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Water Balance in Goats Maintained Under Mild and Hot Weather

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HEAT STRESS increased the total body water of goats from 12.42 ± 1.15 to 13.07 ± 1.21 L. This increase was significant at ($P < 0.01$). Total body water expressed as percentage of live body weight increased also significantly from 63.40 ± 1.80 at 18° to 68.26 ± 1.92 at 38°.

Total body water expressed as percentage of total body solids, increased also significantly from 179.03 ± 16.24 at 18° to 222.75 ± 25.32 at 38°.

The average of TBS in goats 7.29 ± 0.92 decreased significantly ($P < 0.01$) at 38° to 6.32 ± 0.91 kg. When the values were expressed as percentage of live body weight the averages were 36.60 ± 1.80 decreased significantly ($P < 0.01$) to 31.74 ± 1.92, at 18° and 28°, respectively.

Increasing ambient temperature from 18° to 38° increased WTR significantly ($P < 0.01$) from 1.58 ± 0.07 to 2.63 ± 0.11. When the values of WTR were expressed as ml/kg LBW/day, they were 83.30±6.79 at 18° increased significantly to 143.29±9.69 at 38°. WTR, expressed as ml/kg 82°/day, increased also significantly from 140.82 ± 8.92 at 18° to 240.46 ± 16.97 at 38°.

Biological half life time of tritiated water decreased significantly ($P < 0.01$) from 5.42 ± 0.42 at 18° to 3.37 ± 0.20 days at 38°. The decrease in T1/2 under hot conditions was the result of increased water intake and water output.

Water balance in goats maintained under mild climate (18°) was studied, however, total water intake consisted of 1.47 ± 0.03, 0.13 ± 0.00 and 0.07 ± 0.00 L/day for free water, metabolic water and feed water, respectively. Total water loss consisted of 0.54 ± 0.01, 0.50 ± 0.03, 0.27 ± 0.02 and 0.35 ± 0.05, for urinary water fecal water, respiratory water and skin water loss, respectively.

When values of water balance were expressed as percentages of total water intake, the averages were 87.95 ± 0.31, 7.73 ± 0.16 and 4.27 ± 0.28 for free water metabolic water and feed water, respectively and 32.6 ± 1.02, 29.91 ± 2.69, 16.66 ± 1.60 and 20.86 ± 2.97 for urinary, fecal, respiratory and skin water loss, respectively.

When the components of water balance at 38° were expressed as percentages of daily water intake the averages were 93.25 ± 1.78, 4.57 ± 0.29 and 2.16 ± 0.31 for free, metabolic and feed water. Those for urinary, fecal, respiratory, skin swater loss and water retention were 36.48 ± 4.83, 12.03 ± 1.73, 23.58 ± 4.42 and 22.12 ± 2.70 and 4.38 ± 0.13 respectively. The significant differences were found between the 18° and 38° and 38° water balance values. At 18°, the goats were in steady state concerning the live body weight and the physiology of water balance, assumed that total water loss equal with total water inake.

When the goats were exposed to 38°, the retained water took place in water balance then the goats had a positive water balance.

Water metabolism is of a prime importance for animal productivity because water plays a big role in heat regulation particularly under hot desert conditions beside its importance in carrying out the biochemical reactions for all vital activities.

In Egypt, the desert represents 96% of the Egyptian territory and in such desert, the few existing livestock animals walk for distances looking for watering, which may take 3-7 days each time Apparently water in such areas becomes a limiting factor for the expansion in animal production. It is desirable to select for these areas, where water costs more than feed, species, breeds and animals within breeds, most efficient in water economy, which require little amounts of water for maximum milk and meet production.

The objective in this study was to determine all components of water metabolism in goats under controlled mild and hot climates in the climatic chambers using the different tracer techniques. Besides, the heat tolerance index using the TOH tracer technique was used to determine the variability between goats in heat tolerance.

