Global Veterinaria 16 (2): 188-199, 2016
ISSN 1992-6197

DOI: 10.5829/idosi.gv.2016.16.02.10285

Effects of Nutritional Stress and Realimentation on Physiological Responses of Desert Sheep

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Abstract: In semi-arid tropical regions, climate change and recurrent periods of water and feed shortage exert nutritional stress in Desert sheep. This study was designed to assess the effects of water deprivation (WD) or combined feed and water deprivation (FWD) for 3 days and realimentation on physiological responses of desert ewes. The mean body weight (BW) of ewes decreased significantly with WD (11.3%) and FWD (15.9%). The rectal temperature (Tr) was significantly higher with WD than FWD in the afternoon and the afternoon values of respiration rate (RR) were significantly lower with FWD than WD. The PCV and Hb concentration were significantly higher after 3 days with FWD than WD. Both treatments induced an increase in plasma glucose level that was more marked with FWD. Serum levels of Na, total lipids and creatinine were significantly higher after 3 days with FWD and WD. Serum osmolality and cortisol level were increased significantly with FWD and WD. Most of the parameters investigated returned to normal values on day 3 of realimentation. The findings indicate that desert sheep possess the physiological capacity to adapt to nutritional stress.

Key words: Desert Sheep · Water and Food Deprivation · Realimentation · Physiological Sponses

INTRODUCTION

Desert sheep are reared mainly under semi-arid tropical conditions. This demands adaptation to marked environmental temperature fluctuations and recurrent periods of food and water shortage [1]. Scarcity of water and sparse vegetation in the dry period hamper the productivity of sheep [2]. The water scarcity is much more severe during the dry season; consequently animals walk long distances in search of feed and water. Furthermore, sheep may be exposed to relative dehydration and starvation during transport and pre-slaughter conditions [3, 4] water deprivation is considered as a significant stressor in the marketing process for ruminants [5, 6]. The physiological responses under such harsh conditions adversely influence the productivity of ewes. During pregnancy, inadequate nutrients usually result in intrauterine growth restriction and consequently morbidity and mortality of neonates [7]. The rates of abortion and stillbirths, as well as lamb mortality rate, increased when ewes were deprived of drinking water [8]. Limited feed resources can decrease reproductive efficiency to an extent dependent on the degree of nutritional stress [9]. Feed withdrawal during the luteal phase of the oestrous cycle increased serum progesterone level and induced endocrine changes that could perturb the oestrous cycle [10].

Investigations into the thermoregulatory and metabolic responses could yield scientific information required for assessment of stresses and adaptability under changing climatic conditions in the tropics. The knowledge generated could also be utilized in adopting measures and strategies to alleviate the negative impacts of environmental stresses. This study was conducted to assess the effects of nutritional stresses induced by water and food deprivation on physiological responses of desert ewes during tropical summer conditions.

MATERIALS AND METHODS

Location and Climate: This study was performed at the Department of Physiology at Shambat located at 15° 36' N, 32° 35' E and an altitude of 390 m above sea level. The daily maximum, minimum and mean ambient temperature (Ta) and relative humidity (RH) were obtained from the local meteorological station located about 500 meters from

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the experimental site. The daily mean Ta was 34.47 ±1.30ºC (Range: 42.16- 26.71ºC) and the mean RH was 25.86%. The computed temperature - humidity index [11] was 78.77.

Animals and Management: Twelve adult multiparous dry desert breed ewes aged 3.0 -3.5 years were used in the study. Animals were screened for general health and were individually housed in shaded pens under natural photoperiod. The pens were provided with appropriate facilities for feeding and watering. Animals were offered Lucerne hay, *Medicago sativa* (CP:17.3%; ME: 8.41 MJ/kg) and clean tap water *ad libitum*.

Experimental Procedure: Animals were kept for an adaptation period of 7 days in the pens and were offered feed and water *ad libitum*. Then the animals were assigned randomly to three groups of 4 each. Group A served as control (CTRL) and was allowed lucerne hay and tap water *ad libitum*, group B was allowed free°°access to food and deprived of water (WD), while group C was deprived of food and water (FWD). This protocol was continued for 3 consecutive days. Thereafter, all experimental groups were allowed free access to food and water and the responses to realimentation were monitored for 3 days.

During the experimental period, the daily food and water intake was measured. The BW of ewes was determined at the end of the adaptation period, three days after imposing experimental treatments and three days after realimentation of treated groups. The rectal temperature (Tr), respiration rate (RR) and heart rate (HR) were measured daily at 8.00 a.m. and 2:00 p.m. Blood samples were collected from each ewe at 9:00 a.m. before imposing experimental treatments, after three days of imposing treatments and three days following realimentation.

Feed and Water Consumption: Each animal was supplied daily with 2.0 kg of Lucerne hay and 6.0 L of tap water. The feed was weighed on a digital balance while the drinking water was measured (When available), in a graduated bucket. The daily feed intake and water consumption of each animal were obtained by weighing the feed residue to the nearest 10 gm and measuring the water left by a graduated measuring cylinder to the nearest 20ml. Samples of Lucerne hay were collected and dried at 105°C in an oven to constant weight for determination of dry matter content. Loss of water due to evaporation was assessed by measuring the amount lost from an identical bucket kept beyond the reach of animals.

