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Effect of Water Deprivation and Drinking Saline Water on Performance, Blood Metabolites, Nutrient Digestibility, and Rumen Parameters in Baluchi Lambs

Research Article

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ABSTRACT

This study was conducted to evaluate the effects of water deprivation and drinking saline water on the performance, blood metabolites, and nutrient digestibility of Baluchi lambs. To this aim, 20 lambs, 170 ± 5 days of age, and with 31 ± 2.8 kg bodyweight, were assigned to four groups according to a completely randomized design with a 2 × 2 factorial arrangement of treatments: 1) free access to water during the day with a low total dissolved solids (TDS) concentration, 2) access to half their pervious *ad libitum* water intake with a low TDS concentration, 3) free access to water during the day with a high TDS concentration and 4) access to half their pervious *ad libitum* water intake with high TDS concentration and the experiment lasted 42 days. Results showed that the restricted access to water led to significant effect on dry-matter intake, average daily gain, water consumption and ratio of water consumption to feed intake, aldosterone hormone, serum blood urea nitrogen (BUN), cholesterol, triglyceride, packed cell volume (PCV) concentration, serum chloride, potassium and sodium, rumen pH, digestibility of acid detergent fiber (ADF), neutral detergent fiber (NDF), crude protein (CP) and organic matter, fecal output and urine exertion ($P<0.05$). Also drinking saline water had significant effects on dry-matter intake, average daily gain, water consumption and ratio of water consumption to feed intake, serum sodium and urine exertion ($P<0.05$), while either water restriction nor saline water had any significant effect on other measured parameters of experimental-group lambs ($P>0.05$). The results indicated that lambs can subsist under water deprivation and drinking saline water for at least 28 days without harmful effects.

KEY WORDS Baluchi lamb, blood parameter, nutrient digestibility, saline water, water deprivation.

INTRODUCTION

As a result of climate change around the world, the incidence of drought will increase in many areas, particularly in arid and semi-arid regions, consequently, nearly 30% of the global population is expected to be suffering from water shortage in 2025 according to UNECO prospects. The problem of water scarcity is further complicated with increasing water salinity, resulting in reduced rain fall and water salinity, resulting in reduced rain fall and increased water with drawls from wells (Atwa, 1979). Chiy and Phillips (1995) reported that approximately one third of the Earth's land surface is affected by salinity, sodality, and aridity in various combinations. However, even though drinking water is a critical nutrient and its quantity and quality have a significant impact on animal performance, research on drinking water has been neglected. One of the most effective factors in quality issue which determines the

suitability of water for livestock is the concentration of total dissolved saline in the drinking water (Ray, 1989).

The presence of high concentrations of some inorganic ions, e.g. Mg^{2+}, Ca^{2+}, Na^{2+}, Cl^{-}, HCO_3^{-} and SO_4^{2-} in livestock drinking water has harmful effects such as the imbalances of some mineral in the body, poor performance, illness, or even death (Kellems and Chureh, 2002; NRC, 2007).

Several reports are available on water quality issue, showing that water deprivation leads to extensive variations in physiological parameters, including weight loss, blood metabolites, hematic parameters, and feed intake (Alamer, 2010; Casamassima *et al*. 2008; Qinisaa *et al*. 2011; Mpendulo *et al*. 2017).

Most of the time, these two problems (i.e. water restriction and salinity) act together and exacerbate the intensity of stress for grazing animals in arid and semi- arid regions. Sheep and goat breeds differ in dehydration tolerance and saline water.

Furthermore, breeds of ruminants which are well adapted to desert environment demonstrate a greater ability to ameliorate the stressful effect induced by water deprivation (Silanikove, 2000) and salty drinking water (Bell, 1995). The fat-tailed Baluchi sheep is an indigenous breed in the Middle East and one of the most populated breeds of sheep in Iran. This sheep well-known for adaptation to grazing in area where water supply is not enough.

However, little information is available about the level of combined effects of drinking saline water and water deprivation in this breed. Therefore, this project attempted to assess the effect of water deprivation and drinking saline water on performance, blood metabolites, nutrient digestibility, and rumen parameters in Baluchi lambs. The data obtained in this study may help shed light on the risks faced by famers who have to rear their sheep in arid and semi-arid areas.

MATERIALS AND METHODS

The experiment was conducted during June to July 2015 in the Center of Research of Small Ruminants, Ferdowsi University of Mashhad, Iran (CRSFUM) in semi-arid climatic conditions. The experimental protocols were reviewed and approved by the Animal Care Committee in the noted university.

Animals, treatments, experimental design, and housing

Twenty male, fat-tailed Baluchi lambs (170 ±5 days old and of 31 ± 2.8 kg body weight) in well health were randomly assigned to four groups according to a completely randomized design with a 2 × 2 factorial arrangement of treatments.

Experimental treatments consisted of free access to water during the day with a low total dissolved solids (TDS) concentration (400 mg/L) for group (1); access to half their pervious *ad libitum* water intake with a low TDS concentration (400 mg/L) in group (2); free access to water during the day with a high TDS concentration (8000 mg/L) in group (3); and access to half their pervious *ad libitum* water intake with a high TDS concentration (8000 mg/L) in group (4). All the studied lambs were kept in a closed barn and allocated to individual standard metabolic crates with metal grated floors which were designed for urine and feces collection.

