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Research article

Physiological, hematological, and biochemical responses in Hararghe-highland lamb subjected to water salinity levels of Lake Basaka in a semiarid area of Ethiopia

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ABSTRACT

The present study aimed to evaluate the effect of drinking salinity levels in Lake water on the growth performance, and physiological, and blood constituents of Hararghe-highland lambs. A total of 28 lambs (average IBW of 18 ± 1.18kg) were categorized into four levels of water salinity, namely freshwater (510 mg/l TDS), lake Basaka water (LBW; 2600mg TDS/L); lake Basaka water plus 100% TDS of LBW; 5200mg TDS/L) and lake Basaka water plus 200% TDS of LBW; 7900mg TDS/L). The current results suggest that increased total dissolved solid levels in lake water increase the water intake of lambs while not affecting IBW, FBW, AWG, and FCR. Additionally, drinking saline lake with increasing total dissolved solid levels increased rectal temperature and respiration rate and caused a significant ($P < 0.05$) change in the concentrations of glucose, albumin, urea, triglycerides, sodium, AST, and ALT. Some hematological variables and biochemical constituents like creatinine, total protein, cholesterol, chlorides, potassium, magnesium, and calcium showed no significant ($P > 0.05$) differences. In conclusion, Hararghe-highland lambs from Ethiopia could tolerate lake Basaka water with a high salt level (7952 mg/L TDS).

1. Introduction

Global climate change has increased the occurrence of increasing temperatures and pressure all over the world, a threat to livestock production [1]. Dryland sheep breeds have been identified for their ability to withstand harsh environmental variations, water shortage, and poor quality [2]. As the temperature rises due to global warming, increased salinity threatens both underground and surface water [3]. Lake water has become an important source of drinking water for livestock species as a result of groundwater contamination; it is also affected by climate change and variability [4]. The most serious challenges facing dryland livestock farming systems are water shortage and quality [5]. The ability of an animal to cope with water scarcity and quality, on the other hand, is determined by its species, breed, age, sex, environmental conditions, water quality status, physiological state, and productive status [6,7,8].

Several research that focused on the consequence of intake of saline water on small ruminants used NaCl added to freshwater [9,10,11,12,13]. Also, diluted seawater has been used in a few experiments [14,15]. Very few findings have been used on actual natural sources of saline water with the addition of sodium chlorides to Buffalo production in India [16]. Previous studies did not consider naturally saline water with the addition of sodium chlorides, particularly in dry areas of Ethiopia. Many lakes and rivers in Sub-Saharan Africa, particularly in east Africa, are becoming polluted and converting to saline water as a result of climate change. Lake Basaka in Ethiopia is expanding and naturally saline, and it serves as a source of drinking water for livestock, especially during droughts. In Ethiopia, no research has been conducted on the effect of natural saline water from Lake Basaka with the addition of sodium chlorides on sheep and goat production and productivity. Understanding the physiological and biochemical adaptability mechanisms that reinforce small ruminants' ability to adapt to a saline load thus serves as a foundation for developing long-term strategies for raising small ruminants in areas where water is scarce or salt concentrations are high [17]. Furthermore, despite the fact that drinking water is an important nutrient whose quantity and quality have a direct impact on small ruminant production and productivity, little research has been conducted in Ethiopia. The objective of this research was to determine how drinking saline lake Basaka water with added NaCl affected the growth performance, physiological responses, and blood profile of Hararghe highland lambs in eastern Ethiopia.

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2. Materials and methods

2.1. Study site description

The experiment was conducted at Haramaya University Goat Farm, which is located at 42°E longitude and 9°N latitude, and an altitude of 1950m above sea level. The area is founded in the eastern part of Ethiopia and has an average air temperature of 16 °C with a mean annual air temperature ranging from 9.73 and 24.02 °C. The area has a bimodal type of rainfall and receives an average annual total rainfall of 790mm [18].

2.2. Animal, treatments, experimental design

A total of twenty-eight healthy yearling Hararghe highland lambs with an average initial body weight of 18.19 ± 1.18kg were distributed into individual pens which were equipped with drinkers and feeders for water and diet provision, respectively. The design of the experiment was a completely randomized block with four treatments and eight animals per treatment. The experiment took 75 days, containing 15 days of animals' acclimation to the experimental saline water and diet treatments. To control internal and external parasites, all lambs were dewormed against internal parasites and treated with acaricide. The lambs were vaccinated against ovine pasteurellosis and anthrax, two frequent illnesses in the area, as per recommended by [19].

