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Cutaneous evaporative thermolysis and hair coat surface temperature of calves evaluated with the aid of a gas analyzer and infrared thermography

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ABSTRACT

The aim of this study was to assess the cutaneous evaporative thermolysis (CET) of different body regions of calves and its relationship to microclimate and coat surface temperature with the use of a gas analyzer and infrared thermography. Our study addresses two questions: (1) Is CET related to surface temperature and/or ambient temperature? (2) Is CET distributed heterogeneously over the body surface, as observed in adult animals? For the purposes of this study, we used twenty-three confined, crossbred calves (Holstein × Zebu). The microclimate was evaluated for air temperature, relative humidity, wind speed, and black globe temperature. Air temperature was analyzed as temperature classes (< 25 °C, 25–29 °C, and > 29 °C). CET was determined using a ventilated capsule coupled to a CO_2/H_2O analyzer. Hair coat surface temperature was measured using infrared thermography. We chose the same body regions that were analyzed for CET. Body surface temperature did not differ between the flank and hindquarters, but both these areas differed from the neck, which had the highest mean temperature. CET did not differ between body regions. No statistical difference was found for mean CET between TA classes < 25 °C and 25–29 °C. However, there was a significant increase in CET when the air temperature was > 29 °C. Under conditions of high temperature and shading, CET is positively related to environmental temperature and is homogeneously distributed over the body surface of calves.

1. Introduction

Significant changes in the annual distribution and volume of precipitation, as well as higher ambient temperatures, have shown that climatic changes have occurred in recent decades (Giannini et al., 2017). Climate change could cause a rise in the planet's mean surface temperature of between 0.4 °C and 2.6 °C by mid-century, relative to 1986–2005 (IPCC, 2014). In the future, breeding of production animals in extensive and semi-extensive systems may be negatively affected by direct exposure to abiotic factors such as solar radiation, temperature, humidity, and wind.

Understanding the mechanisms by which excess body heat gained from the environment is dissipated is essential. Knowledge of these mechanisms could advance the creation and implementation of new management techniques with the objective of minimizing productive losses (Araujo et al., 2017; Santana et al., 2017; Torres et al., 2017).

It is well known that the entire body surface of an animal is involved in the thermal exchanges with the environment by evaporative and non-evaporative pathway. Small animals such as calves have a greater ability to thermal exchange than adult cattle because of its larger body surface area in relation to their body volume. The body surface area of cattle has been estimated as a function of body mass by predictive equations, from newborn calves to adult animals (Brody, 1945; Johnson et al., 1961).

In this context, cutaneous evaporative thermolysis (CET) plays a key role in the adaptation of cattle thermoregulation to high temperature environments (Berman, 1957). This heat loss pathway is related to environmental factors, as well as some physiological responses of animals to environmental stimuli. The sweating rate has been reported to be higher in *Bos indicus* and its crossbreds than in *Bos taurus* (Amakiri

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and Onwuka, 1980; Blackshaw and Blackshaw, 1994; Jian et al., 2015). The apocrine sweat glands of cattle (Collier et al., 2008) have the same perimeter between *B. indicus* and *B. taurus* (Carvalho et al., 1995). However, *B. indicus* glands are more baggy-shaped and more active (Jian et al., 2014). Zebu breeds also have a higher density, size and volume of sweat glands than in European breeds (Dowling, 1955; Nay and Heyman, 1956; Jian et al., 2014).

In tropical environments, solar radiation is responsible for raising the coat surface temperature (CST) and increasing CET in cattle (Hillman et al., 1998). Shading minimizes overheating by blocking direct solar radiation, but does not abolish the effects of radiant heat load over livestock (West, 2003). Some studies have found a strong relationship between CET and CST of adult cattle (Finch, 1985; Gebremedhin et al., 1981; Maia et al., 2005a) and calves (Taneja, 1958). These authors suggest that CST may be a physiological trigger of high CET rates. However, CET may not be homogeneously distributed over the body surface (de Melo Costa et al., 2014; Scharf et al., 2008; Silva et al., 2013); the same has been observed with CST (Hoffmann et al., 2013).

Thus, the aim of this study was to assess the CET of different body regions of calves and its relationship to microclimate and CST with the use of a gas analyzer and infrared thermography.

2. Material and methods

2.1. Study location

The study was carried out in Mossoró, northeast Brazil (05°11′S, 37°22′W, 18 m altitude) at the Dairy Cattle Sector of the Universidade Federal Rural do Semi-Árido. This study was approved by the Ethics Committee on Animal Use (Protocol number 23091.002083/2011-66) of the Universidade Federal Rural do Semi-Árido.

