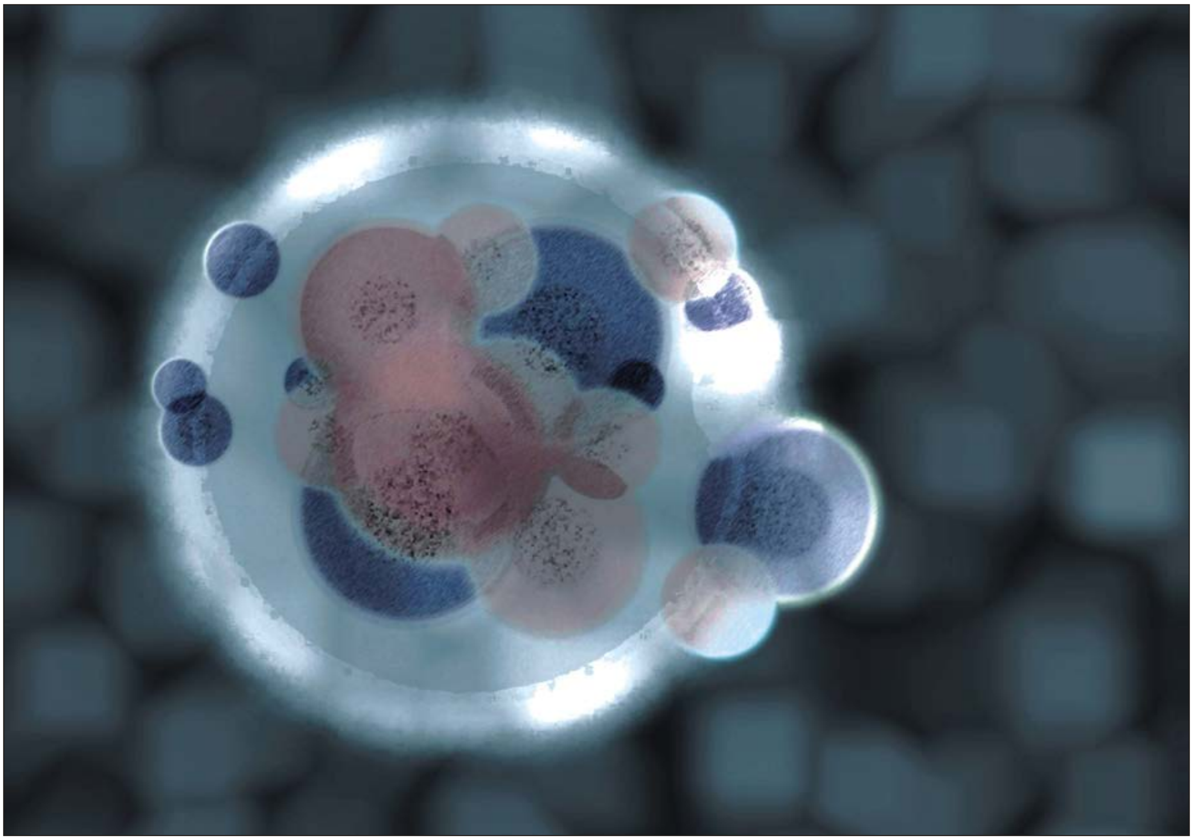

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Effects of Solar Radiation on Thermophysiological and Growth Parameters of Indigenous Black Bedwin Goat Kids in Southern Jordan

