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Effects of level of brackish water and salinity on feed intake, digestion, heat energy, ruminal fluid characteristics, and blood constituent levels in growing Boer goat wethers and mature Boer goat and Katahdin sheep wethers

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A R T I C L E I N F O

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A B S T R A C T

A study was conducted to evaluate effects of the level of a brackish water source (5596 mg/l total dissolve salts; **TDS**) and higher levels of TDS through addition of NaCl on feed intake, digestion, and heat energy in growing Boer goat wethers (**GRO-G**) and mature Boer (**MAT-G**) and Katahdin sheep wethers (**MAT-S**). Five GRO-G (22.1 ± 2.50 kg; 0.76 ± 0.121 yr of age), five MAT-G (52.2 ± 4.99 kg), and five MAT-S (65.5 ± 4.17 kg) were assigned to three simultaneous 5 × 5 Latin squares with 3-wk periods. Treatments within squares were ad libitum intake of fresh water (**0-BRW**), 50% fresh water and 50% brackish water (**50-BRW**), 100% brackish water (**100-BRW**), 100-BRW plus 3450 mg/l NaCl (**Low-SLW**), and 100-BRW plus 6900 mg/l NaCl (**Mod-SLW**). Total water intake was not influenced by TDS level with GRO-G or MAT-S but increased linearly with increasing TDS ($P = 0.004$) for MAT-G (952, 1087, 1284, 1192, and 1372 g/day for 0-BRW, 50-BRW, 100-BRW, Low-SLW, and Mod-SLW, respectively; SEM = 147.7). Organic matter (**OM**) intake was not influenced by water treatment with GRO-G but changed quadratically as TDS increased ($P = 0.049$) with MAT-G (744, 749, 785, 732, and 703; SEM = 76.3) and linearly ($P = 0.065$) with MAT-S (870, 867, 835, 788, and 694 g/day for 0-BRW, 50-BRW, 100-BRW, Low-SLW, and Mod-SLW, respectively; SEM = 80.0). Total tract OM digestion in MAT-G and MAT-S was not influenced by water TDS level but decreased linearly ($P = 0.004$) and tended to change quadratically ($P = 0.054$) in GRO-G (59.3, 55.5, 47.8, 47.0, and 49.5% for 0-BRW, 50-BRW, 100-BRW, Low-SLW, and Mod-SLW, respectively; SEM = 4.67). Intake of metabolizable energy (**ME**) decreased linearly with increasing TDS for MAT-G ($P = 0.014$; 458, 458, 441, 449, and 381; SEM = 34.2) and MAT-S ($P = 0.045$; 384, 361, 328, 317, and 289; SEM = 33.2) and increased linearly and changed quadratically ($P \le 0.031$) for GRO-G (519, 402, 321, 319, and 363 kJ/kg $BW^{0.75}$ for 0-BRW, 50-BRW, 100-BRW, Low-SLW, and Mod-SLW, respectively; SEM = 54.5). In conclusion, increasing TDS concentration in drinking water had effects on intake and digestion that differed among animal types, with ME intake of growing goats more adversely affected by increasing brackish water level compared with mature small ruminants because of decreased digestibility. Conversely, decreases in ME intake for MAT-S with increasing TDS primarily related to decreasing feed intake, with relatively small effects for MAT-G associated with the Mod-SLW treatment.

1. Introduction

Consumption of water moderate to high in total dissolved salts or solids (**TDS**) by livestock and its salinity are expected to increase in the forseeable future. Saline water refers to TDS above 1000 ppm, which includes brackish water with TDS between 1000 and 10,000 ppm, with highly saline water having TDS of 10,000–15,000 (USGS, 2013; Stanton et al., 2017; Stanton and Dennehy, 2017). A better understanding of factors affecting the utilization of brackish/saline water by ruminant livestock species would help identify most appropriate management practices.

There are a number of ways by which saline water can adversely affect performance of ruminants, most importantly intake and digestion (Petersen et al., 2015). Consumption of water with elevated levels of TDS by ruminant livestock has been studied for many years with additions of minerals sources such as NaCl, $MgCl_2$, $NaHCO_3$, and Na_2SO_4,

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Table 1
Composition of water consumed by growing Boer goat wethers and mature Boer goat and Katahdin sheep wethers.

	0-BRW[1]		50-BRW[2]		100-BRW[3]		Low-SLW[4]		Mod-SLW[5]	
Item	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
pH	8.36	0.024	8.14	0.040	8.08	0.073	8.08	0.020	8.06	0.040
Electrical conductivity (dS/m)	0.7	0.02	4.4	0.06	7.8	0.09	14.3	0.15	20.6	0.19
Total dissolved salts (mg/kg)	446	14.6	2977	52.0	5596	53.8	9431	96.3	13,583	127.6
Hardness (mg/kg)	222	3.8	625	22.0	1013	15.4	1020	3.4	1017	11.2
Alkalinity (mg/kg as $CaCO_3$)	175	5.8	164	17.3	177	13.7	192	7.3	177	13.2
Bicarbonate (mg/kg)	210	6.7	199	20.7	216	16.5	234	9.0	216	16.1
Boron (mg/kg)	0.12	0.020	4.64	0.024	9.14	0.040	9.40	0.152	9.34	0.075
Calcium (mg/kg)	38	1.2	170	8.8	297	6.0	297	1.3	296	4.4
Chloride (mg/kg)	85	1.4	682	12.6	1294	25.6	3558	41.0	5754	81.4
Magnesium (mg/kg)	31.2	0.86	49.2	0.37	66.2	0.58	67.6	0.75	67.8	0.37
Nitrate nitrogen (mg/kg)	0.56	0.286	0.42	0.220	1.12	0.449	1.20	0.36	1.10	0.212
Potassium (mg/kg)	6.0	0.78	5.6	0.25	5.0	0.00	8.6	0.40	13.4	0.87
Sodium (mg/kg)	43	4.4	757	12.0	1507	16.7	2977	22.9	4419	31.8
Sodium adsorption ratio	1.3	0.14	13.2	0.21	20.6	0.27	40.5	0.30	60.3	0.45
Sulfate (mg/kg)	30	11.5	1115	14.0	2210	20.0	2172	42.7	2200	23.2

