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Assessment of sperm quality of communal goats in the hard-veld region of Botswana

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Abstract

The objective of this study was to assess semen characteristics of bucks kept under communal management systems in the hard-veld, southern part of Botswana. In early autumn, semen was collected from 22 bucks ranging from ≤ 2 to ≥5 years old across 20 randomly-selected communal farms using an electro-ejaculator. The buck type, age, live weight, and scrotal circumference were recorded prior to semen collection. Semen characteristics assessed were semen colour, ejaculated volume, sperm cell concentration, sperm motility, as well as morphology. The data were examined using analysis of variance with a general linear model in SAS. The common buck breed kept by communal farmers was a non-descript (mixed) breed (86%) and the Boer goat (14%) was in minority. The most predominant semen colour was creamy. The breed did not influence live weight, scrotal circumference, and semen characteristics. The younger bucks (≤2 years) had substantially lower live weight, scrotal circumference, and ejaculated semen volume than the older bucks. Semen characteristics did not differ substantially across the ages except for the sperm concentration, which was lower in bucks ≤2 years compared to ≥5 years. Live weight was strongly correlated (r = 0.81) to scrotal circumference and moderately correlated (r = 0.60) to the ejaculated semen volume. The study provides an insight into semen quality and prediction of fertility for bucks kept under a communal management system.

Keywords: bucks; computer-assisted semen analysis; scrotal circumference; communal goats
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Introduction

Goat rearing plays a major role in food and economic security of under-resourced smallholder farmers in Botswana. Goats are relevant in subsistence farming because of their ability to adapt and tolerate difficult environmental conditions (Braker *et al*., 2002). They play an important socio-cultural role, such as in weddings and funerals, sacrifices and rituals, and as insurance against crop failures (Monau *et al*., 2020). The goat population in Botswana has been fluctuating in the past years from 2008 to 2019 (Statistics Botswana, 2019). The populations declined from 1.8 to 1.5 million in the years 2008 to 2013. The population then increased to 1.6 million in 2014 and declined steeply to 1.2 million in 2017 and 2019 (Statistics Botswana, 2019). These trends cause concern as it affects the effort of improving food security and livelihoods.

The majority of goats in Botswana (about 95%) are kept in communal management systems where there are several factors often attributed to low productivity, among which are inadequate

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quality feed resources, high prevalence of diseases, and poor reproductive efficiency (Monau *et al*., 2017). Reproductive efficiency is the major factor in livestock productivity as it determines the efficiency of breeding stock and, ultimately, the sustainability of goat production. Male fertility plays a critical role in reproductive efficiency and production due to high selection intensity and the ability to share genetic material to a larger population (Yoon *et al*., 2022). Over the years, semen quality and quantity evaluation, physical soundness, sex-drive, and mating ability had been used as indicators for fertility, breeding soundness, and reproduction success in livestock production (Binsila *et al*., 2018). Semen evaluation of communal bucks is imperative, not only in the successful establishment of pregnancy and increasing the productive longevity of bucks, but also in facilitating innovative breeding strategies and genetic improvement (Diskin, 2018). This will contribute to the preservation of genetic material and greatly to the fertility and economics of individual herds and provide insight on factors that affect goat fertility.

Semen quality varies depending on animal characteristics, countries, and sometimes even farms, as well as with methods of collection and processing. Sperm evaluation methods that include conventional microscopic, computer-assisted semen analysis (CASA) and flow cytometric analysis provide precise information related to sperm morphology and function (Tanga *et al*., 2021). CASA is believed to be an efficient method for assessing the quality of fresh semen and can measure multiple dimensions of sperm fertility precisely and accurately (Yata *et al*., 2020; Waberski *et al*., 2021). There are limited studies that have been performed regarding semen evaluation of goats based on CASA methodology in Botswana. It is imperative to understand semen functionality and fertility potential of communal bucks and craft sustainable breeding programs that will eventually contribute to reproductive success and food sufficiency and security. Therefore, the purpose of this study was to assess semen quality of bucks kept under communal management systems in the hard-veld areas of southern Botswana.

