Arab Gulf Journal of Scientific Research, 21 (4), pp 210-216 (2003)

ORIGINAL PAPER

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Heat Tolerance of Local Goat Breeds in Saudi Arabia

Abstract: In order to evaluate the heat tolerance of three local goat breeds of Saudi Arabia, Hipsi, Aardi and Zumri, four bucks from each breed were exposed to direct sun with or without access to water during hot summer. Exposure of goats to direct sun for five hours for five consecutive days (three days with water and the last two days without water) resulted in a significant ($P<0.01$) increase in rectal temperature in all goats; however, it was further increased when the goats were not allowed to drink. Aardi goats had a higher rectal temperature during both pre and post-exposure when they were not watered during exposure to direct sun. Respiration rate was also increased ($P<0.01$) in response to exposure to solar radiation in all breeds but with varying degrees; it was increased by 133%, 205% and 290% in Hipsi, Aardi and Zumri goats, respectively. Also, there was a trend of increase in respiration activity, when water was withheld during exposure time. Sweating rate was slightly increased following exposure to direct sun. Aardi goats showed an increase in cutaneous water loss during water restriction over that recorded when they had free access to water, while it remained unchanged in the other two breeds. Hipsi goats displayed lower sweating rates in comparison to Aardi and Zumri goats. Feed consumed per kg body weight during the time of exposure to direct sun was the highest in Aardi goats, and also their feed intake was less depressed by withholding of water in comparison to the others. Furthermore, feed intake per kg body weight while the goats were kept indoors (other than the time of exposure to direct sun) as well as the daily feed intake was the highest in Aardi goats. It was concluded that there were no differences between breeds in heat tolerance when the water supply was maintained *ad libitum*. However, when water was withheld, Aardi goats enhanced their evaporative heat loss and maintained higher levels of feed intake despite their relatively higher rectal temperature.

Keywords: Heat tolerance, thermal stress, solar radiation, thermo-regulation, Aardi, Hipsi and Zumri goats

مقاومة الحرارة لسلالات الماعز المحلية في المملكة العربية السعودية

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المستخلص: تم إجراء هذه الدراسة، لتقييم مدى مقاومة الحرارة في ثلاث سلالات ماعز محلية في المملكة العربية السعودية، وهى الحبصي، العارضي و الزمري. حيث تم تعريض أربعة ذكور من كل سلالة لأشعة الشمس المباشرة لمدة خمسة أيام متتالية، لفترة خمس ساعات يومياً. وذلك في ظل وجود ماء (ثلاثة أيام) أو عدم توفره (يومان)، تحت ظروف الصيف الحارة. أدى التعرض لأشعة الشمس المباشرة إلى زيادة معنوية في درجة حرارة المستقيم، و التي قد ارتفعت بشكل أكبر عند عدم توفر الماء. تميزت الماعز العارضي بارتفاع في درجة حرارة المستقيم، ليس فقط بعد التعرض للشمس في عدم وجود الماء، وإنما أيضا في فترة ما قبل التعرض. أما بالنسبة لمعدل التنفس، فانه قد ارتفع بشكل كبير نتيجةً للتعرض للإشعاع الشمسي المباشر لكل السلالات، ولكن بنسب متفاوتة، حيث إنها قد ارتفعت بنسبة 133%, 205% و290% لكل من الحبصي، العارضي و الزمري على التوالي. بالإضافة إلى ذلك فان فترة التعرض للشمس، في عدم توفر الماء، تميزت بارتفاع معدل التنفس، مقارنة مع ما هو عليه عند توفر الماء، أما بالنسبة لإفراز العرق، لم يتأثر بشكل كبير، نتيجة التعرض لأشعة الشمس، حيث كان هناك ارتفاع طفيف في معدلات التعرق. أظهرت ماعز العارضي زيادة معنوية في معدل التعرق في فترة عدم وجود الماء، أعلى مما كان عليه في ظل توفر الماء. أما بالنسبة لماعز الحبصي، فإنها قد تميزت بتدني في معدل إفراز العرق، مقارنة مع كل من العارضي و الزمري. كمية العلف المتناولة لكل كجم وزن حي خلال فترة التعرض لأشعة الشمس كانت الأعلى في سلالة العارضي بالإضافة إلى أن الانخفاض الحاصل في مستوى التغذية، كنتيجة لفقدان الماء كان أقل مما هو عليه في السلالتين الآخرتين، بالإضافة إلى ذلك، فان كمية العلف المتناولة لكل كجم وزن حي تحت الظل، وكذلك كمية العلف المتناولة خلال 24 ساعة، كانت الأعلى في ماعز العارضي. يمكن الإستنتاج بأنه لا توجد فروقات ، بين السلالات في مقاومة الحرارة في حال توفر الماء، ولكن عند فقدانها فان ماعز العارضي، أبدت زيادة كبيرة في معدل فقد الحرارة التبخيري، و حافظت على مستوى عالي من تناول العلف على الرغم من إرتفاع حرارة أجسامها.

