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Original Research Paper

ENDOCRINE AND METABOLIC RESPONSES OF MARWARI SHEEP IN ARID TRACT

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Summary: The present investigation was carried out in Marwari sheep belonging to arid tracts to assess the endocrine and metabolic responses during water restriction, hot ambience, road transportation and drought. The mean±SEM values of serum thyroxine (µg/dl), triiodothyronine (ng/dl), aldosterone (ng/dl), cortisol (ng/ml), cholesterol (mg/dl), glucose (mg/dl), sodium (mmol/l), potassium (mmol/l), chloride (mmol/l), total serum protein (g/dl), albumin (g/dl), globulin (g/dl), urea (mg/dl) and creatinine (mg/dl) during control period of water restriction experiment were 4.89±0.04, 123. 1±1.8, 1.79±0.15, 6.89±0.17, 40.2±2.9, 70.3±4.2, 140.1±2.8, 5.0±0.12, 130.3±4.1, 7.4±0.1, 3.7±0.09, 3.5±0.1, 25.5±2.1 and 1.0±0.06, respectively. An increase in glucose, cholesterol, aldosterone, sodium, chloride, total serum protein, albumin, globulin, urea and creatinine concentrations was observed during the water restriction period and decrease in concentrations of the above parameters was seen upon rehydration. Concentrations of thyroxine, triiodothyronine and potassium were decreased during the water restriction period which showed an increase during rehydration. During hot ambience pattern of changes were comparable to those observed during water restriction. A significant ($p \leq 0.05$) increase was observed in endocrine responses after five hours of road transportation. Drought caused an increase in the mean values of aldosterone, cortisol, sodium, chloride, urea and creatinine; no change in glucose and cholesterol and decrease in thyroid hormones, total proteins, albumin and globulin.

Key words: acclimatization; desert climate; endocrine system – physiology; stress – physiopathology; body water – metabolism; aldosterone – blood; cortisol – blood; thyroxine - blood; triiodothyronine - blood; sheep

Introduction

Arid tracts face the problems of recurring droughts and it becomes essential to determine the adaptability level of the animals living in these areas to increase their sustainability by taking proper and timely measures during such periods. The important way to determine physiological response to the external and internal stimuli and an understanding of the physiology of stress in animals is crucial in assessing animal welfare. Examination of the stress and productivity responses is important to develop management strategies (1).

The common problems experienced by the sheep in arid tracts are dehydration, heat, transportation and droughts. When the pressure from these conditions becomes excessive new defense mechanisms are initiated and their determination is an essential part of animal management. Out of all the mechanisms endocrine and metabolic responses are important giving a picture of modulation in physiological mechanisms. The turnover of fluid during dehydration and rehydration shows the adaptation to water deficit and water plus and many endocrinological factors tend to control them. The hypothalamic-pituitary-adrenal axis is important in making the physiological approach to regulate the unusual condition. Increased release of corticotrophin releasing hormone (CRH), adreno-corticotrophin hormone (ACTH) and thyroid stimulating hormone (TSH) during stress are related with increased concentrations of thyroid hormones and adrenal ster-

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oids (1). Adrenal hormone cortisol is equated with the stress level. Another adrenal steroid aldosterone mediates retention of considerable quantities of water along with sodium. Aldosterone is also considered as a hormone of dehydration in animals. It is mainly concerned with sodium retention and potassium excretion into the urine. Cortisol from adrenal cortex exerts some effect on electrolytes and water metabolism (2).

In stressed animals thyroid activity acts to strengthen the body mechanisms. Therefore the thyroidal hormone levels are good indicators of health status of the animals. Determination of serum thyroid hormones along with cholesterol, glucose and proteins is important and correlation of thyroid hormones with cholesterol is studied by few workers in animals (3).Marwari sheep plays an important role in the economy of arid tracts. However, there is paucity of work regarding endocrine and metabolic responses to various types of stress which incited the investigation.

Material and methods

To determine the endocrine and metabolic responses of Marwari sheep belonging to arid tracts, two experiments were designed which were not related with each other according to selection of animals. The first experiment was conducted to determine endocrine and metabolic responses during water restriction and rehydration in female Marwari sheep which were kept in pens. The second experiment was taken up to assess endocrine and metabolic responses during hot ambience, after road transportation and during drought condition on male sheep belonging to farmers' stock of arid region.

