PHYSIOLOGICAL RESPONSES, FEED INTAKE, URINE VOLUME AND SERUM OSMOLALITY OF AARDI GOATS DEPRIVED OF WATER DURING SPRING AND SUMMER

F. D. El-Nouty[1], A. A. Al-Haidary and S. M. Basmaeil

Animal Production Department, College of Agriculture,
King Saud University, P.O. Box 2460, Riyadh 11451,
Saudi Arabia

Summary

In order to evaluate the adaptability of Aardi goats to arid environment, 5 Aardi bucks were deprived of water for four days during spring and summer seasons. The rise in average maximum ambient temperature from 24.8°C in spring to 35.8°C in summer caused a significant rise in rectal temperature (0.3°C), respiratory rate (62%), serum osmolality (8%) and serum sodium concentration (17%). While, it resulted in a significant decline in dry matter intake (50%), urine volume (74%) and fecal water excretion (60%) compared with their values in spring, but had no significant effect on the volume of drinking water. At the end of the 4-days deprivation period during spring, respiratory rate, dry matter intake and urine volume were reduced by 18, 77 and 91% relative to their average in control goats. The corresponding reduction in summer were 58, 100 and 100%. Serum osmolality was risen by 15% in spring deprived goats and 29% in summer deprived goats. Rectal temperature rose by a mean value of 1.3°C only in goats deprived of water in summer. Percent of moisture in the feces declined from 64 in control goats, to 24% in water deprived goats during spring season. The corresponding values in summer were 25 and 6%. These responses of Aardi goats deprived of water in summer indicate that they possess a water economy mechanism enable them to tolerate infrequent drinking in hot-arid environment.

(Key Words: Aardi Goat, Deprivation, Adaptability, Heat Stress)

Introduction

Goats appear to be the most suitable farm animal to be raised in arid desert environment, this is because of their outstanding tolerance to sparse low quality forage and infrequent drinking (Jindal, 1980; El-Nouty et al., 1989). Aardi goats, which are black heavy goats inhabits the central region of Saudi Arabia, were found to be well adapted to arid environment. This conclusion was based on the finding that these goats had similar body weight loss and blood haematological changes during spring (24.8°C) and summer (35.8°C) after 4 days of water deprivation, except that total serum protein rose significantly particularly in summer as dehydration continued (El-Nouty et al., 1989). This study was thus designed in order to examine other possible mechanisms which make these goats well adapted to harsh environment. Therefore, this work was planned to study the effects of season of the year and 4-days of water deprivation on rectal temperature, respiration rate, dry matter intake, water requirements and excretion, serum osmolality, sodium and potassium concentrations.

Materials and Methods

Five Aardi bucks 1-2 years of age were used during spring season (March) and hot summer season (September) to evaluate their adaptability to seasonal variations in air temperature and water deprivation. Animals were housed indoors in metabolism crates and water was offered ad libitum except during the water deprivation period. They were fed on hay ad libitum along with 0.5 kg/day of commercially formulated concentrates (12% crude protein) given at 9.00 hr. The experiments lasted for three weeks during each season. After

[1]Address reprint requests to Dr. F.D. El-Nouty, Animal Production Dept., College of Agriculture., King Saud University P.O. Box 2460, Riyadh 11451, Saudi Arabia.

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one week preliminary period, measurements were recorded during the second week (control period) at the 2nd and 4th day, then water was withheld starting the third week (deprivation period, started at 9.00 hr and ended at 9.00 hr of the 4th day) and measurements were repeated at the corresponding times. Measurements included daily maximum and minimum ambient air temperatures; a.m. and p.m. dry and wet bulb temperatures, rectal temperatures (RT), respiration rates (RR); daily dry matter intake (DMI), drinking water (DW), and urine volume (UV). Feces were collected at the end of each period for average determination of fecal water (FW). Vapor pressure was obtained from Psychrometric chart using dry bulb temperature (°C) and relative humidity (%).

At the same times, blood samples were collected at 9.00 hr before access to feed and water using Plain vacutainer tubes. Serum was obtained by blood centrifugation at 860 xg for 20 min, and stored at −20°C till analysed. Serum osmolality was measured using an osmometer (Wescor, Logan, UT). Serum sodium and potassium concentrations were determined using flame photometer.

