

SWEATING LOSSES OF UREA, SODIUM AND POTASSIUM IN BARKI SHEEP UNDER THE ENVIRONMENTAL STRESS OF SEMI-ARID COASTAL DESERT CONDITIONS

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ABSTRACT

The present study was intended to investigate the effects of watering regimen, protein intake, housing environment and season on the potential losses of urea, sodium and potassium in the sweat of Barki sheep.

Sweating rate, Na⁺, K⁺ and urea concentration in sweat and serum, and sweat Na⁺, K⁺ and urea output were determined in eight non-pregnant non-lactating Barki ewes fed at the maintenance energy level. Half of the animals were watered daily, whereas the other half was intermittently watered once every three days. There were two levels of protein intake, however, 100% and 50% of their estimated maintenance requirements. Moreover, half of 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.

The sweating rate in daily watered sheep was about 108 g/m²/h. The outdoor sheep had significantly higher sweat rates than those kept indoors. Also, the sweating rate of sheep in early and late summer was significantly higher than those in spring. Water deprivation and the level of protein intake did not significantly affect sweat rate. The urea excreted in sweat followed changes in sweat rate. Urea output increased in animals kept outdoors as compared to indoors and in summer as compared to spring. The sweat:serum urea concentration ratio was always less than one. The ratio ranged from 0.5 to 0.1 which possibly indicates passive diffusion of urea into the sweat. Sweat:serum concentration ratio ranged from 1.00 to 1.87 for sodium and from 149.7 to 224.5 for potassium for the different experimental treatments. Consequently, the sweat K⁺ output was much greater than that of Na⁺ even though its serum concentration was much less than Na⁺. The increase in K/Na ratio may suggest the presence of a Na⁺:K⁺ exchange mechanism in the duct of the sweat gland similar to that in the distal tubule of the kidney. The present results gave evidence that losses of potassium, sodium and to some extent urea in sweat could be quantitatively significant affecting the nutritional and physiologic state of the desert animal and in particular the acid-base balance of blood and other body fluids. Quantitative assessment of such losses under different conditions of environmental stress would be essential in devising sound management systems.

Keywords: Sheep, sweat, sodium, potassium, urea, stress.

INTRODUCTION

Animals in hot arid environments lose heat principally by evaporating water through sweating, panting or both. Propensity of a species to use one mechanism or the other, e.g. sweating vs. panting, is a developmental characteristic of that particular species. Invariably it is aided by some other adaptive mechanism, behavioural, physiological or else. The animals' response to heat stress has been evaluated by measuring variations in the body temperature, respiratory rate and heart rate, as well as the sweating rate. As heat stress increases, considerable water and ion losses were

reported in ruminants (Beede and Collier, 1986). Heat stress also leads to the activation of heat loss mechanisms, i.e. dissipating heat to the environment and reducing the production of metabolic heat (Silanikove, 2000). The present study was intended to investigate the effects of watering regimen, protein intake, housing environment and the season of the year on potential losses of urea, sodium and potassium in the sweat of Barki sheep.

MATERIALS AND METHODS

Animals and Management:

Eight non-pregnant and non-lactating adult female Barki ewes of about 4 years old were used in the experiment. Their live body weights averaged 45 kg. 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.

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.

Housing	Season ¹	Tmin (°C)	Tmax (°C)	Ambient (Ta)		Humidity %	
				am	pm	am	pm
Indoors	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

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

Sweating rate:

The sweating rate was measured by the calcium chloride capsule technique as described by Ferguson and Dowling (1955). The capsules were applied to clipped patches of skin on the mid-side of the animal and held there for a specific period of time, usually 30 minutes. The gain in weight of the capsule along with the surface area it covered was used to calculate the sweating rate which was expressed in ml water/m²/hr.

Sweat electrolytes and urea:

After a clipped area on the mid-side of the animal has been washed and dried, it was exposed to open air for two hours. Thereafter, a metal ring of known surface area and with a lip was applied to the skin and the inside area was washed with two portions of distilled water, 10 ml each, and allowed to drain into a 25 ml volumetric flask and the volume was adjusted to the 25 ml mark and kept frozen for pending analyses. These samples were used for the determination of sodium, potassium and urea in sweat. Sodium and potassium were determined using standard flame-photometric procedures. Urea was determined by the diacetyl-monoxime colorimetric procedure as described by Evans (1968). Results were then expressed in mg/m²/hr to indicate rates of output, or loss, of these elements in sweat.

Serum electrolytes and urea:

Jugular blood samples were withdrawn at 2:00 pm, approximately at the time of sweat collection started, and was allowed to clot. Serum was collected after centrifugation in a clinical centrifuge and saved frozen for pending analysis of sodium, potassium, and urea. Analytical procedures were those applied for sweat.

