SUPPLEMENTARY MATERIAL AVAILABLE ONLINE

Indian Journal of Animal Sciences **92** (7): 896–901, July 2022/Article
https://doi.org/10.56093/ijans.v92i7.116126

Effect of drinking water salinity on productive performance and blood biochemical parameters in Surti kids under tropical conditions

K R HARINI[1], RANA RANJEET SINGH[2✉], AMIT KUMAR[3] and K R SRIRANGA[4]

Livestock Research Station, Navsari Agricultural University, Navsari, Gujarat 396 450 India

Received: 27 September 2021; Accepted: 19 May 2022

ABSTRACT

The present study was carried out at Livestock Research Station, Navsari Agricultural University, Navsari, Gujarat to evaluate the effect of drinking water salinity on production and blood biochemical parameters. Apparently healthy 18 Surti kids were selected based on their body weight and subsequently were divided into three groups depending on different types of drinking water provided to them on free choice basis: T_0 (animals receiving potable water available at LRS, NAU, Navsari having TDS about 1500-1600 ppm), T_1 (Animals receiving drinking water having TDS about 4000 ppm.), T_2 (Animals receiving drinking water having TDS about 6000 ppm). The salinity of drinking water significantly affected the dry matter intake and water intake in Surti kids without negatively affecting the bodyweight gain. Blood biochemical parameters such as glucose, total protein, creatinine, urea, and triglycerides were not affected by salinity of water. However, serum albumin and cholesterol had shown significantly higher concentration in the T_2 group. From the findings of our investigation, it could be inferred that the provision of water having TDS up to 6000 ppm to the Surti kids doesn't elicit any adverse effect on their performance up to 105 days.

Keywords: Blood biochemistry, Eye temperature, Production performance, Salinity, Surti kids, Thermography

The salinity of drinking water is a global problem and the water salinity is increasing due to the rising sea levels, climate change, changes in the freshwater flow from the river to the sea, increasing shrimp farming in the coastal region (Vineis *et al*. 2011), tropical and gradual rise of the groundwater level with time. The term salinity is used to refer to the total dissolved concentration of major inorganic ions (i.e. Na, Ca, Mg, K, HCO_3, SO_4 and Cl) in water (Rhoades *et al*. 1992). Estimation of total dissolved salt (TDS) and electrical conductivity (EC) are two commonly employed methods of determining the salinity of water. TDS is calculated by weighing the solid residue present in the water and it can be expressed either as parts per millions (ppm) or as milligrams per litre (mg/l) (Boyles 2009). Based on salt concentration (mg/l), water can be classified into non-saline: less than 500 mg/l, slightly saline: 500-1,500 mg/l, moderately saline: 1,500-7,000 mg/l, highly saline: 7,000-15,000 mg/l, very highly saline: 15,000-35,000 mg/l and brine: more than 35,000 mg/l (Rhoades *et al*. 1992). In general, in most parts of the Gujarat state, the EC value is found to be very high i.e. 3,200 µS/cm to 15,000 µS/cm and more. It has been observed that the groundwater is relatively more saline near-coastal parts of the Navsari district and the average EC value was 1489.64 µS/cm (Kumar 2013).

Tolerance to drinking water salinity varies with the species being higher in camels followed by goats, sheep, cattle, horses, pigs, and poultry in decreasing order (McGregor 2004, Abdalla *et al*. 2013). Goat can tolerate the salinity maximum up to 25,000 µS/cm or 12,500 mg TDS/L (McGregor 2004). However, water with electrical conductivity (salt content) from 8.0 to 11.0 dS/m is optimum goat (Runyan and Bader 1994). The tolerance to salinity also varies with the stages of the animals, the young and lactating animals are more susceptible to salinity in comparison to other stages of animals (Ayers and Westcot 1985). Higher sensitivity in young animals may be due to the presence of more sensitive salt receptors that get activated at lower salinity levels (Runa *et al*. 2019). When the salt load increases, animals cope up by activating the homeostatic mechanism like an increase in the water intake and a decrease in the feed intake (Pierce 1957, Digby *et al*. 2010). An increase in the water salinity above the tolerance level shows a negative effect on the production parameters like growth rate (Pierce 1957, Eltayeb 2006, Abdalla *et al*. 2013, Hekal2015, Zoidis *et al*. 2017, Mdletshe *et al*. 2017) and affected the biochemical parameters like glucose (Zoidis and Hadjigeorgiou 2017), protein (Eltayeb 2006, Hekal 2015, Zoidis and Hadjigeorgiou 2017), creatinine (Eltayeb 2006, Hekal 2015, Zoidis and Hadjigeorgiou

