

## Effect of State of Hydration on Body Weight, Blood Constituents and Urine Excretion in Nubian Goats (*Capra hircus*)

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**Abstract:** The objective of this study was to evaluate the physiological responses to state of hydration in female Nubian goats. The effects of 3 days of dehydration and 2 days of rehydration on body weight (BW), blood constituents and urine excretion were monitored. The daily feed intake was significantly decreased by water deprivation. The feed intake returned to control level within 2 days after rehydration. The mean (BW) decreased significantly (20.2%) in dehydrated animals. The loss in (BW) was recovered immediately after drinking. Water deprivation resulted in a significant increase in rectal temperature (Tr), it returned to normal level after drinking. There was marked significant increase in packed cell volume (PCV) in dehydrated animals, the (PCV) returned to normal level after rehydration. Water deprivation was associated with significant increases in serum concentrations of total protein, albumin, urea and creatinine, after rehydration, these parameters returned to the control level, except albumin. Water deprivation and rehydration had no significant effect on plasma glucose and serum sodium (Na) and potassium (K) levels. Serum osmolality increased progressively and significantly during water deprivation and returned to normal level on the second day of rehydration. The glomerular filtration rate (GFR) and urine volume decreased significantly during dehydration and returned to normal level in the second day of rehydration. Dehydration was associated with significant increase in urine urea concentration; following rehydration the urea level decreased to control level in the second day.

**Key words:** Dehydration • Rehydration • Body weight • Blood constituents • Urine excretion • Goats

### INTRODUCTION

The goat population in Sudan is estimated at about 42 million head [1] distributed mainly in arid and semi-arid zones. The goats play a vital role in rural economy and in traditional agricultural production. Goats fulfil multiple roles in the household nutrition and food security; they provide families with proteins of high biological value as milk and meat; also they provide skin, fibre and manure.

Goats are considered to be adapted to water scarcity and feed shortage. They have the ability to utilize various types of forages and tolerate harsh environments in marginal and semi-arid regions, considered unfavourable for other domestic ruminants [2]. Low rainfall affects water and feed availability and drinking water is often a limiting factor for goats grazing semi-arid zone. The endurance of long periods of watering in semi-arid zones allows the animals to graze at long distances from dispersed watering

points. Under semi-arid conditions in Sudan, goats may be exposed to stressful conditions and constraints which include prolonged heat and periodic droughts, factors which influence critically their water and energy metabolism. Furthermore, goats have to walk long distances in pursuit of feed and water. Derangements in water and energy metabolism influence the health and productivity of goats. However, physiological mechanisms evolved by animals inhabiting arid lands may enable them to survive and reproduce in the marginal areas [3].

The maintenance of water homeostasis by controlling the osmolality and blood volume is essential for survival of animals. The body water is tightly controlled by regulating both water intake and urinary water excretion [4]. During dehydration, an increase in plasma osmolality acts on osmoreceptors in the hypothalamus to stimulate thirst and increase the release of the antidiuretic hormone

arginine vasopressin (AVP) from the posterior pituitary [5]. The hormone (AVP) increases the water permeability of the collecting ducts in kidneys [6]. The kidneys are responsible for maintaining the total body water and its distribution, electrolyte composition of body fluids and acid-base balance [7].

Water deprivation may have detrimental effects on the physiological performance, productivity and welfare of ruminants [8, 9]. Water loss and associated decrease in feed intake reduced milk yield in goats [10-12]. Water deprivation also caused an increase in the viscosity of milk as well as concentrations of protein, fat, lactose and minerals [13]. During dehydration, the physiological changes which take place may alter the disposition of common drugs administered in goats mainly due to reduced distribution of drugs in tissues and slower elimination as a result of diminished liver and kidney functions [14], thus reducing the efficiency of treatments and health status.

The Nubian goats originated in Sudan and they constitute about 46% of the goat population in the country. They are considered as the main dairy breed and are reared mainly in the semi-arid zone in the northern part of the country, north of latitude 12°N [15]. During hot dry summer conditions, the goats may suffer various degrees of dehydration, consequently their physiological responses may be affected. This study was initiated with the objective of evaluation of the effects of water deprivation and rehydration on body weight, feed intake, blood constituents and urine excretion in Nubian goats under tropical summer conditions.

## MATERIALS AND METHODS

**Animals:** Eight healthy adult non-gestating and non-lactating Nubian goats were used in the study. The goats were 2-3 years old and weighed 18-22 kg at the beginning of the study. The animals were kept under shade in the animal house for an adaptation period of 2 weeks. During this period the animals became accustomed to handling and various experimental conditions. All animals were subjected to clinical examination before the beginning and during the course of the study and were given prophylactic antibacterial treatment. The animals were ear tagged for identification and accommodated individually in metabolic cages to facilitate measurements of feed and water intake and collection of total urine volume.

