Available online at www.sciencedirect.com
SCIENCE DIRECT®
Small Ruminant Research 63 (2006) 100–109
Small Ruminant Research
www.elsevier.com/locate/smallrumres

Physiological responses of Saudi Arabia indigenous goats to water deprivation

Mohammed Alamer*

Department of Animal Production Sciences, College of Agricultural Sciences and Foods, King Faisal University, P.O. Box 420, Hofuf 31982, Saudi Arabia

Received 17 November 2003; received in revised form 8 December 2004; accepted 4 February 2005
Available online 12 March 2005

Abstract

This study was conducted to evaluate and compare the physiological responses to water deprivation and rehydration in three local goat breeds (Hipsi, Aardi and Zumri) of Saudi Arabia under hot summer conditions. Six 10–12 months old bucks from each breed with a range in body weight of 30–42 kg were used. Three days of water deprivation resulted in an average reduction of 20.6% in body weigh. Furthermore, feed intake was also decreased immediately following water deprivation from day 1 and continued to decrease until the last day of water deprivation in which feed intake decreased from 123.7 ± 2.7 to 17.0 ± 1.4 g/kg $W^{0.75}$ for the three breeds. Water deprivation had no clear effect on the respiratory activity of Aardi and Zumri goats, while being reduced in the Hipsi breed by 30%. There was an increase in the pm values for rectal temperature (39.3 ± 0.1 to 39.7 ± 0.1 °C) following water deprivation in all breeds. Packed cell volume, plasma osmolality and plasma levels of Na increased by 38, 17.8 and 13.6%, respectively, by the end of the dehydration period. There was a significant increase ($P < 0.01$) in plasma urea from 34.3 ± 1.2 to 85.5 ± 4.8 mg/dl, and plasma creatinine from 0.9 ± 0.1 to 1.7 ± 0.1 mg/dl following water deprivation in all breeds. During the first 15 min of rehydration, goats consumed an average of 6.8 l water that amounted to approximately 23.5% of their dehydrated body weights, and goats were able to regain most of their body weight losses. There was a slow recovery in plasma osmolality and packed cell volume, indicating a slow absorption of water from the gut to the vascular system. It could be concluded that these three local goat breeds showed a great tolerance to water deprivation during hot summer conditions of Saudi Arabia. There were no apparent differences between breeds in their ability to withstand water deprivation, restoration of body weight loss or physiological parameters.
© 2005 Elsevier B.V. All rights reserved.

Keywords: Water deprivation; Rhydration; Goats; Desert environment

1. Introduction

The desert environment is characterized by a long hot summer with high solar radiation, along with poor and sparsely distributed pastures. Furthermore, wa-

* Tel.: +966 3 5800000x1411; fax: +966 3 5801778.
E-mail address: malamer@kfu.edu.sa.

0921-4488/$ – see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.smallrumres.2005.02.004

ter is limited and grazing animals depend on sparsely spaced watering points to satisfy their physiological needs. These harsh environments constitute stressful conditions to animals raised in these areas. Thus, these animals have developed various adaptive mechanisms that enable them to survive under these conditions of extreme heat and water stress. Goats are considered highly suitable animals for raising in such areas, as they were the first domesticated in the hot and arid regions of the world. Goats raised in the arid and desert regions may encounter periods of lack of water, particularly during the dry summer season, they may go into a state of dehydration for several days (Shkolnik and Choshniak, 1985). Several reports have documented the capability of goats tolerating dehydration (Shkolnik and Choshniak, 1985; Silanikove, 1994, 2000). Tolerance to this dehydration is important, as the ability of grazing animals to survive for prolonged periods of water shortage will allow them to graze far away from the watering points and thus exploit the sporadic desert pasture, evenly and efficiently. The three local breeds of goats distributed in different regions of the Kingdom of Saudi Arabia with varying numbers namely the Aardi, Hipsi and Zumri, are raised mainly for meat production. The physiological adaptations utilized by these breeds that allow them to survive and maintain their body functions during water deficiency, especially during the hot summer months, are not known. It is possible that breed differences evoke different responses to the various stressors in a specific environment, and depend on the degree of adaptation to that environment (Jindal, 1980). This study was therefore designed to assess and compare the various physiological responses to dehydration of the three local goat breeds (Hipsi, Aardi and Zumri) under hot summer conditions. Their ability to rehydrate was also assessed by determining their ability to restore their physiological mechanisms following hydration at the end of the water deprivation period.

2. Materials and methods

The experiment was carried out at the Agricultural and Veterinary Research and Training Station of King Faisal University in Alhassa, Saudi Arabia.

The climate in Saudi Arabia is generally classified as desert with a dry climate, very hot and dry summer season. However, Alhassa region is one of the hottest and driest areas of Saudi Arabia, where ambient temperatures may reach 50 °C during the summer. The annual rainfall is 74 mm, spread over an average of 31 days during the winter season, without any precipitations during the lengthy hot summer months.

