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Effects of Exposure to Solar Radiation on Thermoregulation and Semen Characteristics of Sudanese Desert Rams (*Ovis aries*)

[1]Suhair Sayed Mohamed, [2]Abdalla Mohamed Abdelatif and [3]Ahmed Abdel Gadir Adam

[1]Department of Surgery, Obestetrics and Gyaencology,
Faculty of Veterinary Medicine, University of Bahri, Khartoum, Sudan
[2]Department of Physiology, Faculty of Veterinary Medicine,
University of Khartoum, Shambat, Sudan
[3]Department of Physiology and Reproductive Biotechnology,
College of Animal Production, University of Bahri, Khartoum, Sudan

Abstract: This study was conducted to evaluate the effect of exposure to direct wet summer solar radiation for three weeks on rectal temperature(Tr), respiration rate (RR) and semen characteristics in Hamari desert rams. Eight entire rams were divided into two groups: 4 were kept under shade (shaded) and 4 without a shade (unshaded). Both Tr and RR measurements were performed twice daily in the morning and afternoon, the scrotal circumference (SC) was measured once per week. Semen samples were collected at weekly intervals from each ram and the ejaculated samples were evaluated using standard methods. Direct exposure of Desert rams to solar radiation significantly increased morning Tr in 2nd Week, the afternoon Tr in the 1st week and the morning and afternoon RR values in the last two weeks. Compared to the shaded the unshaded rams had a significantly higher afternoon Tr only in the 1st week. The unshaded rams had significantly higher RR throughout the experimental period. Exposure to solar radiation significantly decreased the ejaculate volume (EV) in 3rd week, sperm mass motility (SMM), sperm individual motility (SIM) and sperm cell concentration (SCC) in 2nd and 3rd Weeks. The unshaded rams showed significantly higher values of live sperm (LSP) and abnormal sperm (ASP) percentages in the last two weeks. Compared to the shaded, unshaded rams had a significantly higher EV, SCC in the 2nd and 1st week, respectively. However, the ASP were significantly higher throughout the experimental period. A significant decrease was observed in SIM in the last two weeks and in LSP in the 1st week. It is concluded that exposure to wet summer solar radiation adversely affected thermoregulation and seminal traits of Sudanese desert rams.

Key words: Rams · Solar · Radiation · Thermoregulation · Semen Characteristics

INTRODUCTION

Sudan lies in the northern eastern part of Africa. This area is covered with an intensive solar radiation from march to the end of June and had a mild moist temperature from July to the end of October [1]. The sheep population of Sudan is about 38 million, over 36% of the livestock in the country, are distributed across the low rainfall savannah, semi-desert and desert zones, north of 10°N. These animals are well adapted to arid and semi-arid conditions and can thrive with water scarcity, low quality range grasses and high ambient temperatures [1]. As in other tropical areas, rams in Sudan suffer from the effects of exposure to direct solar radiation and heat stress. Under such extensive system the reproductive performance of rams is influenced by thermal load [2, 3] and they have to combat heat and serve females throughout the year. Exposure of rams to extreme heat was reported to impair heat exchange in the counter current system between the spermatic cord,artery and vein [4]. Direct exposure of desert sheep to solar heat, increased the after noon respiratory rate values up to 159 breaths/min. [5]. It has been reported that an intermittent scrotal temperature increase in rams caused

Corresponding Author: Suhair Sayed Mohammed, Department of Surgery,Obestetrics and Gyaencology,
Faculty of Veterinary Medicine, University of Bahri, Khartoum, Sudan.

falls in the percentage of motile sperms [6]. Elevated testicular temperature increased the apoptosis of germinal epithelium of the seminiferous tubules [7].

The current study was performed to evaluate the impact of exposure to direct solar radiation in wet-summer (October and November) for three weeks on rectal temperature (Tr), respiration rate (RR) and semen characteristics in Hamari desert rams.

MATERIALS AND METHODS

Climate and Location: This Study was performed at the Department of Physiology at Shambat located at 15° 36 N 32° 35E and an altitude of 390 m. The climatic conditions prevailing during the experimental period were obtained from Shambat Meteorological Centre located about 500 meters from the experimental site and are predicted in Table 1.

Animals: Eight adult intact Desert rams aged 2-3 years were randomly assigned to two groups of 4 rams each. Group A was kept under shade (shaded) andgroup B was exposed to direct solar radiation (Unshaded).