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 four main effects and the 2-way interactions. Higher interactions were included in the error term. Duncan's multiple range tests were applied to the means of the main effects as included in the NCSS package.

RESULTS

Free water intake:

On watering day, water deprived sheep drank about 2.5 times more water as compared to the average intake of their daily watered mates. However, when intake was expressed as the daily average through the three-day water deprivation cycle, it was significantly ($P < 0.01$) less than the daily watered ones, 73.8 vs. 105.3 ml/day/kg^{0.82} (Table 2). Daily averages were calculated for both daily and water deprived animals to facilitate the evaluation of the main effects of the housing environment, protein intake and season. Sheep kept outdoors consumed 43% more water ($P < 0.01$). The level of protein intake affected significantly ($P < 0.05$) the free water intake. The animals fed the high level of protein drank 17% more water than those fed the low level. Free water intake was least during the spring season, increasing significantly ($P < 0.01$) during early and more so during late summer. Average free water intake during late summer was 161% of that recorded in the spring.

Sweating rate:

The sweating rate of the water deprived sheep was not significantly ($P > 0.05$) different from the daily watered ones, 108.2 vs. 109.96 ml/m²/hr (Table 2). Housing the sheep outdoor increased their sweating rate significantly ($P < 0.05$) as compared to their sheltered mates housed indoors (around 40%). The level of protein intake did not affect sweating rate whereas the seasonal effect was significant ($P < 0.05$). Sheep produced more sweat during early and late summer than during spring, that is 86.6, 100.7 and 139.9 ml/m²/hr for spring, early and late summer, respectively (Table 2).

Urea output in sweat:

Serum urea concentration, mg/100 ml, was measured four to six hours after feeding, just before sweat measurements were taken. It increased but not significantly ($P > 0.05$) in the water deprived animals, 23.34 vs. 21.40 mg/100 ml (Table 3). Housing the animals indoors or outdoors did not affect serum urea concentration. As the level of protein intake was restricted, serum urea concentration decreased, but this decrease was not significant ($P > 0.05$). Moreover, seasonal effect was also not significant ($P > 0.05$). The concentration of urea in sweat, mg/100 ml, on the other hand, was significantly ($P < 0.05$) affected only by the season of the year (Table 5). It tended to increase in summer (11.2, 32.7, 17.0 mg/100 ml for spring, early and late summer, respectively). The output of urea in sweat, often neglected even though it may be of importance to the nutritional status of the animals, is presented in (Table 3). Water deprivation and housing did not significantly affect urea output ($P > 0.05$), even though it increased 26.7% in animals housed outdoors. It significantly increased 51% in animals fed the lower level of protein and increased 271.9% ($P < 0.05$) during early summer as compared to spring, 7.92 vs. 29.46 mg/m²/hr. The lack of statistical significance ($P > 0.05$) is due to the large individual variation as observed in the magnitude of SEM (Table 3) and should not overshadow the biological significance of the results.

Table (2): Effects of the housing environment, protein intake, season of the year and water deprivation on free water intake and sweating rate in sheep.

Item	Watering Treat.	Environment		Protein intake		Season of year			Water means
		Indoors	Out	High	Low	Spring	E. Sum.	L. Sum.	
Free water intake, ml/day/kg^{0.82}									
	Daily	85.22	107.34	102.98	89.58	71.72	98.13	118.98	96.28 a
	WD	62.32	103.35	90.06	75.61	62.98	87.12	98.40	82.83 b
	Means	73.77 b	105.34 a	96.52 a	82.59 b	67.35 b	92.62 a	108.69 a	
	SEM ±	±3.970		±3.970		±4.862			±3.970
	F-test	**		*		**			*
Sweating rate, ml/m²/hr									
	Daily	75.95	140.47	108.37	108.05	80.62	99.50	144.50	108.21 a
	WD	106.15	113.77	109.20	110.72	92.62	102.00	135.25	109.96 a
	Means	91.05 b	127.12 a	108.78 a	109.38 a	86.62 b	100.75ab	139.87 a	
	SEM ±	±8.378		±8.378		±10.261			±8.378
	F-test	*		N.S		*			N.S

a-b Within a main effect different superscript means significantly different (P<0.05), Duncan Multiple Range-test.

Table (3): Effects of the housing environment, protein intake, season of the year and water deprivation on serum and sweat urea concentrations and sweat urea out put in sheep.

