









Original Article

Influence of water salinity on the adaptability of confined sheep in the Brazilian semiarid region

Influência da salinidade da água na adaptabilidade de ovinos confinados no semiárido brasileiro

Joab Jorge Leite de Matos Júnior¹ , Dermeval Araújo Furtado² , José Pinheiro Lopes Neto³ , Soad Arruda Rached Farias³ , Patrício Gomes Leite¹ , Jordânio Inácio Marques⁴ 

¹ Doutorandos em Engenharia Agrícola, Centro de Tecnologia e Recursos Naturais, UFCG, Campina Grande – PB.

² Professor Titular da UAEA/UFCG, Centro de Tecnologia e Recursos Naturais, Campina Grande – PB.

³ Professores Adjuntos da UAEA/UFCG, Centro de Tecnologia e Recursos Naturais, Campina Grande – PB.

⁴ Professor Substituto da UFMA, Unidade Acadêmica de Engenharia Agrícola, Chapadinha – MA.

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ABSTRACT

The present study aimed to evaluate the thermal comfort indices inside the facilities and the influence of water salinity on the physiological responses of sheep in confinement receiving water with four levels of salinity (1.5, 3.0, 6.0 and 9.0 dS m⁻¹), consuming feed and water at will. The experimental configuration adopted was a completely randomized design (CRD), composed of 4 treatments and 6 replicates, with data submitted to analysis of variance (ANOVA) and means compared by Tukey test at 5% probability level. Air temperature, black globe temperature and humidity index and the thermal load of radiation at the hottest times of the day were above the thermal comfort zone for sheep, with low relative air humidity, factors that did not affect the rectal temperature, but caused elevation in surface temperature, respiratory rate and heart rate. Supplying water with salinity of up to 9.0 dS m⁻¹ did not affect (P>0.05) the physiological responses of sheep.

RESUMO

O presente estudo teve por objetivo avaliar os índices de conforto térmico no interior das instalações e a influência da salinidade da água nas respostas fisiológicas de ovinos ^{1/2} sangue Dorper + ^{1/2} sangue Santa Inês confinados, recebendo água com quatro níveis de salinidade (1,5; 3,0; 6,0 e 9,0 dS m⁻¹), consumindo ração e água a vontade. A configuração delineada experimentalmente adotada foi o delineamento inteiramente casualizado (DIC), composto de 4 tratamentos e 6 repetições, sendo os dados submetidos à análise de variância (ANOVA) e as médias comparadas pelo teste de Tukey a 5% de probabilidade. A temperatura do ar, o índice de temperatura de globo negro e umidade e a carga térmica de radiação, nos horários mais quentes do dia, ficaram acima da zona de conforto térmico para os ovinos, com baixa umidade relativa do ar, fatores que não afetaram a temperatura retal, porém, provocaram elevação na temperatura superficial, frequência respiratória e cardíaca. O fornecimento de água com salinidade de 1,5 até 9,0 dS m⁻¹ não afetou (P>0,05) as respostas fisiológicas dos ovinos.

Palavras-chave:

Ambiência

Confinamento

Ovinocultura

Salinidade

INTRODUCTION

Small ruminants, more specifically sheep, both purebred and crossbred, adapted to tropical regions, tend to show certain adaptation to stressful factors caused by conditions of climates with high temperatures, as is the case of the Brazilian semiarid region, mainly due to the anatomical, physiological and behavioral adjustments

they perform to adapt to these air conditions (SOUZA; BATISTA, 2012; TITTO et al., 2016; FURTADO et al., 2017).

Like other animals, sheep suffer under the influence of the environment and, when kept in an environment with elevations in air temperature, may increase their rectal temperature, surface temperature, respiratory rate and

* Corresponding author: marinhense_97@hotmail.com

heart rate (OLIVEIRA et al., 2013; LUZ et al., 2014; COSTA et al., 2015; NOBRE et al., 2016; TORRES et al., 2017; SEIXAS et al., 2017). When the physiological mechanisms of the animals fail to eliminate excess body heat, their rectal temperature may increase (MARAI et al., 2007; FURTADO et al., 2017), reflecting the elevation in their internal body temperature, resulting in increased respiratory rate and sweating. These are efficient means to dissipate body heat, but may result in a reduction in the amount of body water, reducing blood volume and increasing the osmotic pressure of body fluids (McKINLEY et al., 2017).