Statistical analyses were carried out at King Saud University Computer center using the GLM procedure (Goodnight et al., 1986) to evaluate the effects of season, treatment, length of deprivation, time of the day (if present) and their various interactions. The least squares analyses of variance program was applied to the data. The following model was used:

$$Y_{ijkl} = U + S_i + T_j + L_k + (ST)_{ij} + (SL)_{ik} + (TL)_{jk} + (STL)_{ijk} + e_{ijkl}$$

where, Y_{ijkl} is the 1st observation of the i^{th} season, j^{th} treatment and k^{th} length of deprivation. U is the general mean and e_{ijkl} is the random error associated with the Y_{ijkl} observation. Since no statistical differences were detected between measurements obtained at 2nd and 4th day of control period, percent changes at the fourth day of deprivation were calculated relative to the pooled control data.

Results and Discussion

Average maximum ambient temperatures recorded during spring and summer experimental periods were 24.8°C and 35.8°C, respectively. The corresponding minimum values were 21.8°C and 31.6°C. Average a.m. relative humidity and vapor pressure were 68% and 13.6 mmHg during spring and 40% and 15.1 mmHg during summer. The corresponding p.m. values were 65% and 13.3 mmHg during spring and 41% and 17.2 mmHg during summer.

The overall means of RT were significantly ($p < .01$) affected by season, water deprivation, length of deprivation and time of the day. It was higher in summer compared with spring (39.3 vs 39.0°C) as well as in water deprived goats compared with control ones (39.3 vs 38.9°C) and progressively elevated with the advance of deprivation. RTs recorded in the p.m. were higher than those obtained in the a.m. with overall means of 39.2 and 39.0°C, respectively. Additionally there were significant interactions between season X treatment ($p < .01$), season X length of deprivation ($p < .05$), treatment X length of deprivation ($p < .01$) and season X treatment X length of deprivation ($p < .01$) on RT where the rise in RT in association with water deprivation was only significant in summer and most of it was delayed to the fourth day of deprivation (figure 1).

Mean RR was also higher in summer ($p < .01$) compared with spring (42 vs 26 no./min.), while it was reduced ($p < .01$) in water deprived goats compared with control ones (26 vs 42 no./min.). The significant interaction between season and treatment revealed that RR was insignificantly lowered in water deprived goats during spring season than in control (23 vs 28 no./min.), meanwhile in summer it was significantly reduced in deprived goats (figure 1) than in control ones (28 vs 56 no./min.).

The 0.3°C rise in RT and the 62% increase in RR of Aardi goat during summer above those obtained during spring suggests that they responding to the heat stress of summer. These responses were of greater magnitude in the late afternoon compared with the early morning owing to the diurnal rhythm in air temperature. Panting is known to be the major avenue of heat loss in goat and sheep. This result agrees in general with previous studies on the thermoregulatory responses of sheep and goat (Silanikove, 1987; El-Nouty et al., 1988). Water deprivation for 4-days resulted in an overall increase of 0.4°C in RT and 62% decline in RR. These changes were delayed till the fourth day of deprivation, since it was insignificant