الكلمات المدخلية: مقاومة الحرارة، الماعز، الإجهاد الحراري، الإشعاع الشمسي ، السعودية

Introduction

Desert environmental conditions that prevail for most of the year in parts of Saudi Arabia can be characterized by very high ambient temperatures that might reach up to 50°C, with little or no rain and with intensive solar radiation. Also, food is scarce and sporadic with limited water resources. These

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conditions constitute a great challenge to animals inhabiting such areas, as they need to make various physiological adjustments which are related to thermoregulation and simultaneously, maintain satisfactory performance. Goats are well known for their greater adaptation to heat and aridity since they evolved from arid areas (Devendra, 1987). Furthermore, the presence of a large number of goats inhabiting harsh arid zones of the world is indicative of their great adaptation to such environments. They possess a great ability to thrive and produce better than other ruminants in harsh areas (Silanikove, 2000). Heat stress is considered to be one of the factors that have tremendous depressive effects on animal productivity, but goats are believed to be more resistant to heat load than other ruminant species (Lu, 1989) as they adopt several strategies that enable them to withstand thermal load. They are known for their great adaptation to desert conditions and they possess a water conservation capability, lower basal heat metabolism and high sweating rate (Shkolniak and Choshniak, 1985; Dmi'el, 1986; Silanikove, 2000). Thermoliability is utilized by goats under situations of limited water, which is considered as an adaptive mechanism for water conservation in hot environments where water is scarce. Upon exposure to heat stress, goats reduce their feed intake (Joshi *et al*, 1977), apparently to bring down their heat production and consequently maintain homeothermy, and their performance will certainly be affected. Therefore, resistance to heat load with less depressive effects on productive performance characterize desert-adapted goats. Production of goats in a specific environment is, therefore, determined by the extent of successful adaptations to such an environment. Not only are there possible differences in responses to heat load between species, but also between breeds of the same species (Jindal, 1980). Local goat breeds, which are distributed in different areas of Saudi Arabia, are assumed to be adapted to the prevailing hot dry weather conditions during the summer season. However, the extent of their adaptability to heat is not known, and therefore, this study was designed to evaluate the heat tolerance of three local goat breeds of Saudi Arabia, Hipsi, Aardi and Zumri, when exposed to direct sun with or without free access to water during the hot summer.

Materials and Methods

Four bucks from each of the Hipsi, Aardi and Zumri breeds belonging to the herd of the Agricultural and Veterinary Experimental and Training Station, King Faisal University at Alhassa, Saudi Arabia were used in this study. The bucks were about 12-14 months old and their body weights were 34.25 ± 1.5, 29.00 ± 1.2 and 31.2 ± 1.3kg for Hipsi, Aardi and Zumri breeds, respectively. They were penned indoors (two bucks from the same breed in each pen) and they were fed on 300g of a commercially formulated concentrate (11% protein) per head with alfalfa hay and water provided *ad libitum*. The study, which was conducted during the month of June 2002, consisted of two periods. The first period lasted for three days, during which the goats were moved outdoors and exposed to direct sun without any shade from 06:30h to 11:30h, during this period the goats were provided with hay and water *ad libitum*. During the second experimental period, which immediately followed the first period, the same procedure was applied as during the first period; however, water was withheld during exposure to direct sun. This period lasted for two consecutive days. During exposure to direct sun, the goats from each breed were confined together in one open wire pen. Physiological measurements taken during the study periods included rectal temperature (RT), respiration rate (RR) and sweating rate (SR), all of which were recorded twice daily; in the early morning (before exposure at 05:30h) and at the end of exposure time. Rectal temperature was recorded with a digital thermometer, and RR (breaths per minute) was determined with a stethoscope. Sweating rate was assessed at the left side on sacral region of the body utilizing the cobalt chloride method (Schleger and Turner, 1965). Food and water intakes were determined daily at the end of the solar radiation exposure period as well as when the goats were kept indoors. The goats were weighed each morning before being moved to outside pens.