First experiment was carried out on eleven apparently healthy female Marwari sheep (1-2 years) kept in well ventilated pens to provide stress free environment and were fed with roughage diet of dry leaves of Ziziphus nummularia along with pelleted diet (crude protein-20 %, ether extract 2.5 %, crude fibre 12 %, acid insoluble ash 4 %, calcium 0.5 %, phosphorus 0.5 %, vitamin AD_3 5000 IU/kg and mineral mixture 1 %) and watered ad libitum. Before the beginning of experiment animals were accustomed to the new surroundings and environment so that stress or anxiety due to new ambience could be minimized. This experiment was conducted under the permission of Institutional Animal Ethical Committee, College of Veterinary and Animal Science, Bikaner, India. All the measures were taken for the comfort of the animals and health was monitored regularly.

To determine endocrine and metabolic responses of sheep during water restriction and rehydration, the experiment was divided into three periods i.e. control, water restriction and rehydration. In each period same animals were used so that each animal served as its own control. During the control period of 5 days the animals were fed and watered ad libitum. Water restriction period was of 8 days during which water was restricted completely but animals were fed ad libitum. After completion of water restriction period, rehydration period started when animals were fed and watered ad libitum. It was of 5 days. Blood samples were collected to harvest sera in the morning hours before feeding. During control period samples were collected daily for five days and mean was used as a representative value for each parameter. Sampling was carried out in duplicate on day 4 and 8 of water restriction period. During rehydration period samples were collected on hour 1/2, 24, 48, 72 and 96 of rehydration.

Second experiment was conducted on the Marwari sheep which belonged to farmers' stock of arid region. These animals were not kept in the pens and maintained under semi conservative system and were fed and watered ad libitum. The male animals were selected as these animals were kept for meat purposes and small amount of blood was collected as routine health check up. Male animals are generally transported from villages to cities for meat purposes. Therefore to assess the stress to the animals blood samples were collected.

In this experiment, three groups of animals were taken. The first group constituted of 10 male sheep (1-2 years) from which samples (sera) were collected during moderate (maximum temperature varied between 23 and 27 °C) and hot ambience (maximum temperature varied between 43 and 46 °C). The mean values of various parameters determined during moderate ambience were considered as control for comparison.

Second group comprised of another 10 male sheep (1-2 years) from which blood samples (sera)were collected after 5 hours of road transportation and then after four hours of rest when they reached to destination.

Third group comprised of another 10 male sheep (1-2 years) belonging to farmers' stock of drought stricken arid tract.

In all the experiments endocrine responses were assessed by determining serum hormones by radio-

immunoassay (RIA) in Radio Isotope Laboratory, College of Veterinary and Animal Science, Bikaner. ^{125}I was used for labeling each hormone. Assay was based on the competition between labeled and unlabelled hormones for the limited binding sites of antibody. Gamma Counter was used to count radioactivity for the determinations. RIA kits were used for hormone determinations viz. thyroxine (RIA kit, DiaSorin), triiodothyronine (RIA kit, DiaSorin), aldosterone (RIA kit, DPC) and cortisol (RIA kit, DPC). The metabolic responses were evaluated by determining parameters in the serum viz. total proteins, albumin, globulin, creatinine, urea and cholesterol by colorimetric kits (Wipro) and glucose (Nelson - Somogyi method),sodium, potassium (Flame photometer), and chloride (Schales and Schales) by the standard methods (4). Statistical significance was assessed by 't' test (5).

Results

The mean values of endocrine and metabolic responses during water restriction are presented in table 1 and during hot ambience, drought and after road transportation are presented in table 2.

1. Endocrine and metabolic responses during water restriction and rehydration

During water restriction period the mean values of serum T_4 and T_3 decreased significantly ($p \leq 0.05$) from the respective control mean values. Upon rehydration, at hour 1/2 the mean values of serum T_4 and T_3 were significantly ($P \leq 0.05$) higher from respective day 8 (water restriction period) mean values. Afterwards the values started increasing as the time advanced and at hour 96 differed non-significantly ($P > 0.05$) from respective control mean values.

The mean values of serum glucose and cholesterol increased significantly ($p \leq 0.05$) during water restriction period. During rehydration period at hour 1/2 both the mean values were significantly ($P \leq 0.05$) lower than the respective day 8 mean values. At hour 72 a non -significant ($p > 0.05$) difference from respective control mean value was observed indicating attainment of normalcy.

