

Determinants of Puberty and Age of Sexual Maturity in Nigerian Indigenous Breeds of Male Goats

*Bitrus Ishaku¹, Nnadi, Pius Ajanwachukwu², Makun Hussaina Joan³,
Abonyi Festus Otaka², Gilbert Taidinda Tashara⁵, Danladi Yohanna¹,
Korzerzer Rachel Mngusuur⁵ Chindo Abednego⁴.

¹Department of Animal Science,
Taraba State University,
Jalingo, Taraba state,
Nigeria.

²Department of Animal Health and Production,
University of Nigeria, Nsukka,
Enugu state,
Nigeria.

³National Animal Production Research Institute,
ABU, Shika Zaria,
Kaduna state,
Nigeria

⁴Department of Veterinary Pathology and Microbiology,
University of Nigeria,
Nsukka, Enugu state,
Nigeria.

⁵Department of Veterinary Anatomy,
University of Ibadan,
Ibadan,
Nigeria

⁶Department of Veterinary Anatomy,
Joseph Sarwuan Tarka University,
Makurdi,
Benue state
Nigeria

Email: ishakubitrus1980@gmail.com

Abstract

This study was conducted to ascertain the pubertal and sexual maturity characteristics of Nigerian native goat breeds. The research was carried out on three goat breeds; Sahel (SG), Red Sokoto (RSG), and West African Dwarf (WAD) goats. Each breed was represented by eight (8) animals (n=24) and housed in separate pens based on breed type. All bucks were weighed at birth and bi-weekly using digital weighing scales until they reached puberty. Scrotal circumference measurements were taken every two weeks until the end of the study. Semen was collected immediately after preputial separation and all

*Author for Correspondence

semen samples were labelled and placed in a thermo-flask immediately and subsequently transported to the laboratory for evaluation. The mass motility and the forward motilities of the spermatozoa were observed using a light microscope. The percentage of live, dead, and abnormal sperms were determined after staining with eosin and negrosin stains. The sperm cell concentration was determined by counting spermatozoa with a hemocytometer. Result obtained indicate that at the 14th and 16th weeks of age, the mean scrotal circumference of bucks ranged from 5.14±0.66 cm to 7.06±0.71 cm, 6.32±0.29 cm to 8.05±0.42 cm, and 5.50±0.74 cm to 7.06±0.71 cm in SG, RSG, and WAD bucks, respectively. Puberty in Red Sokoto bucks was achieved at an average age of 14 weeks, with a mean sperm concentration of (116.17±28.47 x 10⁶), progressive sperm motility of (65.00±9.92%), and a mean body weight of 10.17±1.26 kg. Sahelian and WAD bucks reached puberty at the 16th weeks, with sperm concentrations of 106.29±25.18 x 10⁶ and 107.60±19.99 x 10⁶, mean sperm motility of 65.00±9.94% and 76.00±4.8%, and mean body weights of 11.29±1.59 kg and 7.78±0.70 kg, respectively. To summarise, this study revealed that breed, age, scrotal circumference and body weight at puberty played significant roles in determining sperm characteristics and sexual maturity.

Keywords: Age, Indigenous breeds, Male goats, Maturity, Puberty.

INTRODUCTION

Goat production is a customary undertaking primarily practiced as a secondary activity in the rural environs of developing nations. The rearing of goats plays a pivotal function in the socioeconomic development of rural communities in West Africa (Gauthier *et al.*, 2001). In light of the growing socio-economic significance of goats and the mounting requirements for appropriate goat husbandry, which necessitates the use of optimal breeding bucks for lucrative production, a functional system that integrates body conformation and testicular traits evaluation, as well as semen characterization, is indispensable. Evaluation of a buck's ability to mate, physical capability to mount, intromission achievement, and ejaculation can be performed through field assessments (Tanga *et al.*, 2021). Furthermore, evaluation can be conducted on the quality of semen that the buck generates, which is directly associated with the physical attributes of its genitalia (Józków and Rossato, 2017).

Male fertility is a crucial factor in caprine reproduction since multiple does are generally bred to a single buck (Mocé *et al.*, 2022). Consequently, assessing male fertility before breeding is vital in achieving breeding success. The potential fertility of breeding males can be evaluated in the field through assessment of mating ability, physical examination, and a genital tract examination of both the external and internal genitalia, including a scrotal circumference measurement, and semen quality evaluation (Hoflack *et al.*, 2006).

Weaning weight, growth rate, age at complete separation of prepuce from the penis, scrotal circumference at puberty, weight and age at puberty, volume of ejaculate, and individual and mass motility percent of semen, abnormal morphology spermatozoa, and the concentration of spermatozoa are important puberty indicators in goats (Bezerra *et al.*, 2009). A male attains pubertal stage when it starts to display sexual behaviors, mate, and ejaculate semen containing enough viable sperm to impregnate a female (Jimeno *et al.*, 2001). The foundation for a sound comprehension of the male reproductive biology in any species lies in the detailed morpho-functional study of its reproductive organs (Segatelli *et al.*, 2004). Morphometric analysis of the testes of any species or breed is necessary in predicting not only sperm production but also the storage potential and fertilizing capability of the male. In particular, testicular size (either represented by testicular weight or volume) has been reported to be a good indicator of the current and future sperm production in different animal species (Togun and Egbunike, 2006). According to Mickelsen and Memon (2007), testicular size correlates not only with spermatozoa production but also with scrotal circumference. Although some

testicular measurements have been documented in some animal species (Willis, 2001), there is a dearth of information on testicular measurements and their application in the prediction of good sire goats (Bitto and Egbunike, 2006).