Six 10–12 month old male goats (body weight of 30–42 kg) each of the Hipsi, Aardi and Zumri breeds were used in this study. The experimental bucks were maintained as a group in a shaded pen and provided with 10 kg of a commercially formulated concentrate (11% CP); alfalfa hay and water ad libitum. The bucks were maintained under these management conditions for at least a month. Two weeks prior to conducting the trial, the bucks were moved into an adjacent shaded pen where all goats were individually housed (1.5 m × 2.0 m) in an alternating breed sequence. Bucks were individually fed 0.5 kg of the concentrate, with alfalfa hay and water ad libitum, and this was considered as the adaptation period.

The experiment included three periods; 1 day of hydration, 3 days of dehydration and 1 day of rehydration. During the pre-treatment control period (hydration), water was available ad libitum. At 06:00 h of the following day, all water was removed from the pens and the bucks had no access to water for 3 consecutive days (dehydration period). Hay and concentrate, however, were offered twice a day as usual at 08:00 h and 16:00 h. At the end of the third day of the dehydration period (morning of the fifth day of the experiment), water was made available to all goats (rehydration).

Feed intake (hay and concentrate) was recorded daily before the morning feeding, by weighing the remains of the previous day. Water intake, except for the dehydration period, was determined and the amount of water consumed by the goats during the first 15 min following restoration of water was also recorded. Changes in body weight were assessed every day at 08:00 h (prior to feeding). Rectal temperature (RT) and respiration rate (RR) were recorded twice daily (at 06:00 and 13:00 h). Rectal temperature was recorded with the aid of a digital thermometer and RR with a stethoscope. Blood was sampled from the jugular vein (07:00 h) daily in heparinized vacutainers. During the first 6 h of the rehydration period, blood samples were collected hourly.

The packed cell volume (PCV) was determined immediately following blood sampling by centrifu-

gation (Autocrit, USA) of blood samples aspirated into heparinized capillary tubes. Plasma was obtained and stored at −20 °C until analyzed. The plasma osmolality was determined by a freezing point depression method utilizing an osmometer (Osmometer 800CL, Slamed, Germany). Commercial kits were used for determinations of plasma glucose (Glucose Oxidase method, Nubenco Diagnostics, New Jersy, USA), plasma urea (no. 021, United Diagnostics Industry, Dammam, Saudi Arabia), and plasma creatinine (Biosystems, Barcelona, Spain). Plasma Na oncentration was determined by a clinical flame photometer (Jenway, Essex, England).

Data were subjected to the statistical analyses using the Generalized Linear Model Procedures (GLM) of SAS (1996). The model included experimental day, breed, time of the day (for respiration rate and rectal temperature) and various interactions. Duncan's multiple range test was used for comparing significant group differences.

3. Results

Maximum, minimum and average ambient temperatures during the experimental periods were 45.2, 27.8 and 35.8 °C and the corresponding values of relative humidity were 35.5, 13.3 and 23.3%. Body weight decreased significantly ($P < 0.01$) in all groups when subjected to water deprivation (Fig. 1). It started on the first day and continued to decrease gradually with the advance of water deprivation. At the end of the dehydration period, Aardi goats tended to lose more weight than the other two breeds (Table 1). However, body weight losses were regained within 24 h following rehydration (Fig. 1). At the end of the dehydration period, goats drank an average of 6.8 l during the first 15 min of water restoration, which amounted to about 23.5% of their dehydrated body weights. Goats in all groups were able to regain most of their body weight losses during the first few minutes of rehydration (Table 1).

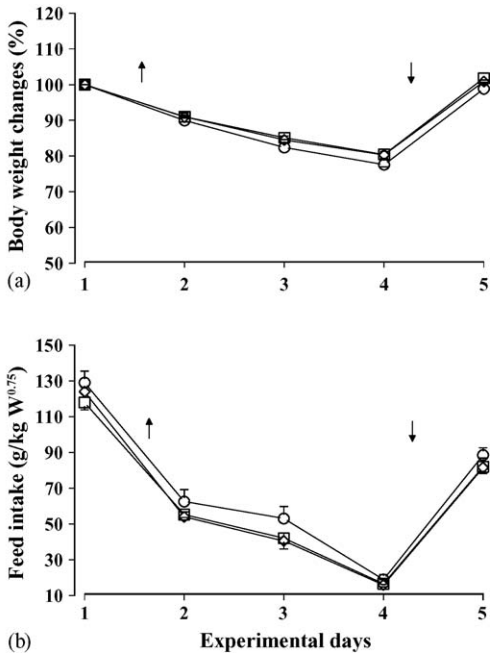


Fig. 1. Changes in body weight (a) and feed intake (b) during water deprivation and rehydration (mean ± S.E.) in Hipsi (□), Aardi (◯) and Zumri (◇) goats. Arrows indicate when water was withdrawn (↑) and restored (↓).

Feed intake (expressed as g/kg $W^{0.75}$) was dramatically reduced ($P < 0.01$) during the first day of water deprivation and continued to decrease, but at a slower rate towards the end of the deprivation period (Fig. 1). At the end of the water deprivation period, feed intake was reduced by 85%. Aardi goats maintained a higher

Table 1
Body weight losses following 3 days of water deprivation and water ingestion after rehydration in Hipsi, Aardi and Zumri goats during hot summer conditions

Breed	BW loss			Water intake during the first 15 min of rehydration		
	Initial BW (kg)	BW loss (kg)	% of BW loss	Water intake (l)	Water intake as % of dehydrated BW	% of dehydrated BW regain
Hipsi	40.0	7.8	19.6	7.3	22.9	94.7
Aardi	34.0	7.6	22.4	6.9	26.6	91.4
Zumri	37.3	7.3	19.7	6.3	21.1	87.3

No significant differences between breeds. BW: body weight.

