PHYSIOLOGICAL RESPONSES OF CAPRINES RAISED UNDER DIFFERENT TYPES OF COVERING

CELSO Y. KAWABATA[1], LINDALVA DE A. DE JESUS[2], ANA PAULA V. DA SILVA[2], THIAGO V. R. DE SOUSA[2], LUIS F. B. DA CRUZ[3]

ABSTRACT: Thermal discomfort inside facilities is one of the factors responsible for low productivity of caprines in the Brazilian Northeast region, because inadequate weather conditions can cause elevated rectal temperature, increased respiratory rate, decreased food ingestion and reduced production. The present paper aimed to study the behavior of physiological thermoregulation of the animals (respiratory rate - RR and rectal temperature - RT) at four different times of the day (8 a.m., 11 a.m., 2 p.m. and 5 p.m.) and their relation to bioclimatic indexes (Temperature Humidity Index - THI, Black Globe Humidity Index - BGHI and Radiant Heat Load - RHL) in order to determine whether the type of covering used in the animals facilities (ceramic covering - CC, asbestos cement covering – AC and straw covering - SC) interferes with the physiology of thermoregulation. The time of data collection was related to the values of environmental and physiological variables. At 2 p.m. it was found the highest values of Radiant Heat Load on the three types of covering. The values of RT and RR were higher at 11 a.m. and 2 p.m., and the straw tile provided better thermal conditions of microclimate for the animals. The increased RR maintained the caprines homeothermy.

KEYWORDS: ambience, respiratory rate, rectal temperature, thermoregulation.

RESPOSTAS FISIOLÓGICAS DE CAPRINOS CRIADOS SOB DIFERENTES TIPOS DE COBERTURAS

RESUMO: O desconforto térmico no interior de instalações é um dos fatores responsáveis pela baixa produtividade de caprinos no Nordeste, pois condições climáticas inadequadas podem acarretar elevação da temperatura retal, aumento da frequência respiratória, diminuição da ingestão de alimentos e redução da produção. Com o presente trabalho, objetivou-se estudar as variáveis fisiológicas de termorregulação dos animais (frequência respiratória – FR e temperatura retal – TR) em quatro horários do dia (8; 11; 14 e 17 horas) e sua relação com os índices bioclimáticos (índice de temperatura e umidade – ITU, índice de temperatura de globo e umidade – ITGU e carga térmica radiante – CTR), a fim de determinar se o tipo de cobertura utilizado na instalação dos animais (cobertura cerâmica – CC, cobertura de fibrocimento – CF e cobertura de palha – CP) interfere na fisiologia de termorregulação. O horário de registro de dados teve relação com os valores das variáveis ambientais e fisiológicas. Às 14 horas, encontraram-se os valores mais elevados de carga térmica radiante nos três tipos de cobertura. Os valores de TR e FR foram maiores às 11 horas e 14 horas, sendo que a cobertura de palha proporcionou melhores condições térmicas do microclima aos animais. O aumento da FR manteve a homeotermia dos caprinos.

PALAVRAS-CHAVE: ambiência, frequência respiratória, temperatura retal, termorregulação.

INTRODUCTION

The largest Brazilian herd of goats is located in the Northeast region, with about 8,538,255 heads (90.6% of the national herd) (IBGE, 2011). Although numerically significant (92.8% of the national herd), the goat herd in the Northeast region maintains low productivity rates (79 liters of milk/month/establishment) when compared to national values (98 liters of

[1] Professor Adjunto do Centro de Ciências Agrárias e Ambientais da Universidade Federal do Maranhão.
[2] Zootecnista Autônomo.
[3] Graduando do Curso de Agronomia do Centro de Ciências Agrárias e Ambientais da Universidade Federal do Maranhão.
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milk/month/establishment) (IBGE, 2011). Among the factors responsible for this low productivity are the climatic factors such as air temperature, relative air humidity and solar radiation, which often lie outside the zone of thermal comfort or thermoneutral zone that for goats ranges from 20ºC to 30ºC according BAÊTA & SOUZA (2010). Besides the low level of technology employed in the region, which is the result of the production system adopted by most farmers: the subsistence crop (SOUZA, 2010).

The thermal comfort of the animals within the facility is a highly important factor, because inadequate weather conditions reduce considerably the production (BRASIL et al., 2000). One of the most efficient devices for building, which can be used to control the weather elements that interfere in the animal welfare are the roofing materials that will directly influence the microclimate generated inside the shelter.

