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SHORT COMMUNICATION
Comunicação Curta

Respiratory heat loss in Morada Nova sheep in Brazilian semi-arid regions

Perda de calor respiratório em ovinos Morada Nova no semiárido brasileiro

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Abstract This study aimed to evaluate the respiratory heat loss in sheep from the equations developed for this species and its relations with meteorological variables in semi-arid regions. The respiratory heat loss (sensible and latent) was estimated through the equations in the literature for four 12-month-old male Morada Nova sheep, kept in an installation with shading of ceramic tiles and a 3-meter-high ceiling. The following environmental variables were measured: air temperature (T_A), wind speed (U), relative humidity (R_H) and partial vapor pressure ($P_P\{t_A\}$). The physiological variables measured: rectal temperature (T_R) and respiratory rate (R_R). Statistical analysis was performed based on regression using PROC REG procedure in SAS. The latent respiratory heat loss showed a linear and positive correlation with ambient temperature. However, the respiratory convection showed a linear and negative correlation, but with incipient values. Therefore, the latent heat loss is more important than the sensible one in the respiratory system to maintain thermoregulation of Morada Nova sheep in a semi-arid region of Brazil.

Keywords respiratory convection, respiratory evaporation, small ruminants, thermoregulation

Resumo Este estudo teve como objetivo avaliar a perda de calor respiratório em ovinos através de equações desenvolvidas para a espécie e suas relações com as variáveis meteorológicas em região semiárida. A perda de calor respiratório (sensível e latente) foi estimada através de equações encontradas na literatura para quatro ovinos da raça Morada Nova com 12 meses de idade, mantidos em uma instalação com sombreamento fornecido por telhas cerâmicas e pé-direito igual a 3 metros de altura. As seguintes variáveis ambientais foram aferidas: temperatura do ar (T_A), velocidade do vento (U), umidade relativa (U_R) e da pressão parcial de vapor (PP $\{t_A\}$). As variáveis fisiológicas aferidas foram: temperatura retal (T_R) e frequência respiratória (F_R). A análise estatística foi realizada com base em equações de regressão utilizando o pacote PROC REG do SAS. A perda de calor latente respiratório apresentou uma relação linear e positiva com a temperatura ambiente. No entanto, a convecção respiratória apresentou uma relação linear e negativa, mas com os valores baixos. Assim, a perda de calor latente é mais importante do que a sensível no sistema respiratório para manter a termorregulação de ovinos Morada Nova na região semiárida do Brasil.

Palavras-chave convecção respiratória, evaporação respiratória, pequenos ruminantes, termorregulação

Introduction

The studies related to the sensible and latent heat loss in the respiratory system of production animals are still incipient. Currently, there are few approaches, and it can be highlighted the studies of Da Silva et al (2003) and Maia et al (2005) in sheep and cows, respectively. The opposite occurs for latent heat loss in the respiratory system, which, besides the aforementioned species, Da Silva et al (2012) also work with dairy cows in semi-arid environments.

However, most of these studies were conducted in environmentally controlled chambers, due to the difficulty of quantifying the respiratory volume current and saturation

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pressure of the breath of the animals in natural environment where face masks are needed to measure the respiration. A viable alternative for these indirect measures was proposed by Da Silva et al (2003), in the case of sheep and Maia et al (2005) for Holstein cows. There is nothing in the literature regarding these mechanisms of heat transfer on the management of animals in semi-arid regions. And this is important information to describe the thermoregulation of small ruminants. The present study aimed to evaluate the respiratory heat loss in Morada Nova sheep from the equations developed for this species and its relations with meteorological variables in semi-arid regions.

Materials and Methods

Location and animal management

The study was conducted in the small ruminants sector of the Universidade Federal Rural do Semi-Árido, located in Mossoró, RN, Brazil (latitude 05°11'S, longitude 37°22'W and 16 m above sea level). Four 12-month-old male Morada Nova sheeps were housed in an installation with shading of ceramic tiles and 3-meter-high ceiling and were fed Tifton hay. The measurements were performed at intervals of 30 minutes, from 6 am to 2 pm.