As the days during water restriction period advanced the mean values of aldosterone started increasing significantly ($P \leq 0.05$). Upon rehydration aldosterone mean value decreased significantly ($P \leq 0.05$) when compared with that of day 8. At hour 24 and 48 it showed an increase and then again showed a decreasing trend and the mean value touched the base line on hour 72.

With the progress of water restriction period the mean values of serum sodium and chloride started rising while potassium showed a declining trend. Upon rehydration the mean values of serum sodium and chloride lowered significantly ($P \leq 0.05$) when compared with the respective day 8 dehydration mean values. The mean values of all the electrolytes during rehydration phase were compared with the respective control mean values to find out the time period when non-significant ($p > 0.05$) variation could be observed showing normalcy. For sodium it was hour 48, while for potassium and chloride it was hour 72.

During water restriction period serum cortisol increased significantly ($P \leq 0.05$) from control mean value and on day 8 increase was approximately 7-fold of the control value. Immediately after rehydration cortisol mean value marked a significant lowering from day 8 mean value and then onward this trend remained continued until the value touched base level at hour 96.

With the progression of water restriction period an increase was observed in the mean values of serum total proteins, albumin, globulin, urea and creatinine. Upon rehydration a decrease was observed in the mean values of all the parameters. The mean values at hour 1/2 were compared with respective day 8 mean values. All the mean values were significantly ($p \leq 0.05$) lower except for globulin. All the mean values touched the base line at hour 72 except that for serum creatinine which touched the base line at hour 96 of rehydration.

2. Endocrine and metabolic responses during hot ambience, after road transportation and drought

The mean value of each parameter during hot ambience, drought, road transportation and rest were compared with the respective mean values during moderate ambience considering it as control. During hot ambience and drought serum thyroxine and triiodothyronine levels decreased and after road transportation increased significantly ($p \leq 0.05$) when compared from respective control mean values. Serum glucose and cholesterol showed significant ($p \leq 0.05$) increase from respective control mean values during hot ambience and after road transportation. Mean values of both the parameters showed non- significant ($p > 0.05$) changes from control during drought.

Table 1: Endocrine and metabolic responses during water restriction in Marwari sheep (N=11)

Parameters (Mean±SEM)	Experimental periods							
	Control	Water restriction (Days)		Rehydration (Hours)				
		4	8	1/2	24	48	72	96
Thyroxine µg/dl	4.89±0.04	3.8±0.09^{b}	2.1±0.07^{b}	2.6±0.07^{bh}	2.9±0.08^{b}	3.4±0.08^{b}	3.9±0.09^{b}	4.6±0.10^{a}
Triiodothyronine ng/dl	123.1±1.8	112±1.2^{b}	75.2 ±2.0^{b}	83±1.17^{bh}	100±1.01^{b}	110±1.1^{b}	116±1.5^{b}	125±1.07^{a}
Aldosterone ng/dl	1.79±0.15	3.8±0.19^{b}	6.0±0.17^{b}	2.0±0.13^{bh}	2.4±0.18^{b}	2.6±0.18^{b}	1.9±0.19^{a}	1.6±0.10^{a}
Cortisol ng/ml	6.89±0.17	13.8±1.19^{b}	43.1±1.27^{b}	20.6±0.17^{bh}	16.9±2.18^{b}	12.4±1.98^{b}	9.9±1.19^{b}	7.0±0.9^{a}
Glucose mg/dl	40.2±2.9	49.2±2.9^{b}	69.2±2.9^{b}	52.2±2.9^{bh}	48.2±3.1^{b}	45.9±2.1^{b}	43.1±2.4^{a}	42.1±3.1^{a}
Cholesterol mg/dl	70.3±4.2	81.3±4.0^{b}	110.3±3.9^{b}	89.3±4.1^{bh}	85.3±3.0^{b}	80.3±3.3^{b}	74.3±4.1^{a}	73.0±3.2^{a}
Sodium mmol/l	140.1±2.8	152±1.8^{b}	175.2 ±2.0^{b}	153±1.17^{bh}	150±1.01^{b}	145±1.1^{a}	141±1.5^{a}	139±1.07^{a}
Potassium mmol/l	5.0±0.12	4.5±0.13^{b}	3.4±0.11^{b}	3.9±0.2^{bh}	4.2±0.1^{b}	4.7±0.1^{b}	4.9±0.2^{a}	5.4±0.1^{a}
Chloride mmol/l	130.3±4.1	138.3±3.0^{b}	170.3±3.9^{b}	153.3±4.1^{bh}	148.3±3.0^{b}	140.3±3.3^{b}	136.3±4.1^{a}	133.0±3.2^{a}
Total proteins g/dl	7.4±0.1	8.2±0.1^{b}	10.2 ±0.2^{b}	9.0±0.17^{bh}	8.5±1.01^{b}	8.2±0.6^{b}	7.8±0.2^{a}	7.6±0.4^{a}
Albumin g/dl	3.7±0.09	4.3±0.08^{b}	5.3±0.07^{b}	4.2±0.09^{bh}	4.0±0.05^{b}	3.8±0.05^{b}	3.5±0.04^{a}	3.1±0.01^{a}
Globulin g/dl	3.5±0.1	4.3±0.3^{b}	4.6±0.1^{b}	4.8±0.1^{b}	4.3±0.3^{b}	4.1±0.3^{b}	3.7±0.1^{a}	3.5±0.2^{a}
Urea mg / dl	25.5±2.1	37.5±2.2^{b}	55.8±2.5^{b}	40.5±3.1^{bh}	34.5±2.4^{b}	30.2±2.6^{b}	28.6±2.2^{a}	26.3±3.1^{a}
Creatinine mg / dl	1.0±0.06	3.5±0.06^{b}	4.9±0.05^{b}	2.9±0.07^{b}	2.0±0.03^{b}	1.7±0.02^{b}	1.5±0.03^{b}	1.1±0.06^{a}

