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Effect of drinking saline water and feed shortage on adaptive responses of sheep and camels

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Abstract

This study investigated the effect of saline load and inadequate feed intake on some of the adaptive physiological responses in female sheep and camels, raised under semi-arid conditions. The experiment comprised five consecutive periods, P1–P5, of 40 days each, during which levels of both energy and protein were gradually decreased by increasing the roughage portion in the diet. Sheep and camels were divided into three groups according to the type of drinking water; namely a fresh water (F) group (280 parts per million total dissolved salts; ppm TDS), low saline (LS) group (7650 ppm TDS) and high saline (HS) group (13,535 ppm TDS). Saline water was obtained by diluting seawater with tap water.

In sheep, live body weights (BWs) decreased significantly ($p < 0.01$) with decreasing nutrient intake, with average final loss equal to 8.4%. Plasma glucose decreased with decreasing protein intake, but as energy intake increased the effect of protein shortage disappeared. Also plasma glucose levels in sheep decreased from a level of 3.51 mmol/l in the F group to 2.89 mmol/l in the HS group. Concentrations of liver enzymes aspartate aminotransaminase (AST) and alanine aminotransaminase (ALT) in sheep increased in plasma in relation to saline load especially at low nutritional level. The activity of the acetylcholine esterase enzyme (AChE) in its three sites; blood, red blood cells and plasma was depressed significantly by both saline load and decreased feed intake. At the P2 period, salinity depressed acetylcholine in its three sites to 60–67% in the HS group as compared to the control. The depression during the P5 period reached 41–54%. Extracellular fluids (ECFs), interstitial fluids (ISF), plasma volume (PV) and blood volume (BV) in the ewes decreased ($p < 0.05$) by increasing salinity concentration. Decreasing feed intake lowered ECF, ISF and BV from the P2 period.

In camels, live BWs decreased insignificantly by decreasing feed intake with a final BW loss of 1.9%. Plasma glucose was not affected by salinity. Protein deficiencies had no effect on plasma AST of camels, but both salinity and low level of nutrient intake affected the concentration of enzyme ALT. Nutrient shortages and saline load affected activity of AChE at the P4 and P5 periods. The inhibition of the enzyme activity during P5 due to high salinity treatment reached 91% in blood, 63% in RBCs and 50% in plasma as compared to the control group. Body fluid compartments of camels were not affected by salinity, only by reduced feed intake. The results indicated better tolerance of camels than sheep to both saline load and feed shortage.

Keywords: Camels; Sheep; Saline water; Feed deficiency; Blood constituents

1. Introduction

Camels, sheep and goats constitute the majority of animal wealth in the desert and play an important role in maintaining human life. Deserts are characterized

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by scarcity of food and water. This is further complicated particularly during the long dry season by the often high salinity of drinking water obtained from wells that could reach 10,797 parts per million total dissolved salts (ppm TDS) in the northwestern coastal desert of Egypt (Atwa, 1979). Ray (1989) reported water salinity to be considered as an important factor in determining the suitability of a particular source for livestock. Animals living in these regions are also exposed to other stress factors such as summer heat and cold during winter nights.

Most previous local studies concerned the effect of water salinity on the performance and physiological responses of desert animals (Abou El Nasr et al., 1988; Assad et al., 1994; Ibrahim, 1995; El-Sherif and El-Hassanein, 1996). From the acclimatization point of view, animals in the field are exposed to several environmental factors. Very few reports were found that dealt with the effects of more than one adverse environmental factor (Azamel et al., 1994; El-Sherif et al., 1995; Assad et al., 1997a). Moreover, not all the farm animal species in Egyptian deserts were included in these studies. Animals in the desert face feed shortages and water salinity for a long dry season from May to December. The present study was designed to determine the combined effects of both saline load and feed scarcity on some physiological responses of sheep and camels to indicate the relative adaptability of both species to the harsh environmental conditions of the desert.

2. Materials and methods

2.1. Animals and management

The present trials were conducted at Maryout Research Station of the Desert Research Center, 35 km southwest of Alexandria. Nine female camels (*Camelus dromedarius*) and nine Barki ewes, the prevailing breed in the northwestern coastal desert of Egypt, were individually penned under shade for five consecutive periods of 40 days each (P1–P5). On average the female camels weighed 543 kg and ewes 47.8 kg. Feed was offered once daily at 08.00 h and water was freely available for 1 h at feeding time. The diet comprised cracked barley grain, a cubed commercial concentrate mixture and chopped rice straw. The concentrate mixture was made up of undecorticated cottonseed cake 50%, wheat bran 18%, yellow maize 15%, rice polishing 11%, molasses 3%, limestone 2% and salt 1%. The amount of feed provided was determined according to locally calculated maintenance requirements. These are 2.2 g digestible crude protein (DCP) and 28.2 g total digestible nutrients (TDNs) per $kg^{0.73}$ body weight (BW) for desert Barki sheep (Farid et al., 1983) and 2.15 g DCP and 26.8 g TDN per $kg^{0.73}$ BW for dromedary camels (Farid et al., 1990). Intended allowances of protein were 120, 100, 80, 60 and 40% of maintenance during the five consecutive periods, while that of energy was 100% throughout. Decreasing protein level was accomplished mainly by increasing the roughage proportion and, to a lesser extent, the barley grain. Actual feed intake was measured and found to be different than that intended due to the variation in feed composition. Digestion trials were conducted to determine the intake of digestible energy and protein during each period. Results of feed utilization, water intake, mineral balance and hematological parameters were previously published (Abou El Nasr et al., 1988; Khamis et al., 1989; Assad et al., 1994, 1997b). Table 1 shows summary of the results of feed and water intake in this experiment (cited from Assad et al., 1997b). Minimum and maximum ambient temperatures during each period are included in Table 1.