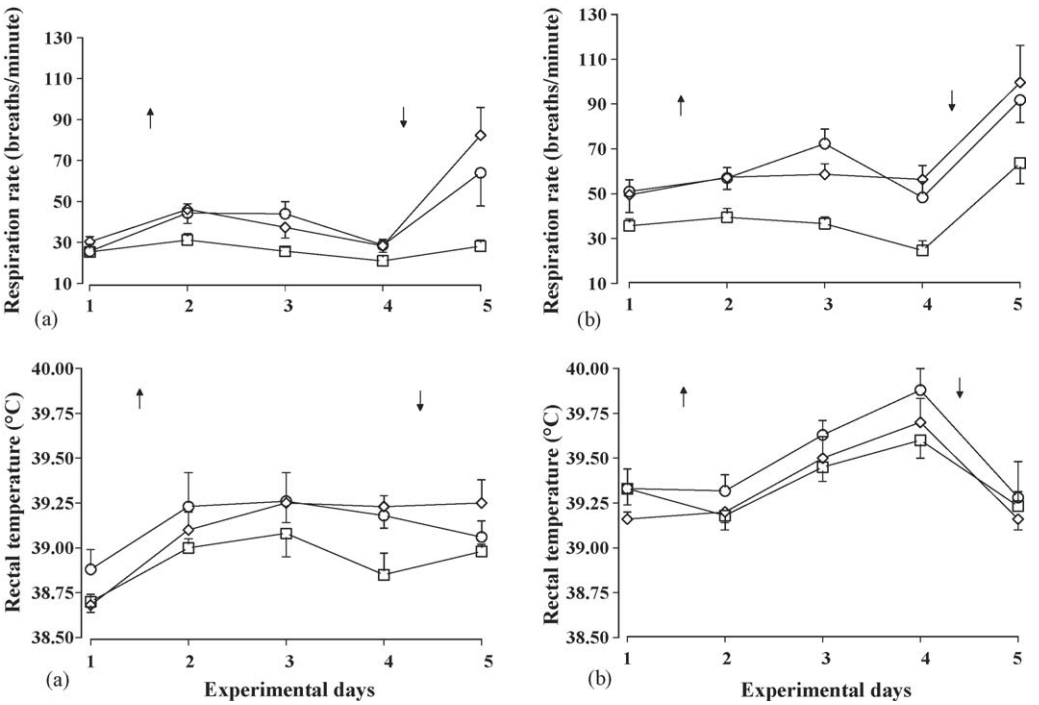


Fig. 2. Morning (a) and afternoon (b) respiration rates and rectal temperatures (mean ± S.E.) during water deprivation and rehydration in Hipsi (□), Aardi (◯) and Zumri (◇) goats. Arrows indicate when water was withdrawn (↑) and restored (↓).

level of feeding throughout experimental periods. Presentation of water did not result in a full recovery of the feed intake and the normal level of feeding was not attained within 24 h following rehydration.

There were significant effects ($P < 0.01$) of breed, day and time of the day on RR (Fig. 2). The Hipsi goats constantly exhibited the lowest RR values, during both the morning and afternoon. During water deprivation, RR was significantly reduced ($P < 0.01$) in the Hipsi goats only. Presentation of water significantly ($P < 0.01$) increased the afternoon's RR during the first day of rehydration in all goats, but it increased in the Aardy and Zumri breeds during the morning.

Rectal temperature was significantly affected ($P < 0.01$) by breed, experimental day and time (Fig. 2). The Hipsi breed maintained a lower RT, compared to the other breeds. Twenty-four hours of water deprivation resulted in an increase in morning RT, which remained elevated until the third day of deprivation but it was lower in the Hipsi goats. Afternoon values were different as the increase was delayed to the second day of water deprivation, but further increased during the third day. A progressive decline towards hydration levels was obvious as a result of rehydration, particularly in the afternoon.

The PCV was significantly affected ($P < 0.01$) by breed, as well as experimental day (Fig. 3). The effect of water deprivation on PCV was small during the first day, but it showed a steady and significant increase ($P < 0.01$) as the water deprivation period advanced. The average increase in all groups following 3 days of water deprivation being 38.4%. Zumri goats recorded the highest PCV values throughout the trial. One hour following rehydration was not sufficient to induce any changes in PCV, but it was significantly reduced by 8.7 % following the second hour and continued to decline slowly thereafter (Fig. 3). Normal hydration levels of PCV were regained by the sixth hour following rehydration in all groups.

