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Mapping the body surface temperature of cattle by infrared thermography

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ABSTRACT

Infrared thermography (IRT) is an alternative non-invasive method that has been studied as a tool for identifying many physiological and pathological processes related to changes in body temperature. The objective of the present study was to evaluate the body surface temperature of Jersey dairy cattle in a thermoneutral environment in order to contribute to the determination of a body surface temperature pattern for animals of this breed in a situation of thermal comfort. Twenty-four Jersey heifers were used over a period of 35 days at APTA Brazil. Measurements were performed on all animals, starting with the physiological parameters. Body surface temperature was measured by IRT collecting images in different body regions: left and right eye area, right and left eye, caudal left foreleg, cranial left foreleg, right and left flank, and forehead. High correlations were observed between temperature and humidity index (THI) and right flank, left flank and forehead temperatures (0.85, 0.81, and 0.81, respectively). The IRT variables that exhibited the five highest correlation coefficients in principal component 1 were, in decreasing order: forehead (0.90), right flank (0.87), left flank (0.84), marker 1 caudal left foreleg (0.83), marker 2 caudal left foreleg (0.74). The THI showed a high correlation coefficient (0.88) and moderate to low correlations were observed for the physiological variables rectal temperature (0.43), and respiratory frequency (0.42). The thermal profile obtained indicates a surface temperature pattern for each region studied in a situation of thermal comfort and may contribute to studies investigating body surface temperature. Among the body regions studied, IRT forehead temperature showed the highest association with rectal temperature, and forehead and right and left flank temperatures are strongly associated with THI and may be adopted in future studies on thermoregulation and body heat production.

1. Introduction

Studies in the area of animal sciences have been conducted over the last decade using thermography as a tool to obtain thermal responses in a rapid and noninvasive manner (Phillips and Heath, 2001). Body core temperature can be used as an indicator of stress due to excess heat or cold since its variation among animals is relatively small in a given environment. According to McDowell et al. (1976), an increase in rectal temperature of 1 °C is sufficient to reduce the productive performance of different animal species. Infrared thermography (IRT) has been used successfully to estimate the body surface temperature of different species (Kotrba et al., 2007; Montanholi et al., 2008).

The use of infrared thermography in animal production is innovative, low cost, fast, efficient and provides important information without the need for physical contact with the animals (McManus et al., 2016). Additionally, IRT permits to detect even small changes in temperature with precision (Knízková et al., 2007; Bowers et al., 2009) and has therefore become important in experiments as a safe assessment method.

The skin surface is a highly efficient radiator, a fact that permits to detect infrared emissions of the skin and to map temperature distributions in a noninvasive manner (Purohit et al., 1985). IRT has been adopted in animal production studies for different analyses such as metabolic responses to thermal stress (Paim et al., 2013), the diagnosis of inflammatory processes (Colak et al., 2008; Hovinen et al., 2008) and adequacy of agricultural facilities. Some studies have associated eye temperature measured by IRT with cortisol levels in cattle and pigs as a result of altered blood flow caused in this region as a response to stress conditions (Stewart et al., 2008; Tan et al., 2009).

Montanholi et al. (2008) analyzed temperatures measured by IRT in cattle and observed different temperature patterns depending on the

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body region available. However, the surface temperature limits that indicate low, medium or high stress are not well established in the literature. One of the factors that influence the variation of a body surface temperature is the environmental temperature, which affects skin surface temperature and heat exchange between the organism and environment (Collier et al., 2006).

The objective of the present study was to evaluate the body surface temperature of Jersey dairy cattle in a thermoneutral environment in order to contribute to the determination of a body surface temperature pattern for animals of this breed in a situation of thermal comfort. Additionally, we evaluated the relationship of body surface temperature at different anatomical sites with environmental variables.

2. Materials and methods

2.1. Data source

The study was conducted at the Experimental Farm of APTA Regional Centro Leste-Ribeirão Preto (21°10′41.08″ S and 47°50′45.43″ W) over a period of 35 days.

The protocol of the study was approved by the Ethics Committee on Animal Experimentation (CETEA/IB, No. 135/14).

Twenty-four Jersey heifers (not pregnant and not lactating) with a mean live weight of 194.4 ± 51.07 kg were used. The animals were adapted to the facility and diet for 6 days. Before temperature measurement, the animals were fasted from food and water for 18 h. Fasting was necessary to minimize the effect of an increase in body temperature resulting from feed digestion. Before data collection, the hair coat of the animals was brushed to remove dirt that could interfere with the images.

