J.Animal and Poultry Prod., Mansoura Univ., Vol.2(10): 411 – 426 ,2011

EFFECTS OF SEASON, HOUSING ENVIRONMENT AND WATER DEPRIVATION ON RECTAL AND SKIN TEMPERATURE REGULATION IN BARKI DESERT SHEEP

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ABSTRACT

This study was conducted at Maryout Experiment Station near Alexandria, 32° latitude, affiliated to the Desert Research Center in Cairo. In this study, the effect of heat stress resulting from the combined effects of water deprivation, the housing environment and season of the year on the changes of rectal (RT) and skin temperature (ST) and their amplitude (differences between morning and afternoon values), as well as gradients between core and surface temperatures and the ambient temperature were investigated in eight non-pregnant and non lactating adult 4-5 years old Barki ewes fed at the maintenance energy level. Half the animals were watered daily whereas the other half was watered intermittently, once every 3 days. Moreover, half the animals were kept outdoors and not sheltered whereas the other half was housed indoors. The experimental treatments were repeated three times between April and August to represent spring, early summer and late summer seasons. Ambient temperature (Ta), relative humidity (RH%) and animal data, rectal (RT) and skin (ST) temperatures were recorded twice daily at 7:00 AM and 2:00 PM for three consecutive days representing a complete water deprivation cycle.

It was noticeable that the housing environment was a significant source of variation affecting RT, ST and their amplitude, as well as core, skin, and ambient temperature gradients. RT and ST were always lower outdoors than indoors in the morning. Conversely, in the afternoon they were higher outdoors than indoors. Therefore, outdoor RT and ST differences (PM-AM) and gradients were greater than those indoors. On the other hand, time of the year (spring, early summer, and late summer) was a statistically significant source of variation affecting ST and rectal-skin gradient in the afternoon and rectal-air and skin-air in the morning and in the afternoon. The effect of water deprivation was not significant on RT, ST, their amplitude or gradients. Evident was the capacity of sheep to maintain constant, the overall rectal-air temperature gradient through varying rectal-skin and skin-air gradients, and invariably in opposite direction. This was aided by the fact that Ta were constantly lower than the RT and ST. Hence, the temperature of the skin and its regulation determines to a large extent the core temperature of sheep. In further studies gradual and long term adaptation experiments, longer cycles of water deprivation and measurement of body fluid changes and stress telated hormones would be needed.

Keywords: Sheep, dehydration, season, shelter, thermoregulation

INTRODUCTION

Desert ungulates must contend with high solar radiation, high ambient temperature, lack of water and shelter, unpredictable food resources, and the challenges these factors present for thermoregulation and water balance (Feld-hamer *et al*., 1999). The factors that influence the heat load imposed on an animal by the environment include direct and reflected solar radiation, air temperature, wind speed, and vapor pressure; the environmental heat load plus the metabolic heat produced by the animal comprise the overall heat load (Porter and Gates 1969). When body temperatures are higher than ambient temperatures, animals lose heat to the environment passively by radiation, convection, and conduction (Mitchell 1977). If the temperature gradient between the animal and the environment becomes too small or when ambient temperature exceeds body temperature, evaporative cooling must be used to maintain body temperature within acceptable limits (Taylor 1977). Desert ungulates use a variety of physiological, morphological, and behavioral mechanisms to deal with the conflicting challenges of maintaining body temperatures within acceptable limits and minimizing water loss.

The present study deals with observations of rectal and skin temperature changes in response to the stress of direct exposure to day and night climatic elements, intermittent water intake and protein deficiency imposed concomitantly on Barki sheep during different seasons.

MATERIALS AND METHODS

Animals and Management:

Eight non-pregnant and non-lactating adult female Barki ewes were used in the experiment. Their live body weights averaged 45 kg and were 4-5 years old. Half the animals were housed individually in floor pens inside a barn whereas the other half was kept outdoors, tied to individual mangers and not sheltered from direct solar radiation and other environmental elements. In addition to housing effects, the animals were subjected to two experimental treatments, i.e. the level of protein intake and daily vs. intermittent watering, once every three days. The experiment was repeated three times between April and August to represent spring, early summer and late summer seasons. Each period lasted six weeks, a 30-day preliminary period, 6 days for a digestion and nitrogen balance trial and 6 days for the study of animal adaptation. Environmental and animal adaptation measurements were taken during 1-7 May, 20-26 June and 4-10 August.

Animals were weighed periodically every two weeks before morning feeding and watering. Feeds were offered in the morning as per treatments detailed below. Refusals if any were collected the following morning and weighed and sampled before the new feeds were offered. Water was made available free choice for one hour at feeding time as per treatments and intake was recorded.