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Abstract: A study was conducted to examine the effects of solar Radiation exposure (RAD) on thermoregulatory and growth performance of goat kids. Five indigenous black Bedwin goat kids were exposed to daytime RAD (Days 8-28) after an initial 7 day Shading (SHD) period, while another 5 kids (n=5) were exposed to SHD regimen throughout the entire 28-day study period as a control group. Daily measurements (3 times, at 0600; morning, 1200; noon and 1900; night) included Respiratory Rate (RR), Heart Rate (HR) and Temperatures of skin (T_{skin}), hair coat (T_{coat}) and rectum (T_{rec}). Growth parameters including Body Weight (BW), Average Daily Weight Gain (ADWG), Average Daily Feed Intake (ADFI) and Feeding Efficiency (FE) were measured on days 1, 7 and 28. Response analyses within the total study duration were divided into 3 stages, stage 1 (first 7 days), stage 2 (next 10 days) and stage 3 (the last 11 days). Noon RR rose transiently from SHD levels for 2 days upon RAD onset and then returned back to SHD levels onwards. Values of HR increased in stages 2 and 3 compared to 1, without a treatment effect. Measurements of T_{skin} and T_{coat} at noon revealed an advantage of RAD over SHD group starting with RAD regimen. However, morning T_{skin} were lower in RAD group as compared to SHD during stage 3 compared to the previous stages. Unlike RR, T_{rec} did not experience any significant rise at any time of the day. Furthermore, no significant alterations were noticed in any growth parameter measured. The indigenous black Bedwin goats of Jordan seem to be highly tolerant to heat stress as evidenced by the lack of significant displacements in thermoregulatory and growth parameters after chronic exposure to solar radiation.

Key words: Solar radiation, heat stress, shade, goat, thermoregulation

INTRODUCTION

Black domestic goat is the primary breed in the Middle East[1]. In Jordan, goat population is estimated around 547,470 heads of which more than 96% is of the indigenous black Bedwin breed and about 2% Damascus line, with the remaining percentage as black Bedwin x-Damascus cross and other breeds[2]. About 10% of the red meat consumed is represented by goat meat (4,200 tons) annually. This particular interest in goats over other farm animals stems from the fact that goats are well known for their superior adaptability to harsh environmental stressors (heat, drought, scarcity of rangeland) compared to other farm animals, especially in predominantly semiarid regions. Excessive heat stress on farm animals from solar radiation in the geographical region around Jordan is well established[3]. However, the extent of thermotolerance to this stress by the indigenous local goat breed has not been thoroughly investigated. The objective of the current study was to assess thermoregulatory and growth performance of black Bedwin goat kids reared within semiarid climates of southern Jordan under 2 regimens, shade and solar exposures.

MATERIALS AND METHODS

Animals, feeding and management: Two groups of indigenous black Bedwin male weaned goat kids (Avg. BW = 24.02±2.80 kg) of similar age (242±6 days) reared under intensive system at the University of Mu'tah Animal Farm, located in southern Jordan were allocated to 2 treatments in a completely randomized design. Each animal was housed in an individual pen made of galvanized metal frames, with dimensions of 90x120 by 80 cm height. The first group of 5 kids was maintained in Shaded (SHD) housing facility for the 28 day duration of the study, while a second similarly sized group was housed for 7 days under SHD, then exposed to RAD onwards. All animals were fed *ad libitum* a standard ration (15% CP; NE of 2.4 Mcal kg^{-1}) composed of (as fed %) 45.3 barley grain, 15.7 soybean meal, 13.6 cracked corn, 13.6 wheat bran, 10.0 wheat straw, 0.9 salt, 0.5 limestone, 0.2 dicalcium phosphate, 0.2 mineral and vitamin premix and had free access to water.

Data collection: Daily thermophysiological data measurements included (in the subsequent order) RR, HR, T_{rec} and average T_{skin} from 3 shaved sites, left shoulder and femur, as well as mid-dorsal point. In addition, T_{coat} from adjacent spots to the shaved skin sites was also measured alongside T_{skin}. These measurements were taken 3 times daily at 0600 (morning), 1200 (noon) and 1900 (night) h throughout the 28 day study period. At each time, RR was measured first by counting inhalations and exhalations (breaths/minute) using a stethoscope placed laterally on the thoracic area, followed by HR (beats/minute) by placing the stethoscope ventrally. Then, T_{skin} and T_{coat} were determined using an infrared thermometer (Model 42530, Extech Instruments Corporation, MA, USA). Finally, T_{rec} was recorded using an immersion probe (YSI403, Cole Parmer Instrument Company, IL, USA) connected to a thermistor thermometer (DigiSense 93210-00, Cole Parmer Instrument Company, IL, USA). In addition to animal thermophysiological measurements, ambient (T_a; RTD PT100 OHM Thermometer, Model 421504, Extech Instruments Corporation, MA, USA) and black globe temperatures (T_{gb}) were concurrently measured at all 3 times daily, in both, shade and sun exposures. Body Weight (BW), Average Daily Feed Intake (ADFI), Average Daily Weight Gains (ADWG) and Feed Efficiency (FE) were determined from measurements on days 1, 7 and 28 of trial.

