedi ewes (10%) and rams (34%).

Table 1: General appearance, age, tail, and coat cover parameters of Bapedi sheep (%)

Characteristics	Categories		Sex	
			Ewes (n = 196)	Rams (n = 35)
1. General Appearance	Body condition score	Very thin (1)	2	0
		Thin (2)	15	0
		Satisfactory (3)	75	97
		Fat (4)	8	3
		Very fat (5)	0	0
2. Age	Year (s) (counting the number of permanent incisors)	1	2	20
		2	21	14
		3	19	9
		4	30	31
		> 5	28	26
3. Tail	Appearance	Straight	98	86
		Skew	2	14
		None	87	91
	Ticks	1	5	6
		2	4	3
		3	2	0
		4	2	0
4. Coat cover	Appearance	Coarse	4	0
		Average	69	49
		Glossy and shine	27	51
	Length	Short	0	0
		Medium	88	97
		Long	12	3
	Color	Single	6	3
		Two	93	97
		More	1	0
	Main color	White	88	97
		Black	2	0
		Brown	11	3
	Head color	Brown	92	94
		White	5	6
		Black	4	0
	Color combination (head x body)	Brown & White	80	91
		Black & White	3	0
		Black & Brown	1	0
		Brown only	11	3
		Black only	1	0
		White only	4	6

Table (3) shows the head, horns, and ears parameters of Bapedi sheep. A high proportion of ewes (83%) had straight noses and forehead shapes, whereas only 37% of Bapedi rams had the same condition. Additionally, 60% of rams and 18% of ewes had convex nose and forehead shape. A high proportion of the ewes (99%) and rams (89%) had brown eyes with an average width and eye banks.

Table (4) shows the neck, chest, hind quarter, shoulder, torso, and leg parameters of Bapedi sheep. Most rams (74%) and ewes (91%) had a fleshed neck. Additionally, 8% of Bapedi ewes had a thin neck, whereas 26% of Bapedi rams were well fleshed. Bapedi ewes (53%) and rams (57%) had narrow chest widths, whereas 34% of both the Bapedi ewes and rams had average chest widths. There was a higher proportion of Bapedi ewes (78%) and rams (77%) that had an ideal attachment of the shoulder and torso. There was a high proportion of Bapedi rams (80%) and ewes (60%) that moderately wither at the top of the shoulder and torso. Additionally, ewes (54%) and rams (63%) had cylindrical torsos. Most rams (97%) and ewes (98%) had straight topline. Most rams (60%) and ewes (59%) had an average rump, whereas 37% of both Bapedi ewes and rams had sloped rump. Additionally, there were traces of Bapedi ewes (4%) and rams (3%) with straight rump. A high proportion of ewes (70%) had long hindquarters length, whereas a high proportion of rams (74%) had average hindquarters length. A high proportion of ewes (79%) and rams (83%) had average hindquarters width. Forty-six percent of ewes had short and flat buttocks, whereas 49% of rams had well-fleshed round buttocks.

Table 2: Skin parameters of Bapedi sheep (%)

Characteristics	Categories		Sex	
			Ewes (n = 196)	Rams (n = 35)
5. Skin	Size	Small and tight	28	11
		Average	46	29
		Big and loose	26	60
	Thickness	Thin	27	8
		Average	47	29
		Thick	26	63
	Neck and chest folds	None	95	80
		Few	5	20
	Pigmentation ratio: eyelids	< 25 %	78	89
		26 - 75%	22	11
		> 75 %	0	0
	Pigmentation ratio: top line	< 25 %	1	0
		26 - 75 %	99	100
		> 75 %	0	0
	Pigmentation ratio: bottom line	< 25 %	1	0
		26 - 75 %	99	100
		> 75 %	0	0
	Pigmentation ratio: leg	< 25 %	1	0
		26 - 75 %	99	100
		> 75 %	0	0
	Pigmentation ratio: under the tail	< 25 %	1	0
		26 - 75 %	99	100
		> 75 %	0	0
	The skin color on the hairless part	Black	10	34
		Brown	1	0
		Red	89	66
		White	0	0
		Fully covered with hair	0	0

Table (5) shows the leg parameters (qualitative) of Bapedi sheep (%). A high proportion of ewes (87%) and rams (86%) had average leg diameter. All rams had normal legs, and only 1% of ewes had X-legged abnormalities. Most ewes (96%) and rams (94%) had average pasterns. Most rams (94%) and ewes (96%) had ideal hocks with average hooves sizes. Additionally,

there was a higher proportion of ewes (87%) and rams (82%) with good and shiny hooves conditions. Half of Bapedi ewes had well-worn hooves, whereas 44% had good hooves length. On the other hand, an average proportion of Bapedi rams had good hooves length, and 31% had well-worn hooves.

Table 3: Head, horns, and ears parameters of Bapedi sheep (%)

Characteristics	Categories		Sex	
			Ewes (n = 196)	Rams (n = 35)
6. Head	Nose and forehead shape	Convex	18	60
		Straight	82	37
		Concave	0	3
	Eye color	Brown	99	89
		Blue	1	11
	Eye width	Narrow	6	11
		Average	93	89
		Wide	1	0
	Eye banks	Absent	37	23
		Average	63	77
		Distinct	0	0
	Look in the eye	Untamed	16	3
		Tamed	84	97
	Nostrils	Small and closed	40	46
		Wide and open	60	54
	Shape of mouth	Narrow	4	09
		Average	96	91
		Wide	0	0
	Lower jaw	Undershot	2	3
		Fits well	97	97
		Overshot	1	0
	Beards	Absent	100	100
		Present	0	0
	Toggles	Absent	99	86
		Present	1	14
7. Horns	Type	Horned	0	2
		Polled	100	88
		Horn buds	0	9
	Growth direction	Backwards	X	3
		Sideways	X	0
		Upright	X	0
	Color	Dark	X	0
		Light	X	100
	Deviation	Undamaged	X	100
		Damaged	X	0
8. Ears	Size	Short	2	3
		Average	86	97
		Long	12	0
	Direction	Soft hanging	8	9
		Stiff sideways	91	91
		Stiff upwards	1	0
	Folds	Lengthwise	28	63
		Breadth wise	72	37