Plasma osmolality (Posm) increased during water deprivation and exhibited a steady increase ($P < 0.01$) with the increase in length of deprivation (Fig. 3). At

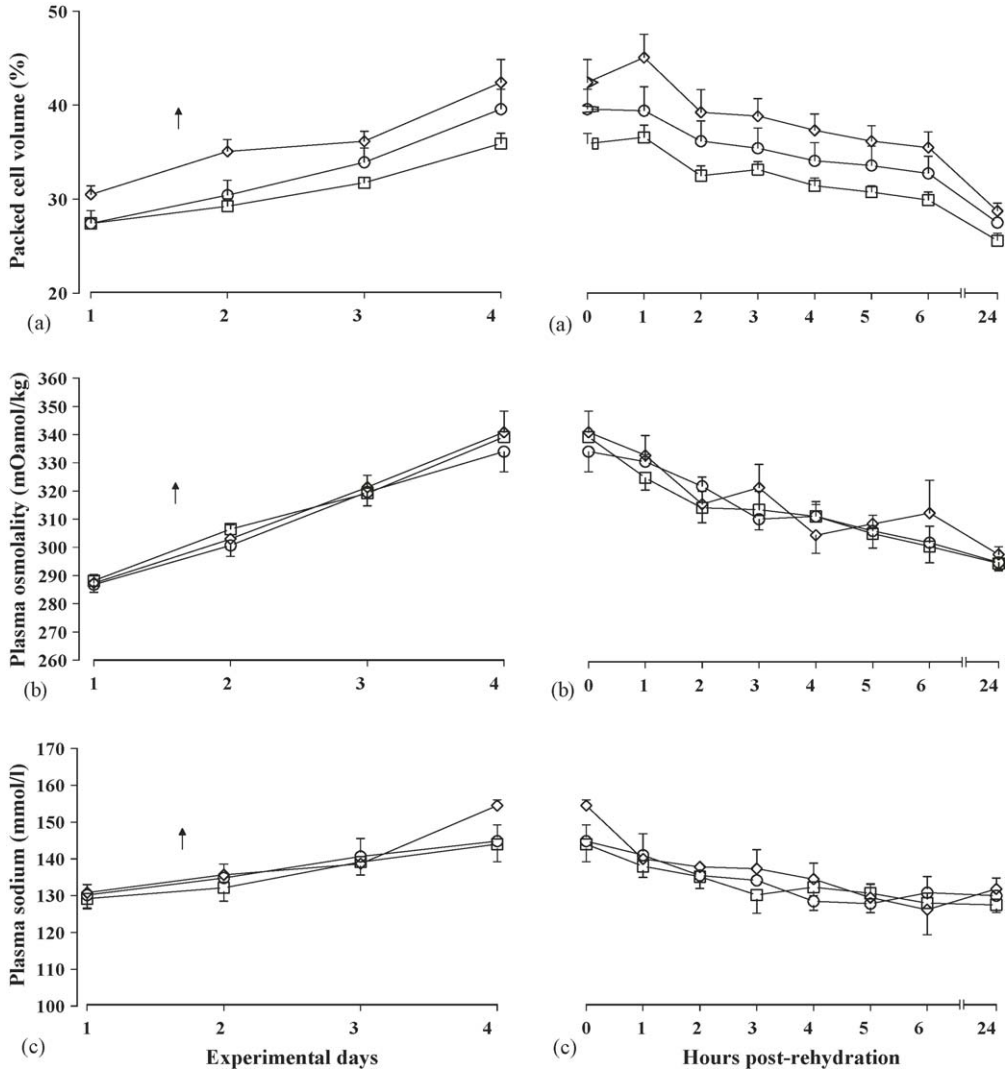


Fig. 3. Changes in packed cell volume (a), plasma osmolality (b) and plasma Na (c) (mean ± S.E.) during water deprivation and rehydration in Hipsi (□), Aardi (◯) and Zumri (◊) goats. Arrows indicate when water was withdrawn (↑).

the end of the dehydration period, the Posm had increased by 17.8% in all breeds without any significant difference between groups. Plasma osmolality declined within 2 h following watering and continued to decline towards the sixth hour of rehydration. By this time a decline of 9.5% was recorded in all groups, but it was still above the normal hydration levels. Plasma osmolality continued to decline during the first 24 h of rehydration towards control values. Plasma Na significantly increased ($P < 0.01$) during the water deprivation period in all breeds, and exhibited a steady and slow increase with the advance of deprivation of water (Fig. 3). At the end of the third day, plasma Na increased by an average of 13.6% in all goats. Restoration of water significantly reduced ($P < 0.01$) the plasma Na immediately following the first hour of watering in all goats. Thus, hydration levels were attained in all goats within 2 h of rehydration.