Material and Methods

A. *Animals, feed, water and management*

Six male goats were used in the present study. They were 2.5 - 3 years old, their weights ranged from 19 - 25 kg. The animals were kept outdoors under open shed before starting the experiment. They were fed on 500 g concentrates, 500 g clover hay and 250 g wheat straw daily through the experimental period. The concentrates which were in the form of pellets, consisted of undecorticated cotton seec cake 60%, wheat bran 10%, rice milling 25%, lime stone 2%, sodium chloride 1% and molasses 2%. The goats were watered three times daily *ad libitum* by buckets.

The experiments on goats were conducted in the climatic chamber of the Tracer Bioclimatology Unit of the ARE USA-NSF Project "Bovine Adaptation to the Sahara" of the Atomic Energy Authority. It was provided with a 7.5 ton air cooled conditioning system, that can regulate the temperature and humidity between 15 and 50° and between 80% and 20% R.H., respectively. A thermohygrograph was used for a continuous recording of temperature and humidity.

B. *Experimental design and Statistical analysis*

Six male goats, were used in the present study. The goats were maintained in the climatic chamber laboratory for 7 days, 7 hours daily at 18° and 65% R.H. followed by 7 days, 7 hr daily at 38° and 50% R.H. The raise of temperature in climatic chamber was gradually and reached to the maximum point (38°) of temperature through one hour. During such time live body weight measurements were carried out before eating and watering on the 1*th* and on 7*th* days in each of mild and hot climates.

The components of water metabolism were determined by the TOH dilution and the conventional techniques. The physiological parameters which were measured consisted of total body water, water turnover rate, biological half life time of TOH, total body solids and heat tolerance coefficient. Milk and urine samples were used for total body water and water turnover rate determinations by extrapolation technique. The differences between the averages of the two treatments were tested by means of the "t" test of significance, according to Snedecor and Cochran (1967).

Total body water (TBW) and calculation of results water intake and water output were determined as described and reviewed after Taymour *et al.* (1983). Tracer technique was carried out for estimation of heat tolerance coefficient (HTC) based on the estimation of total body solids (TBS) under mild and hot climates. The percentage decrease in total body solids content due to heat exposure was subtracted from 100 to obtain the coefficient of heat tolerance as described by Kamal and Johnson (1971) in cattle. The total body solids estimated by subtraction the total body water (TBW) from the live body weight in each of climatic conditions. The equation used for the TBS, HTC is as follows :

$$\text{TBS, HTC} = \frac{100 - \text{TBS\% at } 18^{\circ} - \text{TBS\% at } 38^{\circ}}{\text{TBS \% at } 18^{\circ}} \times 100$$

Results and Discussion

Data presented in Table 1 showed that at 18° for 7 hr daily, total water intake as L/day consisted of $1{\cdot}47 \pm 0{\cdot}03$, $0{\cdot}13 \pm 0{\cdot}00$ and $0{\cdot}07 \pm 0{\cdot}00$ for free, metabolic and feed water, respectively, and total water output consisted of $0{\cdot}54 \pm 0{\cdot}01$, $0{\cdot}50 \pm 0{\cdot}03$, $0{\cdot}27 \pm 0{\cdot}02$ and $0{\cdot}35 \pm 0{\cdot}05$, respectively, for urinary, fecal, respiratory and skin water loss. Total water intake, however equaled the total water output and averaged about $1{\cdot}67 \pm 0{\cdot}04$ L / day.

When the values of water balance were expressed as ml/kg LBW/day, the averages for water intake components were $71{\cdot}06 \pm 6{\cdot}05$, $6{\cdot}26 \pm 0{\cdot}58$ and $3{\cdot}43 \pm 0{\cdot}23$, respectively, for free metabolic and feed water and the total was $80{\cdot}76 \pm 6{\cdot}80$. In this connection, water output components were $26{\cdot}11 \pm 1{\cdot}77$, $23{\cdot}50 \pm 0{\cdot}72$, $13{\cdot}61 \pm 2{\cdot}07$ and $17{\cdot}64 \pm 3{\cdot}44$, respectively, for urinary, fecal, respiratory and skin water loss, where, the total was $80{\cdot}76 \pm 6{\cdot}80$ as shown in Table 1.