X = not found

Table (6) shows the testis and udder parameters of Bapedi sheep (%). Ninety-seven percent of rams had well-balanced testis, while the other 3% had unequal size. Forty-nine percent of Bapedi rams had large testis. All rams had a good attachment to the testis. Ninety-one percent of rams had a straight conformation of the testis, while the other 9% was twisted. There was a higher proportion of rams (97%) which had hair covering the testis. Ninety-one percent of rams had no ticks. Most ewes (75%) had a good attachment to the udder, with 99% having no damage to their udder. There was a high proportion of ewes (99%) with two healthy teats, and 93% had hair covering almost all the udder. There was a high proportion of ewes (98%) with no ticks on the udder, whereas 2% of them had only one tick.

Table 4: Neck, chest parameters, hind quarter and shoulder, torso of Bapedi sheep (%)

Characteristics	Categories		Sex	
			Ewes (n = 196)	Rams (n = 35)
9. Neck	Length	Short	1	0
		Average	84	94
		Long	15	6
	Shape	Thin	8	0
		Fleshed	91	74
		Well fleshed	1	26
10. Chest	Width	Narrow	53	57
		Average	34	34
		Wide	13	9
	Depth	Shallow	42	54
		Average	42	37
		Deep	16	9
11. Shoulder and torso	Attachment to the body	Loose	2	0
		Average	20	23
		Ideal	78	77
	Withers at the top	Sharp	9	3
		Moderate	60	80
		Broad	31	17
	Torso	Narrow	44	37
		Cylindrical	54	63
		Broad and Deep	2	0
	Topline	Pinched	1	0
		Straight	98	97
		Hollow	1	3
12. Hind quarters	Rump	Sloped	37	37
		Average	59	60
		Straight	4	3
		Roofy	0	0
	Length	Short	16	12
		Average	14	74
		Long	70	14
	Width	Narrow	7	3
		Average	79	83
		Broad	14	14
	Buttocks and thighs	Short and flat	46	31
		Long and flat	29	20
		Well-fleshed and round	25	49

Table (7) shows the phenotypic quantitative characteristics of Bapedi ewes and rams (Mean ± SE). The average age for ewes and rams used in the current study was 3.8 years and 3.6 years, respectively. The BCS of the Bapedi ewes and rams was recorded as 2.9 and 3.0, respectively. The weight of the Bapedi rams and ewes used in the study were 62.6 and 45.0 kg,

respectively. Linear body measurements recorded on Bapedi rams included BL (79.4 cm), BH (69.8 cm), BD (24.2 cm), HGC (90.6 cm), and RW (22.8 cm), respectively. While linear body measurements recorded on Bapedi ewes used in the study were BL (65.6 cm), BH (65.5 cm), BD (19.3 cm), HGC (81.5 cm), and RW (18.7 cm), respectively. The TC of the Bapedi rams recorded in the current study was 29.2 cm, while the teat length of the Bapedi ewes was 1.7 cm. The TL of the Bapedi ewes and rams recorded in the study was 32.1 and 33.5 cm, respectively.

Table 5: Legs parameter of Bapedi sheep (%)

Characteristics	Categories	Sex	
		Ewes (n = 196)	Rams (n = 35)
Diameter	Thin	12	9
	Average	87	86
	Thick	1	5
Front	Normal	99	100
	X legged	1	0
	Bow legged	0	0
Pasterns	Short	5	3
	Average	94	94
	Long	1	3
Hocks	Ideal	96	94
	Post legged	4	6
	Cow hocked	0	0
Hooves size	Small (1-2 mm thick)	9	14
	Average (2-3 mm thick)	88	63
	Big (3-4 mm thick)	3	23
Hooves condition	Poor	5	9
	Average	8	9
	Good and shiny	87	82
Hooves length	Well worn	50	31
	Good	44	54
	Too long	6	15

Table (8) shows the Pearson's correlation coefficient values among phenotypic quantitative characteristics of Bapedi sheep (rams and ewes). The age of the Bapedi sheep was significantly ($p<0.05$) positively correlated to BL (r = 0.218), BD (r = 0.204), BH (r = 0.286), HGC (r = 0.303) and RW (r = 0.221). The BCS of the Bapedi sheep was significantly ($p<0.05$) positively correlated to BW (r = 0.150), HGC (r = 0.303), and TL (r = 0.162). While the BL was significantly ($p<0.05$) positively correlated to the BD (r = 0.606), BH (r = 0.511), BW (r = 0.664), HGC (r = 0.622), RW (r = 0.410), HLW (r = 0.311), TL (r = 0.177) and a negative significant ($P<0.05$) correlation with HLLBH (r = 0.144). The BD of Bapedi sheep was significantly ($p<0.05$) high positively correlated to BW (r = 0.811), HGC (r = 0.811), and RW (r = 0.722), and a significant ($p<0.05$) negatively correlated to HLL (r = 0.155) and HLLBH (r = 0.139). Body height (BH) of the Bapedi sheep was significantly ($p<0.05$) positively correlated to the BW (0.565), HGC (r = 0.568), RW (r = 0.356), HLL (r = 0.333), HLLBH (r = 0.182), HLLBK, (r = 0.170) and TL (r = 0.293). The BW of the Bapedi sheep was significantly ($p<0.05$) high and positively correlated to HGC (r = 0.927). The HGC of the Bapedi sheep was significantly ($p<0.05$) positively correlated to RW (r = 0.672), HLW (r = 0.239) and TL (r = 0.247). The Rump Width (RW) of the Bapedi sheep was significantly ($p<0.05$) positively correlated to HLW (r = 0.183), TL (r = 0.215), and a significant ($p<0.05$) negatively correlated to the HLL (r = 0.330). Hind Leg Width (HLW) of the Bapedi sheep was significantly ($p<0.05$) positively correlated to HLLBK (r = 0.134) and a significant ($p<0.05$) negatively correlated to HLL (r = 0.267). Hind Leg Length (HLL) of the Bapedi sheep was significantly ($p<0.05$) positively correlated to HLLBH (r = 0.143), while HLLBH was significantly ($p<0.05$) positively correlated to HLLBK (r = 0.289).