Measurement of Rectal Temperature (Tr), Respiration Rate (RR), Heart Rate (HR) and Body Weight (BW): The rectal temperature (Tr) of ewes was measured to the nearest 0.1ºC with certified clinical thermometer (Hartman, United Kingdom) inserted to a depth of approximately 8 cm. The thermometer was inserted for a minimum of 1 min before obtaining the reading. The RR (breaths/min) of animals was measured by visually counting the flank movements with the aid of a stop-watch; the value was taken for one minute of regular breathing. The HR (Beats/min) was measured using a stethoscope for counting heart sounds for one minute when the animal was standing quietly. During the experimental periods, animals were weighed to the nearest ±0.5 kg using a sling spring balance (Salter -England).

Blood Analysis: Blood samples were collected from animals by jugular venipuncture using 5ml disposable syringes. Immediately 1 ml was transferred to a test tube containing the anticoagulant (Na_2-EDTA). Sodium fluoride was added to inhibit the enzymatic reaction that influences glucose concentration [12]. The sample was centrifuged and plasma separated was used for glucose determination. 1 ml of blood was also transferred to another test tube containing the anticoagulant, the sample was used for measurement of haematological indices. The rest of the blood sample was allowed to say for 2 hrs at room temperature and then centrifuged (Hettich, Germany). Haemolysis-free serum was harvested and transferred to plastic vials and frozen at -20°C.

Haematological Parameters: The PCV was determined using a micro-haematocrit centrifuge (Hettich -Germany). The Hb concentration was determined using a kit (Spinreact-haemoglobin-Drabkin's kit) based on the standard method Baker and Silverton [13].

Blood Metabolites: Plasma glucose concentration was determined by the enzymatic colorimetric method Trinder [14] using a kit (Spinreact S. A.-Spain). The concentration of serum total lipids was determined according to the method described by Stein [15]. The concentration of creatinine was determined according to a colorimetric method Haeckel [16].

Serum Sodium (Na) and Osmolality: Serum sodium (Na) was determined by the flame photometer (Jenway -PFP7, England) using the technique described by Wootton [17]. The osmolality of serum was determined by freezing point depression utilizing a cryoscopic osmometer (Osmomat 030D-10823, Germany).

Serum Cortisol: The concentration of serum cortisol was determined using Enzme Radioimmunoassay (RIA) Microwell Method (RK-240m -China). The absorbance was read using a gamma counter (Oakfield, UK).

Statistical Analysis: The data are presented as mean ± SD. The data were analyzed by analysis of variance (ANOVA) using General Linear Models (GLM) procedure of SAS version [18]. This procedure was used to assess the effects of feed and water deprivation and realimentation on the parameters investigated.

RESULTS

Feed Intake: Table 1 shows that in the water deprived group (WD), the feed intake was significantly decreased ($P \leq 0.01$) compared with the CTRL. In WD group, the feed intake was significantly decreased in days 1 and 2 ($P \leq 0.01$). Following realimentation, in the first day, the feed intake was significantly ($P \leq 0.001$) lower in WD and FWD group compared with CTRL.

Water Intake: Table 2 indicates that the water intake after 3 days of WD and FWD was significantly higher ($P \leq 0.001$) compared to their normal control values. In the first day following realimentation, water intake was significantly ($P \leq 0.001$) higher in WD and FWD groups compared with the CTRL group value.

Body Weight (BW): Table 3 shows the results of the effects of water and feed deprivation in ewes on BW. On the third day, compared to the respective normal control values, the BW decreased significantly in WD group ($P \leq 0.01$) and FWD group ($P \leq 0.05$) accounting for 11.3 and 15.9% of their mean initial BW, respectively. On the third day, the treated groups had significantly ($P \leq 0.05$) lower BW compared to the CTRL group. The ewes regained all the BW loss within 3 days following free access to feed and water at the end of deprivation period.

Rectal Temperature (Tr): Table 4 shows that for the CTRL group, there were no significant changes in Tr values measured at 8.00 a.m. and also for values measured at 2.00 p.m. For the WD group, the 8.00 a.m. value of Tr was significantly ($P \leq 0.05$) higher on day 3. However, the 2.00 p.m. value was significantly ($P \leq 0.05$) higher on day 3. There was a significant ($P \leq 0.01$) diurnal increase in Tr in day 3. For the FWD group, the 8.00 a.m. value of Tr was significantly ($P \leq 0.05$) lower on days 1 and 3. However, the 2.00 p.m. value of Tr was slightly higher in day 3 compared to day 1. For this group, there was significant ($P \leq 0.05$) diurnal increase in Tr in days 1 and 3. When treated groups (WD and FWD) were compared with the CTRL group, it was evident that the two groups had significantly ($P \leq 0.01$) higher Tr value at 2.00 p.m. in day 3. However, Tr was higher for WD compared to FWD.