**Experimental Procedure:** The experimental animals were randomly assigned to two groups of 4 each, control and treated. The experimental protocol comprised 3 phases: phase I: (euhydraton) where water and feed were available *ad libitum* for both control and treated group of animals. In phase 2: (dehydration) the treated group animals were deprived of drinking water for 3 consecutive days, food, however, was offered as usual. In phase 3: (rehydration), at the end of the third day of water deprivation, water was offered freely to the animals; this period lasted for 2 days. The measurements of feed and water intake (when made available), urine volume, body weight (BW), rectal temperature (Tr) and collections of blood and urine samples were performed, initially, every day during dehydration and after 4 hrs and for 2 days following rehydration.

**Climatic Conditions:** The experiment was conducted during dry summer conditions. The daily maximum, minimum and mean ambient temperature (Ta) and relative humidity (RH) were obtained from Shambat Meteorological Station located about 500 meters from the experimental site. The daily mean (Ta) was 34.8°C (range 27.1 - 42.4°C) and the mean (RH) was 25.5%.

**Feed and Water Consumption:** Each animal was supplied daily at 8.00 a.m. with 1.0 kg of lucerne hay (CP: 17.5 %; ME: 7.8 MJ/kg) and 6.0 litres 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 10 mL. Samples of lucerne hay were collected and dried at 105°C in an oven to constant weight for the 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 the animals.

**Rectal Temperature (Tr):** The rectal temperature of goats was measured by a digital clinical thermometer (Hartman -United Kingdom) with an accuracy of  $\pm 0.1^{\circ}\text{C}$ .

**Body weight (BW):** During the experimental period, the animals were weighed in the morning to the nearest 0.20 kg using a spring balance (SALTER - England).

**Blood Collection and Processing:** Blood samples (6 mL) were drawn from the jugular vein of animals using disposable syringes. Immediately 1 mL of blood was transferred to a capped test tube containing an anticoagulant ( $K_3$  EDTA) for blood analysis. 1 ml of blood was kept in a test tube containing sodium fluoride and after centrifugation, the plasma sample was used for glucose determination. The rest of the blood sample was allowed to stay for 4-5 hrs at room temperature and then centrifuged (Gallenkamp Junior) at 3000 r.p.m. for 15 min. Haemolysis-free serum was transferred to clean plastic vials and immediately frozen at  $-20^{\circ}\text{C}$  for subsequent analysis.

**Packed Cell Volume (PCV):** The (PCV) of erythrocytes was determined (in duplicate) using a microhaematocrit centrifuge (Hettich, Tuttlingen, Germany).

**Plasma Glucose:** The plasma glucose level was determined by the enzymatic colorimetric method using a kit (Randox Laboratories Ltd, London).

**Serum Metabolites:** Serum total protein concentration was determined using Biuret reagent [16]. Serum albumin concentration was determined by a colorimetric method [17]. Serum urea concentration was determined by the enzymatic colorimetric test (Berthot) using a kit (Spinreact, S.A., Spain). Serum creatinine level in plasma and urine was measured according to the method described [18].

**Serum Minerals:** The concentrations of serum sodium (Na) and potassium (K) were determined by a flame photometer (Jenway PFP7, United Kingdom ) [16].

**Serum Osmolality:** The osmolality of serum was determined by freezing point depression utilizing an osmometer (Osmometer 030, Gonotec GmbH, Berlin, Germany).

**Glomerular Filtration Rate (GFR):** The endogenous creatinine clearance was used for estimation of (GFR) in goats according to the standard method [19]. In this method, the serum and urine concentrations of endogenous creatinine were determined, also the total urine volume excreted in 24 hrs was collected and measured. The renal clearance was determined by the following equation:

$$C_{cr} = \frac{U_{cr} V}{P_{cr}}$$

Where

$C_{cr}$  = Clearance of creatinine (mL/min),

$U_{cr}$  = Concentration of creatinine in urine (mg /mL);

$V$  = Rate of urine formation (mL / min)

$P_{cr}$  = Concentration of creatinine in plasma (mg/mL).

The standard values for creatinine clearance (GFR) were expressed as (mL/min/kg body weight).

**Urine Collection and Analysis:** Urine was collected daily at 8.20 in plastic bottles fitted beneath the metabolic cages. To each bottle, liquid paraffin was added with the object of stopping evaporation, while 10 mL of concentrated hydrochloric acid were added as a preservative. The volume of urine voided by each animal was measured in a measuring cylinder to the nearest 10 mL. Samples of urine (10 mL) were kept frozen at ( $-20^{\circ}\text{C}$ ) for subsequent analysis of urea according to the technique used for serum samples.