The minimum, maximum and average ambient temperatures were 28.0°C, 43.6°C and 35.1°C during water availability period and 26.6°C, 46.1°C and 36.0°C during the period when water was withheld.

Data were analyzed using the Generalized Linear Model (GLM) procedure of SAS program (1996). The model included breed, exposure to direct sun (before and after), water availability during exposure time (available or withheld), and various interactions. Means were separated using Duncan's Multiple Range Test.

Results

The means of RT, RR, and SR are presented in Table 1. Rectal temperature was affected by breed, exposure to direct sun and water availability (P<0.01). Aardi goats exhibited the highest overall RT mean compared to the other two breeds (39.36°C, 39.16°C and 39.15°C for Aardi, Hibsi and Zumry, respectively). Exposure to solar radiation while water was available resulted in a significant (P<0.01) increase in RT of all goats without any differences between them. The overall mean of RT was significantly higher during water deprivation than while the goats received water during exposure time (39.30°C vs. 39.14°C). There was a significant (P <0.01) interaction of breed with water availability; Aardi goats had the highest RT values for both pre- and post-exposure during water restriction. However, when considering the extent of increase in RT between morning and around noon (after exposure), Aardi goats had the lowest increase in RT (0.45°C, 0.73°C and 0.62°C in Aardi, Hipsi and Zumri breeds, respectively.

Respiration rate was significantly (P<0.01) affected by breed, exposure to direct sun and water availability (Table 1). Zumri goats had an overall mean of RR (86.44 breaths per minute), which was intermediate to those of Aardi (107.23) and Hipsi (54.96). Withholding of water while the goats were under direct sun exposure increased the overall average of RR (68.66 vs. 97.08). As the heat load upon exposure to direct sun increased towards the end of exposure time, all goats increased RR irrespective of water regimen (40.42 vs. 125.33). Analysis of the data indicated that there was a significant (P<0.01) interaction effect of exposure to direct sun with breed on RR. This was caused by the difference in the extent of the rise in RR following direct sun exposure; the highest (290%) was observed in Zumri goats and the lowest (133%) in Hipsi goats while it was (205%) in Aardi goats. There was a significant (P<0.01) interaction between exposure to direct sun with water availability; pre-exposure levels of RR were similar in goats irrespective of water status; however, the magnitude of increase following sun exposure was higher during water deprivation. Morning values of RR were comparable among breeds except for Aardi goats, which showed a trend of increase irrespective of watering regimen during solar radiation exposure. Post-exposure response also followed the same trend for the Aardi goats. On the other hand, Hipsi goats maintained the lowest respiratory activity for both early morning (before exposure) and at the end of exposure time irrespective of water availability. Although morning RR in Zumri and Hipsi goats were similar, Zumri goats responded with much higher RR at the end of exposure period compared to Hipsi goats. Apparently, there was a variation between Aardi and Zumri goats in RR values at the end of exposure period with water availability, but this difference was abolished upon water restriction.

The overall means of SR were affected by breed, direct sun exposure and watering regimen (Table 1). The overall mean of SR was significantly lower (P <0.01) in Hipsi compared to the other two breeds (96.24, 120.87, and 113.67g/m^{2}h for Hipsi, Aardi and Zumri, respectively). Sweating rate was slightly increased as a result of direct sun exposure (104.19 vs. 116.34g/m^{2}h; P <0.01). Despite the lack of water, cutaneous water loss was significantly (P<0.01) higher than that while the goats received water (119.56 vs. 100.97g/m^{2}h). Analysis of the data revealed a significant interaction (P<0.05) between breed with water availability and this was related to the fact that SR response during exposure to direct sun was more pronounced in Aardi goats compared to the other two breeds during water restriction.