No significant differences could be detected in plasma glucose (GLU) levels between breeds or days

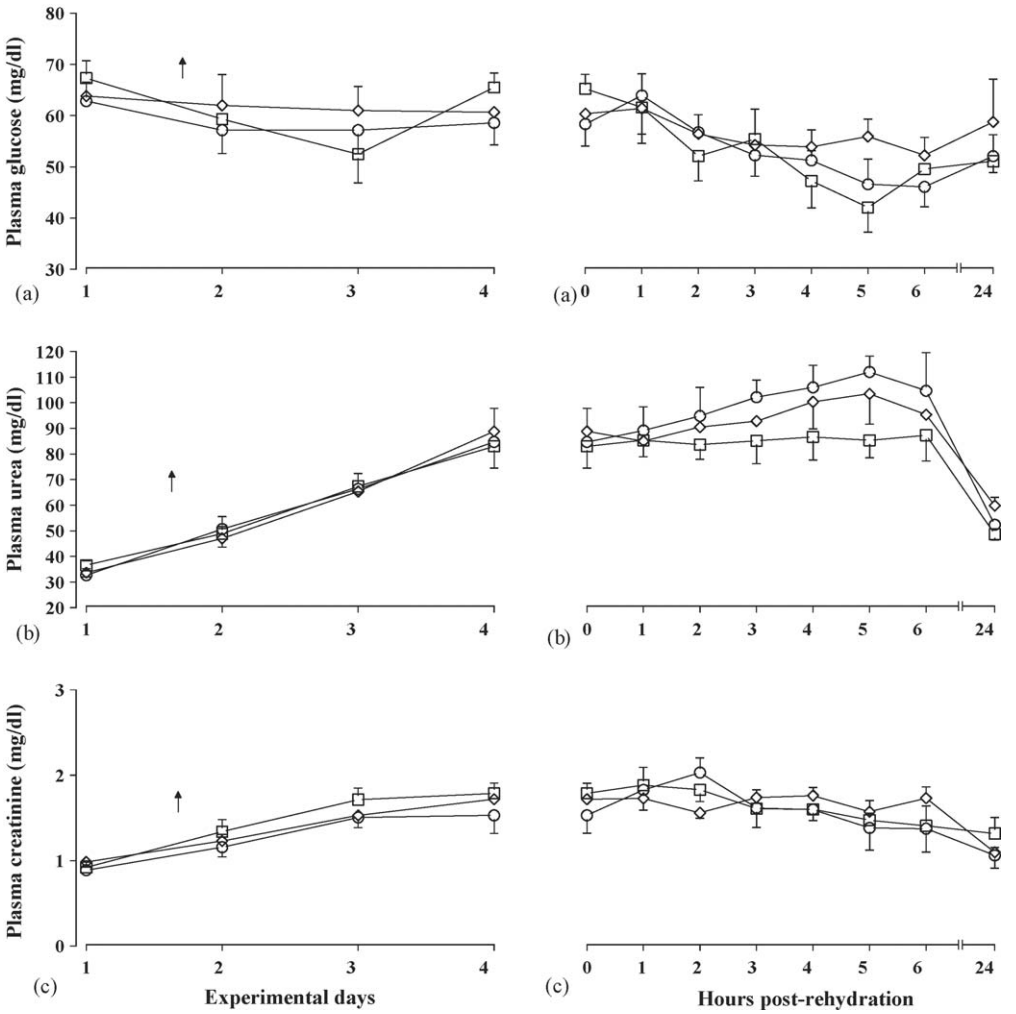


Fig. 4. Changes in plasma glucose (a), urea (b) and creatinine (c) concentrations (mean ± S.E.) during water deprivation and rehydration in Hipsi (□), Aardi (◯) and Zumri (◊) goats. Arrows indicate when water was withdrawn (↑).

(Fig. 4), but it was lower during the second day of water deprivation in Hipsi breed. Following rehydration, plasma GLU tended to decline by the fourth hour following rehydration in Aardi and Hipsi breeds. Plasma urea increased significantly ($P < 0.01$) and progressively with an increase in the interval of water deprivation which ultimately produced an average increase of 149% in plasma urea by the end of dehydration period (Fig. 4). Following rehydration, plasma urea levels did not decline, but rather tended to increase in all goats, which maintained elevated levels throughout the 6 h following rehydration (Fig. 4). A decrease of 37% was recorded at the end of the first day of rehydration, but was still above the hydration levels for the Aardi and Zumri goats. Plasma creatinine (CRE) showed a steady increase from the first day of water deprivation towards the end of water deprivation. The average plasma CRE concentration 72 h following deprivation of water was 80.6% higher than during the pre-deprivation level (Fig. 4). Rehydration did not result in any changes in plasma CRE during the first 6 h of rehydration, but it decreased towards control levels in all goats by the end of the first day of rehydration.

4. Discussion

Three days of water deprivation reduced the body weight in all goats by 21%. Sudanese male goats were reported to lose about 18% of their body weights within the same period of water deprivation, but at a lower ambient temperature (El-Hadi, 1986). Moreover, non-lactating female black Bedouin goats, which are known for their great adaptation to water deficiency, were reported to lose 20% of their body weight within 3 days of total water deprivation under moderate summer conditions (Maltz et al., 1984). When considering the high ambient temperature that prevailed during the study, the great resistance to water deficiency was clearly evident in these local Saudi goats. Body weight loss associated with water deprivation can be ascribed to a reduction in feed and water intake, together with a loss in total body water. Evidence has indicated that most of the body weight losses during dehydration was accounted for body water loss in sheep and goats (El-Hadi, 1986; Degen and Kam, 1992; Parker et al., 2003). However, some loss in body solids cannot be ignored, as there was a marked reduction in feed intake during water restriction.

