ORIGINAL ARTICLE

Behavioral and thermoregulatory characteristics of Dorper sheep

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Received: March 29, 2017 ▪ Revised: May 02, 2017 ▪ Accepted: May 22, 2017

Abstract The objective of this study was to evaluate the behavioral and thermoregulatory characteristics of Dorper sheep. The experiment involved 12 adult females in which the respiratory frequency (RF), heart rate (HR), and rectal temperature (RT) were measured and the following behavioral activities were evaluated: Idling while standing, Idling while lying, Drinking, Ruminating while standing, Ruminating while lying, Defecating, Urinating, Walking, Vocalizing, Biting, Coughing, Playing, Fighting, Rubbing, Self-cleaning, and Sleeping. The physical analysis of the thermal environment in the facility was obtained at the meteorological station of the Technical School of Teresina, where the air temperature (AT) and air relative humidity (ARH) were recorded. The black globe humidity index was obtained using a thermometer inserted in a black globe. A significant difference was detected for AT and ARH, especially the former, which had a higher value in the afternoon period (36.5 ºC). A significant effect was observed for the physiological variables, for which the highest values were found in the afternoon period, as follows: 85.30 mov./min, 93.11 beats/min, and 39.51 ºC (RF, HR, and RT, respectively). Air temperature had positive correlations of 0.572, 0.516, and 0.165 with all thermoregulatory characteristics (RF, HR, and RT, respectively). There was a significant difference for the 'Idling while standing', 'Idling while lying', 'Ruminating while lying', 'Vocalizing', 'Eating', 'Playing', and 'Sleeping' behaviors in relation to the evaluated periods of the day. The animals showed a certain level of thermal discomfort, especially in the afternoon period.

Keywords: ambience, physiological variables, sheep farming, thermal stress, thermoneutrality

Introduction

The rapid expansion of the small ruminant production activity is transforming the scenario of animal production systems. Approximately 17.6 million sheep exist in Brazil, with the northeast region of the country holding the largest part of this total — 9.7 million animals — mainly in the states of Pernambuco, Bahia, Ceará, and Piauí (IBGE 2015).

The Brazilian sheep farming chain has experienced an increase in the introduction of exotic breeds like Dorper and the use of genetic breeding techniques, such as crossbreeding, aimed at exploiting the heterosis and complementarity between breeds to increase meat production in tropical regions qualitatively and quantitatively. However, the acquisition of specialized animals that originate from temperate climates may not provide the desired results, given their low adaptability to tropical conditions, where environmental factors usually do not match the ideal thermal-comfort range for their optimal production efficiency (Rocha et al 2012).

The study of mechanisms that regulate the body temperature of sheep demonstrates the interaction between their thermoregulatory parameters and the environment where they live and shows us the degree of adaptation and the adversities faced by the animal in its rearing environment (Sousa et al 2015). In addition to the physiological mechanisms of thermoregulation, behavioral characteristics should also be investigated, since changes in behavior are an animal's attempt to lessen the heat stress (Silva et al 2015).

Knowing the effects of environmental variables on behavioral and thermoregulatory characteristics is of extreme importance, considering that the production of these animals tends to considerably decrease when the ambient temperature rises (Luz et al 2014). Therefore, research determining thermal comfort indices and the adaptability of these animals should be fostered, since these factors are essential for improving and adjusting the management practices of animal production systems. On this basis, the present study was conducted to evaluate the behavioral and thermoregulatory characteristics of Dorper sheep, under climatic influences, in the morning and afternoon periods during the rainy season.

Materials and Methods

The experiment was conducted in the Sheep-Goat Farming Unit of the Technical School of Teresina (CTT) at

DOI http://dx.doi.org/10.14269/2318-1265/jabb.v5n3p85-90

the Federal University of Piauí (UFPI), located in Teresina, PI, Brazil (05º05'21" S; 42º48'07" W; 74.4 m asl), in December 2016. The average annual precipitation in the region is 1200 mm and the average annual temperature is 28 ºC. The climate in the region is classified, by the Köppen system, as a tropical rainy-savannah Aw type with dry winters (June to November) and rainy summers (December to May).

Twelve adult females of the ovine species (*Ovis aires*), Dorper breed, were housed in collective stalls in a covered sheepfold with cemented floor. The rearing system adopted by CTT is intensive, with animals receiving the feed in the trough. The feed consisted of roughages composed of Tifton 85 (Cynodon spp.) hay and ground whole corn plant. During the experiment, the feed was supplied in the morning (09h00) and afternoon (15h00) periods together with the concentrate (soybean meal-cornmeal mixture) and ad libitum water.