Materials and methods

All procedures were performed in accordance with the Animal Ethics Committees of Botswana University of Agriculture and Natural Resources (reference number BUAN-AEC-2024-02). Furthermore, a veterinary doctor performed data collection to ensure animal welfare. The data were collected once during the natural breeding season in autumn of April 2022, in the morning, over a period of five hours. The farmers signed a consent form before commencement of data collection.

The bucks were in Pelotshetlha village in the southern part of Botswana, approximately 90 km from the Animal Genetic Resources laboratory of the Department of Agricultural Research, Sebele. The area is characterized by hardveld vegetation, which is dominated by Acacia species, such as *Acacia erioloba*, *A. tortilis*, *A. karoo*, *A. mellifera*, *A. robusta,* and shrubs like *Grewia flava* and *Euclea undulata*. It is also a grassland vegetation-based area with dominating species including *Aristidia congesta and Congesta barbicollis*. Other dominant plants include different aloe species. The area receives a minimum precipitation of 2.5 mm and maximum of 115.5 mm annually with average temperatures of 4–11 °C in winter and 15–39 °C in summer. The humidity ranges from 14–39% and the soils range from loose clay to thick sandy soils, known as chromic luvisols (De Wit & Bekker, 1990; Madibela *et al*., 2000).

A total of 20 farms were randomly selected in Pelotshetlha and bucks of various breeds and ages were randomly selected across the farms. The ages of bucks were identified through dentition as stated by Pace and Wakeman (2003): no pairs of permanent incisors and one pair of permanent incisors (1–2 y), two pairs of permanent incisors (2.5–3 y), three pairs of incisors (3.5–4 y), and four pairs of incisors (4.5 to >5 y). The breed was identified based on the farmer's information, phenotypes, and any available records. The farmers in this area practice similar management with very little husbandry regimens. The animals were released for grazing in the morning, kraaled late in the afternoon, and had access to borehole water.

Prior to semen collection, the scrotal circumference was measured with a scrotal tape in centimetres and live weight was estimated in kilograms using weight estimating belt or girth tape. Regarding semen collection, the bucks were restrained in standing position, and the testicles and scrotum were palpated to check for any abnormalities. The semen was collected in the morning before grazing using an electro-ejaculator (Lane Pulsator IV—Auto Adjust™) and a graduated collection tube. The rectal probe was lubricated with liquid paraffin and inserted through the rectum and semen was produced by means of periprostatic electro-stimulation. Electrical stimulation (5–15 V,

500 mA) was applied at intervals of two to three seconds and alternated with rest periods of two seconds. Stimulation kept on with gradual increase of the current until semen was produced. The preputial hair was clipped with a pair of scissors and the preputial ring was cleaned with gauze swab to reduce as much contamination as possible. The collection cone was warmed to 37 °C and placed directly in front of the prepuce and maintained throughout stimulation. The first few ejaculate drops were discarded as it contained some tints of urine normally found in the urethra. The volume of ejaculate and semen colour were recorded immediately after collection. The semen volume was ascertained directly from the graduated transparent tube used for semen collection. The semen colour was categorised as creamy, opaque, yellowish, or watery. The ejaculates were subjected to skimmed milk extender at a ratio of 1:8 (semen extender) per volume. The semen extender was also kept at 37 °C. The diluted semen samples were packed in sterile, capped test tubes and placed in an insulated box with ice and transported to the laboratory by road for further analysis.