By the end of the third day of water deprivation, goats were consuming an amount of feed not exceeding 14.5% of the control level. It is well known that insufficient water supply will suppress feed intake (Silanikove, 2000; Ahmed and El-Kheir, 2004). However, the observed decrease in feed intake during the water deprivation period in this study was higher and faster than reported by others. Egyptian Baladi goats maintained a relatively higher level of feeding, when their feed consumption was 35% of the control level after 3 days of complete water deprivation, but at a lower environmental temperature (Hassan, 1989). Findings of the present study are in accordance with El-Nouty et al. (1990), who reported a dramatic reduction in feed intake in Aardi bucks exposed to water deprivation. The decrease in feed intake during periods of water deficiency can be viewed as an adaptive measure employed by animals inhabiting desert and arid areas for conserving body water. The rapid and greater reduction in feed intake in this study may be related to the high ambient temperatures prevailing. It is recognized that the reduction in feed intake during water restriction is more pronounced following high ambient temperatures in ruminants (Silanikove, 1992). Therefore, the decrease in feed consumption in this study may be attributed to great water conservation associated with digestion and excretion of metabolic waste products. Also, the reduction in the heat increment and thus water loss that could have been used for evaporative cooling to dissipate extra heat. The behavior in the Aardi breed supports this contention and it maintained the highest level of feed intake during water deprivation, which may have contributed to the tendency of a greater loss in body weight.

The local goats were able to consume a volume of water accounting to 23.5% of their dehydrated body weights. El-Nouty et al. (1990) reported similar findings (20%) in Aardi goats deprived of water for 4 days. However, non-lactating female black Bedouin goats were able to drink 28–36% of their body weights at the end of a dehydration session (Choshniak et al., 1984; Maltz et al., 1984). This breed is known for a capacity to rehydrate rapidly as large amounts of water are stored in the extracellular spaces. In this study, local goats are capable of regaining most of their body weight loss within minutes of receiving water. The black Bedouin goats however are able to gulp an amount of water that exceeded the losses in their body weights (Maltz et al., 1984). Awassi sheep replenished only 52% of their body weight loss, and needed 24 h to restore the remainder (Laden et al., 1987). Local Awassi and Najdi sheep can restore up to 77% of their body weight losses during summer (Alamer and Al-hozab, 2004). Local goats thus have the capacity of rapid rehydration, but cannot match the black Bedouin goats in this regard.

A noticeable reduction in respiratory activity during water deprivation has been reported in sheep (Abdelatif and Ahmed, 1994; Ismail et al., 1996) and goats (Hassan, 1989). Certain investigators could not detect any change in the RR in goats (Singh et al., 1982; Baker, 1989; Das et al., 1994). This discrepancy may be related to the heat load imposed on animals during water deprivation. The higher ambient temperature could presumably prevent any reduction in RR. In goats, the excessive heat load with solar radiation exposure during water restriction resulted in a 50% increase in RR (Dmi'el, 1986). Hipsi goats exhibited the lowest respiratory activity throughout the experimental periods, indicating that the thermal load imposed on this breed was lower. The white-short hair covering of the Hipsi, compared to the black-long hair in the other breeds

may have contributed to the possible lower heat gain by reflecting most of the solar radiation (Acharya et al., 1995). Goats in this study were not totally protected from the sun and received a considerable amount of solar radiation during the day.

The goats were able to maintain normal thermoregulatory mechanisms for 24 h following water deprivation, but the RT started to increase when water deprivation was extended. It is recognized that water-deprived goats reduce their thermoregulatory evaporation and therefore allow their body temperature to rise presumably to trigger the water conservation mechanisms (Devendra, 1987). Cutaneous evaporation could have been suppressed due to water deprivation (Alamer, 2003). This indicates that there may be a reduction in evaporative cooling and thus heat dissipation which could have contributed to the increase in RT during the period of water deprivation.

The recorded increase in PCV, Posm and plasma Na following water deprivation in this study has also been reported in other studies on goats (Hassan, 1989; El-Nouty et al., 1990; Rajkhowa et al., 1999). Water deprivation induced a haemoconcentration due to losses in total body water during water restriction (El-Hadi, 1986; Degen and Kam, 1992). The increase in Posm was likely caused by an increase in plasma Na. The rise in Posm during water restriction contributes largely to the maintenance of the plasma volume, by inducing water movement into the vascular system. It took 1 h for a clear decline in Posm and PCV to be observed following rehydration. Studies in goats reveal no changes in Posm or other blood constituents within an hour following rehydration after a period of dehydration, but found it to decline gradually (Choshniak and Shkolnik, 1977; Choshniak et al., 1984; Maltz et al., 1984). In Moroccan goats, however, the Posm exhibited a sharp decline and returned to hydration levels within 2–3 h following rehydration (Hossaini-Hilali et al., 1994). The slow rate of changes in the blood constituents and plasma osmolality observed in the present study may reflect the slow return to normal plasma volume. The water loss from the vascular system during the water deprivation period is gradually restored once the goats gained access to water probably to allow blood constituents to be maintained at normal levels and prevent sudden plasma dilution hence haemolysis is avoided. This water loss could be largely regulated by the rumen as the imbibed water is first retained in the rumen (for about an hour without changes), before being slowly released to the lower part of the gut, which is more permeable than the rumen (Choshniak et al., 1984).