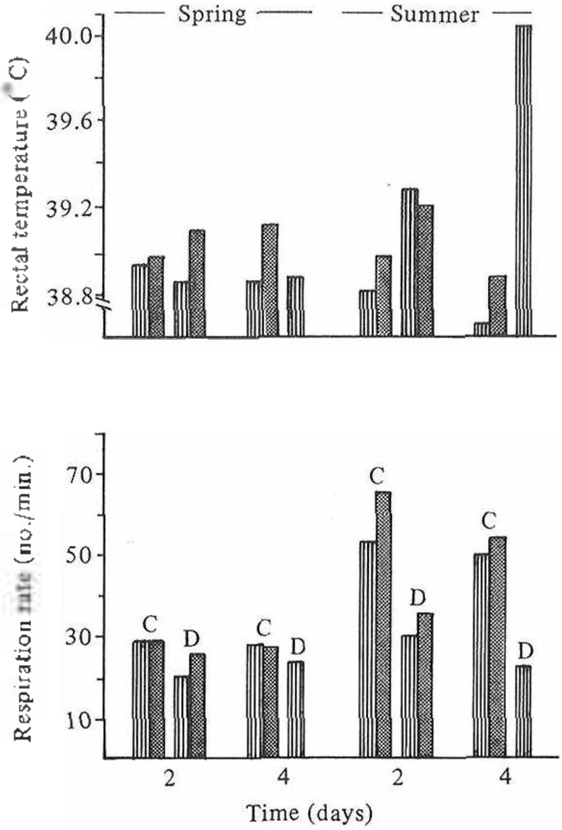

Figure 1. Rectal temperature and respiratory rate of control (C) and deprived (D) Aardi goats as influenced by season, time of the day (a.m. ; p.m.) and length of deprivation.

during the first two days indicating that these goats can tolerate infrequent drinking which is common in the hot arid regions. The 58% decline in RR of Aardi goats deprived of water during summer contributed to the 1.3°C mean rise (ranging from 0.7 to 2°C) in their RT in summer and may suggest that these goat possess a water economy mechanism, a characteristic only demonstrated in ruminants well adapted to hot environment (Houpt, 1982). Shkolnik cited by Degen (1977) stated that sinai goats alllow their body temperature to fluctuate 3-4°C during dehydration and camels 6-8°C (Schmidt-Nielsen et al., 1957). This response of goats differ from that in many sheep breeds which do not use thermolability as a physiological adaptation to heat stress. Even during dehydration, sheep have been found to be thermostable (MacFarlane, 1964).

The body weight losses after 4-days of water deprivation are reported by El-Nouty et al., (1989). To summarize, water deprivation for 4-days caused 17% and 18% loss in body weight during spring and summer season, respectively (table 1). DMI was significantly affected ($p < .01$) by season, treatement, length of deprivation ($p < .05$) and season X treatment. It was significantly higher during spring compared with summer (1.0 vs 0.5 kg/day) and in control goats compared with deprived ones (1.20 vs 0.27 kg/day). This decline progressively increased with the advance of deprivation particularly in summer deprived goats reaching nil values after 2-days of water withhold.

Water ingested was of two sources, i.e. water in feed and drinking water. Feed water decreased significantly ($p < .01$) in summer season and in deprived goats (table 1), but the relative contribution of feed water to total water ingested was very small owing to the dry nature of feed used. Control goats had statistically similar amount of drinking water in spring and summer season (table 1). It is obvious from table 1 that mean urine volume and fecal water decreased ($p < .01$) in the summer than in the spring as well as in deprived goats compared with control ones especially during summer season.

The similarity in body weight losses after 4-days of water deprivation in moderate spring (17%) and hot summer (18%) may suggest that Aardi goats inherit special water economy mechanism. The data available from the present study indicate that this is probably achieved via several means. Firstly, their great ability to reduce DMI which decreased by 77% in spring and about 100% in summer after 4-days of water deprivation. This reduction in DMI is known to reduce heat production and consequently minimize the amount of water loss for evaporative cooling. This view is supported by the observed seasonal changes in DMI and DW of control goats. Control goats, however, drank similar amount of water in both spring and summer season, their DMI was 40% less in summer. Consequently, the ratio between water and feed intake was higher in summer than in spring, which may indicate that Aardi goats reduces feed intake upon rising environmental temperature rather than increasing drinking water. In summer, water deprived goats allowed their RT to rise by 1.3°C at the end of the fourth day

TABLE 1. LEAST SQUARES MEANS AND STANDARD ERRORS OF BODY WEIGHT, DRY MATTER INTAKE, WATER INGESTED, URINE AND FECAL WATER OF AARDI GOAT AS INFLUENCED BY SEASON, WATER DEPRIVATION AND LENGTH OF DEPRIVATION.

