Vet.Med.J.,Giza. Vol.47, No.2. (1999): 213-223.

MAJOR PLASMA CATIONS AND ALDOSTERONE CONCENTRATION OF SHEEP AND GOATS AS AFFECTED BY SOME ENVIRONMENTAL CONDITIONS

NEAMA. A. ASHMAWY and S. A. IBRAHIM

Animal Production Department, Faculty of Agriculture, Cairo University, Giza, Egypt.

Received: 12/10/1998

Accepted :29/11/1998

SUMMARY

Adaptation of small ruminants (sheep and goats) to semi-arid conditions was studied. Blood samples were collected from five adult Ossimi ewes and five Zaraibi goats at weekly intervals for 8 weeks during three seasons; winter (December - January), summer (July - August) and spring (March - April). Water was available *ad libitum*. During August, the responses of the animals to severe heat stress of direct solar radiation were recorded. Water was not available during the exposure period (from 12.00 noon to 3.00 p.m). The responses to salt in drinking water (NaCl 13.0 g/l distilled water) and to water deprivation for a period of 48 hours were studied. The mean values of Na^+ (mg/100 ml) in blood plasma were significantly different among seasons. The values of Na^+ concentration tended to decline gradually from winter (351.5 and 370.2) to spring (211.5 and 207.0) to summer (125.9 and 122.6) in both sheep and goats, respectively, which means that higher ambient temperature might be one of the reasons of this decline. The concentrations of Na^{++} in blood plasma in both stressed sheep and goats were higher (561.7 and 578.6) than those which were given saline water (430.1 and 448.6) and those under water deprivation (465.7 and 505.7), respectively. Potassium concentration in blood plasma (mg/100 ml) showed opposite trend, the higher values were recorded during summer (19.2 and 19.1) and lower values during spring (13.8 and 13.9) in both sheep and goats, respectively. When the two species were compared during periods of water deprivation (WD) and water salinity (WS), goats showed higher concentration of Na^+ accompanied by lower concentration of K^+ than the values in sheep. However, during heat stress period, goats had higher values in both Na^+ and K^+ concentrations than sheep. Aldosterone concentration varied between seasons in both sheep and goats, the higher values were recorded during the hot summer season. During heat stress, plasma aldosterone in goats was double than that in sheep, while opposite trend to heat stress occurred during (WD) and (WS) where sheep recorded higher values than goats.

Keywords: Sheep, goats, season, sodium, potassium, aldosterone.

INTRODUCTION

Although the mineral elements constitute a relatively small amount of the total body tissues, they are essential to many vital processes. Certain mineral elements, principally sodium (Na^+) and potassium (K^+), are major factors in determining the osmotic control of water metabolism and consequently, in adaptation of animals to hot climatic conditions specially in subtropical areas. Since sodium is the major component of the cations of the extracellular fluid (ECF), it is largely associated with chloride and bicarbonate in regulation of acid-base balance. Potassium is the principal cation of the intracellular fluid; but it is also a very important constituent of ECF because it influences muscle activity and contractility of cardiac muscle. In sheep, the fluid spaces and the principal electrolytes are altered by changes in environmental temperature (MacFarlane, 1964). Small ruminants tend to conserve sodium more effectivey, probably to maintain expanded plasma volume during hot periods (More and Sahni; 1980). Seasonal variations were detected in plasma concentrations of Na^+ and K^+ in Ossimi and Merino sheep (Ashmawy, 1994).

The present work was undertaken to study the changes in major blood cations (Na^+ and K^+) and aldosterone concentration in relation to seasons, heat stress under direct solar radiation, water salinity and water deprivation in sheep and goats in a subtropical environment.

MATERIALS AND METHODS

Experimental trials

This work comprised two experiments for testing the response of sheep and goats to the environmental conditions as follows:

1- Seasonal response; the experimental period was divided into three seasons: winter (December - January), spring (March - April) and summer (July - August). Water was available *ad libitum* during different seasons.