Experimental treatments:

Animals were subjected to two water treatments. Half the animals were watered daily whereas the other half intermittently, once every three days. More severe water deprivation was not intended in fear of the combined effect of heat stress and the shortage of water on animal welfare especially those kept unsheltered outdoors.

The sheep were fed at the maintenance level as per maintenance requirements determined locally, being 2.20 g DCP and 28.29 g TDN per $kg^{0.73}$ (Farid *et al.*, 1983). Ingredients used to formulate the rations included a commercial concentrate mixture and corn grains, and rice straw was the roughage. All animals received 100% of their estimated energy requirements for maintenance. There were two levels of protein intake, however, 100% and 50% of their estimated digestible protein requirements for maintenance.

Climatic data:

The experiment was carried out at a site some 35 km south-west the city of Alexandria and about 20 km from the Mediterranean Sea shore. The following climatic elements were measured using standard equipments: 24-hour minimum (Tmin) and maximum (Tmax) temperatures, and dry-bulb ambient temperatures (Ta) and relative humidity (RH) at 7:00 AM and 2:00 PM Egypt standard time, EST = GMT+2. Table 1 summarizes the main climatic elements observed during the three experimental periods. They were typical of conditions prevailing in arid desert areas close to seashores. Both climatic and animal data were recorded for a full water deprivation cycle, i.e. three consecutive days.

Table (1): Average climatic data during the three experimental periods and for measurements taken at 7:00 AM and 2:00 PM

	Season[1]	Tmin (°C)	Tmax (°C)	Ambient (Ta)		Humidity %	
				AM	PM	AM	PM
Housing	SP	16.67	24.17	19.00	22.50	70.09	60.29
	ES	23.97	32.50	26.50	31.67	68.47	48.56
	LS	25.00	31.17	25.33	30.67	79.15	61.82
Outdoors	SP	16.67	26.67	19.33	23.00	69.34	52.18
	ES	24.00	37.00	26.33	24.83	69.37	38.69
	LS	24.33	37.00	25.33	34.50	76.84	44.78

SP = spring period, (1-7 May), ES = early summer period (20-26 June) and LS = late summer period (4 –10 Aug).

Rectal (RT) and skin (ST) temperatures:

Rectal and skin temperatures were measured, also at 7:00 AM and 2:00 PM. A thermocouple thermometer was used (Yellow Springs Instruments Co. Inc., Yellow Springs, Idaho, U.S.A.). Skin temperatures were measured from a shaved area in the mid-side region. Both climatic and animal data were recorded for a full water deprivation cycle (three consecutive days.)

Statistical procedures:

Factorial analysis of variance was performed using the GLM model of the NCSS statistical package (Hintze 2006). F-test was performed for the main effects and the 2-way interactions. Higher interactions were included in the error term. The effects of the level of protein intake were not significant throughout and the data were pooled accordingly. Duncan's multiple range tests were applied to the means of the main effects as performed in the NCSS package.

RESULTS

Observed minimum temperature (Tmin) and maximum temperature (Tmax) were lower in spring than those in early and late summer (Table 1). Minimum temperatures were practically similar indoors and outdoors, but the maximum were (5-6 ^{0}C) higher outdoors. The same applies to AM and PM ambient temperatures measured at 7:00 AM and 2:00 PM except that the AM temperatures were greater than the minimum and the PM temperatures were less than the maximum. As anticipated, RH% was higher in the cool morning than that in the afternoon, and higher indoors than outdoors. It was particularly low outdoors in early summer during PM times.

Rectal Temperature (RT):

Morning RT of the animals kept indoors was significantly ($p < 0.01$) higher than their mates in outdoors. The opposite trend was observed in the afternoon (Table 2). However, the effect of water deprivation was significantly ($p < 0.05$) evident only in the morning. The morning water deprived animals had significantly higher RT than their control mates (38.4 and 38.2 ^{0}C). However, in the afternoon, the RT of animals of both groups increased (39.0 and 39.1 ^{0}C), but the difference between the two groups was not significant.

Table (2): Rectal temperatures (RT, °C) in the morning (7:00 AM) and in the afternoon (2:00 PM) and their amplitude (PM–AM) values in daily watered (W) and water-deprived (W.D.) sheep housed indoors or outdoors and during different seasons (L.S. Means ± SEM)