Table 6: Testis and udder parameters of Bapedi sheep (%)

Characteristics	Categories		Sex	
			Ewes (n = 196)	Rams (n = 35)
15. Testis	General Appearance	Unequal in size	X	3
		Well-balanced/equal	X	97
	Size	Small (10-20 cm)	X	2
		Normal (20-30 cm)	X	49
		Large (30-40 cm)	X	49
	Attachment	Poor	X	0
		Good	X	100
	Twist	Twisted	X	9
		Straight	X	91
	Hair	None	X	0
		Few	X	3
		Almost covered	X	97
	Ticks	None	X	91
		1	X	0
		2	X	3
		3	X	0
		4	X	3
		5	X	3
16. Udder	General Appearance	Small (15-25 cm)	40	X
		Average (25-35 cm)	45	X
		Big (35-45 cm)	15	X
	Attachment	Poor	4	X
		Average	21	X
		Good	75	X
	Damaged	None	99	X
		1	1	X
		2	0	X
	Healthy teats	1	1	X
		2	99	X
	Hair	None	6	X
		Few	1	X
		Almost covered	93	X
	Ticks	None	98	X
		1	2	X
		2	0	X
		3	0	X

X = not found

Table 7: Phenotypic quantitative characteristics of the Bapedi sheep breed (mean ± se)

Characteristics	Categories	Sex	
		Ewes (n = 196)	Rams (n = 35)
Age		3.8 ± 0.1	3.6 ± 0.4
Body	Condition score	2.9 ± 0.0	3.0 ± 0.0
	Weight (Kg)	45.0 ± 0.9	62.6 ± 2.4
	Length	65.6 ± 0.6	79.4 ± 1.4
	Height	65.5 ± 0.3	69.8 ± 0.7
	Depth	19.3 ± 0.3	24.2 ± 0.9
Heart girth	Circumference	81.5 ± 0.7	90.6 ± 1.4
Rump	Width	18.7 ± 0.4	22.8 ± 1.1
Hind leg	Width	12.5 ± 0.1	14.5 ± 0.3
	Length	51.6 ± 0.3	53.3 ± 0.7
	Length below hock	24.7 ± 0.1	24.5 ± 0.2
	Length below knee	20.0 ± 0.1	20.2 ± 0.2
Testis	Circumference	X	29.2 ± 0.7
Teat	Length	1.7 ± 0.0	X
Tail	Length	32.1 ± 0.1	33.5 ± 0.7

X = not found

Table (9) shows Pearson's correlation coefficient values among phenotypic quantitative characteristics of Bapedi ewes. Age of the Bapedi ewes was positively correlated to BL (r = 0.250), BD (r = 0.224), BH (r = 0.207), BW (r = 0.337), HGC (r = 0.328) and RW (r = 0.225). The BCS of the Bapedi ewes was significantly (P<0.05) negatively correlated to BL (r = 0.200) and significantly (p<0.05) positively correlated to age (r = 0.250), HGC (r = 0.143), and TL (r = 0.176). The BL of the Bapedi ewes was significantly (P<0.05) positively correlated to BD (r = 0.562), BH (r = 0.423), BW (r = 0.609), HGC (r = 0.564), RW (r = 0.398), HLW (r = 0.229), TL (r =0.168). The BD of the Bapedi ewes was significantly (P<0.05) positively correlated to BH (r = 0.370), BW (r = 0.821), HGC (r = 0.809), RW (r = 0.715), HLW (r = 0.199), TL (r = 0.223) and significantly (P<0.05) negatively correlated to HLL (r = 0.281). The BH of the Bapedi ewes was significantly (P<0.05) positively correlated to all the quantitative characteristics except the BCS. The BW of Bapedi ewes was significantly (p<0.05) positively correlated to HGC (r = 0.944), RW (r = 0.699), HLW (r = 0.144), TL (r = 0.262), and significantly (p<0.05) negatively correlated to HLL (r = 0.105). The HGC of the Bapedi ewes was significantly (p<0.05) positively correlated to age (r = 0.328), BCS (r = 0.143), BL (r = 0.564), BD (r = 0.809), RW (r = 0.669), BW (0.944), TL (r = 0.302) and significantly (p<0.05) negatively correlated to HLL (r = 0.469). Rump width (RW) of the Bapedi ewes was significantly (p<0.05) positively correlated to HLW (r = 0.110), TL (r = 0.265), and significantly (p<0.05) negatively correlated to HLL (r = 0.469). Hind leg length (HLL) of the Bapedi ewes was significantly (p<0.05) positively correlated to HLLBH (r = 0.252) and HLLBK (r = 0.156). The teat length of the Bapedi sheep was significantly (P<0.05) positively correlated to BL (r = 0.390), BD (r = 0.223), BH (r = 306), BW (r = 496), HGC (r = 0.478), RW (r = 0.224) and significantly (p<0.05) negatively correlated to HLLBK (r = 0.163).