**Statistical Analysis:** The experimental data were subjected to standard methods of statistical analysis [20]. Analysis of variance test (ANOVA) was used to evaluate the effects of state of hydration on the parameters measured. The control and treated group were compared during the course of the experiment. The student (t) test was used to compare the control and treated group initially and during dehydration and rehydration.

## RESULTS

The effects of experimental treatments on water consumption, feed Intake, body weight (BW) and rectal temperature (Tr) are shown in Table 1.

**Water Consumption:** During normal hydration (euhydration) there was no significant difference in water consumption between treated and control group. At the end of dehydration period, treated goats drank an average of 4.6 litres of water during the first 15 min. of rehydration. The mean ingested water accounted for 31% of their dehydrated (BW). In the first day of rehydration the treated group maintained significantly ( $P<0.01$ ) higher water intake compared to the control.

Table 1: Effects of dehydration and rehydration on water consumption, feed intake, body weight (BW) and rectal temperature (Tr) of goats

Parameter		Euhydration	Dehydration			Rehydration		
			Day 1	Day 2	Day 3	4 hr	Day 1	Day 2
Water consumption (L/day)	Control	2.65±0.44 <sup>a</sup>	2.83±0.36	2.82±0.41	2.43±0.98	-	2.80±0.70 <sup>a</sup>	2.52±0.21 <sup>a</sup>
	Treated	2.77±0.56 <sup>a</sup>	-	-	-	-4.6±0.21	5.25±0.54 <sup>b</sup>	1.88±0.67 <sup>a</sup>
	LS	NS	-	-	-	-	**	NS
Feed intake (kg/day)	Control	0.84±0.10 <sup>a</sup>	0.85±0.11 <sup>a</sup>	0.86±0.17 <sup>a</sup>	0.75±0.13 <sup>a</sup>	-	0.81±0.14 <sup>a</sup>	0.83±0.06 <sup>a</sup>
	Treated	0.91±0.11 <sup>a</sup>	0.38±0.13 <sup>b</sup>	0.077±0.22 <sup>b</sup>	0.051±0.025 <sup>b</sup>	-	0.50±0.10 <sup>b</sup>	0.57±0.19 <sup>b</sup>
	LS	NS	**	***	***	-	*	*
Body weight (kg)	Control	20.0±1.15 <sup>a</sup>	20.0±1.15 <sup>a</sup>	20.33±0.97 <sup>a</sup>	20.52±1.05 <sup>a</sup>	20.52±1.1 <sup>a</sup>	20.65±1.07 <sup>a</sup>	20.77±0.75 <sup>a</sup>
	Treated	19.15±1.10 <sup>a</sup>	17.00±0.82 <sup>b</sup>	16.07±1.04 <sup>b</sup>	14.9±0.49 <sup>b</sup>	19.42±1.07 <sup>a</sup>	19.42±1.08 <sup>a</sup>	19.00±0.47 <sup>a</sup>
	LS	NS	**	**	***	NS	NS	-
Tr (°C) 8:0a.m.	Control	38.58±0.36 <sup>a</sup>	38.67±0.29 <sup>a</sup>	38.47±0.23 <sup>b</sup>	37.90±0.35 <sup>b</sup>	38.0±0.20 <sup>a</sup>	37.97±0.33 <sup>a</sup>	38.20±0.08 <sup>a</sup>
	Treated	38.60±0.22 <sup>a</sup>	39.15±0.37 <sup>a</sup>	39.88±0.17 <sup>a</sup>	39.90±0.34 <sup>a</sup>	37.97±0.17 <sup>a</sup>	38.25±0.39 <sup>a</sup>	38.50±0.17 <sup>a</sup>
	LS	NS	NS	*	*	NS	NS	NS

Means bearing different superscripts are significantly different

LS: Level of significance

\*P< 0.05, \*\*P< 0.01, \*\*\*P< 0.001

NS: Not significant

Table 2: Effects of dehydration and rehydration on serum concentrations of (Na), (K) and serum osmolality in goats