The water salinity treatments contained increasing levels of total dissolved solids in the Lake Basaka water, being re-formed by using sodium chloride (NaCl), and freshwater as a control (Table 1). The saline water treatments were categorized into four TDS levels: freshwater (FW) (500 mg/l TDS), (Lake Basaka water (LBW): 2600mg TDS/l), lake Basaka water plus 100%TDS of LBW, which raises the TDS to 5200mg TDS/l, and lake Basaka water plus 200%TDS of LBW; that is 7900mg TDS/l. Freshwater was used from the farm, lake Basaka water was brought from lake Basaka water found at Matahara town, central rift valley of Ethiopia. The lambs were tolerable to adapt to saline water during the adjustment period (days 1–5) of the trial period by slowly increasing the salt concentration of the drinking water until it reached the required concentration.

2.3. Measurements

2.3.1. Climate variables

The daily minimum, maximum, average temperature, and relative humidity of the experimental house were recorded twice a day at 8:00 and 16:30h with a thermohydrometer indoors [20]. The temperature and humidity index (THI) were calculated to quantify the thermal stress levels experienced by the animals (24h per day) during the whole experimental period according to the Equation of [21].

$$THI = TA - [(0.31 - 0.31x\ RH)\ x\ (TA - 14.4)] \quad \text{Equation 1}$$

where AT (°C) is the dry air temperature (in units of °C) and RH is the relative humidity (RH%)/100. The values obtained indicate the following: <27.8 = absence of heat stress, 27.8–28.9 = moderate heat stress, 28.9–30.0 = severe heat stress, and 30.0 and more = very severe heat stress.

2.3.2. Water and feed intake and body weight

Water was accessible to the animal twice per day (at 10:00 am and 4:00 pm) using 5 litter (L) buckets and removed after 45 min during which the animals were allowed to drink as much as they wanted. The water intake of the animals was measured in litter and calculated as the difference between the amounts offered and remaining in the bucket. Water lost through evaporation was also considered in the water intake calculation. The variable was estimated using separate buckets, with an equal volume of water for each treatment, randomly dispersed across the experimental shed, being calculated as the difference in the litter for water provided for animals.

Experimental animals have consumed a diet composed of dry hay *ad libitum* and concentrates based on wheat bran, Noug seed cake, Vitamin premix, and common salt (Table 2) and formulated conferring to the National Research Council- NRC (2007) to meet the maintenance rations of the animals. The hay and the concentrate were offered in individual feeding troughs twice a day at 08:00 am and 4:00 pm. The amount of concentrate supplement was based on the maintenance requirements of their body weight. Feed residual was collected and weighed by digital balance and those which are contaminated with feces and urine were discarded. Weekly samples of supplied feed and refusals were taken for chemical analyses.

The experimental animals were balanced at fifteen days intervals after a solid-feed withdrawal of 12 h. Average daily weight gain (ADG) was calculated as the difference in weight between the final and initial body weight divided by the interval in days from the dates the initial and final body weights were taken. Feed conversion efficiency (FCE) was calculated as a proportion of ADG to daily dry matter (DM) intake.

$$\text{Conversion efficiency} = \frac{\text{Average daily gain}\left(\frac{g}{day}\right)}{\text{Average daily dry matter intake}\left(\frac{g}{day}\right)}$$

2.3.3. Physiological variables

The physiological variables of experimental lambs were taken every fifteen days in the morning (8:30 am) and afternoon (4:30 pm). Rectal temperature (RT) was measured by using a digital clinical thermometer with a scale of 32–43.9 °C, which was inserted into the animal's rectum so that the bulb was in contact with the mucosa, remained there for a period until a sound signal signifying the temperature stabilization. The respiratory rate (RR) and pulse rates (PR) were obtained by counting

Table 1. Physio-chemical composition of the water treatments.

Parameters*	Water Salinity Treatments			
	FW	LB	LB100	LB200
pH	7.61	8.77	8.68	8.58
Temperature	23.46	23.85	22.91	23.95
Electrical conductivity (EC)	738.5	3860.01	7856.5	11865.50
Total dissolved solids (TDS)	510.50	2560.02	5277.02	7952.01
Calcium (Ca^{2+})	1.66	2.45	3.87	4.22
Magnesium (Mg^{2+})	1.24	2.28	2.11	2.18
Sodium (Na^{+})	268.29	1582.52	2574.84	2985.06
Potassium (K^{+})	3.95	55.92	59.28	58.81
Chloride (Cl^{-})	131.50	847.63	2002.93	2913.78
Carbonate (CO_3^{2-})	210.00	342.00	374.00	311.50
Bicarbonate (HCO_3^{-})	240.00	1020.00	1730.00	2280.00

* All are in units of mg L^{-1}, except Temperature (°C) and EC (µS cm^{-1}); FW: Fresh Water; LB: Lake Basaka water; LB100: Lake Basaka water plus 100%TDS; LB200: Lake Basaka water plus 200%TDS.

