Revista Brasileira de Zootecnia
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ISSN 1806-9290
www.sbz.org.br

R. Bras. Zootec., 43(10):556-560, 2014

Short Communication

Effects of heat stress on the physiological parameters and productivity of hair sheep in tropical and coastal environments

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ABSTRACT - The experiment was carried out with sheep during the finishing phase in a partial confinement system to evaluate the following physiological parameters: rectal temperature (RT), respiratory rate (RR), heart rate (HR), productive performance and carcass characteristics. Fourteen uncastrated sheep with an average initial age of 90 days belonging to two genetic groups were used. There were seven Santa Inês animals, whose average initial live weight (ILW) was 23.65 kg, and seven F1 Dorper × St. Inês animals, with an ILW of 20.02 kg. The treatments were the two genetic groups and two times for the collection of the physiological parameters, at 09.00 h and 15.00 h. Evaluation took place once a week, in a shared stall, always following a 20-min grazing activity. The animals had daily access to a *Megathyrsus maximus* (Jacquin) pasture, cultivar Masai, from 08.00 h to 17.00 h and their feed was placed in a trough, at a forage:concentrate ratio of 51:49 in the total dry matter. The concentrate consisted of 900 g/kg of ground corn and 100 g/kg of soybean meal, and the roughage supplied was alfalfa hay. There was no interaction between treatments for the studied variables. The physiological parameters were affected only by the time of day. The variables RR and RT were higher at 15.00 h, while the highest HR values were observed at 09.00 h. Neither of the two genetic groups differed for performance and carcass characteristics. Hair sheep belonging to close genetic groups show no differences in performance, carcass characteristics and physiological responses when subjected to heat stress.

Key Words: adaptability, animal production, bioclimatology

Introduction

The introduction of the Dorper sheep breed in Brazilian regions dominated by Creole breeds has allowed for the achievement of earlier animals, which are heavier at slaughter. There is a lack of bioclimatic studies on growth performance of new genetic groups or products resulting from crosses between Dorper and Brazilian animals. Such crossings can result in products whose adaptability favors performance because the animals may be more resistant to the tropical environment.

Under heat stress, sheep initially use peripheral vasodilation, which promotes diversion of blood flow to body surface area, increases temperature in animal skin and facilitates heat dissipation by non-evaporative mechanisms. However, if ambient temperature continues to rise, heat losses through sensible ways will be less effective and the temperature of the central nucleus will increase (Curtis, 1983; Müller, 1989; Baêta and Souza, 2010). The animal body circumvents this problem by enhancing heat dissipation via latent mechanisms, e.g., by sweating and increasing the respiratory rate (Curtis, 1983). However, if animals cannot dissipate excess heat through the aforementioned mechanisms, which can be worsened by higher relative air humidity in the humid tropics, rectal temperature increases above normal physiological values and heat stress worsens, which partially explains the low productivity of animals of temperate breeds in the humid tropics.

Thus, the evaluation of a genetic group or breed by considering not only weight gain ability and carcass yield, but also adaptability, prolificacy and offspring survival rate will improve our capability to increase sheep productivity under tropical conditions (Olivier, 2000). It is necessary to obtain information about tolerance and adaptability of Dorper sheep and the products from its crosses with native sheep in humid tropical areas. Therefore, the objective of the present study was to evaluate the physiological parameters, performance, and carcass characteristics of Santa Inês sheep and its crosses with the Dorper breed in a region of humid tropical and coastal climate.

Received March 19, 2014 and accepted June 24, 2014.
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http://dx.doi.org/10.1590/S1516-35982014001000008

Material and Methods

The experiment was carried out in the county of Campos dos Goytacazes - RJ from October 1 to November 26, 2011. The experimental area is located in the coastal zone (altitude 14 m; 21°45'14" S; and 41°19'26" W). Its climate is classified as Aw according to Köppen standards. In 2011, the average minimum temperature in October was 21 ºC and the maximum, 26 ºC; in November, the minimum was 20 ºC and the maximum, 27 ºC. The total precipitation in October was 63 mm and there were no rain events in November. The average wind speed in October was 2.02 m/s, and in November it was 1.99 m/s, according to Instituto Nacional de Meteorologia (INMET, Brazil). Other climatic data were collected during the experiment (Table 1).