Item	Water	Housing		Season			Means (water)
		Indoors	Outdoors	Spring	E-Summer	L-Summer	
Rectal T, AM	W	38.6	73.8	38.2	38.2	38.3	**38.2^{b}**
	W.D.	38.6	38.1	38.7	38.1	38.3	**38.4^{a}**
	Means	**38.6^{a}**	**38.0^{b}**	**38.4^{a}**	**38.1^{b}**	**38.3^{a}**	
	SEM±	0.04		0.05			**0.04**
	F Test	**		**			*
Rectal T, PM	W	38.8	39.1	38.8	39.1	39.0	**39.0^{a}**
	W.D.	38.9	39.3	39.0	39.1	39.1	**39.1^{a}**
	Means	**38.8^{b}**	**39.2^{a}**	**38.9^{a}**	**39.1^{a}**	**39.0^{a}**	
	SEM±	0.05		0.06			**0.05**
	F Test	**		N.S			**N.S**
Amplitude	W	0.21	1.3	0.54	0.96	0.73	**0.74^{a}**
	W.D.	0.25	1.2	0.39	1.02	0.75	**0.72^{a}**
	Means	**0.23^{b}**	**1.2^{a}**	**0.47^{c}**	**0.94^{a}**	**0.74^{b}**	
	SEM±	0.06		0.07			**0.06**
	F Test	**		**			**N.S**

Means with different superscripts in each subcell differ significantly at (P<0.05) level

In spring, RT tended to increase as water deprivation progressed, and controls had lower RT than their water deprived mates. In early and in late summer, morning RT was particularly constant or tended to decrease slightly

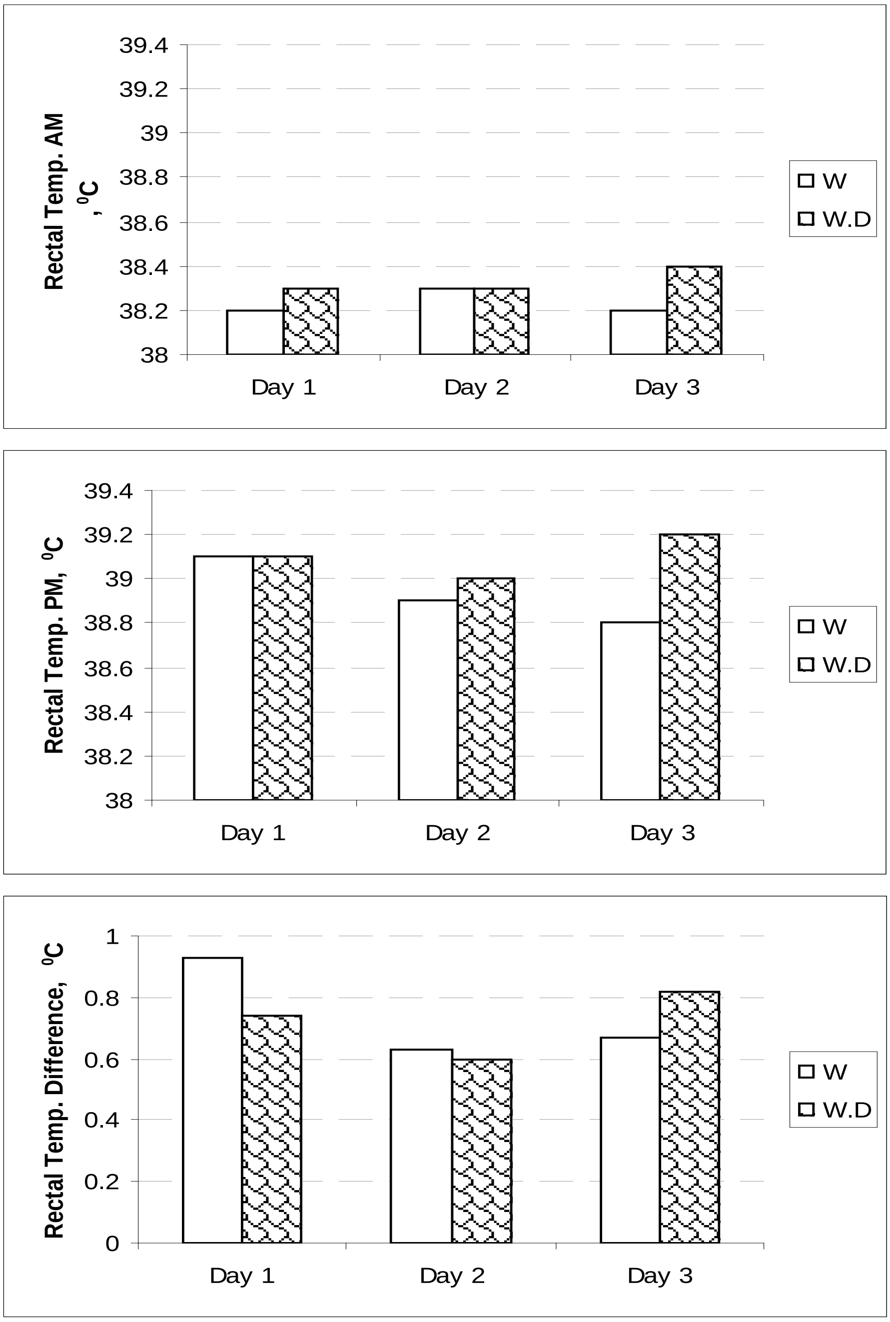

Figure (1): Rectal temperature AM and PM of daily watered (W)and water-deprived (W.D.) sheep and their amplitude during the3-day water deprivation cycle

(Table2). It was interesting to note that the water deprived animals in early summer had significantly lower RT than the other seasons. The afternoon RT, on the other hand, was less ($P<0.05$) in the spring than in early and late summer.