N=Number of animals

The mean value of each parameter in each period has been compared with the respective mean value during control period. Significant variation ($p \leq 0.05$) has been shown by using superscript 'b' and non-significant ($p > 0.05$) by using 'a'.

Superscript 'h' on the mean value of a parameter at hour 1/2 shows significant ($p \leq 0.05$) difference from the respective day 8 (water restriction period) mean value.

Serum aldosterone was significantly ($p \leq 0.05$) higher during hot ambience, drought and after road transportation from control mean value. Serum sodium and chloride were significantly ($p \leq 0.05$) higher during hot ambience only and non significantly ($p > 0.05$) higher during drought and after road transportation. Serum potassium was significantly ($p \leq 0.05$) lower during hot ambience, drought and after road transportation.

During hot ambience serum cortisol, total proteins, albumin, globulin, urea and creatinine showed a significant ($p \leq 0.05$) increase. After road transportation only serum cortisol increased significantly ($p \leq 0.05$). During drought condition cortisol, urea and creatinine showed a significant ($p \leq 0.05$) increase while total proteins, albumin and globulin showed significant ($p \leq 0.05$) decrease. All the parameters showed non significant ($p > 0.05$)

Table 2: Endocrine and metabolic responses in Marwari sheep during hot ambience, drought and after road transportation

Parametrs (Mean±SEM)	Control (Moderate ambience) (10)*	Hot ambience (10)*	Drought (10)	Road transportation (10)**	Rest Period (10)**
Thyroxine µg/dl	4.9±0.05	2.6±0.09^{b}	2.5±0.11^{b}	7.2±0.2^{b}	5.2±0.05^{a}
Triiodothyronine ng/dl	120.6±1.3	101±1.3^{b}	100.3±1.1^{b}	130.2 ±2.9^{b}	123.3±1.2^{a}
Aldosterone ng/dl	1.66±0.11	4.8±0.16^{b}	4.9±0.2^{b}	2.7±0.15^{b}	1.7±0.10^{a}
Cortisol ng/ml	6.83±0.17	20.0±1.7^{b}	26.0±0.19^{b}	40.6±3.1^{b}	7.99±0.13^{a}
Glucose mg/dl	42.8±3.2	57.5±3.3^{b}	42.6±0.29^{a}	53.2±3.2^{b}	52.8±3.2^{b}
Cholesterol mg/dl	74.7±5.3	90.1±3.9^{b}	72.1±4.09^{a}	70.3±4.1^{a}	70.7±5.0^{a}
Sodium mmol/l	137.1±2.3	165±1.6^{b}	142.6±5.09^{a}	146±1.3^{a}	133.1±2.9^{a}
Potassium mmol/l	5.2±0.11	4.0±0.12^{b}	4.6±0.19^{b}	4.5±0.1^{b}	5.5±0.19^{a}
Chloride mmol/l	133.3±3.1	158.3±3.5^{b}	140.2±5.01^{a}	141.3±3.1^{a}	136.3±3.0^{a}
Total proteins g/dl	7.4±0.1	8.2 ±0.3^{b}	6.0±0.1^{b}	7.8±0.2^{a}	7.6±0.1^{a}
Albumin g/dl	3.7±0.09	4.3±0.08^{b}	3.0±0.02^{b}	3.8±0.09^{a}	3.7±0.1^{a}
Globulin g/dl	3.5±0.1	3.9±0.2^{b}	3.0±0.03^{b}	3.4±0.1^{a}	3.1±0.1^{a}
Urea mg / dl	25.5±2.1	40.1±2.1^{b}	56.0±4.1^{b}	24.5±3.0^{a}	21.5±2.0^{a}
Creatinine mg / dl	1.0±0.06	1.7±0.03^{b}	3.6±0.1^{b}	1.2±0.05^{a}	0.8±0.02^{a}