Present address: [1]Livestock Production Management Division, ICAR-Indian Veterinary Research Institute, Bareilly, Uttar Pradesh. [2]Department of Livestock Production Management, Navsari, Kamdhenu University, Gujarat. [3]Animal Genetics and Breeding Division, ICAR-Indian Veterinary Research Institute, Bareilly, Uttar Pradesh. [4]Livestock Production Management Division, ICAR-National Dairy Research Institute, Karnal, Haryana. ✉Corresponding author email: drexplicit@gmail.com

2017), urea (AbouHussien *et al*. 1994, Eltayeb 2006, Zoidis and Hadjigeorgiou 2017), cholesterol and triglyceride level (Mehdiel G Harbi *et al*. 2015).

Our present investigation was carried out on kids of Surti goats native to Vadodara and Surat districts of the South Western part of Gujarat. It is a dual-purpose breed and well suited for rearing under complete confinement and stall-feeding conditions (Acharya 1982, Banerjee 1998). Not much information is available on the adaptation capacity of Surti goat kids to saline water. So, the present study was conducted to investigate the effect of drinking water salinity on dry matter intake, water intake, rectal temperature, ear temperature, and growth performance in Surti kids.

MATERIALS AND METHODS

Location of the study and climatic variables: The present investigation was carried out from November, 2018 to February, 2019 in the kids of Surti breed of goats maintained at Livestock Research Station, Navsari Agricultural University, Navsari, Gujarat, situated geographically at an altitude of 11.89 meters above mean sea level, at latitude of 20° 57' 0" North and longitude of 72° 54' 0" East. The climate of the area forms a part of the tropical and coastal areas. Generally, summer (March to June) is moderately hot and humid while monsoon (July to September) is warm and extremely humid and winter (November to February) remains fairly cold and dry. During our study period, the temperature varied from 35.1°C (maximum) to 9.9ºC (minimum), humidity from 88.2% (maximum) to 48.5% (minimum), and wind speed from 3.1 to 1.2 km/hr.

Animals and management: Animals were maintained under loose housing and group management system. Housing space for the animals was given as per BIS specifications. The management practices were uniform to all the animals under study. Kids were allowed to suckle their dams twice daily. Green fodders (tree leaves) were provided in the open paddock and the concentrate mixture of 0.15 kg/head/day for kids was provided inside the pen. The animals had free access to fresh and clean designated type of drinking water at all the time inside the pens. Animals were checked for the incidences of external and internal parasitic infestations and proper preventive and curative measures were undertaken periodically for such cases.

Selection and grouping of animals: Eighteen apparently healthy Surti kids of 3-months age including both males and females were selected based on their age and bodyweight and subsequently divided into three groups based on different types of drinking water provided to them on the free choice basis. The control group (T_0) of animal were provided with normal tap water of concentration 1,600 ppm. The T_1 and T_2 group were provided with 4,000 and 6,000 ppm water, respectively which was prepared freshly everyday by adding NaCl salt to the tap water to attain particular concentration. The concentration of salt (TDS in ppm) in water was estimated by Horiba LAQUA twin pocket meters (Model: LAQUAtwin-EC-33, S070) with the measuring principle of 2 Electrode Bipolar AC.