Feed and water intakes during exposure to direct sun are presented in Table 2. Feed intake during solar radiation exposure in the three breeds was comparable when they had free access to water but Aardi goats tended to consume more feed per kg body weight. Water restriction resulted in a dramatic fall in feed intake of all goats, but Aardi goats exhibited less depressive effects compared to Hipsi and Zumri goats; feed intake was reduced by 69%, 76% and 60% in Hipsi, Zumri and Aardi goats, respectively. The amount of feed consumed per kg body weight followed a similar trend in all goats. Aardi goats tended to consume more water than Hipsi whereas water consumption was the lowest in Zumri goats. Feed and water intakes while the goats were kept under shade (between 11:30h to 06:30h) are shown in Table 3. Feed intake while the goats were indoors with water available to them during exposure to direct sun were similar in all goats; however, when water was withheld a significant (P<0.05) fall in feed intake in Zumri goats occurred, whereas it was maintained almost unchanged in Hipsi and Aardi goats. Feed consumption in relation to body weight followed the same trend but Aardi goats displayed the highest levels during water restriction. There was a comparable feed intake during the entire 24 hours in

all breeds while they had free access to water during exposure to solar radiation. On the other hand, withholding of water decreased the level of feeding in all goats with varying degrees; it was decreased by 22%, 16% and 37% in Hipsi, Aardi and Zumri goats, respectively. Water deprivation during exposure caused Hipsi and Aardi goats to compensate for the deficiency of water by increasing water intake (by almost 37%) when they were moved back indoors at the end of direct sun exposure, while water intake remained unchanged in Zumri goats.

Table 1. Means of rectal temperature (RT), respiration rate (RR) and sweating rate (SR) during exposure to solar radiation in three breeds of local goats

Water	Breed	Exposure time	RT (°C)	RR (breath/min)	SR (g/m²h)
Available	Hipsi	before exposure	38.93 ± 0.07^{c}	29.00 ± 2.31^{e}	87.93 ± 7.90^{e}
		after exposure	39.33 ± 0.02^{b}	61.83 ± 6.60^{d}	96.02 ± 6.40^{de}
	Aardi	before exposure	38.90 ± 0.14^{c}	47.66 ± 2.70^{de}	94.55 ± 3.82^{de}
		after exposure	39.42 ± 0.12^{b}	137.00 ± 11.40^{b}	113.77 ± 4.90^{bcd}
	Zumri	before exposure	38.91 ± 0.09^{c}	31.33 ± 3.72^{e}	97.36 ± 6.73^{cde}
		after exposure	39.36 ± 0.06^{b}	105.17 ± 11.11^{c}	116.16 ± 7.42^{bcd}
Not available	Hipsi	before exposure	38.81 ± 0.06^{c}	37.00 ± 3.93^{de}	93.53 ± 7.26^{de}
		after exposure	39.54 ± 0.15^{ab}	92.00 ± 5.59^{c}	107.51 ± 9.19^{cde}
	Aardi	before exposure	39.34 ± 0.04^{b}	58.25 ± 14.20^{de}	129.76 ± 7.96^{ab}
		after exposure	39.79 ± 0.08^{a}	186.00 ± 8.24^{a}	145.40 ± 8.36^{a}
	Zumri	before exposure	38.86 ± 0.06^{c}	39.25 ± 5.85^{de}	122.00 ± 6.72^{b}
		after exposure	39.48 ± 0.03^{b}	170.00 ± 9.12^{a}	119.17 ± 4.59^{bc}

Means in a column with different superscripts are different ($P < 0.05$).

Table 2. Means of feed intake, water intake, feed intake per kg body weight, and feed to water ratio during exposure to solar radiation in three breeds of local goats

	Available water			Water withheld		
	Hipsi	Aardi	Zumri	Hipsi	Aardi	Zumri
Feed intake (gm)	483.33	500.00	475.00	150.0	200.0	112.5
Feed intake (gm/kg bw)	13.83	16.83	14.53	4.21	6.47	3.36
Water intake (litres)	2.80	3.14	2.67	-	-	-
Water intake to feed intake ratio	6.23	6.37	5.62	-	-	-

Table 3. Feed intake, water intake, and feed intake per kg body weight while the goats were indoors (11:30h to 06:30h) during the days of exposure to solar radiation in three breeds of local goats