Henceforth, it is possible to collect semen and assess reproductive capacity to employ it for genetic enhancement (Bezerra *et al.*, 2009). In any approach towards genetic improvement of animal breeds, their reproductive performance is of utmost significance. In this context, the purpose of this research was to ascertain the pubertal and sexual maturity characteristics of three indigenous male goat breeds of Nigeria, comprising weaning weight, growth rate, scrotal circumference at puberty, weight and age at puberty, volume of ejaculate, mass motility, percentage of live semen, abnormal morphology of spermatozoa, and concentration of spermatozoa.

MATERIALS AND METHODS

Care and Housing of Experimental Male Goats

The study was carried out on male kids of Sahel (SG), Red Sokoto (RSG) and West African Dwarf (WAD) goat breeds at the Small Ruminant Research Farms of the National Animal Production Research Institute, Shika, Ahmadu Bello University (ABU), Zaria with geo-reference of 11° 12' 0" North, 7° 34' 0" East (Inichinbia and Sule, 2018). Each breed was represented by eight (8) animals (n=24) and housed in separate pens according to breed type. The kids were kept with their dams to feed on milk till the age of 6 weeks. They were then given a concentrate made at the farm at a rate of 200 gm per day. This ration was formulated with groundnut cake, maize, maize offal, bone meal, cotton seed cake, mineral mixture and sodium chloride. They were offered water and different species of *Brachiria* grasses *ad libitum*. The kids were weaned at the age of 12 weeks. They were vaccinated against *peste des petit ruminants* (PPR) with PPR vaccine obtained from the National Veterinary Research Institute (NVRI), Vom. They were treated against ectoparasites and endoparasites with Ivermectin (1 ml/50 kg intravenous). The animals were managed intensively on the farm.

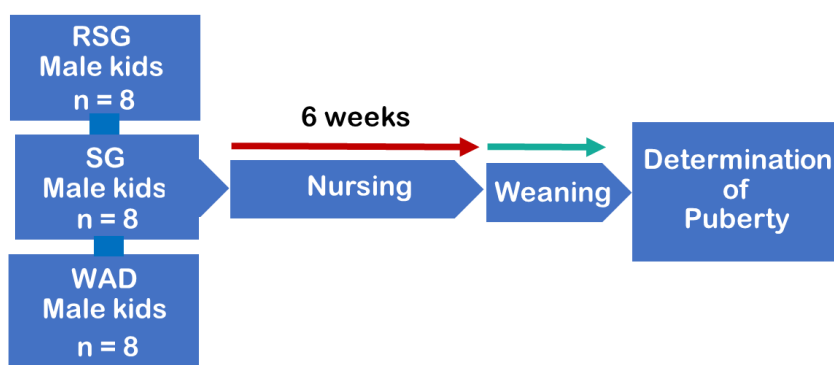


Figure 1: Experimental schedule

Measurement of live body weight and scrotal circumference

The male goat kids of the three breeds were weighed at birth and their body weights were recorded bi-weekly using digital weighing scale until they reached puberty. Measurement of scrotal circumference was also carried out every two weeks in the bucks till the end of the study. The scrotal circumference was measured with a flexible tape at the point of the greater circumference of the scrotum.

Semen collection and analysis

Trials of semen collection started immediately after preputial separation using electro-ejaculator. The procedure was carried out as described by Matshaba (2010), which involved the insertion of 3-5 volts rectal probe through the rectum of the bucks. This caused electric stimulation of the bulbourethral gland for the release of semen. Following semen collection, the semen volume was recorded using 15 mL graduated falcon tubes. All the semen samples were labelled and then placed in the thermo-flask at 37 °C immediately after collection and transported to the laboratory for evaluation within one hour after collection. The mass motility and the forward motilities of the semen were taken and recorded using light microscope. Sperm morphological abnormalities (sperm with coiled midpiece, looped tail, double headed or tail) was determined as described by Mitshaba (2010). The percentage of live, dead and abnormal sperms were determined after staining with eosin and negrosin stains. The sperm cell concentration was determined by counting sperms with a hemocytometer as demonstrated by Leboeuf *et al.* (2000).

Statistical Analysis

The data were statistically analyzed and the variables concerning body weight, scrotal circumference and seminal parameters (Mean \pm SE) were subjected to ANOVA. Correlation among body weight, scrotal circumference and semen parameters was also determined ($P < 0.05$).