Table 8: Overall Pearson correlation coefficient values among phenotypic quantitative of Bapedi sheep (rams and ewes)

Variables	Age	BCS	BL	BD	BH	BW	HGC	RW	HLW	HLL	HLLBH	HLLBK	TL
Age	1												
BCS	-0.118	1											
BL	0.218*	-0.109	1										
BD	0.204*	0.108	0.606*	1									
BH	0.231*	0.013	0.511*	0.450*	1								
BW	0.286*	0.150*	0.664*	0.814*	0.565*	1							
HGC	0.303*	0.158*	0.622*	0.811*	0.568*	0.927*	1						
RW	0.221*	0.082	0.410*	0.722*	0.356*	0.691*	0.672*	1					
HLW	0.076	-0.049	0.311*	0.286*	0.130	0.253*	0.239*	0.183*	1				
HLL	-0.016	-0.024	0.061	-0.155*	0.333*	-0.013	-0.012	-0.330*	-0.267*	1			
HLLBH	-0.011	0.091	-0.144*	-0.139*	0.182*	-0.065	-0.037	-0.111	-0.026	0.143*	1		
HLLBK	0.047	0.003	0.080	0.080	0.170*	0.131*	0.082	0.127	0.134*	0.115	0.289*	1	
TL	0.069	0.162*	0.177*	0.210*	0.293*	0.177*	0.247*	0.215*	-0.003	0.019	0.079	0.003	1

** Significant at P < 0.05. BCS = Body condition score, BL = Body length, BD = Body depth, BH = Body height, BW = Body weight, HGC = Height girth circumference, RW = Rump width, HLW = Hind leg width, HLL = Hind leg length, HLLBH = Hind leg length below hock, HLLBK = Hind leg length below knee and TL = Tail length*

Table (10) shows Pearson's correlation coefficient values among phenotypic quantitative characteristics of Bapedi rams. Age of the Bapedi rams was significantly (p<0.05) positively correlated to the BL (r = 0.387), BH (r = 0.451), HGC (r = 0.376), and TC (r = 0.490). Body length (BL) of the Bapedi rams was significantly (p<0.05) positively correlated to BD (r = 0.479), BH (r = 0.620), HGC (r = 0.691), HLW (r = 0.471), HLL (0.370), TL (r = 0.355) and TC (r = 0.444). Body depth (BD) of the Bapedi rams was significantly (p<0.05) positively correlated to BH (r = 0.565), BW (r = 0.648), HGC (r = 0.699), RW (r = 0.696), HLW (r = 0.592), HLL (r = 0.325) and TC (r = 0.541). Body height (BH) of the Bapedi rams was significantly (p<0.05) positively correlated with BW (r = 0.494), HGC (r = 0.640), RW (r = 0.519), HLW (r = 0.608), HLL (r = 0.666), TL, (r =

0.440) and TC (r = 0.477). Body Weight (BW) of the Bapedi rams was significantly (p<0.05) positively correlated to HGC (r = 0.841), RW (r = 0.621), HLW (r = 0.564), and TC (r = 0.415). Heart Girth Circumference (HGC) of the Bapedi rams was significantly (p<0.05) positively correlated to RW (r = 0.591), HLW (r = 0.692) and TC (r = 0.584). Rump Width (RW) of the Bapedi rams was significantly (p<0.05) positively correlated to HLW (r = 0.480), HLL (r = 0.376), TC (r = 0.512) and significantly (p<0.05) negatively correlated to HLBH (r = 0.429). Hind leg width (HLW) of the Bapedi rams was significantly (p<0.05) positively correlated to HLL (r = 0.518), HLLBK (r = 0.484), and TC (r = 0.342). Hind Leg Length (HLL) of the Bapedi ram was significantly (p<0.05) positively correlated to TL (r = 0.378) and TC (r = 0.357).

Table 9: Pearson's correlation coefficient values among phenotypic quantitative characteristics of Bapedi ewes

Parameters	Age	BCS	BL	BD	BH	BW	HGC	RW	HLW	HLL	HLLBH	HLLBK	TL	Teat L
Age	1													
BCS	-0.139	1												
BL	0.250*	-0.200*	1											
BD	0.224*	0.090	0.562*	1										
BH	0.207*	-0.015	0.423*	0.370*	1									
BW	0.337*	0.135	0.609*	0.821*	0.519*	1								
HGC	0.328*	0.143*	0.564*	0.809*	0.516*	0.944*	1							
RW	0.225*	0.083	0.398*	0.715*	0.287*	0.699*	0.669*	1						
HLW	0.073	-0.067	0.229*	0.199*	0.015*	0.144*	0.143*	0.110*	1					
HLL	-0.041	-0.035	-0.043	-0.281*	0.266*	-0.105*	-0.149*	-0.469*	0.005	1				
HLLBH	0.073	0.114	-0.147*	-0.110	0.271*	-0.027	-0.095	-0.038	-0.052	0.252*	1			
HLLBK	0.050	0.003	-0.016	-0.071	0.215*	-0.004	-0.039	0.039	0.050	0.156*	0.373*	1		
TL	0.028	0.176*	0.168*	0.223*	0.274*	0.262*	0.302*	0.265*	0.032	-0.064	0.083	-0.011	1	
Teat L	0.092	0.006	0.390*	0.223*	0.306*	0.496*	0.478*	0.224*	0.201**	-0.080	0.024	-0.163*	0.036	1

** Significant at P < 0.05. BCS = Body condition score, BL = Body length, BD = Body depth, BH = Body height, BW = Body weight, HGC = Height girth circumference, RW = Rump width, HLW = Hind leg width, HLL = Hind leg length, HLLBH = Hind leg length below hook, HLLBK = Hind leg length below knee, TL = Tail length and Teat L = Teat length*

Table 10: Pearson's correlation coefficient values among phenotypic quantitative characteristics of Bapedi rams

Parameters	Age	BCS	BL	BD	BH	BW	HGC	RW	HLW	HLL	HLLH	HLLK	TL	TC
Age	1													
BCS	0.032	1												
BL	0.387*	0.254	1											
BD	0.257	0.000	0.479*	1										
BH	0.451*	-0.015	0.620*	0.565*	1									
BW	0.329	-0.030	0.216	0.648*	0.494*	1								
HGC	0.376*	0.058	0.691*	0.699*	0.640*	0.841*	1							
RW	0.276	-0.203	0.127	0.696*	0.519*	0.621*	0.591*	1						
HLW	0.183	-0.194	0.471*	0.592*	0.608*	0.564*	0.692*	0.480*	1					
HLL	0.141	-0.100	0.370*	0.325*	0.666*	0.142	0.334	0.376*	0.518*	1				
HLBH	-0.312	-0.103	-0.075	-0.226	-0.140	-0.154	-0.107	-0.429*	-0.004	-0.211	1			
HLLBK	0.064	-0.124	-0.111	-0.263	0.051	0.267	0.266	0.264	0.484*	0.041	0.270	1		
TL	0.191	0.141	0.355*	0.204	0.440*	-0.100	0.031	0.018	0.193	0.378*	0.066	0.021	1	
TC	0.490*	-0.049	0.444*	0.541*	0.477*	0.415*	0.584*	0.512*	0.342*	0.357*	-0.269	-0.116	0.176	1