Minerals such as chlorine, potassium and sodium are essential components of body fluids, which guarantee osmotic balance, acid-base balance and membrane permeability, besides helping regulate water distribution in the body (PEDREIRA; BERCHIELLI, 2011). Sheep are tolerant to the intake of forage with high salt concentration in its chemical composition (MORENO et al., 2015) and to the intake of saline water (ARAÚJO et al., 2010; MOURA et al., 2016). However, high salinity may affect the concentration of extracellular fluids, interstitial fluids, and plasma and blood volumes in sheep (ASSAD; EI-SHERIF, 2002). The technical recommendation, stipulated by the U.S. National Academy of Sciences (1972) and cited by Ayers and Westcot (1999), regarding saline water consumption for domestic animals in any situation, is below 5.0 dS m⁻¹, and Araújo et al. (2010) cite that the intake of saline water by small ruminants with electrical conductivity above 8.0 dS m⁻¹ is limiting. Yousfi et al. (2016) concluded that the consumption of saline water (7.0 g NaCl/L and 40 g of NaNO₂) by sheep did not affect nutrient intake, apparent digestibility, nitrogen retention, ruminal pH and microbial nitrogen supply.

Therefore, the objective of this study was to evaluate the thermal comfort indices inside the facilities and the influence of saline water ingestion on the physiological responses of ½ Dorper + ½ Santa Inês sheep in confinement, receiving water with four levels of salinity (1.5, 3.0, 6.0 and 9.0 dS m⁻¹).

MATERIAL AND METHODS

The experiment was carried out in a private property called Soares Farm, located in the district of Marinho, belonging to the municipality of Boqueirão, Cariri

Oriental microregion in Paraíba state, Brazil, located at 355 m altitude, 07° 28' 54" S latitude and 36° 08' 06" W longitude (IBGE, 2010). According to Köppen's classification, the climate of the region is Bsh - tropical hot and dry or semiarid, with averages of maximum temperature of 37.0 °C and minimum temperature of 16.0 °C. Its precipitation is considerably irregular, with peaks of 883.2 mm and levels below 256.3 mm a year (AESAs, 2015).

The study was conducted from March to May 2015, with duration of 67 days, under the approval of the Ethics Committee of the Federal University of Campina Grande (UFCG), nº 105-2013, using 24 crossbred sheep, ½ Dorper + ½ Santa Inês, confined in 2 sheds. Each shed measured 8 x 5 m and was divided into two stalls, with ceiling height of 2.9 m, in a total of 4 collective stalls, covered with ceramic tile, screens on the sides, cemented floor, with average area 3.33 m² per animal, equipped with wooden troughs with 1 linear meter per stall. Each stall received a lot composed of six randomly selected animals, aging on average 7.0 ± 0.47 months and weighing 18.33 ± 4.16 kg at the beginning of the confinement and weighing on average 30.81 kg at the end of the experiment.

To start the experiment, the animals were weighed, identified and were treated against ectoparasites and endoparasites with the vermifuge IVOMECS® (1% ivermectin), administered by subcutaneous injection at dose of 1 mL per 50 kg of live weight, subsequently undergoing a 7-day period of adaptation to the facilities and feeding. Feed and water were offered *ad libitum* and the feed consisted of Tifton-85 hay (22.5%), prickly pear (32.5%), ground maize (25.0%), soybean meal (18.0%) and mineral salt (2.0%). The feed offered and the leftovers were weighed every day in order to calculate the feed consumption by the group of animals, readjusting the quantity offered to the animals based on a minimum limit of 15% of leftovers.