Feed and water intake: Feed and water intake of kids of all three groups were recorded for three consecutive days at 21-days intervals. The average value obtained from observations was considered for estimation of feed and water intake. The kids were given 150 g of concentrate along with 1 to 1.5 kg roughage per day. The leftover roughage was weighed and the feed intake of the animal was calculated by the difference. Kids were provided with 2 litres of water per day per head. The water left was measured and the water intake was calculated by the difference.

Growth performance: The bodyweights of kids were measured at weekly intervals before offering milk or feed. Average daily weight gain (g/day) was calculated.

Blood collection and biochemical analysis: Approximately 5 ml of blood was collected from the experimental kids from the jugular vein at 21 days intervals during the experimental period. The serum and plasma were stored in the plastic vials at -20°C in an ultra-low temperature freezer. Serum was used for the analysis of glucose, total protein, albumin, creatinine, blood urea nitrogen (BUN), cholesterol, and triglycerides. The serum biochemical parameters were determined using standard kits according to manufacturer's instructions.

Body surface temperature: Body surface temperature of the eye region was measured using Infrared thermal camera (FLIR T420) at 21 days interval during the whole experiment. While doing thermography, animals were properly restrained and a constant distance of 0.5 to 1 m was maintained from camera to animal body. An instant value of ambient temperature and relative humidity were recorded with the help of an automatic data logger. The captured images were further processed using the FLIR image tool for recording the temperature of eye region after correcting distance, ambient temperature, and humidity.

Statistical analysis: Statistical analysis of data obtained was carried out by One-way ANOVA using PROC-GLM procedure using SAS 9.3 software for investigating the effect of different groups on the traits under study. Duncan multiple range test (DMRT) was used for mean separation at 5% level of significance.

RESULTS AND DISCUSSION

Dry matter intake (DMI): The results of dry matter intake have been presented in Table 1. Dry matter intake was not affected significantly by salinity during the initial period of the experiment in Surti kids. However, DMI significantly ($p<0.05$) decreased in both the groups provided with saline drinking water as compared to T_0 from the 84th day onwards. Overall, kids in control group had more DMI in comparison to T_1 and T_2 groups (Supplementary Fig. 1). The higher salinity level tends to decrease the average daily feed intake of goats owing to higher salinity stimulating the CSF to decrease the parotid salivary secretion and increase the ruminal *p*H (McGregor 2004, Eltayeb 2006, Mdletshe *et al*. 2017, Zoidis and Hadjigeorgiou 2017). This supports

Table 1. LSM ± SE of Dry Matter Intake (g) in Surti kids

Group	Day of observation				
	21st day	42nd day	63rd day	84th day	105th day
T_0	247.50±6.45 (6)	269.86±10.60 (6)	284.02±8.14 (6)	309.72^a±6.79 (6)	303.88^a±5.50 (6)
T_1	241.25±4.98 (6)	272.63±4.88 (6)	271.25±11.08 (6)	262.48^b±1.66 (5)	263.00^b±6.02 (5)
T_2	252.08±7.11 (6)	260.13±8.39 (6)	262.77±11.51 (6)	273.33^b±7.73 (6)	276.25^b±8.26 (6)
Overall	246.94±3.55 (18)	267.54±4.68 (18)	272.68±6.00 (18)	282.98±6.11 (17)	282.10±5.61 (17)

LSM showing different superscripts in lower case letters in a column differ significantly at $p<0.05$.