Female camels and ewes were randomly divided into three groups of three animals from each species per group. Two groups were offered diluted seawater containing 7650 and 13,535 ppm TDS and designated low and high salinity groups, respectively. Animals in the remaining group received fresh water containing 280 ppm TDS to be used as the control and were referred as the fresh water (F) group. The seawater used in dilution contained 39,600 ppm TDS, 12,000 ppm Na^+, 22,700 ppm Cl^-, and 1400 ppm Mg^{++}.

2.2. Measurements

Experimental animals were observed daily in order to record any clinical abnormal signs. At the end of each period (after the lapse of 40 days), animals were weighed after fasting for 12 h, then blood samples were collected in heparinized tubes from all animals early in the morning prior to feeding and watering. Plasma was obtained for chemical analysis by

Table 1
Average daily intakes of water, dry matter, TDN and DCP for sheep and camels in addition to minimum and maximum temperature during different periods[a]

	Periods				
	P1	P2	P3	P4	P5
Sheep					
Average daily water intake (ml/100 kg BW)	5478	4444	3190	3235	2793
Average dry matter intake (g/kg$^{0.73}$ per day)	61.0	51.9	49.7	54.7	49.9
Average nutrient intake (g/kg$^{0.73}$ per day)					
TDN	32.7	32.9	29.6	29.7	24.4
DCP	3.12	2.81	2.09	1.57	1.57
Maintenance (%)					
TDN	116	116	105	105	86
DCP	142	128	95	71	71
Camels					
Average daily water intake (ml/100 kg BW)	2276 a	2295 a	1095 b	972 b	1565 b
Average dry matter intake (g/kg$^{0.73}$ per day)	51.0 a	46.7 ab	43.3 b	48.8 a	49.9 a
Average nutrient intake (g/kg$^{0.73}$ per day)					
TDN	31.4	29.0	26.0	27.9	24.8
DCP	2.70	2.67	1.68	1.56	1.21
Maintenance (%)					
TDN	117	108	97	104	92
DCP	125	124	78	72	56
Air temperature (°C)					
Min.	22.1	23.7	12.8	12.0	10.1
Max.	28.8	29.5	23.0	18.9	17.3

[a] a,b means in the same row with the same letter are not significantly different.

centrifugation of blood at 3000 rpm then preserved at −20 °C. Glucose, aspartate aminotransaminase (AST) and alanine aminotransaminase (ALT) assays were determined using kits provided by Sentinel, Ch., Milano, Italy. AChE activity was determined in three sites; whole blood, plasma and red blood cells (RBCs) by the method of Metcalf (1951). Plasma volume (PV) was recorded using Evans blue dye (T-1824), according to the method of Hawk et al. (1965). Extracellular fluid (ECF) or thiocyanate space was determined using the method as described by Cornelius and Kaneko (1963). Interstitial fluid (ISF) and blood volumes (BVs) were calculated as follows:

$$\text{ISF} = \text{ECF} - \text{PV}, \text{ and } \text{BV} = \frac{\text{PV}}{1} - \text{packed cell volume}$$

All fluid compartments were expressed as ml/kg BW.

2.3. Statistical analysis

Statistical analysis was conducted using SAS package (SAS, 1998). Split plot design for repeated measurements was applied to test the effect of salinity (fixed model) against Error (a) that was animals within salinity, while effects of period and interaction (variable models) were tested against Error (b). Standard error for each source was calculated.