When the values were expressed as percentages of daily water intake, the averages were 87·95 ± 0·31, 7·73 ± 0·16 and 4·27 ± 0·28, respectively, for free, metabolic and feed water and those for urinary, fecal, respiratory and skin water loss were 32·56 ± 2·97, respectively as shown in Table 1.

TABLE 1 : Water balance as l/day, ml/kg LBW/day and as percent of daily water intake in goats maintained under mild weather.

Water intake	l/day			ml/kg LBW/day			Percent of		
	$\bar{x}$	SE	C.V.%	$\bar{x}$	SE	C.V.%	$\bar{x}$	SE	C.V.%
Free	1.47	0.03	5.45	71.06	6.05	19.06	88.0	0.31	0.79
Metabolic . .	0.13	0.00	9.42	6.26	0.58	21.05	7.70	0.16	4.71
Feed	0.07	0.00	11.95	3.43	0.23	15.33	4.30	0.28	14.83
Total	1.67	0.04	5.41	80.76	6.80	18.83			
Water output .									
Urinary . . .	0.54	0.01	7.59	26.11	1.77	15.20	32.56	1.02	7.06
Fecal	0.50	0.03	17.60	23.50	0.72	6.91	29.91	2.69	20.14
Respiratory . .	0.27	0.02	20.53	13.61	2.07	34.15	16.66	1.60	21.57
Skin	0.35	0.05	36.17	17.64	3.44	34.66	20.86	2.97	31.86
Total	1.67	0.04	5.41	80.76	6.80	18.83			

When ambient temperature was increased to 38° for 7 hr daily there was an apparent increase in each of water intake and water output components, where, they averaged 2·58 ± 0·07, 0·12, 0·06 L/day for free, metabolic and feed water, respectively, and 1·06 ± 0·14, 0·33 ± 0·05, 0·64 ± 0·1 and 0·60 ± 0·07 L/day, respectively, for urinary, fecal, respiratory and skin water output (Table 3). The difference between total water intake and total water output represents the increase in total body water or water retained in the goat's body amounting to 0·12 L/day. Water balance, expressed as ml/kg LBW/day at 38° averaged 134·52 ± 9·84, 125·31 ± 8·67, 6·20 ± 0·69 and 3·01 ± 0·60, respectively, for total, free, metabolic and feed water, whereas, the water output averaged 128·62 ± 9·42, 51·46 ± 7·20, 16·10 ± 2·46, 31·73 ± 6·33 and 29·31 ± 3·53, respectively, for total, urinary, fecal, respiratory and skin water loss (Table 2).

Data presented in Table 2 revealed that the components of water intake and output expressed as percentages of daily water intake were 93·25 ± 1·78, 4·57 ± 0·2 and 2·16 ± 0·31 for free water metabolic water and feed water, respectively and skin water loss were 36·48 ± 4·83, 12·03 ± 1·73, 23·58 ± 4·42 and 22·12 ± 2·70, respectively.

It can be noted that the average of water retention as percent of total water intake at 38° was 4·38 ± 0·13, then the animals had a positive water balance under high temperature. The significant differences ($P < 0\cdot01$) were found between the 18° and 38° water balance values (Table 2).