Statistics and calculations: All animal thermophysiological measurements (RR, HR, T_{skin}, T_{coat} and T_{rec}) and growth performance parameters (BW, ADFI, ADWG and FE) were analyzed by split plot ANOVA in time for repeated measures using General Linear Models (GLM) of Statistical Analysis Systems (SAS®)[4]. The random effect animal within treatment was used as the error term. Due to initial animal to animal slight variations in thermophysiological parameters, data was further transformed such that the change in stages 2 and 3 were compared to the averaged first 7 days (stage 1; baseline).

All values were expressed as means±SE. Statistically significant differences between any 2 means (determined by Fischer's LSD) were associated with p value less than 0.05, unless indicated otherwise. Wet Black Globe Temperature index (WBGT) was calculated using the equation: $WBGT = (0.7\ T_{wb}) + (0.2\ T_{bg}) + (0.1\ T_{db})$, where, T_{wb} is wet bulb temperature (°C), T_{gb} is black globe temperature (°C); T_{db} is dry bulb temperature (°C). Temperature Humidity Index (THI) was computed according to NOAA[5]. Finally, Black Globe Humidity Index (BGHI), was calculated as described by Buffington *et al.*[6]. All meteorological measurements during the experiment are presented in Table 1.

Table 1: Meteorological measurements during the experiment

	Time of day			
Parameters	Morning	Noon	Night	SEM
Dry bulb temperature				
Shade	22.47	35.47	29.84	0.11
Sun	22.47	35.47	29.84	0.11
Wet bulb temperature				
Shade	16.86	19.59	18.18	0.06
Sun	16.86	19.59	18.18	0.06
Black globe temperature				
Shade	20.53	34.62	29.56	0.13
Sun	30.49	45.17	40.15	0.28
Wet black globe temperature				
Shade	18.12	24.21	21.84	0.06
Sun	20.11	26.39	23.84	0.07
Black globe humidity index				
Shade	66.50	79.38	74.75	0.12
Sun	76.46	89.93	85.34	0.29
Temperature humidity index				
Shade	68.35	80.16	74.96	0.04
Sun	68.35	80.16	74.96	0.04

Table 2: Effects of noon solar Radiation (RAD; Day 8-28) or Shading (SHD) regimens on percentage change of skin Temperatures (T_{skin}) of goat kids

	Treatment group		
Stages	RAD	SHD	SEM[a]
1	0.00[bd]	0.00[bd]	
2	2.48[be]	1.23[ce]	0.67
3	-1.77[bcf]	-2.89[bf]	0.67

[a]Standard error of means
[bc]Row means with different superscripts differ(treatment by stage interaction)
[def]Column means with different superscripts differ (stage effect)

Table 3: Effects of noon solar Radiation (RAD; Day 8-28) or Shading (SHD) regimens on morning-time percentage change of skin Temperatures (T_{skin}) of goat kids

	Treatment group		
Stages	RAD	SHD	SEM[a]
1	0.00[bd]	0.00[bd]	
2	-0.40[bd]	0.34[bd]	0.67
3	-4.93[be]	-0.97[cd]	0.67

[a]Standard error of means
[bc]Row means with different superscripts differ (treatment by stage interaction)
[de]Column means with different superscripts differ (treatment by stage interaction

Table 4: Body Weight (BW), Average Daily Feed Intake (ADFI) and Weight Gain (ADWG) and Feeding Efficiency (FE) of goat kids exposed to noon solar Radiation (RAD; Day 8-28) or Shading (SHD) regimens[a]