** Significant at P < 0.05. BCS = Body condition score, BL = Body length, BD = Body depth, BH = Body height, BW = Body weight, HGC = Height girth circumference, RW = Rump width, HLW = Hind leg width, HLL = Hind leg length, HLLBH = Hind leg length below the hock, HLLBK = Hind leg length below knee, TL = Tail length and TC = Testis circumference*

Discussion

Qualitative Characteristics

The Bapedi sheep (rams and ewes) used in this study had satisfactory BCS, and none were very fat (> four obesity) or thin. Obesity in rams usually causes low libido and susceptibility to heat stress (Letsoalo, 2017). The study found that Bapedi rams (97%) and ewes (93%) used in the study were multi-colored, with a white coat and a brown head being more dominant. These results are similar to the description documented in previous studies (Almeida, 2011). However, some of the Bapedi sheep can either have only one color or a combination of all these colors (black, brown, and white). Coat color plays a vital role in heat absorption and heat loss, especially in high ambient temperate environments (Akpa *et al.*, 2013). It has been stipulated that lighter colors absorb less heat than darker colors, thus resulting in more adaptation and prevalence of

whiter Bapedi sheep. On the contrary, in other countries such as Ethiopia, black sheep are more dominant as they are cold, and the absorption of solar radiation helps maintain optimum body temperature (Hailemariam *et al.*, 2018).

The Bapedi sheep used in the study had a glossy medium-length coat cover. According to Akpa *et al.* (2013), hair type (especially short or medium hair length) plays a vital role in avoiding external parasites, thus resulting in higher body weight. However, one of the disadvantages of glossy hair is that it is less adaptable to hot climates, resulting in less production in hot ambient temperatures (Ramukhithi, 2016). Smooth hair was also observed in indigenous sheep types in Ethiopia (Michael *et al.*, 2016). Most of the Bapedi ewes (47%) had average skin size, while Bapedi rams (63%) had big and loose thick skin. Only 9% of the Bapedi rams had ticks on the testis, while 2% were found on the udder of the ewes. This may be due to the big and loose, thick skin found in Bapedi rams, which is mostly associated with the prevalence of ticks (Ramukhithi *et al.*, 2019). However, the Bapedi sheep showed good resistance to ticks, as expected. The eyelid, top line, bottom line, leg, and under tail pigmentation ratio of both the Bapedi sheep (rams and ewes) was good, and the skin color was mostly red, which showed that there were no internal parasites. A high proportion of Bapedi sheep, both rams and ewes, had brown eyes, with a lower proportion having blue eyes (Cloete, 2016). As expected, a high proportion of Bapedi sheep used in the experiment were tamed, and their lower jaw fit well.

Most of the Bapedi ewes (82%) had a straight nose and forehead shape, whereas the Bapedi rams (60%) had a convex nose and forehead. These characteristics have also been reported by Indigenous sheep in Northern Ethiopia where the sheep were characterized as straight heads with slightly convex shapes in male sheep (Michael *et al.*, 2016). The Bapedi sheep had average ear sizes that were stiff and hanging sideways with lengthwise and breadthwise folds. This horizontal ear orientation has been reported in Tswana sheep in Southern Botswana (Moreki *et al.*, 2016) and Zulu sheep across different locations of Kwazulu-Natal in South Africa (Mavule, 2012). The Bapedi sheep (rams and ewes) used in the study had moderate neck lengths and were well-fleshed. The well-fleshed neck was expected as most of the Bapedi sheep had a good BCS. Both Bapedi rams and ewes had narrow to average chest width with a shallow to average depth. Their shoulder moderately withers at the top with an ideal attachment, while the torso is cylindrical to narrow, and the top line is straight.

The Bapedi sheep lacked beards, and a significant number of both rams and ewes also had no toggles. These traits are comparable to those observed in Indigenous sheep in Northern Ethiopia (Michael *et al.*, 2016). In small stock (goats), toggles and beards are very vital for thermoregulation and are associated with reproductive traits (such as higher conception rates, litter size, and milk yield) (Chokoe *et al.*, 2020). As expected, the Bapedi ewes used in the study were polled, as horns are usually found in males, and those that had horns were growing backward and were light in color. On the contrary, the presence of horns has been reported in female Balami sheep of Maiduguri in Nigeria (Dauda *et al.*, 2018). Horns that grow backward were also reported on Tswana sheep in Southern Botswana (Moreki *et al.*, 2016). While on indigenous Ethiopian sheep, a high proportion had curved horns, while a low proportion had straight horns (Michael *et al.*, 2016). According to Kunene *et al.* (2007), the production of horns utilizes the energy that could be used for meat production. In that essence, Bapedi sheep are likely to have increased energy for production since they are predominantly polled. While horns can offer advantages such as protection against predators and aiding in heat regulation through blood circulation (Ramukhithi, 2016), the absence of horns may allow these sheep to allocate more energy towards growth and productivity. A high percentage (91%) of both the Bapedi ewes and rams had ears that were stiff and hanging sideways. The horizontal ear form was also reported in Gamo highland sheep in South Ethiopia (Dea *et al.*, 2023).