The tiles are used for the purpose of draining rainwater from roofs and thermal control within the premises. The most widespread tiles used are ceramic, asbestos cement, metal and plastic. For the covering act improving climatic conditions it must display thermal isolation and high reflectivity to solar radiation, thereby reducing the thermal stress (OLIVEIRA et al., 2009).

Although goats are considered rustic animals, the association between high temperatures, high humidity and radiation can cause behavioral and physiological changes, such as elevated rectal temperature, increased respiratory rate, decreased food ingestion and reduced productivity (OLIVEIRA et al., 2005).

The animal and environment interaction must be considered when seeking greater efficiency on the farm, because the different responses of the animal to the peculiarities of each region are crucial to the success of productive activity and the adequacy of the production system (SILVA et al., 2006; SOUZA et al., 2007; SOUZA et al., 2008a; ROBERTO & SOUZA, 2011).

The present research aimed to study the physiological variables of thermoregulation of the animals during records at four different times of the day. To characterize the environment and to assess its relation with physiological variables of animals in order to determine whether the type of covering used interferes in the physiology of animal thermoregulation.

MATERIAL AND METHODS

The experimental phase was performed on a property located in the rural zone of Chapadinha city – state of Maranhão (MA), Brazil, in the month of July, 2011 (hot and dry). The city of Chapadinha-MA, is located in the Lower Parnaíba situated at 03º44'33"S latitude, 43°21'21"O longitude and altitude of 106m. The average value related to the temperature during the experiment was 29.16°C; the relative air humidity had a mean of 50.72%.

Six animals were used in each type of covering: ceramic, asbestos cement and straw of babassu palm (*Orbignya oleifera*). A shelter was built with 4.0m long, 3m wide, 2.5m ceiling height, and the covering was single water with 10° inclination with East-West direction.

Six caprines of about one year of age without defined breed were submitted to the different types of covering. Water and food were given at ease based on elephant grass (*Pennisetum purpureum*) and commercial concentrate for goats. In each covering, six animals were housed and after five days of adaptation the climatic and physiological data were recorded for two consecutive days with straw covering, and after the registration of the data, the covering has been replaced by cement and ceramics, respectively.

The experimental delineation used for the climatic variables was completely randomized (CRD), in subdivided plots and for the physiological variables was the Latin square with subdivided plots, testing the factorial 3x4 (three shelter covering in the plots and four times of the day in the subplots), with six replicates assembled in two 3x3 Latin squares.

It was recorded the air temperature, relative air humidity, black globe temperature and wind speed, at four different times of the day (8 a.m., 11 a.m., 2 p.m. and 5 p.m.), through thermo hygrometers and black globe thermometers allocated in geometric center inside the shelters.

The animal physiological variables (rectal temperature and respiratory rate) were recorded at four different times of the day (8 a.m., 11 a.m., 2 p.m. and 5 p.m.). The rectal temperature was measured by a clinical thermometer inserted directly into the rectum of the animal and the respiratory rate performed by counting the number of movements of the flank for 15 seconds and the obtained value multiplied by four to determine the respiratory rate in movements per minute (mov/min).

The characterization of the environment inside the shelters was conducted through the use of the recorded data and calculation of temperature and humidity index (THI) (Equation 1) according to THOM (1958), black globe humidity index (BGHI) (Equation 2) according to BUFFINGTON et al. (1981) and the radiant heat load (RHL) (Equation 3) according to ESMAY (1969).

With the results of these indexes and the measurement of physiological responses of animals (rectal temperature and respiratory rate) we found that the type of covering used in the commercial installation is suitable for goat breeding in the region of Chapadinha-MA.

$$THI = Dbt + 0.36\ Dpt + 41.5 \tag{1}$$

in which,

Dbt – dry-bulb temperature, ºC
Dpt – dew point temperature, ºC

$$BGHI = Bgt + 0.36\ Dpt + 41.5 \tag{2}$$

in which,

Bgt – Black globe temperature, ºC
Dpt – dew point temperature, ºC

$$RHL = \sigma\ (MRT)^4 \tag{3}$$

in which,

σ - Stefan-Boltzmann Constant, 5.67. 10^{-8} W.m^{-2}.K^{-4}
MRT – mean radiant temperature, $100 \sqrt[4]{2.51 \sqrt{v}\,(Bgt - Dbt) + (Bgt.100^{-1})^4}$,

in which:

v – velocity of wind, m.s-^{1}
Bgt – Black globe temperature, K
Dbt – dry-bulb temperature, K

The variance analysis was performed using an Infostat program and the means were compared by the Student’s t-test at 5% of probability.