	Treatment group		
Parameters	RAD	SHD	SEM[b]
Initial BW (kg)	24.84	23.20	2.80
Final BW (kg)	28.92	26.19	3.14
BW Gain (kg)	4.08	2.99	0.95
ADFI (kg day^{-1})	1.14	1.05	0.06
ADWG (kg day^{-1})	0.15	0.13	0.34
FE[c]	7.93	9.48	1.77

[a]No significant differences ($p>0.24$) occurred across treatment groups for all parameters measured, [b]Standard error of means
[c]Feeding Efficiency = body weight gain/total feed intake

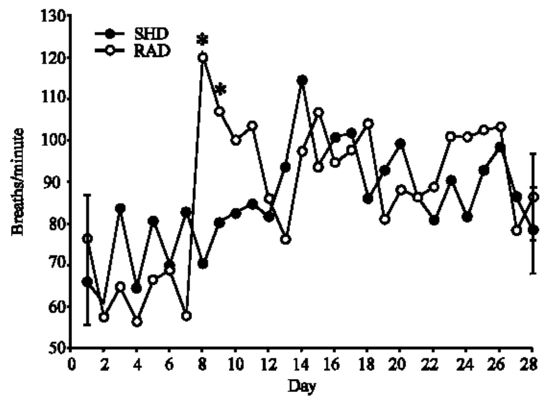

Fig. 1: Effect of noon solar Radiation (RAD; Day 8-28) or Shade (SHD) regimens on Respiratory Rate (RR) of goat kids *= Treatment by day interaction (p<0.05)

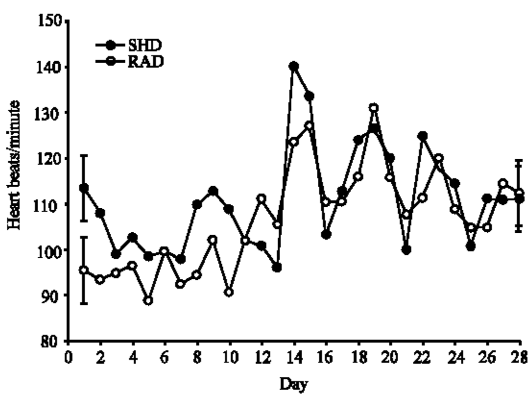

Fig. 2: Effect of noon solar Radiation (RAD) or Shading (SHD) regimens on Heart Rate (RR) of goat kids

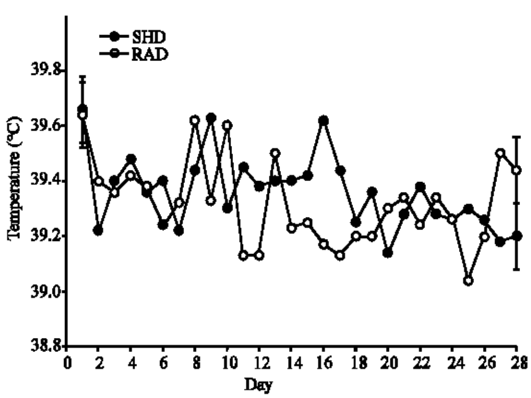

Fig. 3: Effect of noon solar Radiation (RAD; Day 8-28) or Shading (SHD) regimens on rectal Temperature (T_{rec}) of goat kids

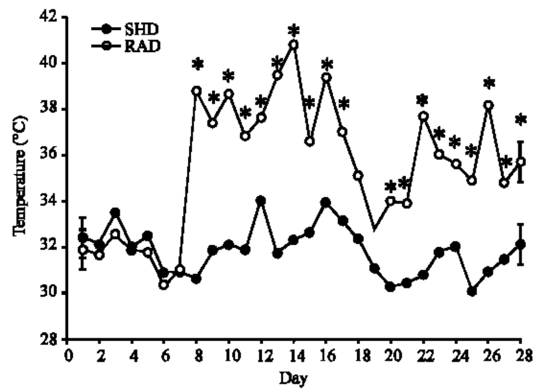

Fig. 4: Effect of noon solar Radiation (RAD; Day 8-28) or Shading (SHD) regimens on Temperature of hair coat (T_{coat}) of goat kids *= Treatment by day interaction (p<0.05)