3. Results and discussion

3.1. Live BW

Live BWs at the onset of the study of the saline treatment groups F, LS and HS were respectively 44.9, 46.8 and 51.6 kg for ewes, and 524.0, 525.3 and 579.7 kg for female camels (Table 2). The heavier animals were allotted to the high saline concentration groups (LS and HS) to ensure that they would tolerate the treatment for a long time (200 days). Table 2 shows the average live BW of each treatment group at the end of each period and the BW change from the previous weighing. For sheep, live BW was

Table 2
Least squares means of live BW in kg and average body weight change (BC), of sheep and camels as affected by water salinity (S) and diet level (P)[a]

Periods	Aspects	Sheep				Camels			
		Water type			Overall	Water type			Overall
		F	LS	HS		F	LS	HS	
At onset	BW	44.9	46.8	51.6	47.77	524.0	525.3	579.7	543.0
P1	BW	45.7	48.0	52.5	48.72 a	539.0	511.3	585.0	545.1 a
	BC	+0.8	+1.2	+0.9	+0.95	+15.0	−14.0	+5.3	+2.1
P2	BW	42.0	47.5	51.0	46.83 b	537.0	510.0	592.3	546.4 a
	BC	−3.7	−0.5	−1.5	−1.89	−2.0	−1.3	+7.3	+1.3
P3	BW	42.2	46.3	50.7	46.39	523.3	526.0	580.7	543.3 a
	BC	+0.2	−1.2	−0.3	−0.44	−13.7	+16.0	−11.6	−3.1
P4	BW	39.3	43.8	48.2	43.78 c	526.0	505.7	565.3	532.3 a
	BC	−2.9	−2.5	−2.5	−2..61	+2.7	−20.3	−15.4	−11.0
P5	BW	39.5	43.3	48.5	43.78 c	524.3	510.3	563.3	532.7 a
	BC	+0.2	−0.5	+0.3	0.0	−1.7	+4.6	−2.0	+0.4
Overall BW means		41.73 a	45.80 b	50.17 a	45.90	529.9 b	512.7 b	577.3 a	539.96
Final BC (P5 − onset) (%)		−5.4 (12%)	−3.5 (7.5%)	−3.1 (5%)	−3.99 (8.4%)	+0.3 (0.0%)	−15.0 (2.9%)	−16.4 (2.8%)	−10.3 (1.9%)
S.E.	S			0.37**				8.0**	
	P			0.48**				10.4	
	S × P			0.84				17.9	

[a] +: Weight gain, −: weight loss, F: fresh water (280 ppm TDS), LS: low saline water (7650 ppm TDS), HS: high saline water (13,535 ppm TDS), S.E.: standard error, S: salinity, P: period, a, b, c: means in the same row or the same column with the same letter are not significantly different.

** $p < 0.01$.

significantly ($p < 0.01$) decreased as time progressed, mainly due to the decreased nutrient intake. The live BW of the female camels decreased also over time but to a lesser extent, and the effect of the period was not significant. At the end of the experiment the ewes lost on average 8.4% of their initial live BW, while the female camels lost only 1.9% in spite of their lower dry matter intake per unit of metabolic body size as compared to the ewes (Table 1). This indicates the better tolerance for camels than sheep to feed shortage.

The final changes in the live BW as kg and % from the weight at the onset of the experiment for the F, LS and HS treated groups were respectively, −5.4 (12%), −3.5 (7.5%) and −3.1 (5%) for sheep and +0.3 (0.0%), −15 (2.9%) and −16.4 (2.8%) for female camels. The highest loss in BW of the ewes occurred in the fresh watered group (control). Female camels showed an inverse trend where the final BW loss was proportional to water salinity (Table 2), which indicates a deleterious effect of salinity on camels' BW. It seems that the lower BW loss in the HS concentration treated ewes was due to the increase in their body water content. Increasing saline concentration in drinking water was found to increase water consumption by sheep (El-Sherif and El-Hassanein, 1996) as compared to those drinking fresh water. El-Sherif and El-Hassanein (1996) found that a large portion of the additional water that was taken by saline treated rams was kept within the body and finally encountered in the intracellular space (ICF). Both species increased water intake as saline concentration increased in water (Assad et al., 1997b), but the female camels had lower average relative water intake (ml/100 kg BW) than the ewes (Table 1). In addition salinity had insignificant effect on body water distribution in camels (Table 4). This meant that the female camels did not behave like the ewes in preserving extra water intake inside the body. The present results of BW changes cannot give a clear comparison between the two species for the effect of water salinity on body composition. The effects of water salinity on the body tissues

need to be examined through chemical analysis of the carcass.