RESULTS

Table 1: Weekly mean variations in semen of experimental goats

Breed	Weeks	BW	SC	VOL	COL	MOT	PH	CONC	MORPH
SG		10.07±1.53	5.14±0.66	0.30±0.08	1.86±0.34	37.86±14.96	5.86±0.98	68.57±29.15	12.29±5.38
RSG	14	10.17±1.26	6.32±0.29	0.22±0.06	2.17±0.17	65.00±9.92	6.83±0.11	116.17±28.47	19.17±6.32
WAD		7.4±0.71	5.50±0.74	0.06±0.02	2.20±0.20	59.00±12.88	6.60±0.19	68.40±20.76	9.00±2.95
SG		11.29±1.59	6.3±0.74	0.39±0.09	2.29±0.18	65.00±9.94	6.71±0.15	106.29±25.18	15.43±4.72
RSG	16	10.63±1.24	6.63±0.31	0.133±0.02	2.33±0.21	67.50±14.30	6.75±0.17	127.50±33.40	13.33±2.77
WAD		7.78±0.70	5.92±0.33	0.10±0.00	1.80±0.20	76.00±4.8	6.90±0.10	107.60±19.99	17.00±1.64
SG		12.44±1.59	6.90±0.66	0.49±0.06	2.14±0.14	75.71±4.14	6.71±0.15	123.14±17.36	11.57±1.66
RSG	18	11.17±1.26	7.40±0.39	0.15±0.02	2.17±0.31	82.50±2.81	7.00±0.00	158.00±23.88	12.50±1.65
WAD		8.10±0.68	6.84±0.64	0.18±0.06	2.00±0.00	83.00±3.74	7.00±0.00	124.60±20.47	10.40±1.33
SG		13.31±1.55	7.91±0.67	0.56±0.06	2.00±0.00	80.00±2.18	7.00±0.00	167.57±11.50	10.86±1.20
RSG	20	11.78±1.22	8.05±0.42	0.35±0.03	1.83±0.17	87.00±1.83	7.00±0.00	168.33±20.54	10.00±2.06
WAD		8.70±0.72	7.06±0.71	0.20±0.03	1.80±0.20	84.00±2.92	7.00±0.00	152.00±20.57	10.60±1.50
SG		14.19±1.47	8.61±0.70	0.60±0.04	2.00±0.00	82.43±2.11	7.00±0.00	175.14±15.81	14.43±5.13
RSG	22	12.33±1.17	8.28±0.48	0.48±0.04	1.83±0.17	86.67±2.79	7.00±0.00	202.33±22.36	10.67±1.31
WAD		9.10±0.68	7.40±0.67	0.22±0.02	1.60±0.25	87.00±1.23	7.00±0.00	163.20±16.38	9.20±1.02
SG		14.76±1.32	8.89±0.68	0.66±0.04	1.71±0.18	87.14±1.84	7.00±0.00	202.29±13.51	9.43±0.69
RSG	24	13.22±1.14	8.63±0.47	0.60±0.07	1.50±0.22	88.33±2.11	7.00±0.00	215.67±21.123	10.50±0.62
WAD		9.68±0.71	7.82±0.76	0.32±0.05	1.40±0.25	92.00±1.23	7.00±0.00	177.00±12.19	9.40±0.68
SG		15.21±1.33	9.59±0.67	0.86±0.17	1.71±0.18	85.00±1.54	7.00±0.00	218.57±16.68	9.71±0.57
RSG	26	13.75±1.09	9.17±0.78	0.58±0.05	1.17±0.17	90.00±2.58	7.00±0.00	259.00±13.55	8.0 ±1.29
WAD		10.40±0.61	8.10±0.75	0.42±0.02	1.20±0.20	93.00±1.23	7.00±0.00	193.60±11.39	9.40±0.75
SG		15.69±1.30	10.04±0.64	0.76±0.06	1.43±0.20	89.57±2.06	6.92±0.07	225.71±20.34	12.71±3.08
RSG	28	13.92±1.13	9.72±0.61	0.57±0.04	1.83±0.17	87.50±2.50	7.00±0.00	230.67±19.46	13.83±1.28
WAD		11.10±0.67	8.44±0.75	0.44±0.02	1.40±0.25	92.00±1.21	7.00±0.00	224.80±9.71	10.80±1.66
SG		16.20±1.25	10.96±0.56	0.83±0.03	1.43±0.20	84.29±3.17	6.92±0.07	252.29±18.85	10.14±1.64
RSG	30	14.42±1.11	10.22±0.57	0.70±0.04	1.33±0.21	93.33±1.05	7.00±0.00	253.00±23.37	9.50±1.29
WAD		11.74±0.65	8.92±0.73	0.54±0.04	1.00±0.00	92.00±2.00	7.00±0.00	240.00±20.98	8.80±0.80
SG		17.39±1.17	11.80±0.51	0.82±0.05	1.43±0.20	88.43±1.99	7.00±0.00	268.57±19.07	8.86±1.12
RSG	32	15.22±1.06	10.58±0.55	0.67±0.05	1.00±0.00	91.00±2.34	7.00±0.00	262.00±21.13	8.33±0.95
WAD		12.50±0.61	9.16±0.72	0.56±0.07	1.20±0.20	92.40±1.12	7.00±0.00	276.40±11.87	7.40±0.75

*Body weight (BW), scrotal circumference (SC), volume (VOL), color (COL), motility (MORT), sperm concentration (CONC), and morphology (MORPH). *SG = Sahelian goats, RSG = Red Sokoto goats, WAD = West African Dwarf goats *1 = watery, 2 = milky, 3 = creamy

Table 2: Correlation coefficients in relationship to live body weights, scrotal circumference and seminal parameters among Sahel, Red Sokoto and West African Dwarf goats.

Parameters	BW	SC	EV	EC	Mot	pH	Conc	Mor
Body Weight (BW)	1.000							
Scrotal Circumference (SC)	0.847**	1.000						
Ejaculatory Volume (EV)	0.670**	0.712**	1.000					
Ejaculatory Colour (EC)	-0.147*	-0.358**	-0.381**	1.000				
Motility (Mot)	0.179*	0.337**	0.392**	-0.388**	1.000			
Potential of hydrogen (pH)	0.073	0.169*	0.194*	0.089	0.527**	1.000		
Concentration (Conc)	0.381**	0.536**	0.584**	-0.571**	0.729**	0.353**	1.000	
Morphology (Mor)	-0.064	-0.127	-0.074	0.153*	0.146	0.116	-0.139	1.000

Table 3: Age related quantitative sperm characteristics of West African Dwarf Bucks

	BW	SC	VOL	COL	MOT	pH	CONC	MORPH
Age	.769**	.652**	.894**	-.638**	.614**	.415**	.864**	-.333*
BW		.844**	.783**	-.671**	.565**	.402**	.800**	-.255
SC			.705**	-.651**	.422**	.304*	.621**	-.289*
VOL				-.618**	.566**	.357*	.813**	-.307*
COL					-.577**	-.435**	-.708**	.102
MORT						.880**	.723**	-.038
pH							.533**	-.044
CONC								-.292*

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Body weight (BW), scrotal circumference (SC), volume (VOL), color (COL), motility (MOT), sperm concentration (CONC), and morphology (MORPH).