Table 2. LSM ± SE of Water Intake (L) in Surti kids

Group	Day of observation				
	21st day	42nd day	63rd day	84th day	105th day
T_0	1.11±0.10 (6)	1.17±0.20 (6)	0.82±0.07 (6)	0.91^b±0.10 (6)	0.92^b±0.12 (6)
T_1	1.18±0.09 (6)	1.43±0.12 (6)	1.18±0.09 (6)	0.91^b±0.12 (5)	1.26^a±0.09 (5)
T_2	1.32±0.10 (6)	1.50±0.11 (6)	1.21±0.26 (6)	1.43^a±0.09 (6)	1.31^a±0.09 (6)
Overall	1.20±0.05 (18)	1.37±0.09 (18)	1.07±0.10 (18)	1.09±0.08 (17)	1.16±0.07 (17)

LSM showing different superscripts in lower case letters in a column differ significantly at $p<0.05$.

our finding that the feed intake was significantly ($p<0.05$) lower in the treatment groups. In contrast, Runa *et al*. (2019) reported that the higher salinity tends to increase the feed intake in the Boer goat, as the small amount of salt in the drinking water increases the microbial activity in rumen which in turn increases the digestion. However, when the rumen microflora gets adapted to the high salinity, DM intake remains constant (Paiva *et al*. 2017).

Water intake: Similar to DMI, drinking water salinity did not significantly affect the water intake among various groups of experimentation initially and the results pertaining to water intake have been presented in Table 2. Nevertheless, on the 84th day of observation water intake was significantly ($p<0.05$) higher in the T_2 group of kids consuming drinking water with 6,000 ppm salinity, and on the 105th day, kids provided with saline drinking water had shown significantly ($p<0.05$) higher water intake as compared to T_0 group (Supplementary Fig. 1). The results of the present study showed higher water intake in the kids that were provided with saline drinking water which is similar to earlier reports (Eltayeb 2006, Paiva *et al*. 2017, Runa *et al*. 2019), and it is the key physiological mechanism to decrease the high salt intake by excreting through urine. Younger goats had shown higher sensitivity to drinking water salinity owing to greater sensitivity of salt taste receptors to water salinity (Runa *et al*. 2019). Furthermore, the young animal body contains more water, and a regulation mechanism will be activated at a lower salt concentration by increasing the Na^+ concentration to the tissue. In contrast, Mdletshe *et al*. (2017) reported a decrease in water intake with an increase in salinity. Due to adaptive response to salt load at high salt concentration, there could be an increase in the plasma colloidal osmolality resulting in lesser water loss from the cells (Zoidis and Hadjigeorgiou 2017).

Average daily gain: The overall average daily gain in experimental groups T_0, T_1, and T_2 was 53.49±7.93, 63.28±8.77, and 59.71±5.29 g/day, respectively (Table 3). The body weight of kids measured at weekly interval is given in Supplementary Table 1. Increasing drinking water salinity did not have a significant effect on the average daily gain of body weight in the kids. The findings of the present study are in coordination with the results of El-Gawad (1997). However, few authors reported that the drinking water salinity negatively affects the body weight gain in goats (Eltayeb 2006, Abdalla *et al*. 2013, Mdletshe *et al*. 2017, Zoidis and Hadjigeorgiou 2017), and sheep (Pierce 1957, Zarkawi *et al*. 2005, Hekal 2015). In our study, significant reduction in DMI of kids provided with saline water was evident only after the 84th day of the experiment. This could be the possible reason for non-significant differences in bodyweight gain among various groups under study up to the 105th day. Similarly, Zoidis and Hadjigeorgiou (2017) also reported that the live body weight of goats was not affected by increasing NaCl concentration; however, there was a slight tendency decrease in bodyweight at the highest (20%) salt concentration.

Biochemical parameters: The results pertaining to blood biochemical parameters have been presented in the Table 4. Serum biochemical parameters such as glucose, total protein, creatinine, urea, and triglycerides did not get significantly affected by drinking water salinity up to 6,000 ppm in Surti kids. However, serum albumin concentration was significantly ($p<0.05$) higher in the T_2 group as compared to T_0 and T_1 groups on the 63rd and 84th day of observation. Besides, serum cholesterol concentration was also significantly ($p<0.05$) higher in the T_2 group of kids