	Available water			Water withheld		
	Hipsi	Aardi	Zumri	Hipsi	Aardi	Zumri
Feed intake (gm)	787.5 ±21^{cb}	841.6 ±24^{ab}	875.0 ± 43^{ab}	850.0 ±14^{ab}	925.0 ±28^{a}	737.5 ± 36^{c}
Feed intake (gm/kg bw)	22.2 ± 0.4^{c}	28.2 ± 1.9^{a}	26.8 ± 1.5^{ab}	23.8 ± 1.2^{bc}	29.8 ± 1.3^{a}	22.1 ± 1.3^{c}
Total feed intake (gm/d)	1270.8 ±21^{b}	1341.7 ±24^{a}	1350.2 ± 43^{a}	1000.0 ±14^{c}	1125.0 ±28^{b}	850.0 ± 36^{d}
Water intake (litres)	4.5 ± 0.2^{b}	4.5 ± 0.3^{b}	4.6 ± 0.4^{b}	6.1 ± 0.2^{a}	6.3 ± 0.2^{a}	4.6 ± 0.01^{b}

Means in a row with different superscripts are different ($P < 0.05$).

Discussion

Exposing goats to direct sun for five hours daily for five consecutive days during hot summer conditions significantly increased RT in all goats. Under the experimental conditions of this study, RT was increased by 0.40°C to 0.73°C and the highest RT recorded following exposure to direct sun was 39.79°C in Aardi goats. RT was lower than reported by Singh and Saxena, (1995) in Indian goats following six hours of exposure to direct sun for five consecutive days (39.9°C to 41.1°C). Withholding of water resulted in a further increase of RT. The ambient temperature during the period of deprivation (the last two days) was higher than during the previous period, and this could have contributed to this increase in RT. Aardi goats displayed higher RT than the other two groups following exposure to direct sun. The Aardi goats have a black coat, and it has been reported that black-colored goats, as well as predominantly black Holstein dairy cows, exhibited higher RT than light-colored ones when they were exposed to solar radiation (Hansen, 1990; Acharya, *et al.* 1995). This can be explained by the fact that a black coat absorbs more short wave radiation from the sun than a white coat (Finch, *et al.* 1980) and therefore gain more radiant heat. Feed consumption during solar radiation exposure was the highest in Aardi goats. Since feed intake is associated with heat production it would be expected that the higher feed consumption seen in Aardi breed was associated with a higher body heat increment. Taken together, the black coat and the higher feed intake of the Aardi goats could have contributed to the rise in RT. On the other hand, Zumri goats also possess black coats, yet their RT was lower than that of Aardi, particularly when water was withheld. This was mostly related to the lower feed intake and thus lower body heat production in this breed. In fact, Zumri goats had consumed feed (relative to body weight) which was almost half that of Aardi goats when deprived of water during sun exposure. Aardi goats maintained higher RT before exposure (early morning) during the water deprivation period, as they were not able to dissipate the stored heat during the cool part of the day (night time). Similar results were also observed in the study of Singh and Saxena, (1995).

Exposure to solar radiation increased respiration activity in all goats, as they need to get rid of the extra heat gained from solar radiation. When exposed to high ambient temperature, goats can utilize two evaporative cooling avenues, panting and sweating (Jendal, 1980). Generally, panting is the most important avenue of heat loss in goats, and sweating represents a small proportion of total evaporative cooling (Devendra, 1987). The magnitude of increase in RR was highest in Zumri followed by Aardi, while it was the lowest in Hipsi goats. The lowest RR in Hipsi goats during exposure to direct sun was mostly related to the color of their body coat; in those with white hair, the rate of absorption of short wave radiation was low and so was their heat gain, which was associated with lower RR when compared to the black colored goats. This was in agreement with the results reported by Acharya, *et al.*, (1995) when goats with different coat colors were exposed to direct sunlight. The observed elevation of RR in this study when water was not available to goats over that recorded during water availability was mostly related to the increase in ambient temperature, which resulted in an increase in heat load imposed on the goats. This apparently resulted in further augmentation of the respiratory frequency in order to enhance the rate of heat dissipation.

Unlike RR, cutaneous moisture loss was slightly increased upon exposure to direct sun with a tendency to increase when water was withheld. Das, (1994) also could not find any significant increase in SR when ambient temperature increased from early morning to afternoon in goats. The reliance on panting or sweating for heat dissipation in goats depends on the way they get the heat load. Apparently, when goats gained heat from solar radiation they utilize sweating as a major avenue of heat dissipation. By contrast, when they were stressed by elevation of ambient temperature in a climatic chamber, panting is their major avenue of evaporative heat loss (Borut, *et al.* 1979; Dmi'el and Robertshow, 1983). In the study of Borut, *et al.* (1979), the SR of the Black Bedouin goats was 143 g/m^2h and RR reached 180-220 breaths per minute at noon when they were exposed to hot desert conditions and the calculated heat loss via cutaneous evaporation was twice as much as respiratory evaporation. Our findings of RR and SR following exposure to direct sun, at least with the Aardi goats, were somewhat similar to those reported in the Borut study. Therefore, evaporative heat loss via SR was much higher than that of respiratory activity. The mean of SR under these experimental conditions was found to be higher in black colored goats (Aardi and Zumri) compared to white ones (Hipsi goats). The higher rate of cutaneous moisture