Table 2. Chemical composition (% for DM and %DM for others) of the experimental diets.

Feed ingredients	DM	CP	OM	NDF	ADF	ADL	Ash
Hay	91.58	12.47	80.80	77.03	41.59	7.97	10.77
Wheat bran	89.66	17.49	86.23	55.50	11.80	3.57	4.42
Noug-seed cake	91.58	29.16	81.35	42.27	29.34	14.37	10.23
Concentrate mix	90.62	23.32	83.79	48.88	20.57	8.97	7.33

DM: dry matter, OM: organic matter, CP: crude protein, NDF: neutral detergent fiber, ADF: acid detergent fiber, ADL: Acid detergent lignin. The concentrate mix consists of wheat bran (92%), Noug-seed cake (6%), Vitamin premix (1%), and salt (1%).

respiratory movements per minute using a flexible stethoscope placed at the level of the laryngotracheal region. The number of respiratory movements was taken in 20 s and then multiplied by 3, thus obtaining the number of movements per minute [20].

2.3.4. Blood collection and analysis

Blood samples were taken from each animal into 5ml vacuum tubes containing 10% anticoagulant ethylene diamine tetraacetic acid (EDTA) for hematological tests. The samples were withdrawn from the jugular vein between 08:00 am and 09:00 am before feeding. The animals were also evaluated for the presence of ectoparasites, lymphadenitis, or other types of skin problems just after the blood collection. All samples were taken immediately to the laboratory to determine blood hematology, including packed cell volume, hemoglobin, white blood cells (WBC), red blood cells (RBC), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) by automated hematology analyzer (Sysmex kx-21, Japan) [22].

Another blood sample was collected from each animal in vacuum tubes of 7ml without anticoagulant and centrifuged for 15 min at 3000 rpm and 20 °C (centrifugation force: 1620 g). The serum and plasma samples were pipetted into labeled glass vials and stored at −20 °C for later analysis. Glucose, blood urea nitrogen, creatinine, cholesterol, triglyceride, total protein, albumin, serum aspartate aminotransferase (AST), and alanine aminotransferase (ALT) were determined by an automated biochemical analyzer (Biotechnical, Targa 3000) using a commercial kit. In addition, blood electrolytes including calcium, phosphorus, sodium, potassium, magnesium, and chlorine were assayed using an electrolyte analyzer (Diamond Diagnostics Smart Lyte, USA).

2.4. Data analysis

Analysis of variance was performed based on averages per treatment group using the GLM procedure of SAS version 9.4 (SAS – Statistical Analysis Systems Institute Inc., 2013). For all statistical analyses, significance was stated at $P < 0.05$.

The model used for physiological variables was as follows:

$$Y_{ijk} = \mu + P_i + W_j + e_{ijk}$$

The model used for blood and growth parameters:

$$Y_{ijk} = \mu + W_j + e_{ijk}$$

where Y_{ijk} is the individual observation, μ is the overall mean, P_i is the period effects, W_j is the water treatment effects, and e_{ijk} is the error.

3. Results

3.1. Climate variables during the experimental period

The average weather data throughout the trial period including ambient temperature (Ta), relative humidity (RH), and temperature-humidity index (THI) are presented in Table 3. According to the present result, the minimum, maximum and mean temperature and temperature-humidity index of the experimental house were significant higher ($p < 0.05$) in the afternoon when compared to the morning, whereas, the minimum, maximum and mean relative humidity were significantly lower ($p < 0.05$) in the afternoon (Table 2). The air temperature, relative humidity, and THI in the experimental house were variable but showed a relatively increasing train across the period of the experiment.

Table 3. Climate variables of experimental houses during the study period.

Climate Variables		Morning (8:30 am)	Afternoon (16:30pm)	SEM	P-value
Ta (°C)	Minimum	11.57^b	19.55^a	0.560	0.0001
	Maximum	25.90^b	30.14^a	0.401	0.0001
	Mean	18.74^b	24.84^a	0.346	0.0001
RH (%)	Minimum	37.31^a	32.37^b	1.352	0.0001
	Maximum	75.25^a	60.81^b	1.816	0.0001
	Mean	56.28^a	46.59^b	1.312	0.0001
THI (°C)	Minimum	12.14^b	18.46^a	0.441	0.0001
	Maximum	25.00^b	28.21^a	0.370	0.0001
	Mean	18.11^b	23.06^a	0.277	0.0001

[ab] Means within the same row are significantly different at $P < 0.05$. Ta: ambient temperature; RH: Relative humidity; THI: Temperature humidity index; SEM: Standard error of means.