2- The response to specific experimental harsh conditions; animals were exposed to direct solar radiation daily without providing water from 12.00 noon to 3.00 p.m during 7 consecutive days of August, the response to salinity in drinking water (NaCI 13 g/I distilled water) during other seven days, and the response to water deprivation for 48 hrs repeated 7 times during August were investigated.

Animals

The study was carried out on five adult non-pregnant Ossimi ewes aging 2.5-3 years, weighing 50-55 kg and five Zaraibi female goats aging 3.0 years, weighing 30-40 kg. The animals were housed in semi-open pens with shaded yard. Animals were fed hay (3 kg/head/day) plus concentrates (2 kg/head/day) and rice straw. The concentrate ration was composed of, undecorticated cotton seed cake, rice bran, yellow corn, limestone and common salt plus molasses. The nutrients contents were approximately 16% crude protein, 15% crude fiber and 3% crude fat.

Blood samples

Blood samples were collected at weekly intervals for 8 consecutive weeks in each season and plasma was stored at-20°C until analyzed. During the periods of heat stress and saline water, blood samples were collected once a day for one week meanwhile, during water deprivation, samples were drawn day after day throughout a period of 14 days. Blood samples were collected at 10:00 a.m in all seasons and treatments except for heat stress which were Sodium and potassium concentrations in the plasma samples were estimated by atomic absorption spectrophotometry (Perkin-Elmer, 1982). Plasma aldosterone concentration was determined by using kits of aldosterone (Immunotech, A Coulter Co., France). To specify sensitivity of the kit, the pamphlet stated that the limit of detection, defined as the lowest concentration of aldosterone significantly different from zero with a probability of 95%, was 6 pg/ml (16.6 pmole/l). The cross-reactivity (%) of some endogenous steroids was 0.042 with corticosterone, 0.001 with cortisone and 0.2 with 11-desoxycorticosterone. In each of these experiments climatic conditions were recorded.

Statistical analysis

Relevant analyses of data were carried out applying SAS package (1990). Differences among means were checked according to Duncan (1955).

RESULTS AND DISCUSSION

Throughout the experimental period the means of ambient temperature (Ta) during winter, spring and summer were 15.8, 21.6 and 30.8°C, respectively. The mean values of relative humidity (RH) were 68,64 and 67%, respectively at the time of blood sampling. When animals were subjected to special harsh treatments, the means for (Ta) were 40,29.4 and 30°C for heat stress (HS), water salinity (WS) and water deprivation (WD), respectively and RH for these treatments ranged between 68-70% at the time of blood sampling.

1- Season effect

The mean values of Na^+ and K^+ (mg/100ml) in the blood plasma were significantly ($P<0.05$) different among seasons (Table 1). The values of Na^+ concentration declined significantly ($P<0.05$) from winter to spring to summer in both sheep and goats, the results of the present study (Table 1) showed a negative relationship between plasma sodium concentration and (Ta). The low values of sodium concentration might be attributed to different reasons, animals turned over more water during summer and spring than during witner (El-Nouty et al., 1988) in sheep, or due to water turnover rates were also significantly different between winter and summer. It was higher during summer indicating higher water requirement during the hot season for evaporative cooling (MacFarlane, 1964). Also, Guerrini et al., (1980) indicated that, increases in urine output in sheep during hot environment were correlated with increases in the respiratory rate and in water intake, whereas during cool-humid exposure The respiratory rate and water intake were declined. That increase in water intake might serve to eliminate heat during hot-dry exposure by evaporation. Harrison et al., (1975) Found that plasma volume of sheep was greatest during hot-humid exposur and accounted for the lower plasma electrolyte concentrations. The low values of plasma Na^+ in summer than winter may be due to Na^+ elimination in urine. Ashmawy (1994) found that in Ossimi sheep an increase Na^+ in urine during summer than in witner by 9%.