Salinity control was carried out with the addition of NaCl and monitored with a portable digital conductivity meter (Instrutemp - ITC-1000). Conductivity was initially read in the water (Table 1) and then NaCl was added until the solution reached the desired level of electrical conductivity. The treatments were based on the offer of solutions with the following levels of salinity: T1 - 1.5 dS m⁻¹, T2 - 3.0 dS m⁻¹, T3 - 6.0 dS m⁻¹ and T4 - 9.0 dS m⁻¹.

Table 1. Chemical characteristics of the water used for producing the solutions offered to the sheep

Variables	Results found in the samples*
pH	7.90
Temperature (°C)	25.60
Chloride (mg L ⁻¹)	351.40
Calcium (mg L ⁻¹)	69.40
Magnesium (mg L ⁻¹)	148.30
Hardness (mg L ⁻¹)	237.50
Salinity (%)	0.60
Total dissolved solids (mg L ⁻¹)	614.00
Alkalinity (mg L ⁻¹)	95.00

*Source: CAGEPA (2016)

The highest and lowest daily temperatures within the facilities were collected by maximum and minimum mercury thermometers, taken once a day, at 16:00 h. Air temperature, relative humidity and wind speed were collected daily from 06:00 to 18:00 h, at 2-h intervals, with a portable digital thermo-hygro-anemometer-luxmeter (Instrutherm – Thal-300), positioned always at the height equivalent to the center of the animals' bodies. Black globe temperature was obtained through black globes, positioned at the center of the facilities, at approximately 1 meter height from the floor. These environmental data were then used to calculate the black globe temperature and humidity index (BGHI), according to the equation of Buffington et al. (1981) and the thermal load of radiation (TLR), according to the equation of Esmay et al. (1969).

The physiological responses were measured twice a day (at 10:00 and 14:00 h), two days a week (Mondays and Wednesdays), by collecting data of rectal temperature (RT), surface temperature (ST), respiratory rate (RR) and heart rate (HR). RT was obtained by inserting a digital thermometer bulb into the rectum of the animal, until reading stabilization. ST was measured by collecting the temperatures of the forehead, neck, loin, ribs, belly and shank, and calculating their average, in order to obtain the average surface temperature of the animals. ST was measured using a digital infrared thermometer (Instrutherm – ITTI-380).

RR and HR were obtained through indirect auscultation of heart sounds using a flexible stethoscope positioned in the left thoracic region, close to the humeral-scapular junction of the animal, by counting the number of movements and beats, respectively, for 1 minute, thus obtaining the value in minute, expressed in mov min^{-1} for RR and in bt min^{-1} for HR.

The normality of data residuals was tested using the Shapiro-Wilk test. The data were subjected to analysis of variance (ANOVA) and the means were compared by Tukey test at 5% probability level, using the computer program ASSISTAT (SILVA; AZEVEDO, 2016).