2.2. Animals and data collection protocol

Twenty-three crossbred calves (3/4 Holstein and 1/4 Zebu), with predominantly black hair coats, were evaluated when they were between 30 and 90 days old. The animals were confined in pens measuring 3.00 × 3.90 m, with concrete floors, ceramic roofs, 0.90 m high short walls and 2.50 m high ceilings. The calves were fed twice a day with Tifton 85 hay (94.64% dry matter, 7.85% mineral matter, 7.33% crude protein, 1.77% ethereal extract, 75.01% neutral detergent fiber, and 36.78% acid detergent fiber) and commercial ration (94.78% dry matter, 9.86% mineral matter, 18.98% crude protein, 5.62% ethereal extract, 36.78% neutral detergent fiber, and 6.00% acid detergent fiber). Water was freely available. Data (animal and environmental) were collected during eight days, between 0700 and 1800 h, with a one-hour interval between data collections. Three calves were evaluated per day, and on the last day only two calves were evaluated, totaling twenty-three animals.

2.3. Microclimate evaluation

The measured environmental variables were air temperature (TA; °C), relative humidity (RH; %), wind speed (U; m s^{-1}) and black globe temperature (TG; °C). To measure TA and RH, a digital thermo-hygrometer (Model HT-300, Instrutherm, Sao Paulo, Brazil) was used; to measure U, a precision anemometer was used (Model YK-2005AH, Lutron, Kolkata, India). Black globe temperature was measured using a thermosensor (Type K, Salcas, Sao Paulo, Brazil), which was connected to a digital thermometer (Model MT-600, Minipa, Sao Paulo, Brazil) and inserted in the center of a black globe (a hollow copper sphere with 0.15 m diameter) that was placed in the center of the pen, 0.5 m above the floor. The mean radiant temperature (MRT; °C) was estimated according to the equation proposed by Silva et al. (2010).

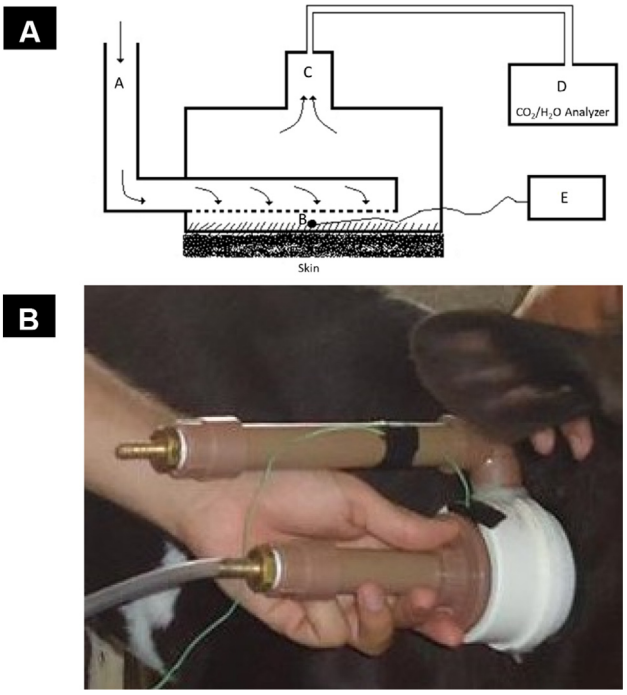

Fig. 1. Design of the system for cutaneous evaporative thermolysis mensuration (A), adapted from Maia et al. (2005a,b), and ventilated capsule used manually on the body surface of calves (B). In Fig. 1A: A is the air intake tube, B is a thermocouple sensor (type K), C is the air outlet tube, D is a CO_2/H_2O analyzer and E is a digital thermometer (Minipa, MT-600, São Paulo, Brazil).

2.4. Cutaneous evaporative thermolysis

A 7 cm diameter ventilated capsule (Fig. 1B) coupled to a CO_2/H_2O analyzer (Model Li-7000, LI-COR, Nebraska, USA) was used to determine the CET (W m^{-2}) of the calves, as proposed by Maia et al. (2005a,b). This analyzer was connected to a computer which provided measurements of atmospheric pressure (P_{ATM}; kPa), partial vapor pressure (P_{AIR}; kPa) and partial vapor pressure inside the capsule (P_{CAP}; kPa) (Fig. 1A). To standardize the estimates of water loss through the skin, the airflow of the ventilated capsule was kept constant at 1.88 L min^{-1}, making the BST inside and outside the capsule equal (Maia et al., 2005b). Three distinct body regions (hindquarters, flank, and neck) were evaluated. The values for CET were obtained through the equation

$$CET = A^{-1}\lambda\Phi(\Psi_S - \Psi_A)$$

where *A* represents the cutaneous surface area under the capsule (m^2), λ is the latent heat of water vaporization (J g^{-1}), Φ is the rate of air flow through the capsule (m^3 s^{-1}), and Ψ_S and Ψ_A are the absolute air humidity at the outlet of the capsule and in the atmosphere respectively (g m^{-3}) (Maia et al., 2005a).

2.5. Hair coat surface temperature

Thermal images (Fig. 2) were taken by an infrared thermocamera (Model ThermaCAM b60, FLIR® Systems Inc., Massachusetts, USA; resolution 0.01 °C with 2% accuracy), which was calibrated at atmospheric temperature and emissivity of biological tissues ε = 0.98. FLIR QuickReport 1.2 software (FLIR® Systems Inc.) was used to analyze the infrared images. We used the same body regions that were analyzed for CET.

2.6. Data analysis

Descriptive statistics for the environmental variables were obtained