Table 4: Age related quantitative sperm characteristics of Red Sokoto Bucks

	BW	SC	VOL	COL	MOT	pH	CONC	MORPH
Age	.524**	.787**	.824**	-.616**	.488**	.342**	.676**	-.336**
BW		.866**	.573**	-.270*	.315*	.103	.402**	-.250
SC			.773**	-.459**	.394**	.248	.520**	-.285*
VOL				-.599**	.516**	.246	.648**	-.258*
COL					-.418**	-.283*	-.701**	.192
MORT						.687**	.709**	.086
pH							.431**	.015
CONC								-.144

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Body weight (BW), scrotal circumference (SC), volume (VOL), color (COL), motility (MOT), sperm concentration (CONC), and morphology (MORPH).

Table 5: Age related quantitative sperm characteristics of Sahel Bucks

	BW	SC	VOL	COL	MOT	pH	CONC	MORPH
Age	.522**	.774**	.658**	-.461**	.560**	.263*	.784**	-.156
BW		.867**	.534**	-.109	.156	.125	.185	-.018
SC			.666**	-.280*	.310**	.187	.397**	-.002
VOL				-.308**	.524**	.333**	.543**	.084
COL					-.232	.287*	-.377**	.104
MORT						.544**	.739**	.195
pH							.395**	.149
CONC								-.100

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Body weight (BW), scrotal circumference (SC), volume (VOL), color (COL), motility (MOT), sperm concentration (CONC), and morphology (MORPH).

Changes in the Scrotal Circumference of Sahel, Red Sokoto and West African Dwarf

The findings of the present study indicate that, at the age range of 14-16 weeks, the average scrotal circumference of male goats fell within the range of 5.14±0.66 cm to 7.06±0.71 cm, 6.32±0.29 cm to 8.05±0.42 cm and 5.50±0.74 cm to 7.06±0.71 cm for SG, RS, and WAD breeds, respectively (Table I). Subsequently, a rapid increase in scrotal circumference was observed between 14 and 20 weeks, followed by a slower rate of growth between 22 and 30 weeks of age. The maximum value of scrotal circumference was recorded at 11.80±0.51 cm, 10.58±0.55 cm, and 9.16±0.72 cm for SG, RS, and WAD breeds, respectively, at the 32nd weeks. Furthermore, Spearman's rank correlation coefficient analysis indicated a significant (P<0.05) association between age and scrotal circumference (r=0.522, r=0.787, and r=0.652) in SG, RS, and WAD breeds, respectively. Additionally, a significant (P<0.05) correlation was observed between body weight and scrotal circumference (r=0.867, r=0.866, and r=0.844) in SG, RS, and WAD breeds, respectively.

Age and Body Weight at Puberty of Sahel, Red Sokoto and West African Dwarf Bucks

Results from the current study indicate that the Red Sokoto bucks achieved sexual maturation at a mean age of 14th week, exhibiting mean sperm concentration (116.17±28.47 x 10⁶), progressive sperm motility (65.00±9.92%), and mean body weight of 10.17±1.26 kg. On the other hand, the Sahelian and WAD bucks attained puberty at 16th week of age, manifesting sperm concentration of 106.29±25.18 x 10⁶ and 107.60±19.99 x 10⁶, mean sperm motility of 65.00±9.94% and 76.00±4.8%, and mean body weight of 11.29±1.59 kg and 7.78±0.70 kg, respectively (Table I). Notably, the sexual maturity was attained when the juveniles had attained 49.55% of their final body weight. By utilizing Spearman's rank correlation coefficient, it was observed that body weight and age exhibited a statistically significant (P<0.05) relationship with respect to puberty, depicting r = 0.524, r = 0.522, and r = 0.769 in RS, SG, and WAD bucks, respectively.

Body Weight Changes During Puberty of Sahel, Red Sokoto and West African Dwarf Bucks

The relationship between chronological age and body weight is shown in Table 1. From the 14th week of age, the body weights increased at a fairly constant rate, reaching maximum values of 14.19±1.47, 12.33±1.17 and 9.10±0.68 kg in SG, RS and WAD bucks respectively, at the age of 22nd week. A transient decrease in the body weight changes was observed at the 24th and 26th week.

Ejaculate Characteristics

Tables 1 to 2 provide the characteristics of the ejaculates collected from individual kids of the three breeds at sexual maturity. In all of the bucks from the three breeds, the first ejaculation was

observed to be yellowish-white in color at 14th week of age, while in the subsequent weeks, it had a creamy-white appearance with thin consistency. At 32nd week of age, SG, RS, and WAD bucks were observed to have reached full sexual maturity and could thus be used for breeding purposes. At this age, the means ejaculatory volumes were 0.82 ± 0.05 , 0.67 ± 0.05 , and 0.56 ± 0.07 mL in SG, RS, and WAD, respectively. The means sperm concentrations were $268.57 \pm 19.07 \times 10^6$, $262.00 \pm 21.13 \times 10^6$, and $276.40 \pm 11.87 \times 10^6$ in SG, RS, and WAD, respectively. The percentages of individually dead and morphologically abnormal sperm were 8.86 ± 1.12 , 8.33 ± 0.95 , and $7.40 \pm 0.75\%$ in SG, RS, and WAD, respectively. When comparing the sperm output of the first ejaculate of all goats using Spearman's rank correlation coefficient, age, body weight, and scrotal circumference at the time of sexual maturity were positively significant ($P < 0.05$) in all three bucks breeds. The Spearman's rank correlation coefficient, with age and morphologically abnormal sperm at the 32nd week of sexual maturity, were inversely significant ($P < 0.01$) $r = -0.292$, $r = -0.144$ in WAD and RS bucks respectively, while it was statistically insignificant ($P < 0.05$) in Sahel bucks.

