

Thermal equilibrium of Nellore cattle in tropical conditions: an investigation of circadian pattern

Cíntia Carol de Melo Costa¹, Alex Sandro Campos Maia¹, Marcos Chiquitelli Neto², Vinicius de França Carvalho Fonsêca¹, Bruno Rodrigo Simão¹, Patric André Castro¹

¹Innovation group of Animal Biometeorology (INOBI); São Paulo State University (Unesp), School of Agricultural and Veterinarian Sciences, Jaboticabal-SP, Brazil. E-mail: cintiacarolmc@yahoo.com.br, alex.maia@fcav.unesp.br, vinicius_fosenca86@hotmail.com, bruno@ufersa.edu.br, patric.castro@ymail.com.br

²Nucleo de Manejo Racional (MANERA); São Paulo State University (Unesp), School of Natural Sciences and Engineering, Ilha Solteira-SP, Brazil. E-mail: machine@bio.feis.unesp.br

Abstract: The aim of this study was to evaluate the circadian pattern of the thermal equilibrium of Nellore cattle in a tropical environment. The study was conducted at the Animal Biometeorology Laboratory of the São Paulo State University, Jaboticabal, Brazil (21.25° S, 601 m altitude) in December of 2016. Six Nellore cattle with similar weight, age and body condition were assigned in two Latin Square experimental design (24 classes of hours (1-2h; 3-4h; ...; 23 - 24h; 24 -1h) during twelve days). Evaluations were performed with subjects protected from direct solar radiation and rain overnight. Respiratory parameters as percentage of oxygen (O₂; %), carbon dioxide (CO₂; %), water vapor pressure ($e\{T_E\}$; kPa) respiratory rate (R_R; breaths min⁻¹) and ventilation (V_E; L s⁻¹) were quantified using an indirect calorimetry system; furthermore, hair coat surface (T_S, °C), skin (T_{EP}, °C) and rectal temperature (T_R, °C) were recorded with thermocouple. Metabolic heat production (q_{met}), sensible heat flow (q_{sens}), heat loss from respiratory tract (q_{er}) and cutaneous evaporation (q_{es}) were calculated. Air temperature (T_A, °C), relative humidity (R_H, %), partial vapor pressure ($e\{T_A\}$, kPa), solar irradiance (G_S, W m⁻²), black globe temperature in shade (T_G, °C), and under direct sunlight (T_{GSUN}, °C) were measured at regular one-minute intervals during each day with a portable weather station. Data were analyzed by the least square method. T_{AR} showed, on average, 9°C of amplitude, with higher value at 13:00 h (30.9 ± 0.2 °C). Average metabolism of 158.43 ± 13.97 W m⁻² was observed, presenting highest value of 174.62 ± 2.63 W m⁻² at 11:00 h, during the morning; thenceforth, it was gradually decreasing, and start to increase one hour after feeding time. The sensible heat flow through the body surface was represented, in highest percentage, by long wave radiation. Interestingly, even with the fall of the T_{AR} at night, we observed lower values for q_{rad}. q_{es} was more expressive during the warmer temperatures. The q_{er} seems to be a mechanism of minor significance for the thermal of Nellore cattle. Under tropical condition, from 21 to 30 °C thermoregulatory responses of Nellore cattle remain stable over the 24 hours when protected from direct solar radiation and rain overnight, which seems to be a good indicative of lower energetics costs for homoeothermic maintenance.

Keywords: beef cattle, indirect calorimetry, thermal balance

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Introduction

Nellore cattle is a breed adapted to tropical conditions (Hansen, 2004) having great representation in Brazilian livestock, which corresponded to about 80% of total beef cattle (IBGE, 2006). Low metabolism, hair coat and skin properties explain much of the thermotolerance of zebu cattle when compared with *Bos taurus* breeds raised in warm climates (Finch et al., 1984; Finch, 1985); however, little is investigated about the mechanisms of the heat and mass transfer in Nellore cattle. Preliminary studies was performed by de Melo Costa et al. (2017), determining the thermal equilibrium of these animals during diurnal period protected from direct solar radiation. Findings addressed that physiological responses as metabolism, respiratory rate of Nellore animals were stable over the range of air temperature from 24 to 35 °C. Tropical regions are characterized by the high thermal amplitude over the day, which low temperature at night associated with other meteorological variables as wind speed can bring challenges to animals not adapted to cold conditions. There are no reports about the circadian pattern of the thermal balance of Zebu breeds. Thus, we decided to study the thermal equilibrium of Nellore cattle during 24 hour under tropical conditions.

Material and Methods

This experiment was conduct at the Animal Biometeorology Laboratory of the São Paulo State University, Jaboticabal, Brazil (21°08' S, 48°11' W, 583 m altitude) in December 2016. Six adult Nellore cattle with similar weight, age and body condition were assigned in two Latin Square experimental design (24 classes of hours (1-2h; 3-4h; ...; 23 - 24h; 24 -1h) during twelve days). At the end of the trials all animals were evaluated in each time period. The data collection was running in a room where the animals were protected from the direct solar radiation. They were fed twice daily, with forage (corn silage) and concentrate (corn, soybean and urea), at a ratio of 70:30, and water, that was provide ad libitum. Daily feed consumption was approximately 2.5% of body weight.