3.2. Plasma glucose concentration

Plasma glucose concentrations in sheep was affected significantly ($p < 0.01$) by period (Table 3). The highest overall mean was that of P3 period (4.01 mmol/l), while the lowest values were those of the P2, P4 and P5 periods (2.50–2.92 mmol/l). Plasma glucose levels of the fresh water group (F) changed in the range of 2.73–4.43 with an evident increase during the periods P3–P5. During these periods protein intake as DCP decreased to 71–95% of maintenance (Table 1). In the F group also, plasma glucose levels did not appreciably differ (3.07 vs. 3.47 mmol/l) during both the P4 and P5 periods, when DCP intake was the same (71% of maintenance) while energy intakes as TDN were 105% and 86% of maintenance, respectively. This indicated no effect due to decreasing energy intake. In the same group, decreasing protein intake from 95% (P3) to 71% (P4) with the same energy intake (105%) resulted in a significant ($p < 0.01$) decrease in plasma glucose concentration from 4.43 to 3.07 mmol/l. However, there was no difference in plasma glucose during the P1 and P2 periods when energy intake was 116% of maintenance while protein intakes were 142 and 128% of maintenance, respectively. This trend demonstrated that protein level affected plasma glucose under normal or low energy intake (less than 100% of maintenance) but this effect disappeared when energy intake increased over 100%. The two saline treatment groups (LS and HS) recorded the highest values of plasma glucose (3.70 and 3.90 mmol/l) during the P3 period when intake was 105% of TDN and 95% of DCP maintenance requirements. The lowest plasma glucose levels (2.27 and 2.17 mmol/l) occurred during the P4 period when intake was 105% of TDN and 71% of DCP maintenance requirement which confirmed the importance of dietary protein under low (less than 100% of maintenance) energy intake.

Statistical analysis revealed an insignificant effect of saline treatment on plasma glucose levels in sheep (Table 3). However, total mean of plasma glucose was 3.51 mmol/l for the F group which declined with increasing saline concentrations in water to reach 2.89 mmol/l for the HS group. Peirce (1966) recommended the tolerable salt concentration for sheep to range from 11,000 to 13,000 ppm in sodium chloride type water. In the present study, the observed decline in plasma glucose in sheep by increasing water salinity may be due to the long period of administration of saline in addition to using diluted seawater that contained different minerals and not only sodium chloride. Long term administration of diluted seawater (13,100 ppm TDS) was found to adversely affect the growth rate of growing rams (El-Sherif and El-Hassanein, 1996), semen quality in rams (El-Hassanein, 1996) and increase white blood cell count (El-Hassanein and El-Sherif, 1996).

Plasma glucose level in camels was generally higher than that of sheep (5.643 vs. 2.923 mmol/l). Similar to sheep, period had significant ($p < 0.01$) effect on plasma glucose of female camels, while saline intake did not (Table 4). The means of plasma glucose concentration in saline groups ranged between 5.59 and 5.75 mmol/l. This trend indicated a better tolerance of camels to saline load compared to sheep. Assad et al. (1997b) reached a similar conclusion by studying haemograms of camels and sheep in response to similar treatments. Plasma glucose concentrations in camels did not change through the periods P1–P3 (6.11–6.62 mmol/l) when intake was 97–117% of TDN and 78–125% of DCP maintenance requirements. This meant that low protein intake (78% of DCP requirements) did not affect plasma glucose level since energy intake was satisfactory (97–117% of TDN requirements). Plasma glucose declined significantly ($p < 0.01$) during the period P5 (4.03 mmol/l) when feed intake was 92% of TDN and 56% of DCP requirements. Inadequate protein intake affected plasma glucose in camels only under energy intake lower than 100% of TDN requirements.

3.3. Liver enzymes

The changes of AST or GOT in sheep was affected significantly by salinity ($p < 0.05$), period ($p < 0.01$) and the interaction between period and salinity ($p < 0.01$). The level of AST was normal in the F group (44.13 IU/l) and increased significantly ($p < 0.05$) with increasing saline intake to reach 53.00 IU/l for the HS group. The means for the periods P2–P4 were in the normal range, while the mean for the P5 period (56.89 IU/l) was the highest ($p < 0.01$) one. During

Table 3
Least squares means of BW, blood components and fluid compartments of sheep as affected by water salinity and diet level[a]