The experiment was conducted using 14 uncastrated sheep at mean age of 90 days, belonging to two genetic groups. Seven animals belonged to the Santa Inês breed, whose average initial live weight (ILW) was 23.65 kg (standard deviation = 2.8 kg) and the other seven resulted from F1 Dorper × Santa Inês crosses, whose ILW was 20.02 kg (standard deviation = 5.7 kg).

Practices carried out in experimental animals were in accordance with ethical standards and approved by the Ethics Committee on Animal Use (CEUA – UENF), protocol 133.

Before the adaptation period of 30 days, the animals were weighed, identified with earrings and treated against ecto- and endoparasites. During the adaptation period the animals were subjected to the same diet applied during the experimental period. At the end of this stage, the animals were weighed again and then started the 56-day experimental period.

The experiment was carried out during the finishing phase in a partial confinement system. The animals had daily access to *Megathyrsus maximus* (Jacquin) pasture, cultivar Masai, from 08.00 h to 17.00 h. The pasture presented, on average, a daily availability of 0.488 kg of dry matter (DM) per animal, assessed by the square method. In addition, the animals received supplementary feed in a common trough, made of concentrate and forage at a 51:49 ratio on a dry matter basis, twice a day. The concentrate, on a dry matter basis, consisted of 900 g/kg of ground corn and 100 g/kg of soybean meal. Alfalfa hay was used as forage. In total, each animal received about 0.505 kg of alfalfa hay and 0.443 kg of concentrate a day. Furthermore, a mineral mixture consisting of 147 g of Na, 120 g of Ca, 87 g of P, 18 g of S, 3,800 mg of Zn, 1,800 mg of Fe and 1,300 mg of Mn per kg of mixture was provided *ad libitum*. According to AFRC (1993), this diet is sufficient for a daily gain of 0.267 kg per animal.

The animals had free access to a barn of 36 m^2. The stall was two meters high and its sides were made of wooden slats with a spacing of eight centimeters between them. Six shared drinkers and six 0.56 m-long feeders with hay-feeders above were displaced in the barn.

The readings of the environmental variables were performed at 09.00 h and 15.00 h (Brasil, 1992) and always twice a week. For such, a portable digital thermo-hygrometer equipped with a sensor that records dry bulb temperature and relative humidity was used. In addition, temperature values were collected using a black globe thermometer. All these devices were installed primarily on pasture, where the animals stayed, and then in the barn. The recording equipments were always placed at half-height of the animal body.

The following physiological variables of the animals were measured: rectal temperature (RT), respiratory rate (RR), and heart rate (HR). These variables were evaluated once a week in the shade of the barn immediately after a 20-min grazing period. Two teams of three people each were used for the collection of physiological variables, each team performing collections in seven animals. The average collection time for each animal was two minutes.

The RT was determined by inserting a veterinary thermometer ranging up to 44 ºC into the rectum. The RR was determined by indirect auscultation with the use of a

Table 1 - Minimum, maximum and mean values of dry bulb temperature (DBT), black globe temperature (BGT), and relative humidity (RH), collected during the months of October and November 2011 in Campos dos Goytacazes-RJ

Period	DBT (ºC) Pasture		DBT (ºC) Stall		BGT (ºC) Pasture		BGT (ºC) Stall		RH (%) Pasture		RH (%) Stall	
	09.00 h	15.00 h	09.00 h	15.00 h	09.00 h	15.00 h	09.00 h	15.00 h	09.00 h	15.00 h	09.00 h	15.00 h
October												
Minimum	24	23.7	20	21.9	25.5	24.5	19.5	21.5	47	63	58	63
Maximum	30.7	31.4	29	30.7	47	43	28	29.5	81	70	86	74
Average	27.3	27.5	24.5	26.3	36.2	33.7	23.7	25.5	64	66.5	72	68.5
November												
Minimum	24.8	28.2	22	24.2	36	40	21.5	24	58	43	57	45
Maximum	29.4	35.1	27.9	31.6	48	45	30	46	64	52	63	56
Average	27.1	31.6	24.9	27.9	42	42.5	25.7	35	61	47.5	60	50.5

flexible stethoscope placed at the laryngotracheal region and expressed in movements per minute. The HR was also obtained with the aid of a flexible stethoscope, this time placed at the left thoracic region at the aortic arch, expressed in beats per minute. Data collection also occurred at 09.00 h and 15.00 h.