RESULTS AND DISCUSSION

The mean values of climate variables that characterize the thermal environment, RHL, THI and BGHI are in Tables 1, 2 and 3, respectively. And the average respiratory rate (RR) and rectal temperature (RT) are shown in Tables 4 and 5, respectively.

Observing the average RHL described in Table 1, we note that there was no significant difference at 5% probability in values of shelters with asbestos cement tiles in any of the analyzed schedules, which may be explained by the possible reduction of solar radiation (which defines the values of RHL) mainly at 2 p.m. in the days of collection (FIORELLI et al., 2012) when the RHL should reach its highest value, which was described in the study of FIORELLI et al. (2010).

TABLE 1. Mean values of radiant heat load (RHL) in $W.m^{-2}$, for different times and analyzed types of covering: ceramic covering - CC, asbestos cement covering – AC and straw covering – SC.

	Schedule			
Treatment	8	11	2	5
CC	460.57^{Aa}	489.72^{BCa}	513.04^{Ca}	480.47^{ABa}
AC	493.22^{Aa}	509.45^{Aa}	497.64^{Aa}	505.09^{Aa}
SC	470.23^{Aa}	504.56^{Ba}	513.91^{Ba}	500.78^{Ba}

Means followed by the same letter, capital in the lines and small in the columns, do not differ statistically in the Student's t-test ($P \geq 0.05$).

According to the average values of RHL (Table 1), we observed that at 2 p.m. the shelters with straw and ceramics covering have the highest daily values, 513.04 $W.m^{-2}$ and 513.91 $W.m^{-2}$ respectively, especially due to the darker coloration of these covering when compared with the asbestos cement covering, resulting in greater absorption of solar radiation at this time of collection, corroborating the results found by FIORELLI et al. (2010), JÁCOME et al. (2007), RIBEIRO et al. (2008), SANTOS et al. (2005), and SOUZA et al. (2008b), that found the highest values of RHL at 2 p.m. or close to that time.

JÁCOME et al. (2007) stated when assessing the RHL in animal facilities, located in the Northeast region of Brazil that, at the hottest times of the day the ceramic tile showed lower RHL compared to the sheds covered with asbestos cement tile, which comes against with the results obtained for the times of 8 a.m., 11 a.m. and 5 p.m. in this study, although it does not present significant statistically difference but were numerically different (presented close thermal behavior).

At 5 p.m. there was a statistically significant decrease in treatment with straw tiles 480.47 $W.m^{-2}$, while in the shelters covered with ceramic and asbestos cement tiles there was no decrease in RHL, mainly due to the process of air convection present within the facility that found less difficulty in transposing straw covering. According to FIORELLI et al. (2010) the RHL reaches the highest values near noon when the sun is positioned as perpendicular to the plane of the horizon. In the study of RIBEIRO et al. (2008) the RHL grew throughout the day, until 3 p.m., when it began to decline. In the research of JÁCOME et al. (2007) there is an increase of RHL until 2 p.m., decreasing thereafter.

The THI values (Table 2) were statistically similar in schedule of 2 p.m. in the three types of covering. The THI values in ceramic covering treatment at 8 a.m., 11 a.m. and 5 p.m. were significantly lower compared to the values recorded in the shelter with straw covering. The THI values were higher starting at 11 a.m. in all treatments, being in accordance with LIMA et al. (2009), who observed a tendency to worsening the conditions of temperature and humidity during the peak heat (close at noon).

TABLE 2. Mean values of temperature and humidity index – THI, for different times and analyzed types of covering: ceramic covering - CC, asbestos cement covering – AC and straw covering – SC.

	Schedule			
Treatment	8	11	2	5
CC	77.75^{Ab}	82.05^{Bb}	83.44^{Ba}	82.44^{Bb}
AC	75.25^{Aab}	78.63^{Bab}	79.35^{Ba}	79.05^{Bab}
SC	73.41^{Aa}	77.78^{Ba}	80.72^{Ba}	77.46^{Ba}

Means followed by the same letter, capital in the lines and small in the columns, do not differ statistically in the Student's t-test ($P \geq 0.05$).

For ovines and caprines the THI values below 82 indicates absence of heat stress, between 82 and 84 moderate heat stress, between 84 and 86 severe heat stress and THI as from 86 extremely severe heat stress (SALLES, 2010; NEVES, 2008). The results of this study showed that only in the treatment with straw covering, in the hottest times of the day, we found a moderate heat stress condition, while the other THI values are in a situation of thermal comfort.