The values of K^+ tended to declined significantly ($P < 0.05$) from summer (19.1) to winter (15.5) to spring (13.8) in both sheep and goats (Table 1). This is probably due to the increase in ECF with rise in Ta which exhibit aldosterone secretion, consequently, urine K^+ concentration increased. It is clear that Na^+ and K^+ showed opposite trend of change due to seasonal variations.

Variations in the concentration of plasma aldosterone between seasons in both sheep and goats were narrower than in plasma electrolytes (Table 2 and Figure 1). The higher values were recoreded during the hot summer season. This increase may be due to the increase in plasma K^+ concentration, concomitant with reduction in Na^+ concentration during summer (Table. 1), science, aldosterone secretion promotes Na^+ reabsorption with simultaneous K^+ excretion. Breazile (1971), after repeated exposure of ruminant animals to hot environment, reported increase in the blood levels of aldosterone and 17-hydroxycortisone. Frandson (1986) indicated that, a low plasma sodium or high plasma K^+

concentration stimulates aldosterone secretion into the blood. Ganong (1981) reported that, aldosterone secretion was stimulated when plasma K^+ increased only 1m. eq/1or less. Francesconi et al. (1983) found that human plasma aldosterone levels were generally increased by exercise in heat. They also demonstrated that heat acclimation did not alter the response of plasma aldosterone to exercise in the heat.

2- Species effect

Statistical analysis revealed that species had no-significant effect on plasma Na^+ and K^+ concentrations during different seasons. Estimation of the effect of breed on Na^+ concentration showed that goats had higher values during summer than sheep (Table 1). This may be attributed to differences between the two species in body size and nature and character of body coat. Eyal (1963) found that because of the nature of the Awassi wool, there is a rise in relative humidity in the fleece with a rise in (Ta) resulting in a higher thermal conductivity of the wool fibers.

Even though goats showed slightly higher values of plasma K^+ than sheep during winter, the values during summer and spring were approximately equal (Table 1). During periods of water deprivation and water salinity, goats showed higher concentration of Na^+ accompanied by lower concentration in K^+ than the values in sheep. However, during heat stress

Table 1: Means ± S. E. of plasma $Na^+$and K^+ (mg/100 ml) of sheep and goats as affected by seasonal variations and exper imental harsh treatments.

Experimental periods	Sodium (Na+)		Potassium (K+)		Potassium (K+)		Na+ / K+ ratio	
	Sheep	Goats	Sheep	Goats	(Na+)	(K+)	Sheep	Goats
Different seasons:[1]								
winter	351.5 ± 6.3 [a]	370.2 ± 5.7 [a]	14.8 ± 0.6 [b]	16.3 ± 0.4 [b]	360.7 ± 4.4 [a]	15.5 ± 0.4 [b]	23.8	22.7
spring	211.5 ± 7.1 [b]	207.0 ± 4.9 [b]	13.8 ± 0.3 [c]	13.9 ± 0.3 [c]	209.2 ± 4.9 [b]	13.8 ± 0.2 [c]	15.3	14.9
summer	125.9 ± 1.8 [c]	122.6 ± 1.5 [c]	19.2 ± 0.8 [a]	19.1 ± 0.8 [a]	124.2 ± 1.2 [c]	19.1 ± 0.6 [a]	6.6	6.4
Overal means	229.6 ± 9.1 [A]	232.1 ± 9.9 [A]	15.9 ± 0.4 [A]	16.4 ± 0.4 [A]	230.8 ± 6.7	16.2 ± 0.3	14.4	14.2
Special treatments:[2]								
heat stress	561.7 ± 4.6 [B]	578.6 ± 4.2 [A]	18.6 ± 0.4 [A]	20.8 ± 0.4 [A]	570.1 ± 3.3	19.7 ± 0.3	30.2	27.8
water salinity	430.1 ± 7.3 [B]	448.6 ± 4.5 [A]	19.8 ± 0.6 [A]	18.7 ± 0.8 [B]	439.2 ± 4.4	19.4 ± 0.4	21.7	24.0
water deprivation	465.7 ± 7.2 [B]	505.7 ± 7.8 [A]	19.5 ± 0.3 [B]	17.8 ± 0.5 [A]	485.7 ± 5.8	18.7 ± 0.3	23.9	28.4