The pattern of RT changes of the water deprived animals and controls through the three-day cycle, both AM and PM are presented in Figure 1. In general, the rectal temperature of the daily watered (W) and water deprived (WD) animals were practically similar in the first two days. Thereafter, the RT of WD sheep increased in the last day of the water deprivation cycle.

On average, the rectal temperature amplitude (i.e. PM-AM difference) were almost similar in control and water deprived animals, 0.74 ^{0}C and 0.72 ^{0}C, respectively (Table 2 and Figure 1). However, it was about 5 folds greater ($P<0.01$) in outdoor than indoor animals (1.20 and 0.23 ^{0}C, respectively.

On the other hand, RT amplitude increased significantly ($P<0.01$) in early and late summer, and was lowest in spring (0.47, 0.94, 0.74 ^{0}C). During the water deprivation cycle, RT differences of the water deprived animals were lower than that of their control mates, but in the last day of water deprivation, it increased to be higher than that of the controls, in accordance with the observed increase in RT of the WD animals on the last day of the cycle as indicated above. In general, these amplitude differences were small and not exceeding one degree, pointing out the thermoregulation capability of the animals under the prevailing set of environmental conditions (Table 1).

Skin temperature (ST):

Variations in ST were of a similar trend to the observed variations in RT indicated above. The skin temperature of sheep was found to be significantly affected by the housing environment (Table 3). In general, morning ST was significantly higher ($P<0.01$) indoors than outdoors (37.5 vs 36.9 ^{0}C, respectively). The opposite trend was observed in the afternoon, 37,3 vs 38.2 ^{0}C for indoors and outdoors respectively. On the other hand, morning ST did not change significantly through seasons, whereas in the afternoon it increased significantly ($P<0.01$) in early and late summer as compared to the spring (36.4, 38.6, 38.3 ^{0}C). Although the skin temperatures of the WD ewes were always higher than the controls, water deprivation was not a statistically significant ($P>0.05$) source of variation affecting the skin temperature.

The housing environment affected significantly ($P<0.01$) the Skin temperature amplitude, i.e. PM-AM difference (Table 3). The outdoor sheep had about eight times the ST differences as their indoor mates, -0.16 *vs*. 1.39 ^{0}C for indoors and outdoors, respectively. Water deprivation was found to be a non-significant source of variation affecting ST differences. The ST differences was almost the same of the WD animals and controls, 0.55 *vs.* 57 ^{0}C, respectively. The (ST) differences of the animals increased significantly ($P < 0.01$) in early and late summer than in the spring.

Table (3): Skin temperatures (ST, °C) in the morning (7:00 AM) and in the afternoon (2:00 PM) and their amplitude (PM–AM) values in daily watered (W) and water-deprived (W.D.) sheep housed indoors or outdoors and during different seasons (L.S. Means ± SEM)

Item	Water	Housing		Season			Means (water)
		Indoors	Outdoors	Spring	E-Summer	L-Summer	
Skin T, AM	W	37.4	36.8	36.9	37.3	37.1	**37.1^a**
	W.D.	37.5	37.1	37.5	37.1	37.3	**37.3^a**
	Means	**37.5^a**	**36.9^b**	**37.2^a**	**37.2^a**	**37.2^a**	
	SEM ±	0.08		0.09			**0.08**
	F Test	**		N.S			**N.S**
Skin T, PM	W	37.3	38.0	36.1	38.7	38.1	**37.6^a**
	W.D.	37.3	38.5	36.6	38.6	38.4	**37.9^a**
	Means	**37.3^b**	**38.2^a**	**36.4^c**	**38.6^a**	**38.3^b**	
	SEM ±	0.1		0.12			**0.1**
	F Test	**		**			**N.S**
Amplitude	W	-0.07	1.2	-0.77	1.36	1.06	**0.55^a**
	W.D.	-0.24	1.4	-0.90	1.50	1.12	**0.57^a**
	Means	**-0.16^b**	**1.3^a**	**-0.84^b**	**1.4^a**	**1.1^a**	
	SEM ±	0.121		0.148			**0.121**
	F Test	**		**			**N.S**