Prior to the beginning of the experiment, the animals were visually assessed for clinical signs of healthiness and morphological characteristics. To draw inferences about their health, we used the color of the conjunctival mucosa (FAMACHA), body condition score (BCS), and body weight at adult age (BWA) as parameters. The color of the ocular conjunctiva was determined by the FAMACHA© scoring method, by assigning scores from 1 to 5 (Pan Wyk, Malan and Bath 1997). Body condition score was determined by following the methodology proposed by McManus et al (2009), whereas the body weight was obtained using a clock-type weighing scale of 0 to 120 kg.

A completely randomized design with two treatments was adopted: one corresponded to the morning period (MP), and the other, to the afternoon period (AP). MP was considered from 08h00 to 13h00, while AP was between 13h00 and 18h00. The experimental period was 18 days, the first six of which were used for the animals to adapt to facilities and diet. Thermoregulatory characteristics were measured from the seventh to the twelfth days. From the 13th to the 18th days, the animals were observed visually, individually, for the evaluation of behavioral characteristics.

The following thermoregulatory variables were evaluated: respiratory frequency (RF) - obtained by a direct observation of the movements of the left flank of the animals for one minute; heart rate (HR) - obtained by using a clinical stethoscope positioned on the left side of the thorax of the animal to count the number of heart beats in one minute; and rectal temperature (RT) - obtained by inserting a clinical veterinary thermometer directly in the rectum of the animal and keeping it for two minutes.

The following behavioral activities were evaluated: Idling while standing, Idling while lying, Drinking, Ruminating while standing, Ruminating while lying, Defecating, Urinating, Walking, Vocalizing, Biting, Coughing, Eating, Playing, Fighting, Scratching, Self-cleaning, and Sleeping. The frequency of all behavioral activities was observed by a visual assessment every five minutes. Observers attempted to keep the environment as natural as possible by preventing sudden movements that might affect the naturally occurring situation in the environment.

Environmental variables were obtained at the meteorological station of CTT, where the air temperature (AT) and the air relative humidity (ARH) were recorded. The black globe humidity index (BGHI) was determined by inserting a thermometer in a black globe positioned at the middle height of the animal, following the methodology used by Moraes et al (2008), and using the following formula:

$$BGHI = BGT + 0.36 \times DPT + 41.5$$

where BGT is the black globe thermometer temperature (ºC); DPT is the dew point temperature (ºC); and 41.5 is a constant.

The obtained behavioral data were tabulated and subjected to an analysis of variance in the NPAR1WAY statistical package, using the $\chi2$ (chi-squared) test at the 5% probability level. For the thermoregulatory characteristics, the obtained data were subjected to analyses of variance and correlation. For a comparison of results, the PROC GLM and PROC COR procedures of the SAS (2003) software were applied. Means were compared by Tukey's test ($P<0.05$) at the 5% significance level.

Results and Discussion

The evaluated animals showed the respective average weight, FAMACHA, BCS, and age values of 32.45±5.67 kg, 2±0.42, 3.66±0.61, and 1.33±0.49 years. The average weight value found here is within the standards of the breed according to the Brazilian Association of Sheep Breeders (ARCO 2017), characterizing them as in a good condition closely related to the management to which they were subjected. As for the mean FAMACHA and BCS values, the animals are within the optimal range for the development of physiological functions.

Mean values for the analyzed environmental variables are described in Table 1. The air temperature (AR) and air relative humidity (ARH) values differed significantly ($P<0.05$) between the two periods of the day.

The highest AT values (36.5 ºC) and the lowest ARH values (43.50%) were observed in the afternoon period. This fact can be explained by the greater incidence of sun rays observed during this period of the day. These values corroborate those described by Sousa et al (2015), who evaluated the thermoregulation and climatic adaptability of Santa Inês sheep in the municipality of Bom Jesus, PI, Brazil, and found mean temperature and air relative humidity of 22.88 ºC and 87.27% in the morning and 28.73 ºC and 64.55% in the afternoon. According to Bezerra et al (2011), the thermal comfort zone for sheep is around 27.5 ºC.

DOI http://dx.doi.org/10.14269/2318-1265/jabb.v5n3p85-90

Table 1 Mean values for air temperature (AT), air relative humidity (ARH), and black globe humidity index (BGHI) in the morning and afternoon periods.

Meteorological variable	Morning	Afternoon
AT (°C)	30.80^{b}	36.50^{a}
ARH (%)	64.66^{a}	43.50^{b}
BGHI	88.40^{a}	88.05^{a}

Means followed by common letters in the row do not differ by Tukey's test at the 5% probability level.