loss observed in goats with black hair could be considered as an adaptive mechanism in these goats for the high absorption rate of radiant heat from the sun in goats inhabiting areas with incidence of high solar radiation (Finch, *et al.* 1980). Aardi goats were able to respond to the rise in ambient temperature by increasing their sweating activity even in the absence of drinking water. They maintained higher feed consumption relative to their body weights. Thus, a minimal depressive effect of water restriction under thermal load exposure on feed intake had occurred in Aardi goats compared to other breeds. Although their SR was the highest during water restriction, RT was not decreased but indeed it was the highest among the groups. The heat dissipation activity by RR and SR avenues might have not been enough to bring down their thermal balance. The situation of Aardi goats might be considered as an adaptive mechanism of goats in hot and dry regions as it has been found that well-adaptive animals in hot areas are able to tolerate hyperthermia and maintain high performance during periods of heat exposure (Jendal, 1980; Devendra, 1987).

The interaction of coat color and level of feed intake has been noted by Acharya, *et al.*, (1995) when they observed lower feed consumption in black goats upon exposure to direct sunlight. In this study, feed consumption of goats when water was available was comparable among all goats, but Aardi goats showed a trend to higher levels of feed intake. On the other hand, water restriction caused distinct responses between breeds; Zumri goats consumed the least feed, followed by Hipsi, but Aardi goats had the highest feed intake despite their black color.

Different breeds react differently to rising ambient temperature depending on their degree of heat tolerance. The reduction in feed intake seen herein when the water was not available during exposure time was an attempt by goats to reduce their heat production, which could be considered as an adaptive measure against hyperthermia (Lu, 1989). However, performance is certainly affected, as the amount of feed consumed by goats did not meet their nutritional requirements for productive purposes. As a consequence, performance would have been affected. In this study, there was no clear correlation between heat tolerance capacity in terms of thermoregulatory responses and feed intake. Similarly, no correlation has been found between changes in RT during exposure to solar radiation and changes in body weight gain in goats (Abdel-Samee, 1997). It has been acknowledged that animals exhibiting less rise in RT when exposed to heat stress are considered to be more adapted to hot regions than animals that exhibit higher RT and RR. Hipsi goats displayed low values of RT and RR during heat stress, suggesting higher heat tolerance capability among the local breeds under the present conditions. The most important features of heat tolerance are the ability to maintain feed intake during heat stress and reduce metabolic rate and water turnover (Garcia and Gall, 1981). Furthermore, Quartemain and Broadbent (1974) as cited by Garcia and Gall (1981) have suggested that heat tolerance can be attributed to maintaining feed consumption, allowing body temperature to rise, increasing respiration frequency and reducing water loss.

It can be concluded that the three breeds have similar tolerance to radiant heat exposure when they have free access to water despite the variation in coat color. Aardi and Zumri goats increased their rate of heat dissipation by increasing the rate of cutaneous and respiratory evaporation. However, when water was not available, Aardi goats seemed to be more tolerant to radiant heat as judged from their physiological responses related to heat dissipation and feed intake level, higher SR and tolerance to hyperthermia. Aardi goats have been shown to be well adapted to hot desert conditions, as they were able to tolerate dehydration in hot summer conditions since they have a water conservation mechanism and they have been shown to be able to tolerate hyperthermia (El-Nouty, *et al.* 1990). Hipsi goats are white, and therefore, with low heat gain as well as lower heat increment associated with lower feed intake. However, their RT was not statistically different from that of Aardi bucks. This might be an indicative of less efficiency in heat dissipation during shortage of water. In the case of Zumri goats, they coped with heat load by further reduction in feed intake and enhanced their evaporative heat loss, thereby maintaining homoeothermy.

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Ref. 2220
Received 21/01/2002.
In revised form 08/11/2003