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IMPACT OF SEASONAL DYNAMICS ON REPRODUCTIVE PARAMETERS AND SEMEN QUALITY IN SUBTROPICAL MALE GOATS

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ABSTRACT

Seasonal variation significantly influences the reproductive efficiency of small ruminants, particularly in subtropical regions. This study was conducted to evaluate the seasonal variations in semen quality and reproductive parameters of Barbari and Sirohi bucks raised under subtropical environments. A total of 96 ejaculates were collected fortnightly from 12 healthy adult breeding bucks of the Barbari and Sirohi breeds during the summer and winter seasons of 2024 using an artificial vagina. Scrotal temperature was significantly higher and scrotal circumference was significantly lower in summer as compared to winter season in both breeds. Ejaculates collected during summer season had significantly lower mean values of semen volume, sperm concentration, mass motility, individual motility and live sperm countthan those collected during winter time in both breeds. Hormonal profiles (testosterone) were assessed to establish correlations with reproductive performance. The results revealed that semen quality and reproductive traits were superior during winter and autumn, while summer heat stress significantly impaired sperm motility, concentration and morphology. Testosterone levels also exhibited seasonal fluctuations, peaking in cooler months. These findings highlight the pronounced impact of climate-induced seasonality on reproductive efficiency, suggesting the need for improved breeding management and nutritional supplementation during heat-stressed periods in subtropical goats.

Keywords: Reproductive parameters, seasonal variation, semen quality, subtropical climate

INTRODUCTION

Livestock forms the backbone of the Indian agricultural economy, contributing significantly to food security, employment and rural livelihoods. Among the livestock species, goats hold a special place due to their adaptability, low maintenance cost and high economic returns. Recognizing their potential, the ICAR–Central Institute for Research on Goats (CIRG) has predicted the goat to be the “Future Animal” for ensuring both rural and urban prosperity in India. Goat husbandry is a source of livelihood and income among poor farmers (Kumar *et al*., 2018). Goats are believed to be more resistant to temperature fluctuations than other farm animals because they can reduce their metabolic rate while increasing their respiratory and cardiac rates (El-Sherbiny *et al.*, 2022). Additionally, depending on their breed and individual responses, goats respond to environmental stress in different ways (Sharma *et al.*, 2013). Season and environment affect livestock production and reduce fertility (Sejian *et al.,* 2018). The climate seasons (summer and winter) have variable ambient temperatures, relative humidity and temperature humidity index (THI). The THI is the main indicator to monitor the thermal stress condition of animals (Ribeiro *et al*., 2018). Increased THI negatively impacts the animal welfare, productivity and reproduction (Jamal *et al*., 2021). Many studies have reported that heat stress negatively affects sperm quality and fertility in males (Al-Kanaan *et al*., 2015). Heat stress influences sperm quality in buck semen, although decreased semen quality is due to high THI during collection (Isnaini *et al.*, 2020). Artificial insemination (AI) is advanced technology to improve genetic quality and increase the livestock population. A superior and highly productive livestock could be obtained by farmers with the aid of AI. However, the success of AI greatly depends on the semen quality of bucks (Ranjan *et al.*, 2021). Several studies have focused on the development of frozen semen technology in goats (Wang *et al*., 2015); however, information on the evaluation of fresh semen quality, particularly in indigenous breeds such as Barbari and Sirohi bucks, remains limited. Considering the growing importance of goats in livestock-based rural economy, it is essential to understand how seasonal and climatic variables influence semen attributes in these breeds under tropical conditions. Such knowledge would not only provide insights into reproductive efficiency but also facilitate the preparation of high-quality sperm doses for artificial insemination, thereby meeting the increasing demand for buck semen in goat farming.

MATERIALS AND METHODS

Location of study

The study was conducted at Department of Veterinary Physiology and Biochemistry, College of Veterinary Science & Animal Husbandry and Livestock Farm Complex (Amanala Goat Farm) Nananji Deshmukh Veterinary Science University, Jabalpur (India) in winter and summer seasons of 2023-24. The city Jabalpur is located at latitude 23º10’N and longitude 79º56̀E at an altitude of 411 m above sea level in central India. It has a humid subtropical climate, typical of North-Central India with a seasonal variation in temperature ranging from 10.2°C to 41.9°C.

Experimental animals

The experiment was conducted as per the guidelines of Institutional Animal Ethics Committee (IAEC) vide No. 07/IAEC/Vety/2023. All breeding bucks were managed under organized Amanala Goat Farm, College of Veterinary Science & Animal Husbandry, NDVSU, Jabalpur (India). Twelve healthy adult breeding bucks (Sirohi and Barbari breeds), aged 1.5-4.0 yr, were included in this study.