Table 3. LSM ± SE of Average Daily Gain (ADG) in Surti kids

Group	ADG (kg)	ADG (g)
T_0	0.05±0.01	53.49±7.93
T_1	0.06±0.01	63.28±8.77
T_2	0.06±0.00	59.71±5.29
Overall	0.06±0.00	58.71±4.09

Table 4. LSM ± SE of blood biochemical parameters in Surti kids

Parameter	Groups	Day of observation				
		21st day	42nd day	63rd day	84th day	105th day
Serum glucose (mg/dL)	T_0	93.52±7.48 (6)	61.52±5.38 (5)	64.67±9.49 (6)	71.58±6.61 (6)	93.85±14.06 (6)
	T_1	78.33±5.72 (6)	67.24±6.81 (5)	63.17±8.91 (6)	69.86±8.44 (5)	84.04±10.75 (5)
	T_2	75.67±9.56 (6)	74.48±8.79 (4)	59.44±8.91 (5)	60.45±8.44 (6)	93.80±10.75 (6)
Total protein (g/dL)	T_0	5.45±1.23 (5)	4.11±0.36 (4)	5.41±0.22 (6)	5.26±0.70 (6)	5.79±0.39 (6)
	T_1	5.22±0.83 (6)	4.09±0.56 (4)	5.11±0.19 (6)	5.42±0.45 (5)	5.98±0.58 (5)
	T_2	5.43±0.88 (6)	3.71±0.08 (6)	5.73±0.50 (5)	4.93±0.30 (6)	6.19±0.71 (6)
Albumin (g/dL)	T_0	3.19±0.20 (5)	2.43±0.54 (4)	4.12^{b}±0.26 (6)	2.20^{b}±0.10 (6)	2.48±0.36 (6)
	T_1	2.89±0.14 (6)	2.18±0.46 (4)	3.87^{b}±0.18 (6)	2.47^{b}±0.16 (5)	2.12±0.15 (5)
	T_2	2.83±0.22 (6)	2.42±0.23 (6)	4.98^{a}±0.22 (5)	3.26^{a}±0.44 (6)	2.88±0.38 (6)
Creatinine (mg/dL)	T_0	1.75±0.07 (5)	1.49±0.11 (4)	1.59±0.12 (4)	1.41±0.09 (4)	1.47±0.08 (4)
	T_1	1.50±0.09 (5)	1.71±0.11 (4)	1.55±0.05 (4)	1.40±0.06 (4)	1.38±0.03 (5)
	T_2	1.73±0.20 (6)	1.76±0.10 (6)	1.70±0.09 (4)	1.45±0.05 (5)	1.37±0.03 (6)
Urea (mg/L)	T_0	24.45±2.55 (6)	35.07±6.22 (6)	20.93±2.99 (6)	27.05±4.05 (6)	17.98±3.81 (6)
	T_1	25.13±3.09 (6)	26.96±6.02 (5)	21.57±2.56 (6)	21.82±3.05 (5)	17.56±1.82 (5)
	T_2	33.06±5.22 (6)	31.13±6.87 (6)	27.30±2.36 (6)	28.02±4.08 (6)	18.43±2.86 (6)
Triglycerides (mg/dL)	T_0	22.80±2.92 (5)	42.75±9.24 (4)	18.83±2.59 (6)	39.50±4.44 (6)	42.67±4.25 (6)
	T_1	31.67±5.96 (6)	35.50±10.17 (4)	30.00±5.32 (6)	40.33±5.94 (5)	42.50±6.26 (5)
	T_2	29.67±3.48 (6)	42.67±1.76 (6)	21.80±3.54 (5)	40.33±2.81 (6)	42.50±5.07 (6)
Cholesterol (mg/dL)	T_0	145.50±7.14 (4)	99.50^{b}±7.77 (4)	101.83^{b}±10.03 (6)	80.00^{b}±4.12 (6)	77.17^{b}±8.73 (6)
	T_1	121.00±9.39 (6)	117.25^{b}±14.80 (4)	129.50^{b}±15.53 (6)	108.20^{b}±17.17 (5)	111.20^{a}±5.47 (5)
	T_2	131.67±11.68 (6)	156.17^{a}±14.60 (6)	154.00^{a}±17.25 (5)	151.00^{a}±23.90 (6)	138.83^{a}±14.63 (6)

LSM showing different superscripts in lower case letters in a column differ significantly at $p<0.05$.

in comparison to T_0 and T_1 groups from the 42nd day onwards (Fig. 1).