Metabolic crates were composed with two pads: first, a steel pad with small holes for the collection of feces, and then a pad under the first one and designed for urine collection. The experiment lasted 42 days, including 14 days considered for adaptation to the environment and determining the amount of drinking water intake in a day for each lamb (to impose a 50% restriction on water intake), and 28 experiment days.

Diet, feed intake, water consumption, and water preparation

The experimental diet was formulated in order to fulfill the nutritional requirements of growing-finishing lambs according to NRC (2001). The diet was fed as a total mixed ration (TMR) with a 70:30 forage to concentrate ratio. It was weighed and offered twice daily *ad libitum* at 8:00 and 16:00, and the daily feed intake was measured before replenishment with fresh feed according to the difference between the amount of feed offered and the residue left. The same protocol was applied for measuring water consumption. Feed ingredient and composition are presented in Table 1.

In order to formulate the water for different treatments, it was routinely available for sheep in this farm containing 400 mg TDS/L. The water a high TDS was prepared daily by adding and mixing 650 g of sodium chloride, 13 g of calcium chloride, 128 g of magnesium sulfate, 80 g of sodium sulfate, and 32 g of sodium bicarbonate to every 100 L of water routinely to give the TDS content of 8000 mg TDS/L (Valtorta *et al*. 2007). The chemical composition of the water utilized for treatments is presented in Table 2.

Rectal temperature, respiration rate, and environmental temperature

Rectal temperature was monitored daily for the final 7 days of experiment between 7:00 and 7:30 using a digital rectal thermometer (AccuMed, TK-120, China). Respiration rate (RR) was individually measured by counting the rate of thoracic cage movement with a stop watch over a period of 1 min (Mengistu *et al*. 2007).

Table 1 Ingredients and chemical composition of experimental diet

Ingredients	**(% DM)**
Alfalfa hay	40
Wheat straw	5.0
Barley grain	30
Soybean meal	8.0
Wheat bran	15.0
Calcium carbonate	0.5
Vitamin-mineral mix[1]	0.7
Salt	0.3
Urea	0.5
Chemical composition (% DM)	
Dry matter (DM)	90.0
Metabolizable energy (ME)[2] (Mcal/kg of DM)	2.58
Crude protein (CP)	16.0
Neutral detergent fiber (NDF)	36.7
Non fibrous carbohydrates (NFC)[3]	40.0
Ether extract (EE)	2.7
Ca	0.9
P	0.6

[1] Contained (/kg of premix; DM basis): vitamin A: 330000 IU; vitamin D: 60000 IU; vitamin E: 1000 IU; Ca: 160 g; P: 85 g; Na: 63 g; Mg: 45 g; Zn: 2100 mg; Mn: 1500 mg; Cu: 535 mg; Se: 12 mg and I: 45 mg.
[2] ME calculated by NRC (2001).
[3] NFC calculated as: 100 − (CP+Ash+NDF+EE).

Table 2 Chemical composition of the water utilized during the trial, for treatments containing different amounts of total dissolved salts

Component (mg/L)	Low total dissolved solids (TDS) water (400 mg/L)	High total dissolved solids (TDS) water (8000 mg/L)
SO_4^{-2}	72	1464
CO_3^{-2}	9	160
Na^+	85	1790
Cl^-	72	1810
Ca^{2+}	36	490
Mg^{2+}	39	870

Environmental temperature and relative humidity were also recorded through the trial. During the experimental period, environmental temperature ranged between 34 and 37 ˚C while relative humidity was between 29 and 42.

Body weight, urine, feces, blood, and rumen sampling

Lambs were weighed after a 16 h fast before the morning feeding in the morning at the beginning and the end of the experimental period to determine the average daily gain (ADG), was also the total amount of feces (g/d) individually gathered and recorded daily for the final 7 days of experiment, the daily total volume of urine (mL/d) excretion individually collected using a calibrated cylinder.

Feeds and orts were sampled daily during the collection period and further composited. The composite samples of the TMR, feed refusal, and feces were dried in an oven, then ground to pass through a 1 mm screen, and stored for further analysis. Feed and feces samples were analyzed for dry matter (DM), ether extract (EE), crude protein (CP), and ash by standard procedures (AOAC, 1990). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined according to Van Soest *et al*. (1991).

In order to determine blood parameters, two blood samples per lamb were taken from jugular veins in the morning at the end of trial.

One sample was injected in a sterile lithium- heparin tube to determine blood hematology, including packed cell volume, hemoglobin, white blood cells (WBC), red blood cells (RBC), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) by automated hematology analyzer (Sysmex kx-21, Japan).

Another blood sample was collected in a (non-heparinized) tube and centrifuged at 3000 × g for 10 min, followed by separation of serum, and finally frozen at −20 ˚C for later analysis. Glucose, blood urea nitrogen, creatinine, cholesterol, triglyceride, total protein, albumin, globulin, insulin, aldosterone, serum aspartate aminotransferase (AST), alanine aminotransferase (ALT) and cortisol concentration were determined by an automated biochemical analyzer (Biotechnical, Targa 3000, Italy) using a commercial kit (Pars Azmoon Company, Iran). In addition, blood electrolytes including calcium, phosphorus, sodium, potassium, magnesium, and chlorine were assayed using an electrolyte analyzer (Diamond Diagnostics Smart Lyte, USA).