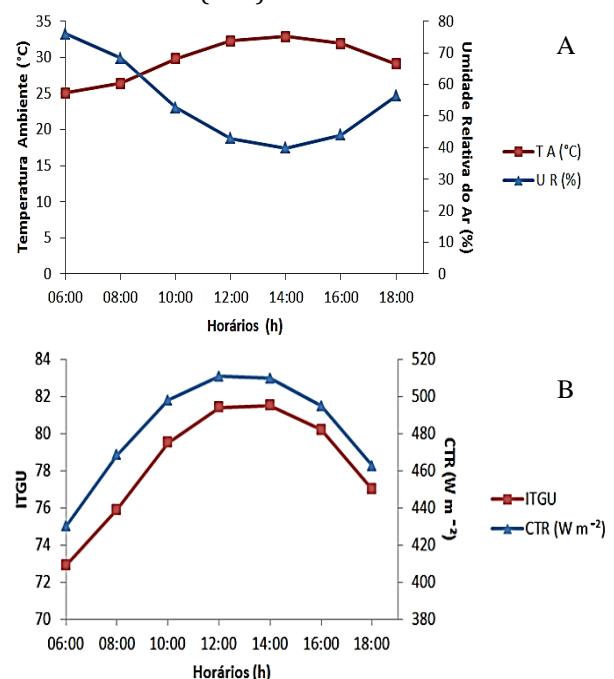
RESULTS AND DISCUSSION

Inside the facilities, the averages of maximum temperature ($33.2\text{ }^{\circ}\text{C}$) and minimum temperature ($22.3\text{ }^{\circ}\text{C}$) were respectively above and within the thermal comfort zone (TCZ) for the species, which should be below $25.0\text{ }^{\circ}\text{C}$ with relative air humidity of 65.0% according to Eustáquio Filho et al. (2011). The amplitude between these temperatures was $9.8\text{ }^{\circ}\text{C}$. Luz et al. (2014) and Oliveira et al. (2005) cite the occurrence of high temperatures in the Brazilian semiarid region, above the thermal comfort zone, and that such occurrence and the high amplitude during the day require from the animals a rapid daily adaptation in their physiological responses.

The average air temperature (AT) showed an increasing behavior throughout the day, reaching its maximum

value at 14:00 h ($33.2\text{ }^{\circ}\text{C}$), when it started to decrease (Figure 1). Between 12:00 and 16:00 h, it remained above the thermal comfort zone for sheep, which may affect their physiological responses, since in this period the animals showed considerable alterations, which are believed to be a defense mechanism of their own organisms in an attempt to adapt to the condition of the moment. Furtado et al. (2017), in experiments in the Brazilian semiarid region, cite that air temperature remained high in both the internal and external environments of the facilities, causing discomfort and changes in the physiological variables of the animals. Oliveira et al. (2013) also cite high temperatures in this region, highlighting the use of shading to mitigate the effect on the animals.

Figure 1. (A) Average values of ambient temperature (AT), relative air humidity (RH); and (B) black globe temperature and humidity index (BGHI) and thermal load of radiation (TLR).



In most of the times, the relative air humidity (RH) was ideal for sheep (Figure 1A). 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 (SILVA; MAIA, 2013), which makes the exchange of energy through the respiratory tract difficult. It should be pointed out that in these periods high values of AT, which is associated with low RH, can negatively influence the physiology and consequently the production of the animals (FURTADO et al., 2017), especially with regard to their heat exchange with the environment. This may have occurred when the animals were producing internal heat and, in the attempt to dissipate it to the environment, they also found a high temperature, combined with low humidity and low wind speed, which possibly caused the heat to concentrate in

their bodies, leading to the increment of other responses to the imposed conditions.

Wind speeds between 1.3 and 1.9 m s⁻¹ are considered ideal for the rearing of domestic animals (McDOWEL, 1989), and the values obtained were on average 0.7 m s⁻¹, which can be considered low, compromising the thermal comfort of the animals and affecting the exchange of sensible heat in the form of convection. Considering that the experiment was carried out in the semiarid region of Paraíba in the dry season of the year and that the animals were confined, this may have negatively influenced their thermal comfort.

BGHI values of up to 74, from 74 to 79, from 79 to 84 and above 84 define situations of comfort, alertness, danger and emergency, respectively (SOUZA et al., 2002). Although these values were initially established for dairy cows by Buffington et al. (1981), research studies such as those conducted by Furtado et al. (2017) and Torres et al. (2017) concluded that the above-mentioned scale can be satisfactorily extrapolated to sheep. Therefore, an alert situation was observed at 8:00 and 18:00 h and a danger situation was observed between 10:00 and 16:00 h (Figure 1B). Oliveira et al. (2013), in a study in the Brazilian semiarid region with sheep exposed to a shaded environment and exposed to the sun, observed high values of BGHI (85.91 and 96.07 in the shaded environment and exposed to the sun, respectively),

which led to situations of thermal discomfort for the animals.

For the thermal load of radiation, the highest value occurred at 12:00 h (510.8 W m⁻²) and the lowest value at 6:00 h (430.1 W m⁻²), with an average of 482.0 W m⁻² (Figure 1b). Oliveira et al. (2005), working with sheep confined in environments covered with clay tile and fiber cement tile, cite that inside the facilities high values of TLR were observed in both environments and periods (morning and afternoon), which left the animals under thermal stress.