Experimental Procedure: Both groups of rams were allowed an adaptive period of 2 weeks for new rearing regimen and housing facilities, followed by an experimental period of 3 weeks. During the experimental period a general management protocol was held, including deworming, clinical examination, claws trimming and sanitary measures were adopted. Rams were examined for general health and breeding soundness. Animals were fed chopped lucerene hay (Medicago Sativa) (CP:17.5%; ME:8.48MJ/Kg) and were given tap water *adlibitum*.

Through out the experiment, measurement of Tr and RR were performed twice daily in the morning (7:00 a.m.) and afternoon (2:00p.m.) Semen samples were collected weekly by the electro-ejaculatation method, at 9:00-11:00 a.m. and analyzed.

Table 1: The prevailing climatic conditions during the experimental period

	Temperature (°C)			
Time (weeks)	Max.	Min.	Mean	RH (%) (Mean)
1	35.6	19.7	27.7	23
2	38.5	20.6	29.6	25
3	36.5	20.2	28.4	26
Mean ±SD	36.87±1.5	20.17±0.45	28.5±0.96	24.67±1.52

Solar radiation: 143 W/m^2

Measurements of Rectal Temperature (Tr) and Respiration Rate (RR): The rectal temperature (Tr) was measured with clinical thermometer with an accuracy of ± 0.1°C for one minute. The respiration rate (RR) was measured visually by counting the flank movement using a stop watch and the values were taken to one minute for regular breathing with the animal standing quietly. Both Tr and RR measurements were performed twice daily in the morning (7:00 am) and afternoon (2:00 pm).

Semen Collection and Evaluation: Semen samples were collected once weekly from each ram in each group using an electro-ejaculator (The Ruakura MK1V Ram ejaculator; Alfred Cox, Surrey, England). The probe was inserted into the rectum so that the ring electrodes penetrated to the depth of approximately 11 cm Semen samples were evaluated using standard methods [8, 9]. The ejaculate volume (EV) was measured in a graduated tube. The sperm mass motility (SMM) was evaluated by transferring a drop of undiluted semen to a warm slide, placing a cover slip and observing under a microscope (x 40). The assessment of SMM was performed on a scale from 0 (immotile) and 5 (vigorous motility). The sperm individual motility (SIM) was estimated using a scale from 1-10 representing increments of 10%. Sperm cell concentration (SCC) was determined after diluting semen with a 0.05% formaldehyde saline solution (1: 400) and use haemocytometer examined under the microscope (x45) adopting the method for RBC counting. The proportion of live and dead spermatozoa and abnormal sperms percent were determined using Nigrosin-Eosin staining technique by counting 100 spermatozoa under oil immersion objective (x 1000) random fields. Indicator papers (E. Merck Company, Darmstadt, Germany) with the range of 5.2 to 8.0 were used to determine the pH of semen samples.

Statistical Analyses: The effect of exposure to solar radiation and duration was evaluated by two way ANOVA using the statistical software (SAS, 10). The data obtained were presented as means ± S.E.

RESULTS AND DISCUSSION

The prevailing climatic conditions during the experimental period are presented in Table 1.

Table 2 shows that exposure to solar radiation significantly ($p<0.05$) increased the values of the morning and afternoon rectal temperature (Tr) in the unshaded group of rams in the second and first week, respectively

Table 2: Effect of exposure to solar radiation on rectal temperature (Tr,°C) in the Desert rams

	7: 00 a.m		2: 00 p.m.	
Week	Shaded	Unshaded	Shaded	Unshaded
1	38.18±0.29^{Aa}	38.25±0.39^{Ba}	38.80±0.10^{Ab}	39.98±0.27^{Aa}
2	38.48±0.10^{Aa}	38.95±0.30^{Aa}	39.28±0.19^{Aa}	39.68±0.23^{Ba}
3	38.48±0.06^{Aa}	38.88±0.11^{Ba}	38.83±0.11^{Aa}	39.30±0.40^{Ba}

Values (mean ± S.E.) within the same row bearing similar lowercase (small) letters and values within the same column bearing similar uppercase (capital) letters are not significantly different at p< 0.05

Table 3: Effect of exposure to solar radiation on respiration rate (RR, breaths/min) in Desert rams

	7: 00 a. m		2: 00 p. m.	
Week	Shaded	Unshaded	Shaded	Unshaded
1	22.15±0.29^{Bb}	24.4±1.12^{Ba}	32.98±1.55^{Bb}	78.30±7.03^{Ba}
2	26.20±0.97^{Ab}	29.28±0.69^{Aa}	57.73±5.89^{ABb}	109.78±9.17^{Aa}
3	23.83±0.91^{Bb}	28.50±1.54^{Aa}	71.75±0.85^{Ab}	108.55±8.82^{Aa}