Rumen fluid samples were taken from animals by stomach tubes with vacuum pumps 2 h after the morning feeding at the end of trial. The pH values of the fluid samples were determined and recorded using a pH meter (Metrohm 691).

Approximately 100 mL of ruminal content was strained through four layers of cheesecloth. A subsample of 5 mL was combined with 5 mL of 0.2N HCl for NH_3-N analysis.

Another sample was put into a plastic bottle containing 1 mL of 0.25 g/mL metaphosphoric acid and 1 mL of 0.006 g/mL 2-ethylbutyric acid (internal standard) which was used for volatile fatty acid (VFA) analysis.

Ruminal subsamples were frozen at −20 ˚C until conductance laboratory analyses. After that, ruminal fluid samples were thawed and then centrifuged at 1200 × g for 10 min, than the supernatant fluid was analyzed for VFA by gas chromatography (Hewlett-Packard, Model 5890, Avondale, PA). The NH_3-N concentration of rumen fluid samples was analyzed by the procedure developed by Weatherburn (1967).

Statistical analysis

Data were analyzed by a completely randomized 2 × 2 factorial design using a general linear model (GLM) procedure (SAS, 2003).

$$Y_{ijk}= \mu + TDS_i + RES_j + (TDS+RES)_{ij} + E_{ijk}$$

Where:

Y_{ijk}: dependent variable.

μ: overall mean of the population.

TDS_i: effect of water TDS.

RES_j: effect of water restriction.

$(TDS+RES)_{ij}$: interaction between water TDS and water restriction.

E_{ijk}: unexplained residual element assumed to be independent and normally distributed.

For all statistical analyses, significance was declared at $P < 0.05$.

RESULTS AND DISCUSSION

The result of dry matter intake (DMI), average daily gain (ADG), and ratio of water consumption to dry matter intake are presented in Table 3. Overall, the DMI was significantly lower for lambs whose water consumption was restricted (805.29 g *vs*. 1360.19 g; P<0.05) and the same for groups with a high content of TDS in drinking water (975.24 g *vs*. 1190.24 g; P<0.05).

Moreover, ADG decreased (33.76 g *vs*. 106.92 g; P<0.05) as a result of restricting the drinking water, and similar results were observed by rising TDS in water consumption (84.56 g *vs*. 129.36 g; P<0.05).

The interaction of RES × TDS had no significant effect on DMI or ADG (P>0.05).

Furthermore, water consumption and ratio of water consumption to DMI were significantly lower in lambs to which water restriction was applied (2231.25 mL *vs*. 6346.69 mL; P<0.05) compared to groups that had free access to water (2.80 *vs*. 4.77; P<0.05).

On the other hand, water consumption and the ratio of water to DMI progressively increased in saline water treatments (4791.36 mL *vs*. 3786.58 mL; P<0.05) compared with well water treatments (4.52 g *vs*. 3.05 g; P<0.05).

The results showed that the RES × TDS interaction was significant with respect to water consumption and the ratio of water consumption to DMI (P<0.05), such that lambs in groups with restricted water plus a high TDS had a lower water consumption than those in other treatment groups (Table 3). Similarly, water/DMI was the lowest in lambs allocated to groups that consumed restricted water.

Rectal temperature increased by water restriction (39.73 ˚C *vs*. 39.63 ˚C), although this difference was non-significant (Table 4). The same was true about rising the content of TDS in water (39.71 ˚C *vs*. 39.65 ˚C). In addition, respiratory rate was reduced by water deprivation (42.13 min^{-1} *vs*. 42.75 min^{-1}) and consumption of saline water (42.25 min^{-1} *vs*. 42.63 min^{-1}).

Nevertheless, these differences were not significant (P>0.05). The interaction of RES × TDS had no significant effect on rectal temperature and respiratory rate in lambs (P>0.05). The effect of water restriction and water salinity on the pattern of insulin, aldosterone, and cortisol secretion is presented in Table 5.

The deprivation of water led to a liner decrease in the concentration of insulin (4.15 pmol/L *vs*. 4.19 pmol/L) and an increase in cortisol (1.37 mmol/L *vs*. 1.26 mmol/L). However, these variations were not statically significant (P>0.05). Moreover, insulin and cortisol serum concentration remained significantly unaffected (P>0.05) in lambs following the consumption saline water (Table 5).

Water deprivation and rising the amount of TDS elevated the concentration of aldosterone, but this difference was not significant (P>0.05) for salinity (2.84 mmol/L *vs*. 2.71 mmol/L), but it was statically significant for water restriction (3.08 mmol/L *vs*. 2.47 mmol/L; P<0.05). The interaction of water restriction and TDS of water had no significant effect (P>0.05) on insulin, aldosterone, and cortisol.

Table 6 demonstrates the effect of treatments on blood chemistry in experimental-group lambs. Overall, findings suggest that treatments with water restriction resulted in a higher serum glucose, creatinine, total protein, globulin, ALT, and AST, in comparison with the group which had free access to water. Nevertheless, this difference was not statically significant (P>0.05), similar to treatments with a high content of TDS in drinking water (P>0.05).