Respiration Rate (RR): Table 5 shows the results of the effects of water and food deprivation on RR. For CTRL group, there was a significant ($P \leq 0.05$) diurnal increase in RR, in days 1 and 3. For the WD group, compared to the 8.00 a.m. control values, there was significant ($P \leq 0.05$) decrease on the third day of water deprivation. However, there was no significant change in RR values measured at 2.00 p.m. The diurnal change in RR was more pronounced in day 3 compared to days 1 of water deprivation. For the FWD group, the 8.00 am values indicated that there was significant ($P \leq 0.05$) decrease in RR in the third day. Also the RR value at 2.00 pm decreased significantly ($P \leq 0.05$) between days 1 and 3 of deprivation. The diurnal change in RR was significant ($P \leq 0.05$) only in day 3 of deprivation. When WD and FWD groups were compared to the control (CTRL) group, the former had significantly lower values of RR at 2.00 pm in day 1 ($P \leq 0.05$) and in day 3 ($P \leq 0.01$).

Heart Rate (HR): The data in Table 6 indicate that for the CTR group, there was no significant change in HR during the experimental period. For WD group, the HR was significantly ($P \leq 0.05$) lower only at 8.00 am on day 3 compared to its control value. For FWD group, HR was significantly ($P \leq 0.05$) higher at 8.00 am and 2.00 pm on days 1 and 3 of deprivation of food and water. When comparing the treated groups (WD and FWD) to the control group (CTRL), it is evident that the HR was significantly ($P \leq 0.05$) higher with FWD at 8.00 am and at 2.00 pm on day 3.

Packed Cells Volume (PCV): Table 7 shows the results of the effects of water and food deprivation on PCV. The PCV level was significantly ($P \leq 0.05$) higher with WD and FWD when compared with control group on day 3 of the deprivation period.

Haemoglobin (Hb): Table 8 indicates that for the CTRL group, there was no significant change in Hb concentration during the experimental period. For WD group, Hb concentration was higher on the third day of water deprivation. Also it was significantly ($P \leq 0.01$) lower compared to control values on realimentation.

Table 1: Effect of experimental treatments on feed intake (kg/day) of desert ewes. (CTRL: control; WD: water deprivation; FWD: food and water deprivation)

		Treatment (days)			Realimentation (days)			
	Normal	1	2	3	1	2	3	*P* value
CTRL	^{A}1.26±0.18^{a}	^{A}1.32± 0.19^{a}	^{A}1.52± 0.36^{a}	^{A}1.34± 0.22^{a}	^{A}1.33± 0.12^{a}	^{A}1.28± 0.28^{a}	^{A}1.34± 0.63^{a}	0.51
WD	^{B}1.24±0.29^{a}	^{D}0.79± 0.10^{b}	^{D}0.17± 0.29^{b}	^{D}0.04± 0.14^{b}	^{C}1.08± 0.25^{b}	^{B}1.23± 0.14^{a}	^{A}1.33± 0.20^{a}	0.001
FWD	^{A}1.23±0.23^{a}	-	-	-	^{B}1.05±0.13^{b}	^{A}1.24±0.13^{a}	^{A}1.25±0.63^{a}	0.001
P value	0.23	0.01	0.01	0.03	0.01	0.44	0.31	

Mean values within the same row bearing different superscripts (Capital letter) are significantly different.

Mean values within the same column bearing different superscripts (Small letter) are significantly different

* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$, ^{ns}Not significant.

Table 2: Effect of experimental treatments on water intake (L/day) of desert ewes. (CTRL: Control; WD: Water deprivation; FWD: Food and water deprivation)

		Treatment (days)			Realimentation (days)		
	Normal	1	2	3	1	3	*P* value
CTRL	^{A}5.01± 0.12^{a}	^{A}5.34± 0.32	^{A}5.51± 0.10	^{A}5.15±1.50	^{A}5.13±1.25^{b}	^{A}5.21± 0.91^{a}	0.11
WD	^{B}5.32± 0.50^{a}	-	-	-	^{A}8.12± 1.50^{a}	^{B}4.79± 1.63^{a}	0.001
WFD	^{B}4.92±1.50^{a}	-	-	-	^{A}7.23± 0.50^{a}	^{B}5.22± 0.57^{a}	0.001
P value	0.63	-	-	-	0.001	0.22	

Mean values within the same row bearing different superscripts (capital letter) are significantly different.

Mean values within the same column bearing different superscripts (small letter) are significantly different.

** $p \leq 0.01$, *** $p \leq 0.001$, ^{ns}Not significant.

Table 3: Effect of experimental treatments on mean body weight (kg) of desert ewes. (CTRL: Control; WD: Water deprivation; FWD: Food and water deprivation)

		Treatment (days)		Realimentation (day)	
	Normal	1	3	3	*P* value
CTRL	^{A}24.12±1.70^{a}	^{A}24.25±1.5^{a}	^{A}24.92±1.45^{a}	^{A}25.15±1.5^{a}	0.43
WD	^{A}25.50±0.10^{a}	^{A}25.20±0.50^{a}	^{B}22.62±1.49^{ab}	^{A}26.12±0.16^{a}	0.01
FWD	^{A}25.87±0.28^{a}	^{A}25.25±0.25^{a}	^{B}21.75±0.50^{b}	^{A}25.76±0.25^{a}	0.02
P value	0.17	0.06	0.03	0.20	

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Mean values within the same column bearing different superscripts (small letter) are significantly different.