To study the behavior of the physiological variables of the animals, the treatments used were the two genetic groups and the two collection times. In both, the collection schedules were performed for all animals of each genetic group.

The physiological variables were analyzed by multivariate analysis so as to obtain the first canonical variable related to the linear combination for the three variables RT, RR, and HR. Thus, the correlation among these physiological measures was preserved and analyzed as a single canonical variable:

$$VC_j = aRT_j + bRR_j + cHR_j,$$

in which VC refers to the j-th canonical variable related to the j-th animal; a, b and c are the canonical coefficients estimated from the measured variables; RT_j refers to body temperature; RR_j refers to respiratory rate; and HR_j refers to heart rate of the j-th animal, respectively. Once obtained for each animal, the first canonical variable was then treated as a random variable and subjected to analysis of repeated measures in time by the following statistical model:

$$Y_{ijk} = \mu + \alpha_i + a_{ij} + \tau_k + \alpha\tau_{ik} + e_{ijk},$$

in which Y_{ijk} refers to the value of the canonical variable estimated for the j-th animal of the i-th genetic group, obtained at the k-th hour of the day; μ is a constant of the model; α_i is the fixed effect of the i-th genetic group (i = 1, 2, 3); a_{ij} is the random effect of the j-th animal belonging to the i-th genetic group; τ_k is the fixed effect of the k-th hour of the day; $\alpha\tau_{ik}$ refers to the fixed effect of the interaction between group and hour; and e_{ijk} refers to the random error. This model was fitted to the canonical variables using the mixed model procedure (PROCMIXED) of the SAS (Statistical Analysis System, version 9) software. Furthermore, the variance-covariance structure (Σ) was tested for this experimental design of repeated measures over time as described by Vieira et al. (2012). Akaike's criterion (Akaike, 1974) and its derived measures were used to calculate the likelihood for the different Σ structures (Burnham and Anderson, 2004).

At the end of the experiment, the animals were slaughtered after an 18-h fasting period. The animals were bled and eviscerated to obtain the carcasses, which were divided into two halves with a chainsaw and weighed individually. The two half carcasses were taken to a cold room, where they remained for 24 hours at 5 ºC. Subsequently, the loin-eye-area of the *longissimus dorsi* muscle and the subcutaneous fat thickness were measured in the left half carcass at the 12th rib.

The performance variables and carcass characteristics were analyzed by the MIXED procedure of SAS in order to fit the completely randomized model ($Y_{ij} = \mu + \alpha_i + e_{ij}$) to the data, in which the possibility of heterogeneous variances for the variables measured in the two genetic groups was checked, based on likelihood criteria described by Burnham and Anderson (2004). Estimates per confidence interval were obtained by considering 0.05 as the probability of type I error.

Results

There was no interaction between genetic groups and hours of the day for the studied variables. Therefore, the effects of genetic group and time of day were treated independently. The physiological variables were not affected by the genetic groups; nonetheless, the time of day did affect the physiological variables of the sheep (Table 2).

The variables RR and RT were higher at 15.00 h, whereas the highest values for HR were observed in the morning (09.00 h).

The genetic groups Santa Inês and F1 Dorper × Santa Inês showed no differences for productive performance and carcass characteristics (Table 3). After transforming the measured physiological variables (RT, RR, and HR) into the first canonical variable (Table 2), the most suitable structure of variances and covariances detected was that of autoregressive correlations, with a likelihood probability equal to 0.999. After a multivariate analysis of the first canonical variable, no effects were observed for genetic group (P = 0.307) and for the treatment × hour of the day interaction (P = 0.956); nevertheless, differences were observed between the hours of the day when measurements were taken (P = 0.001).

Table 2 - Average least squares and P-values for physiological parameters respiratory rate, heart rate and rectal temperature of hair sheep

Item	Genetic group			Schedule			P-value interaction
	Santa Inês	F1 Santa Inês × Dorper	P-value	09.00 h	15.00 h	P-value	
Respiratory rate	113±27	135±27	0.246	106±20	142±20	0.001	0.966
Heart rate	134±9	141±9	0.276	142±7	133±7	0.001	0.567
Rectal temperature	39.6±0.1	39.7±0.1	0.079	39.5±0.1	39.8±0.1	0.001	0.532