Parameter		Euhydration	Dehydration			Rehydration		
			Day 1	Day 2	Day 3	4 hr	Day 1	Day 2
Na (mEq/L)	Control	133.25±2.87 <sup>a</sup>	135.00±3.55 <sup>a</sup>	135.00±3.65 <sup>a</sup>	133.5±1.73 <sup>a</sup>	129.50±4.60 <sup>a</sup>	133.25±1.71 <sup>a</sup>	128.5±2.35 <sup>a</sup>
	Treated	129.75±3.42 <sup>a</sup>	132.00±1.83 <sup>a</sup>	134.75±1.70 <sup>a</sup>	133.25±1.5 <sup>a</sup>	134.50±0.58 <sup>a</sup>	133.75±0.96 <sup>a</sup>	130.25±3.78 <sup>a</sup>
	LS	NS						
K (mEq/L)	Control	4.12±0.32 <sup>a</sup>	4.77±0.74 <sup>a</sup>	4.52±0.60 <sup>a</sup>	4.4±0.37 <sup>a</sup>	4.15±0.13 <sup>a</sup>	4.38±0.33 <sup>a</sup>	4.20±0.21 <sup>a</sup>
	Treated	4.25±0.17 <sup>a</sup>	4.55±0.17 <sup>a</sup>	4.57±0.67 <sup>a</sup>	4.70±0.18 <sup>a</sup>	4.10±0.21 <sup>a</sup>	4.13±0.29 <sup>a</sup>	4.10±0.29 <sup>a</sup>
	LS	NS						
Osmolality (mOsmol/ kg)	Control	287.5±7.14 <sup>a</sup>	287.0±6.21 <sup>b</sup>	292.7±3.86 <sup>b</sup>	276.5±10.34 <sup>b</sup>	280.2±8.73 <sup>b</sup>	286.6±8.66 <sup>a</sup>	284.5±7.76 <sup>a</sup>
	Treated	297.0±7.78 <sup>a</sup>	305.0±7.83 <sup>a</sup>	330.7±9.38 <sup>a</sup>	344.0±11.26 <sup>a</sup>	309.6±11.56 <sup>a</sup>	289.2±9.78 <sup>a</sup>	284.3±8.14 <sup>a</sup>
	LS	NS	*	**	**	*	NS	NS

Means bearing different superscripts are significantly different

LS: Level of significance

\*P< 0.05, \*\*P< 0.01

NS: Not significant

Table 3: Effects of dehydration and rehydration on (PCV), serum concentrations of total protein, albumin, urea, creatinine and plasma glucose in goats

Parameter		Euhydration	Dehydration			Rehydration		
			Day 1	Day 2	Day 3	4 hr	Day 1	Day 2
PCV (%)	Control	24.25±0.50 <sup>a</sup>	24.75±0.50 <sup>b</sup>	25.50±0.58 <sup>b</sup>	25.75±0.96 <sup>b</sup>	25.86±0.96 <sup>b</sup>	26.00±0.82 <sup>b</sup>	25.25±1.70 <sup>a</sup>
	Treated	24.50±0.58 <sup>a</sup>	26.75±0.90 <sup>a</sup>	31.50±1.00 <sup>a</sup>	37.00±0.82 <sup>a</sup>	30.10±0.50 <sup>a</sup>	29.00±0.73 <sup>a</sup>	25.50±0.50 <sup>a</sup>
	LS	NS	*	**	***	**	*	NS
Total protein (g/dL)	Control	7.60±0.42 <sup>a</sup>	7.33±0.66 <sup>a</sup>	7.35±0.49 <sup>b</sup>	7.10±0.55 <sup>b</sup>	7.15±0.34 <sup>b</sup>	7.10±0.58 <sup>a</sup>	7.10±0.74 <sup>a</sup>
	Treated	7.00±0.22 <sup>a</sup>	7.92±0.40 <sup>a</sup>	8.97±0.91 <sup>a</sup>	8.90±0.60 <sup>a</sup>	7.85±0.31 <sup>a</sup>	6.68±0.49 <sup>a</sup>	7.20±0.52 <sup>a</sup>
	LS	NS	NS	*	*	*	NS	NS
Albumin (g/dL)	Control	3.27±0.46 <sup>a</sup>	3.48±0.34 <sup>a</sup>	2.90±0.29 <sup>b</sup>	3.00±0.26 <sup>b</sup>	3.20±0.37 <sup>b</sup>	2.90±0.32 <sup>b</sup>	3.15±0.31 <sup>a</sup>
	Treated	3.10±0.51 <sup>a</sup>	3.50±0.33	3.62±0.70 <sup>a</sup>	4.30±1.10 <sup>a</sup>	3.90±0.53 <sup>a</sup>	3.55±0.51 <sup>a</sup>	3.21±0.21 <sup>a</sup>
	LS	NS	NS	*	*	*	*	NS
Urea (mg/dL)	Control	28.00±3.10 <sup>a</sup>	27.75±2.86 <sup>a</sup>	26.5±2.18 <sup>b</sup>	29.75±2.86 <sup>b</sup>	27.25±3.19 <sup>b</sup>	25.25±2.98 <sup>a</sup>	24.50±3.74 <sup>a</sup>
	Treated	29.30±2.91 <sup>a</sup>	36.00±2.13 <sup>a</sup>	39.50±3.10 <sup>a</sup>	40.50±3.80 <sup>a</sup>	40.10±3.91 <sup>a</sup>	26.25±3.84 <sup>a</sup>	26.50±2.11 <sup>a</sup>
	LS	NS	NS	*	*	*	NS	NS
Creatinine (mg/dL)	Control	0.630±0.17 <sup>a</sup>	0.67±0.10 <sup>a</sup>	0.60±0.10 <sup>b</sup>	0.68±0.10 <sup>b</sup>	0.70±0.10 <sup>b</sup>	0.60±0.10 <sup>a</sup>	0.68±0.11 <sup>a</sup>
	Treated	0.60±0.14 <sup>a</sup>	0.82±0.10 <sup>a</sup>	0.93±0.17 <sup>b</sup>	1.10±0.13 <sup>a</sup>	0.90±0.12 <sup>a</sup>	0.75±0.21 <sup>a</sup>	0.67±0.21 <sup>a</sup>
	LS	NS	NS	*	*	*	NS	NS
Glucose (mg/dL)	Control	70.50±3.41 <sup>a</sup>	68.00±5.65 <sup>a</sup>	70.0±4.32 <sup>a</sup>	69.50±6.14 <sup>a</sup>	71.50±5.74 <sup>a</sup>	66.0±2.71 <sup>a</sup>	62.74±5.73 <sup>a</sup>
	Treated	71.75±1.50 <sup>a</sup>	67.00±6.83 <sup>a</sup>	69.50±5.19 <sup>a</sup>	68.25±4.27 <sup>a</sup>	67.50±1.00 <sup>a</sup>	61.00±4.54 <sup>a</sup>	63.00±3.65 <sup>a</sup>
	LS	NS						