* $p \leq 0.05$, ** $p \leq 0.01$, ^{ns}Not significant.

Table 4: Effect of experimental treatments on rectal temperature, T_r (ºC) of desert ewes. (CTRL: Control; WD: Water deprivation; FWD: Food and water deprivation)

		Treatment					
		(day 1)		(day 3)		Realimentation (day 3)	
	Normal 8:00 a.m.	8:00 a.m.	2:00 p.m.	8:00 a.m.	2:00 p.m.	8:00 a.m.	*P* value
CTRL	^{A}38.53±0.11^{a}	^{A}38.51±0.20^{a}	^{A}38.85±0.34^{a}	^{A}38.32±0.15^{a}	^{A}38.42±0.10^{ab}	^{A}38.51±0.32^{s}	0.61
WD	^{B}38.41±0.15^{a}	^{B}38.21±0.34^{a}	^{A}38.60±0.34^{a}	^{A}38.90±0.46^{a}	^{A}39.52±0.62^{a}	^{B}38.62±0.59^{a}	0.02
FWD	^{A}38.90±0.33^{a}	^{B}38.53±0.22^{a}	^{A}38.70±0.17^{a}	^{B}38.51±0.22^{a}	^{A}39.21±0.70^{a}	^{B}38.20±0.40^{a}	0.03
P value	0.29	0.56	0.61	0.21	0.01	0.15	

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Mean values within the same column bearing different superscripts (small letter) are significantly different.

* $p \leq 0.05$, * * $p \leq 0.01$, ^{ns} Not significant.

Table 5: Effects of experimental treatments on respiration rate, RR (breaths/min) of desert ewes (CTRL: Control; WD: Water deprivation; FWD: Food and water deprivation)

		Treatment					
		(day 1)		(day 3)		Realimentation (day 3)	
	Normal 8:00 a.m.	8:00 a.m.	2:00 p.m.	8:00 a.m.	2:00 p.m.	8:00 a.m.	*P* value
CTRL	$^{B}30.42\pm2.30^{a}$	$^{B}33.44\pm2.30^{a}$	$^{A}58.11\pm2.30^{a}$	$^{B}33.23\pm2.30^{a}$	$^{A}57.24\pm1.90^{a}$	$^{B}31.03\pm2.30^{a}$	0.02
WD	$^{B}32.40\pm2.30^{a}$	$^{B}33.20\pm2.30^{a}$	$^{A}37.50\pm2.30^{b}$	$^{C}28.51\pm2.30^{b}$	$^{A}38.53\pm2.30^{b}$	$^{B}31.51\pm3.40^{a}$	0.04
FWD	$^{A}33.51\pm3.30^{a}$	$^{A}32.43\pm5.30^{a}$	$^{A}35.52\pm2.30^{b}$	$^{C}25.62\pm4.30^{b}$	$^{B}30.40\pm7.30^{c}$	$^{A}33.10\pm3.20^{a}$	0.05
P value	0.95	0.21	0.02	0.03	0.01	0.64	

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Mean values within the same column bearing different superscripts (small letter) are significantly different.
*$p\leq0.05$, ** $p\leq0.01$, ^{ns} Not significant.

Table 6: Effect of experimental treatments on heart rate, HR (beats/min) of desert ewes. (CTRL: Control; WD: Water deprivation; FWD: Food and water deprivation)

		Treatment					
		(day 1)		(day 3)		Realimentation (day 3)	
	Normal 8.00 a.m.	8.00 a.m.	2.00 p.m.	8.00 a.m.	2.00 p.m.	8.00 a.m.	*P* value
CTRL	$^{A}56.4\pm5.6^{a}$	$^{A}55.5\pm2.5^{a}$	$^{A}56.4\pm0.7^{a}$	$^{A}58.4\pm5.6^{b}$	$^{A}56.4\pm0.4^{b}$	$^{A}56.5\pm2.5^{a}$	0.17
WD	$^{A}57.5\pm3.7^{a}$	$^{A}55.4\pm3.2^{a}$	$^{A}58.4\pm3.8^{a}$	$^{A}56.4\pm5.^{b}$	$^{A}56.1\pm0.3^{b}$	$^{A}57.4\pm2.0^{a}$	0.02
FWD	$^{B}55.4\pm2.0^{a}$	$^{A}62.7\pm1.5^{a}$	$^{A}64.4\pm3.2^{a}$	$^{A}68.4\pm0.5^{a}$	$^{A}66.4\pm0.6^{a}$	$^{B}57.5\pm5.6^{a}$	0.03
P value	0.69	0.41	0.21	0.05	0.02	0.13	

Mean values within the same row bearing different superscripts (capital letter) are significantly different.
Mean values within the same column bearing different superscripts (small letter) are significantly different.
* $p\leq0.05$, ^{ns} Not significant

Table 7: Effect of experimental treatments on packed cell volume, PCV (%) of desert ewes. (CTRL: Control; WD: Water deprivation; FWD: Food and water deprivation)