Item	Watering Treat.	Environment		Protein intake		Season of year			Water Means
		Indoors	Outdoors	High	Low	Spring	E. Sum.	L. Sum.	
Serum Urea concentration, mg/100ml									
	Daily	22.90	19.90	21.82	20.98	24.35	20.07	19.78	21.40 a
	WD	21.45	25.23	24.55	22.13	22.62	25.10	22.30	23.34 a
	Means	22.18 a	22.57 a	23.18 a	21.56 a	23.49 a	22.59 a	21.04 a	
	SEM ±	±1.642		±1.642		±2.012			±1.642
	F-test	N.S		N.S		N.S			N.S
Sweat Urea concentration, mg/100ml									
	Daily	29.25	14.72	12.84	31.14	12.05	31.95	21.96	21.99 a
	WD	14.97	22.34	16.90	20.42	10.35	33.54	12.08	18.66 a
	Means	22.12 a	18.53 a	14.87 a	25.78 a	11.20 b	32.75 a	17.02 ab	
	SEM ±	±3.586		±3.586		±4.392			±3.586
	F-test	N.S		N.S		*			N.S
Sweat Urea output, mg/m²/hr									
	Daily	21.29	20.98	15.02	27.26	8.47	26.00	28.94	21.14 a
	WD	14.08	23.88	16.92	21.04	7.38	32.92	16.65	18.98 a
	Means	17.69 a	22.43 a	15.97 b	24.15 a	7.92 b	29.46 a	22.79 a	
	SEM ±	±2.061		±2.061		±2.524			±2.061
	F-test	N.S		*		**			N.S

a-b Within a main effect different superscript means significantly different (P<0.05), Duncan Multiple Range-test.

Sodium output in sweat:

Water deprivation and housing were not significant (P>0.05) sources of variation affecting serum and sweat concentration or output (Table 4). Sweat concentration and sweat Na⁺ output increased in the animals fed the low protein level. However, only the increase of Na⁺ sweat output was significant (P<0.05), 503.5 vs. 672.9 mg/m²/hr for high and low protein levels, respectively (Table 4). Serum and sweat Na⁺ concentration were significantly (P<0.01) affected by season (Table 4). It is also noted that as the sweating rate increased the sweat Na⁺ concentration decreased. The serum Na⁺

concentration increased significantly in late summer, 499.36 mg/100 ml, while sweat Na⁺ concentration decreased significantly in the same season, 410 mg/100 ml. Sweat Na⁺ output also decreased in late summer, about 12%, but this decrease was not significant (P>0.05).

Table (4): Effects of the housing environment, protein intake, season of the year and water deprivation on serum and sweat sodium concentrations and sweat sodium out put in sheep.

Item	Watering Treat.	Environment		Protein intake		Season of year			Water Means
		Indoors	Out	High	Low	Spring	E. Sum.	L. Sum.	
Serum Na concentration, mg/100ml									
	Daily	449.15	464.98	449.96	464.18	412.45	422.51	536.24	457.07a
	WD	432.86	442.02	432.94	441.94	464.31	385.54	462.47	437.44a
	Means	441.01 a	453.50 a	441.45 a	453.06 a	438.38ab	404.02 b	499.36 a	
	SEM ±	±13.193		±13.193		±16.158			±13.193
	F-test	N.S		N.S		**			N.S
Sweat Na concentration, mg/100ml									
	Daily	914.08	435.3	426.15	923.24	977.78	745.85	300.45	674.69 a
	WD	546.42	618.49	579.88	585.02	664.84	450.06	542.45	582.45 a
	Means	730.25 a	526.90 a	503.02 a	754.13 a	821.31 a	642.96 a	421.45 b	
	SEM ±	±81.057		±81.057		±99.274			±81.057
	F-test	N.S		N.S		*			N.S
Sweat Na output, mg/m²/hr									
	Daily	592.17	538.173	371.33	759.00	684.75	609.75	401.0	565.17 a
	WD	574.33	648.17	635.67	586.83	573.0	542.25	718.50	611.25 a
	Means	583.25 a	593.17 a	503.50 b	672.92 a	628.87 a	576.0 a	559.75 a	
	SEM ±	±39.22		±39.22		±48.032			±39.22
	F-test	N.S		*		N.S			N.S

a-b Within a main effect different superscript means significantly different (P<0.05), Duncan Multiple Range-test.

Table (5): Effects of the housing environment, protein intake, season of the year and water deprivation on serum and sweat potassium concentrations and sweat potassium out put in sheep.