The Bapedi sheep used in the study had average hoof sizes that were well-worn and shiny, indicating good hoof health. The exceptional condition of the hooves proves that the farms implement good management practices, as hooves require regular trimming to prevent lameness. The study found that Bapedi sheep had fat, straight tails, as expected. The results of this study concur with the findings from Soma *et al.* (2012) that Bapedi sheep had fat straight tails. The fat tail in sheep breeds is an adaptive characteristic for energy reservation, and it allows the sheep to survive feed fluctuations throughout the year and in times of drought, while the type of tail only depends on genetics (Moreki *et al.*, 2016). In the past, the fat found in the tail was used as cooking oil and a source of dietary energy (Khaldari *et al.*, 2020). Recently, in commercial sheep production, tail docking has become common to prevent fat accumulation and enhance other economically important traits (Fisher & Roadknight, 2024).

The study found that 97% of the Bapedi rams had well-balanced testis, and 98% of those had normal to large testis with proper attachment and adequate hair coverage. The testes were firm, mobile within the scrotum, and of suitable size, indicating a healthy condition (Ramukhithi, 2016). The Bapedi rams are not prone to ticks, as 91% of those used in the study had no ticks. A high proportion of the Bapedi ewes used in the study had small udder to average udder size with good attachment and no damages. Almost all of the ewes had two healthy teats, hair covering almost all the udder, and no ticks. Similar results were found on Tankwa goats at

Carnarvon Research Station (Ramukhithi, 2016). The good condition of the udder and testis was not a surprise since, in most conservation farms, good quality care and management practices are being followed. Therefore, there was no chance for ticks and lice to feed on the hairless skin (Kumar *et al.*, 2024).

Quantitative Characteristics

Linear body measurements have been used to phenotypically characterize small ruminants across the world as they provide morphometric information on the breed (Moreki *et al.*, 2016). At the same time, their correlations can be used to determine the genetic potential of the breed in trait improvement programs (Moreki *et al.*, 2016). Age usually influences linear body measurements as it often results in a bigger body structure as the animal grows older (Dauda *et al.*, 2018). Similarly, the age of Bapedi sheep (rams and ewes) was positively correlated to the BL, BD, BH, BW, HGC, and RW. Similar results were reported by Kunene *et al.* (2007), where age contributed to the variation in linear body measurements of Zulu sheep. However, this study found that there was no significant ($p>0.05$) correlation between age and the BCS of the Bapedi sheep. The Bapedi ewes and rams used in the study had a body condition score of 3.8±0.1 and 3.6±0.4, respectively. Additionally, the study recorded a lower significant ($p<0.05$) correlation with BW, HGC, and TL on Bapedi sheep. The Bapedi rams and ewes used in the current study had a BW of 62.6±2.4 and 45.0±0.9 kg, respectively. These results show that the Bapedi sheep are heavier than the Tswana sheep (38.93±2.4 kg) (Moreki *et al.*, 2016) and the indigenous sheep in Northern Ethiopia (29.0±0.2 kg) (Michael *et al.*, 2016). The current data was collected in autumn at a time when there was enough feed and water, which has a major impact on the growth of animals, hence the higher weight of Bapedi sheep. The BL (65.6±0.6; 79.4±1.4 cm) and RW (18.5±0.7; 22.8±1.1 cm) of the ewes and rams recorded in the current study are higher than those of Indigenous Tswana sheep over 4 years in Southern Botswana (Moreki *et al.*, 2016). Additionally, the study recorded a higher significant ($p<0.05$) positive correlation between RW and BD ($r = 0.722$) of the Bapedi sheep.

The study recorded a higher HGC in Bapedi rams (90.6±1.4 cm) and Bapedi ewes (81.5±0.7 cm). The HGC recorded in the current study is higher than that recorded on Tswana sheep in Southern Botswana (Moreki *et al.*, 2016). The study recorded a high positive correlation (0.944) between the HGC and BW of Bapedi sheep. The results of the study concur with those reported on four breeds of Iranian sheep (Shirzeyli *et al.*, 2013). According to Moreki *et al.* (2016), various linear body measurements (such as the HGC and BL) can be used to predict the BW of different sheep breeds, and the results of this study concur with that. Some researchers have been advocating for HGC to be the sole predictor of BW (Dea *et al.*, 2023). Therefore, in rural areas where there are no weighing scales, the linear body measurements, especially the HGC, can be used in selection for breeding purposes. However, contrary to that, moderate correlations (0.57) were observed between HGC and BW in East Gojam female sheep (Michael *et al.*, 2016). Additionally, the HGC of the Bapedi sheep was positively correlated to the age, BCS, BL, BD, BH, BW, RW, HLW, TL, Teat L and TC.

As mentioned above, HGC and BL, along with various linear body measurements, can be used to predict the BW of different sheep breeds (Michael *et al.*, 2016). However, in the current study, the correlation between BL and BW was moderate. The BD of the Bapedi sheep showed a significant ($p<0.05$) high correlation with BW and HGC. This suggests that BD, along with HGC, can be used to predict BW in Bapedi sheep.

The testis circumference of the Bapedi ram (29.2±0.7 cm) was relatively lower than that recorded by Maqhashu *et al.* (2024) on ex-situ (39.2±0.5 cm) and in-situ (38.2±0.7 cm) conserved Bapedi rams in winter. Zulu sheep had larger testis circumference in autumn as compared to winter. However, the current study found the opposite in Bapedi sheep (Ngcobo *et al.*, 2023). Additionally, the testis circumference recorded in the current study was lower than that of Zulu rams recorded by Ngcobo *et al.*, 2023 in all seasons. According to Martin *et al.* (2024), animals grazing on natural pastures with fluctuating quality can either have a decrease or an increase in the testicular circumference. Therefore, in pastures, the lower testicular circumference recorded in this study might have been caused by the loss of fat from the scrotal tissues when the quality of the grazing deteriorates (César Mugabe *et al.*, 2023). TC of the Bapedi rams was positively correlated to age, BL, BD, BH, BW, HGC, RW, HLW, and HLL. According to Letsoalo (2017), as the rams grow, so does the testicular size. Both the Bapedi rams and ewes had lower significant ($p<0.05$) correlations on HLLBH, HLLBK, and TL, which shows that they have less effect on the growth status of the Bapedi sheep (Aikins-Wilson *et al.*, 2021). The tail length recorded in the current study was lower than those reported on Tswana sheep aged 3 years in Southern Botswana (Moreki *et al.*, 2016). Shorter tails are essential for the improvement of animal welfare and disease prevention (Johnson *et al.*, 2023).