There was no significant difference (P>0.05) for black globe humidity index (BGHI). However, mean values were 88.40 and 88.05 for the morning and afternoon periods, respectively. Andrade (2006) did not classify an environment with a BGHI of 85.1 as a thermal discomfort zone, working with Santa Inês sheep, because of the high degree of adaptability of the animals to the semi-arid climate. The same adaptation has been observed in Dorper sheep, and, for this reason, that author recommends not using values above 84 as emergency.

Table 2 presents the values referring to the thermoregulatory characteristics of the evaluated animals. There was a significant difference (P<0.05) for all characteristics in relation to the evaluated periods.

Table 2 Mean values for rectal temperature (RT), respiratory frequency (RF), and heart rate (HR) of Dorper sheep in the morning and afternoon periods.

Thermoregulatory characteristic	Morning	Afternoon
RT (°C)	39.10^{b}	39.51^{a}
RF (mov./min)	64.38^{b}	85.30^{a}
HR (beats/min)	79.88^{b}	93.11^{a}

Means followed by common letters in the row do not differ by Tukey's test at the 5% probability level.

There was a significant increase (P<0.05) in thermoregulatory characteristics during the afternoon, probably because of the higher AT values (36.5 ºC) recorded in this period of the day. Despite the significant difference between rectal temperature (RT) values in the different periods, the animals maintained their RT very close to the average value for sheep, which is 39.1 ºC, according to Swenson and Reece (1996).

Marai et al (2007) asserted that sheep commonly maintain their homeothermy by dissipating the excess heat from their bodies when exposed to high temperatures, which is normally accompanied by an increase in respiratory frequency and rectal temperature. For Silva (2000), the rectal temperature and respiratory frequency are the main mechanisms of thermoregulation to heat stress and represent the best references to measure the degree of adaptability of sheep to warm climates.

The highest values for respiratory frequency (RF) and heart rate (HR) were recorded in the afternoon period: 85.30 mov./min and 93.11 beats/min, respectively. The RF values indicate that the animals had a stress level varying from medium-high to high, since the respiratory rate quantifies the severity of heat stress, wherein the frequencies of 40-60, 60-80, and 80-120 movements per minute characterize low, medium-high, and high stress, respectively, for ruminants. When they perform over 200 movements per minute, sheep are classified as under severe stress (Silanikove 2000).

Swenson and Reece (1996) reported that the average RF of sheep is around 16 to 34 mov./min, which is below the mean values obtained in the present study. Santos et al (2006), on the other hand, submitted that RF is better as an indicator of thermoregulation rather than of thermal stress; in this way, if the animal was efficient in eliminating heat, maintaining homeothermy, even if its RF is high, this might not be indicative of heat stress. The above-mentioned authors also claimed that RF varies from environment to environment depending on the effectiveness of the sensible heat mechanisms (conduction, convection, and radiation), because if these are not effective, the organism of the animal activates insensible heat dissipation mechanisms, e.g., sweating and/or RF, to dissipate the heat and perform the homeothermic regulation.

A significant increase was detected for HR (P<0.05) between the evaluated periods of the day, ranging between 79.88 and 93.11 beats/min in the morning and afternoon, respectively. Cezar et al (2004) also found a higher frequency of heart beats in the afternoon (115.30 beats/min) as compared with the morning (105.67 beats/min), in Dorper sheep from the semi-arid region of northeast Brazil. The most likely explanation for this increase in number of heartbeats in the afternoon period is the thermal stress caused by the increase in AT and reduction of ARH, both shown in Table 1. The afore-mentioned authors also reported that temperatures greater than 31 ºC lead to an increase in both RT and HR in sheep.

The correlation coefficients between the meteorological variables and thermoregulatory variables are presented in Table 3. Air relative humidity was negatively correlated with AT (–0.906), RT (–0.300), RF (–0.539), and HR (–0.440). These findings reveal that ARH is the main meteorological index influencing the heat-dissipation mechanisms, evidencing that the stress generated by AT is at a level at which the animal organism reached its threshold of homeothermy. Pires and Campos (2009) stated that when the air temperature exceeds the maximum value of comfort for the animal, the relative humidity of the air starts to have a critical importance for the heat-dissipation mechanisms.

DOI http://dx.doi.org/10.14269/2318-1265/jabb.v5n3p85-90

Air temperature showed positive correlations of 0.165, 0.572, and 0.516, with the thermoregulatory variables RT, RF, and HR, respectively. This demonstrates that an increase in AT also results in a significant elevation of thermoregulatory values. Rectal temperature presented a positive correlation with RF (0.503) and HR (0.311), whereas RF had a positive, high-magnitude correlation with HR (0.629). This means that as the limit of thermoneutrality draws nearer, the animal starts to make use of physiological responses to dissipate the heat stress imposed by the environment. When the internal level of heat of the animal equals to that of the environment through heat-exchange mechanisms, the animal is said to be under homeothermy (Luz et al 2014).