Table 3 The Effect of water deprivation and drinking saline water on feed and water intake and weight gain in experimental lambs

Variable	Treatment				SEM	P-value	
	Low TDS		High TDS				
	RES	FRE	RES	FRE		RES	FRE
Dry matter intake (DMI, g/day)	894.97	1485.51	715.60	1234.88	45.109	0.001	0.453
Average daily gain (kg)	46.84	129.36	20.69	84.45	6.344	0.000	0.165
Water intake (mL/day)	2275.00	5298.16	2187.50	7395.22	419.325	0.034	0.023
Water/DMI	2.55	3.55	3.05	5.99	0.278	0.000	0.004

TDS: total dissolved solids; RES: restrict to half *ad libitum* water intake and FRE: free access to water during the day.
SEM: standard error of the means.

Table 4 The Effect of water deprivation and drinking saline water on rectal temperature (RT) and respiration rate (RR) in experimental lambs

Variable	Treatments				SEM	P-value		
	Low TDS		High TDS					
	RES	FRE	RES	FRE		RES	TDS	RES × TDS
RT (ºC)	39.66	39.64	39.79	39.62	0.124	0.445	0.664	0.582
RR (min^{-1})	42.25	43.00	42.00	42.50	1.116	0.586	0.743	0.913

TDS: total dissolved solids; RES: restrict to half *ad libitum* water intake and FRE: free access to water during the day.
SEM: standard error of the means.

Table 5 The Effect of water deprivation and drinking saline water on plasma hormone of experimental lambs

Variable	Treatment				SEM	P-value		
	Low TDS		High TDS					
	RES	FRE	RES	FRE		RES	TDS	RES × TDS
Insulin (pmol/L)	4.20	4.15	4.18	4.14	0.230	0.870	0.954	0.962
Aldosterone (mmol/L)	3.02	2.41	3.15	2.52	0.207	0.013	0.551	0.925
Cortisol (mmol/L)	1.34	1.28	1.39	1.23	0.094	0.281	0.990	0.596

TDS: total dissolved solids; RES: restrict to half *ad libitum* water intake and FRE: free access to water during the day.
SEM: standard error of the means.

Table 6 The Effect of water deprivation and drinking saline water on blood parameters and liver enzymes of experimental lambs

Variable	Treatment				SEM	P-value		
	Low TDS		High TDS					
	RES	FRE	RES	FRE		RES	TDS	RES × TDS
Glucose (mg/dL)	66.75	64.50	66.85	63.75	1.775	0.378	0.312	0.731
Blood urea nitrogen (mg/dL)	42.50	40.25	42.75	42.00	0.586	0.025	0.114	0.225
Creatinine (mg/dL)	1.08	1.00	1.13	1.05	0.043	0.096	0.244	0.954
Cholesterol (mg/dL)	66.00	62.75	70.50	63.50	1.663	0.010	0.140	0.282
Triglyceride (mg/dL)	31.50	30.50	33.50	31.25	0.703	0.039	0.074	0.392
Total protein (mg/dL)	7.30	6.98	7.38	7.08	0.226	0.191	0.705	0.957
Albumin (g/dL)	3.85	3.70	3.90	3.80	0.092	0.201	0.433	0.791
Globulin (g/dL)	2.90	2.65	2.92	2.88	0.219	0.507	0.579	0.659
ALT (IU/L)	13.75	12.75	14.25	13.50	0.949	0.375	0.523	0.897
AST (IU/L)	69.25	65.50	70.00	67.75	3.601	0.421	0.684	0.839

TDS: total dissolved solids; RES: restrict to half *ad libitum* water intake; FRE: free access to water during the day; ALT: alanine aminotransferase and AST: aspartate aminotransferase.
SEM: standard error of the means.

Findings revealed that serum cholesterol and triglyceride tended to increase and were significantly higher in animals in restricted groups (68.25 mg/dL *vs*. 63.13 mg/dL) compared with groups which had free access to water (32.50 mg/dL *vs*. 30.88 mg/dL), the respect to cholesterol and triglyceride ($P<0.05$). Furthermore, increasing concentration of TDS elevated serum cholesterol and triglyceride, although these differences were not statically significant ($P>0.05$). Restricted access to water led to a significant increase ($P<0.05$) in BUN concentration (42.63 mg/dL *vs*. 41.13 mg/dL), while the consumption saline water had no significant effect on BUN concentration ($P>0.05$).

In addition, no interaction was observed between RES × TDS among experimental treatments with respect to serum glucose, creatinine, cholesterol, triglyceride, total protein albumin, globulin, ALT, AST, or BUN ($P>0.05$).

The result for blood hematology is given in Table 7. Neither water deprivation nor rising the content of TDS in water had any significant effect on RBC, WBC, HGB, MCV, MCH, or MCHC ($P>0.05$). Water restriction caused a significant increase in PCV concentration ($P<0.05$) in the event that salinity had no significant effect on this parameter ($P>0.05$). There was no RES × TDS interaction observed for the blood hematology parameters.