Conclusion

Bapedi sheep are characterized as multi-colored with white bodies and brown heads being more dominant. Bapedi sheep have no beards or toggles. The body weight of Bapedi sheep was positively correlated to age, heart girth circumference, rump width, body condition score, length, depth, and height. The results from this study can be used for effective conservation, improvement, and selection programs.

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Author's Contributions

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Ethics

This is the original work and contains unpublished material. All the authors have read and agreed to the published version of the manuscript.

References

Aikins-Wilson, S., Bohlouli, M., & König, S. (2021). Maternal and Direct Genetic Parameters for Tail Length, Tail Lesions, and Growth Traits in Pigs. *Journal of Animal Science*, *99*(1), skaa398. https://doi.org/10.1093/jas/skaa398

Akpa, G. N., Ambali, A. L., & Suleiman, I. O. (2013). Body Conformation, Testicular and Semen Characteristics as Influenced yy Age, Hair Type and Body Condition of Red Sokoto Goat. *New York Science Journal*, *6*(7), 44-58.

Akpa, G. N., Suleiman, I. O., & Alphonsus, C. (2012). Relationships Between Body and Scrotal Measurements, and Semen Characteristics in Yankasa Ram. *Continental Journal of Animal and Veterinary Research*, *4*(1), 7-10. https://doi.org/10.5707/cjavres.2012.4.1.7.10

Almeida, A. M. (2011). The Damara in the Context of Southern Africa Fat-Tailed Sheep Breeds. *Tropical Animal Health and Production*, *43*(7), 1427-1441. https://doi.org/10.1007/s11250-011-9868-3

Aminisarteshnizi, M. (2023). Molecular Characterization of Burkholderia Using 16s Rdna Isolated from Cabbage, Limpopo Province, South Africa. *Research on Crops*, *24*(2), 316-318. https://doi.org/10.31830/2348-7542.2023.roc-952

César Mugabe, L., Pereira Lents, M., Emydio Gomes Pinheiro, E., & Alexandre Muchanga, R. (2023). Alternative Animal Feeding for Intensive Livestock Farming Systems and Their Impact on Reproductive Performance of Ruminants. *Intensive Animal Farming - A Cost-Effective Tactic*. https://doi.org/10.5772/intechopen.106061

Chokoe, T. C., Matelele, T. C., Maqhashu, A., Ramukhithi, F. V., Mphahlele, T. D., Mpofu, T. J., Nephawe, K. A., & Mtileni, B. (2020). Phenotypic Diversity of South African Indigenous Goat Population in Selected Rural Areas. *American Journal of Animal and Veterinary Sciences*, *15*(1), 59-66. https://doi.org/10.3844/ajavsp.2020.59.66

Chun, J. L., Bang, H. T., Ji, S. Y., Jeong, J. Y., Kim, M., Kim, B., Lee, S. D., Lee, Y. K., Reddy, K. E., & Kim, K. H. (2019). A Simple Method to Evaluate Body Condition Score to Maintain the Optimal Body Weight in Dogs. *Journal of Animal Science and Technology*, *61*(6), 366-370. https://doi.org/10.5187/jast.2019.61.6.366

Cloete, S. (2016). Selection as a Strategy for Improving Resistance to Parasites in Sheep: Production. *Red Meat/Rooivleis*, *7*(4), 76-79.

Dauda, A., Okon, B., Ibom, L. A., & Abbaya, H. Y. (2018). Phenotypic Characterization of Balami Breed of Sheep in Maiduguri, North-Eastern Nigeria. *Nigerian Journal of Animal Science*, *20*(2), 26-32.

Dea, D., Eramo, E., & Gemiyo, D. (2023). Phenotypic Characterization of the Gamo Highland Sheep Population in Gamo Zone, South Ethiopia. *Journal of Agriculture and Environmental Sciences*, *8*(1), 73-84. https://doi.org/10.4314/jaes.v8i1.5

Fisher, A. D., & Roadknight, N. (2024). Welfare of Sheep. *Sheep Veterinary Practice*, 19-38. https://doi.org/10.1201/9781003344346-2

Galina, C. S., & Geffroy, M. (2023). Dual-Purpose Cattle Raised in Tropical Conditions: What Are Their Shortcomings in Sound Productive and Reproductive Function? *Animals*, *13*(13), 2224. https://doi.org/10.3390/ani13132224

Hailemariam, F., Gebremicheal, D., & Hadgu, H. (2018). Phenotypic Characterization of Sheep Breeds in Gamogofa Zone. *Agriculture and Food Security*, *7*(1), 27. https://doi.org/10.1186/s40066-018-0180-6

Harbur, M. L., Moore, K., Mowers, R., Merrick, L., & Mahama, A. A. (2023). Randomized Complete Block Design. *Quantitative Methods*.

Johnson, P. L., Scobie, D. R., Dodds, K. G., Powdrell, S.-J. H., Rowe, S. J., & McRae, K. M. (2023). Genetic Parameter Analysis of Bareness and Tail Traits in New Zealand Sheep. *Journal of Animal Science*, *101*, skad161. https://doi.org/10.1093/jas/skad161

Khaldari, M., Azarfar, A., & Pahlavan, R. (2020). The Size of Fat Tail Does not Have an Effect on Growth Performance and Carcass Characteristics in Lori-Bakhtiari Lambs. *Small Ruminant Research*, *187*, 106088. https://doi.org/10.1016/j.smallrumres.2020.106088

Kumar, A., Rana, T., Bhatt, S., & Kumar, A. (2024). Insecta Infestations in Dogs and Cats. *Principles and Practices of Canine and Feline Clinical Parasitic Diseases*, 61-72.