3.2. Water intake and body weight change

Water intake of experimental lambs was significantly ($p < 0.05$) increased with TDS levels in lake Basaka water when compared to freshwater drinkers (Table 4). The trend showed a slight decrease in water intake as TDS increased. No differences were observed in, initial body weight (IBW), average daily gain (ADG) and final body weight (FBW), and feed conversion efficiency (FCE) of Hararghe-highland lambs consuming saline water of lake Basaka with a TDS concentration of salt up to7952 mg/L (Table 4).

3.3. Physiological variables

Among the physiological variables commonly assessed in the studies of the adaptability of the experimental lambs are respiration rate, rectal temperature, and pulse rate (Table 5). The finding revealed that the respiration rate (RR) and rectal temperature (RT) were significantly different ($p < 0.05$) among saline water treatments and between periods, whereas pulse rate (PR) is different significantly only between periods of the day (higher in the afternoon). Animals are active during the day, which is the source of adjustments in their physiological variables to maintain their body temperature. Lower rectal temperature of lambs was observed in freshwater consumers than that in saline lake water with the addition of NaCl. The respiration rate was significantly higher ($P < 0.05$) in lambs that drank Lake Basaka water and additional NaCl levels (LB100% and LB200% TDS) than in that consumed freshwater.

3.4. Relationship between THI and physiological parameters

The study revealed that the temperature humidity index (THI) was positively correlated with rectal temperature (RT) and respiration rate (RR). The Pearson correlation test showed that there was a relationship between THI and RT ($r = 0.003$, $p = 0.005$) and THI and RR ($r = 0.071$, $p = 0.005$) during the study period. The result also showed a positive relationship between HR and RR as illustrated in figure 1. Thus, from this

Table 4. Water intake and body weight of lambs consumed saline water of lake Basaka

Variables	Water saline treatments				SEM	P-value
	FW	LB	LB100	LB200		
WI (L/day)	1.42^b	1.67^a	1.65^a	1.60^a	0.0327	0.0183
IBW (kg)	18.19	17.66	18.01	18.23	0.4279	0.9698
FBW (kg)	22.19	22.23	22.16	21.74	0.3335	0.9574
ADG (g/day)	66.67	76.07	69.17	58.57	2.9815	0.2251
FCE	11.29	12.92	11.70	9.94	0.5197	0.2473

[ab] Means bearing different letter superscripts differ significantly ($P < 0.05$). FW: Freshwater; LB: Lake Basaka water; LB100: Lake Basaka water plus 100%TDS; LB200: Lake Basaka water plus 200%TDS; WI: water intake; IBW: initial body weigh; FBW: final body weight; ADG: average daily gain; FCE: feed conversion efficiency; SEM: Standard error of the mean.

Table 5. Mean values of the rectal temperature (RT), respiratory rate (RF), and pulse rate (PR), of the sheep, subjected to water salinity levels (WT) with periodic (Pr).

Variable	Period (Pr)		Water treatment (WT)				SEM		P-value	
	08:30	16:30	FW	LB	LB100	LB200	Pr	WT	Pr	WT
RT (°C)	38.50^b	39.25^a	38.59^b	38.95^a	38.93^a	39.01^a	0.039	0.055	0.001	0.001
RR (mov/min)	27.76^b	30.97^a	27.87^b	28.97^a	30.14^a	30.49^a	0.326	0.462	0.001	0.008
PR (beat/min)	83.46^b	93.02^a	90.60	87.21	87.94	87.20	0.702	0.993	0.001	0.066

^{a,b} Means within the rows bearing changed superscript letters differ significantly *($P < 0.05$)*. FW: Fresh Water; LB: Lake Basaka water; LB100: Lake Basaka water plus 100%TDS; LB200: Lake Basaka water plus 200%TDS; SEM: Standard error of the mean.

study, it can be noticed that the THI value of 28^{o}c is a critical value for all physiological parameters considered in this particular breed of sheep under the current situation. Up to this critical value, animals could perform well since heat stress had minimal effect. However, as THI advances sheep may lose their performance to maintain their constant body temperature.

3.5. Blood parameters

3.5.1. Hematological parameters

Blood hematological variables of lamb drinking water salinity levels of lake Basaka were presented in Table 6. The finding revealed that except for hemoglobin concentration levels insignificant differences were noticed in the hematological parameters of experimental animals drinking lake Basaka water with an increase in TDS concentration of salt up to 7900 mg/L.