[1] 0-BRW = 100% fresh or tap water and 0% brackish water.
[2] 50-BRW = 50% fresh water and 50% brackish water.
[3] 100-BRW = 100% brackish water.
[4] Low-SLW = 100-BRW plus 3450 mg/l NaCl.
[5] Mod-SLW = 100-BRW plus 6900 mg/l NaCl.

often to simulate natural sources of available saline water (Peirce, 1957, 1959, 1966, 1968a, 1968b; Wilson, 1966; Weeth and Hunter, 1971; Wilson and Dudzinski, 1973). Most experiments, however, have been with NaCl added to fresh water (Kil and Dryden, 2005; Yousfi et al., 2016; Castro et al., 2017; Paiva et al., 2017). Diluted seawater has been used as well (Assad and El-Sherif, 2002; Attia-Ismail et al., 2008).

Very few studies have used actual natural sources of saline drinking water. Ones identified include Harper et al. (1997) and Hunter et al. (2002) with beef cattle consuming coal mine pit water in Australia, Longeragan et al. (2001) with beef cattle consuming blends of a water from a well high in sulfate and fresh water, and Sharma et al. (2017) with growing buffalo calves consuming mixtures of a brackish water source and fresh water. For small ruminants, recently Tsukahara et al. (2016) evaluated effects of 0, 33, 67, and 100% of a brackish water source with 6900 mg/l TDS on intake, digestibility, and heat energy by young Boer and Spanish goat wethers. Intake of metabolizable energy as well as heat energy were assessed, as results of Arieli et al. (1989) suggest that high salt intake could affect efficiency of energy metabolism. Although Tsukahara et al. (2016) noted some effects such as decreased digestion when brackish water was included, the overall conclusion was that effects on performance with long-term feeding would be unlikely. This is in line with suggestions of McGregor (2004) that young goats can consume water with 7000 mg/l TDS without deleterious effects, a level higher than young sheep (i.e., 5000 mg/l), less than adult sheep (10,000 mg/l), and much less than adult goats (14,000 mg/l). Hence, the primary objective of this experiment was to evaluate effects of level of this brackish water source and with higher levels of salinity achieved through addition of NaCl on feed intake, digestion, and heat energy in growing Boer goats and also older animals, mature Boer and Katahdin sheep wethers. Other measures such as levels of some ruminal fluid and blood constituents were evaluated to more fully characterize conditions and as secondary objectives.

2. Materials and methods

2.1. Animals and housing

The experimental protocol was approved by the Langston University Animal Care and Use Committee. Five growing Boer goat wethers (**GRO-G**) (22.1 ± 2.50 kg; 0.76 ± 0.121 yr of age), five mature Boer goat wethers (**MAT-G**; 52.2 ± 4.99 kg), and five mature Katahdin sheep wethers (**MAT-S**; 65.5 ± 4.17 kg) were used. The mature wethers were born in the spring of 2013 and, thus, were nearly 3 yr old when the experiment began in November, 2015. They were treated for internal parasites before a 2-wk period of adaptation to individual housing in 1.05 × 0.55 m elevated pens and plastic-coated expanded metal floors. Wethers also were situated in 0.7 × 1.2 m metabolism crates with 'training' head boxes for 2 days during this period. The study occurred in the winter/spring period and the facility included heating units. Ambient temperature and relative humidity were determined with Hobo® Temperature/RH Data Loggers (model number U12-011; Onset Computer Corp., Bourne, MA). Average hourly temperature, relative humidity, and temperature-humidity index (Amundson et al., 2006) were 17.4 ± 0.083 °C, 44.9 ± 0.26, and 61.6 ± 0.10, respectively.

The experiment consisted of three simultaneous 5 × 5 Latin squares, with periods 3 wk in length. The first 13 days were for adaptation to treatments and the last 8 days were for measurements. Animals of each type were divided into four sets, three with four animals and one with three. Sets consisted of animals subjected to different water treatments each period. During the 8-day measurement segments, feces and urine were collected each day and calorimetry measures occurred on 2 days that varied among sets (e.g., days 14–15, 16–17, 18–19, and 20–21 for sets 1, 2, 3, and 4, respectively). There was 1 wk between periods 1 and 2 and between periods 3 and 4 when wethers were moved to group pens with partial earthen floors and pine shavings for bedding.

2.2. Treatments

All five wethers of a type were assigned to the same Latin square, with five water treatments within squares as the subplot. Water treatments were fresh or tap water (**0-BRW**), 50% fresh water and 50% of brackish water from a well on the University farm (**50-BRW**), 100% brackish water (**100-BRW**), 100-BRW plus 3450 mg/l of NaCl (**Low-SLW**), and 100-BRW plus 6900 mg/l of NaCl (**Mod-SLW**). The levels of added salt were based on a TDS level of 6900 mg/l in the brackish water source noted in a previous study (Tsukahara et al., 2016), so that there would be 50 and 100% increases in TDS relative to 100-BRW.

Water was collected and water treatment mixtures were created, stored in plastic containers, and sampled weekly. Water treatment composition was determined at the Oklahoma State University Soil, Water, & Forage Analytical Laboratory (Stillwater, OK, USA; Table 1).