Item	Watering Treat.	Environment		Protein intake		Season of year			Water Means
		Indoors	Outdoors	High	Low	Spring	E. Sum.	L. Sum.	
Serum K concentration, mg/100ml									
	Daily	18.80	18.52	18.37	18.95	20.62	16.45	18.90	18.66 a
	WD	19.50	18.26	18.49	19.27	22.58	16.12	17.90	18.88 a
	Means	19.15 a	18.39 a	18.43 a	19.11 a	21.60a	16.30 c	18.41 b	
	SEM ±	±0.405		±0.405		±0.497			±0.405
	F-test	N.S		N.S		**			N.S
Sweat K concentration, mg/100ml									
	Daily	5323.6	2596.8	2738.3	5182.2	5288.3	4264.2	2328.1	3960.2 a
	WD	3275.8	3860.1	3548.6	3587.3	4378.6	3142.0	3183.3	3567.9 a
	Means	4299.7 a	3228.4 a	3143.4 a	4384.8 a	4833.4 a	3703.1ab	2755.7 b	
	SEM ±	±407.16		±407.16		±498.67			±407.16
	F-test	N.S		N.S		*			N.S
Sweat K output, mg/m²/hr									
	Daily	3578.6	3392.7	2548.3	4423.0	3747.5	3607.0	3102.5	3485.7 a
	WD	3484	4096.5	3920.8	3660.0	3887.0	3206.0	4278.2	3790.4 a
	Means	3531.5 a	3744.5a	3234.5a	4041.5a	3817.2a	3406.5a	3690.3a	
	SEM ±	±298.71		±298.71		±365.8			±298.71
	F-test	N.S		N.S		N.S			N.S

a-b Within a main effect different superscript means significantly different (P<0.05), Duncan Multiple Range-test.

The sweat sodium concentration was greater than that of the serum in both indoor and outdoor animals (about 1.6 and 1.2 times, respectively). Indoors, sweat sodium concentration was 730.25 mg/100 ml, whereas in serum it was only 441.0 mg/100 ml (Table 4). Similarly, in the outdoors animals corresponding values were 526.9 mg/100 ml sweat, whereas in serum it was only 453.5 mg/100 ml. The same was observed when comparing daily watered and water deprived animals. Sweat sodium concentration was higher (1.47-1.33 times) than its serum concentration, 674.6 mg/100 ml and 457.07 mg/100 ml, respectively, in daily watered animals. Corresponding values in the water deprived sheep were 582.45 and 437.44 mg/100 ml. This indicates that sheep were able to maintain the sweat to serum ratio of sodium concentration practically constant so as to achieve homeostasis.

Potassium output in sweat:

The serum and sweat concentration and its output were not affected significantly by the housing environment, indoors vs. outdoors, protein intake or water deprivation (Table 5). The serum potassium and sweat concentration differed significantly in different seasons. The highest serum and sweat levels of potassium were observed in the spring and the lowest were in summer, 21.6 and 4833.4 mg/100 ml for serum and sweat K⁺ concentration, respectively, in spring. It was 16.3 and 2755.7 mg/100 ml in serum and sweat, respectively, in summer. The trend of changes of the sweat K output was similar to that of serum and sweat K⁺ concentration (Table 5) but the changes were not significant (P>0.05). The lowest values of serum and sweat K⁺ concentrations were in early summer. Animals maintained a practically constant ratio of K⁺/Na⁺ in each of serum and sweat: 0.05, 0.04 and 0.04 in serum and 5.9, 5.8 and 6.5 in sweat; in spring, early summer and late summer, respectively.

The relationships between free water intake and the sweating rates, and between sweating rate and the quantitative sweat losses of urea, sodium and potassium during the different seasons of the year are illustrated in Figure 1.