Means with different superscripts in each subcell differ significantly at (P<0.05) level

Temperature gradients:

The skin might be considered as a protective barrier between the core temperature, and the surrounding environment, i.e. temperature, humidity, solar radiation, wind velocity, etc. Therefore, the rectal/skin (R/S) and skin/air (S/A) gradients are of paramount importance to heat dissipation to, or gain from the environment, as the case may be. Those gradients were evaluated in the present experiment. At the outset, it is noteworthy to mention that through the experiment the ambient temperature was always lower than both core and skin temperatures irrespective of the housing environment, season or the water treatment. That is, there was no net direct heat gain from the environment, perhaps except for some heat gain from solar radiation. However, as gradients varied between seasons, housing and water treatments, effective heat dissipation may have been different in magnitude.

Overall, R/A gradient amounted to 12.05 ^{0}C (14.6 AM and 9.5 PM) was due to the fact that Ta was always lower than the animals' core temperature, more so in the morning (Tables 4, 5 and 6). The R/S gradient was only a small fraction of the total R/A gradient, 1.18 ^{0}C and was not different between morning and afternoon. On the other hand, the S/A gradient was five folds greater (10.82 ^{0}C) and was different between AM and PM, 13.50 ^{0}C and 8.15 ^{0}C, respectively.

Irrespective of treatments, S/A and R/A gradients were greater in the morning than in the afternoon because of the lower morning ambient temperature. However, the R/S gradient was greater in the afternoon ($P>0.05$). The S/A and R/A gradients decreased significantly ($P<0.01$) in summer than the spring due to the increased ambient temperature. The effect of housing environment was also related to the ambient temperature and the other climatic variables. Of particular importance were the afternoon gradients, and the morning to a lesser extent. The R/A and S/A gradients decreased significantly ($P<0.01$) in the outdoor animals in the morning and in the afternoon. However, the R/S gradient changes significantly decreased only in the afternoon.

The effect of water deprivation on temperature gradients was not significant ($P>0.05$) and was minor in magnitude. Evident was the capacity of the animals to maintain constant overall R/A gradient, i.e. achieving thermo-stability through minimal variation in R/S gradient and changing the S/A gradient.

Table (4): Rectal-skin temperature gradients (RT - ST, °C) in daily watered (W) and water-deprived (W.D.) sheep housed indoors or outdoors and during different seasons (L.S. Means ± SEM)

Item	**Water**	**Housing**		**Season**			**Means (water)**
		indoors	**outdoors**	**spring**	**E-summer**	**L-summer**	
7:00 AM	W	1.2	0.95	1.4	0.84	1.1	**1.1^{a}**
	W.D.	1.1	1.0	1.1	1.0	1.1	**1.1^{a}**
	Means	**1.2^{a}**	**1.0^{a}**	**1.2^{a}**	**0.92^{a}**	**1.1^{a}**	
	SEM±	0.09		0.108			**0.09**
	F Test	N.S		N.S			**N.S**
2:00 PM	W	1.5	1.2	2.7	0.44	0.88	**1.3^{a}**
	W.D.	1.6	0.86	2.5	0.57	0.71	**1.2^{a}**
	Means	**1.6^{a}**	**1.0^{b}**	**2.6^{b}**	**0.51^{a}**	**0.79^{a}**	
	SEM±	0.09		0.107			**0.09**
	F Test	**		**			**N.S**

Means with different superscripts in each subcell differ significantly at ($P<0.05$) level

Table (5): Skin-air temperature gradients (ST - Ta, °C) in daily watered (W) and water-deprived (W.D.) sheep housed indoors or outdoors and during different seasons (L.S. Means ± SEM)

Item	**Water**	**Housing**		**Season**			**Means (water)**
		Indoors	**Outdoors**	**Spring**	**E-Summer**	**L-Summer**	
7:00 AM	W	13.8	13.1	17.6	10.9	11.8	**13.4^{a}**
	W.D.	13.9	13.4	18.4	10.6	11.9	**13.6^{a}**
	Means	**13.8^{a}**	**13.2^{b}**	**18.0^{a}**	**10.8^{c}**	**11.8^{b}**	
	SEM±	0.09		0.11			**0.09**
	F Test	**		**			**N.S**
2:00 PM	W	8.9	7.2	13.3	5.3	5.6	**8.0^{a}**
	W.D.	8.9	7.6	13.8	5.3	5.8	**8.3^{a}**
	Means	**9.0^{a}**	**7.4^{b}**	**13.6^{a}**	**5.3^{b}**	**5.7^{b}**	
	SEM±	0.11		0.13			**0.11**
	F Test	**		**			**N.S**