TABLE 2. **Water balance as 1/day, ml/kg LBW day and as percent of daily water intake in goats maintained under hot climate for 7 hr daily.**

Water intake	1/day			ml/kg LBW/day			Percent of		
	$\bar{X}$	SE	C.V.%	$\bar{X}$	SE	C.V.%	$\bar{X}$	SE	C.V.%
Free	2.58	0.07	6.23	125.31	8.67	15.48	93.25	1.78	1.04
Matabolic . .	0.12	0.00	9.50	6.20	0.69	25.01	4.57	0.29	14.41
Feed	0.06	0.00	27.38	3.01	0.60	45.40	2.16	0.31	32.59
Total	2.76	0.06	5.55	134.52	9.84	16.36			
Water output									
Urinary . . .	1.06	0.14	30.83	51.46	7.20	31.29	36.48	4.83	29.64
Fecal	0.33	0.05	36.76	16.10	2.46	34.19	12.03	1.73	32.31
Respiratory . .	0.64	0.10	35.51	31.73	6.33	44.67	23.58	4.42	41.93
Retention . . .	0.12	0.00	12.36	5.75	0.46	17.99	4.38	0.13	7.01
Skin	0.60	0.07	27.42	29.31	3.53	26.95	22.12	2.70	27.30
Total	2.64	0.06	5.27	128.62	9.42	16.38			

It is worthnoting, that the increase in total water intake under high environmental temperature in the present study is in accordance with other studies in different ruminants (Kamal *et al.*, 1962 ; Roy *et al.*, 1964 ; Maloiy, 1972 ; Kellaway and Colditz, 1975).

The mechanism responsible for heat-induced increase in water consumption has been suggested by Kamal *et al.* (1962). They stated that the increase in ambient temperature caused significant increase in water output through urine and vaporization in ruminants. Such water output would cause a temporary body water deficit with resultant increase concentration of body fluids (extracellular) including the fluids of the thirst center of hypothalamus. The latter, thus, passes nerve impulses to higher brain centers producing the sensation of thirst and active drinking.

It has been shown that animals with distructed rostal hypothalamus increased their water intake (Stevenson *et al.*, 1964). Moreover, warming the preoptic area and rostal hypothalamus of the goats with thermodes evoked a large increase in water consumption (Andersson, 1971).

About the urine excretion, however, in ruminants the increase in urine excretion under high temperatures was due to an increase in water intake (Kellaway and Colditz, 1975). Moreover, there was a positive correlation between the rise in ambient temperature and each of urine excretion, total vaporization and water intake (Kamal, 1965) had demonstrated that in panting animals exposing to heat lead to a loss of water and Na+ was left behind, however, under very severe conditions, quantities of saliva containing Na+ might be drooled from the goats mouth and such loss of Na+ amight lead to aldosterone secretion. In addition, the significant diuresis of ruminants at high temperatures may be due to high glutocorticoids, low mineral corticoids and low antidiuretic hormone secretion (Kamal *et al.*, 1962).

Concerning, fecal water output, Schmidt-Nielsen (1964) reported that, since heat caused a decrease in feed consumption, particularly in roughages, a decrease in fecal water output was likely to occur. The same finding were reported by Wilson (1970) and Maloiy and Taylor (1971). Therefore, the results presented in this study concerning fecal water output are in accordance with those obtained by the above investigators. It is worth noting that heat load had a great effect on decreasing fecal water output in goats.

The increase in respiratory water output in response to rise in air temperature has been studied in goats (Maloiy and Taylor, 1971 and Hans and Peter, 1979). When the animals are exposed to heat, some evaporation of water from the mucosa takes place. In spite of the fact that, the temperature of inspired air is high, the mucosa is cooled because the latent heat of vaporization of water is 538 Cal per gram. This is coupled with the fact that air having al ower specific heat that if warms the mucosa very little, results in an efficient cooling of mucosa during inspiration of hot dry air (Walter *et al.*, 1961).

The observed increase in skin water loss under high temperature in this study on goats is in accordance with other studies reported before on cattle (Brody *et al.*, 1955, Kamal *et al.*, 1962, Temor *et al.*, 1969, Moran, 1973, Herz and Steinbaut, 1978) and on sheep (Brook and Siebert, 1960, Alexander, 1961 and Baiely, 1964).