[1] Each value represented 40 observations (8 observations x 5 animals) in both sheep and goats.
[2] Each value represented 35 observations (7 observations x 5 animals) in both sheep and goats.
abc within columns, means with different superscript letters differ superscript letters differ significantly ($P < 0.05$).
AB within rows, means with different superscript letters differ significantly ($P < 0.05$).

Table 2: Means ± S. E. of plasma aldosterone concentration (pg/ml) of sheep and goats as affected by seasonal variations and experimental harsh treatments.

Experimental periods	Aldosterone concentration		
	Sheep	Goats	Overall means
Different seasons:[1]			
winter	5.00 ± 0.42^{bA}	5.91 ± 0.24^{bA}	5.44 ± 0.26^{b}
spring	4.50 ± 0.54^{bA}	6.00 ± 0.67^{bA}	5.20 ± 0.46^{b}
summer	6.81 ± 1.00^{aA}	6.70 ± 0.72^{aA}	6.71 ± 0.57^{a}
Overal means	5.22 ± 0.39^{A}	6.14 ± 0.31^{A}	5.68 ± 0.26
Special treatments:[2]			
heat stress (HS)	5.60 ± 0.41^{A}	10.90 ± 2.86^{A}	8.04 ± 1.47
water salinity	11.94 ± 2.87^{A}	9.60 ± 1.84^{A}	10.92 ± 1.79
water deprivation	7.60 ± 0.85^{A}	6.64 ± 1.29^{A}	7.15 ± 0.73

1- Each mean represented 8 original observations (4 observations x 2 animals) in both sheep and goats.
2- Each mean represented 6 original observations (3 observations x 2 animals) in both sheep and goats.
abc within columns, means with different superscript letters differ significantly ($p<0.05$).
AB within rows, means with different superscript letters differ significantly ($P<0.05$).

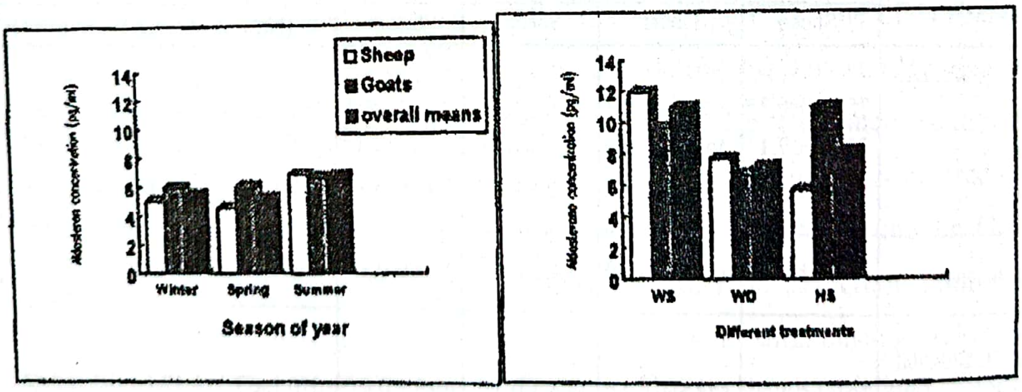

Figure (1): Plasma aldosterone concentration (pg/ml) during different seasons and special treatments in sheep and goats. WS = water salinity, WD = water deprivation and HS = heat stress.

period, goats had higher values of Na^+ and K^+ concentrations than sheep. This is probably, due to the different sweating rate and excretory pattern of water and potassium between sheep andgoats. Moeover the sweat glands of sheep are apocrine type in nature, the secretory material being derived from the dissolution of cellular secretory granules forming a clear liquid that is pinched off into the lumen of the gland (Ingram & Mount, 1975).

