Adaptation Capacity of Indigenous Sheep to Saline Lake Drinking Water in Dry Area of Ethiopia Under Climate Change

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Abstract

Climate change-induced water salinization and scarcity is a growing global phenomenon that poses new threats to farm animal production in dry regions. However, the adaptation capacity of livestock to water stress depends on species, breeds, and environmental situation. Therefore, the study aimed to evaluate the adaptation capacity of local sheep to drinking lake water salinity levels based on their growth performance, behaviour, physiology, and blood constituents in eastern Ethiopia. A total of 28 lambs were categorized into four groups based on their initial body weight with eight replicates and allocated into levels of water salinity, namely freshwater (510mg/l TDS (Total Dissolved Solids), 2600mg/l TDS, 5200mg/l TDS) and 7900mg/l TDS). The results revealed that increasing TDS levels in lake Basaka water varies water intake watering frequency, time spent on drinking, inactive behaviour, and, increased rectal temperature and respiration rate. Additionally, the concentration of blood haemoglobin, glucose, albumin, urea, triglycerides, sodium, triiodothyronine, enzymes of alanine, and aspartate aminotransferases were changed with slightly decreased thyroxine hormone. Generally, the Hararghe-highland sheep breed was adapted to water with a high salt level (7952mg/L TDS) with some notable physiological changes, indicating that increased salinity beyond the level in the present study may affect animal welfare and productivity.

Keywords: blood, performance, physiology, water quality

1. Introduction

Global warming has increased the occurrence of rising temperatures all around the globe, forcing livestock production under stress conditions [1]. Sheep breeds native to drylands are identified for their capacity to tolerate harsh environmental variations, water scarcity, and poor water quality [2]. So, as the temperature rises due to global warming, both increased salinities have threatened underground and surface water [3]. As a consequence of the contamination of groundwater, lake water has become a crucial source of drinking water for livestock species; it is also affected by climate change and variability. [4]. Water scarcity and quality are the most serious challenges encountering dryland livestock farming systems [5]. However, the ability of the animal to water scarcity and qualities depends on their species, breed, age, sex, environmental conditions, water quality status, physiological state, and production status.

The number of researches that focused on the consequence of intake of saline water on small ruminants used NaCl added to freshwater. (Yousfi and Ben Salem, 2017; Paiva et al., 2017; Ghanem et al., 2018; Vosooghi-Postindoz et al., 2018). Also, diluted seawater has been used in a few experiments (Assad and

El-Sherif, 2002; Attia-Ismail et al., 2008). Very few findings have been used on actual natural sources of saline water with the addition of sodium chlorides [13]. Furthermore, understanding the physiological and biochemical adaptability mechanisms that reinforce small ruminants' ability to adapt to a saline load serves as a foundation for developing long-term strategies for raising small ruminants in areas where water is scarce or salt concentrations are high. [14]. Also, even though drinking water is a vital nutrient whose quantity and quality have a direct impact on small ruminant production and productivity, a little finding has been conducted in Ethiopia. Thus, the purpose of this study was to evaluate the effects of drinking saline lake Basaka water with the addition of NaCl on the growth performance, physiological responses, and blood profile of Hararghe highland lambs in eastern Ethiopia.

2. Materials and Methods

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 [15].

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.

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. The saline water treatments were categorized into four TDS levels: freshwater (FW) (500mg/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 to 5) of the trial period by slowly increasing the salt concentration of the drinking water until it reached the required concentration. 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 and formulated conferring to the National Research Council- NRC (2007) to meet the maintenance rations of the animals.

Measurements

Water 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 minutes 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 experimental animals were balanced at fifteen days intervals after a solid-feed withdrawal of 12 hours. 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.

Conversion efficiency = (Average daily gain (g/day))/(Average daily dry matter intake (g/day)))

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 to 43.9 °C, which was inserted into the animal's rectum so that the bulb was in contact with the mucosa, remaining there for a period until a sound signal signifying the temperature stabilization. The respiratory rate (RR) and pulse rates (PR) were obtained by counting 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 seconds and then multiplied by 3, thus obtaining the number of movements per minute [16].