Table 7 The Effect of water deprivation and drinking saline water on blood parameters and liver enzymes of experimental lambs

Variable	Treatment				SEM	P-value		
	Low TDS		High TDS					
	RES	FRE	RES	FRE		RES	TDS	RES × TDS
RBC (× 109/L)	7.65	7.43	7.69	7.53	0.340	0.586	0.849	0.934
WBC (× 10^9/L)	14.00	13.73	14.05	13.55	0.471	0.427	0.897	0.815
Hemoglobin (g/dL)	10.70	10.60	10.88	9.95	0.305	0.119	0.452	0.202
PCV (%)	28.00	26.80	29.00	25.63	0.710	0.007	0.904	0.151
MCV (fL)	36.73	36.51	37.70	3410	1.559	0.244	0.653	0.301
MCH (Pg)	14.13	14.41	14.15	13.23	0.738	0.669	0.447	0.432
MCHC (%)	38.51	39.55	37.56	38.90	1.838	0.518	0.683	0.923

TDS: total dissolved solids; RES: restrict to half *ad libitum* water intake and FRE: free access to water during the day.
RBC: red blood cell; WBC: white blood cell; PVC: packed cell volume; MCV: mean cell volume; MCH: mean cell hemoglobin and MCHC: mean cell hemoglobin concentration.
SEM: standard error of the means.

Table 8 show the effect of water restriction and water salinity on serum electrolytes of lambs. Calcium, chloride, phosphors, and magnesium did not show any significant difference (P>0.05) due to water restriction or salinity. Restricted access to water led to an increase in sodium (149.63 mmol/L *vs*. 142.00 mmol/L) and chloride (97.25 mmol/L *vs*. 98.38 mmol/L) and a reduction in potassium serum (4.36 mmol/L *vs*. 4.71 mmol/L) in experimental-group lambs (P<0.05).

On the other hand, the TDS of water had no significantly effect on chloride or potassium (P>0.05), although sodium serum tended to significantly rise by the increased concentration of TDS in drinking water (P<0.05), (147.75 mmol/L *vs*. 143.88 mmol/L). No interaction occurred between RES and TDS for serum electrolytes of lambs.

The mean of ruminal fermentation parameters is presented in Table 9. The rumen pH of lambs was influenced (P<0.05) by water restriction (27.31 *vs*. 24.59) but not by water salinity (6.56 *vs*. 6.50).

The concentration of ammonia-N and molar proportion of acetate, propionate, butyrate, valerate, and total VFA was not affected by water restriction or water salinity (P>0.05). Furthermore, No interaction occurred for any ruminal fermentation parameters (P>0.05).

Based on Table 10, the digestibility of ADF (37.02 g/kg *vs*. 33.61 g/kg), NDF (53.26 g/kg *vs*. 50.84 g/kg), CP (65.49 g/kg *vs*. 63.17 g/kg), and OM (70.21 g/kg *vs*. 68.81 g/kg) exhibited a progressive rise in the lambs that were affected by water restriction (P<0.05), while the digestibility of EE was not affected by water restriction (P>0.05). Generally, no effect for water salinity was observed on the digestibility of ADF, NDF, CP, EE, and OM (P>0.05). Moreover, no RES×TDS interaction was observed for the digestibility of ADF, NDF, CP, EE, and OM (P>0.05).

Fecal output (441.7 g DM/d *vs*. 776.5 g DM/d) and urine exertion (330.7 mL/d *vs*. 1661.5 mL/d) were effected by water restriction (P<0.05) and both of them significantly decreased (Table 11). Increasing TDS in drinking water led to a significant increase (P<0.05) in urine exertion (1628.6 mL/d *vs*. 363.5 mL/d) while it had no effect on fecal output (P>0.05).

In addition, no RES × TDS interaction occurred for fecal output (P>0.05), but no RES × TDS interaction was seen for urine exertion (P<0.05).

In the present study, water deprivation led to a reduction in DMI, ADG, water consumption, and ratio of water consumption to DMI, the observed values were consistent with the findings from other studies (Hamadeh *et al*. 2006; Silanikove, 2000).

Previous studies showed that there is a correlation between water consumption and feed intake (Forbes, 1968) that a sufficient amount of water is required for a proper fermentation and digestive function (Hadjigeorgiou *et al*. 2000). Nevertheless, Ghassemi Nejad *et al*. (2014) reported that water restriction does not have any significant effect on feed intake.

Hadjigeorgiou *et al*. (2000) reported that the ratio of water consumption to DMI decreases when sheep are exposed to water restriction. The greatest physiological consequence of water restriction accompanied with decreased DMI is the reduction of weight gain (Ghanem *et al*. 2008; Mpendulo *et al*. 2017). It seems that part of this weight loss is related to body dehydration, while other reason may be fat loss as a result of fat mobilization used to compensate for reduced food intake.

In the present study, a high concentration of TDS in drinking water resulted in a significant reduction in DMI of the lambs. According to Pierce (1959), feed intakes of are slightly reduced when these animal are given high-salinity water (2000 mg TDS). Wilson (1966) also observed that the DMI of sheep declines at higher concentrations of NaCl in drinking water. This reduction may be related to the negative effect of saline water on saliva secretion and activity rumen microflora. Moreover, DMI during a meal can be limited by increasing the osmolality of rumen fluid. In this regard, Phillips and Chiy (1995) observed a reduction in DMI associated with a rise in the osmolality of ruminal fluid as a result of the ruminal infusion of NaCl solution.