For rectal temperature, there was significant difference ($P < 0.05$) between the treatments with salinity levels of 1.5 and 6.0 dS m⁻¹ (Table 2), with higher values in animals that consumed water with higher salt content. The average rectal temperature was 39.3 °C, which is within normality for the species (CUNNINGHAM, 2004), as it can range from 38.5 to 39.9 °C. Santa Inês sheep were tolerant to high temperatures, corroborating the results found by TITTO et al. (2016), who cite lower variation of RT in Santa Inês animals compared to other breeds of sheep, when exposed to different environmental conditions. FURTADO et al. (2017), in studies with Santa Inês sheep and their crossbreeds, cite that even the animals kept in environments considered above the TCZ, especially in the afternoon period, the means of rectal temperature were within the range of normality.

Table 2. Physiological responses of crossbred sheep as a function of water salinity

Treatments	Rectal temperature (°C)	Respiratory rate (mov min ⁻¹)	Heart rate (bt min ⁻¹)	Surface temperature (°C)
T1 (1.5 dS m ⁻¹)	39.2 b	52.9 bc	104.8 a	34.3 a
T2 (3.0 dS m ⁻¹)	39.3 ab	63.5 a	110.0 a	33.9 b
T3 (6.0 dS m ⁻¹)	39.4 a	57.1 ab	106.6 a	33.3 b
T4 (9.0 dS m ⁻¹)	39.3 ab	46.7 c	109.6 a	34.1 ab
Mean	39.3	55.0	107.7	33.9
CV%	0.96	46.34	16.65	3.33

Means in the columns followed by the same letter do not differ at 5% probability level by Tukey test.

Although the sheep were kept in an environment with high AT, BGHI and TLR, with low RH in most of the day, and consuming water with salinity above the recommended (ARAÚJO et al., 2010), their RT was within normality, demonstrating capacity of these animals to maintain a stable body temperature even under conditions of hot weather and receiving water with high levels of salts, which can be explained by the adaptability of Santa Inês sheep to the semiarid climate conditions and to the consumption of saline water. MOURA et al. (2016) cite that saline waters can be an alternative of strategic and seasonal use for watering crossbred Santa Inês sheep reared in the semiarid region of northeastern Brazil.

Water salinity caused significant effect ($P < 0.05$) on the respiratory rate, with highest values in animals consuming water with 3.0 dS m⁻¹ and 6.0 dS m⁻¹. This is possibly due to the ionic dissociation of NaCl in aqueous

medium, producing HCl (MACHADO, 1905), making the blood and body fluids acidic. Such acidity can reduce blood pH, causing the breathing to be deeper and faster, since the body is trying to release the excess acid found in the blood (GONZÁLEZ; SILVA 2017).

The average respiratory rate was 55.0 mov min⁻¹, above the normality for the species, which in thermoneutral environments may vary between 24.0 and 36.0 mov min⁻¹ (REECE, 1996). This elevation is due to high air temperature, BGHI and TLR, associated with low relative air humidity and wind speed, so the animals used this physiological adjustment to eliminate body heat. The average RR can be characterized as of low stress (SILANIKOVE, 2000), where the animals spend energy in the dissipation of heat by respiration in order to maintain homeothermy. Santa Inês sheep have excellent adaptability to the semiarid climate, and the increase in RR is not necessarily indicative of stress; it can be an

efficient mechanism of heat dissipation (OLIVEIRA et al., 2013; LUZ et al., 2014).

Costa et al. (2015) concluded that Morada Nova sheep showed positive physiological responses to heat stress, with elevation of respiratory rate and reduction in T_3 and T_4 serum levels, indicating excellent capacity of adaptation to the Brazilian semiarid environment. Morais et al. (2008), Oliveira et al. (2013) and Luz et al. (2014), analyzing the thermoregulatory characteristics of sheep in the semiarid region of Brazil, reported elevation in their respiratory rate, and this mechanism is used by the animals to dissipate body heat to the environment. High respiratory rate can be an efficient way to lose heat for short periods; however, if kept for several hours, it may result in serious problems for the animals (McDOWELL, 1989).