Parameter	Water type	Periods					Overall	S.E.		
		P1	P2	P3	P4	P5		Salinity	Period	Interaction
Glucose (mmol/l)	F	2.90	2.73	4.43	3.07	3.47	3.51	0.160	0.207**	0.358
	LS	3.60	2.70	3.70	2.27	2.70	2.97			
	HS	3.43	2.37	3.90	2.17	2.60	2.89			
Total		3.58	2.60	4.01	2.50	2.92	2.923			
AST (IU/l)	F	53.00	47.00	34.00	41.67	45.00	44.13	1.07*	1.39**	2.40**
	LS	52.23	49.33	41.33	51.67	61.67	51.27			
	HS	52.33	52.33	45.67	50.67	64.00	53.00			
Total		52.56	49.56	40.33	48.00	56.89	49.46			
ALT (IU/l)	F	11.33	10.00	11.00	10.33	9.33	10.40	0.379**	0.489**	0.848**
	LS	11.67	12.67	15.33	17.00	16.33	14.60			
	HS	11.00	14.33	17.00	18.67	18.33	15.87			
Total		11.33	12.33	14.44	15.33	14.67	13.62			
AChE in blood (mmol/ml/h)	F	113.9	111.5	99.1	84.4	71.1	95.98	6.078**	7.846**	13.590**
	LS	114.2	73.8	68.0	49.4	36.5	68.34			
	HS	113.4	74.8	66.4	45.4	29.4	65.21			
Total		113.8	85.58	77.85	59.62	45.68	76.75			
AChE in RBCs (mmol/ml/h)	F	113.9	111.5	97.5	85.3	69.5	95.57	5.951*	7.683**	13.306
	LS	114.2	73.7	64.0	56.6	46.3	70.97			
	HS	113.4	71.5	58.7	54.0	37.5	66.99			
Total		113.8	85.57	73.40	65.31	51.11	77.84			
AChE in plasma (mmol/ml/h)	F	17.4	15.8	14.2	12.5	9.6	13.90	0.629*	0.812**	1.407
	LS	17.2	10.9	9.2	7.6	5.3	10.04			
	HS	16.7	9.5	8.0	5.6	4.6	8.89			
Total		17.08	12.07	10.50	8.57	6.51	10.94			
ECF (ml/kg BW)	F	358.1	293.6	268.7	258.4	234.6	282.7	8.12*	10.48**	18.16
	LS	354.1	240.9	228.8	210.7	190.5	245.0			
	HS	353.6	228.2	221.6	194.5	164.6	232.5			
Total		355.2	254.2	239.7	221.2	196.6	246.7			
ISF (ml/kg BW)	F	310.0	226.9	227.9	182.3	187.8	227.0	9.33*	12.04**	20.85
	LS	300.0	196.2	194.0	157.1	150.6	199.6			
	HS	313.3	188.5	188.0	147.1	141.9	195.8			
Total		307.8	203.9	203.3	162.2	160.1	200.8			
PV (ml/kg BW)	F	51.93	66.67	40.80	76.17	46.87	56.39	3.074*	3.968**	6.874
	LS	54.07	44.67	34.17	53.57	39.97	45.30			
	HS	40.23	39.17	33.57	47.30	36.03	39.26			
Total		48.58	50.17	36.20	59.01	40.96	47.01			
BV (ml/kg BW)	F	83.37	92.80	62.57	102.9	66.83	81.69	3.728*	4.813**	8.336
	LS	87.03	67.23	52.43	67.53	58.20	66.49			
	HS	67.57	56.00	59.27	63.13	57.33	60.86			
Total		79.66	72.01	58.09	77.86	60.79	69.61			

[a] F: fresh water (280 ppm TDS), LS: low saline water (7650 ppm TDS), HS: high saline water (13,535 ppm TDS), AST: aspartate aminotransferase, ALT: alanine aminotransferase, S.E.: standard error.

* $p < 0.05$.

** $p < 0.01$.

Table 4
Least squares means of BW, blood components and fluid compartments of camels as affected by water salinity and diet level[a]

Parameter	Water type	Periods					Overall	S.E.		
		P1	P2	P3	P4	P5		Salinity	Period	Interaction
Glucose (mmol/l)	F	6.33	6.27	6.86	5.07	4.27	5.75	0.144	0.186**	0.322
	LS	5.67	6.43	6.60	5.23	4.00	5.59			
	HS	6.33	6.27	6.43	5.10	3.83	5.59			
Total		6.11	6.32	6.62	5.13	4.03	5.643			
AST (IU/l)	F	49.67	49.33	34.67	29.33	33.67	39.33	1.808*	2.334**	4.043
	LS	51.67	54.33	39.00	36.67	46.67	45.67			
	HS	49.33	53.33	41.33	41.67	49.33	47.00			
Total		50.22	52.33	38.33	35.89	43.22	44.00			
ALT (IU/l)	F	10.67	9.33	10.33	10.00	7.33	9.53	0.454**	0.586*	1.010**
	LS	11.33	11.00	11.33	13.00	15.67	12.47			
	HS	11.00	10.67	12.67	13.67	17.00	13.00			
Total		11.00	10.33	11.44	12.22	13.33	11.67			
AChE in blood (mmol/ml/h)	F	87.2	87.2	86.8	84.0	67.4	82.52	3.56	4.60**	7.96
	LS	87.7	95.2	91.3	79.5	61.6	83.06			
	HS	87.6	90.8	88.2	77.1	61.3	81.02			
Total		87.51	91.07	88.79	80.21	63.42	82.19			
AChE in RBCs (mmol/ml/h)	F	118.5	129.0	128.9	113.8	92.3	116.5	11.28	14.56*	25.22
	LS	118.5	131.5	125.3	92.2	71.8	107.9			
	HS	122.6	131.8	122.4	70.2	58.4	101.1			
Total		119.9	130.8	125.5	92.09	74.14	108.5			
AChE in plasma (mmol/ml/h)	F	13.63	14.87	14.50	15.57	13.07	14.33	0.950	1.227**	2.125
	LS	14.97	16.70	15.63	14.07	8.33	13.94			
	HS	15.60	16.20	15.73	14.13	6.47	13.63			
Total		14.73	15.92	15.29	14.59	9.29	13.97			
ECF (ml/kg BW)	F	398.7	372.7	379.7	347.1	323.7	364.4	23.85	30.79*	53.34
	LS	400.3	371.0	365.7	299.7	289.1	345.2			
	HS	400.7	371.1	364.6	321.3	228.0	337.1			
Total		399.9	371.6	370.0	322.7	280.3	348.9			
ISF (ml/kg BW)	F	353.3	332.9	324.3	304.4	301.2	323.8	24.62	31.79*	55.06
	LS	400.3	328.5	330.1	290.8	264.5	322.8			
	HS	400.7	335.9	335.5	282.0	198.1	310.4			
Total		384.8	332.4	330.0	292.4	254.6	318.8			
PV (ml/kg BW)	F	45.2	39.8	38.8	42.7	22.5	37.79	1.91	2.46**	4.27
	LS	35.1	42.5	35.6	42.3	24.6	36.02			
	HS	35.5	34.5	29.1	39.3	29.9	33.67			
Total		38.61	38.96	34.49	41.42	25.7	35.83			
BV (ml/kg BW)	F	64.3	59.7	57.3	61.4	32.5	55.05	2.60	3.35**	5.80
	LS	50.4	64.0	54.9	58.2	34.2	52.33			
	HS	52.5	55.1	47.4	58.8	47.4	52.25			
Total		55.73	59.60	53.22	59.47	38.02	53.21			