DISCUSSION

The present study has demonstrated that the scrotal circumference of experimental goats increased with age. This observation is consistent with the results of a study conducted by Kridli *et al.* (2005) on Mountain black goats and their cross-breeds, which found that scrotal circumference increased with age in growing yearlings. Notably, a rapid increase in scrotal circumference was observed between the 14th and 20th week of age, followed by a period of slow growth. However, it was not possible to confirm the first phase of slow growth, as the study began at 14th week and no data was available prior to that age. It is important to note that an increase in scrotal circumference reflects the growth of testicular tissues (Perumal, 2014). Histological studies of goat testes have revealed that spermatogonia and primary spermatocytes appear at 69-84 days of age, while secondary spermatocytes and spermatids appear from 92-112 days (Yao and Eaton, 1954; Lee *et al.*, 1985).

A significant positive correlation was observed between scrotal circumference, age, and body weight, which may be attributed to the fact that testes are body parts that respond to tissue growth, as evidenced by the improvement of body weight. This finding is consistent with the results of Belibasaki and Kouimtzis (2000) and Kridli *et al.* (2005), who also reported significantly higher scrotal circumference in heavier breeds. A marked increase in scrotal circumference in the ages of the experimental goats ranging between the 14th and 20th weeks indicates the onset of active spermatogenesis and suggests that pubertal changes occur at this age (Bilaspuri and Singh, 1992). The gradual increase in scrotal circumference in this study could account for the gradual increase in ejaculate volume observed in all three breeds of bucks. Other studies have also reported a positive correlation between increasing age and body weight and testicular sizes in goats (Mekasha *et al.*, 2008; Raji *et al.*, 2008; Kabiraj *et al.*, 2011; Shoyombo *et al.*, 2012). Additionally, larger testes correlated with their scrotal circumferences (Alade *et al.*, 2006; Shoyombo *et al.*, 2012; Alade *et al.*, 2007; Alade *et al.*, 2009; Alade *et al.*, 2009). Moreover, testicular and cauda epididymal sperm reserves positively correlated with testicular weights and scrotal circumferences in Red Sokoto goats (Daudu, 1984).

The Spearman's rank correlation coefficients in the relationships among the variables are presented in Table 2. Remarkably, the gradual increase in scrotal circumference occurred in alternating periods of significant growth and stability from the 14th to 32nd weeks (Table 4), which is similar to the observations made in native Brazilian goats (Eloyand Santa Rosa, 1998).

Even after reaching sexual maturity, changes in scrotal circumference can occur in goats due to the influence of photoperiod, nutritional status, and temperature (Coelho *et al.*, 2006; Almeida *et al.*, 2007; Delgadillo *et al.*, 2007). As age increased, a high positive correlation was observed between live weight and scrotal circumference ($r = 0.847$). Similar to the findings of the present study, Daudu (1984) observed a high positive correlation ($r = 0.78$) between live weight and scrotal circumference in Red Sokot goats, while Keith *et al.* (2009) found the same in Boer goats (32°N), and Raji *et al.* (2008) in White Borno goats (11°N) with a correlation coefficient of 0.82. These results collectively support the notion that testicular growth is closely associated with live weight in goats, irrespective of breed and latitude. The study also demonstrated that sperm production and concentration increased as the bucks aged, in all three breeds, from 14th week (3 and ½ months) onwards. This finding is consistent with earlier reports that sperm production in Sahel goats is adequate at 3 months of age, with sperm cell concentration increasing with age (Maina *et al.*, 2006). Additionally, the quality of sperm was found to improve with age (Maina *et al.*, 2006; Oyeyemi *et al.*, 2011).

Although the histological development of the testes was not examined in this study, previous research has shown that bucks' first mating occurs on average 47 days after first ejaculation using an electro-ejaculator (Madani and Rahal, 1988). As sexual maturity is determined by the acquisition of mating competence, it is possible that semen was collected at a younger age using an electro-ejaculator. This possibility is supported by the observation of rapid testes growth from 14th week in the studied bucks. Lee *et al.* (1985) reported identifying spermatozoa in the testes of 20-week-old bucks after histological examination, although a few spermatozoa were also observed as early as 92 days of age (Yao and Eaton, 1954).

Sperm motility is a crucial indicator of male fertility (Jia *et al.*, 2021). The study's results revealed that individual progressive motility varied significantly with an increase in age: an average of 65.00% in the 14th week and 93.33% in the 30th week. It was also observed that sperm morphology reduced as the experimental goats advanced in age (from $12.29 \pm 5.38\%$ at the 14th week to $7.40 \pm 0.75\%$ at the 32nd week). Souza *et al.* (2011) reported a high incidence of abnormalities in the intermediate segment and tail of the sperm as the responsible factor for low sperm motility. Furthermore, Horn *et al.* (2002) noted that the epididymis epithelium was responsible for selecting and phagocytizing sperm cells with specific defects, with this process becoming more efficient as reproductive maturity is reached. Therefore, the high value of individual progressive motility at a given age (32nd week) can be interpreted as an indication of sexual maturity having been reached.