Meteorological variables

Meteorological data, including ambient temperature, relative humidity and sunshine duration, were obtained from the Meteorological Centre, Anand Nagar, Adhartal, Jabalpur, Madhya Pradesh. The experimental period comprised two seasons, namely summer and during 2023-24. The months included in the respective seasons were (May-June) and (November-December). The temperature-humidity index (THI) was calculated daily throughout the experimental period using the recorded dry-bulb and wet-bulb temperatures according to the following equation (NRC, 1971):

$$THI = 0.72\ (T_{db} + T_{wb}) + 40.6$$

Where, T_{db} = Dry bulb temperature (ºC); T_{wb} = Wet bulb temperature (ºC)

Reproductive parameters

Scrotal circumference (cm) was measured using flexible commercially available measuring tape. Scrotal temperature (ºC) was measured by thermo-scanner.

Semen collection and evaluation

Four ejaculates of semen were collected fortnightly by the artificial vagina method (Memon *et al.*, 1986), early morning from 12 adult breeding bucks of Sirohi and Barbari breed during summer and winter season. A total of 96 ejaculates, 4 from each buck during summer (48 ejaculates) and winter (48 ejaculates) were collected. Immediately after collection, the semen samples were placed in a water bath (35°C) and the initial evaluation was carried out within 5 min. Fresh semen samples were evaluated as per Hafez and Hafez (2000). Ejaculate volume was measured in a graduated tube and pH was determined using pH strips. Mass motility was assessed on a pre-warmed glass slide using a binocular light microscope (Olympus CX23, Evident Scientific, Japan) at 10X objective magnification. Individual sperm motility was assessed at 40X objective magnification using appropriately diluted semen. Sperm concentration ($\times 10^9$ mL^{-1}) was estimated with a Neubauer haemocytometer (Sultana *et al*., 2013) and Sperm viability was assessed by eosin-nigrosin staining, in which unstained spermatozoa were considered live, whereas spermatozoa showing pink/red staining were considered non-viable, following the procedure described by Blom (1950).

Hormonal assay

Blood samples (5 mL) were collected from the jugular vein of each buck by venipuncture. Following clot formation, the samples were centrifuged to separate the serum, and used for testosterone estimation. Serum testosterone concentrations were determined using an enzyme linked immunosorbent assay (ELISA) kit (Calbiotech, USA) according to the manufacturer's instructions. The optical density of the assay was measured using a LISA Plus ELISA reader, while washing steps were performed using a LISA Wash ELISA plate washer (Dhilon *et al*., 2020).

Statistical analysis

The data was analysed with the help of SPSS software using repetitive measure ANOVA and obtained data from different experiments were presented as mean ± SE. The difference at $p < 0.05$ was considered to be satisfactory significances.

RESULTS AND DISCUSSION

The mean values of seasonal ambient temperature, relative humidity and temperature humidity index (THI) are presented in Table 1.

The summer season was characterized by markedly higher maximum and minimum temperatures, elevated dry and wet-bulb readings, reduced relative humidity and extended sunshine duration (>8 h day^{-1}) compared with winter (<6 h day^{-1}). Consequently, mean THI values were significantly greater in summer, reflecting higher heat stress conditions. These climatic differentials are likely to have contributed to seasonal variations in semen quality and reproductive attributes of the experimental bucks.

Table 1: Average meteorological parameters during summer and winter seasons of the study period

Parameters	Seasons	
	Summer (May-June)	Winter (Nov-Dec)
Average maximum temperature (°C)	39.88 ± 0.37	26.05 ± 0.42
Average minimum temperature (°C)	26.50 ± 0.32	14.18 ± 0.44
Average dry bulb temperature (°C)	33.19 ± 0.26	20.12 ± 0.29
Average wet bulb temperature (°C)	22.63 ± 0.22	17.57 ± 0.31
Mean relative humidity (%)	41.23 ± 1.66	78.95 ± 1.23
Temperature-humidity index (THI) (%)	80.84 ± 0.21	67.74 ± 0.42

Table 2: Reproductive parameters of Barbari and Sirohi goats during summer and winter seasons (mean ± SE)