The computer assisted semen analysis (CASA, Androvision) system was used to assess sperm concentration, motility, and morphology. The semen was warmed to a temperature of 37 °C, and a drop of diluted semen was placed on a pre-warmed, labelled slide and examined under the computer assisted microscope with a cover slip at 20× zoom. For each sample, sperm motility analysis was performed on at least 200 sperm from four new fields of each slide. The following CASA motion characteristics were recorded: total motility, progressive motility, local motility, immotile, total progressive motility, progressive fast motility, and progressive slow motility. Total motility was defined as the percentage of spermatozoa that displayed any type of movement in the entire ejaculate and was calculated by dividing the number of motile sperm by the total number counted, multiplied by 100% (Mortimer & Mortimer, 2013). Progressive motility was defined as the number of sperm moving forward and was determined by calculating the number of spermatozoa with forward movement in relation to those with other than forward movement. Immotile sperm were interpreted as the total of dead sperm relative to live ones. Local motility was interpreted as motility of sperm in a stationery position. In addition to evaluation of sperm motility, the CASA calculated the kinetic values of each spermatozoan, which covered the velocity of movement, the width of the sperm head's trajectory, and frequency of the change in direction of the sperm head, as described by Taylor *et al*. (2008).

Regarding morphology parameters, a semen smear was placed on one end of a pre-warmed glass slide and a thin film smear was prepared using a spreader slide at a 30° angle to disperse the semen suspension over the slide's length and was fixed by air drying. The smear was stained in three Farley stain dyes. The slides were first flooded with formalin solution for 10 s, then flooded with Aniline-Blue solution for 20 s, and lastly with Crystal-Violet solution for 5 s. The stained slides were air dried for 12 h and evaluated using a computer assisted microscope at a magnification of 100× under oil immersion. Morphology parameters were assessed by selecting 100 to 200 sperm on the slide and subjecting them to morphometric analysis in CASA. Morphological abnormalities were categorized according to the affected part of the sperm cell, i.e., head, mid-piece, or tail. A report was created from this analysis.

The data were analysed using analysis of variance (ANOVA) with a general linear model (GLM) using SAS (version 9.0). Age and breed were fixed effects and the differences were considered significant at P <0.05. The dependent variables were live weight, scrotal circumference, and semen characteristics. Correlations between live weight, scrotal circumference, and semen characteristics were computed using Pearson's correlation coefficient (r) in SAS (version 9.0). The following model was used for data analysis:

$$Yijk= \mu+Xi+Zj+ (X \times Z)ij +Eijk \quad (1)$$

where Yij is the observation on the dependent variables, μ is the overall mean, Xi is the fixed effect of breed, Zj is the fixed effect of age, (X × Z)ij is the interaction effect of breed and age, and Eijk is the random error. The data was, however, imbalanced as some breeds and age had low replications.

Results

A total of 22 semen ejaculates of bucks kept under traditional management systems were analysed. The observed breeds of bucks were categorized into two groups i.e. mixed or nondescript genotypes (n = 19) and Boer goats (n = 3). There was no difference (P >0.05) between the breeds in

live weight, scrotal circumference, and ejaculated volume (Table 1). The ages of bucks were grouped as ≤2, 3,4, and ≥5 years. Age influenced live weight, scrotal circumference, and ejaculated volume. The older bucks had higher body weight and larger scrotal circumference compared to the younger bucks (P <0.05). The ejaculated volume increased with age (P <0.05; Table 1). There was no difference (P >0.05) in the interaction of the two factors, i.e., age and breed. The predominant semen colour was creamy and the minor colours were opaque, yellowish, or watery.

Table 1 Means (± SE) of live weight, scrotal circumference, and volume per ejaculate of different breeds and ages of bucks kept in the hard-veld area of Botswana

Factor		N	Live weight (kg)	Scrotal Circumference (cm)	Ejaculated Volume (ml)
Breed					
	Mixed	19	56.16 ± 1.70	25.75 ± 0.35	1.66 ± 0.14
	Boer	3	60.00 ± 4.40	26.57 ± 0.93	2.35 ± 0.36
	P-Value		0.43	0.99	0.09
Age (y)					
	≤2	4	41.75 ± 3.61^{a}	23.58 ± 0.76^{a}	1.10 ± 0.29^{a}
	3	6	52.50 ± 3.11^{b}	24.31 ± 0.66^{a}	1.66 ± 0.25^{ab}
	4	7	65.75 ± 3.88^{c}	28.49 ± 0.82^{b}	2.28 ± 0.34^{b}
	≥5	5	66.40 ± 3.21^{c}	26.98 ± 0.68^{b}	2.40 ± 0.26^{b}