RESULTS

Throughout the first 7 days of the experiment (stage 1), average daily values of noon RR of animals across both treatment groups exhibited similar values (Fig. 1). Starting on day 8 (first day of RAD), however, RAD group experienced a pronounced RR elevation over SHD group (120.0 and 70.4±10.4 breaths/minute, respectively) with a significant ($p<0.05$) correlation between RR of RAD kids with WBGT ($r^2 = 0.61$). Two days later (Day 10), nevertheless, values of RR were comparable among both groups and remained so until the end of the experiment on day 28. No significant differences were found among treatment groups or stages of morning or night times.

No significant differences were noticed in HR among treatment groups throughout the study period at any time of the day (Fig. 2).

The percentage change in T_{skin} showed a significant elevation during noon in sun-exposed groups over SHD counterparts (Table 2) in stage 2. Interestingly, however, the RAD group exhibited significantly lower ($p<0.01$) morning T_{skin} than SHD group during stage 3 (Table 3). No other differences were found in T_{skin} among treatment groups in other periods tested. Relative to T_{coat}, average daily values (Fig. 3) in RAD group rose significantly for 19 out of the 20 days total of stages 2 and 3 over SHD averages during noon time. No other significant changes were found during morning or night between the 2 groups. Both treatment groups exhibited similar ($p>0.05$) values of T_{rec} throughout the study period (Fig. 4). Likewise, ADFI, ADWG and FE were similar ($p>0.24$) across treatments (Table 4).

DISCUSSION

Exposure to the RAD regimen resulted in a noticeable divergence in RR among treatment groups, indicating an increase in respiratory evaporative cooling mechanism to counterbalance elevated heat load from radiative heat. This tachypnea (increased respiration frequency) following heat stress is in agreement with previous studies on goats[7], sheep[8] and cattle[9].

Animals exposed to solar radiation maintained a significant lead over SHD in percentage change of T_{skin} during stage 2 at noon (Table 2). This is expected primarily because of the direct exposure of skin surfaces to sun rays and possibly due to the likely peripheral vasodilation triggered by heat stress. Unexpectedly, however, morning percentage change in T_{skin} during stage 3 revealed significant ($p<0.01$) down regulation in RAD group relative to SHD equivalents (Table 3), implying a compensatory backshift in blood distribution from peripheral to splanchnic regions during the cooler morning hours following periods of cutaneous vasodilation during peak heat stress to visceral blood supply. It is unlikely though, that the cardiovascular adjustments and peripheral vasodilation were extensive as evidenced by lack of noticeable alteration in HR.

Previous reports with other breeds of goats have demonstrated prolonged elevations of T_{rec} in animals experiencing heat stress[10]. However, in the present experiment, such a displacement was only noticed for 2 days coinciding with sudden shift from SHD (Day 7) to RAD (Days 8 and 9), suggesting a great extent of thermotolerance by the indigenous black bedwin goats of Jordan. In fact, the absence of correlation between RR and T_{rec} in RAD group indicates that these animals have the ability to maintain homeothermy against solar radiative insult by a transient and agile shift in RR and subsequent maximization of evaporative cooling.

The absence of variation in growth parameters among treatment groups in the weaned and growing black bedwin kids reinforces the basic axis that this domestic breed has acquired long term adaptation to harsh environmental conditions in predominantly semiarid locations within the Middle East, in agreement with Silanikove[11,12].

This study sheds basic light upon the thermoregulatory and growth performance of the black bedwin goats of Jordan exposed to summer-time solar heat stress. This particular species and breed appears to have a great extent of thermoregulatory agility proven by rapid adjustment of RR to encounter heat stress in order to maintain core body temperature reflected by T_{rec} within subtle alteration. Also, this is further emphasized by the lack of deviation in growth performance after chronic heat stress. More studies are needed to further investigate other qualities of the black bedwin goats underlying its superior thermotolerance.

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