Means bearing different superscripts are significantly different

LS: Level of significance

\*P< 0.05, \*\*P< 0.01, \*\*\*P< 0.001

NS: Not significant

Table 4: Effect of dehydration and rehydration on urine volume, (GFR) and urine concentrations of urea in goats

Parameter	Euhydration	Dehydration			Rehydration			
		Day 1	Day 2	Day 3	4 hr	Day 1	Day 2	
Urine volume (L/day)	Control	0.73±0.12 <sup>a</sup>	0.78±0.12 <sup>a</sup>	0.77±0.11 <sup>a</sup>	0.75±0.20 <sup>a</sup>	-	0.76±0.21 <sup>a</sup>	0.87±0.29 <sup>a</sup>
	Treated	0.89±0.41 <sup>a</sup>	0.56±0.10 <sup>b</sup>	0.41±0.10 <sup>b</sup>	0.31±0.09 <sup>b</sup>	0.48±0.18	1.12±0.25 <sup>b</sup>	0.89±0.54 <sup>a</sup>
	LS	NS	*	**	**		**	NS
(GFR) (ml/min/kg)	Control	2.30±0.56 <sup>a</sup>	2.38±0.25 <sup>a</sup>	2.28±0.25 <sup>a</sup>	2.25±0.45 <sup>a</sup>	2.27±0.25 <sup>a</sup>	2.20±0.36 <sup>a</sup>	2.30±0.31 <sup>a</sup>
	Treated	2.43±0.41 <sup>a</sup>	1.77±0.17 <sup>b</sup>	1.45±0.24 <sup>b</sup>	1.40±0.31 <sup>b</sup>	1.75±0.37 <sup>a</sup>	2.20±0.20 <sup>a</sup>	2.47±0.34 <sup>a</sup>
	LS	NS	*	**	**	NS	NS	NS
Urea(g/dL)	Control	1.48±0.15 <sup>a</sup>	1.30±0.42 <sup>a</sup>	0.72±0.25 <sup>b</sup>	1.150.61 <sup>b</sup>	1.13±0.22 <sup>a</sup>	1.0±0.29 <sup>a</sup>	1.20±0.31 <sup>a</sup>
	Treated	1.33±0.28 <sup>a</sup>	1.20±0.36 <sup>a</sup>	1.62±0.35 <sup>a</sup>	1.78±0.22 <sup>a</sup>	1.32±0.45 <sup>a</sup>	1.27±0.44 <sup>a</sup>	1.17±0.39 <sup>a</sup>
	LS	NS	NS	*	*	NS	NS	NS

Means bearing different superscripts are significantly different

LS: Level of significance

\*P< 0.05, \*\*P< 0.01

NS: Not significant

**Feed Intake:** The daily food intake was significantly (P<0.01) decreased during water deprivation. After rehydration, the normal level of food intake was not restored within 2 days.