2.2. Sample collection and chemical analysis

Data collection was started at 6 a.m. and the animals were fed immediately after the measurements. This procedure was repeated five times at intervals of 7 days between samplings to prevent harm to the animals, as shown in Fig. 1.

During the experiment, the heifers remained in the experimental barn for 6 h per day (8:00 a.m. to 2:00 p.m.). The barn was equipped with individual drinkers and feeders and the animals were restrained with halters for feeding. After 2:00 p.m., the heifers were transferred to the outdoor courtyard with cement floor next to the barn, which contained a drinker and trough with mineral salt, and returned again to the experimental barn at 8:00 a.m. of the following day for feeding, except for the days of data collection when they were transferred to the barn at 6:00 a.m. The heifers had free access to corn silage and commercial concentrate (COONAI) at a proportion of 50:50 (Table 1), with an average intake of 7.27 ± 2.19 kg dry matter (DM) per day.

The amounts of feed offered and leftovers of each animal were recorded daily to estimate daily feed intake. During the experiment, diet samples were collected once a week. All samples were stored in paper bags and frozen for the analysis of chemical composition (Table 1).

Table 1
Diets and chemical composition of the experimental diets (%DM).

Ingredients (%)	Experimental diets		
Corn silage		50.00	
Soybean meal		3.75	
Dicalcium phosphate		0.25	
Corn		30.25	
Mineral complex		1.00	
Refinazil		12.5	
Salt		0.75	
Urea		0.50	
Limestone		1.00	
Nutrients (%DM)	**Concentrate**	**Corn silage**	**Experimental diet**
Dry matter (%)	89.61	29.44	59.52
Crude protein	20.50	7.47	13.98
Neutral detergent fiber	30.44	55.65	43.04
Acid detergent fiber	8.54	28.96	18.75
Nitrogen bound to NDF	0.42	0.29	0.36
Non-fibrous carbohydrates	39.48	31.19	35.34
Lignin	1.12	3.86	2.49
Ether extract	3.50	2.52	3.01
Mineral matter	7.87	5.31	6.59
Total digestible nutrients	76.87	65.74	71.31

The bromatological analyses were carried out at the Laboratory of the Department of Animal Sciences, Esalq/USP. The samples were analyzed for DM, mineral matter (MM), ether extract (EE), and crude protein (CP) according to the Association of Official Analytical Chemists (1990). Neutral detergent fiber (NDF), acid detergent fiber (ADF), and lignin were determined according to the method of Van Soest et al. (1991). Nitrogen-bound NDF was analyzed as described by Goering and Van Soest (1970). The content of non-fibrous carbohydrates (NFC) was calculated as proposed by Hall (2001): NFC=100−(%CP+%NDFcp+%EE+%MM). Total digestible nutrients (TDN) were calculated using the formula of Weiss et al. (1992).

Data collection was started at 6:00 a.m. First, the following physiological parameters were obtained: respiratory rate measured as flank movements per minute counted for 15 s; heart rate measured with a stethoscope for 15 s; rectal temperature (RT) measured with a clinical digital thermometer inserted 3 cm into the animal's rectum. These parameters were also used to monitor for possible interferences of stressed or sick animals.

Body surface temperature was measured by IRT in all animals, collecting images in different body regions: left (IRTlea) and right eye area (IRTrea), right (IRTre) and left eye (IRTle), caudal left foreleg (IRTcfg), cranial left foreleg (IRTfl), right (IRTrfl) and left flank (IRTlfl), and forehead (IRTfh). For eye area, the site of highest temperature in this region was chosen. Eye temperature was determined as the mean of three sites within the eye. In the caudal left foreleg, the measurements were made in the foreleg above (marker 1) and below (marker 2) the dewclaw. In the cranial left foreleg, the measurements were made in the palmar side of the distal end of the

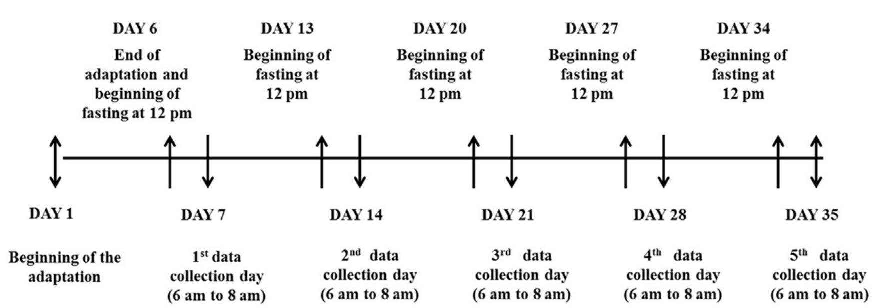

Fig. 1. Scheme of the experimental collections.