3.5.2. Serum biochemical variables

The finding revealed that the serum concentration of glucose, albumin, urea, and triglycerides significantly differs ($P < 0.05$) among water salinity levels, whereas the concentration of total protein, cholesterol, and creatinine did not significantly ($P > 0.05$) differ (Table 7). Lambs consuming freshwater had lower glucose levels than saline water treatments. Additionally, albumin, urea, and triglycerides concentration were lower for lambs that drank fresh water and increased with increasing saline levels in lake water (Table 6). Except for sodium (Na^+), serum mineral concentrations in the blood of experimental animals were insignificant differences ($P > 0.05$) among saline water levels of lake water (Table 6). Sodium serum concentration was significantly ($P < 0.01$) greater in LB100 and LB200 treatments than in FW, while LB did not differ from the other treatments (Table 6). Increasing sodium chloride concentration in the drinking saline water of lake Basaka increased the concentration of AST when compared to the freshwater drinking group. Alanine aminotransferase (ALT) exhibited the same trend as AST.

4. Discussion

4.1. Climate variables during the trial period

The temperature and humidity are within the thermal comfort zone (TCZ) for the species (<25.0 °C and 65.0%) [23]. Most of the time, the relative air humidity (RH) was ideal for sheep. The temperature-humidity index accounts for the combined effect of temperature and relative humidity and is considered one of the best methods to evaluate heat stress in animals [24]. In a hot and dry environment, evaporation occurs quickly, leading to skin irritation and overall dehydration, causing the animal to tend to force the air into the lungs, generating an extra energy expenditure [25], which makes the exchange of energy through the respiratory tract difficult. High values of air temperature, which is associated with low relative humidity, can influence physiology and consequently the production of the animals [26], especially concerning their heat exchange with the environment. The temperature-humidity index (THI) is a sensitive indicator of heat stress in animals that is influenced more by ambient temperature than relative humidity. In the current trial, the temperature and humidity index is within the thermal comfort zone (TCZ) for the sheep (<25.0 °C and 65.0%) [23]. Similarly, conferring to Maria et al [21] the mean average THI in the current study is within the range that does not cause heat stress on animals.

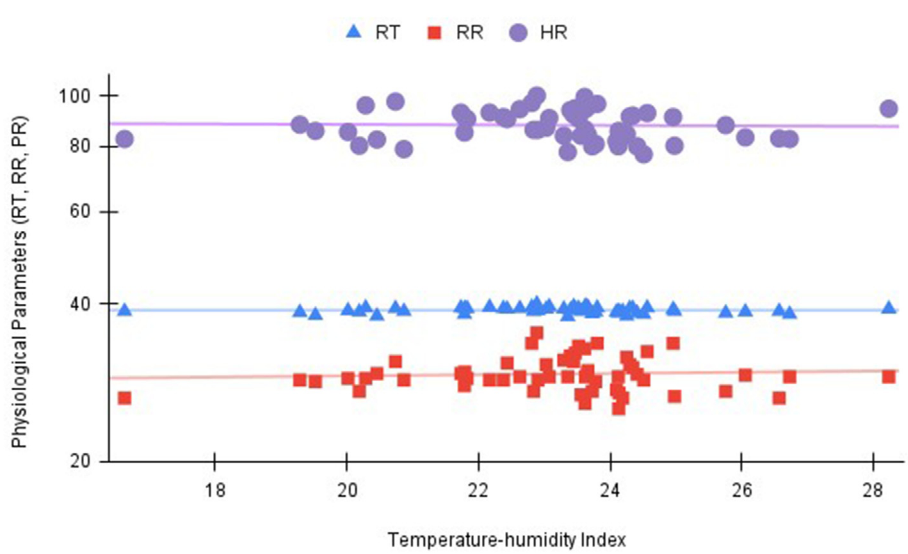

Figure 1. Correlation between the temperature–humidity index and physiological parameters of experimental sheep. THI: temperature-humidity index (oc); RT: rectal temperature (oc) RR: respiration rate (breaths per minute); PR: heart rate (beats per minute).

Table 6. Hematology of lambs drank levels of saline water (mean ± SEM).

