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Effect of sodium chloride, sodium sulfate or sodium nitrite in drinking water on intake, digestion, growth rate, carcass traits and meat quality of Barbarine lamb

Ibrahim Yousfi [a,b,*], Hichem Ben Salem [a], Dorra Aouadi [a], Sourour Abidi [a]

[a] *Institut National de la Recherche Agronomique de Tunisie (INRAT), Université de Carthage, Laboratoire des Productions Animales et Fourragères, Rue Hédi Karray, 2049 Ariana, Tunisia*

[b] *Institut National Agronomique de Tunisie (INAT), Université de Carthage, 43 Avenue Charles Nicolle, 1082 Tunis, Tunisia*

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ABSTRACT

The 79 day-experiment reported herein was conducted to determine through a completely randomized design the effects of the enrichment of drinking water for lamb with sodium chloride (NaCl), sodium sulfate (Na_2SO_4), or sodium nitrite ($NaNO_2$) on water and feed intakes, apparent diet digestibility, nitrogen balance, microbial nitrogen supply, rumen fermentation (pH, ammonia nitrogen and protozoa concentrations), blood metabolites, carcass traits and meat quality (i.e. ultimate pH, cooking loss, and fatty acids (FA) profile). Four groups of eight Barbarine lamb each (initial BW 21.1 ± 2.4 kg, 5–6-month old) were housed in individual boxes and received oat hay *ad libitum* and 400 g concentrate. Each group was assigned randomly to one of the following treatments: *ad libitum* access to fresh water (control, group 1) or to fresh water enriched with either 7 g NaCl/L (group 2), or 2 g Na_2SO_4/L (group 3) or 40 mg $NaNO_2$/L (group 4). Lambs having access to salt-enriched water consumed more water than control lambs. Such effect was important ($P < 0.05$) in group 2 (4.6 *vs* 2.48 l/day). Compared to control group, the three sources of salt administrated in water had no effect ($P > 0.05$) on diet intake and apparent digestibility, N retention and microbial N supply. Rumen pH, ammonia-N and protozoa remained unchanged ($P > 0.05$) with the consumption of saline water. The lack of variation of diet intake and digestibility and rumen fermentation could justify the absence of significant variation of the growth rate of lambs (44–63 g/day). Serum creatinine increased ($P < 0.05$) with the administration of the three salts in drinking water. Serum glucose was higher ($P < 0.001$) in lamb assigned to Na_2SO_4 and $NaNO_2$ treatments. Nitrite treatment (40 mg $NaNO_2$/L) reduced ($P = 0.034$) the concentration of triglycerides in the blood. The enrichment of water with the three sources of salts had no adverse effect on carcass yield and the FA profile of lamb meat, except for *iso*-heptadecanoic acid (C17:0 iso) which was higher ($P = 0.024$) in the meat of lambs in group 3 than in the meat of control group. The proportion of 10-heptadecenoic acid (C17:1(n-7)) in the meat of lambs drinking $NaNO_2$-enriched water was 25–30% lower ($P = 0.041$) than that of the three other groups. The ratio Omega 6 to Omega 3 was similar among the four lamb groups (4.68–5.01). It is concluded that the doses and types of salts intentionally used in the present study to reflect water quality in some Tunisian zones home to Barbarine sheep had no effect on lamb's growth, carcass traits and meat quality. However, the increased creatinine and reduced triglycerides in the blood justify the need to emphasize further investigations on the effect of these salts on lamb's health.

1. Introduction

The dry areas worldwide share many features including reliance on livestock breeding as main source of farmers' income, arid to semiarid climate, limited water resources compromising agriculture development and high economic and social value of water. Annual rainfall is in major parts of the dry areas like North Africa low (*e.g.* below 200 mm in southern Tunisia) meaning that surface water is proportionally low among the available water sources. Under such circumstances farmers are intensively using groundwater (*i.e.* deep and phreatic aquifers) for food-feed cropping and livestock watering. The overexploitation of groundwater rendered water a scarce public good and is, at the same time, causing soil

* Corresponding author at: Institut National de la Recherche Agronomique de Tunisie (INRAT), Université de Carthage, Laboratoire des Productions Animales et Fourragères, Rue Hédi Karray, 2049 Ariana, Tunisia.
E-mail address: yousfi79@hotmail.com (I. Yousfi).