Table 8 The Effect of water deprivation and drinking saline water on blood electrolytes of experimental lambs

Variable	Treatment				SEM	P-value		
	Low TDS		High TDS					
	RES	FRE	RES	FRE		RES	TDS	RES × TDS
Ca^{+2} (mmol/L)	10.23	10.20	10.25	10.21	0.282	0.914	0.948	0.983
P^{-} (mmol/L)	10.35	10.19	10.53	10.48	0.412	0.801	0.585	0.894
Na^{+} (mmol/L)	146.75	141.00	152.50	143.00	1.180	0.001	0.039	0.283
K^{+} (mmol/L)	4.27	4.67	4.45	4.75	0.117	0.011	0.306	0.676
Mg^{+} (mmol/L)	2.63	2.62	2.52	2.48	1.129	0.925	0.401	0.777
Cl^{-} (mmol/L)	97.00	93.50	97.50	93.25	0.161	0.006	0.916	0.752

TDS: total dissolved solids; RES: restrict to half *ad libitum* water intake and FRE: free access to water during the day.
SEM: standard error of the means.

Table 9 The Effect of water deprivation and drinking saline water on rumen parameters of experimental lambs

Variable	Treatment				SEM	P-value		
	Low TDS		High TDS					
	RES	FRE	RES	FRE		RES	TDS	RES × TDS
Acetate (mmol/L)	46.55	44.95	45.10	43.75	0.931	0.142	0.184	0.896
Propionate (mmol/L)	17.85	17.50	17.62	16.80	0.348	0.117	0.209	0.505
Butyrate (mmol/L)	15.03	14.75	14.05	15.13	0.370	0.093	0.433	0.300
Isobutyrate (mmol/L)	0.32	0.35	0.30	0.30	0.054	0.747	0.963	0.818
Valerate (mmol/L)	1.16	1.14	1.15	1.15	0.057	0.855	0.526	0.784
Total (mmol/L)	80.96	78.63	78.45	76.08	2.204	0.306	.0274	0.992
NH_3-N (mg/dL)	27.42	25.68	27.20	26.50	0.804	0.156	0.710	0.529
pH	6.40	6.61	6.45	6.68	0.062	0.004	0.354	0.875

TDS: total dissolved solids; RES: restrict to half *ad libitum* water intake and FRE: free access to water during the day.
SEM: standard error of the means.

Table 10 The Effect of water deprivation and drinking saline water on nutrient digestibility of experimental lambs

Variable	Treatment				SEM	P-value		
	Low TDS		High TDS					
	RES	FRE	RES	FRE		RES	TDS	RES × TDS
Acid detergent fiber (ADF) (g/kg)	36.80	33.40	37.25	33.83	0.697	0.000	0.154	0.986
Neutral detergent fiber (NDF) (g/kg)	53.37	49.98	53.15	51.70	0.434	0.000	0.314	0.130
Crude protein (CP) (g/kg)	65.32	63.00	65.66	63.35	0.355	0.000	0.352	0.986
Ether extract (EE) (g/kg)	66.78	66.53	66.10	66.47	0.984	0.950	0.719	0.756
Organic matter (OM) (g/kg)	70.28	68.35	70.15	69.28	0.384	0.003	0.318	0.197

TDS: total dissolved solids; RES: restrict to half *ad libitum* water intake and FRE: free access to water during the day.
SEM: standard error of the means.

Table 11 The Effect of water deprivation and drinking saline water on fecal output and urine exertion of experimental lambs

Variable	Treatment				SEM	P-value		
	Low TDS		High TDS					
	RES	FRE	RES	FRE		RES	TDS	RES × TDS
Fecal output (g DM/d)	533.00	820.30	350.50	732.70	87.15	0.002	0.147	0.596
Urine (mL/d)	236.50	490.60	425.00	2832.30	139.42	0.000	0.000	0.000

TDS: total dissolved solids; RES: restrict to half *ad libitum* water intake and FRE: free access to water during the day.
SEM: standard error of the means.

Results indicated that mean ADG was significantly lower in the groups which consumed saline water, in line with of the results of the study on beef cattle by Patterson and Johnson (2003) but contrary to the findings of El-Gawad (1997) who reported that body weight is not affected in goats offered moderate saline water for 6 weeks.

Increasing TDS in water from 400 to 800 mg/L increased water consumption in lambs. Increased water intake related to drinking saline water has been reported by El-Gawad (1997) and Mpendulo *et al.* (2017) in goats and Meintjes and Engelbrecht (2004) in sheep, similar to our study. This increase may be related to the maintenance of the Na conte-

nts of body fluid compartments within physiological limits by increasing water intake (YapeKii and Drydent, 2005). This result can be partially attributed to the reported decline in DMI.

The present results showed that a rise in the ratio of water consumption to DMI in groups with access to saline water compared to other groups is attributed to the increase in water consumption and the decrease in DMI for groups with access to saline water.

According to our results, water deprivation had no significant effect on rectal temperature, consistent whit the findings of a study which reported that sheep are thermostable even during dehydration (MacFarlane, 1964).

The slight increase in rectal temperature in animals that were under water deprivation was mainly attributed to the decrease in the rate of evaporation which results from body deficit (Silanikove, 1992). Respiration rate was not affected by water deprivation, similar with the results of a study on German black-head mutto sheep (Al-Ramamneh *et al*. 2010) but contrary to the findings of Alamer (2010) who reported that water deprivation leads to an increase in respiration rate. This can be attributed to the decline of dry matter intake and the consequent reduction in metabolic heat production which may help lambs maintain body water by reducing pulmonary ventilation (Bianca, 1966).