The observed increase in plasma urea levels in this study has also been reported in goats and sheep during water deprivation (Laden et al., 1987; Abdelatif and Ahmed, 1994; Ahmed and Abdelatif, 1995). This may be related to a decline in urinary total N and urea output which results in an increase in N retention (More, 1982; Mousa et al., 1983; Brosh et al., 1987). The decline in the rate of urea excretion associated with water restriction (Mousa et al., 1983) is expected as a reduction in glomerular filtration rate is evident during water deprivation (Wittenberg et al., 1986). Urea concentration remained unchanged an hour following watering, but tended to increase during the next 5 h. Similar findings were reported by Choshniak et al. (1984) and may be related to a decrease in urea excretion and clearance rate indicating a tendency for urea retention (Laden et al., 1987).

A similar rate of increase (88%) in plasma CRE levels was reported in Awassi sheep, but following 5 days of water deprivation (Laden et al., 1987). Abd El-latif et al. (1997) reported a moderate increase (13%) in plasma CRE following 3 days of water restriction in Barki sheep. This increase in plasma CRE may be a consequence of a general reduction in the urinary excretion rate during water deprivation, as reported in sheep (More, 1982). The increase in plasma CRE may also be related to changes in the clearance rate, as the endogenous CRE clearance rate was found to be correlated to the glomerular filtration rate in sheep (Nawaz and Shah, 1984). Thus, plasma CRE can be used as an indicator of glomerular filtration rate in domestic animals (Finco, 1997). As adaptation to the water balance during water deficiency, sheep and goats reduce their glomerular filtration rate which eventually results in a reduction of urine volume. Therefore, the rise in plasma CRE could be related to the maintenance of renal function at a lower level, which consequently reduces the clearance rate of plasma CRE. Plasma CRE concentration remained relatively unchanged during the first 6 h post-watering. Urine flow as well as glomerular filtration rate decreased following rehydration in goats, which even maintained at levels below or close to that during water deprivation levels (Choshniak et al., 1984; Wittenberg et al., 1986). Therefore, the maintenance of plasma CRE levels during rehydration may be at-

tributed to the delay in the return of renal function to normal levels.

5. Conclusions

The Hipsi, Aardi and Zumri breeds tolerated water deprivation for 3 days during hot conditions. Water conservation mechanisms were evoked during water deprivation by a dramatic reduction in feed intake, and increase in rectal temperature, while renal function may have been retarded and maintained below normal levels. The Hipsi goats exhibited less thermal discomfort as indicated by lower respiratory activity and their response to water deprivation by reducing their RR indicating better water conservation mechanisms. Local Saudi goats could be categorized as rapid recovers as they are able to restore most of their body weight loss shortly following watering but they are slow absorbers as indicated by the slow changes in PCV and Posm.

Acknowledgements

Support provided by King Abdulaziz City for Science and Technology (project no. LGP-6-9) is greatly appreciated. The author is also grateful to the Agricultural and veterinary Research and Training Station of King Faisal University for providing the necessary facilities to conduct the study.

References

Abdelatif, A.M., Ahmed, M.M.M., 1994. Water restriction, thermoregulation, blood constituents, and endocrine responses in Sudanese desert sheep. J. Arid Environ. 26, 171–180.

Abd El-latif, H., Ismail, E., Salem, M., Hassan, G.A., 1997. Effect of dehydration on some biochemical constituents of blood in Barki, Suffolk and their crossbred sheep. Indian J. Anim. Sci. 67, 786–791.

Acharya, R.M., Gupta, U.D., Sehgal, J.P., Singh, M., 1995. Coat characteristics of goats in relation to heat tolerance in the hot tropics. Small Rumin. Res. 18, 245–248.

Ahmed, M.M.M., Abdelatif, A.M., 1995. Effect of dietary protein level on thermoregulation, digestion and water economy in desert sheep. Small Rumin. Res. 18, 51–56.

Ahmed, M.M.M., El-Kheir, I.M., 2004. Thermoregulation and water balance as affected by water and food restrictions in Sudanese desert goats fed good-quality and poor-quality diets. Trop. Anim. Health Prod. 36, 191–204.

Alamer, M., 2003. Heat tolerance of local goat breeds in Saudi Arabia. Arab Gulf J. Sci. Res. 21, 210–216.

Alamer, M., Al-hozab, A., 2004. Effect of water deprivation and season on feed intake, body weight and thermoregulation in Awassi and Najdi sheep breeds in Saudi Arabia. J. Arid Environ. 59, 71–84.

Baker, M.A., 1989. Effects of dehydration and rehydration on thermoregulatory sweating in goats. J. Physiol. 417, 421–435.

Brosh, A., Shkolnik, A., Choshniak, I., 1987. Effects of infrequent drinking on the nitrogen metabolism of Bedouin goats maintained on different diets. J. Agric. Sci. (Camb.) 109, 165–169.

Choshniak, I., Shkolnik, A., 1977. Rapid rehydration in the black Bedouin goats: red blood cells fragility and role of the rumen. Comp. Biochem. Physiol. 56A, 581–583.

Choshniak, I., Wittenberg, C., Rosenfeld, J., Shkolnik, A., 1984. Rapid rehydration and kidney function in the Black Bedouin goat. Physiol. Zool. 57, 573–579.