[a] F: fresh water (280 ppm TDS), LS: low saline water (7650 ppm TDS), HS: high saline water (13,535 ppm TDS), AST: aspartate aminotransferase, ALT: alanine aminotransferase, S.E.: standard error.

* $p < 0.05$.

** $p < 0.01$.

the P5 period, the F group showed a normal value (45.0 IU/l) while the other two saline treatment groups recorded their highest averages (61.67 and 64.0 IU/l for LS and HS, respectively). These different trends of the treatment groups within the P5 period made the interaction period × salinity significant. Feed intake during this period was low in both energy (81% of TDN requirement) and protein (71% of DCP requirement). Similar trend was found during the P4 period when feed intake was 105% of TDN and 71% of DCP requirements. It seemed that saline load affected AST release in the blood of sheep under low protein intake. However, during the P1 period there was a tendency for all saline treatment groups to increase the AST level to reach a mean of 52.56 IU/l as compared to the known normal level in the range 48–50 IU/l. This may indicate an effect on liver function due to increased intake of both energy (116% of TDN requirement) and protein (142% of DCP requirement).

ALT or GPT in sheep was significantly ($p < 0.01$) affected by all sources of variance in this experiment (Table 3). The mean ALT concentration was 13.62 IU/l. On average the level of ALT increased with increasing salinity of the drinking water (10.40, 14.60 and 15.87 IU/l for F, LS and HS groups, respectively). Values of the fresh water group (control) along the experimental period ranged between 9.33 and 11.33 IU/l. The low salinity group (LS) recorded high values of ALT (15.33 to 17.0 IU/l) from the P3 to P5 period, while the HS group showed high values (14.33 to 18.67 IU/l) for a longer period of time (P2–P5). The highest means for ALT were during the P3, P4 and P5 periods (14.44, 15.33 and 14.67 IU/l, respectively) when TDN intake was 105–86% and DCP intake was 95–71% of maintenance. It can be concluded that ALT was released more, indicating liver hyperfunction in sheep due to the increase in salinity of drinking water, especially at a decreased nutrient intake. In addition, glucose level decreased with saline administration. This indicated the incidence of energy expenditure by sheep for coping with saline load, which exerted a stress on the liver function. Other stress such as high environmental temperature was found to increase the level of both enzymes in sheep by inducing an increase in gluconeogenesis, stimulated by higher secretion of the glucocorticoids (Boyd and Ford, 1967; Madian, 1989; Badawy, 1999). High saline concentration and feed shortage were found by Assad et al. (1997b) to increase adrenocorticotrophic hormones index in both sheep and camels.

The level of AST recorded in camels was generally lower than in sheep. The changes of AST concentration in camels was significantly ($p < 0.01$) affected by salinity and the period (Table 4). The fresh water group exhibited normal values (34.67, 29.33 and 33.67 IU/l) during the P3, P4 and P5 periods, respectively. Throughout these periods protein intake was low (78, 72 and 56% of maintenance, respectively), which indicated that low protein intake did not affect liver function in camels in contrast to what happened in sheep. All groups exhibited normal values of AST during the P3 and P4 periods, which had the lowest values (38.33 and 35.89 IU/l, respectively). Intake during these two periods was 97 and 104% of TDN and 78 and 72% of DCP maintenance requirements, respectively. The highest values of AST were recorded during the P1 and P2 periods (50.22 and 52.33 IU/l, respectively). Protein intake during these two periods was 124 and 125%, while TDN intake was 117 and 108% of maintenance requirements, respectively (Table 1). High energy and protein intake seemed to exert a load on liver function of camels. During all periods, saline treated groups had higher values than the control. High saline concentration (13,535 ppm DS) affected liver function under low nutrient intake, as the HS group recorded high AST value (49.33 IU/l) during the P5 period when intake was 92% of TDN and 56% of DCP requirements. Metwally (2001) found an increase in the AST level in camels due to drinking saline water (14,540 ppm TDS) from 49.3 in group drinking fresh water to 55.3 IU/l in group drinking saline water during summer. He found the corresponding AST values in winter were 50.0 and 54.9 IU/l, respectively.