Variables	Water Treatment				SEM	P-value
	FW	LB	LB100	LB200		
Hemoglobin (g/dl)	10.63^a	10.13^a	9.97^b	9.64^b	0.214	0.2026
PCV (%)	31.98	30.85	30.43	32.27	0.701	0.2306
RBC (×106/μl)	10.35	9.89	10.09	10.40	0.205	0.2974
WBC (×106/μl)	8.45	7.98	8.45	7.30	0.458	0.2723
MCV (fl)	31.25	31.33	30.36	31.19	0.571	0.6068
MCH (pg)	10.31	10.23	10.07	10.16	0.121	0.5629
MCHC (g/dl)	44.30	32.58	33.13	44.30	5.561	0.3893

[a,b] Means within row bearing different superscript letters differ significantly (** = $p < 0.01$); FW: Fresh Water; LB: Lake Basaka water; LB100: Lake Basaka water plus 100%TDS; LB200: Lake Basaka water plus 200%TDS; Hb: Haemoglobin; PCV: Packed cell volume; RBC: Red blood cell; WBC: White blood cell; MCV: Mean corpuscular volume; MCH: Mean corpuscular hemoglobin; and MCHC: Mean corpuscular hemoglobin concentration.

4.2. Water intake and bodyweight change

Water quality (salinity levels) is one of several factors that influence water intake. Arid and semi-arid species may consume more water than others. The high-water consumption of livestock is a significant environmental disadvantage. Furthermore, the fact that arid or semi-arid areas have high salinity water can reduce the quality of the products derived from these animals [27]. The significantly higher water intake for the group that drank saline water compared with the control group might be attributed to the increased thirst feeling caused by the incidence of polydipsia resulting from lesions of the thirst center [28]. An excessive TDS in drinking water decreases the secretion of renin [29] and increases angiotensin II which acts on the adrenal cortex, triggering it to release aldosterone, a hormone that causes the kidneys to retain sodium and lose potassium, which leads to increased water consumption [30]. The increased water consumption induces urination thereby increasing urine output, enabling animals exposed to drinking water with high salt or in the diet to get rid of the excessive amount of salt through increased urine production. Vosooghi-Postindoz et al. [13] reported that the ratio of water to DMI progressively increased in saline water compared with the well water. Furthermore, dramatically increased water consumption of an Egyptian Ossimi lamb offered NaCl in drinking water with levels of 0 and 15 g/l was reported by Hussein and Abdelsattar [31].

An insignificant change in the body weight of sheep consuming saline water of Lake Basaka with TDS levels of up to 7952 mg/L agrees with the result of Albuquerque *et al.* [32] who noted that average daily gain, final body weight, and feed conversation efficiency in sheep were not affected by water salinity levels up to 8326 mg/l TDS. In contrast, the Bodyweight gain of Baluchi lambs was reduced from 129.4 to 84.6 g/day due to a salinity of 8 g/l in drinking water [13]. The difference in variation from the current study was might be due to differences in the breed of sheep, water types, and environmental conditions.

4.3. Physiological parameters

Physiological variables like rectal temperature, respiration rate, and pulse rate under water stress are especially vital because evaporation is the primary route of heat dissipation in sheep, at a time when the animal is under pressure to conserve water [27]. Physiological variables of the animal are influenced by many factors like breed, temperature, species' environmental condition, feed, and water stress. Physiological parameters are influenced by the time of day because the ambient temperature is higher in the afternoon than in the morning [25, 33]. The study was agreeing with Araújo *et al.* (2010) observed rectal temperature (RT) within the normal range through the sheep was kept in an environment with high ambient temperatures and low relative humidity on most of the days while consuming water with salinity above the recommended level.

Table 7. Blood biochemical of lambs drank levels of saline water.

Variables	Water Treatments				SEM	P-value
	FW	LB	LB100	LB200		
Glucose (mg/dl)	56.32^b	60.21^{ab}	64.11^a	63.86^a	1.38	0.0024
TP (g/dl)	6.18	6.33	6.38	6.06	0.15	0.4153
Albumin (g/dl)	3.37^b	3.68^a	3.77^a	4.02^a	0.09	0.0008
Urea (mg/dl)	20.32^c	24.79^b	28.11^a	28.93^a	0.92	0.0001
Cholesterols (mg/dl)	27.14	23.04	21.86	19.79	1.02	0.8851
Creatinine (mg/dl)	59.61	61.75	61.43	62.07	2.38	0.1755
Triglycerides (mg/dl)	29.00^c	30.57^c	31.86^b	33.24^a	0.58	0.0005
Na^+ (mmol/L)	136.36^c	140.14^b	142.96^a	142.50^a	1.21	0.0042
Cl^- (mmol/L)	101.11	102.46	102.75	106.18	2.34	0.4826
K^- (mmol/L)	4.33	5.21	5.11	4.70	0.26	0.1046
Mg^{2+} (mmol/L)	2.15	2.16	2.16	2.34	0.06	0.1201
Ca^{2+} (mg/dl)	5.84	5.86	5.94	5.97	0.10	0.7461
AST (u/l)	85.52^c	90.06^b	96.48^a	101.78^a	1.48	0.0001
ALT (u/l)	30.77^c	32.10^c	35.62^b	40.02^a	0.77	0.0001