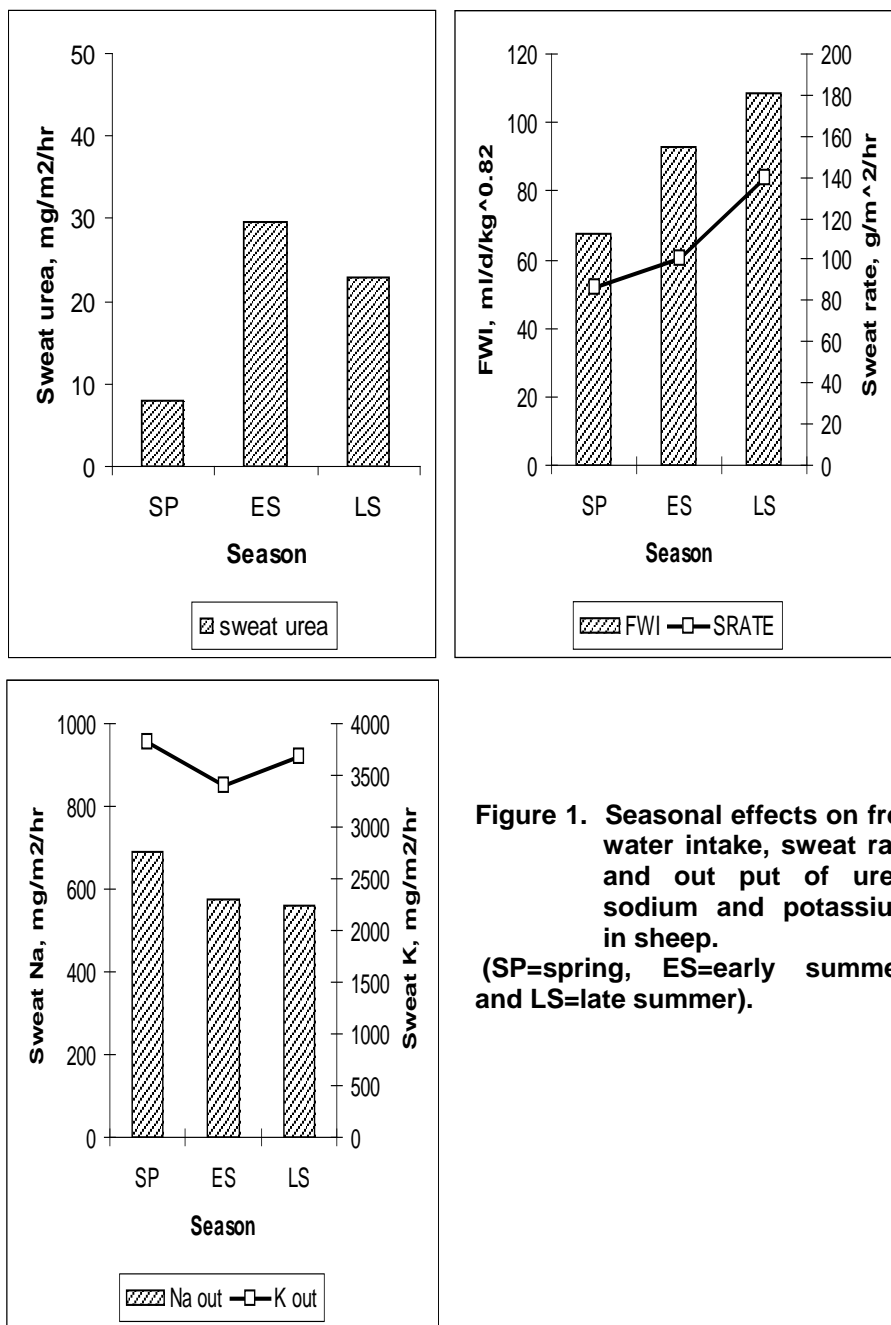


Figure 1. Seasonal effects on free water intake, sweat rate and out put of urea, sodium and potassium in sheep. (SP=spring, ES=early summer, and LS=late summer).

DISCUSSION

Sweat rate:

Desert ungulates use a variety of physiological, morphological, and behavioural mechanisms to deal with the conflicting challenges of maintaining body temperature within acceptable limits and at the same time minimizing water loss. Animals use evaporative cooling, i.e. sweating or panting, or both, when their total heat load exceeds level that can be dissipated by non-evaporative means. Many ruminants, such as cattle and sheep, employ both sweating and panting for heat regulation (Schmidt-Nielsen 1964, Robertshaw and Finch, 1984).

The published evidence about the relative importance of cutaneous and respiratory evaporative heat loss in the sheep is conflicting. Riek *et al.* (1950) and Knapp and Robinson (1954) concluded that at ambient temperatures of 30-40 °C, cutaneous evaporative heat loss was quantitatively two to three times more important than respiratory evaporative loss. Brook and Short (1960a,b) also demonstrated a considerable increase in cutaneous evaporation in shorn sheep when moved from an ambient temperature of 20 °C to one of 40 °C. On the other hand, Alexander and Williams (1962) found approximately equal and consistent evaporative loss from the skin and respiratory tract at a temperature below 30 °C; above that temperature there was a considerable increase in respiratory evaporation and smaller increase in cutaneous evaporation. Brockway *et al.* (1965), Hofmeyer *et al.* (1969) and Hales and Brown (1974) concluded that about 60% of the total heat loss was through respiratory activity (panting) when exposed to air temperature of 25 °C. This could be as high as 80% for individual sheep. Although there is ample evidence of sweating in sheep, its physiological importance remained of doubtful significance. Nevertheless, Knight and Hopkins (1976) reported that shorn and unshorn Merino sheep exposed to eight hours of heat stress, 45 °C and 26% RH, non-respiratory evaporative water loss amounted to 4-6 ml/kg/hr whereas the respiratory evaporative water loss amounted to only 0.9-1.4 ml/kg/hr, and shearing had no effect.