Physiological control mechanisms in animals have evolved to limit the losses of body fluids, and the elevation of respiratory rate (Table 2) for a longer period may reduce the total amount of body water. Mammals have osmoreceptors in the brain, which suppress heavy breathing and sweating when the effective osmotic pressure (tonicity) increases, preserving body water (McKINLEY et al., 2017).

Heart rate (HR) was not significantly affected ($P > 0.05$) by the different levels of water salinity, averaging $107.7 \text{ bt min}^{-1}$, above the normality for the species, which may range from 70.0 to 80.0 bt min^{-1} (REECE, 1996). Marai et al. (2007) cite that sheep exposed to high ambient temperature may have their biological functions negatively affected, which compromises their performance. These high HR 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 HR, there is a greater circulation of blood, which takes the warm blood from the center of the body to its peripheral parts. As a result, the skin surface of the sheep is warmed and starts releasing heat to the environment through, conduction, convection and/or radiation (INCROPERA et al., 2008).

Among the clinical signs observed in animals consuming excess NaCl, hypertension stands out, a process in which Na acts on the walls of the arteries, causing their constriction and leading to increased resistance (pressure) to the passage of blood and a lower vasodilation capacity. However, the elevation of salt concentration in the water used in the present experiment did not alter the heart rate of the sheep, demonstrating the tolerance of these animals to this type of water (ARAÚJO et al., 2010; MOURA et al., 2016).

MdLesh et al. (2017) reported higher values of pulse rate with the elevation of water salinity level in Nguni goats, pointing out that these animals have a physiological mechanism to excrete excess salt from the body and that they direct more energy to the heart, elevating the pulse rate, in order to assist in eliminating this excess. Assad and El-Sherif (2002) cite a reduction in

plasma glucose and also that the concentration of the hepatic enzymes aspartate aminotransaminase and alanine aminotransaminase increased in the blood plasma with the consumption of saline water.

There was a slight variation in the surface temperature of the animals among the treatments, and the average ST was $5.4 \text{ }^\circ\text{C}$ below the rectal temperature, which characterizes a low amplitude. This is related to the environmental conditions, as the animals used blood circulation and peripheral vasodilation to eliminate heat from the center of the body, leading to its extremities so that it would be eliminated to the medium. Peripheral vasodilation is dependent on the thermal gradient between the surface temperature of the animals and the environmental temperature, and the higher the gradient, the greater the dissipation of sensible heat. In the present experiment, the thermal gradients between ST and AT and between ST and RT were low and, according to Luz et al. (2014), homeothermy through peripheral vasodilation tends to have relatively low efficiency when the gradient between body temperature and air temperature is small, limiting the heat flow through non-evaporative process.

The coat of the animals had mixture of black/white and brown/white colors, resulting from the Santa Inês x Dorper cross, with predominance of the light-colored coat in most of their bodies, reflecting greater amount of heat and performing less absorption, becoming an efficient ally in the maintenance of their thermal balance (CENA; MONTEITH, 1975). EUSTÁQUIO FILHO et al. (2011) observed a significant linear effect on sheep coat temperature, which increased with the elevation of ambient temperature, and as it increases, the efficiency of sensible heat losses decreased due to the lower gradient of temperature between the animal skin and the environment.

There was a significant effect ($P < 0.05$) of water salinity levels on the surface temperature of sheep, with the highest values for treatments with 1.5 and 9.0 dS m^{-1} water. YOUSFI et al. (2016) cited that the consumption of saline water by lambs did not interfere in their performance and carcass traits, but there was a reduction in serum creatinine concentration in animals that consumed water with high concentration of salts, which reflects a possible alteration in the kidneys, indicating that further research is needed with saline water for sheep.

CONCLUSIONS

The environmental indices during most of the day were above the thermal comfort zone for sheep, but the animals maintained their rectal temperature within the normality limit, increasing the respiratory rate, heart rate and also surface temperature. Supplying water with salinity of up to 9 dS m^{-1} did not significantly affect the physiological responses of the animals.

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