Table 3 - Average least squares and P-values for body measurements of hair sheep

	Santa Inês	F1 Santa Inês × Dorper	P-value
Body weight at slaughter (kg)	37.7±3.1	34.0±3.1	0.087
Average daily gain (g/day)	213±19	224±19	0.382
Carcass yield (kg/100 kg)	43.97±2.56	44.20±0.77	0.811
Loin-eye area (cm^2)	14±2	15±2	0.861
Fat thickness (mm)	3±1	2±1	0.377

Discussion

The present study showed that, in the afternoon, 20-min exposure of animals to the sun promoted some stress (Table 2), but not enough to detect possible differences between the genetic groups for rectal temperature (RT), respiratory rate (RR) and heart rate (HR). On the other hand, Quesada et al. (2001) found higher values for these physiological variables in Morada Nova than Santa Inês sheep after a 6-h period of exposure of animals to the sun.

According to Baêta and Souza (2010), the thermal comfort zone for sheep ranges from 15 ºC to 30 ºC, and the critical temperature is above 35 ºC. These values are based on conditions of effective temperatures. Thus, the black globe thermometer is the most suitable device for gathering such data, as it associates the ambient temperature to the effects of solar radiation and convection. In this case, we observed that the animals in our study underwent heat stress, because data on physiological variables were collected after they had been allowed to graze at ambient temperatures of the black globe above the comfort zone (Table 1).

The lower heart rate found in the present study is probably because, under heat stress, animals tend to reduce their movement (Curtis, 1983), in an attempt to produce less body heat. Thus, walking and grazing might have been less intense in the afternoon, which may explain the reduced heart rate recorded in this study.

Whereas there was stress when animals were exposed to the sun for 20 min due to the increased RT and RR (Table 2), it is possible to propose heat tolerance tests by promoting a shorter period of stress, unlike the proposals found in previous works (Rhoad, 1944; Rauschemback and Yerokin, 1975), in which heat tolerance tests were developed. However, other periods of time must be used and compared with 20 min, because it seems that significant differences in sensitivity to heat stress are less likely to occur among animals of close genetic groups. It is important to emphasize, however, that such heat tolerance tests should be coupled with performance experiments so as to obtain the level of correlation between these two aspects concerning the animal.

Despite expectations of heterosis effect on crossbred animals, the genetic group F1 Dorper × Santa Inês presented performance and carcass characteristics similar to those of Santa Inês animals (Table 3). Therefore, it can be said that the thermal environment to which the animals were exposed in this study did not favor any genetic group regarding performance.

The values of the confidence interval for average daily gain (ADG; Table 3) are similar to the estimate point of 0.247 kg/d found by Neiva et al. (2004), working with Santa Inês animals fed about 0.880 kg/d of concentrate, but are greater than the ADG of 0.147 kg/day for ¾ Dorper animals given 0.680 kg/d of concentrate, reported by Burke and Apple (2007). It should be noted that in both studies more concentrate was offered than the amount fed to the animals of the present study.

In the present study, the absence of differences in the results for carcass characteristics may be explained by the fact that the animals from both genetic groups had the Santa Inês breed in common and were acquired in the same property, i.e., they underwent the same rearing procedures. Moreover, they were given the same experimental diet. These aspects may explain the absence of differences in the results for the physiological parameter estimates, productive performance, and carcass characteristics because animal growth depends on breed, nutrition, gender and physiological stage (Berg and Butterfield, 1976; Lawrence and Fowler, 1997; Luchiari Filho, 2000).

The differences in response according to the time of the day (9.00 h and 15.00 h) show that it is more interesting to propose systems in which most grazing activity is performed in the morning, so that animals during the afternoon period, i.e., the warmer part of the day, have the opportunity to consume higher amounts of high-quality hay and concentrate available as they tend to move less and search for shadow. In this case, it is interesting to provide most of the concentrate during the afternoon-evening period, when animals are prone to rest or reduce their activity.

This study contributes to a better understanding of issues related to hairy sheep in tropical coastal environments, considering the lack of results in the national literature.

Conclusions

Hair sheep belonging to close genetic groups, which are the case of Santa Inês breed and its crosses with Dorper, show no differences in performance, carcass characteristics, or physiological responses when subjected to heat stress. Under such conditions, which occurred at 15.00 h, sheep respiratory rate increases to dissipate excess heat as also indicated by higher rectal temperatures; nevertheless, a heart rate increase is not necessarily required for an improved efficiency in this process.

Acknowledgments

Financial support was provided by FAPERJ (Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro – Brazil).

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