Parameters	Spring					Summer				
	Control		Deprived		Average	Control		Deprived		Average
	2d	4d	2d	4d		2d	4d	2d	4d	
Body weight	40.9±1.9	41.9±1.9	36.7±1.9	34.6±1.9	38.5±1.0^{B}	47.9±1.9	46.1±1.9	41.4±1.9	38.2±1.9	43.4±1.0^{A}
(kg)	41.4±1.4^{b}		35.7±1.4^{c}			47.0±1.4^{a}		39.8±1.4^{b}		
Dry matter	1.5±0.1	1.5±0.1	0.7±0.1	0.3±0.1	1.0±0.05^{A}	0.9±0.1	0.8±0.1	0.01±0.1	–	0.5±0.05^{B}
intake (kg/day)	1.5±0.1^{a}		0.5±0.1^{c}			0.9±0.1^{b}		0.01±0.1^{d}		
Drinking water	4,582±324	3,684±324	–	–	–	4,564±324	3,626±324	–	–	–
(ml/day)	4,133±226		–			4,095±226		–		
Feed water	118±7.0	117±7.0	53±7.0	26±7.0	78±4^{A}	77±7.0	68±7.0	0.8±7	–	36±4^{B}
(ml/day)	117±5^{a}		40±5			72±5^{b}		0.4±5^{d}		
Urine volume	1,202±214	1,226±214	196±214	113±214	684±107^{A}	331±214	368±214	–	–	175±107^{B}
(ml/day)	1,214±151^{a}		154±151^{b}			349±151^{b}		–		

^{a,b,c,d}Means in the same row bearing different superscripts differ ($p < .05$).
^{A,B}Averages in the same row bearing different superscripts differ ($p < .05$).

of deprivation while in spring no changes occurred in RT of water deprived goats. This may mean that these desert adapted goats are able to store heat and hence lowering the requirement for evaporative losses when water supply is limited. These results agree in general with previous reports on sheep and goats which indicated a decline in feed intake due to water deprivation, a tendency to increase water consumption with the rise in ambient temperature and the ability of goat core body temperature (More and Sahni, 1978; Singh et al., 1982; Dahlborn, 1985; Kaushish et al., 1987).

Secondly, their outstanding ability to reduce urine volume and to excrete dry feces. In control goats, urine volume was reduced by 71% with the rise in environmental temperature from spring to summer with concomitant decline in the moisture content of the feces from 64% to 25%. In deprived goats, the moisture content of the feces furtherly decreased to 24% in spring and 6% in summer. Furthermore these goats were able to ingest 5-6 liter of water (~20% of their body weight) in one drink after the end of the deprivation periods without any visible harmful effect.

Mean serum osmolality was significantly ($p < .01$) higher in summer compared with spring (330.7 ± 5.1 vs 307.5 ± 5.1 mOs/kg). This was associated with higher ($p < .01$) mean serum sodium concentration (192.7 ± 2.4 vs 164.9 ± 2.4 meq/l), but lower ($p < .05$) mean potassium concentration (5.6 ± 0.2 vs 6.1 ± 0.2 meq/l). The overall means of serum osmolality and serum sodium concentration rose significantly ($P < .01$) in water deprived goats compared with control ones, while mean serum potassium concentration was significantly ($p < .01$) lowered. In control goats, the overall means of serum osmolality, sodium and potassium concentrations were 296.5 ± 5.1 mOs/kg, 169.1 ± 2.4 and 6.3 ± 0.2 meq/l, respectively. The corresponding mean values for deprived goats were 341.6 ± 5.1 mOs/kg, 188.6 ± 2.4 and 5.3 ± 0.2 meq/l. Serum osmolality and sodium concentration were significantly influenced ($p < .01$) by the interaction of treatment X length of deprivation where they rose with the advance of deprivation, meanwhile potassium concentration was slightly reduced (figure 2).