ALT levels in camels were significantly affected by salinity ($p < 0.01$), period ($p < 0.05$) and the interaction between salinity and period ($p < 0.05$). The mean concentration of this enzyme in camels was 11.67 IU/l. The mean for both the P4 (12.22 IU/l) and the P5 (13.33 IU/l) periods were highest throughout the experimental period. The fresh water group or control showed normal levels (7.33–10.00 IU/l) throughout these two periods, while saline treatment groups had higher values (13.0–16.67 IU/l for the LS group and 13.67–17.0 IU/l for the HS group). This trend made the significant ($p < 0.01$) interaction and

indicated that this enzyme was affected by saline load under low feed intake. High nutrient intake did not affect this enzyme. Metwally (2001) found an increase in the ALT level in camels due to drinking saline water (14,540 ppm TDS) from 15.9 in group drinking fresh water to 17.8 IU/l in group drinking saline water during summer. He found the corresponding ALT values in winter were 14.9 and 16.3 IU/l, respectively.

3.4. Acetylcholine esterase enzyme (AChE)

In sheep, salinity and period significantly affected the activity of this enzyme in the three respective sites, blood, RBCs and plasma (Table 3). During the P1 period, when intake was 116% of TDN and 142% of DCP requirements, all groups showed the maximum enzyme activity in blood, RBCs and plasma, without any differences due to saline treatment. From the P2 period, decreasing nutrient intake led to progressive depression in the overall mean activity of AChE reaching 40% in blood, 45% in RBCs and 38% in plasma at the P5 period as compared to its activity during the P1 period. Reducing protein intake might inversely affect the enzyme synthesized. Bell et al. (1961) stated that lack of thiamin disturbs properties of the nerve fibers. Protein deficiency might cause a blockage to the system acetylcholine, choline acetylase and acetylcholine esterase in cholinergic nerve fibers.

The effect of saline treatment on AChE started at the P2 period (after 80 days of the start) with a similar inhibition in both salinity levels. During this period, activity of AChE of HS group in blood and RBCs decreased from its basal level in the control group to about 67% and 64%, respectively. Plasma AChE (pseudo enzyme) in the HS group during the same period (P2) decreased to 60% of its level in the control group, while in the LS group that enzyme decreased to 69% only. The damage of the cells of brain, liver and muscle due to salt poisoning would lead to decrease of pseudo enzyme in serum according to the results of Ganong (1977) and Moursi et al. (1979). The high increase of the AST level in the HS group during the P2 period (52.33 IU/l) might reflect a change in liver cells of the experimental ewes due to salt intake resulting in the reduction in pseudo AChE level in plasma as it is manufactured in the liver cells. With longer periods the effect of saline treatment was augmented. During the P5 period (after 200 days of the start of the treatment), activity of AChE was depressed due to LS treatment to 51, 67 and 55% of its original activity (control group), in blood, RBCs and plasma, respectively. The corresponding inhibited percents due to HS level were 41, 54 and 48%. These results indicated an inverse correlation between salt concentration and the activity of AChE enzyme. This is in agreement with Assad and Bayoumi (1991) who found that AChE enzyme activity in adult rams was reduced by increasing salt intake via the water to 73.4, 71.1 and 57.6% in blood, RBCs and plasma, respectively. The inhibition of true AChE enzyme activity due to saline treatment could be interpreted on the base of osmotic fragility of RBCs. Georgiev (1968) reported a reduced haematocrit, reduced capillary resistance, and increased osmotic fragility of RBCs of rats, rabbits and hens given NaCl. Moreover, the enzyme choline–cholinesterase system in nervous tissues was stated to be affected by the presence of magnesium and calcium (Bell et al., 1961). Excess magnesium reduces the release of acetylcholine at motor nerve endings. In the present study, diluted seawater was rich in magnesium as shown previously.

In camels, the inhibition in AChE enzyme occurred at later stages as compared to sheep. The mean AChE activity in blood and RBCs decreased during the P4 and P5 periods, while that in plasma decreased only at the P5 period. Decreased nutrient intake had lower effect on the activity of AChE in camels as compared to sheep.