Table 3 Correlation coefficients between meteorological variables and thermoregulatory characteristics of Dorper sheep observed in the morning and afternoon periods.

	AT	ARH	RT	RF	BGHI	HR
AT	1.000	–0.906	0.165	0.572	0.133	0.516
ARH		1.000	–0.300	–0.539	–0.282	–0.440
RT			1.000	0.503	0.222	0.311
RF				1.000	0.136	0.629
BGHI					1.000	0.194
HR						1.000

Air temperature (AT), air relative humidity (ARH), rectal temperature (RT), respiratory frequency (RF), black globe humidity index (BGHI), and heart rate (HR).

Santos et al (2005) and Souza et al (2005) stressed that rectal temperature, respiratory frequency, and consequently the heart rate of animals are affected according to the time and period of the day, with lower RT in the morning that increases through the afternoon. Starling et al (2002) noted that the positive correlation between RF and RT indicates that the respiratory mechanism was very important for thermolysis and maintenance of homeothermy in the animals to prevent an increase in body temperature.

Table 4 presents the significance results for the evaluated behavioral variables. There was a significant difference ($P<0.05$) for ‘Idling while standing’, ‘Idling while lying’, ‘Ruminating while lying’, ‘Vocalizing’, ‘Eating’, ‘Playing’, and ‘Sleeping’ in relation to the periods of the day, suggesting the behavioral variation presented throughout the experimental periods in relation to the morning and afternoon periods.

Table 4 Significance test for the behavioral activities of Dorper sheep in the morning and afternoon periods.

Behavior	Time	Period	Drinking	Eating
Time	-	<0.0001*	0.0353^{ns}	<0.0001*
Period	<0.0001*	-	0.2019^{ns}	0.0012*
Animal	1.0^{ns}	1.0^{ns}	0.0207*	<0.0001*
Idling while standing	<.0001*	0.0330*	<0.0001*	<0.0001*
Idling while lying	<.0001*	<0.0001*	<0.0001*	<0.0001*
Drinking	0.0044*	0.2019^{ns}	-	<0.0001*
Ruminating while standing	<0.0001*	0.1358^{ns}	0.0781^{ns}	<0.0001*
Ruminating while lying	<0.0001*	<0.0001*	0.0004*	<0.0001*
Defecating	0.0458*	0.3070^{ns}	0.4605^{ns}	0.0071*
Urinating	<0.0001*	0.0969^{ns}	0.3377^{ns}	<0.0001*
Walking	<0.0001*	0.0869^{ns}	0.0064*	<0.0001*
Vocalizing	<0.0001*	0.0138*	0.5113^{ns}	0.0004*
Biting	0.4420^{ns}	0.0920^{ns}	0.4479^{ns}	<.0001*
Coughing	0.5594^{ns}	0.5486^{ns}	0.8194^{ns}	0.2201^{ns}
Eating	<0.0001*	0.0012*	<0.0001*	-
Playing	<0.0001*	0.0008*	0.2875^{ns}	<0.0001*
Fighting	0.0036^{ns}	0.2300^{ns}	0.6477^{ns}	0.0141*
Scratching	0.1430 ^{ns}	0.4055^{ns}	0.5332^{ns}	<0.0001*
Self-cleaning	0.6351^{ns}	0.8631^{ns}	0.7626^{ns}	0.1047^{ns}
Sleeping	<0.0001*	<0.0001*	0.0088*	<0.0001*

DOI http://dx.doi.org/10.14269/2318-1265/jabb.v5n3p85-90

For the ‘Eating’ behavior, there was a significant difference between the evaluated periods. The animals preferred to eat more in the morning, likely because of the lower temperature and higher relative humidity of the air in this period of the day, since they did not need to activate their heat-dissipation mechanisms to maintain their body in the comfort zone and thus used their time and availability to eat.

The period of the day influenced the ‘Ruminating while lying/standing’ behaviors, of which highest frequency was observed in the afternoon period. This may be explained by the need the animals had to fragment the feed consumed in the morning. Silva et al (2007) evaluated the behavioral aspects and performance of sheep kept on Tanzania grass (*Panicum maximum*) pastures in an intermittent grazing system and observed the influence of solar radiation on the behavioral characteristics of the animals, especially on rumination-related activities. It is noteworthy that, according to Santos et al (2011), changes in animal behavioral patterns are consequences of an attempt to escape stressing agents/stimuli.

Conclusions

The meteorological variables influenced the behavioral and thermoregulatory characteristics of the evaluated animals. The sheep exhibited thermal discomfort during the afternoon period and thus need to make use of their physiological mechanisms to maintain their bodies in the thermoneutrality zone.

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