^{abc} superscripts across the columns are significantly different (P <0.05); SE, standard error

Table 2 shows the sperm concentrations and motility parameters of bucks at different ages. Most of the sperm motility parameters did not differ (P >0.05) between breeds, except in progressive slow motility, where Boer goat bucks had higher values (P <0.05). Sperm cell concentration differed substantially across ages. Younger bucks (≤ 2 y) had lower (P <0.05) sperm cell concentrations than older bucks of ≥5 y (Table 2). The semen motility parameters, such as progressive motility (fast and slow), total motility, immotile, and local motility were not affected (P >0.05) by age of bucks (Table 2). An interaction (P <0.05) between age and breed was observed in progressive slow motility at 4 y of age.

Table 2 Sperm concentration and motility characteristics of bucks kept in communal areas (mean ± SE)

Factor	n	SPC (x10^{9} sperm/ml)	Progressive Fast Motility	Progressive slow Motility	Immotile	Local Motility	Total Progressive Motility	Total Motility
Breed								
Mixed	19	1.11 ± 0.12	17.91 ± 4.56	31.83 ± 4.28^{a}	49.27 ± 5.68	49.27 ± 5.68	48.19 ± 5.89	50.73 ± 5.82
Boer	3	1.68 ± 0.30	17.28 ± 11.67	62.00 ± 10.96^{b}	19.75 ± 14.54	19.75 ± 14.54	79.32 ± 15.01	80.25 ± 14.53
P-value		0.10	0.96	0.02	0.08	0.51	0.07	0.08
Age (y)								
≤2	4	0.89 ± 0.25^{a}	21.38 ± 9.52	27.30 ± 8.95	49.89 ± 11.87	1.45 ± 0.70	48.68 ± 12.29	50.15 ± 11.87
3	6	1.13 ± 0.20^{ab}	21.67 ± 7.77	46.10 ± 7.30	31.47 ± 9.69	0.98 ± 0.57	67.39 ± 10.04	68.50 ± 11.87
4	7	1.28 ± 0.27^{ab}	20.70 ± 10.28	46.32 ± 9.66	32.51 ± 12.82	1.10 ± 0.75	66.38 ± 13.24	67.49 ± 12.82
≥5	5	1.61 ± 0.23^{b}	10.90 ± 8.69	46.63 ± 8.17	45.12 ± 10.84	1.18 ± 0.64	51.29 ± 11.22	54.88 ± 10.84

SE, standard error; SPC, sperm concentration; ^{abc} superscripts across the columns are significantly different (P <0.05)

Table 3 shows the kinetic parameters for Boer goats (n = 2) and mixed breed goats (n = 3). The numbers for age groups were too small and not statistically sound, hence not reported. The results showed that there was no difference (P <0.05) between the breeds based on the kinetic parameters (Table 3).

Table 3 Kinetic parameters (mean ± standard error) of Boer goat and mixed breed bucks kept under communal management systems

Parameter	Boer (n = 2)	Mixed (n = 3)	P-value (*P* <0.05)
Velocity curved line (µm/s)	60.58 ± 7.77	115,24 ± 13.71	0.48
Velocity straight line (µm/s)	14.62 ± 7.70	68,87 ± 2.52	0.12
Velocity average path (µm/s)	23.37 ± 8.45	64,64 ± 6.83	0.19
Linearity (%)	24.01 ± 0.03	38.30 ± 0.02	0.17
Straightness (%)	63.20 ± 0.03	79.00 ± 0.02	0.13
Radius (%)	1.53 ± 0.19	3,74 ± 0.63	0.38
Amplitude of lateral head displacement (µm)	0.73 ± 0.12	1,21 ± 0.05	0.71
Rotational motion (%)	0.08 ± 0.03	0,27 ± 0.04	0.21
Beat cross frequency (Hz)	10.22 ± 3.31	16,8 ± 1.68	0.36
Wobble (%)	39.04 ± 0.02	48.30 ± 0.02	0.22