Plasma aldosterone concentration in goats showed a slight increase during winter and spring than that in sheep. This may be due to the greater concentration of plasma K^+ ingoats during winter than sheep. Plasma aldosterone level in goats during heat stress was double than that in sheep, and may be attributed to a reduction in plasma volume and to an increase in K cation. Aldosterone level showed opposite trend to (HS) during (WD) and (WS) since sheep recorded higher values than goats. This might be due to the increase in K^+ concentrations in sheep during the two treatments (WD & WS) than in goats (Table 1). Also, the ability of sheep kidney to concentrate urine and conserve water caused variations in blood volume when compared to goats and consequently, variations in blood osmosis between the two species.

3- Heat stress (HS) effect

The concentration of Na^+ in the plasma in both sheep and goats was significantly ($P<0.05$) affected by HS with greater values were noted in goats than in sheep (Table 1). This increase evokes adrenal response to stress in an attempt to maintain normal Na^+ concentration. This result agrees with that of Ashmawy, (1994) in Ossimi and Merino sheep, she found that, the change in Na^+ concentration showed similar trends in urine and blood. The difference between the two breeds in Na^+ concentration values may be due to the rapid exchange of water between rumen contents and blood, when considering differences in body size and rumen fluid volume between goats and sheep (Parthasarathy and Phillipson, 1953).

In the present study, the two species did not drink water during the period of exposure to solar radiation which could compensate the water loss by evaporation through the respiratory tract and skin surface. The coating colour of goats was black, and thus under summer heat stress, goats absorbed more radiation resulting in an increased sensitivity to heat.

The concentration of K^+ in blood plasma was greater in stressed goats than sheep (Table 1). This agrees with results of Singh et al., (1982) in Chokla sheep in India. The increase in K^+ concentration may be due to the increase in breakdown of red blood cells with leakage of K^+ during the exposure period (Olbrich et al., 1972). Also, Ashmawy (1994) found that urine potassium decreased due to exposure to direct solar radiation, by 21% in Ossimi vs. 34% in

Merino sheep.

During heat stress, plasma aldosterone concentrations in goats were as much as twice that in sheep (Table 2 and Figure 1). This may be due to the black coat of goats which absorbed more radiation and caused more evaporative cooling in addition to the small size of goats when compared to sheep.

4- Water salinity (WS) effect

Plasma Na^+ concentrations were significantly ($P<0.05$) increased when sheep and goats were given saline water. The values differed significantly between the two species (Table 1). The higher values in goats may be attributed to higher absorption of Na^+ from the small intestine. These results agreed with those of Singh and Taneja (1981). Rahnema & Fontenot (1990). Constable et al., (1991) and Ashmawy (1994). The greater values of Na^+ concentration in goats than in sheep in the present study were probably due to rapid elimination of excess sodium through efficient renal mechanisms which agrees with the results of Khamis et al., (1989) in Barki sheep.

When animals were offered saline drinking water, plasma concentration of K^+ tended to be significantly lower in goats than in sheep (Table 1). This result agreees with that of Khamis et al., (1989) in camels and Barki sheep. Ashmawy (1994) found that, potassium concentration in urine decreased when Ossimi and Merino ewes were given drinking salt water.

Plasma aldosterone concentration was higher in sheep than in goats after drinking saline water (Table 2). Frandson (1986) indicated that when K^+ concentration is high relative to the Na^+ concentration aldosterone causes reabsorption of one and excretion of the other in order to re-establish the normal sodium to potassium ratio in the extracellular fluid of the animal.