[a,b] Means within a row bearing different superscript letters differ significantly at $p < 0.05$). FW: Fresh Water; LB: Lake Basaka water; LB100: Lake Basaka water plus 100%TDS; LB200: Lake Basaka water plus 200%TDS; TP: Total protein; AST: Aspartate aminotransferase; ALT: Alanine aminotransferase; SEM: Standard error of the mean.

In the current study, the increased RT with salinity levels is possibly due to the ionic dissociation of NaCl in the aqueous medium, producing HCl making the blood and body fluids acidic. Such acidity can reduce blood pH, causing breathing to be deeper and faster since the body is trying to release the excess acid found in the blood [34]. In addition, the higher respiration rate is possibly indicating a determination of animals to preserve their normal body temperature by increasing their heat dissipation through increasing respiratory evaporation [35]. The finding was comparable with Júnior et al. (2019) who reported that t the rectal temperature of Santa Inês lambs drank water containing salinity of 1.5dSm-1 (39.2 °C) and 6.0dSm-1 (39.4 °C) was significantly different and with the highest values of RR in animals consumed water with 3.0 dS m-1 (63.5 mov min-1) and 6.0 dS m-1 (57.1 mov min-1). Hekal [36] similarly reported that Barki ram lambs offered saline water containing 2886ppm TDS had a higher rectal temperature and respiration rate than the 275ppm TDS group (39.30 vs 39.10 °C and 55.34 vs 48.80 breaths/min, respectively). Accordingly, the present sheep breed may be adapted to saline water by increasing rectal temperature and respiration rate under no heat stress conditions. Relationship between THI and Physiological Parameters.

Temperature-humidity index (THI), is a combination of temperature and humidity that is a measure of the degree of discomfort experienced by an individual in warm weather; it was originally called the discomfort index [37]. A temperature-humidity index (THI) is a single value representing the combined effects of air temperature and humidity associated with the level of thermal stress. This index has been developed as a weather safety index to monitor and reduce heat-stress-related losses [38, 39, 40]. The tolerance of animals to high air temperatures depends on the amount of water vapor in the air as this affects the rate of heat loss by evaporation.

The average respiratory rate was 29.3 mov min^{-1}, which is within the normal range for the species that vary between 24.0 and 36.0 mov min^{-1} in thermoneutral environments. The animal's respiration rate is influenced by the number of times it is exposed to sunlight and environmental factors This elevation is due to the high ambient temperature associated with low relative humidity, so the animals used this physiological adjustment to eliminate body heat [41] where the animals spend energy in the dissipation of heat by respiration to maintain homeothermy. Physiological control mechanisms in animals have evolved to limit the losses of body fluids, and the elevation of respiratory rate underwater salinity stress for a longer period may reduce the total amount of body water [42].

Correlation analysis indicated that the pulse rate of the lambs consuming saline water was slightly higher in the afternoon than in the morning (Figure 1). Marai *et al.* [43] noted that the biological functions of sheep exposed to high ambient temperature could be negatively affected and compromises their performance. The high pulse rate values are due to the exposure of the animals to unfavorable climatic conditions, as they used this variable to eliminate body heat because, with the increase in pulse rate, there is a greater circulation of blood, which takes the warm blood from the center of the body to its peripheral parts.

4.4. Blood parameters

Temperature changes affect the blood system, which is an important indicator of physiological responses to stressful situations. Blood haemato-chemical parameters are crucial methods for determining the physiological and health status of animals and are almost mandatory in organic farming. They are affected by a wide range of factors such as breed, age, reproductive status, housing, starvation, environmental factors, stress, and transportation [44, 45, 46].

4.4.1. Hematological parameters

Several factors can influence the pattern of hematological values, including species, breed, sex, age, nutrition, diseases, physiological stage, and seasonal variations [47]. The observed change in hemoglobin concentration of sheep consuming water salinity levels in the current study was in agreement with the findings of Eltayeb (2006) reported blood hemoglobin in female Nubian goats offered saline water. Similarly, Barki sheep hemoglobin was decreased in 2800 ppm TDS (10.74 mg/dl) than that in 244 ppm TDS (2.38 mg/dl) [48]. In the current study, the reduction in Hb might be attributed to the haemodilution effect resulting from an increase in water intake [49]. Biochemical parameters.