Cutaneous evaporative cooling in sheep also depends on the nature of the fleece coat (Rai *et al.*, 1979a). Macfarlane (1968) concluded that Merino sheep with dense coat under hot conditions mainly depend on pulmonary evaporative cooling whereas hairy sheep depend on the cutaneous route. In the present experiment, the value of the sweating rates are higher than those reported by Brook and Short (1960b) and Maloiy and Taylor (1971), but are in agreement with those recorded by Riek *et al.* (1950), Knight and Hopkins (1976) and Rai *et al.* (1979a).

Sweating rates were significantly influenced by thermal stress. The sheep kept outdoors increased their sweating rate as compared to their sheltered mates housed indoors, and the sweat rate in summer was greater than that in spring. This increase is due to the fact that the exposure to direct solar radiation is important in stimulating sweating in ungulates (Maloiy and Hopcraft, 1971; Purohit *et al.* 1974; Dmi'el 1986 and Robertshaw, 1985). Also, sweating rates increased with increased ambient temperatures.

Therefore, it is affected by season (Parker and Robbins 1984, Taylor 1970a&b, Alamer and Al-Hozab, 2004 and James *et al.*, 2006).

On the other hand, the insignificant changes in the sweat rate in response to water deprivation indicate that the extent of stress of 3-day water deprivation was not enough to suppress sweating. This suggestion is also supported by the practically constant level of electrolytes in serum and sweat during the water deprivation cycle. Also, the unchanged sweat rate during water deprivation may be due to the regional variation in the sweating rate in different parts of the body in sheep, which may be attributed to the different activities of the sweat glands (Ghosal *et al.*, 1977; Rai *et al.*, 1979b, Carter and Dowling, 1954 and Zeine Felali *et al.* 1992). Further research would be needed to investigate the activities of the sweat glands in different regions of the skin of sheep.

Sweat urea losses

Present results indicated that urea excreted in sweat followed changes in sweating rate. Output increased in animals kept outdoors as compared to indoors, and in summer as compared to spring, i.e. under conditions conducive of increased sweating.

It is known that the sweat urea is derived mostly from blood urea (Slegers, 1966), but there is a lack of association between sweat and serum urea concentrations (Huang *et al.*, 2002). It is not yet known whether the sweat gland itself produces some urea. Several investigators have proposed that urea in the sweat may have its origin in the metabolism of the sweat glands themselves. Weiner and Heyningen (1952) found correlation between lactate and urea under diverse conditions. Hier *et al.* (1946) suggested that arginine, which they identified in sweat, might be split into urea and ornithine. This is supported by results of Rothman and Sullivan (1949).

The final sweat concentration depends upon the rate at which it is secreted in the coil of the sweat gland and by subsequent ductal modification, excretion or absorption. Therefore, it is influenced by the sweating rate because ductal modification is a function of the flow rate (Taylor *et al.* 1994). In humans, sweat urea concentration is two to four times greater than serum concentration at low sweat rate and only 1.2-1.5 times as sweat rate increases. In sheep in the present experiment, the sweat/serum urea ratio was low ranging from 0.5 to 1.0, which possibly indicates passive diffusion of urea into the sweat and possibly subsequent net reabsorption in the duct of the sweat gland. The high diffusibility of urea through membranes supports this conclusion. This interpretation is in agreement with that of Gregory *et al.* (1966).

In man, sweat is a means for urea excretion whereas the sheep can conserve some of the urea excreted in sweat as observed in the high and low protein intake groups in the present experiments when the sheep were water deprived. If so, the sweat gland plays a role in urea conservation similar to that of the kidney (Farid *et al.*, 1979) especially under adverse physiological and nutritional conditions. In general, the increase of serum urea concentration during water deprivation may be due to the decreases in body water content, blood plasma volume, extracellular, intracellular and interstitial

fluid volumes (Macfarlane *et al.*, 1958, Schaefer *et al.*, 1990; Igbokwe, 1997 and Abdelatif *et al.*, 2010).

Urea appears to play a significant physiological role during dehydration. By the osmotic effect, urea attracts the water towards the plasma from other body fluid compartments. Therefore, the metabolism of urea is strongly influenced by dehydration. In the present result, the non-significant increase of serum urea in the water deprived sheep may be due to urea recycling (Farid *et al.*, 1979 and Swenson, 1984) and renal tubular reabsorption of urea, in addition to water moving into the plasma from other body fluid compartments. After prolonged water deprivation, plasma urea concentration return to normal (Igbokwe, 1993) or decrease (Leng *et al.*, 1987).