The findings of our study indicate that the milky or creamy appearance of semen, along with semen volume ranging from 0.30 ± 0.08 to 0.56 ± 0.07 mL, is consistent with the results reported by Daudu (1984). Interestingly, Souza *et al.* (2011) reported a similar phenomenon in Anglo-Nubian male goats, where milky sperm was observed from the 20th week to the 34th week, while all ejaculates recorded from the 36th week of age were creamy. Within the RSG, there was a significant increase in sperm concentration in animals between the 18th and 26th weeks (Table 1). In contrast, the SG and WAD showed significant increment in sperm concentration from the 20th to 32nd week and 26th to 32nd week, respectively. According to Aguiar *et al.* (2006) and Souza *et al.* (2011), this remarkable increase in spermatogenic activity during the referred age range is due to the development of seminiferous tubules and the differentiation of the Sertoli cells.

Despite advancing age, the pH of goat semen remained buffered within the normal goat pH range of 6.8-7.0. This neutrality in pH was observed across all three indigenous goat breeds, and the results are in agreement with those obtained by Hahn *et al.* (2019), where 65% of bucks studied had pH within the range of 6.4-7.0. The findings of our study indicate that puberty was reached in Red Sokoto bucks at 14th week (104 days) and a mean body weight of 10.17 ± 1.26 kg, while Sahelian and WAD bucks reached puberty at the 16th week (120 days) and a mean body weight of 11.29 ± 1.59 and 7.78 ± 0.70 kg, respectively. This finding is consistent with the hypothesis that breed modifies the onset of puberty in goats (Sakurai *et al.*, 2004). Similarly, in the study conducted by Nishimura *et al.* (2000), Damascus breed bucks reached puberty at the 17th month, while Tokara breed bucks attained puberty at the 4th month. Furthermore, body weight plays a crucial role in modifying the age of sexual maturity in goats, as observed by Zarazaga *et al.* (2009). Lastly, Madani and Rahal (1988) described the influence of the season of birth on the age of puberty in native Libyan goats, with animals born in winter being more precocious than those born in summer (22nd versus 27th week of age, respectively).

Hence, it is apparent that the initiation of sexual activity in small ruminants can fluctuate based on breed, management practices, and date of birth (Madani and Rahal, 1988; Ahmad and Noakes, 1996; Abi Saab *et al.*, 1997; Almeida *et al.*, 2007). Boer goats reached puberty at an average age of 157.5 days and a body weight of 46.3 lbs, as observed by the emergence of spermatozoa in semen collected via electro-ejaculation (Louw and Joubert, 1964). The puberty age for local and Southern Libyan goats was 192.1 and 158.7 days, respectively, with body weights of 22.0 and 18.9 kg (Madani and Rahal, 1988). In Nubian goats, puberty occurred at 227 days of age and 37.7 kg body weight (Chakraborty *et al.*, 1989). Sexual maturity, as determined by the attainment of mating competence, was documented at the ages of 239.4 and 254.4 days and weights of 25.7 and 26.8 kg, for local and Southern Libyan goats, correspondingly (Madani and Rahal, 1988). Sexual maturity in the British goat breeds is achieved at a younger age than most of the other breeds studied. Elwisy and Elswaf (1971) reported that the age and body weight at maturity in Damascus goats were 509.2 days and 36.6 kg, respectively. The current study did not consider other factors such as the time of year when the kids were born, plane of nutrition, management system, and climatic conditions.

Conclusion

In conclusion, this study found that breed, age, scrotal circumference and body weight at puberty are the major determinants of sperm characteristics, puberty and/or sexual maturity in Nigerian indigenous goat breeds (Sahel, Red Sokoto and WAD).

Conflict of Interests

None is declared.

Acknowledgments

The authors are thankful to Prof. Joan H. Makun and the entire staff of the Small Ruminant Research Unit of the National Animal Research Institute (NAPRI) Zaria, for the permission to carry out this research on her facility and for the assistance with semen collection and Laboratory analyses.

REFERENCES

- Abi Saab, S., Sleiman, F. T., Nassar, K. H., Chemaly, I. and El-Skaff, R. (1997). Implication of high and low protein levels on puberty and sexual maturity of growing male kids. *Small Ruminants Research*, v.25, p.17-22.
- Aguiar, G. V., Araújo, A. A. and Moura, A. A. A. (2006). Desenvolvimento testicular, espermatogênese e concentrações hormonais em touros Angus. *Revista Brasileira de Zootecnia*, v.35, n.4, p.1629-1638.
- Ahmad, N. and Noakes, D. E. (1996). Sexual maturity in British breeds of goat kids. *British Veterinary Journal*, 152. 93.
- Alade, N. K., Shettima, A. A. and Watirahyel, I. B. (2006). "Differences between the testicular and semen quality characteristics of three breeds of goats in a semi-arid environment," *Journal of Arid Agriculture*, vol. 16, pp. 145-149.
- Alade, N. K., Abdulkareem, A. and Adamu, S. B. (2007). Breed differences in body weight, body and testicular measurements and Veterinary Medicine International 5 their relationship in Red Sokoto and Sahel goats at weaning. *Sahel Journal of Veterinary Science*, vol. 6, no. 1, pp. 13-17.
- Alade, N. K., Ezeokoli, C. L. and Mohammed, I. D. (2009). "The relationships between body weight, testicular weight, age and the scrotal circumference of goats in the semi-arid Maiduguri, Nigeria," *Animal Production Research Advances*, vol. 5, no. 1.
- Almeida, A. M., Schwalbach, L. M. J., Cardoso, L. A. and Greyling, J. P. C. (2007). Scrotal, testicular and semen characteristics of young Boer bucks fed winter veld hay: the effect of nutritional supplementation. *Small Ruminants Research*, v.73, p.216-220.
- Belibasaki, S. and Kouimtzis, S. (2000). Sexual activity and body and testis growth in repubertal ram lambs of Friesland, Chios, Karagouniki and Serres dairy sheep in Greece. *Small Ruminant Research*, Volume 37, Issues 1-2, pp 109-113.
- Bezerra, F. Q. G., Aguiar Filho, C. R., Freitas Neto, L. M., Santos Junior, E. R., et al. (2009). Body weight, scrotal circumference and testosterone concentration in young Boer goat males born during the dry or rainy seasons. *South African Journal of Animal Science*, 39, (4): 301-306, 2009.
- Bitto, I. I. and Egbunike, G. N. (2006). Seasonal variation in sperm production, gonadal and extragonadal sperm reserves in pubertal West African Dwarf bucks in their native tropical environment. *International Journal Morphology*, 18(9): 24:637-642.
- Bilaspuri, G. S. and Singh, K. (1992). Developmental changes in body weight and testicular characteristics in Malabari goat kids. *Theriogenology*. 37 (2), pp 507-520.
- Chakraborty, P. K., Stuart, L. D. and Brown, J. L. (1999). Puberty in the male Nubian goats: Serum concentration of LH, FSH and testosterone from birth through puberty and semen characteristics at sexual maturity. *J. Animal. Reprod., Sci.*, 20: (2), 91-101.
- Coelho, L. A., Sasa, A., Nader, C. E., Celeguini, E. C. C. (2006). Características do ejaculado de caprinos sob estresse calórico em câmara bioclimática. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, v.58, n.4, p.544-549.
- Daudu, C. S. (1984). "Spermatozoa output, testicular sperm reserve and epididymal storage capacity of the Red Sokoto goats indigenous to northern Nigeria, *Theriogenology*, vol. 21, no. 2, pp. 317-324.
- Delgadillo, J. A., Santiago-Miramontes, M. A. and Carrillo, E. (2007). Season of birth modifies puberty in female and male goats raised under subtropical conditions. *Animal*, v.1, n.6, p.858-864.