Means with different superscripts in each subcell differ significantly at ($P<0.05$) level

Table (6): Rectal-air temperature gradients (RT - Ta, °C) in daily watered (W) and water-deprived (W.D.) sheep housed indoors or outdoors and during different seasons (L.S. Means ± SEM)

Item	Water	Housing		Season			Means (water)
		indoors	**outdoors**	**spring**	**E-summer**	**L-summer**	
7:00 AM	W	15.0	14.0	19.0	11.7	12.8	**14.5^{a}**
	W.D.	15.0	14.4	19.5	11.6	13.0	**14.7^{a}**
	Means	**15.0^{a}**	**14.2^{b}**	**19.2^{a}**	**11.7^{c}**	**12.9^{b}**	
	SEM±	0.07		0.09			**0.07**
	F Test	**		**			**N.S**
2:00 PM	W	10.4	8.3	16.0	5.7	6.4	**9.4^{a}**
	W.D.	10.6	8.5	16.3	5.9	6.5	**9.6^{a}**
	Means	**10.5^{a}**	**8.4^{b}**	**16.2^{a}**	**5.8^{c}**	**6.5^{b}**	
	SEM±	0.10		0.11			**0.10**
	F Test	**		**			**N.S**

Means with different superscripts in each subcell differ significantly at (P<0.05) level

DISCUSSION

Thermo-regulatory mechanisms:

Heat stressed, normally-hydrated desert-adapted ungulates including ruminants with free access to drinking water typically maintain body temperature within a fairly narrow range. This is achieved by activating evaporative cooling mechanisms (Taylor 1970a, 1970b). While some species must maintain body temperature within narrow range regardless of their state of dehydration, body temperature of other species fluctuate over wider range when dehydrated. The larger the range over which body temperature fluctuates in dehydrated versus hydrated animals is often attributed to "adaptive heterothermy" which is a heat-dissipating but water-conserving function (Schmidt-Nielsen *et al*, 1957, Taylor 1970a, 1970b, 1972, Taylor and Layman 1972, and Shoen, 1972).

Selective brain cooling, i.e. the reduction of brain temperature below that of arterial blood, is most evident in animals which possess a specialized anatomical structure, the “carotid rete”. Traditionally it has been considered to protect the brain during exertional hyperthermia. Rather, it has been also found that animals use it at rest under moderate heat load (Baker, 1979). Also, selective brain cooling is enhanced in animals under conditions of drinking water deficit (Jessen *et al,* 1998, and Fuller *et al.*, 2007). Countercurrent heat exchange at the carotid rete can result in arterial blood entering the brain to be $\leq$ 3.9°C cooler than the rest of the body (Taylor 1972). Moreover, Mitchell *et al*., (2002) hypothesized that selective brain cooling is used in free ranging animals to switch from evaporative to non-evaporative routes of heat dissipation and therefore has a water conserving thermoregulatory function unrelated to "adaptive heterothermy" and may be an addition to it. Also selective brain cooling is not a passive side-effect of panting, but a controlled thermoregulatory mechanism possibly with the temperature of hypothalamus as the regulated variable (Johnson *et al*, 1987). Its effect is to economize the onset of panting (and shivering), and to establish a range of internal temperatures within which metabolic rate and respiratory evaporative heat loss are simultaneously at low level (Kuhnen and Jessen, 1992).

Sheep are among the species which exhibit diurnal variation in rectal temperature in response to varying environmental conditions (Khalifa 1982, Christopherson and Cosgrove 2000, Khalil *et al*. 1985 and Khalil. 1990). Sheep have been lately reported also to employ selective brain cooling during dehydration and heat stress (Fuller *et al*, 2007). These authors concluded that dehydrated sheep exposed to heat exhibit selective brain cooling up to three folds greater than that when hydrated.

In the present work, sheep were able to maintain their body temperature within fairly narrow range, even under conditions of water deprivation in the hot environment of unsheltered outdoor housing. Housing environment was found to affect rectal and skin temperatures significantly ($P<0.01$) in the morning and in the afternoon. RT and ST were always lower in outdoors than indoors in the morning. In the afternoon, RT and ST increased in outdoors than indoors. Therefore, rectal and skin differences (PM-AM) were higher outdoors than indoors. The higher magnitude of increase in RT during period of increased heat stress suggests that these animals can store body heat during the hot day to be lost passively during the cooler night. This can help economize the loss of water needed for evaporative heat loss (Schmidt-Nielsen *et al*. 1957 and Srikandakumar *et al*. 2003). Similar results on sheep were obtained by Shalaby, (1985), Marai *et al*. (1997, 2000) and others. The increase of RT and ST outdoors may be due to heat gain mainly from solar radiation because throughout the experiment the ambient temperatures were always lower than those of the animals' RT and ST. The present results are in agreement with those obtained by Johnson (1987), Marai *et al*. (1997, 2007), Ismail *et al*. (1996) and Mckinley *et al*. (2009).