**Body Weight (BW):** The mean (BW) of treated goats decreased significantly in the first and second (P<0.01) and the third day (P<0.001) of dehydration. At the end of dehydration period, treated goats lost 22.2% of the initial BW. They regained the (BW) loss at 4 hrs after rehydration.

**Rectal Temperature (Tr):** Dehydration resulted in a significant (P<0.05) increase in rectal temperature (Tr) in days 2 and 3. (Tr) of treated group tended to decrease following rehydration.

The results of the effects of treatments on blood constituents are shown in Tables 2 and 3.

**Packed Cell Volume (PCV):** The (PCV) was significantly higher in the first (P<0.01) as well as the second and third day (P<0.001) of water deprivation. Within 4 hrs following drinking, there was significant (P<0.01) decrease in (PCV) of rehydrated goats; the decrease in day 2 was just significant (P<0.05). The normal (PCV) level was recovered 2 days after rehydration.

**Serum Total Protein:** Water deprivation resulted in a significant (P<0.05) increase in serum total protein concentration for treated group in days 2 and 3. Within 4 hrs of rehydration, the total protein level decreased significantly (P<0.05) and recovered the control level in the second day of rehydration.

**Serum Albumin:** The albumin level for treated group increased significantly (P<0.05) in days 2 and 3 in response to water deprivation. After rehydration, it decreased significantly (P<0.05); the normal control level was recovered in the second day of rehydration.

**Serum Urea:** The urea level increased significantly (P<0.05) during water deprivation. The urea level decreased 4 hrs after rehydration and maintained control level in the second day of rehydration.

**Serum Creatinine:** The creatinine level showed a significant (P<0.05) increase in response to water deprivation. The creatinine level restored normal value in the second day of rehydration.

**Plasma Glucose:** The plasma glucose level was not affected significantly by water deprivation and rehydration.

**Serum (Na) and (K):** The levels of (Na) and (K) were not influenced significantly by dehydration and rehydration.

**Serum Osmolality:** The osmolality of serum exhibited a significant increase in day 1 (P<0.05) and in days 2 and 3 (P<0.01). After rehydration, serum osmolality decreased significantly (P<0.01) and it recovered the normal level in the second day.

The effects of treatments on urine parameters are shown in Table 4.

**Urine Volume:** The volume of urine decreased significantly in the first day (P<0.05) and in the second and third day (P<0.01) of dehydration. Following

rehydration, urine volume increased significantly ( $P < 0.01$ ) in the first day and restored the control value in the second day.

**Glomerular Filtration Rate (GFR):** The (GFR) showed a significant decrease in the first day ( $P < 0.05$ ) and in the second and third day ( $P < 0.01$ ) of water deprivation. Rehydration resulted in gradual increase in (GFR) of treated group; the control value was recovered in the third day of rehydration.

**Urine Urea:** The urea concentration increased significantly ( $P < 0.05$ ) during the second and third day of water deprivation. Following rehydration, the urea level tended to decrease and it attained the control group value in the second day.

## DISCUSSION

The results showed that Nubian goats lost 22.2% of their initial body weight (BW) during 3 days of water deprivation (Table 1). The major loss occurred in the first day. This result is in agreement with previous findings [21] which reported that local Saudi Arabian goats lost an average of 20.6% of their initial (BW) during 3 days of water deprivation. It has been noted that Aaradi goats lost 20% of their initial (BW) when water-deprived for 4 days [22]. The black Bedouin goats were reported to lose 20% of their (BW) within 3 days under moderate summer conditions [23]. Therefore the Nubian goat is comparable to other goat breeds in the Middle East with respect to (BW) loss during dehydration. The reported loss in (BW) is associated with loss of body water as well as reduction in feed and water intake. However, body mass loss during water deprivation is largely related to a reduction in total body water [24-26] particularly in hot environments. A close relationship between the magnitude of (BW) loss and body water loss was previously reported in Desert goats and sheep [25].

The Nubian goats, when rehydrated, ingested immediately (within 15 min.) a volume of water accounting for 31 % of dehydrated (BW). This corresponded to their (BW) loss or slightly more. This result is in general conformity with findings which indicated that black Bedouin goats were able to drink a volume of water that amounted to 28-36% of their (BW) at the end of dehydration session [23, 27], occasionally the water intake exceeded their loss in (BW). However, it has been reported that Saudi goat breeds consumed water equivalent to 23.5 % of dehydrated (BW) after 3 days of

water deprivation [21]. For comparison, Dorper sheep were able to restore the entire (BW) loss immediately following watering that terminated 4 days of dehydration [26], while Awassi sheep replenished only 52% of their (BW) loss, but needed 24 hrs to restore the remainder [28]. Therefore the capacity for rehydration following water deprivation could be influenced by breed and species, physiological characteristics as well as thermal environment.