Figure 1 shows the morphological characteristics, i.e., intact sperm, abnormal heads, and abnormal midpiece of ejaculated semen of bucks kept in communal areas. A total of 14 bucks were analysed for morphological parameters (Boer goats = 3; mixed breed = 11). Generally, the variations on intact sperm, abnormal sperm heads, and abnormal sperm midpieces were not different (*P* >0.05) across the breeds and ages. However, the total number of sperm was affected by age. The bucks of 4 y had higher (*P* <0.05) numbers of total sperm than 5-year-old bucks. The interaction between age and breed was not significant (*P* >0.05) for morphological parameters.

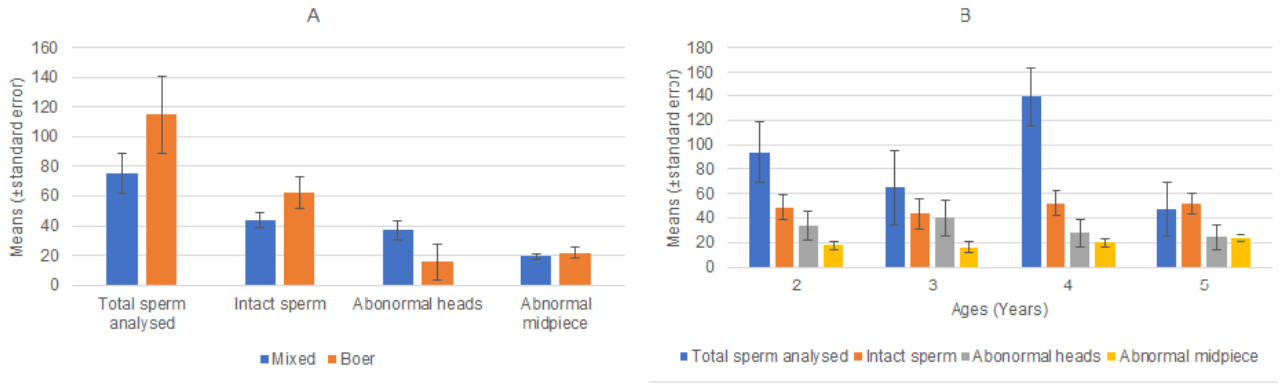

Figure 1 Means (± standard error) of morphological characteristics of sperms of mixed breed and Boer goats (A) at different ages (B)

The Pearson correlation coefficients of different traits of bucks in communal areas are presented in Table 5. Live weight was (*P* <0.01) highly correlated (r = 0.8) with scrotal circumference and moderately correlated (r = 0.60) with the ejaculated semen volume. The progressive fast motility was moderately correlated with total progressive motility and total motility of sperm. Immotile sperm was negatively correlated (*P* <0.01) with progressive fast motility (r = -0.61), progressive slow motility (r = -0.78), total progressive motility (r = -0.99), and total motility (r = - 0.99). The progressive slow motility was positively correlated (*P* <0.01) with total progressive motility (r = - 0.76), as well as total motility (r = 0.78). Total progressive motility was highly correlated with total motility (r = 0.99) (Table 5).

Table 5 Pearson correlation coefficients between traits in bucks kept under communal management systems

	LW (kg)	SC (cm)	Vol (ml)	SPC (×10^9/ml)	PFM	PSM	IM	TPM	TM
LW (kg)	1.00	0.81**	0.60**	0.29	-0.22	0.20	-0.03	-0.01	0.03
SC (cm)		1.00	0.35	0.14	-0.02	0.02	0.01	-0.03	-0.01
Vol (ml)			1.00	0.27	-0.13	0.35	-0.20	0.16	0.20
SPC (×10^6/ml)				1.00	-0.25	0.36	-0.12	0.07	0.12
PFM					1.00	-0.03	-0.61**	0.62**	0.61**
PSM						1.00	-0.78**	0.76**	0.78**
IM							1.00	-0.99**	-0.99**
TPM								1.00	0.99**
TM									1.00