- Eloy, A. M. X. and Santa Rosa, J. S. (1998). Perfis plasmáticos de testosterona durante a puberdade de machos caprinos da raça Moxotó. *Pesquisa Agropecuária Brasileira*, v.33, n.10, p.1645-1652.
- Elwishy, A. B. and Elsayaf, S. A., (1971). Development of sexual activity in male Damascus goats. *Indian J. Anim. Sci.* 41, 350-356.
- Gauthier, M., Pierson, J., Drolet, M., Bhatia, B., Baldassarre, H., and Keefer, C. L. (2001). Sexual maturation and fertility of male Nigerian Dwarf goat (*Capra hircus*) clones produced by somatic cell nuclear transfer. *Cloning and Stem Cells*, 3(3), 151-155. <https://doi.org/10.1089/153623001753205106>
- Hoflack, G., Van Soom, A., Maes, D., De Kruif, A., Opsomer, G. and Duchateau L. (2006). Breeding soundness and libido examination of Belgian Blue and Holstein Friesian artificial insemination bulls in Belgium and The Netherlands, *Theriogenology*, 66: 207- 216.
- Horn, M. M., Moraes, J. C. F. and Edelweiss, M. I. A. (2002). Evidência de seleção espermática diferencial no epidídimo de touros de genótipo híbrido com alterações na espermatogênese. *Revista Portuguesa de Ciências Veterinárias*, v.97, n.544, p.171-174.
- Inichinbia S. and Sule, P. O. (2018). 2D Geo-Electrical Imaging for Groundwater Exploration in Shika, along Zaria-Funtua Road North of Ahmadu Bello University Main Campus, Samaru, Zaria. *J. Appl. Sci. Environ. Manage.* Vol. 22 (4) 609 – 612.
- Jia, X., Burugula, B. B., Chen, V., Lemons, R. M., Jayakody, S., Maksutova, M. and Kitzman, J. O. (2021). Massively parallel functional testing of MSH2 missense variants conferring Lynch syndrome risk. *Am J Hum Genet.* 108(1): 163-175. doi: 10.1016/j.ajhg.2020.12.003.
- Jimeno, V., Castro, T. and Rebollar, P. G., 2001. Interacción-Reproducción en ovinos de leche. XVII Curso de Especialización FEDNA, 131-160.
- Józków, P., and Rossato, M. (2017). The Impact of Intense Exercise on Semen Quality. *American journal of men's health*, 11(3), 654–662. <https://doi.org/10.1177/1557988316669045>
- Kabiraj, K. S., Hoque, M. S. A., Khandoker, M. A. M. and Husain, S. S. (2011). "Testicular biometry and its relationship with body weight and semen output of Black Bengel bucks in Bangladesh," *Journal of Cell and Animal Biology*, vol. 5, no. 2, pp. 27-32.
- Keith, L., Okere, C., Solaiman, S. and Tiller, O. (2009). Accuracy of predicting body weights from body conformation and testicular morphometry in pubertal boer goats. *Research Journal of Animal Science*, v.3, n.2, p.26-31.
- Kridli, R. T., Tabbaa, M. J., Sawalha, R. M. and Amashe, M. G. (2005). Comparative Study of Scrotal Circumference and Semen Characteristics of Mountain Black Goat and its Crossbred with Damascus Goat as Affected by Different Factors. *Jordan Journal of Agricultural Sciences*, Volume 1, No. 1.
- Leboeuf, B., Restall B. and Salamon S. (2000). "Production and storage of goat semen for artificial insemination." *Animal Reproduction Science*, 62(1): 113-141
- Lee, V. W. K. and Burger, H. G. (1983) Pituitary testicular axis, during pubertal development In: Kretser DM, Burger HG, Hudson B, editors. *The Pituitary and Testis*, Clinical and Experimental Studies Berlin, Germany: Springer, pp. 44-83
- Louw, D. F. J. and Joubert, D. M. (1964). Puberty in the male Dorper sheep and Boer goat. *S. Afr. J. Agric. Sci.*, 7, 509-520.
- Madani, M. O. K. and Rahal, M. S. (1988). Puberty in Lybian male goats. *Animal Reproduction Science*, v.17, n.3, p.207-216.
- Maina, V. A., Chaudhari, S. U. R. and Mshelia, G. D. (2006). "Spermiogram of the white ecotype of Sahel bucks in Maiduguri Metropolis," *Pakistan Journal of Biological Sciences*, vol. 9, no. 2, pp. 307-309.