Blood collection and analysis

Blood samples were taken from each animal into 5ml vacuum tubes containing 10% anticoagulant ethylene diamine tetraacetic acid (EDTA) for haematological 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 haematology, including packed cell volume, haemoglobin, white blood cells (WBC), red blood cells (RBC), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), and mean corpuscular haemoglobin concentration (MCHC) by automated haematology analyzer (Sysmex kx-21, Japan) [17].

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 labelled 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).

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 $P < 0.05$.

3. Results

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 3). 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 to7952mg/L (Table 1).

Table 1. 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[ab]	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; SEM: Standard error of the mean.

Behavioural parameters

Time spent on drinking and inactive and watering frequency were significantly different (P<0.05) among salinity levels (Table 2), which can be explained by the fact that confined animals tend to present similar behaviour, due to the permanence in individual pens, and by the similarity between nutrient sources in the diets (Nomura et al., 2008). Alterations in the feeding, rumination, and idle activities can be often verified in studies where the experimental diets vary in fiber contents, as observed in an experiment conducted by [19], who supplied increasing levels of NDF from the forage in diets for dairy goats and found an increase in the feeding and rumination times and decrease in the idle time. Lambs drank fresh water spent more time drinking and less frequent, and lambs drinking Lake Basaka water plus 200%TDS of Lake Basaka water spent less time on drinking and more frequent when compared to others. Freshwater groups spent more time inactive than other salinity level groups. Moura et al. (2016) suggested that water with different levels of total dissolved solids (640; 3,188; 5,740; and 8.326 mg/l) did not cause alterations in the Ingestive behaviour of sheep and Leite et al. (2019) found that animals that consumed water with a salinity level of 9.0dS/m spent a greater amount of time drinking water compared to those consuming water with a salinity level of 3.0dS/m. In fact, during day time, there is a higher rate of turnover of water and consequently a greater digestibility of the ruminal fluid resulting in greater assimilation of sodium chloride and its concentration in extracellular liquids; thus, the thirst sensation of the animals increased when they consumed water with higher concentrations of sodium, which make them consume water more frequently (Assad and El-Sherif, 2002). Besides, the elevation of water salinity caused increased idle time in sheep and reduced the time they remained inactive at the night (Leite et al., 2019).

Table 2. Percentage Ingestive behavioural parameters of lambs drank water with levels of salinity (Mean ± SEM)

Behavioral Parameters	Water Treatments				SL
	FW	LB	LB100	LB200	
Feeding (%)	16.42±0.71	18.69±1.11	17.81±0.89	18.05±0.54	Ns
Drinking (%)	0.59±0.07[a]	0.56±0.07[a]	0.43±0.05[ab]	0.31±0.04[b]	**
Inactive (%)	30.91±0.69[a]	29.38±0.89[ab]	27.73±0.92[ab]	27.52±0.86[b]	*
Sleeping (%)	18.19±0.98	18.50±1.11	18.10±1.23	17.93±0.91	Ns

Ruminating (%)	30.23±0.46	29.29±0.43	31.36±1.17	31.62±0.26	Ns
Others (%)	3.66±0.85	3.59±0.50	4.58±0.70	4.58±1.06	Ns
Feeding frequency (n/d)	9.48±0.50	8.62±0.34	10.19±0.55	8.71±0.52	Ns
Watering frequency (n/d)	2.95±0.17^{c}	3.24±0.32^{bc}	4.19±0.27^{ab}	4.81±0.25^{a}	***

^{a,b,c} Means within row bearing different superscript letters differ significantly (*=p<0.05; **=p<0.01; ***=p<0.001). 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 mean; SL: Significant level; n/d: Number per day; %: Percent; ns: not significant.

Physiological variables

Among the physiological variables commonly assessed in the studies of adaptability of the experimental lambs are respiration rate, rectal temperature, and pulse rate (Table 3). 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) differed 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 that consumed freshwater (Table 3).

Table 3. 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.

Blood parameters

Hematological variables

Blood hematological variables of lamb drinking water salinity levels of lake Basaka were presented in Table 4. The finding revealed that 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 7900mg/L.

Table 4. 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	10.13	10.17	10.64	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: Hemoglobin; 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.