When the dehydrated animal is exposed to an ambient temperature higher than body temperature, they reduce water loss by reducing thermoregulatory evaporation through the skin and lungs and allow body temperature to rise (Bianca, 1966, 1968, Seif *et al*, 1973, Robertshaw and Dmi'el, 1983 and Igbokwe 1997). However, where ambient temperature is lower than or comparable to body temperature, rectal temperature of water deprived ruminants may remain around normal range or decrease, so that tendency to hyperthermia may be reduced. The water deprivation factor did not affect RT or ST temperature significantly under the present experimental conditions.

On the other hand, the time of the year (spring, early summer, and late summer) was a statistically significant ($P<0.01$) source of variation affecting ST in the afternoon, whereas RT was slightly affected by season. This latter result revealed that the skin temperature of sheep was more sensitive than rectal temperature to the climatic conditions throughout seasons, especially solar radiation, because the ambient temperatures throughout the experiment were always lower than that of the animals' RT and ST.

As indicated above, the insignificant changes of the rectal temperature through seasons, although the ambient temperature increased in summer, can be attributed to the significant increase of skin temperature. As the ambient temperature increased, the cutaneous thermo-receptor would initiate sweating as an immediate defense mechanism and relay signals to the anterior hypothalamus regulating centers causing peripheral vasodilatation and increased sweating and/or panting. Increased peripheral blood flow (vasodilatation) results in elevated skin temperature and a greater heat loss from the skin to the environment (Folk, 1974). The increased skin temperature resulted in decreased rectal-skin and skin-ambient gradients, which in turn decreases the heat gain from the environment. The sweat rate of the same animals increased significantly in summer and also did the skin temperature (El Zeiny 2011). The significant ($P<0.05$) sweat differences through seasons and in outdoors than indoors may be due to the fact that the exposure to direct solar radiation is important in the stimulation of sweating in ungulates (Maloiy and Hopcraft, 1971, Finch 1972, Dm'iel, 1986, and Robertshaw 1985). The effect of water deprivation on temperature gradients was not significant and was minor in magnitude. Evident was the capacity of the animal to maintain constant overall R/A gradient, i.e. achieving thermo-stability through minimal variation in R/S gradient and changing the S/A gradient.

The role of body fluids:

The observed pattern of changes in RT and ST from day to day and from time to time revealed that during water deprivation 3-day cycle, the rectal temperature of watered and water-deprived animals was practically similar in the first two days, but the RT of water deprived animals increased on the third day of water deprivation. This result may be due to the fact that thermoregulation in mammals is linked inextricably with body fluid balance (Taneja 1965, Macfarlane and Howard 1972, Purohit 1979, Simon *et al*. 1986, Olsson and Dahlborn 1989 and Abdelatif and Ahmed 1994). Plasma volume and blood volume of the same animals in the same experiment also decreased on the third day of water deprivation (Asaad, 1997). This result is in agreement with that of Abdelatif *et al* (2010) and Simon *et al* (1986).

Also in the same experiment with same animals, there was statistically significant increase in the blood and plasma volume in outdoor animals (Asaad, 1997). This result was in agreement with Silanikove (1987) and Chaiyabtur *et al* (1990). This is attributed to the fact that the requirement of sheep to water (water intake) at higher ambient temperature (outdoors) is significantly higher than that of animals sheltered under low temperature indoors (El Zeiny, 2011). Such a response allows animals to buffer themselves against short periods of water deprivation, as an adaptive reaction (anticipatory drinking, Silanikove, 1987) to ameliorate heat stress. An increase in body water content is a sign of an animal under stress that is adapted to its environment. Consequently, the insignificant changes in RT, ST, and the sweating rate in response to water deprivation indicate that the animals in the present experiment were not truly stressed, even though their skin temperature increased and skin coat barrier appeared effective in protecting them against the increased ambient temperature during the summer and when housed outside. In the present work the maximum ambient temperature was always lower than the rectal temperature. This result may be due to the fact that the present work was carried out at a site about 20 Km from the Mediterranean Sea shore. The prevailing mild climatic conditions were typical of conditions in other desert areas close to sea shores. However, deep in the desert, the environment is characterized by extremely low temperatures before sunrise, much higher temperatures in the mid-afternoon and much lower relative humidity (Schmidt-Nielsen *et al.* 1957).