The concentrations of blood serum biochemical measured in the current study were associated with those found in the literature [9, 50, 51] with small differences that could be ascribed to the different breeds used, types of water used, and the experimental conditions. Also, Hekal [36] reported that Barki sheep who drank saline water (2800ppm TDS) had higher glucose (99.11 *vs* 72.97) mg/dl than those who drank tap water (240 ppm TDs) group, which might be ascribed to a reduction in feed intake by the treated group. Assad and El-Sherif [14] stated that the reduction in glucose levels could be associated with the fact that a rise in TDS in drinking water with a reduction in food intake. In this current study, the factor accountable for the variation in glucose concentration was not determined but seemed independent of reduced feed intake, which is the subsequent no effect of saline water treatment on dry matter intake.

Albumin, triglycerides, and total protein concentrations in the serum of animal blood are indicators of liver function and the dietary status of the animal [52]. In the present study, the increased serum Albumin concentration could be attributed to sodium's role in the absorption of amino acids from the gut and subsequent utilization of the amino acids in the formation of plasma proteins [53]. Moreover, the increases in concentrations of triglycerides reflect the mobilization of body fat to support additional energy needs for activated metabolic functions to cope with the stress of drinking water and to produce metabolic water [54].

Compatible, serum creatinine and urea are indicators of kidney function [55]. The urea concentration was lower for lambs that drank fresh water and higher for treatment with a high level of TDS and the result following that reported by Yousfi and Salem [9] who reported significantly higher plasma urea in Barbarine sheep who drank saline water containing 11 or 15g NaCl/l compared to those offered tap water, suggesting an alteration of kidney function. In Barki sheep [12], showed saline water (4557 or 8934ppm TDS) drinking for 9 months significantly increased the serum urea compared with the tap water group. In the present study, an increase in blood urea concentration may indeed be related to the increase in urea production in the liver [56]. In the current study, an increase in serum Na^+ concentration in lambs is linked with an increase in NaCl intake from drinking salty water, which could then be attributed to haemoconcentration caused by the animals' increased intake of salty water [14, 57].

Enzymes (ALT and AST) are considered indicators of liver health, and significant changes in their concentration can indicate liver damage [58]. In this finding, although the values increased with increasing levels of TDS in drinking lake water, they remained within the sheep's physiological range [59]. Thus, it could be concluded that some adverse effect was seen in liver functioning but that was not to the extent which could cause an ill effect on the health of the animal. Assad and El-Sherif [14] studied the effect of saline water on these liver enzymes in sheep and reported a rise in plasma concentration concerning saline load, expressly at a low dietary level. In another study done by Shaker [60] on sheep-fed salt-tolerant fodder, an increasing trend was observed when high salt-water was offered. Similarly [12], reported that ALT and AST concentrations in the medium saline water (4,557ppm) and high saline water (8, 934) groups of Barki sheep were higher than that of Tap water (350ppm). It can be concluded that ALT was released more, indicating liver hyperfunction in sheep as a result of the increase in salinity of drinking water, particularly when nutrient intake was low. Furthermore, saline administration reduced glucose levels. This demonstrated the frequency of energy expenditure by sheep to cope with the saline load, which imposed stress on liver function.

5. Conclusions

This finding suggests that Hararghe-highland lambs can tolerate lake water with up to 7952mg TDS/L without adverse effects. This study also found that this sheep breed is better adapted to living and possibly reproducing in areas where fresh water is scarce or has a high TDS concentration. These conclusions are crucially significant because they explain the resilience of native sheep to saline lake waters found in a semi-arid rift valley of eastern Ethiopia where water is scarce and of poor quality, as well as allowing these animals to be watered without adversely affecting their performance. For further recommendations, more research on long-term drinking saline water of Lake Basaka on different species, breeds, diets, and temperatures should be needed.

Ethical approval

The procedure of this study was approved (SARS 38/050, dated October 20/2019) by the Haramaya University's Established Animal Care and Ethics Committee following the European Union directive number 2010/63/EU regarding the care and use of animals for experimental and scientific purposes.

Declarations

Author contribution statement

Diriba Tulu: Conceptualizes, Data curation; Funding acquisition; Investigation; Methodology; Software; Writing- original draft; Writing-review, and editing. Mengistu.

Urge: Conceptualizes, Supervision; Validation; Funding acquisition; Visualization, editing.

Yisehak Yusuf: Supervision; Validation; Writing-review, and editing.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no competing interests.

Additional information

No additional information is available for this paper.

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