Serum glucose concentration indicates the energy status in animals. In our study, the serum glucose concentration was not significantly affected by the salinity of drinking water though the DMI was lower in saline water groups from the 84th day onwards. This might be attributed to higher digestibility of feed or increased mobilization of body fat reserve (Hekal 2015, Zoidis and Hadjigeorgiou 2017). The mobilization of fat from adipose tissue leads to an increase in cholesterol concentration in goats provided with saline water (Vosooghi-Postindoz *et al.* 2018). Besides, dehydration of the body may also cause an increase in serum cholesterol concentration (Casamassima *et al.* 2008) which supports the findings of the present study where higher water intake and elevated serum cholesterol concentration in saline water provided groups is observed.

The serum total protein and albumin level indicate the level of dehydration in the animal body especially, albumin is considered as the true indicator of plasma level (Zoidis and Hadjigeorgiou 2017, Vosooghi-Postindoz *et al.* 2018). Thus, the increase in the albumin concentration in our study may be due to the dehydration of the body subsequently leading to an increase in water intake in kids.

Serum creatinine and blood urea nitrogen level (BUN) indicate renal function in animals. Saline water provision did not significantly affect the serum creatinine and BUN concentration indicating water salinity level up to 6,000 ppm does not affect the renal function in kids. Similarly, Abou Hussien *et al* (1994) and Zoidis and Hadjigeorgiou (2017) reported that salinity up to 0.5% did not affect the serum concentrations of creatinine and BUN. However, higher salinity levels up to 20% may affect renal functioning in goats (Zoidis and Hadjigeorgiou 2017).

Body surface temperature: Body surface temperature is a non-invasive indicator of the physiological state of animals. Body surface temperature is affected by the metabolic process (Ward and Slater 2005) and the amount of blood flow in peripheral vessels (Busnardo *et al.* 2010). In the present study, body surface temperature was measured in the eye region using thermal imaging. The results of eye temperature have been presented in the Supplementary

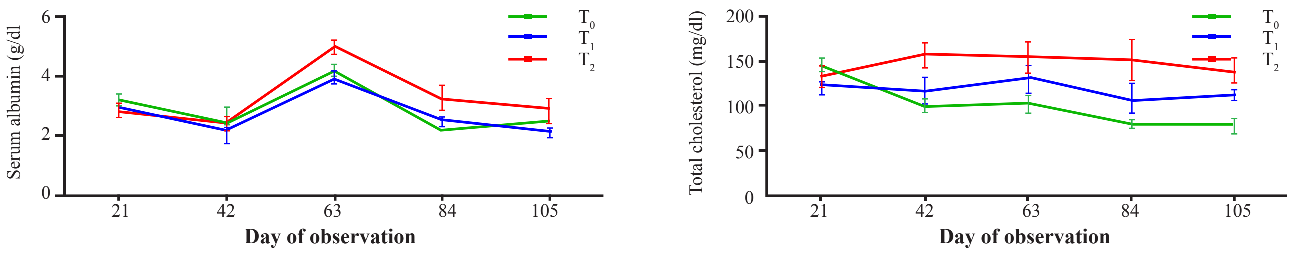
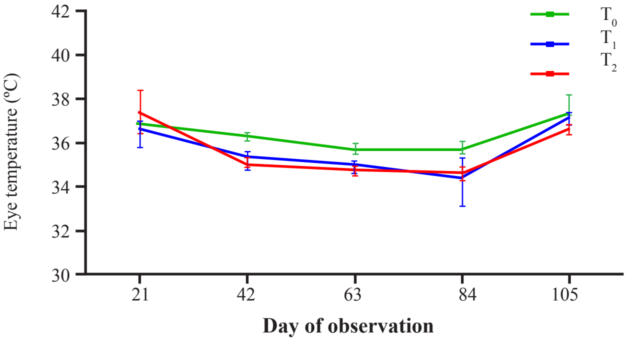


Fig. 1. Periodic changes in Serum albumin (g/dL) and Cholesterol (mg/dL) concentration of Surti kids in different treatment groups.