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 5). 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 drinking saline water of lake Basaka increased the concentration of AST when compared to the freshwater drinking group (Table 7). Alanine aminotransferase (ALT) exhibited the same trend as AST.

Table 5. Blood biochemical of lambs drank levels of saline water

Variables	Water Treatments				SEM	P-value
	FW	LB	LB100	LB200		
Glucose (mg/dl)	56.32^{bb}	60.21^{ab}	64.11^{aa}	63.86^{aa}	1.38	0.0024
TP (g/dl)	6.18	6.33	6.38	6.06	0.15	0.4153
Albumin (g/dl)	3.37^{bb}	3.68^{ab}	3.77^{aa}	4.02^{aa}	0.09	0.0008
Urea (mg/dl)	20.32^{c}	24.79^{bb}	28.11^{ab}	28.93^{aa}	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^{cc}	30.57^{bc}	31.86^{ab}	33.24^{aa}	0.58	0.0005
Na^{+} (mmol/L)	136.36^{bb}	140.14^{ab}	142.96^{aa}	142.50^{aa}	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^{b}	90.06^{bb}	96.48^{a}	101.78^{aa}	1.48	0.0001
ALT (u/l)	30.77^{c}	32.10^{cc}	35.62^{b}	40.02^{a}	0.77	0.0001

a,b Means within 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.

4. Discussion

Water intake and Bodyweight change

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 centre [22]. An excessive TDS in drinking water decreases the secretion of renin [23] 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 [24]. 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. [10] reported that the ratio of water to DMI progressively increased in saline water (8000mg/L vs 400mg/L TDS) (4791.36 mL vs. 3786.58 mL; $P<0.05$) compared with the well water (4.52 g vs. 3.05 g). An insignificant change in the body weight of sheep consuming saline water of Lake Basaka with TDS levels of up to7952mg/L, agrees with the result of Albuquerque et al. (2019) who noted that average daily gain, final body weight, and feed conversation efficiency in sheep were not affected by water salinity levels up to 8326mg/l TDS. Inconstant, the Bodyweight gain of Baluchi lambs was reduced from 129.4 to 84.6 g/day due to salinity of 8 g/l in drinking water [10]. The difference in variation from the current study was might be due to differences in the breed of sheep, water types, and environmental conditions.

Physiological parameters

Physiological parameters are influenced by the time of day because the ambient temperature is higher in the afternoon than in the morning [27] [28]. In the current finding, the RT of lambs consumed saline water was higher in the afternoon than morning (Table 6), which is positively related to the ambient temperature indicating that RT is increased when evaporative processes of heat exchange are insufficient and that sheep have difficulty in dissipating heat under high ambient temperatures [29]. The study was agreeing with Araújo et al. (2010) observed 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.

Accordingly, 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 [30]. 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 [31]. 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(39.2oC) and 6.0dSm-1(39.4oC) 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 [32] 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 ºC 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.

Blood Serum biochemistry

The concentrations of blood serum biochemical measured in the current study were related to those found in the literature [33] [34] [7] with small differences that could be ascribed to the different breeds used, types of water used, and the experimental conditions. Also, Hekal [32] 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 [11] 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 [35]. 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. [36]. 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 in drinking water and to produce metabolic water [37].

Compatibly, serum creatinine and urea are indicators of kidney function [38]. The urea concentration was lower for lambs that drank fresh water and higher for treatment with a high level of TDS and the result was following that reported by Yousfi and Salem [7] 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, [9] 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 [39]. 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. [11] [40].

Enzymes (ALT and AST) are considered indicators of liver health, and significant changes in their concentration can indicate liver damage. [41]. In this finding, although the values increased with increasing levels of TDS in drinking lake water, they remained within the sheep's physiological range. [42]. 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 [11] 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 [43] on sheep-fed salt-tolerant fodder, an increasing trend was observed when high saltwater was offered. Similarly, [9] 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.

Authors Contribution

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. All authors have read and agreed to the published version of the manuscript.

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.

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Availability of data and material: Upon a reasonable request, the datasets of this study can be obtainable from the corresponding author.

Conflicts of Interest: The authors declare that they have no conflicts of interest.

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