In conclusion, Barki ewes have the ability to efficiently withstand 3-day water deprivation and heat stress with ambient temperatures up to 37.0 °C (Table 1). Sheep adapt to these stresses by some adjustments of temperature gradients without affecting the overall animal health status. The present study is considered a chronic experiment comprising 14 cycles of water deprivation, 3-days each. Thus animals were able to progressively adapt to lose water gradually during dehydration and compensating on watering day. This is supported by the finding that, extracellular fluid space (ECF) expanded gradually and reach their high value one day after dehydration (Asaad, 1997). Macfarlane *et al*. (1963 and 1959) and Hecker *et al* (1964) also reported that during water deprivation animals are known to lose water from rumen, blood and extracellular fluid. In addition, Farid and Abdel-Aziz (1984) confirmed the possible refill of these compartment on watering days enabling the animal to temporarily store water which was later lost gradually during the following days of the water deprivation cycles.

Conclusion:

The ability of the sheep to survive the hot harsh conditions of desert ecosystems is not explained simply and only by diurnal variations and the PM-AM amplitude of its rectal and skin temperatures. Rather, and especially when water deprived, sheep can regulate its core temperature through several thermoregulatory mechanisms including, among others, adaptive heterothermy, selective brain cooling and metabolic rate. These are integrated with mechanisms of water conservation. The dynamics of body fluids, the metabolic status and behavioral adaptations/adjustments all play significant role as well.

In further studies, gradual and long-term adaptation experiments, longer cycles of water deprivation, concurrent measurements of body fluid changes and the study of key stress-related hormones in blood would be needed and may prove beneficial for better understanding of adaptation of sheep and other ruminants to arid environments.

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تأثير فصل السنة وبيئة الإعاشة والتعطيش على تنظيم درجة حرارة المستقيم والجلد لدى الأغنام البرقي

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تم تقييم تأثير الإجهاد الحراري بسبب ظروف البيئة المحيطة والعطش وفصل السنة من خلال متابعة التغيرات في درجة حرارة المستقيم والجلد ومدى الاختلاف بين درجات الحرارة صباحا ومساء والفرق بين درجة حرارة المستقيم والجلد ودرجة حرارة البيئة المحيطة بالحيوان وذلك في ثمان نعاج برقي غير حوامل وغير مرضعات عمرها 4-5 سنوات ، كان نصفها يشرب كل يوم والنصف الآخر يشرب كل ثلاثة أيام. أيضا كانت نصف الحيوانات داخل حظيرة مسقوفة ، أما النصف الآخر فكان دون مأوى ومعرض للشمس والظروف الجوية المختلفة ليلا ونهارا. كانت النعاج تعطي علائق توفر المستوى الحافظ من التغذية. كررت معاملات التجربة ثلاث مرات في الفترة من إبريل إلى أغسطس لتمثل فصل الربيع وبداية الصيف وآخره. سجلت القياسات الخاصة بالمناخ وشملت درجة حرارة الجو والرطوبة النسبية والقياسات الخاصة بالحيوانات وشملت درجة حرارة الجلد والمستقيم في الساعة السابعة صباحا والثانية مساء خلال دورة التعطيش الكاملة في ثلاث أيام.

أظهرت النتائج أن البيئة المحيطة بالحيوان أثرت تأثيرا معنويا على درجات حرارة الجلد والمستقيم في الصباح والمساء ، كما أثرت على مدى التغيير فيهما من الصباح إلى المساء ، وكذلك على الفرق بين كل منهما وبين درجة حرارة الجو. كانت درجة حرارة المستقيم والجلد في الصباح أقل معنويا في الحيوانات خارج الحظيرة عنها في الداخل ، أما في المساء فقد كان العكس تماما. ولذلك فقد كان متوسط مدى الاختلاف في درجة حرارة المستقيم والجلد خارج الحظيرة أعلى من الداخل.

من ناحية أخرى أثر فصل السنة تأثيرا معنويا على درجة حرارة الجلد والفرق بينه وبين درجة حرارة المستقيم في المساء ، كما أثر على الفرق بين درجة حرارة المستقيم والجو ودرجة حرارة الجلد والجو في الصباح والمساء ، غير أن التعطيش لم يكن له تأثير معنوي على أي من القياسات قيد التجربة ، وبدا جليا قدرة الغنم على المحافظة على فرق ثابت تقريبا بين درجة حرارة المستقيم ودرجة حرارة الجو من خلال تغيرات طفيفة في الفرق بين درجة حرارة المستقيم والجلد والفرق بين درجة حرارة الجلد والجو. لذلك فإن درجة حرارة الجلد تحدد إلى درجة كبيرة درجة حرارة الجسم في الأغنام. ساعد على ذلك أن درجة حرارة البيئة المحيطة في هذه الدراسة كانت على الدوام أقل من درجة حرارة المستقيم والجلد.

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