- Maina, V. A., Chaudhari, S.U. R., Mshelia, G.D. and Williams, A. (2006). "Influence of season on semen characteristics of Sahel bucks in Borno state," *Journal of Applied Sciences*, vol. 6, no. 2, pp. 353–356.
- Matshaba, B. (2010). *Characterization and cryopreservation of South African unimproved indigenous goat semen* (Doctoral dissertation, University of the Free State).
- Mekasha, Y., Tegegne, A., Abera, A. and Rodriguez-Martinez, H. (2008). "Body size and testicular traits of tropically-adapted bucks raised under extensive husbandry in Ethiopia," *Reproduction in Domestic Animals*, vol. 43, no. 2, pp. 196–206.
- Mickelsen, W. D. and Memon, M. A. (2007). Infertility and diseases of the male reproductive organs of bucks. In: *Current Therapy in Large Animal Theriogenology*, Second edition (RS Youngquist, WR Threfall, editors). Saunders Elsevier, Missouri, Columbia, USA. Pp 519- 523.
- Mocé, E., Mocé, M. L., Lozano-Palazón, S. A., Bernácer, J., Martínez-Granell, M. M., Esteve, I. C., Bernat, F., Contreras, S. J., Villalba, I., & Gómez, E. A. (2022). Fertility prediction in dairy goats from Murciano-Granadina breed: The role of sperm evaluation and female traits. *Animal: an international journal of animal bioscience*, 16(5), 100525. <https://doi.org/10.1016/j.animal.2022.100525>
- Nishimura, S., Okano, K., Yasukouchi, K., Gotoh, T., Tabata, S., and Iwamoto, H. (2000). Testis developments and puberty in the male Tokara (Japanese native) goat. *Animal reproduction science*, 64(1-2), 127–131. [https://doi.org/10.1016/s0378-4320\(00\)00197-4](https://doi.org/10.1016/s0378-4320(00)00197-4)
- Oyeyemi, M. O., Fayomi, A. P., Adeniji, D. A. and Ojo, O. M. (2011). "Gonadal and extragonadal spermogram of Sahel buck in the humid zone of Nigeria," *Current Research Journal of Biological Sciences*, vol. 3, no. 5, pp. 468–471.
- Perumal P. (2014). Scrotal Circumference and Its Relationship with Testicular Growth, Age, and Body Weight in Tho Tho (*Bos indicus*) Bulls. *International Scholarly Research Notices*. 2014:6 249537, <http://dx.doi.org/10.1155/2014/249537>
- Raji, A. O., Igwebuike, J. U. and Aliyu, J. (2008). "Testicular biometry and its relationship with body weight of indigenous goats in a semi-arid region of Nigeria," *Journal of Agricultural and Biological Sciences*, vol. 3, no. 4, pp. 6–9.
- Sakurai, K., Ohkura, S., Matsuyama, S., Katoh, K., Obara, Y. and Okamura, H. (2004). Body growth and plasma concentrations of metabolites and metabolic Puberty in subtropical goats hormones during the pubertal period in the female Shiba goats. *Journal of Reproduction and Development* 50, 197–205.
- Sagatelli, T. M., Renato de Franca, L., Pinheiro, P. F. F., Ademida, C. C. D., Martinez, M. and Martinez, F. E. (2004). Spermatogenic Cycle Length and Spermatogenic Efficiency in the Gerbil (*Meriones unguiculatus*). *Journal of Andrology* 25(6):872-80.
- Souza, L. E. B., Cruz, J. F., Neto, M. R. T., Nunes, R. C. S. and Cruz M. H. C. (2011). Puberty and sexual maturity in Anglo-Nubian male goats raised in semi-intensive System. *R. Bras. Zootec.*, v.40, n.7, p.1533-1539.
- Shoyombo, A., Fasanya, O., Bunjah, U. and Yakubu, H. (2012). On-farm prediction of testicular characteristics in bucks at specific ages. *World Journal of Life Sciences and Medical Research*, vol. 2, no. 3, pp. 114–117.
- Tanga, B. M., Qamar, A. Y., Raza, S., Bang, S., Fang, X., Yoon, K., & Cho, J. (2021). Semen evaluation: methodological advancements in sperm quality-specific fertility assessment - A review. *Animal bioscience*, 34(8), 1253–1270. <https://doi.org/10.5713/ab.21.0072>
- Togun, V. A. and Egbunike, G. N. (2006). Seasonal variations in the sperm production characteristics of Zebu (White Fulani) cattle genitalia in the humid tropical environment. *Middle East Journal of Science Research*, 1(1): 87-95.

- Willis, B. M. (2001). Breeding Policies in Developing Regions. In: Dalton's Introduction to Practical Animal Breeding, Fourth edition). Oxford, Blackwell Science, Pp 1328
- Yao, T. S. and Eaton, O. N. (1954). Postnatal growth and histological development of reproductive organs in male goats. *American Journal of Anatomy*. V.95, n.3, p.401-431.
- Zarazaga, L. A., Guzman, J. L., Domínguez, C., Pérez, M. C., Prieto, R. and Sañchez, J. (2009). Nutrition level and season of birth do not modify puberty of Payoya goat kids. *Animal*, 3:1, pp 79-86. doi:10.1017/S1751731108003376