Values (mean ± S.E.) within the same row bearing similar lowercase (small) letters and values within the same column bearing similar upercase (capital) letters are not significantly different at p< 0.05

compared to values obtained in other weeks of the experiment. This response is clearly associated with the prevailing high ambient temperature (Table 1) and to the magnitude of solar heat absorbtion that stimulate peripheral thermoreceptors [11] and increase rectal temperature for heat dissipation [12]. Compared to shaded rams, the unshaded exhibited a significantly ($p<0.001$) higher afternoon Tr values. This response could be attributed to an increase in the rate of heat gain from solar radiation Kalifa *et al.* [13] indicated that heat storage induced an increase in body core temperature of sheep. Abdelatif [14] reported that afternoon Tr of desert sheep exposed to summer solar radiation increased to 41°C. Similar findings reported an increase in Tr on exposure of other breed of sheep to direct solar radiation particularly in the afternoon [15, 16].

The unshaded rams showed a significantly ($p<0.05$) higher respiration rate (RR) (Table 3) in the last two weeks. These values coincide with the prevailing ambient temperature, Tr values reported at 7:00 a.m. and related to heat loss by thermal gradient between body and air [17, 18] However, compared to the shaded rams, the significantly higher morning RR values obtained in 1st, 2nd ($p<0.05$) and 3rd weeks ($p<.0.01$) for the unshaded rams are presumably related to the influence of solar heat load and the need for enhancement for evaporative heat loss from the respiratory tract. Excess solar heat enhances sheep to adjust their body temperature by panting [19, 20]. The significantly higher afternoon values of RR observed in unshaded rams ($p<.0.01$) in the last two weeks is related to the prevailing maximum ambient and trials for maintaining heat balance. On exposure to excessive heat load, sheep increase their respiration rate in order to negate the excessive heat load [21]. Also the significantly higher RR values observed in the unshaded rams, compared to the shaded in the 1st ($p<.0.001$), 2nd and 3rd week ($p<.0.01$) indicated that heat stressed animals combat hyperthermia and augment the efforts to dissipate excess body heat by increasing rectal temperature and panting [22]. Previous work reported high RR values in the afternoon on exposure of sheep to solar radiation [23, 24].

Table 4 shows that ejaculate volume (EV) of unshaded rams was progressively reduced, particularly in the 3rd week ($p<0.05$). This response could be related to disturbance in hormone secretion in response to heat stress. High thermal load results in hypo-function of the anterior pituitary gland and consequently insufficient gonadotrophin secretion which affects androgen dependent accessory genital glands [25, 26]. Curtis [27] reported a reduction in serum testosterone level in rams exposed for 14 days to an average environmental temperature of 30°C. The decline in EV in heat stressed rams could partially be associated with the reduction in rete testis fluid in response to heat stress. Rete testis fluid contains hormones considered as intermediates in biosynthesis of testosterone, which may reduce the secretory function of the androgen dependant accessory genital glands [28]. The present findings are in agreement with previous studies [29, 30].

The unshaded rams showed a progressive significant reduction in sperm mass motility (SMM)(Table 4) in the last two weeks ($p<0.05$). This could be related to the cumulative effects of direct exposure to solar radiation and impairment of testicular and epididymal thermo-regulation [31]. Also this reduction in SMM could be associated with the increase in spermatozoal metabolism with concurrent need for excess oxygen to sustain aerobic metabolism [32]. Setchell [33] reported that in rams, blood flow changes little in response to increase in testicular temperature and consequently hypoxia develops. Similar decline in SMM was reported in heat stressed rams [29, 34].

The sperm individual motility (SIM) (Table 4) of unshaded rams significantly ($p<0.0.5$) decreased in the last two weeks of exposure to solar radiation compared to the 1st week and to values obtained for shaded rams (Table 4). These changes are related to the effects of high

Table 4: Effect of exposure to solar radiation on ejaculated semen characteristics from Desert rams