Das, S.K., Kumar, P., Singh, D., Singh, K., 1994. Effect of water restriction on thermoregulatory responses in bucks. Indian J. Anim. Sci. 64, 899–901.

Degen, A.A., Kam, M., 1992. Body mass loss and body fluid shifts during dehydration in Dorper sheep. J. Agric. Sci. (Camb.) 119, 419–422.

Devendra, C., 1987. Goats. In: Johnson, H.D. (Ed.), Bioclimatology and the Adaptation of Livestock. Elsevier Science Publishers, New York, pp. 157–168.

Dmi'el, R., 1986. Selective sweat secretion and panting modulation in dehydrated goats. J. Therm. Biol. 11, 157–159.

El-Hadi, H.M., 1986. The effect of dehydration on Sudanese desert sheep and goats. J. Agric. Sci. (Camb.) 106, 17–20.

El-Nouty, F.D., Al-Haideray, A.A., Basmaeil, S.M., 1990. Physiological responses, feed intake, urine volume and serum osmolality of Aardi goats deprived of water during spring and summer. Aust. J. Anim. Sci. 3, 331–336.

Finco, D.R., 1997. Kidney function. In: Kaneko, J.J., Harvey, J.W., Bruss, M.L. (Eds.), Clinical Biochemistry of Domestic Animals, fifth ed. Haracourt Brace and Company Asia PTE, Ltd., Delhi, India, pp. 441–484.

Hassan, G.E., 1989. Physiological responses of Anglo-Nubian and Baladi goats and their crossbreds to water deprivation under subtropical conditions. Livest. Prod. Sci. 22, 295–304.

Hossaini-Hilali, J., Benlamlih, S., Dahlborn, K., 1994. Effects of dehydration, and hyperhydration in the lactating and non-lactating black Moroccan goat. Comp. Biochem. Physiol. 109A, 1017–1026.

Ismail, E., Hassan, G.A., Abo-Elezz, Z., Abd El-latif, H., 1996. Physiological responses of Barki and Suffolk sheep and their crossbreeds to dehydration. Egypt J. Anim. Prod. 33, 89–101.

Jindal, S.K., 1980. Effect of climate on goats: a review. Indian J. Dairy Sci. 33, 285–292.

Laden, S., Nehmadi, L., Yagil, R., 1987. Dehydration tolerance in Awassi fat-tailed sheep. Can. J. Zool. 65, 363–367.

Maltz, E., Olsson, K., Glick, S.M., Fyhrquist, F., Silanikove, N., Choshniak, I., Shkolnik, A., 1984. Homeostatic responses to

water deprivation or hemorrhage in lactating and non-lactating Bedouin goats. Comp. Biochem. Physiol. 77A, 79–84.

More, T., 1982. Effect of water deprivation on urinary concentrations of creatinine and nitrogen in sheep. J. Agric. Sci. (Camb.) 98, 233–236.

Mousa, H.M., Ali, K.E., Hume, I.D., 1983. Effects of water deprivation on urea metabolism in camels, desert sheep and desert goats fed dry desert grass. Comp. Biochem. Physiol. 74A, 79–84.

Nawaz, M., Shah, B.H., 1984. Renal clearance of endogenous creatinine and urea in sheep during summer and winter. Res. Vet. Sci. 36, 220–224.

Parker, A.J., Hamlin, G.P., Coleman, C.J., Fitzpatrick, L.A., 2003. Dehydration in stressed ruminants may be the result of a cortisol-induced diuresis. J. Anim. Sci. 81, 512–519.

Rajkhowa, S., Hazarika, G.C., Arundhati, B., 1999. Haematological changes due to water deprivation in goats under hot climatic conditions. Indian J. Vet. Med. 19, 86–88.

Shkolnik, A., Choshniak, I., 1985. Physiological responses and productivity of goats. In: Yousef, M.K. (Ed.), Stress Physiology in Livestock, vol. II, Ungulates. CRC Press Incorporation, Boca Ration, FL, pp. 39–57.

Silanikove, N., 1992. Effects of water scarcity and hot environment on appetite and digestion in ruminants: a review. Livest. Prod. Sci. 30, 175–194.

Silanikove, N., 1994. The struggle to maintain hydration and osmoregulation in animals experiencing severe dehydration and rapid rehydration: the story of ruminants. Exp. Physiol. 79, 281–300.

Silanikove, N., 2000. The physiological basis of adaptation in goats to harsh environments. Small Rumin. Res. 35, 181–193.

Singh, M., More, T., Rai, A.K., Karim, S.A., 1982. A note on the adaptability of native and cross-bred sheep to hot summer conditions of semi-arid and arid areas. J. Agric. Sci. (Camb.) 99, 525–528.

Statistical Analysis Systems, 1996. SAS Users Guide: Statistics. SAS Institute for statistical analysis, Cary, NC.

Wittenberg, C., Choshniak, I., Shkolnik, A., Thurau, K., Rosenfeld, J., 1986. Effect of dehydration and rapid rehydration on renal function and plasma renin and aldosterone levels in the black Bedouin goat. Pflugers Arch. 406, 405–408.