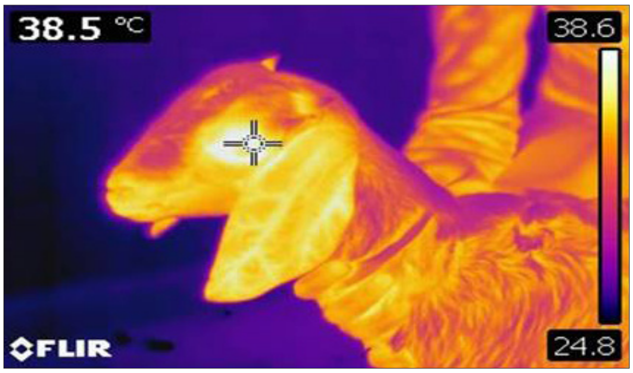


Fig. 2. Periodic changes in Eye temperature (°C) of Surti kids in different treatment groups and measurement of body surface temperature at eye region using thermal imaging.

Table 2. The eye temperature was significantly ($p<0.05$) lower in kids receiving 6,000 ppm saline water as compared to other two groups on the day 42, 63 and 105 (Fig. 2). The decrease in eye temperature might be due to vasodilation accompanied by consumption of water containing high salinity. Besides, higher water intake in the T_2 group might also have contributed to the reduced eye temperature as the quantity of water consumed significantly affects the body temperature by altering reticuloruminal temperature for an extended period (Yamada *et al.* 2001).

Goats show higher tolerance to salinity of drinking water as compared to other ruminants. Though young animals are more sensitive to water salinity in comparison to adult animals, findings of the current study show that the Surti kids can tolerate the water salinity up to 6,000 ppm without negatively affecting the production performance and blood biochemistry. More studies are necessary to evaluate the threshold level of drinking water salinity that can be offered without compromising the performance in various categories of animals at different age groups.

ACKNOWLEDGEMENTS

The authors are thankful to NAHEP-CAAST-NAU for providing financial support. We are grateful to Dean, Veterinary College; Research scientist-LRS; Professor and Head, ILFC for providing necessary facilities.

REFERENCES

Abdalla E B, Gawish H A, El-Sherbiny A M, Ibrahim N H and El-Hawy A S. 2013. Reproductive efficiency of Damascus goats in salt affected lands in South Sinai, Egypt. *Journal of American Science* **9**: 170–77.

AbouHussien E R M, Gihad E A, El-Dedawy T M and Abdel Gawad M H. 1994. Response of camels, sheep and goats to saline water. 2. Water and mineral metabolism. *Egyptian Journal of Animal Production* **31**: 387–401.

Acharya R M. 1982. *Sheep and Goat Breeds of India*. Food and Agriculture Organization of the United Nations, Rome, Italy.

Ayers R S and Westcot D W. 1985. *Water Quality for Agriculture.* Food and Agriculture Organization of the United Nations, Rome, Italy.

Banerjee G C. 1998. *The Textbook of Animal Husbandry.* Oxford and IBH Publishing Company Pvt. Ltd., New Delhi, India.

Busnardo C, Tavares R F, Resstel L B, Elias L L and Correa F M. 2010. Paraventricular nucleus modulates autonomic and neuroendocrine responses to acute restraint stress in rats. *Autonomic Neuroscience* **158**(1-2): 51–57.