Parameters	Seasons	Breeds	
		Barbari	Sirohi
Scrotal circumference (cm)	Summer	$24.98^a \pm 0.27$	$24.96^a \pm 0.16$
	Winter	$25.83^b \pm 0.12$	$25.78^b \pm 0.33$
Scrotal temperature (°C)	Summer	$35.40^b \pm 0.25$	$35.26^b \pm 0.12$
	Winter	$30.12^a \pm 0.26$	$30.18^a \pm 0.43$

Means bearing different superscript letters within same column and same row differs significantly ($p < 0.05$)

Sejian *et al.* (2018) defined an animal's status as being under heat stress if their THI was elevated to a level greater than 75. Heat stress influences sperm quality in buck semen, although decreased semen quality (Isnaini *et al.,* 2020). Seasonal variation in reproductive traits is presented in Table 2. Scrotal circumference was significantly ($p < 0.05$) higher during winter compared to summer in both breeds, no significant ($p > 0.05$) difference was observed between Barbari and Sirohi bucks. The reduction in scrotal circumference during summer may be attributed to elevated ambient temperature and extended photoperiod, consistent with earlier reports (Mohamed *et al*., 2023). Increased scrotal circumference during the breeding season (winter) is likely associated with elevated testosterone concentrations (Shi *et al*., 2018). High THI exerts a detrimental effect on male fertility (Boni, 2019) and the observed reduction in scrotal circumference during summer was concomitant with a decline in sperm quantity and quality.

Scrotal temperature was significantly ($p < 0.05$) higher in summer compared to winter, with no significant breed effect ($p > 0.05$). Spermatogenesis is reported to decrease by approximately 14% for every 1°C rise in testicular temperature (Durairajanayagam *et al*., 2015), while heat stress is known to reduce testicular blood flow and impair testicular function (Hedia *et al*., 2020). Furthermore, subtropical climatic conditions contribute to pronounced seasonal variation in reproductive performance (Salles *et al*., 2020).

Seasonal variation was evident in semen quality parameters (Table 3). Semen volume did not differ significantly between breeds, but was significantly ($p < 0.05$) higher in winter compared to summer, corroborating earlier reports (Kulaksiz *et al*., 2019). The increase during winter is largely attributed to greater accessory sex gland and epididymal secretions, which are androgen dependent (Leboeuf *et al*., 2000). Semen pH did not differ significantly between breeds or seasons, indicating adequate buffering capacity of epididymal secretions even under summer stress.

Table 3: Semen physiological parameters of Barbari and Sirohi goat breeds during summer and winter season (mean ± SE)

Parameters	Seasons	Breeds	
		Barbari	Sirohi
Semen volume (mL)	Summer	$0.78^{a} \pm 0.07$	$0.77^{a} \pm 0.05$
	Winter	$1.04^{b} \pm 0.09$	$0.98^{b} \pm 0.04$
pH	Summer	6.88 ± 0.03	6.95 ± 0.05
	Winter	6.93 ± 0.06	6.94 ± 0.07
Sperm concentration (10^{9}cells mL^{-1})	Summer	$4.03^{a} \pm 0.38$	$3.93^{a} \pm 0.33$
	Winter	$5.12^{b} \pm 0.22$	$4.99^{b} \pm 0.19$
Mass activity (grade)	Summer	3.50 ± 0.06	3.54 ± 0.11
	Winter	3.70 ± 0.04	3.58 ± 0.03
Individual motility (%)	Summer	$69.71^{a} \pm 2.56$	$71.58^{a} \pm 1.37$
	Winter	$82.67^{b} \pm 0.58$	$81.71^{b} \pm 0.79$
Live sperm count (%)	Summer	$74.38^{a} \pm 1.54$	$73.18^{a} \pm 1.54$
	Winter	$87.17^{b} \pm 2.16$	$86.63^{b} \pm 1.69$

Means bearing different superscript within same column and same row differs significantly ($p < 0.05$)

Sperm concentration was significantly ($p < 0.05$) higher in winter than summer across both breeds, likely due to increased testicular dimensions and higher testosterone levels that enhance spermatogenesis during the breeding season. Mass motility showed a non-significant increase in winter, whereas individual motility was significantly ($p < 0.05$) higher in winter than summer. The reduction in sperm motility during summer may be attributed to high THI, which diminishes accessory sex gland secretions and compromises sperm quality.