	Ejaculate volume (ml)		Mass motility (MM)		Individual motility (IM)		Cell conc. (SSC) ($x10^9$/ml)		Live sperm (LSP) %		Abnormal sperm (APS) %		Semen pH	
Weak	Shaded	Unshaded	Shaded	Unshaded	Shaded	Unshaded	Shaded	Unshaded	Shaded	Unshaded	Shaded	Unshaded	Shaded	Unshaded
1	1.88 ± 0.18^{Ba}	2.80 ± 0.63^{Aa}	3.75 ± 0.14^{Aa}	4.25 ± 0.14^{Aa}	65.06 ± 11.9^{Ba}	65.01 ± 6.45^{Aa}	1.84 ± 0.22^{Ab}	3.59 ± 0.82^{Aa}	99.15 ± 0.32^{Aa}	91.23 ± 2.97^{Bb}	1.38 ± 0.38^{Bb}	9.65 ± 5.11^{Ba}	7.30 ± 0.03^{Ab}	7.25 ± 0.14^{Aa}
2	2.22 ± 0.53^{Ab}	2.55 ± 0.26^{Aa}	4.00 ± 0.00^{Aa}	3.25 ± 0.48^{Ba}	60.15 ± 7.07^{Ba}	43.75 ± 15.99^{Bb}	2.18 ± 0.23^{Aa}	1.48 ± 0.25^{Ba}	95.30 ± 3.02^{Aa}	98.63 ± 0.48^{Aa}	4.83 ± 2.81^{Ab}	22.10 ± 11.25^{Aa}	6.88 ± 0.13^{Ba}	6.95 ± 0.05^{Aa}
3	2.38 ± 0.65^{Aa}	2.23 ± 0.32^{Ba}	3.13 ± 0.31^{Ba}	2.88 ± 0.31^{Ba}	76.25 ± 3.75^{Aa}	55.10 ± 6.45^{Bb}	2.85 ± 0.85^{Aa}	1.93 ± 0.42^{Ba}	98.18 ± 1.41^{Aa}	97.78 ± 0.43^{Aa}	3.55 ± 2.16^{Ab}	39.63 ± 16.78^{Aa}	7.38 ± 0.13^{Aa}	7.13 ± 0.13^{Aa}

Values (mean ± S.E.) within the same row bearing similar lowercase (small) letters and values within the same column bearing similar upercase (capital) letters are not significantly different at $p< 0.05$

thermal load on the scrotum [6]. Increased testicular temperature disturbs the normal absorptive and secretory function of epididymis and induces changes in ions and proteins of cauda epididymis which lower the progressive motility of sperms [31, 35].

During the experimental period the unshaded rams had a significantly ($p<0.05$) lower values of sperm cell concentration (SCC) (Table 4) in the last two weeks. This could be associated with the heating up of testes and damage in all stages of spermatogenesis and consequently decreased number of sperm produced. Elevated testicular temperature blocks A-spermatogonia differentiation [36, 37] and decreases Sertoli cells androgen binding protein [38, 39]. More over increased scrotal temperature induced dedifferentiation of adult Sertoli cells [51] and the number of immature sperms increase [4, 41]. The significantly ($p<0.05$) higher SCC in the unshaded rams in the 1st week compared to the shaded could be attributed to the fact that the secretion of the testicular fluid begins before spermatogenesis is fully established and persists if the sperm production is temporarily stopped by testicular heating [42].

The unshaded rams had a significantly ($p<0.05$) lower life sperms percent (LSP) in the 1st week and to the value obtained for the shaded rams (Table 4). This reduction could be related to the alteration of scrotal and epididymal thermoregulation mechanism of rams. and the insufficient independent testicular thermoregulation [43]. The lowered LSP could also be related to the depression in food intake, disturbance in the presence of nutritive materials necessary for spermatozoa and other germinal cells [42]. Similar findings of an increase dead sperm percent on exposure of testis and epidydimis to solar radiation were reported [16].

The exposure to direct solar radiation significantly ($p<0.05$) increased the abnormal sperms percent (ASP) in the last two weeks (Table 4). Compared to the shaded the unshaded rams showed a significantly higher values of ASP in the 1st ($p<0.05$), 2nd ($p<0.01$) and 3rd ($p<0.001$) weeks. The abnormal forms of head and tail were probably associated with metabolic and structural changes. During epididymal transit spermatozoa acquire certain selected proteins secreted by epithelial cells, the transformation of some of these proteins from cauda epididymal fluid to sperm cell surface is temperature sensitive being more efficient at 32-37C at optimal pH 6.0-6.5. Excess temperature prevents protein transformation and sperm maturation is not completed [44] and induces DNA break [45,]. Increased scrotal temperature increases the proportion of sperms with DNA damage [46]. apoptic changes [47] which is associated with high percentage of clusterin [48], a protein suggested to be a spermatozoal survival gene, the transcription of which is up regulated in physiologically adverse conditions. Similar findings were reported [30, 49].

This study indicates that exposure of desert rams to we-summer solar radiation in the tropics, influences their thermoregulation and semen characteristics. Accordingly, these findings should be considered in the breeding programs of desert rams in the tropics to improve their productivity. Further studies are needed to elaborate the effects of exposure of both male and female desert sheep to direct solar radiation and seasonal variation on their reproductive performance.

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