The increase in the overall mean of serum osmolality from spring to summer by less than 8% in face of about 11°C rise in ambient temperature may indicate the ability of this goats to maintain homeostasis in extreme heat. The rise in serum osmolality in summer was apparently due to elevated serum sodium concentration which could be attributed to increased evaporative water loss via

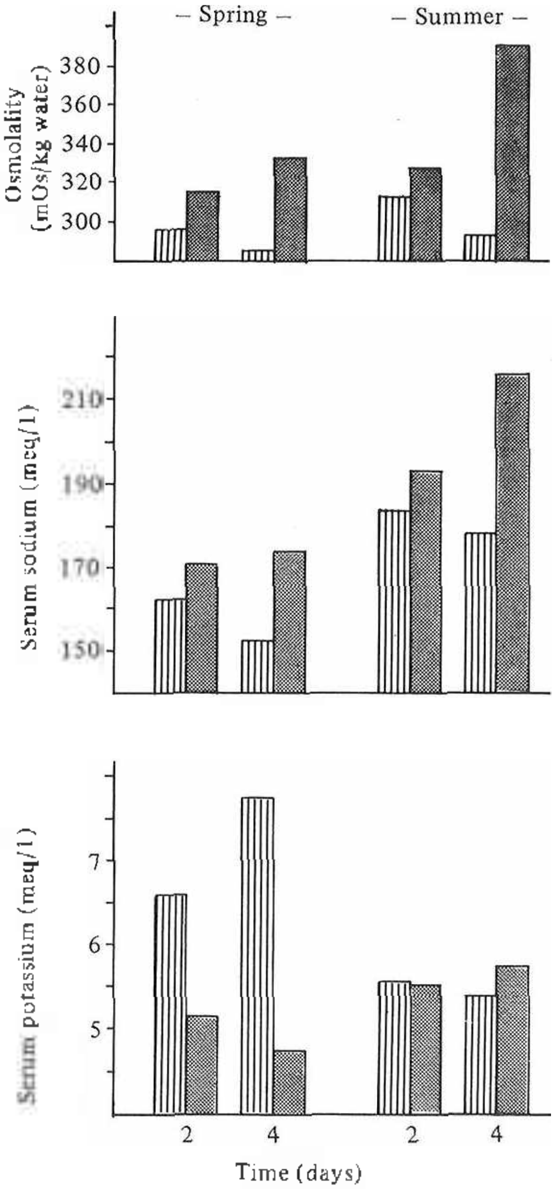

Figure 2. The effects of season, water deprivation and length of deprivation on control [vertical bars] and deprived [shaded] Aardi goats serum osmolality, serum sodium and potassium concentrations.

respiratory enhancement. In spring, deprived goats had by the end of the fourth day 15% and 11% rise in serum osmolality and sodium concentration and 34% decline in serum potassium concentration. Meanwhile, the corresponding values in summer were all rose by 29%, 20% and 4%.

The higher osmolality in water deprived goats in summer relative to spring reflects acceralated body fluid loss by high environmental temperature. Therefore, Aardi goats deprived of water in summer responded by remarkable reduction in urine volume and excreted almost dry feces and lowered their RR. These in addition to previously reported increase in plasma albumin (El-Nouty et al., 1989) should contribute to the maintenance of plasma volume. Maltz et al. (1984) working with non-lactating sinai goats deprived of water for 4-days at an ambient temperature of 25°C reported 15% rise in plasma osmolality which is higher than that obtained in the present study during spring season but lower than that observed during summer season owing to difference in ambient temperature. Also, Degen (1977) found that the plasma osmolality of Awassi and German Mutton Merino sheep to rise from about 310 mOs/l H_2O to 380 (23%) when their daily water intake was only reduced from 4.5 l to 1 l. In sinai goats both plasma arginine vasopressin and plasma renin activity was reported to rise after 4-days of water deprivation (Maltz et al., 1984). This rise in body fluid controlling hormonal system may be responsible for the observed reduction in water loss and elevated serum sodium concentration. The lower potassium concentration in deprived goats compared to control ones during spring season (figure 2) may be ascribed to deprivation-induced low DMI in the former, since most feedstuffs are rich in potassium. Meanwhile, the low potassium concentrations in both control and deprived goats during summer season may be attributed not only to their low DMI but also to increased potassium loss in sweat. Potassium is known to be the main electrolyte in animal perspiration (MacFarlane, 1968).

In conclusion Aardi goats are able to tolerate about 3-days without drinking in summer and more than 4-days in spring when eating feed with dry nature. When these goats were deprived of water for 4 days in summer, they were able to lower their RR, UV, FW, DMI and allow their body temperature to rise indicating their thermolability.

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