		Treatment (days)		Realimentation (days)	
	Normal	1	3	3	*P* value
CTRL	$^{A}26.51\pm2.82^{a}$	$^{A}26.50\pm2.30^{a}$	$^{A}27.70\pm2.52^{b}$	$^{A}27.25\pm0.5^{a}$	0.08
WD	$^{A}27.25\pm4.57^{a}$	$^{A}27.51\pm3.46^{a}$	$^{A}29.52\pm0.57^{a}$	$^{A}25.20\pm0.95^{a}$	0.56
FWG	$^{A}27.70\pm3.77^{a}$	$^{A}28.50\pm2.82^{a}$	$^{A}30.50\pm2.70^{a}$	$^{A}25.51\pm2.51^{a}$	0.24
P value	0.80	0.63	0.03	0.20	

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Mean values within the same column bearing different superscripts (small letter) are significantly different.
* $p\leq0.05$, ^{ns} Not significant.

Table 8: Effect of experimental treatments on haemoglobin concentration, Hb (g/dL) of desert ewes. (CTRL: Control;WD: Water deprivation; FWD: Food and water deprivation)

		Treatment (days)		Realimentation (days)	
	Normal	1	3	3	*P* value
CTRL	$^{A}10.37\pm1.28^{a}$	$^{A}9.92\pm1.18^{a}$	$^{A}10.02\pm0.25^{b}$	$^{A}9.60\pm1.81^{a}$	0.07
WD	$^{A}11.17\pm1.72^{a}$	$^{A}11.05\pm0.28^{a}$	$^{A}13.50\pm0.70^{a}$	$^{B}10.37\pm1.28^{a}$	0.01
FWD	$^{AB}11.10\pm0.28^{a}$	$^{B}10.13\pm0.28^{a}$	$^{A}13.75\pm1.85^{a}$	$^{AB}11.37\pm1.28^{a}$	0.03
P value	0.06	0.24	0.02	0.16	

Mean values within the same row bearing different superscripts (capital letter) are significantly different.
Mean values within the same column bearing different superscripts (small letter) are significantly different.
* $p\leq0.05$, ** $p\leq0.01$, ^{ns} Not significant.

Table 9: Effect of experimental treatments on plasma glucose level (mg/dL) of desert ewes (CTRL: Control; WD: Water deprivation; FWD: Food and water deprivation)

		Treatment (days)		Realimentation (days)	
	Normal	1	3	3	*P* value
CTRL	^{A}53.07± 0.18^{a}	^{A}55.67± 2.01^{a}	^{A}56.50± 2.88^{b}	^{A}57.47± 0.14^{a}	0.08
WD	^{B}54.01±2.01^{a}	^{B}58.30±2.40^{a}	^{A}68.80±1.10^{a}	^{B}59.60±2.31^{a}	0.01
FWD	^{B}55.60±0.68^{a}	^{A}60.60±1.14^{a}	^{A}65.52±1.95^{a}	^{A}60.52±1.95^{a}	0.02
P value	0.25	0.79	0.01	0.57	

Mean values within the same row bearing different superscripts (Capital letter) are significantly different.

Mean values within the same column bearing different superscripts (Small letter) are significantly different

** $p \leq 0.01$, * $p \leq 0.05$, ^{ns} Not significant.

Table 10: Effect of experimental treatments on serum sodium, Na concentration (MEq/L) of desert ewes. (CTRL: Control; WD: Water deprivation; FWD: Food and water deprivation)

		Treatment (days)		Realimentation (days)	
	Normal	1	3	3	*P* value
CTRL	^{A}134.02±0.35^{a}	^{A}134.25±4.71^{b}	^{A}133.12±1.41^{b}	^{A}136.01±1.41^{a}	0.07
WD	^{A}134.25±4.03^{a}	^{A}135.05±3.41^{b}	^{A}135.25±0.95^{ab}	^{A}133.25±2.87^{a}	0.33
FWD	^{B}132.25±0.34^{a}	^{A}138.50±1.05^{a}	^{A}138.82±1.63^{a}	^{B}132.50±2.38^{a}	0.02
P value	0.14	0.04	0.01	0.23	

Mean values within the same row bearing different superscripts (capital letter) are significantly different.

Mean values within the same column bearing different superscripts (small letter) are significantly different.

* $p \leq 0.05$, ** $p \leq 0.01$, ^{ns}Not significant.

Table 11: Effect of experimental treatments on serum total lipids concentration (mg/dL) of desert ewes. (CTRL: Control; WD: Water deprivation; FWD: Food and water deprivation)

		Treatment (days)		Realimentation (days)	
	Normal	1	3	3	*P* value
CTRL	^{A}130.98±0.54^{a}	^{A}131.27±1.53^{a}	^{A}131.87±0.56^{b}	^{A}130.67±o.82^{a}	0.24
WD	^{B}134.72±1.13^{a}	^{B}132.60±1.10^{a}	^{A}139.52±0.87^{ab}	^{C}131.92±0.92^{a}	0.01
FWD	^{B}135.95±1.51^{a}	^{C}130.98±0.62^{a}	^{A}141.12±0.66^{a}	^{C}132.92±0.51^{a}	0.02
P value	0.52	0.13	0.04	0.24	

Mean values within the same row bearing different superscripts (capital letter) are significantly different.