Such an excretion of small amounts of urea via sweat is insignificant compared to the amount of urea normally excreted in the urine. Therefore, the conclusion here is that the concentration and amount of urea excreted by sweat in sheep was not enough to consider sweat as an important route for excretion whether the animal is in normal physiological range or dehydrated.

Sweat sodium and potassium losses:

Electrolytes, especially Na^+ and K^+ , have been found in the sweat of all species studied to date (Mcfarlane *et al.*, 1958; Johnson, 1970; Jenkinson and Mabon, 1973). In ruminants, which have a high K^+ intake relative to man, the loss of K^+ in sweat exceeds that of Na^+ in warm conditions, in contrast to human sweat which normally has high Na^+/K^+ ratio (Collins, 1962). Recent studies of the losses of Na^+ and K^+ from cattle skin during sweating, however, indicate that either active secretion or tubular reabsorption of these electrolytes occurs, and suggest the possibility of at least an osmotic mechanism (Johnson, 1970 and Jenkinson and Mabon, 1973).

In the present study, the sweat to serum concentration ratios of sodium and potassium were persistently greater than one, possibly indicating net secretion in the secretory coil of the glands. Sweat to serum concentration ratios ranged from 1.00 to 1.87 for sodium and 149.7 to 224.5 for potassium for the different experimental treatments. Therefore, the sweat output of potassium was much greater than that of sodium even though its serum concentration was much less than sodium. There are suggestions (Grand *et al.*, 1967 and Sato and Dobson, 1970b) that aldosterone may play a role modifying excretion and reabsorption of sodium and potassium in the duct of the sweat gland. This is an appealing possibility and warrants further experimentation. The decrease in sweat Na^+/K^+ ratio suggests the presence of electrolyte exchange in the duct as in the distal tubular of the kidney (Sato *et al.*, 1971). The presence of Na^+ , K^+ and ATPase has been demonstrated in both duct and secretory coil of the sweat gland (Sato and Dobson, 1970a; Sato *et al.*, 1971 and Grandchamp *et al.*, 1968). There are, however, several reports of both reduction in sweat rate and increase in sodium concentration after administration of ADH (Fasciolo *et al.*, 1969 ; Quatralo and Spire, 1970 and Slegers and Hot-Grootenboer, 1971).

In the present results, although the sweat rate increased in summer season, the sweat Na^+ and K^+ concentrations decreased significantly, their out put was not significantly changed. That is increased sweating was

counter balanced with decreased concentration. This pattern of change may help achieve a practically constant sweat/serum Na⁺ ratio and K⁺/Na⁺ ratio in both serum and sweat so as to achieve homeostasis under different physiological conditions. Furthermore, the hypertonicity of Na⁺ and K⁺ in the final sweat may reflect the possibility that they are secreted initially in the coil at hypertonic concentration. Such a function would explain the fact that K⁺ and Na⁺ were independent of rates (Quinton, 1987).

In an interesting study (Rai *et al.*, 1982) sweating rates, and concentrations and out put of Na⁺ and K⁺ were studied at 27.5 °C and 41.0 °C, similar to conditions prevailing under Indian range conditions. The study involved two local breeds, Chokla and Malpura, in addition to Rambouillet. Increasing ambient temperature did not affect sweating in Rambouillet but it increased 3-6 folds in the local breeds, possibly an adaptation effect. Sodium concentration and quantitative out put in sweat was less than that of potassium. Differences between breeds and the effects of ambient temperature on Na⁺ and K⁺ concentrations were erratic and not conclusive even though it tended to decrease or were not changed. This is in general agreement with our results as indicated above.

The present results did not reveal significant changes in sweat rate, serum, Na⁺, K⁺ and urea in response to water deprivation. The unchanged level of serum Na⁺ could be related to naturesis that was reported previously during water deprivation in animals including sheep, McKinley *et al.* (1983). Similarly, the plasma Na⁺ level remained unchanged during water deprivation in Yankasa sheep, (Igbokwe, 1993), in Bramer and Nubian goats (Khan *et al.*, 1978 and Abdelatif *et al.* 2010) and in camels (Kataria *et al.*, 2002). The stability of serum K⁺ level during water deprivation could be associated with the decline in food intake (Abdelatif *et al.*, 2010 and Igbokwe, 1993). However, other studies reported a tendency to increased plasma Na⁺ and K⁺ levels in water deprived sheep under hot summer conditions (Laden *et al.*, 1987 and Abdelatif and Ahmed, 1994).