Kunene, N., Nesamvuni, E. A., & Fossey, A. (2007). Charaterisation of Zulu (Nguni) Sheep Using Linear Body Measurements and Some Environmental Factors Affecting These Measurements. *South African Journal of Animal Science*, *37*(1), 11-20. https://doi.org/10.4314/sajas.v37i1.4020

Leroy, G., Besbes, B., Boettcher, P., Hoffmann, I., Capitan, A., & Baumung, R. (2016). Rare Phenotypes in Domestic Animals: Unique Resources for Multiple Applications. *Animal Genetics*, *47*(2), 141-153. https://doi.org/10.1111/age.12393

Letsoalo, P. T. (2017). *Characterisation and Cryopreservation of Semen from Indigenous Namaqua Afrikaner Sheep Breed, in Comparison with Dorper and Dohne Merino Breeds*.

Mafolo, K. S., Pilane, C. M., Chitura, T., & Nedambale, T. L. (2020). Use of Phosphatidylcholine in Tris-Based Extender with or without Egg Yolk to Freeze Bapedi Ram Semen. *South African Journal of Animal Science*, *50*(3), 389-396. https://doi.org/10.4314/sajas.v50i3.5

Maqhashu, A., O'Neill, H. A., Ngcobo, J. N., Nephawe, K. A., Ramukhithi, F. V., Sebei, J. P., Mapholi, N. O., Bovula, N., Mphaphathi, M. L., & Nedambale, T. L. (2024). Relationship Between Body Morphometry in Bapedi Rams and Sperm Characteristics Measured Using Computer-Aided Sperm Analysis. *South African Journal of Animal Science*, *54*(1), 1-10. https://doi.org/10.4314/sajas.v54i1.01

Martin, G. B., Fordyce, G., McGowan, M. R., & Juengel, J. L. (2024). Perspectives for Reproduction and Production in Grazing Sheep and Cattle in Australasia: The Next 20 Years. *Theriogenology*, *230*, 174-182. https://doi.org/10.1016/j.theriogenology.2024.09.017

Michael, A., Kefelegn, K., & Yoseph, M. (2016). Phenotypic Characterization of Indigenous Sheep Types in Northern Ethiopia. *Journal of Natural Sciences Research*, *6*(15), 16-27.

Moreki, J. C., Nelson, K., & Boitumelo, W. (2016). Assessment of Management Practices of Tswana Chickens at North East District of Botswana. *Journal of Animal Science and Veterinary Medicine*, *1*(2), 29-38. https://doi.org/10.31248/jasvm2016.008

Mzimela, Z., Sibanda, M., Nomlala, B., & Ndlela, H. (2022). Evidence from South African Construction and Industrial Transportation Businesses on Asset Revaluation. *Eurasian Journal of Business and Management*, *10*(4), 239-251. https://doi.org/10.15604/ejbm.2022.10.04.004

Ngcobo, J. N., Nedambale, T. L., Mpofu, T. J., Nephawe, K. A., Chokoe, T. C., & Ramukhithi, F. V. (2023). Seasonal Variations in Semen Quality, Testosterone Levels, and Scrotal Size Following Dietary Flaxseed Oil and Ascorbic Acid in South African Indigenous Rams. *Animals*, *13*(7), 1213. https://doi.org/10.3390/ani13071213

Nyamushamba, G. B., Mapiye, C., Tada, O., Halimani, T. E., & Muchenje, V. (2016). Conservation of Indigenous Cattle Genetic Resources in Southern Africa's Smallholder Areas: Turning Threats into Opportunities - A Review. In *Asian-Australasian Journal of Animal Sciences* (Vol. 30, Issue 5, pp. 603-621). https://doi.org/10.5713/ajas.16.0024

Ramukhithi, F. V. (2016). *Prediction of Male Fertility in South African Indigenous Goats Using Semen and Phenotypic Parameters [Thesis*.

Ramukhithi, F. V., Lehloenya, K. C., Kotze, A., Nephawe, K. A., Chokoe, T. C., Seshoka, M. M., Jonker, T., & Nedambale, T. L. (2019). Phenotypic Characterisation of South African Unimproved Indigenous and Tankwa Goats. *American Journal of Animal and Veterinary Sciences*, *14*(4), 207-220. https://doi.org/10.3844/ajavsp.2019.207.220

SAS (2019). User guide: Statistical release 9.4. *Statistical Analysis System Institute*. https://documentation.sas.com/doc/en/shrref/9.4/titlepage.htm

Shirzeyli, F. H., Lavvaf, A., & Asadi, A. (2013). Estimation of Body Weight from Body Measurements in Four Breeds of Iranian Sheep. *Songklanakarin Journal of Science and Technology*, *35*(5), 507-511.

Soma, P., Kotze, A., Grobler, J. P., & van Wyk, J. B. (2012). South African Sheep Breeds: Population Genetic Structure and Conservation Implications. In *Small Ruminant Research* (Vol. 103, Issues 2-3, pp. 112-119). https://doi.org/10.1016/j.smallrumres.2011.09.041

Tamminen, S. (2015). Changing Values of Farm Animal Genomic Resources. From Historical Breeds to the Nagoya Protocol. *Frontiers in Genetics*, *6*, 279. https://doi.org/10.3389/fgene.2015.00279

Zonabend König, E., Mirkena, T., Strandberg, E., Audho, J., Ojango, J., Malmfors, B., Okeyo, A. M., & Philipsson, J. (2016). Participatory Definition of Breeding Objectives for Sheep Breeds Under Pastoral Systems-The Case of Red Maasai and Dorper Sheep in Kenya. *Tropical Animal Health and Production*, *48*(1), 9-20. https://doi.org/10.1007/s11250-015-0911-7

Zonabend König, E., Ojango, J. M. K., Audho, J., Mirkena, T., Strandberg, E., Okeyo, A. M., & Philipsson, J. (2017). Live Weight, Conformation, Carcass Traits and Economic Values of Ram Lambs of Red Maasai and Dorper Sheep and Their Crosses. *Tropical Animal Health and Production*, *49*(1), 121-129. https://doi.org/10.1007/s11250-016-1168-5