The feed intake of Nubian goats was affected by hydration state. During the first day of water deprivation, Nubian goats reduced feed intake by about 60% and feed intake continued to decline as water deprivation was extended (Table 1) during the third day of water deprivation, the goats consumed only 5% of the control level of food intake. Drinking was shown to be associated with feed intake in ruminants [29-31]. The osmolality of rumen fluid which increases during water deprivation represents an important feedback signal for control of feeding [32, 33] and infusion of water into the rumen was shown to stimulate feeding in sheep [34]. Furthermore, studies on pygmy goats indicated that (AVP) which is elevated during dehydration inhibits food intake by activation of alpha 1-adrenergic receptors [35]. The decline in food intake during water deprivation could also be viewed as an adaptive measure employed by animals inhabiting arid areas for conserving body water. Egyptian Baladi goats maintained a relatively higher level of feeding; their feed intake was 35% of the control level after 3 days of water deprivation [36]. However, Aaradi goats almost ceased feeding following 2 days of water deprivation during summer [22] and in local goats of Saudi Arabia, 3 days of water deprivation resulted in 85% reduction in feed intake [21].

Water deprivation influenced the heat balance of Nubian goats; despite the marked decrease in feed intake that could influence the energy budget, the rectal temperature ( $T_r$ ) increased significantly in the third day of water deprivation (Table 2). Thermoregulation in mammals is linked inextricably with body fluid balance [37], particularly in conditions when heat load may originate from a hot environment or metabolic generation of heat [38]. Evaporative cooling via sweating which constitutes a major cooling avenue during heat stress for goats adapted to hot arid zone [39], is usually reduced in dehydrated animals [40, 41]. Dehydration-induced hyperthermia may be adaptive in conserving water as it increases the temperature at which the animals switch from thermoregulation via convection and radiation to evaporative cooling [42]. The decrease in rectal

temperature of Nubian goats during water deprivation is in agreement with the findings of other researchers who reported significantly higher body temperature in dehydration than in euhydration in goats exposed to hot environment [21, 22, 43].

The results showed a steady and significant increase in (PCV) as water deprivation advanced, reaching the highest level in the third day of dehydration (Table 3). Four hours following drinking, there was a decrease in (PCV) of rehydrated goats. The euhydration (PCV) level was recovered after 2 days of rehydration. An increase in (PCV) following water deprivation was observed in goats under hot dry conditions [21, 36]. The reported increase in (PCV) during water deprivation is clearly associated with reduced plasma volume. Previous studies indicated that blood as well as plasma volume were reduced during water deprivation in goats and sheep [23, 25, 26]. Change in plasma volume during dehydration can be assessed indirectly by utilizing the increase in (PCV) [44]. Elevations in (PCV) and plasma osmolality are usually associated with reduced plasma volume in response to water restriction [25]. However, use of gut water helps to attenuate the rise in plasma osmolality during dehydration [45].

The plasma protein concentrations are affected by fluid balance; dehydration causes loss of fluid and subsequent hyperproteinaemia [46]. Accordingly, the reported increase in serum total protein and albumin concentrations during water deprivation in Nubian goats (Table 2) is related largely to a decrease in plasma volume. It has been indicated that the increase in total plasma protein concentration during thermal dehydration may enhance preservation of plasma volume [47]. Furthermore, plasma albumin is considered vital for osmotic equilibrium between the blood and body tissues [48]. An increase in protein concentration during water deprivation has been reported in other goat breeds [11, 49-51].

The significant rise in serum urea concentration during water deprivation (Table 2) is attributed to haemoconcentration. Similar responses were reported in goats and sheep [21, 28, 52]. However, a decline in urinary total nitrogen and urea output was reported in connection with water deprivation in goats and sheep [53, 54], which resulted in nitrogen retention. Short periods of water deprivation in goats and sheep can improve nitrogen balance [2] by increasing urea recycling, particularly with low quality feeds [53]. A decline in the rate of urea excretion associated with water restriction may occur as the (GFR) is usually reduced during water deprivation [55]. The increase in serum urea level may also be related

partially to increase in secretion of the hormone (AVP). It has been reported that water deprivation increased (AVP) level in goats [56] and this would have opposed loss of urea as (AVP) promotes urea reabsorption in the kidney [57]. The rise in urea level could also be associated with catabolism of body proteins during dehydration [58]. The results indicated that in Nubian goats, urine urea concentration increased significantly with prolongation of water deprivation; following rehydration the urea level tended to decrease and it assumed the control level in the second day (Table 4). These changes in urea concentration seem to be related inversely to the volume of urine excreted.