The insignificant changes of sweat Na⁺ and K⁺ levels in response to water deprivation may indicate that the animals were not severely dehydrated. It is noteworthy to stress the fact that the present experiment was carried out at a site about 20 km from the Mediterranean Sea shore. The prevailing mild climatic conditions were typical of conditions existing in other desert areas close to sea shores. However, deep in the desert there are much higher temperatures, day and night temperature differences and much lower relative humidity (Schmidt-Nielsen *et al.*, 1957). It is noteworthy to stress that the water deprived sheep in the present experiment were adapted to long-term cyclic water deprivation. Other experiments in the literature, on the other hand, relied on measurements taken during acute dehydration followed by sudden rehydration.

In further experiments, longer cycles of water deprivation might prove beneficial experimentally and concurrent measurements of body fluid changes and determination of key stress related hormones in blood would be needed. Further studies would also need to consider the course of long-term adaptation to dehydration, a situation imitating natural conditions prevailing in arid zones.

Conclusion

The present results gave evidence that losses of potassium, sodium and to some extent urea in sweat could be quantitatively significant affecting the nutritional and physiologic state of the desert animal and in particular the acid-base balance of blood and other body fluids. Quantitative assessment of such losses under different conditions of environmental stress would be essential in devising sound management systems.

In further experiments, longer cycles of water deprivation might prove beneficial experimentally, and concurrent measurements of body fluid changes and the determination of key stress related hormones in blood would be needed.

Further studies would also need to consider the course of long-term adaptation, a situation imitating natural conditions prevailing in arid zones.

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**إخراج اليوريا والصوديوم والبوتاسيوم في عرق الأغنام البرقي تحت تأثير الظروف الصحراوية في المناطق الساحلية شبه الجافة
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قسم فسيولوجيا الحيوان والدواجن ، مركز بحوث الصحراء ، المطرية ، القاهرة .**

تم تقييم معدل العرق وتركيز الصوديوم والبوتاسيوم واليوريا في العرق وسيرم الدم وذلك في ثمان نعاج غير حوامل وغير مرضعات كان نصفها يشرب كل يوم والنصف الآخر يشرب كل ثلاثة أيام ، نصف الحيوانات كانت داخل حظيرة مسقوفة أما النصف الآخر فكان دون مأوى ومعرض للشمس والظروف الجوية المختلفة ليلا ونهارا. كانت النعاج تعطي علائق توفر المستوى الحافظ للطاقة وكان هناك مستويين للبروتين في الغذاء 100% و 50% من احتياجاتهم الحافظة. كررت معاملات التجربة في الفترة من إبريل إلى أغسطس لتمثل فصل الربيع ، وبداية الصيف وآخره. تهدف هذه الدراسة إلى تقييم تأثير التعطيش ومستوى البروتين في الغذاء وبيئة الإعاشة للحيوان وفصل السنة على الفقد المحتمل لليوريا والصوديوم والبوتاسيوم في عرق الأغنام البرقي. أظهرت النتائج أن معدل العرق في الأغنام التي تشرب كل يوم كان حوالي 108 ملليجرام/متر²/ساعة ، وكان معدل إفراز العرق في الأغنام المعرضة للظروف الجوية المختلفة في الخارج أعلى معنويا من معدله في الأغنام داخل الحظيرة ، كما كان معدل عرق الأغنام في أول الصيف وأخره أعلى معنويا من معدله في الربيع ، بخلاف ذلك فإن التعطيش ومستوى البروتين في الغذاء لم يؤثر على مستوى العرق في الأغنام تأثيرا معنويا . وكانت كمية اليوريا الموجودة في العرق تتبع التغيرات في معدل إفراز العرق فكانت تزيد في الحيوانات الموجودة في الخارج عنها في داخل الحظيرة وفي الصيف مقارنة بالربيع ، وأظهرت النتائج أيضا أن النسبة بين تركيز اليوريا في العرق إلى تركيزها في الدم كانت دائما أقل من 1 (0.5 – 0.1) وهذه النسبة تعني نفاذية سلبية لليوريا إلى العرق ، وكانت نسبة تركيز الصوديوم والبوتاسيوم في العرق إلى تركيزها في الدم في المعاملات المختلفة (1-187) و (149.7-224.5) على التوالي. ولذلك كانت كمية البوتاسيوم في العرق أعلى كثيرا من الصوديوم ، وقد تفسر هذه الزيادة وجود تبادل بين أيونات الصوديوم والبوتاسيوم في قناة الغدة العرقية كما في قناة النفرون في الكلى.

قام بتحكيم البحث

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