Figures in parentheses indicate number of animals

* and ** = Same animals, respectively

The mean value of each parameter in each effect has been compared with the respective mean value of control. Significant variation ($p \leq 0.05$) has been shown by using superscript 'b' and non-significant ($p > 0.05$) by us 'a'.

changes after rest except glucose when compared from control.

Discussion

1. Endocrine and metabolic responses during water restriction and rehydration

The decrease in serum T4 and T3 during water restriction period could be related with dearth of feed and water as thyroid hormones elevate basal metabolic rate and heat production for thermoregulation (3). Therefore reduction was beneficial in terms of reducing water losses with each respiration and thereby decreasing oxygen consumption and helped the animal to conserve water. The decreased thyroid activity was related with increased serum cholesterol values (3). Suppression of thyroid activity reduced energy metabolism resulting in higher blood energy nutrient levels (6).

Increased serum aldosterone level during water restriction period (7) probably helped the animals to withstand dehydration stress by water and sodium retention (8). Higher aldosterone values are related to stress (9). In addition to anti diuretic hormone, aldosterone is also important in regulating the body's

water balance. Serum aldosterone was also used as a marker of water and electrolyte homeostasis in sheep (10).

After rehydration decrease in aldosterone mean value was probably due to dilution effect (2). In present study at hour 24 and 48 aldosterone showed an increasing trend followed by a decrease. Earlier literature has also reported an increase in serum aldosterone upon rehydration in sheep (11, 12).

With the progress of water restriction period the mean values of serum sodium and chloride started rising while potassium showed a declining trend (13). Hypernatraemia helped the dehydrated sheep to conserve water by holding it in water compartments and circulation. Decrease in serum potassium during dehydration indicated towards the role of aldosterone on increasing excretion rates of potassium (2).

Upon rehydration the mean values of serum sodium and chloride lowered significantly ($P \leq 0.05$) when compared with the respective day 8 dehydration mean values. The decreased values indicated towards haemodilution. At hour 1/2 slight increase in the mean value of potassium could be due to lowering of aldosterone levels.

Increased serum cortisol during water restriction period indicated towards stress (14) which worked through CRH and ACTH and was essential to supply glucose by gluconeogenesis and glycogenolysis. A rise was observed in the serum glucose. Upon re hydration serum cortisol started declining and touched the base line at hour 96 as observed by earlier workers also (2).

With the progression of water restriction period an increase was observed in the mean values of serum total proteins, albumin, globulin, urea and creatinine which probably helped the animals to hold the water. An increase in serum proteins during dehydration have also been reported in goats (15). Uraemia helped the animals to hold the water during dehydration which resulted due to the combined effect of absorption and reabsorption from the kidneys and alimentary tract (16). Increased creatinine levels during dehydration could be due to decrease in urine output or glomerular filtration rate. Cortisol through muscle wasting was related with increased serum creatinine during dehydration.

2. Endocrine and metabolic responses during hot ambience, after road transportation and drought

During hot ambience and drought serum thyroxine and triiodothyronine levels decreased probably to decelerate basal metabolic rate as a part of thermoregulation. In sheep thyroids are more active during winter months (17). Decreased thyroid activity during hot ambience could also be related with increased concentrations of energy metabolites (glucose and cholesterol) in the serum. However, decreased thyroid activity during drought was not related with the increased concentrations of glucose and cholesterol as there was non significant ($p > 0.05$) difference from control. Increased thyroid activity after road transportation did not bring significant change in the levels of cholesterol. However, serum glucose showed significant rise.