In the current study, during water deprivation, serum creatinine level increased significantly compared to control value (Table 2). An almost similar rate of increase was reported in local goats of Saudi Arabia [21]. However, a moderate increase in plasma creatinine level was observed following 3 days of water restriction in Barki sheep [59]. The accumulation of creatinine in plasma might be a consequence of general reduction in urinary excretion rate during water deprivation [60], or it could be related to changes in clearance, since the endogenous creatinine clearance rate was found to be closely correlated to (GFR) [61]. The plasma creatinine can be used as an indicator of (GFR) in domestic animals [62]. As an adjustment to water balance during water deprivation, goats reduced (GFR) which eventually resulted in a reduction in urine volume. The rise in serum creatinine could be related to the maintenance of renal function at a lower level, which consequently reduced the rate of clearance of creatinine.

Water deprivation did not induce significant change in plasma glucose level (Table 2). Similarly, previous studies have not reported significant changes in glucose level in response to water restriction in goats [21, 63]. However, other studies reported a decline of 13% in plasma glucose level of Sudanese desert sheep watered every 72 hrs [52]. The decrease in feed intake that accompanied water restriction should have resulted in a decrease in plasma glucose level. However, it seems that a decrease in plasma glucose level does not necessarily parallel that of food intake [63]. In the present study the great extent of reduction in food intake was not accompanied by a similar trend in plasma glucose level. In the camel, a high plasma glucose level during water deprivation was related to a decrease in insulin secretion [64]. In contrast, glycogenolysis and gluconeogenesis might have been provoked since plasma glucagon level increased in response to water deprivation in rats [65].

Furthermore, previous studies indicated that (AVP) which is elevated during water deprivation, increased blood glucose level in pygmy goats by an alpha - adrenergic mechanism [66]. These possible changes in endocrine responses might have been involved in the maintenance of normal glucose level despite the great reduction in food intake of Nubian goats in the present study.

The results did not reveal significant changes in serum (Na) levels in response to water deprivation (Table 3). This pattern of response could be related to natriuresis that was reported previously during dehydration in animals including sheep [67]. Similarly the plasma (Na) level remained unchanged during water deprivation in Barmer goats [49] and Yankasa sheep [68]. The stability of serum (K) level during water deprivation in the current study could be associated with the reported marked decline in food intake (Table 1). Previous studies reported that plasma (K) level in Barmer goats was unchanged after 4 days of water deprivation [49]. However, other studies reported a tendency of increase in plasma (K) level in water-deprived sheep under hot summer conditions [63].

Water deprivation in Nubian goats resulted in significant progressive rise in serum osmolality (Table 3). This response is in agreement with previous reports in goats [21, 51] and sheep [28, 52]. The increase in serum osmolality is presumably related to increase in colloid osmotic pressure associated with increase in concentrations of plasma proteins (Table 2). The rise in osmolality during water restriction may contribute to the maintenance of plasma volume by encouraging water movement from the interstitial fluid into the vascular system.

The results indicate that the hydration state of Nubian goats resulted in marked changes in renal function. During water deprivation, the significant decrease in urine volume to 35 % of euhydration value (Table 4) indicates activation of water saving mechanisms. The kidneys assume a major role in controlling water loss in response to the action of the antidiuretic hormone (AVP) which usually increases in dehydrated goats [11,51]. The normal urine volume in Nubian goats was restored after 2 days following rehydration, indicating that there was moderate diuresis in response to drinking. This suggests a delay in absorption of water from the rumen which has been previously reported in the black Bedouin goat [69] and the camel [70]. However, lactating Swedish goats developed marked diuresis after water loading [71] and cattle are known to be susceptible to water intoxication following rehydration [72].

In the present study, the decline in urine volume during water deprivation was associated with significant decrease in (GFR) to 58% of the value obtained in euhydration state (Table 4). In black Bedouin goats that were dehydrated to a loss of about 30% of their initial (BW), the (GFR) decreased to 50 % of the level measured in hydrated state and urine flow dropped to 24 % of the value measured in hydrated animals [73]. Following rehydration, the normal (GFR) level in Nubian goats was restored in the second day.

## CONCLUSION

The results indicate that the Nubian goat is adapted to acute changes in state of hydration. The rate of (BW) loss during water deprivation is comparable to values reported for other breeds adapted to hot dry conditions. The moderate diuresis following rehydration suggests that both the stomach and kidney were involved in mechanisms of homeostasis. Future studies should investigate the effect of state of hydration on endocrine responses and productivity traits including milk yield and composition.

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