5- Water deprivation (WD) effect

The WD treatment had a significant effect on Na^+ and K^+ concentration. Sodium concentration in the plasma was significantly ($P<0.05$) different between sheep and goats when deprived of water apparently due to adrenal response to stress in an attempt to maintain plasma volume (Table 1), or probably due to a decrease in ECF volume (More and Sahni, 1980). MacFarlane et al., (1961) reported that Merino sheep in a tropical climate when subjected to conditions of dehydration during summer, voided concentrated urine which reached a maximum osmolarity of 3.8 Osmoles/l. This remarkbale ability of sheep's kidney to concentrate urine and conserve water supports the results obtained in the present study. Also, More & Sahni (1980) found that WD in sheep caused a significant increase in urine osmolarity and conductivity. There was also a rise in urine Na^+

concentration and thereby a reduction in urine K^+ / Na^+ ratio. Under the condition of WD the increase of Na^+ concentration was more pronounced in goats than in sheep (Table 1) probably due to differences in body and rumen fluid volume between the two species.

During WD period plasma K^+ concentration remained unaffected in sheep, but, in goats the increase of plasma Na^+ concentration was accompanied by decrease in K^+ concentrations (Table 1). Khan et al., (1978), found that the urinary K^+ / Na^+ ratio was increased when Barmer goats were deprived of water for 96 hours. There was a decrease in urinary sodium conentration after WD. The present data support the possibility of a decrease in the amount of the excreted urine which was expected as a sharp decline in glomerular filtration rate in the water restricted goats.

During WD, aldosterone concentration was higher in sheep than that in goats. WD causes a decline in blood volume which stimulates the secretion of renin and consequently, aldosterone release into the blood. Also, WD as a type of stress, stimulates the release of ACTH which increases animal resistance and increases output of aldosterone during adrenal response to adaptation, (Reece, 1991). Under WD antiduretic hormone (ADH) is also released to restore normal blood volume by stimulating water reabsorption in the kidneys.

6- Relationship betwen K^+ / Na^+ ratio and aldosterone concentration

In sheep and goats, the highest Na^+ / K^+ ratio was recorded in winter while the lowest was that of summer. The Na^+ / K^+ ratio of spring was intermediate (Table 1). Aldosterone concentration showed the opposite trend since the highest values were recorded during summer (Table 2) to conserve and retain more Na^+ in the blood. When considering the special treatments, goats had higher Na^+ / K^+ ratio than sheep during water salinity and water deprivation. In sheep, the highest Na^* / K^* ratio was recorded during heat stress (Table 1). Aldosterone concentration was the least during heat stress in sheep and during water deprivation in goats (Table 2).

It could be concluded that sheep and goats are able to tolerate some environmental harsh conditions, using all possible mechanisms to achieve homeostasis. Therefore, it is recommended that sheep and goats would be the most appropriate animals to survive and produce in the newly-reclaimed desert areas.

REFERENCES

Ashmawy, Neama A. (1994): Adaptation of sheep to hot-arid conditions. Ph. D. Thesis, Fac. Agric., Cairo Univ., Egypt.

Breazile, J. E. (1971): Skin. Textbook of Veterinary Physiology, P. 552. Edited by: J. E. Breazile; G. G. Beames, Jr; P. T. Cardielhac and W. S. Newcomer. Lea

& Febiger, Philadelphia, USA.

Constable, P.; L. Michael; W. W. Muir and G. F. Hoffsis (1991): Respiratory, renal, haematologic and serum biochemical effects of hypertonic saline solution in endotoxemic calves. Am. J. Vet. Res. 52 (7): 990.

Duncan, D. B. (1955): Multiple range and multiple "F" tests. Biometrics 11:1.

El-Nouty, F. D.; G. A. Hassan; T. H. Tahed; M. A. Samak; Zahraa Abo-Elezz and M. H. Salem (1988). Water requirements and metabolism in Egyptian Barki and Rahmani sheep and Baladi goats during spring. summer and winter seasons. J. Agric. Sci. Camb., 111, 27-34.