Evaluating the physiological parameters of goats without defined breed, black and white, at shade, in moist tropical climate, in the rainy season, MEDEIROS et al. (2007) obtained values of THI, in the morning from 7 a.m. to 11 a.m. ranging from 73.88 to 76.66 and in the afternoon the THI ranged from 80.61 to 82.76, featuring the afternoon shift as the most unpropitious, similar to that observed by this experiment. This result is important to adequate the handling of animals, avoid doing it in the most stressful times of the day (afternoon shift).

Analyzing the BGHI (Table 3) it was noted that, as what happened in RHL in asbestos cement covering, there was no difference in any of the schedules. From 8 a.m. there was an increase in the BGHI treatments of straw and ceramic covering until 2 p.m. decreasing at 5 p.m. similar to the research of JÁCOME et al. (2007) who found in the ceramic covering a significant increase in BGHI, for 8 a.m. and 4 p.m.

According to the Tukey test ($P \geq 0.05$) the BGHI values found in this study at 2 p.m. in the straw covering were significantly higher than those of asbestos cement covering, possibly due to the color of the asbestos cement tiles being lighter than the straw covering tiles enabling greater reflectivity of solar radiation. LIMA et al. (2009) evaluating the internal thermal environment in sheds with different roofing materials in the middle region of Belém city – Pará state (PA), in Brazil, reported BGHI values of the sheds environment with ceramic tile better than the sheds with asbestos cement tile.

TABLE 3. Mean values of black globe humidity index - BGHI, for different times and analyzed types of covering: ceramic covering - CC, asbestos cement covering – AC and straw covering – SC.

Treatment	Schedule			
	8	11	2	5
CC	77.53^{Aa}	82.26^{BCa}	84.24^{Cb}	80.51^{Ba}
AC	76.52^{Aa}	79.45^{Aa}	77.93^{Aa}	78.65^{Aa}
SC	74.94^{Aa}	78.43^{Ba}	79.88^{Bab}	77.93^{Ba}

Means followed by the same letter, capital in the lines and small in the columns, do not differ statistically in the Student's t-test ($P \geq 0.05$).

The BGHI values at 2 p.m. in the three treatments were 84.24, 77.93 and 79.88 in shelters with straw, asbestos cement and ceramic covering, respectively, higher than the values found by SOUZA et al. (2010) at 2 p.m. which was 75 in shaded environments. In the study of FIORELLI et al. (2009) it was possible to identify an increase in BGHI throughout the day, reaching a maximum at 2 p.m. in all the tested covering, ceramic tile, painted white ceramic tile, recycled tile, asbestos cement tile, the same behavior exhibited by SC and CC in this study.

The BGHI values of 8 a.m. for the three treatments can be characterized as a situation of alert, and the ones found at 11 a.m., 2 p.m. and 5 p.m. as danger situation according to BAÊTA (1985), BGHI values up to 74, 74 to 78, 79 to 84 and above 84 define situation of comfort, alert, danger and emergency, respectively. The values found in the afternoon were higher than those shown by SOUZA et al. (2005). SANTOS et al. (2005) reported values of BGHI at 9 a.m. and 3 p.m. of 77.5 and 85.5 respectively, both confirming the values observed in this study.

We observed that the highest values of RR (Table 4) obtained in this study were at 11 a.m. and 2 p.m. for all studied covering. The mean RR values of the animals housed in the shelter with straw covering were significantly lower compared to the other two types of covering during the four collection times, except at 8 a.m. when the value was numerically lower but statistically similar to AC demonstrating the efficiency of this type of material as covering in animal facilities.

The mean values of RR obtained in this study for all treatments and times are above the normal average that is considered normal to caprines when it presents 15 respiratory movements per minute, and these values can vary between 12 and 25 respiratory movements per minute (REECE, 1996). As the temperature increases, the efficiency of sensible heat loss decreases and increases the insensible (SOUZA et al. 2008b), i.e., increases the heat dissipation in latent or evaporative form through the respiratory rate and the heat dissipation of non-evaporative or sensible form which occurs through conduction, convection and radiation decreases.

TABLE 4. Mean values of respiratory rate (RR) in mov.min^{-1} for different times and analyzed types of coverage: ceramic covering - CC, asbestos cement covering – AC and straw covering – SC.

Treatment	Schedule			
	8	11	2	5
CC	19.33^{Aa}	24.67^{Ba}	27.67^{Ca}	21.00^{Aa}
AC	21.33^{Aab}	29.67^{Cb}	32.67^{Cb}	25.00^{Bb}
SC	23.00^{Ab}	29.67^{Bb}	32.67^{Cb}	27.67^{Bb}

Means followed by the same letter, capital in the lines and small in the columns, do not differ statistically in the Student's t-test ($P \geq 0.05$).