The decrease recorded during the P4 and P5 periods was mainly due to the lower values in both the LS and HS groups (Table 4). The effect of saline on the activity of AChE enzyme in camels started at a later stage, compared to its effect on sheep. The activity of AChE in the blood of the LS group decreased during the P4 and P5 periods to 95 and 91% of the values recorded in the control group. The corresponding concentration decrease in the HS group was 92 and 91%, respectively. Concerning AChE concentration in the RBCs during the P4 and P5 periods, the decrease was 81 and 78% in LS group and 62 and 63% in HS group, respectively. Plasma AChE activity was affected by salinity only during the P5 period, when it decreased to 64 and 50% in LS and HS groups, respectively. These results indicated less inhibition due to saline treatment than in sheep. Camels demonstrated a higher tolerance to saline load and feed shortages than sheep.

3.5. Body fluid compartments

In sheep, all fluid compartments were affected by both saline intake ($p < 0.05$) and the level of feed intake ($p < 0.01$). It should be mentioned that water intake of these animals was increased by increasing saline intake and declined by decreasing nutrient intake (Assad et al., 1997b). Average water intake was 3005, 4305 and 4115 ml/100 kg BW for the F, LS and HS groups, respectively. Water intake decreased from 5478 at the P1 period to 2793 ml/100 kg BW at the P5 period (Table 1), due to the decrease in air temperature and low feed intake (Table 1). Both ECFs and ISFs were at the highest level during the P1 period without an effect due to salinity. These two compartments started to decrease at the P2 period with an augmented decline as the period advanced and the adverse effect of saline water on ECF and ISF became clear. In contrast to the amounts of water intake these two compartments showed a decline inversely proportional to salinity concentration (Table 3). Extra water intake under saline treatment seemed to be reserved in other fluid compartments. In growing rams El-Sherif and El-Hassanein (1996) recorded that by drinking diluted seawater (13,100 ppm TDS), after 5 months treatment, a large portion of the increased total body water was encountered within the ICF with a decrease in both ECF and PV. This situation may be due to the excessive excretion of sodium (Na) from ISF and retention of potassium (K) within ICF in animals drinking saline water (Peirce, 1962; Tomas et al., 1973; Kawashti et al., 1983; Ahmed et al., 1985; Khamis et al., 1989). In the present study, the decline in ISF with time reflected either the effect of low feed and water intake, or exhaustion due to the long time of drinking saline water, or both. Restricting feed intake would reduce available energy for renal filtration, reabsorption and excretion, which complicate the water and mineral balance.

PV was lowest (36.20 ml/kg BW) at the P3 period (after 120 days of start), while the highest value (59.01 ml/kg BW) was recorded at the P4 period (after 160 days of start) without any obvious relation to feed and water intake or ambient temperature. Estimated BV had the lowest level (58.09 ml/kg BW) at the P3 period. The highest level of BV (79.66 ml/kg BW) was recorded at the P1 period, where feed intake was 116% of TDN and 142% of DCP requirements. In the same type of animals Assad et al. (1997b) found a high feed intake led to an increase in blood cell content, where packed cell volume increased from 31.0 to 39.4%, resulting in an increase in BV and specific gravity. The inverse effect of salinity was observed from onset especially in the HS group. The decrease in PV and BV in sheep due to salinity was stated to result in hemoconcentration (Assad et al., 1994; El-Hassanein and El-Sherif, 1996). In addition, reduction in ISF and PV values would decrease the animal's efficiency in thermoregulation under hot desert conditions. These two compartments (ISF and PV) were proved by Kamal et al. (1978), Mishra et al. (1983) and Assad et al. (1997a) to play an important role in coping with heat stress, by evaporation.

In camels, the time intervals affected body fluid compartments examined (Table 4). The means of both ECF and ISF declined as time progressed from 399.9 and 384.8 ml/kg BW during the P1 period to 280.3 and 254.6 ml/kg BW during the P5 period. Both PV and BV recorded the lowest values at P5 (25.70 and 38.02 ml/kg BW, respectively), while it fluctuated during other periods. Water intake of camels declined significantly ($p < 0.05$) from 2276 ml/100 kg BW per day during the P1 period to 1565 ml/100 kg BW per day at the P5 period (Table 1). This decline was due to the decrease in ambient temperature and feed intake during the P5 period. High saline treatment significantly ($p < 0.05$) increased water intake from 1340 to 1912 ml/100 kg BW per day (Assad et al., 1997b), without any effect on the camels' body fluid. This indicated again a better tolerance of camels to drinking saline water compared to sheep. It worth noting in this experiment that camels had higher ECF and ISF but lower PV and BV relative to BW unite as compared to sheep.

4. Conclusion

In conclusion, the results of this study indicate that camels are more tolerant than sheep to effects of both saline load and nutrient shortage. Feed shortage led to a final decrease in live BW of camels amounted to 1.9% only compared to 8.4% for sheep. In addition saline load did not affect blood glucose and ECF levels of camels. Camels protected themselves from salt stress by lowering the amount of water intake per unit of body size as compared to sheep. In addition,

both saline load and feed shortage showed a delayed suppressive effect on the activity of AChE of camels compared to sheep. Moreover, the low and high protein intake had less effect on liver function of camels as compared to sheep.

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