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and water salinization. Currently, major proportion of saline water available in southern Tunisia falls in the range of 3000–7000 ppm of salt. Higher salt levels (>7000 ppm) in water could be encountered in some zones where farming is difficult to practice. The presence of some other water pollutants, mainly sulfates, nitrates and fluoride leads to further deterioration of water quality (Rahaingomanana, 1998; Hannachi et al., 2014) in Tunisia. According to Zaara (2008) tap water salinity in the major part of southern Tunisia ranges between 1500 and 3580 ppm in which around 700–1500 ppm are sulfates. The sulfate ion is available in most natural waters and it originates from the dissolution of soil and rocks minerals. Under anaerobic conditions, bacteria in water could reduce sulfate to sulfur resulting in the release of hydrogen sulfur that makes water taste and smell unpleasant. According to ANZECC (2000), MAF (2004) and CCME (2008), 1000 mg sulfate/l of water represent a maximum threshold above which the sulfate in drinking water could have serious negative effects on the animal (*e.g.* diarrhea). Nitrates and nitrites are oxidized forms of nitrogen. Groundwater could contain high levels of nitrates originating mainly from the contamination of water by certain pollutants (*e.g.* nitrogen fertilizers, manure, industry residues, *etc.*). The content of tap water could exceed in some parts of Tunisia the threshold (50 mg/L) fixed for human safety (Zghibi et al., 2013). Concentrations of nitrite in water above 30 mg/L could be dangerous for livestock health (ANZECC, 2000; CCME, 2008). Salinization of groundwater is expanding in the arid zones; therefore, the development of biosaline agriculture has become a prerequisite for the improvement of farmers' livelihood (Gaaloul and Zouari, 2004). The introduction of salt-tolerant crops for food (*e.g.* vegetables and cereals) and fodder (*e.g.* halophytes) productions and building the adaptation of livestock to salty diets and or to saline drinking water have become key elements in the strategies targeting agriculture development in these zones. However, when it comes to human nutrition and health, the effects of saline water containing the above mentioned contaminants on the quality of crop and animal products should be taken into consideration when developing strategies for saline agriculture. Barbarine sheep, a fat-tailed breed, is the main breed raised in almost all livestock-based production systems in Tunisia from humid to arid climates. This sheep breed withstands the harsh conditions prevailing in southern Tunisia. The merits of this breed have been discussed by Ben Salem et al. (2011), and include adaptation to heat stress and feed restriction and high feed efficiency, but its adaptation to drinking saline water and its response to the main water contaminants (*i.e.* sulfates and nitrates or nitrites) is, to our knowledge, not yet investigated. In general, ruminants having access to salt-rich diets consume more water to help the kidney removing excessive salt from their body. However, when the drinking water is excessively high in salts, the animal could face digestive and metabolic disorders which may affect productive performance (Masters et al., 2007) and could provoke intoxication (McKenzie et al., 2004). Research studies on the later topic had been focusing on the response of ruminants, mainly sheep, to NaCl and occasionally potassium in the diet or in drinking water. Sulfate or other sulfur-containing compounds may induce anorexia mediated through the formation of sulfide in the rumen. Nitrate in the diet and or in drinking water is transformed to ammonia and nitrite. Therefore, the level of nitrite in the rumen is also important to control (Olkowski, 2009). To the best of our knowledge the response of sheep to sulfate and nitrite in water is not well documented. Also, information on the effect of water pollutants (*e.g.* sodium chloride, sulfate and nitrite) on meat quality is scarce. Having data on the response of Barbarine sheep to these salts would help developing watering strategies to increase productive performance of this breed. Therefore, the current study was designed to determine the effects of sodium chloride, sodium sulfate and sodium nitrite in drinking water at amounts close to those in the groundwater available in southern Tunisia on feed and water intakes, apparent diet digestibility, nitrogen balance, rumen fermentation parameters, blood profile, growth rate, carcass traits and meat quality in Barbarine lamb.