Findings from current study indicated that the increased TDS content in drinking water had no significant effect on rectal temperature and respiration rate, comparable with the findings of El-Gawad (1997) for goats.

Insulin is a key hormone in energy metabolism and has an important role in regulating the response to the declined feed intake (Vernon, 1992). The reduced concentration of insulin facilitates lipolysis. The results of our experiment indicated that water restriction decreases insulin secretion, consistent with the study of Jaber *et al*. (2011).

When the animal is exposed to dehydration, blood volume decreases and thus the secretion of aldosterone hormone is enhanced to help the body maintain water (Carlson, 1996).

The results of the present study are in agreement with those reported by Kataria (2007), indicating that water restriction for 6 days leads to an increase in aldosterone.

Cortisol is a hormone secreted to deal with stress and plays a crucial role in maintaining the balance of water and electrolytes (Parker *et al*. 2003). In this study, blood cortisol concentration was higher in groups that were under water restriction. In agreement with our study, Kataria (2007) reported that water restriction elevate serum cortisol in Marwari sheep. The results of cortisol should be carefully considered because this variable is influenced by several factors such as handling, circadian rhythm, and short-term vs. long- term stressors (Mostle and Palme, 2002).

Serum insulin level was not affected by the elevated amount of TDS in drinking water in this trial. Also, serum cortisol level remained unchanged as a result of drinking saline water. This finding revealed that the level of salinity is not an effective stress factor for experimental lambs. Congruent with our study, Ahmed and Abdel-Rahman (2004) concluded that drinking natural saline water has no effect on serum cortisol in rabbits.

Plasma aldosterone concentration in our study tended to increase in groups which consumed saline water, but this increase was not significant. Similarly, Zoidis and Hadjigeorgiou (2017) concluded that adding up to 20% NaCl to drinking water has not significant effect on plasma aldosterone in goats.

The blood chemistry can reflect the degree of dehydration of body. With this in mind, the serum glucose level did not change by water restriction in this experiment and other studies on Awassi sheep (Hamadeh *et al*. 2006).

Serum creatinine can be affected by protein intake or proteolysis. In an experiment conducted on Marwari sheep, Kataria (2007) reported that the serum creatinine increase is due to the destruction of muscles following dehydration. Besides, Jaber *et al*. (2004) observed that serum creatinine tends to increase with water restriction in Awassi sheep, which is consistent with our results.

Total protein and especially albumin are used as indicators for assessing the level of dehydration in the body. Their concentration rises by the reduction of plasma volume due to dehydration (Cork and Halliwell, 2002). In addition, albumin plays an important role in the regulation of blood pressure and osmotic balance between blood fluids and tissue (Tucker, 1975). In the present study, total protein, albumin, and globulin tended to rise with water deprivation, although this difference was not significant. Similar results were reported that total protein, albumin, and globulin concentrations are increased depending on the degree and intensity of water restriction (Alamer, 2005; Casamassima *et al*. 2008).

Furthermore, ALT and AST are indicators considered for liver health, and major changes to their concentration can indicate liver damage (Badakhshan and Mirmohamadi, 2016). In our experiment, ALT and AST were not affected by water restriction. These findings revealed that the level of water restriction in the experimental duration cannot create changes in the concentration of the noted liver enzymes.

Water depravation elevates water absorption in nephrons, consequently, an increase in area reabsorption is expected as it is a highly permeable molecule (Casamassima *et al*. 2016). In our experiment, by reducing water availability, blood urea concentration significantly increases. These results are consistent with pervious work of Igbokwe (1993)

on Yansaka sheep and MacFarlane *et al*. (1961) on the Merino.

Cholesterol and triglyceride level significantly increased during the trial by water deprivation, in compliance with other reports (Casamassima *et al*. 2008; Igbokwe, 1993).

When the animal has free access to feed, it stores extra energy as adipocytes subcutaneously and in the tail so that it can use it when faced with a lack of energy (Atti *et al*. 2004). It can be concluded that the decreased DMI due to dehydration leads to a rise in the concentration of cholesterol and triglyceride through fat mobilization.

Serum glucose did not change by increasing the TDS concentration of the drinking water throughout the present study. Despite the lower feed consumption by these group, serum glucose concentration was not affected by or expanded the mobilization of body reserves in the present study (Silanikove, 1992).

Congruent with our results, reported that increasing TDS concentrations in water up to 13535 pm has not significant effect on serum glucose in sheep. Statistical analyses revealed the insignificant effect of saline water treatment on serum creatinine in lambs. This finding was confirmed by Kattnig *et al*. (1992) who reported no significant response to the increasing level of salinity in drinking water in steers.

In the present study, the serum concentrations of total protein, albumin, and globulin were not significantly affected by the increased salinity of drinking water during the experiment. This result can be attributed to the hemodilution which occurred as a result of the elevated water consumption by the lambs.

Serum ALT and AST were not affected by water restriction during the trial, in line with the study on yearling Holstein steers by Kattnig *et al*. (1992). Nevertheless, our results were contrary to the findings of El-Sherif and El-Hassanein (1996) who reported that drinking saline water leads to significant changes in serum ALT and AST in Barki ewes. It seems that the discrepancies between results may have been due to the level of salinity and duration of consumption.

Results revealed that blood urea nitrogen, cholesterol, and triglyceride tended to increase by increasing salinity in drinking water, but these differences were not significant. Similar findings were reported by Meintjes and Engelbrecht (2004) and Kattnig *et al*. (1992).