Comparing these values with those found by SILVA et al. (2004) in the morning or in the afternoon, we noticed that they were higher than those found by these authors and also those reported by SANTOS et al. (2005) in goats maintained in the shade. SILVA et al. (2004) studying physiological parameters of goats in semiarid, observed that RR is influenced by the time of the day, being observed in the morning shift 30 mov.min^{-1} and 49 mov.min^{-1} in the afternoon.

When there is accentuated elevation of temperature, the thermoregulatory mechanisms are triggered. The elevation of RR in this study occurs as a response to increased temperature as a mechanism that animals use in order to dissipate the heat and maintain the homeothermy (MARTINS JUNIOR et al. 2007). The maintenance of the high respiratory rate if maintained for several hours can result in serious problems for the animals such as reduction in food ingestion and rumination (SOUZA et al. 2012), which did not happen in this study, since the average values of RR obtained at 5 p.m. were lower than those from 11 a.m. and 2 p.m. in all treatments, demonstrating the reduction of heat stress for the animals.

The research conducted by SOUZA et al. (2010) demonstrated the efficiency of the shadow used to improve the thermal comfort conditions for the animals, as well as to confirm the effectiveness of the RT and RR parameters to indicate the state of thermal comfort in which the animal is.

TABLE 5. Mean values of rectal temperature (RT) in ºC for different times and analyzed types of covering: ceramic covering - CC, asbestos cement covering – AC and straw covering – SC.

Treatment	Schedule			
	8	11	2	5
CC	38.03^{Aa}	38.79^{Ba}	39.11^{Ba}	38.85^{Ba}
AC	38.36^{Aa}	39.42^{Cb}	39.43^{Ca}	38.85^{Ba}
SC	38.08^{Aa}	39.01^{Bab}	39.07^{Ba}	38.82^{Ba}

Means followed by the same letter, capital in the lines and small in the columns, do not differ statistically in the Student's t-test ($P \geq 0.05$).

The average values of RT (Table 5) obtained in the study were similar for all treatments at 8 a.m., 2 p.m. and 5 p.m., statistically differing only at 11 a.m., where the animals of the treatment with asbestos cement tiles presented an average of RT higher than the animals placed under the other covering, but still presenting values within the patterns for the goats, ranging from 38.5 to 39.7°C (RECE, 1996), indicating a low level of heat stress to animals in all types of covering.

The daily behavior of rectal temperature with gradual increase of its value until reach the maximum at 2 p.m. and with reduction of its value at 5 p.m. is related to the same behavior presented by ambient temperature, which can be demonstrated by the presented values of THI. The means of RT observed in the four hours, presented close to those described by SANTOS et al. (2005) who studied the adaptability of four breeds of goats raised in semi-arid climate, obtained means of RT of 39.39ºC, 39.33ºC, 39.72ºC and 39.37ºC for Boer, Anglo-Nubian, Moxotó and Pardo-Sertaneja, respectively.

The RT values at all times for treatments with asbestos cement and ceramics covering were higher than those reported by OLIVEIRA et al. (2005) which in the fold with asbestos cement covering the animals showed values of 31.9ºC and 37.5ºC at 9 a.m. and 3 p.m., respectively, and in the ceramic covering the RT was 30.7ºC and 36.1ºC at 9 a.m. and 3 p.m.

The highest RT values were found at 11 a.m. and 2 p.m. in the treatment with asbestos cement covering, which were 39.42°C and 39.43°C respectively. In all treatments, the RT was significantly higher at 11 a.m., 2 p.m. and 5 p.m. than in the morning at 8 a.m., due to the additional thermal load received, resulting in increased internal heat, corroborating the observed by other authors (SILVA et al., 2005; SOUZA et al., 2005; SILVA et al., 2006; MEDEIROS et al., 2008). Therefore, the high ambient temperature in the afternoon is the origin of high rectal temperature of animals in the afternoon.

CONCLUSIONS

The time influenced the physiological responses presented by the animals, being the values at 11 a.m. and 2 p.m. always higher than at 8 a.m. and 5 p.m., since the ambient temperature is higher at these times as well. The straw covering influenced the values found for respiratory rate of the animals that were smaller and statistically different from those identified for ceramics and asbestos cement covering. The increase in the respiratory rate was effective in maintaining the homeothermy, since the rectal temperature was maintained within the range considered suitable for caprines.

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