Table 1
Contents and properties of drinking water.

	Salts added to the drinking water			
	Control	NaCl	Na_2SO_4	$NaNO_2$
TDS (mg/l)	760	8045	2645	790
pH	7.25	7.1	7.35	7.92
Sodium (mg/l)	70	2460	725	120
Potassium (mg/l)	4.3	4.6	3.5	4.2
Calcium (mg/l)	120	135	110	90
Magnesium (mg/l)	19	25	23	17
Chlorides (mg/l)	285	4830	375	265
Sulfates (mg/l)	105	90	1230	95
Nitrates (mg/l)	55	43	48	50
Bicarbonates (mg/l)	60	79	63	77
Sodium adsorption ratio	4.5	69.5	30	15
Hardness degree (°fH)	29.1	35.5	37	35

2. Materials and methods

A 79-day experiment was carried out from April to July 2012 at the National Institute of Agricultural Research of Tunisia (INRAT) experimental unit of Bourbia station (Zaghouan governorate).The average temperature during this period is 30 °C and 10–12 sunshine hours.

2.1. Animals, diets and experimental design

Thirty-two Barbarine male lambs (5–6-month old) with an initial body weight (BW) of 21.1 ± 2.4 kg were treated with an enterotoxemia vaccine then with Ivermectyl (1 ml/50 kg BW, 1 g Ivermectine/100 ml; Médivet Santé Animale, Soliman—Tunisia) to free them from external and internal parasites. Animals were housed in individual pens, each equipped with feed and water troughs. All of them received oaten hay *ad libitum* (0.2 kg in excess of the previous day's intake) and 400 g concentrate (Table 2). The concentrate was composed of ground barley (570 g/kg), faba bean (400 g/kg) and commercial mineral and vitamin supplement (MVS, 30 g/kg). The declared composition of MVS (g/kg) was 600 g calcium carbonate, 300 g sodium chloride, 50 g trace minerals and 50 g vitamins. The concentrate was offered once daily at 0900 while oaten hay was offered twice a day at 0900 and 1600. Lambs were used in a completely randomized design, with four treatments and eight replicates: Group 1 (Control) had free access to water taken from general running water available on tap in the Experimental Station of INRAT at Bourbia where this experiment was conducted and provided by the National Water Distribution Utility through the drinking water network (*i.e.* without salt addition). The three remaining groups received each *ad libitum* tap water enriched with NaCl (7 g/L, Group 2), Na_2SO_4 (2 g/L, Group 3) or $NaNO_2$ (40 mg/L, Group 4). The amount of salt was setup to simulate the quality of drinking water for livestock available in areas, which are prone to water salinization. Experimental drinking water was prepared daily in 40 L plastic pail by totally dissolving the respective doses of these salts in tap water initially containing 760 mg/L TDS. The physico-chemical composition of the tap water is reported in Table 1. Doses of these compounds were close to those available in the groundwater in some zones of Tunisia where sheep production is the main source of smallholders' income. Animals were adapted to housing conditions and diets for 10 days before starting a 50-day growth trial. The first adjustment 5-day was allowed to adapt to water by gradually increasing the compound concentration of the drinking water until it reached the required concentration for the concerned groups, the second 5-day period was for the animal's adaptation to the experimental watering regimes. At the end of the growth trial, animals were transferred into individual metabolic cages. They were acclimated for 4 days to new housing conditions before starting a 7-day total collection period for diet digestibility determination. One week later all lambs assigned to the same treatments were slaughtered.

2.2. Measurements and sampling

Lambs were weighed at the beginning, the end and at weekly intervals throughout the feeding trial to determine their growth rates. Daily feed and water intakes were calculated on the basis of the amounts of distributed and refused feed and water.

Along with the total collection period, feed intake was determined daily by weighing the amounts of feeds distributed and corresponding individual refusals. Feces and urine were collected daily between 0800 and 0900, weighed, and a 10% aliquot (by weight) was collected from each sample, and then stored in a cooling chamber. Fecal and urine aliquots were composited by lamb within the 7-day collection period, and a subsample of feces and urine were frozen for later analyses.