**Correlation is significant at P <0.01

PFM = progressive fast motility; PSM = progressive slow motility; TPM = total progressive motility; TM = total motility; IM = immotile; SPC = sperm concentration; LW = live weight; SC = scrotal circumference; Vol = semen volume per ejaculate

Discussion

The similar live weights and scrotal circumferences across the breeds observed in this study can be attributed to the influence of exotic breeds, particularly the Boer goat, that have been selected for growth parameters and often used haphazardly for breed improvement by communal farmers. Similar findings of lack of breed effect on live weight and scrotal circumference have been reported by Gore *et al*. (2020) on goats kept extensively under tropical environments. This result, however, disagrees with Kridli *et al*. (2005) and Gemeda & Workalemahu (2017), who explained a breed factor on live weight and scrotal circumference in goats.

A similar phenomenon of a lack of a breed effect on semen volume and sperm concentration has been reported by several authors (Gore *et al*., 2020; Hafizuddin *et al*., 2021; Isnaini *et al*., 2021). The average semen volume observed in this study was relatively high compared to Toggernburg (1.00 ± 0.10 ml) and Saanen (0.97 ± 0.09 ml) goats raised in tropical conditions (Gore *et al*., 2020), but similar to the findings of Isnaini *et al*. (2021). The average sperm concentration observed in this study was slightly higher than the Anglo Nubian (0.87 billion/ml) and Etawah grade (0.94 billion/ml) goat breeds (Hafizuddin *et al*., 2021), but lower than the Toggernburg (2.87 billion/ml) and Saanen (1.67 billion/ml) goat breeds (Gore *et al*., 2020). There are several reasons that lead to such variation in results, such as nutrition, genotype, season, method used for semen collection, and heat stress.

Jiménez-Rabadán *et al*. (2016) stated that the electro-ejaculator tends to lead to increased accessory gland production, reduced sperm cell concentration, and high chances of urine in the semen sample leading to greater semen volume. In addition, during consultation with most farmers, it was realized that even if the bucks were allowed to feed on communal pastures, supplementation of minerals and vitamins such as zinc, copper, cobalt, manganese, as well as vitamin A, D3, and E, which are most essential for semen production after protein and energy (Rowe *et al*., 2014), were not provided. Mellado *et al*. (2006) studied the association between semen quality and rangeland diets on mixed-breed male goats and observed that higher proportions of *Acacia gregii* in diets yielded 23–50% less semen, reduced sperm motility by 3–8%, and lowered percentages of normal sperm morphology. This acacia species is the most dominant in the study area and could have an impact on semen production of the bucks and possibly have led to the semen abnormalities observed in this study. The other possible reason could be that goats are seasonal breeders, and their spermatogenesis circle is approximately 42 d (França *et al*., 1999). The synthesis of such sperm would have been initiated in January to February in the summer months. During this period, however, the temperatures were high, ranging from 37–40 °C and rains were minimal, which also affected the pasture (Department of Meteorological Services, 2022). The bucks were seen to be inactive and had reduced ability to successfully breed for a length of time, whilst even does did not show any signs of

oestrus. Heat stress increases testicular temperature leading to sperm abnormalities, decreased fertility, and productivity (Sabés-Alsina *et al*., 2019; Luceño *et al*., 2020).

The marked differences across age groups in live weight, scrotal circumference, semen volume, and sperm concentration were expected during growth and physiological development. The results indicate stage of development and performance of the accessory sex organs, as well as testosterone level. A linear connection between live weight, scrotal circumference, and age has been previously reported (Siddiqui *et al*., 2008). The age effect on body weight and scrotal circumference has been noted by several authors (Tabbaa *et al*., 2006; Siddiqui *et al*., 2008; Gore *et al*., 2020). The effect of age on semen volume and sperm concentration observed in the current study concurred with El-Saidy *et al*. (2007) in Egyptian bucks but was inconsistent with the findings of Harighi *et al*. (2022) in Boer goats and Gore *et al*. (2020) in Saanen and Toggernburg goats.