Boyles S. 2009. Livestock and water, Ohio: The Ohio State University. *North Dakota State University: Extension Service Bulletin* **18**.

Casamassima D, Pizzo R, Palazzo M, D'alessandro A Gand Martemucci G. 2008. Effect of water restriction on productive performance and blood parameters in Comisana sheep reared under intensive condition. *Small Ruminant Research* **78** (1-3): 169–75.

Digby S N, Blache D, Masters D G and Revell D K. 2010. Responses to saline drinking water in offspring born to ewes fed high salt during pregnancy. *Small Ruminant Research* **91**(1): 87–92.

El-Gawad E I A. 1997. Physiological responses of Barki and Damascus goats and their crossbred to drinking saline water. *Alexandria Journal of Agricultural Research* **42**: 23–36.

Eltayeb E E. 2006, Effect of salinity of drinking water and dehydration on thermoregulation, blood and urine composition in Nubian goats Doctoral dissertation, University of Khartoum, Khartoum, Sudan.

Hekal F. 2015. 'Homeostatic responses of sheep to salinity and heat stress conditions.' CU Theses. Department of Animal Production Faculty of Agriculture, Cairo University, Giza, Egypt.

Kumar A. 2013. District ground water brochure Navsari district Gujarat state. Government of India ministry of water resources central ground water board, West Central Region, Ahmedabad, Gujarat, India.

McGregor B A. 2004. Water quality and provision for goats: A report for the Rural Industries Research and Development Corporation, RIRDC publication, Australia.

Mdletshe Z M, Chimonyo M, Marufu M C and Nsahlai I V. 2017. Effects of saline water consumption on physiological responses in Nguni goats. *Small Ruminant Research* **153**: 209–11.

Paiva N G, Garcia Leal de Araújo G, Toledo Henriques L, Nunes Medeiros A, Mesquita Beltrão Filho E, Germano Costa R and Bezerril Freire R M. 2017. Water with different salinity levels for lactating goats. *Semina: Ciências Agrárias* **38**(4): 2065–74.

Peirce A W. 1957. Studies on salt tolerance of sheep. I. The tolerance of sheep for sodium chloride in the drinking water. *Australian Journal of Agricultural Research* **8**: 711–22.

Rhoades J D, Kandiah A and Mashali A M. 1992. The use of saline waters for crop production (FAO Irrigation and Drainage Paper no. 48). Food and agriculture organization of the United Nations, Rome, Italy.

Runa R A, Brinkmann L, Riek A, Hummel J and Gerken M. 2019. Reactions to saline drinking water in Boer goats in a free-choice system. *Animal* **13**(1): 98–105.

Runyan C and Bader J. 1994.Water quality for livestock and poultry. Water quality for agriculture. pp. 186 (FAO Irrigation and Drainage Papers no. 29). Food and agriculture organization of the United Nations, Rome, Italy.

Vineis P, Chan Q and Khan A. 2011. Climate change impacts on water salinity and health. *Journal of Epidemiology and Global Health* **1**(1): 5–10.

Vosooghi-Postindoz V, Tahmasbi A, Naserian A A, Valizade R and Ebrahimi H. 2018. Effect of water deprivation and drinking saline water on performance, blood metabolites, nutrient digestibility, and rumen parameters in Baluchi lambs. *Iranian Journal of Applied Animal Science* **8**(3): 445–56.

Ward S and Slater P J B. 2005. Heat transfer and the energetic cost of singing by canaries Serinus canaria. *Journal of Comparative Physiology A* **191**(10): 953–64.

Yamada A, Sutoh M and Imura T. 2001. The changes of rumen temperature with grazing behavior in the daytime. *Journal of Japanese Society of Grassland Science* **47**: 491–93.

Zoidis E and Hadjigeorgiou I. 2017. Effects of drinking saline water on food and water intake, blood and urine electrolytes and biochemical and haematological parameters in goats: a preliminary study. *Animal Production Science* **58**(10): 1822–28.