Mean values within the same column bearing different superscripts (small letter) are significantly differe

* $p \leq 0.05$, ** $p \leq 0.01$, ^{ns} Not significant.

Table 12: Effect of experimental treatments on serum creatinine concentration (mg/dL) of desert ewes (CTRL: Control; WD: Water deprivation; FWD: Food and water deprivation)

		Treatment (days)		Realimentation (day)	
	Normal	1	3	3	*P* value
CTRL	^{A}0.90±0.18^{a}	^{A}1.02±0.33^{a}	^{A}0.95±0.12^{b}	^{A}1.35±0.42^{a}	0.07
WD	^{A}0.91±0.20^{a}	^{A}1.40±0.08^{a}	^{A}1.30±0.21^{a}	^{A}1.27±0.25^{a}	0.19
FWD	^{A}1.40±0.68^{a}	^{A}1.07±0.28^{a}	^{A}1.35±0.23^{a}	^{A}1.22±0.40^{a}	0.06
P value	0.79	0.14	0.03	0.89	

Mean values within the same row bearing different superscripts (capital letter) are significantly different.

Mean values within the same column bearing different superscripts (small letter) are significantly different

*$p \leq 0.05$, ^{ns} Not significant.

Table 13: Effect of experimental treatments on serum osmolality (mOsmol/kg) of desert ewes. (CTRL: Control; WD: Water deprivation; FWD: Food and water deprivation)

		Treatment (days)		Realimentation (days)		
	Normal	1	3	3	F value	*P* value
CTRL	$^{A}285.75\pm1.08^{a}$	$^{A}281.75\pm2.04^{a}$	$^{A}288.00\pm3.53^{b}$	$^{A}288.00\pm3.53^{a}$	0.35^{ns}	1.00
WD	$^{B}286.25\pm2.79^{a}$	$^{B}289.25\pm1.44^{a}$	$^{A}299.5\pm1.62^{a}$	$^{B}285.25\pm5.21^{a}$	22.23^{**}	0.01
FWD	$^{B}282.11\pm1.14^{a}$	$^{B}284.10\pm5.33^{a}$	$^{A}302.5\pm0.61^{a}$	$^{A}292.75\pm8.34^{a}$	30.05^{**}	0.01
F value	0.18^{ns}	1.02^{ns}	20.59^{**}	0.05^{ns}		
P value	0.68	0.34	0.01	0.83		

Mean values within the same row bearing different superscripts (capital letter) are significantly different.

Mean values within the same column bearing different superscripts (small letter) are significantly different.

** $p\leq0.01$, ^{ns}Not significant.

Table 14: Effect of experimental treatments on serum cortisol level (nmol/L) of desert ewes. (CTRL: Control; WD: Water deprivation; FWD) Food and water deprivation)

		Treatment (days)		Realimentation (days)		
	Normal	1	3	3	F value	*P* value
CTRL	$^{A}48.95\pm2.09^{a}$	$^{A}46.72\pm2.88^{a}$	$^{A}44.15\pm0.27^{b}$	$^{A}45.52\pm2.92^{a}$	0.72^{ns}	0.49
WD	$^{B}45.15\pm0.43^{a}$	$^{A}48.82\pm1.61^{a}$	$^{A}55.92\pm2.57^{a}$	$^{B}46.65\pm1.58^{a}$	8.72^{**}	0.01
FWD	$^{B}46.27\pm1.87^{a}$	$^{B}45.92\pm0.60^{a}$	$^{A}52.92\pm3.67^{a}$	$^{B}48.62\pm2.80^{a}$	3.07^{*}	0.02
F value	1.89^{ns}	3.42^{ns}	4.82^{*}	2.17^{ns}		
P value	0.21	0.07	0.04	0.17		

Mean values within the same row bearing different superscripts (capital letter) are significantly different.

Mean values within the same column bearing different superscripts.

* $p\leq0.05$, ** $p\leq0.01$, ^{ns} Not significant

For FWD group, Hb concentration was significantly ($P\leq0.05$) higher compared to the control group on the third day of treatment and it decreased significantly ($P\leq0.05$) on realimentation. When comparing the WD and FWD groups with CTRL group, it is evident that Hb concentration was significantly ($P\leq0.05$) higher with both treatments.

Plasma Glucose: Table 9 shows that for WD group, the glucose level was significantly ($P\leq0.01$) higher on day 3 of water deprivation compared to the CTRL. For FWD group, the glucose level was significantly ($P\leq0.05$) higher on days 1 and 3. The treated groups had significantly ($P\leq0.01$) higher glucose level compared to the CTRL group on day 3 of the treatments.

Serum Sodium (Na): Table 10 shows the effects of water and food deprivation on serum Na level. For WD group, there was no significant difference in serum Na level during the course of the experiment. For FWD group, there was significant ($P\leq0.05$) increase in Na level in days 1and 3. When comparing treated groups with control group, it is evident that both treated groups had significantly ($P\leq0.01$) higher Na level in day 3.

Serum Total Lipids: Table 11 shows that for WD group, the total lipid level was significantly ($P\leq0.01$) higher on the third day of treatment. For FWD group, there was significant ($P\leq0.05$) increase in serum total lipids level on the third day of treatment. When comparing treated groups with CTRL group, it is evident that both groups had significantly ($P\leq0.05$) higher serum total lipids concentration on the third day of treatment.