The increase in cutaneous moisture loss as a response to high temperature and to catecholamine administration was attributed by Alvarez, *et al.* (1970) to an increase in cutaneous blood flow, which is turn increases the water supply to the sweat glands and the volume of interstitial fluid in the epiderms. Accumulation of fluid around the epithelial cells of the sweat glands, would create a difference in hydrostatic pressure and flow of water from the site of higher pressure (Interstitial space) to the site of lower pressure (Lumen of the sweat gland).

From the above discussion we have noticed that in mild climate the primary problem for goats is conserving the heat they produce, an end achieved by insulative and behavioral adaptation. Urinary and fecal water output as well as the respiratory and skin water loss had a normal physiological role because the major heat loss is then through non evaporative channels (radiation, convection and conduction). The water balance was, therefore, balanced.

Under hot conditions, fecal water loss was reduced and there was a definite increase in respiratory and skin water loss because the problem was one of water output for heat dissipation through evaporative channels. Moreover, there was an increase in water output through increased urine excretion to assist somewhat in heat dissipation by drinking water cooler than body temperature and excrete it in urine at a higher temperature.

When the goats were exposed to high temperature, their bodies had a positive water balance because the goats retained some of water in their bodies. The water retention helped the animals under heat stress to keep their fluids in a normal range for continuing of physiological process and to maintain normal deep body temperature, by virtue of the high specific heat of water and by its effective evaporative cooling.

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الميزان المائى فى الماعز تحت ظروف المناخ المعتدل والمناخ الحار

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ان وجود الماعز تحت تأثير العبء الحرارى أدى الى زيادة المتوسط ± الخطأ القياسى لماء الجسم الكلى من ١٢ر٤٢ ± ١ر١٥ على درجة ١٨°م الى ١٣ر٠٧ ± ١ر٢١ لتر على درجة حرارة ٣٨°م لفترة ٧ ساعات لمدة ٧ أيام متتالية وهذه الزيادة فى ماء الجسم كانت زيادة حقيقية •

ازداد ماء الجسم الكلى باللتر لكل ١٠٠ كيلو جرام من وزن الجسم زيادة حقيقية من ٦٣ر٤ ± ١ر٨ على درجة ١٨°م الى ٦٨ر٢٦ ± ١ر٩٢ على درجة ٣٨°م •

كان متوسط المادة الصلبة الكلية عندما عرضت الماعز لدرجة ١٨°م ٧ر٢٩ ± ٩٢ر انخفض انخفاضا حقيقيا عند درجة ٣٨°م الى ٦ر٣٢ ± ٩١ر كجم • وعندما حسبت القيم كنسبة مئوية من وزن الجسم الحى انخفضت المتوسطات من ٣٦ر٦ ± ١ر٨ الى ٣١ر٧٤ ± ١ر٩٢ عند ١٨°م ، ٣٨°م على التوالى •

ارتفاع درجة الحرارة من ١٨°م الى ٣٨°م أدى الى زيادة معدل استبدال ماء الجسم زيادة حقيقية من ١ر٥٨ ± ٠٧ر الى ٢ر٦٣ ± ١١ر لتر/يوم • وعندما حسبت قيم معدل استبدال الماء بالملليلتر/كيلو جرام من وزن الجسم الحى كانت ٨٣ر٣ ± ٦ر٧٩ على درجة ١٨°م ازدادت زيادة حقيقية الى ١٤٣ر٢٩ ± ٩ر٦٩ على درجة ٣٨°م • وعندما حسبت القيم على أساس ملليلتر/كجم ٨٢ر حدثت أيضا زيادة حقيقية من ١٤٠ر٨٢ ± ٨ر٩٢ على درجة ١٨ الى ٢٤٠ر٤٦ ± ١٦ر٩٧ على درجة ٣٨°م •