Sperm motility had significant positive correlation with other semen attributes *viz*., semen volume, semen concentration and mass activity, and negative correlation with reproductive parameters (scrotal circumference and scrotal temperature) [Table 2 and 3]. Our findings align with previous studies (Roca *et al*., 2006), which reported better semen traits during cooler seasons in goats. The reduced testosterone levels (Fig. 1) in summer further explain the seasonal suppression of reproductive performance, as high ambient temperatures negatively influence hypothalamic-pituitary-gonadal (HPG) axis regulation. Scrotal circumference showed strong positive correlations with semen output, supporting its role as a reliable predictor of reproductive efficiency (Salhab *et al*., 2001). This suggests that routine monitoring of scrotal size and semen traits can serve as effective indicators for buck fertility management in subtropical climates.

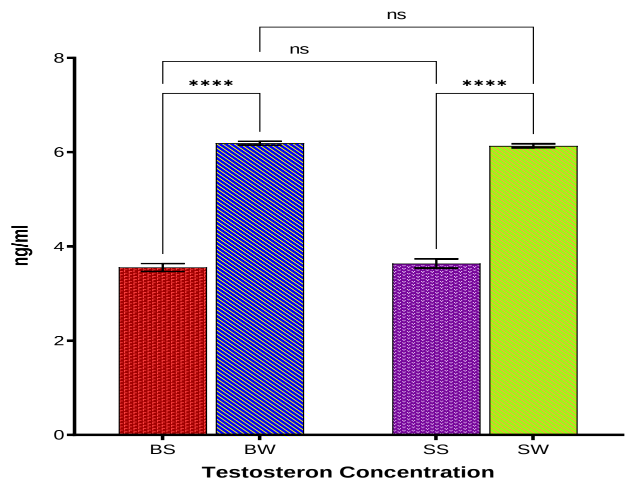

Fig. 1: Testosterone concentration (ng mL^{-1}) (mean ± SE) of Barbari and Sirohi during summer and winter season (BS - Barbari Summer, BW - Barbari Winter, SS - Sirohi Summer, SW - Sirohi Winter)

Table 4: Pearson's correlation coefficients between sperm attributes and reproductive parameters of Barbari and Sirohi bucks with THI

A. Barbari bucks	THI	MA	SV	SC	IM	SC	ST
Temperature humidity index (THI)	1.00	-0.23	-0.38	-0.52	-0.78	0.64	0.90
Mass activity (MA)		1.00	0.06	0.41	0.22	-0.09	-0.18
Semen volume (SV)			1.00	0.05	0.24	-0.11	-0.43
Semen concentration (SC)				1.00	0.43	-0.54	-0.41
Individual motility (IM)					1.00	-0.47	-0.75
Scrotal circumference (SC)						1.00	0.63
Scrotal temperature (ST)							1.00
B. Sirohi bucks							
Temperature humidity index (THI)	1.00	-0.07	-0.30	-0.51	-0.82	0.67	0.90
Mass activity (MA)		1.00	0.36	0.07	0.03	-0.11	-0.18
Semen volume (SV)			1.00	0.21	0.36	-0.34	-0.27
Semen concentration (SC)				1.00	0.24	-0.31	-0.44
Individual motility (IM)					1.00	-0.62	-0.82
Scrotal circumference (SC)						1.00	0.77
Scrotal temperature (ST)							1.00

THI had significant ($p < 0.05$) negative correlation with semen attributes (Semen volume, semen concentration, individual motility and mass activity), whereas positive correlation with reproductive parameter (Scrotal circumference and scrotal temperature) (Table 4). The percentage of live sperm was also significantly ($p < 0.05$) higher in winter compared to summer for both breeds, consistent with findings in Barbari bucks (Ranjan *et al*., 2020). Elevated ambient temperature exerts detrimental effects on male fertility by impairing spermatogenesis and increasing sperm mortality.

Conclusion: It may be concluded that elevated THI during the summer season exerted a detrimental effect on semen quality and seminal attributes of Barbari and Sirohi bucks under subtropical conditions. High THI was associated with significant reductions in semen volume, sperm concentration, motility and livability. In contrast, the comparatively lower THI during winter provided a more favourable environment, making winter the optimal season for the production of good-quality semen.

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Conflict of interest: The authors declare that there is no conflict of interest.

Ethical statement: All experimental procedures involving animals were conducted in accordance with the guidelines of the Institutional Animal Ethics Committee (IAEC), College of Veterinary Science and Animal Husbandry, Nanaji Deshmukh Veterinary Science University (NDVSU), Jabalpur, Madhya Pradesh, India. The study was conducted following the ethical approval granted by the IAEC vide approval No. 07/IAEC/Vety/2023. All animals were maintained under standard farm management and handling practices throughout the experimental period.

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