The present results indicate that hematological parameters, except for PCV, were not influenced by water restriction. PCV progressively increased in treatments with limited drinking water, this result Supported by Laden *et al*. (1987), Ghosh *et al*. (1976) and Aganga (1992) on goats, and Laden *et al*. (1987) and MacFarlane *et al*. (1961) on sheep.

This increase in PCV in groups with water restriction can be related to a decrease in plasma volume due to water loss.

In the present study, no substantial difference was noted in the examined hematological parameters by increasing salinity in drinking water. In agreement with these results, Zoidis and Hadjigeorgiou (2017) reported that the addition of 5, 10, and 20% NaCl to drinking water has no effect on hematological parameters in Alpine male goats.

As one of the main indicators of dehydration condition, osmolality has been proven to be strongly affected by dehydration. Decreased plasma volume leads to hyperosmolality that includes an increase in blood electrolytes as a result of dehydration (Qinisaa *et al*. 2011). In our study, the main electrolytes were examined and it has been shown that Na^+, Cl^-, and K^+ were intensively affected by water deprivation. This increase in serum sodium and chlorine is related to increased renal retention under the influence of aldosterone and ADH. In similar studies on sheep and goats (Casamassima *et al*. 2008; Ghanem *et al*. 2008; Mengistu *et al*. 2007), similar variations were reported in sodium and chlorine in response to water deprivation. Studies on sheep showed the negative correlation between serum Na^+ and K^+. Blood potassium was reported to decrease in sheep under water restriction (Jaber *et al*. 2004).

This may be due to the intra-erythrocyte diffusion of potassium or loss of it in urine in exchange of sodium reabsorption (Igbokwe, 1993). In the present study, the serum sodium concentration significantly increased as the TDS concentration in drinking water was enhanced from 400 to 8000 mg/L. In congruence with our results, Constable *et al*. (1991) reported that when experimental calves consuming saline water, serum sodium concentration increased while other elements remained almost stable, this increase may be associated with the increase in NaCl intake through the drinking water, and similar findings were reported by Abou Hussien *et al*. (1994) and Zoidis and Hadjigeorgiou (2017).

Our results revealed that water restriction leads to a significant increase in the digestibility of nutrients including ADF, NDF, CP, and OM, and this increase is probably related to the slower passage rate of digesta from the reticlurumen to the intestine and a rise in nutrient utilization by allocating more time for microbial enzymes to attach to feed particles. Similarly, Ghassemi Nejad *et al*. (2014) reported that water restriction in Holstein cows for 2 and 3 h following feeding increased nutrient digestibility.

Water salinity did not affect the nutrient digestibility of lambs. Hadjipanayiotou (1984) reported similar results in Chios sheep when they were given saline water. Furthermore, Kattnig *et al*. (1992) observed that, compared with normal water, saline water containing a combination of Ca^{2+}, Mg^{2+}, Na^+, and SO_4^{2-} ions at 2300 mg TDS had no ef-

fect on *in situ* digestibility. Sager and Casagrande (1998) observed that the effect of saline water on digestion was positive for low-quality forages only. It seems that the discrepancies among the results of different studies may have been due to the difference in the degree of salinity in drinking water, type of feed, and experimental method.

The analysis of rumen fluid revealed that rumen pH is significantly lower in lambs which were under water restriction. The significance of this finding in not entirely clear, but this reduction may be attributed to the increased total VFA and reduced saliva secretion in these lambs. The rumen parameters were not influenced by water deprivation, and our findings was in agreement with the results of Asplund and Pfander (1972) on sheep. Based on the present findings, no rumen parameter was affected by water salinity.

Similarly, Valtorta *et al*. (2007) concluded that no rumen parameter, including pH, NH_3-N, and VFA, was not significantly changed by the rise in water TDS up to 10000 mg/L in Holstein cows. This finding confirms that rumen has a high buffering capacity and the buffering system in rumen is influenced by factors as a saliva and feed (Van Soest, 1994).

Fecal out (g DM/d) and urine volume (mL/d) declined by implementing water deprivation on lambs, probably because of the less feed intake, more water absorption, and less water exertion in lambs that were under deprivation.

In agreement with our result recently Ghassemi Nejad *et al*. (2017) observed that water deprivation following feeding reduced the urine output of ewes. Based on the result of our experiment, water salinity has no significant effect on fecal out (g DM/d), while increasing the TDS concentration in drinking water elevates water consumption in lambs and is associated with a more than fourfold increase in urine excretion. Abou Hussien *et al*. (1994) reported that the control of the salt load of sheep and goats by excreting more urine and increasing the glomerular filtration rate in order to reduce salt load resulting from high consumption of saline water.

CONCLUSION

The tolerance of animals to water shortage and drinking water salinity differs based on species, adaption, and environment. Generally, small ruminant breeds of arid and semi-arid regions show good adaption to water shortage and water salinity according to their morphological and physiological characteristics. This result implies that Baluchi sheep can tolerate water restriction up to 50% and can drink water containing up to 8000 mg TDS/L for a minimum of 28 days without harmful effects. This research also indicated that Baluchi sheep can be better adapted to maintain their lives and possibly their reproduction in areas where fresh water is scare or contains a high TDS concentration.

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