During hot ambience serum cortisol, total proteins, albumin, globulin, urea and creatinine showed a significant increase as reported by earlier workers (18). After road transportation only serum cortisol increased significantly, however, it did not bring significant ($p \leq 0.05$) changes in the levels of metabolites like total proteins, cholesterol, urea and creatinine but serum glucose was significantly ($p \leq 0.05$) higher despite of higher thyroid activity. This indicated towards glucocorticoid function. Cortisol response of animal was faster than the body responses to bring about the resultant alterations in metabolic concentrations except serum glucose which showed immediate response. It was interesting to note that rise in serum cortisol after road transportation was higher than drought but there was no decrease in total serum proteins in former as was observed in latter. This could be explained on the basis that drought conditions have scarcity of water and feed resulting in long term effect of cortisol while transportation appeared to be short term stress to animals. Further, very high creatinine concentration during drought support the explanation. Effect of hot ambience, transportation and drought appeared to be similar on serum aldosterone, sodium, potassium and chloride. However, rise in aldosterone concentration during hot ambience and drought was double than that observed due to transportation.

From the investigation it was concluded that endocrine and metabolic responses elicited during various conditions were variables in animals. Changes in endocrine and metabolic responses due to water restriction were great but reversible. After

elimination of stressor the homeostasis was obtained. After transportation changes in endocrine responses were faster than metabolic responses. Sampling after four hours of rest showed decrease in the levels of all the hormones with non- significant ($p>0.05$) change in serum glucose level.

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ENDOKRINI IN PRESNOVNI ODZIVI PRI OVCAH PASME MARVARI V SUŠNIH PODROČJIH

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Povzetek: Raziskavo smo opravili na ovcah pasme marvari, ki živijo v sušnih področjih. Zanimali so nas presnovni in endokrini odzivi na pomanjkanje pitne vode, visoke temperature, cestni transport in splošno sušo. Med poskusom omejevanja pitne vode so bile izmerjene vrednosti pri kontrolni skupini (povprečje ± SEM) serumskega tiroksina (µg/dl), trijodtironina (ng/dl), aldosterona (ng/dl), kortizola (ng/ml), holesterola (mg/dl), glukoze (mg/dl), natrija (mmol/l), kalija (mmol/l), klorida (mmol/l), skupnih serumskih proteinov (g/dl), albumina (g/dl), globulina (g/dl), ureje (mg/dl) in kreatinina (mg/dl) 4,89 ± 0,04, 123,1 ± 1,8, 1,79 ± 0,15, 6,89 ± 0,17, 40,2 ± 2,9, 70,3 ± 4,2, 140,1 ± 2,8, 5,0 ± 0,12, 130,3 ± 4,1, 7,4 ± 0,1, 3,7 ± 0,09, 3,5 ± 0,1, 25,5 ± 2,1 in 1,0 ± 0,06, v enakem zaporedju. Pri omejevanju pitne vode smo ugotovili povečanje koncentracije serumske glukoze, holesterola, aldosterona, klorida, skupnih serumskih proteinov, albumina, globulina, ureje in kreatinina, po rehidraciji pa so koncentracije navedenih parametrov spet upadle. Koncentracije tiroksina, trijodtironina in kalija so bile med omejevanjem vode znižane, po rehridraciji pa so se zvišale. Podobne spremembe kot pri omejevanju vode smo ugotovili pri skupini ovc, ki so bile nastanjene pri višji temperaturi okolice. Izrazit porast endokrinega odziva ($p \leq 0.05$) smo ugotovili tudi po petih urah prevoza po cesti. Suša je povzročila povečanje srednjih serumskih vrednosti aldosterona, kortizola, natrija, klorida, ureje in kreatinina, zmanjševanje koncentracije hormonov ščitnice, skupnih proteinov, albuminov in globulinov, ni pa bilo sprememb v ravneh glukoze in holesterola.

Ključne besede: aklimatizacija; puščavska klima; endokrinisistem - fiziologija; stres - patofiziologija; telesne tekočine - metabolizem; aldosteron - kri; hortizol - kri; tiroksin - kri; trigotironin - kri; ovce