Serum Creatinine: Table 12 shows the effects of water and food deprivation on serum creatinine concentration. When comparing treated groups with CTRL group, it is evident that both treated groups had significantly ($P\leq0.05$) higher creatinine level on the third day of treatments.

Serum Osmolality: Table 13 indicates that for WD group, there was a significantly ($P\leq0.01$) higher osmolality in the third day of treatment and the normal value was recovered on day 3 of realimentation. For WFD group, there was significant ($P\leq0.01$) increase in serum osmolality on day 3 of treatment and the normal was not recovered on the third day of realimentation. When comparing treated groups with CTRL group, it is evident that both treated groups had significantly ($P\leq0.01$) higher serum osmolality on the third day of treatment.

Serum Cortisol: Table 14 shows the effects of water and food deprivation on serum cortisol level. For WD group, there was significantly ($P \leq 0.01$) higher serum cortisol level on the third day of treatment and the normal value was recovered on day 3 of realimentation. For FWD group, there was significant ($P \leq 0.05$) increase in serum cortisol level on the third day of treatment and it decreased to normal value on day 3 of realimentation. When comparing treated groups with control group, it is evident that both treated groups had significantly ($P \leq 0.05$) higher serum cortisol level on day 3.

DISCUSSION

The results indicate that in WD ewes, the feed intake on the third day was only 3% of the normal level of intake (Table 1). This response could be associated with the observed increase in serum osmolality (Table 13). Water deprivation induced increase in serum osmolality causes inhibition of ventromedial hypothalamic region of feed intake [19]. Also hypertonicity of rumen contents has been proposed to exert a major control of feed intake in ruminants [20]. The decrease in feed intake could be considered as an adaptation mechanism to reduce water expenditure associated with feed utilization and heat dissipation in sheep [21]. The reduction in feed intake during water deprivation can be viewed as an adaptive measure employed by animals inhabiting desert and arid areas for conserving body water [22]. A water medium is needed for both the physical softening and the biochemical digestion of feed [23]. An adequate supply of water could therefore aid the breakdown of food and hence facilitate the fermentation and digestion processes. Furthermore, the numbers of rumen bacteria and protozoa tend to decrease following water deprivation. The decrease in food intake of water deprived ewes agrees with previous studies in sheep [24].

Following rehydration, the feed intake increased significantly with WD group than FWD compared with the control. During realimenation in day 1, the mean water intake was higher in WD group than FWD group compared with CTRL (Table 3.3). Water intake depends on the degree of BW loss as well as the volume of the rumen which could accommodate the volume of water ingested on rehydration. The rumen is known to be a water reservoir that can store a large volume of water ingested at the end of dehydration period [25, 26]. Similarly, previous studies reported that dehydrated sheep breeds adapted to arid environments take large amounts of water rapidly and satisfy their needs when rehydrated [27, 28]. Dorper sheep were able to restore the entire BW loss immediately following watering that terminated 4 days of dehydration [29].

The BW of ewes decreased by 11.3% with water deprivation and by 15.9% with food and water deprivation (Table 3). Loss of BW associated with WD and FWD can be attributed to reduction in food and water intakes together with loss of total body water. However, quantitative measurements indicated that BW loss was attributed mainly to reduction in total body water in water deprived sheep [29-31]. A similar trend was obtained in sheep watered every 3 days [32] and in water restricted desert rams, loss in BW amounted to 14% in 3 days [33]. The ewes regained all of their BW loss within 3 days following free access to water and feed after realimintation.

The results indicate that the rectal temperature (Tr) was significantly higher with WD than FWD (Table 4). Hyperthermia may be considered as a mechanism that allows animals inhabiting extremely hot-arid regions to avoid excessive water expenditure by evaporative cooling during the hot part of the day before dissipating heat at night time by sensible avenues of heat loss. This response is attributed to the changes in water balance and metabolism that influenced body core temperature. Water deprivation reduced thermoregulatory evaporation and therefore allowed body temperature to be elevated presumably to enforce the water conservation mechanism [34]. Dehdration-induced hyperthermia is an upward shift of body temperature, associated with water deficit [35].

The respiration rate (RR) of ewes was significantly lower with FWD than WD in the afternoon in day 1 and in the morning and afternoon in day 3 when compared with CTRL (Table 5). The decline in RR is clearly related to decrease in metabolic rate and reduced requirement for evaporative cooling. Respiratory water loss is one of the avenues which has been implicated in water conservation mechanism during water shortage [36]. Selective brain cooling may allow sheep to conserve body water during water deprivation with heat exposure [31]. This pattern indicates that depressed metabolism may help desert sheep to maintain body water through reduction of pulmonary ventilation. Lowering of the metabolic activity is usually associated with reduction in oxygen requirements and hence ventilation and respiration are reduced [37]. A similar trend was noted with water restriction in desert rams [33].