Eyal, E. (1963): Shorn and unshorn Awassi sheep. IV-Skin temperature and changes in the temperatures and humidity in the fleece and its surface. J. Agric. Sci., Camb., 60, 183-193.

Francesconi, R. P.; M. N. Sawka and K. B. Pandolf (1983): Hypohydration and heat acclimation: Plasma renin and aldosterone during exercise. J. App. Physiol., 55: 1790-1794

Frandson, R. D. (1986): *Anatomy* and *Physiology* of Farm Animals. PP: 378-395. Lea and Febiger, Philadelphia, USA.

Ganong, W. F. (1981): *Review of Medical Physiology*. pp: 284-307. Lange Medical Publications, Los Altos, California. Librairie du Liban, Beirut, Lebanon.

Guerrini, V. H.; N. Koster and H. Bertchinger (1980): Effect of ambient temperature and humidity on urine output in sheep. Am. J. Vet. Res. Vol. (41) No:11 pp: 1851.

Harrison, H. M.; J. R. Edwards and R. D. Leitch (1975): Effect of exercise and thermal stress on plasma volume. J. Appl. Physiol. 39: 925-930

Ingram, D. L. L. E. Mount (1975): *Man* and Animal in Hot Environment. P: 54. Springer-Verlag. Brlin.

Khamis, H. S.; M. F. Farid; M. H. Ahmed; S. M. Shawkat and H. M. Abouelnasr (1989): Studies on saline drinking water for camels and sheep: sodium and potassium metabolism. Computer Sci. & Dev. Res., 25: 17-29.

Khan, M. S.; P. K. Ghosh and T. O. Sasidharan (1978): Effect of acute water restriction on plasma proteins and on blood and urinary electrolytes in Barmer goats of the Rajasthan desert. J. Agric. Sci., Camb., 91: 395-398.

MacFarlane, W. V. (1964): Terrestrial animal in dry heat. Ungulates. In: *Handbook of Physiology.* 4th ed., p: 509 (ED) D. B. American Physiological Socity, Washington, D. C.

MacFarlane, W. V.; R. J. H. Morris; B. Howard; J. Mcdonald and O. E. Budts-Olsen (1961): Aust. J. Agric. Res. 12:889. Cited by: Macfarlane, W. V. (1964): Terrestrial animal in dry heat. Ungulates. In: *Handbook of Physiology.* 4th ed., p: 509 (ED) D. B. American Physiological Society, Washington, D.C.

More, T. and K. L. Sahni (1980): Effect of water deprivation on blood and urine components of lactating sheep under semi-arid conditions. Indian J. Anim. Sci. 50: 411-416.

Olbrich, S. E.; F. A. Martz; M. E. Tumbeson; H. D. Johnson and E. S. Hilderbrand (1972): Effect of constant environmental temperature of 10°C and 31°C on serum biochemical and haematological measurements of heat-tolerant and cold-tolerant cattle. Comp. Biochem. Physiol., 41 (A): 255-266.

Parthasarathy, D. and A. T. Phillipson (1953): The movement of potassium, sodium, chloride and water across the rumen epithelium of sheep . J . Physiol. 121: 452.

Perkin-Elmer (1982): Analytical methods for atomic absorption spectrophotometry. Perkin-Elmer, Norwalk, CT.

Rahnema, S. H. and J. P. Fontenot (1990): Effect of intravenous infusion of high levels of potassium and sodium on mineral metabolism in sheep, J. Anim. Sci., 68: 2833-2838.

Reece, W. O. (1991): *Physiology of Domestic Animals.* pp: 330-346. Lea and Febiger, Philadelphia. London.

SAS: Statistical Analysis System Institute (1990): SAS User's Guide. Statistics, Version 5 Edition, SAS Institute Inc., Cary, NC,USA.

Singh, M. and G. C. Taneja (1981): Variability for salt tolerance in pure-bred and cross-bred sheep of Rajasthan desert. Indian J. Anim. Sci., 51 (3): 324-327.

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