Physiological and environmental analisys

Relative humidity (R_H, %) and air temperature (T_A, °C) were measured using a digital thermohygrometer (Instrutherm, HT-300, São Paulo, Brazil). The wind speed (U, m s^{-1}) was measured with a hot wire anemometer (Lutron, YK-2005AH, Kolkata, India). The mean radiant temperature (M_{RT}, K) was estimated from the following data: air temperature, wind speed and black globe temperature (0.15 m diameter copper black globe), which was measured with a thermocouple sensor (Type K) connected to a digital thermometer (Minipa, MT-600, São Paulo, Brazil). The MRT was used to calculate the radiant heat load ($R_{HL}=\sigma M_{RT}^4$, W m-2) and was estimated using the equation proposed by Da Silva et al. (2010).

The respiratory rate (R_R, breaths.min^{-1}) was determined by observing the movements of the flank of the animals and the rectal temperature (R_T, °C) was measured with a thermo-sensor (PT-100) inserted approximately 10 cm in the animal and connected to a digital thermometer (Salvi, SALVTERMOMETRO 200, São Paulo, Brazil).

Heat and mass transfer

Respiratory sensible and latent heat losses were estimated using the equations proposed by Da Silva et al (2002) for sheep in a tropical environment. Respiratory evaporation (ER, W m-2) was estimated by the equation:

$$E_R = \frac{\lambda m \rho^{-1}(\Psi_{EXP} - \Psi_A)}{A}$$

where λ is the latent heat of vaporization of water (g J^{-1}), ρ is the air density at the temperature of expired air (g m^{-3}), A is the body surface area (m) estimated from the weight (w, kg), where $A=0.094\ w^{2/3}$ (Bennett 1973), while Ψ_A (g m^{-3}) and Ψ_{EXP} (g m^{-3}) are the absolute humidity of the atmosphere and expired air, respectively, are estimated:

$$\Psi_A = \frac{2166{,}87 P_P\{t_A\}}{T_A}$$

$$\Psi_{EXP} = \frac{2166{,}87 P_P\{t_{EXP}\}}{T_{EXP}}$$

where $P_P\{t_A\}$ is the partial vapor pressure of the air (kPa), which was measured with an analyzer CO2/H2O (Li-Cor, LI-7000, Lincoln, NE). $P_P\{t_{EXP}\}$ is the partial vapor pressure of the expired air (kPa) and the expired air temperature (TEXP, °C) was determined by the equation:

$$P_P\{T_{EXP}\} = 0{,}61078 \times 10^{7{,}5 t_{EXP}/(t_{EXP}+237{,}5)}$$

where T_{EXP} is the expired air temperature (K) estimated according to Da Silva et al (2002):

$$T_{EXP} = -142{,}6193 + 0{,}291T_A + 2{,}5865P_P\{t_A\} + 7{,}3525T_R - 0{,}0016T_A^2 - 0{,}2027P_P\{t_A\}^2 - 0{,}0797T_R^2$$

while m is the mass flow rate (kg s-1) given by:

$$m = \frac{V_{RC} F_R \rho}{60}$$

where R_{MV} is the respiratory minute volume (m^3 $resp.^{-1}$) obtained according to Silva et al (2002):

$$R_{MV} = 0{,}0496 F_R^{-1{,}1557}$$

Convection respiratory (C_R, W m^{-2}) was estimated using the same variables for the estimated respiratory evaporation and it is given by the equation:

$$C_R = \frac{m C_p (T_{EXP} - T_A)}{A}$$

where C_P is where the specific heat of air (J g^{-1} $°C^{-1}$).

Statistical analysis

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Statistical analysis was performed based on regression using PROC REG procedure in SAS (SAS 1999).

Results and Discussion

The means and their standard errors, including maximum and minimum values, of the environmental variables that were observed during the study are presented in Table 1. The T_A had a mean of 31.10 °C. The relative humidity was high during the study, with a minimum of 50.0 %. The R_{HL} values ranged from 481.39 to 515.21 W.m^{-2}. Wind speed (U) was elevated (2.2 m.s^{-1}), with maximum 5.2 m s^{-1}.