انخفضت فترة نصف العمر البيولوجية انخفاضا حقيقيا من ٥ر٤٢ ± ٤٢ر يوم على درجة ١٨°م الى ٣ر٣٧ ± ٢ر يوم على درجة ٣٨°م •

درس الميزان المائى فى الماعز تحت ظروف الجو المعتدل (١٨°م) وكان الماء الكلى المأخوذ مكون من ١ر٤٧ ± ٠٣ر ، ١٣ر ، ٠٧ر لتر/يوم وذلك فيما يتعلق بماء الشرب وماء التمثيل الغذائى وماء الغذاء على التوالى – أما الماء المفقود فكان مكون من ٥٤ر ± ٠١ر ، ٥٠ر ± ٠٣ر ، ٢٧ر ± ٠٢ر ، ٣٥ر ± ٠٥ر – وذلك فيما يختص بماء البول والماء الخارج فى الروث وماء التنفس والماء المفقود عن طريق الجلد على التوالى • وعندما حسبت قيم مكونات الميزان المائى كنسبة مئوية من كمية ماء الشرب الكلى فان متوسطاتها كانت ٨٧ر٩٥ ± ٣١ر ، ٧ر٧٣ ± ١٦ ، ٢ر٢٧ ± ٢٨ر – وذلك لكل من ماء الشرب وماء التمثيل الغذائى وماء الغذاء على التوالى •

وعندما عرضت الماعز لدرجة ٣٨°م لفترة ٧ ساعات وذلك لمدة ٧ أيام متتالية حدثت زيادة واضحة فى كل من الماء المأخوذ والماء المفقود من الجسم وكانت المتوسطات ٢ر٥٨ ± ٠٧ر فيما يختص بماء الشرب ، ١٢ر لماء التمثيل الغذائى ، ٠٦ر لتر/يوم فيما يتعلق بماء الغذاء وكانت ١ر٠٦ ± ١٤ لماء البول ، ٣٣ر ± ٠٥ر لماء الروث ٦٤ر للماء الخارج مع هواء التنفس ، ٦٠ر ± ٠٧ر لتر/يوم للماء المفقود عن طريق الجلد • وعندما حسبت قيم مكونات الميزان المائى كنسبة مئوية من الماء الكلى المأخوذ على درجة ٣٨°م كانت المتوسطات ٩٣ر٢٥ ± ١ر٧٨ ، ٤ر٥٧ ± ٢٩ر ، ٢ر١٦ ± ٣١ر – وذلك لماء الشرب الحر والماء التمثيلى وماء الغذاء وكانت متوسطات كل من

ماء البول وماء الروث وماء التنفس والمـاء المفقود عن طريق الجلد هى ٣٦ر٤٨ ± ٤ر٨٣ ، ١٢ر٠٣ ± ١ر٧٣ ، ٢٣ر٥٨ ± ٤ر٤٢ ، ١٢ر٢٢ ± ٢ر٧٠ على التوالى مع ملاحظة أن قيمة المـاء المحتجز فى الجسم كانت ٣٨ر٤ ± ١٣ر كنسبة مئوية من المـاء الكلى المـأخوذ عى درجة ٣٨°م ٠

ووجد أن هناك فروق حقيقية بين قيم مكونات ميزان المـاء على درجة ١٨ ، ٣٨°م ولقد لوحظ أن على درجة ١٨°م كان هناك ثبات فى وزن الجسم والحالة الفسيولوجية للحيوان مع افتراض أن المـاء الكلى المـأخوذ يساوى المـاء الكلى الخارج من الجسم ، وتبعا لذلك كان هناك ثبات فى ميزان المـاء ٠ وعندما عرضت المـاعز لدرجة ٣٨°م فان المـاء المحتجز فى الجسم أصبح له دور فى تقدير ميزان المـاء وحينئذ أصبحت المـاعز فى حالة ميزان مائى موجب ٠