The heart rate (HR) was decreased significantly in WD group and increased with FWD (Table 6). The increase in peripheral blood flow during FWD requires compensatory actions to avoid a fall in arterial blood pressure that results from the breakdown of cardiovascular homeostasis during stress. The HR was shown to be influenced by metabolizable energy intake in cattle [38] under most circumstances the HR was considered to be correlated with the rate of oxygen consumption and hence metabolic rate in animals [39]. In cattle, a decrease in ruminoreticular fill may result in a reflex slowing of HR, due mainly to increase in parasympathetic tone [40]. However, alterations in metabolic activity and body temperature may influence HR in fasted animals.

The results indicate that the increase in PCV and Hb concentration was higher with FWD than WD when compared with control (Table 7). The increase in PCV and Hb is related mainly to haemoconcentration as a consequence of decrease in plasma volume. Blood as well as plasma volumes were reduced during water lack in goats [36, 41]. An increase in PCV during water deprivation was reported previously for sheep [24, 30]. Water deprivation caused an increase in Hb level of Awassi sheep [42, 43] and Merino sheep [44]. In contrast, Hb concentration was significantly lower with water deprivation in Yankasa sheep [45, 46].

The increase in plasma glucose level with WD and FWD compared with the CTRL group (Table 9) could be associated with nutritional stress. The plasma glucose level is affected by stress hormones; cortisol facilitates the conversion of protein to glucose (Gluconeogenesis). However, in camels, water deprivation induced hyperglycaemia was explained partially by a significant decrease in plasma insulin [47]. The reported increase in glucose level with feed and water deprivation in desert sheep could be related to insulin deficiency [10]. A similar increase in glucose level following water restriction was reported in Marwari sheep [37]. However, a reduction in plasma glucose level during water restriction was previously reported in desert rams [33] and in Barki sheep [48].

The significant increase in serum Na concentration with WD and FWD (Table 10) indicates that water deprived animals could not dilute the plasma Na and excrete it by increasing the GFR. Nevertheless, dehydrated sheep may develop natriuresis [44, 49, 50]. Sheep water-deprived for 3 days had higher plasma Na level compared with sheep that had access to water [51]. In contrast, serum Na was decreased in sheep during feed deprivation [24]. Water deprivation was associated with reduction in feed intake and negative Na balance [49]. This resulted in water deprived animals becoming Na depleted as well as water deficient. Previous studies indicated that decrease in feed intake was not the cause of the natriuresis in water deprived sheep [52].

Serum concentration of total lipids increased significantly with WD and FWD compared with the CTRL group (Table 11). The increase in total lipids could be associated with fat mobilization induced by feed restriction. Fat mobilization was reported previously in energy deficient sheep [53, 54]. The observed increase in total lipids may also be related to the increase in serum cortisol which mobilizes lipids from adipose tissue and increases ketone-body formation in the liver [55, 56]. The increase in total lipids is in agreement with Gaal *et al*. [57] who reported that three-day fasting of sheep produced an increase in plasma levels of total lipids and total cholesterol.

The serum creatinine level increased significantly in WD and FWD compared with control group (Table 12). Increased creatinine levels during dehydration could be related to decrease in urine output. The reported increase in cortisol level (Table 17), through muscle wasting, could be implicated in increased serum creatinine during dehydration [37]. In Awassi sheep, serum creatinine increased with water deprivation for 5 days [42]. However, previous studies [58] reported a moderate increase in serum creatinine level following 3 days of water restriction in sheep. Swenson [59] indicated that increased creatinine concentration may be associated with dehydration. Therefore, the rise in serum creatinine could be related to the maintenance of renal function at a lower level, which consequently reduces the clearance rate of serum creatinine [28, 60].

The significant increase in serum osmolality with both FWD and WD (Table 13) is clearly associated with haemoconcentration and increase in plasma colloid osmotic pressure. An increase in serum osmolality was observed with water restriction in sheep [31, 42, 61, 62]. A similar pattern has been reported in sheep watered every 24, 48, 72 hr [33, 45]. The observed rise in plasma osmolality during water restriction may contribute to the maintenance of plasma volume by enhancing water movement from the interstitial fluid into the vascular system [28, 42].

The results indicate that serum cortisol level increased significantly with WD than FWD when compared with CTRL (Table 14). The nutritional stress of fasting may lead to stimulation of adrenal cortical activity. However, cortisol has a short-term response after which it returns to normal levels [33, 63]. Water deprivation induced an increase in plasma cortisol level after 60 hours in sheep [6]. Blair-West *et al*. [64] demonstrated a significant increase in plasma cortisol level in sheep after 9 days water restriction. Kataria and Kataria [37] reported that water restricted sheep increased serum cortisol level. Previous studies [51, 65] indicated that water deprivation is a stressor that can activate the hypothalamus-pituitary-adrenal axis (HPA) and elevate plasma cortisol. However, studies on desert rams reported progressive depression of the morning values of plasma cortisol level during water restriction [33].

CONCLUSION

The results indicate that both water deprivation and combined food and water deprivation disturbed physiologically established homeostasis in desert ewes. The patterns of thermoregulation and blood constituents responses indicate that the combined effect of water and feed deprivation was more pronounced. The ewes could re-establish normal levels of most of the variables monitored within three days of realimentation, which indicates possession of capacity of adaptation to nutritional stresses.

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