Table 1 Means and standard errors, including maximum and minimum values, of the meteorological variables observed during the study.

Environmental variable	Mean	Minimum	Maximum
TA (°C)	31.10±0.31	26.40	35.20
UR (%)	63.42±1.09	50.00	81.3
U (m s^{-1})	2.22±0.18	0.10	5.2
R_{HL} (W.m^{-2})	515.21±2.35	481.39	553.12

The low values of C_R may be disregarded in the contribution of thermoregulation of these animals in semi-arid environment (Figure 1). Thus, it can be ignored in models of thermal balance without loss, due to its insignificant contribution to heat transfer from the animal to the environment. Similar results were found by Maia et al (2005) studying Holstein cows and Da Silva et al (2003) in sheep. The heat loss by respiratory convection is primarily used to maintain the temperature of the brain. This is performed between the venous blood which is cooled by the airway with the carotid to irrigate the brain with blood at temperature lower than that of the rest of the body. This process is called counter-current (Jessen and Pongratz 1979). However, this was not observed in this study.

The latent heat loss, which is important at high temperatures, does not depend on the temperature gradient between the environment and animals. It showed values higher than the sensible heat loss. When the T_A was 26.0 °C the E_R contribution to heat loss was about 10.0 W.m^{-2} (Figure 2), but when it reached a value TA 36.0 °C, the latent heat loss in the respiratory system was about 40.0 W.m^{-2}. These results show that based on the models proposed by Da Silva et al (2002) applied to data of sheep in semi-arid regions, each 1.0 °C rise in temperature of the atmosphere represents an increase of 4.0 W m^{-2} in the loss of latent heat in the respiratory system of these animals. Similar results were observed by Maia et al (2005) studying Holstein cows in a subtropical climate and Da Silva et al (2012) who studied dairy cows in semi-arid environment.

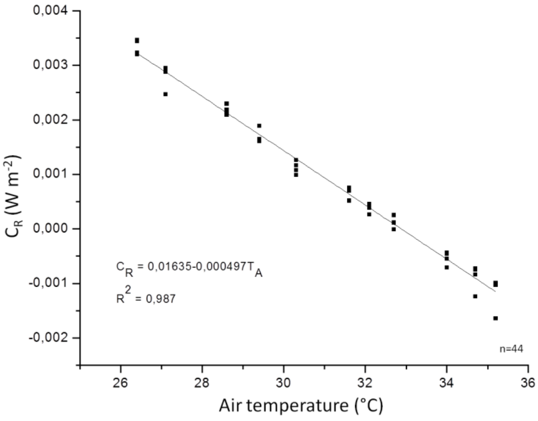

Figure 1 Relationship between heat transfer by respiratory convection in sheep and air temperature in the semi-arid environment.

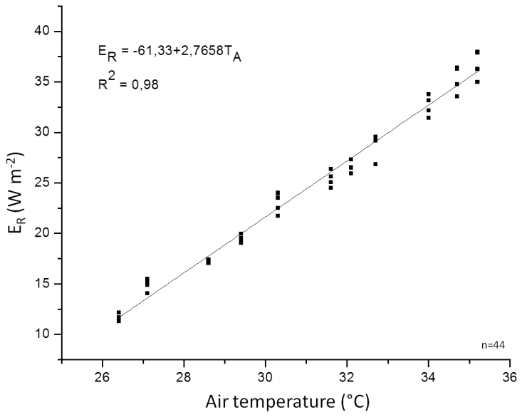

Figure 2 Relationship between heat loss by respiratory evaporation in sheep and air temperature in the semi-arid environment.

Conclusions

The respiratory convection can be regarded as invalid in the heat transfer of the studied animals to the environment. The latent heat loss in the respiratory system plays a fundamental role in the thermal equilibrium of sheep in semi-arid environment.

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