The lack of breed and age effects on sperm motility parameters has been previously noted by Kridli *et al*. (2005) and Tabbaa *et al*. (2006). The findings are, however, different from Gore *et al.* (2020), who reported an increase in motility with age. Various factors such as breed, heat stress, distance from point of semen collection to the laboratory, time, and temperature influence sperm motility (Hahn *et al.,* 2019). Heat stress can impair sperm motility within a few hours after heat exposure, decreasing progressive motility to 40% (Rizzoto & Kastelic, 2020). In the literature however, there are different paradigms on transportation distance of semen from point of collection to the laboratory for analysis. A semen quality assessment of buffalo bulls where semen was collected from farmer's doorstep indicated highly efficient semen sample preservation up to 150 km from the field (Singh *et al*., 2013). In contrary, Aurich *et al.* (2015) hypothesized that prolonged transportation distances of semen elevated the oxidative stress response by a hormone, cortisol, and this decreased testosterone concentrations and semen quality. In general, the progressive motility of goat spermatozoa should be ≥70% straightness with an average velocity of 25 µm/s for successful fertilization (Sundararaman & Edwin, 2008). The velocity parameters and large amplitude of lateral head displacement observed in the current study could be a good indicator for post-coital tests such as artificial insemination and sperm fertilizing ability (Robayo *et al*., 2008).

The sperm morphology observed in this study contained high abnormal sperm defects thus degrading its quality and possibly indicating challenges of low reproductive performance faced by communal farmers. According to Chandler *et al*. (1988) and Beltran *et al*. (2013), the percentage of semen abnormalities should preferably not exceed 10–14%. The observed abnormal sperm defects could be due to environmental factors such as low plane of nutrition and heat stress. Rahman *et al*. (2018) stated that the proportion, severity, and moment of appearance of abnormal sperm in the ejaculate depend on the intensity and duration of heat stress and the developmental stages of affected germ cells. Often, predominant abnormalities are found in the sperm heads (acrosome defects, pyriform-shaped heads, micro- and macro-cephalic heads) and tails (Rahman *et al*., 2011). An abnormal midpiece, although not common in this study, affects the structure of mitochondria, which are responsible for sperm energy. The sperm will have low energy generation ability and low motility, leading to low fertility (Kushawaha *et al*., 2021). Wang *et al*. (2015) studied the effect of season on spermatozoa morphology in fresh and frozen-thawed semen of Xinong Saanen bucks. The authors observed that good quality semen with very low incidences of sperm abnormalities were obtained in summer and autumn rather than in spring and winter.

The study further revealed positive associations between live weight, scrotal circumference, and semen volume. This relationship was expected because testes are body parts that respond to tissue growth, which is observed with an improvement in live weight (Kridli *et al*., 2005). This finding corroborates Gemeda & Workalemahu (2017) and Gore *et al*. (2020). Similar findings have also been reported in other species such as cattle. Latif *et al*. (2009) observed a positive correlation between scrotal circumference of crossbred bulls and semen volume, as well as sperm concentration. The associations between semen motility parameters were expected as they give indications of individual sperm motility.

Conclusions

The non-descript genotype, plane of nutrition, and heat stress might have an impact on semen quality of bucks in communal areas. The study has elucidated semen quality and prediction of

fertility for bucks kept under communal management systems. This is a useful reference for developing breeding programs and management strategies for goats in communal areas. The study had small sample sizes therefore, further studies should be conducted with larger samples sizes in other agro-ecological regions of Botswana with the inclusion of a vegetation effect, seasonal effect, and use of different methods of semen collection.

Declaration of Interest

None

Authors Contributions

KF conceptualized, conducted data collection and semen analysis, and wrote the first draft of the manuscript. PM assisted in the data analysis and edited the manuscript. UM assisted in the CASA analysis and manuscript editing. EW assisted in data collection and edited the manuscript.

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