Air temperature (T_A , °C), relative humidity (R_H , %), partial vapor pressure (P_V , kPa), local solar irradiance (G_s , $W\ m^{-2}$; 0.300 to 3.6 μm), black globe temperature in shade (T_G , °C), and under direct sunlight (T_{GSUN} , °C) were measured at regular one-minute intervals during each trial day with a portable weather station (Model 110 - Nova Lynx). The black globe temperature were measured with a thermocouple (Type K) inserted into the center of a hollow 0.15 m diameter copper sphere, matt-black painted, placed 50 cm above the ground. Furthermore, mean radiant temperature (T_{RM} , K) in the shade and under sun was obtain according to Silva et al. (2000). Respiratory parameters as percentage of oxygen (O_2 ; %), carbon dioxide (CO_2 ; %), water vapor pressure ($e\{T_E\}$), respiratory rate (R_R ; breaths min^{-1}) and ventilation (V_E , $L\ s^{-1}$) were quantified from a system of indirect calorimetry using a facial mask developed by Innovation group of Animal Biometeorology (INO BIO); furthermore, hair coat surface (T_S , °C), skin (T_{EP} , °C), and rectal temperature (T_R , °C) were recorded with a thermocouple. Metabolic heat production, sensible heat flow (long wave radiation and surface convection), heat loss from respiratory tract and cutaneous evaporation were determined as described in de Melo Costa et al. (2017).

Data were analyzed by the least-squares method for data composition, frequency distribution, descriptive statistics and analyses of variance. Pearson correlations were tested. The mathematical model used to describe this study was:

$$Y_{ijklmn} = \mu + D_i + A_j + Q_k + H_l(Q_k) + e_{ijklmn}$$

Y_{ijklmn} is a n^{th} observation of variables; D is the random effect of i^{th} day; A is the random effect of j^{th} animal ($j = 1, \dots, 6$); Q is the fixed effect of k^{th} latin square ($Q = 1$ and 2); H is the fixed effect of l^{th} hour ($1, \dots, 24$) withing k^{th} latin square; μ is the overall mean and $e_{ijklmno}$ is the residual term, including the random error. The statistical package used for all analyses was SAS (SAS Institute 1995).

Results and Discussion

Meteorological variables over the 24 hours can be observed in Figure 1. Air temperature (T_{AR}) presented mean of 9°C of amplitude, with higher value (30.9 ± 0.2 °C) at 13:00 h; conversely, at this time, relative humidity showed lowest values ($55.1 \pm 0.9\%$). Wind speed (U) increased from 07:00 h, reaching $1.5\ m\ s^{-1}$ at

11:00 h. At night, it was observed below 0.5 m s^{-1} . Short wave of solar radiation (0.300 to $3.6 \mu\text{m}$) reached $749.6 \pm 22.9 \text{ W m}^{-2}$ at 14:00 h.

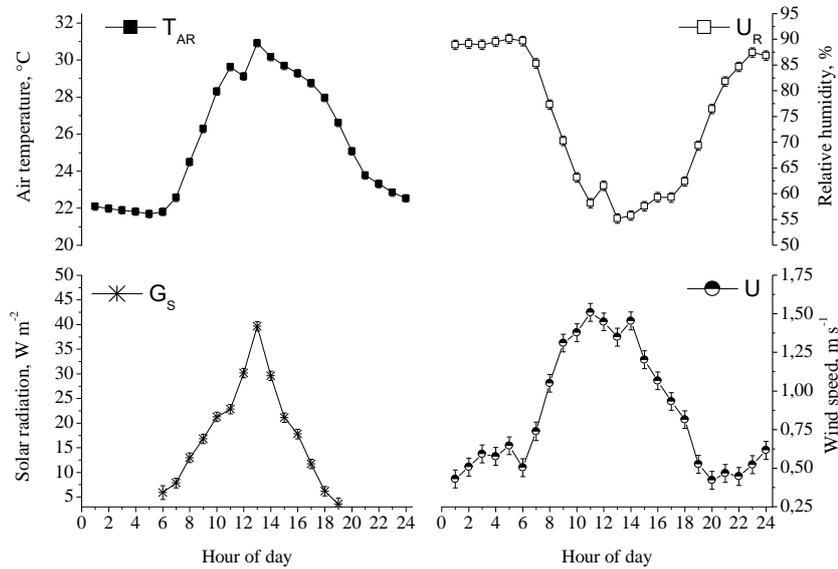


Figure 1: Least square mean (\pm SEM) of air temperature (T_{AR}), relative humidity (U_R), wind speed (U) and solar radiation (G_S) over the 24 hours.

Thermal energy content of animal body was estimated by rectal temperature (T_R), which presented lowest ($39 \pm 0.2^\circ\text{C}$) and highest ($39.5 \pm 0.4^\circ\text{C}$) value at 6:00 h and 19:00, respectively (Figure 2); T_S , T_{EP} and T_{EXP} had a similar pattern of T_{AR} (Figure 2). T_S and T_{EP} , interchanged during all day, showing minimal differences between them. The low insulation of hair coat (layer thickness $< 3 \text{ mm}$) that covers the Nellore skin favors heat transfer through this interface; According to Silva et al. (2003) Nellore cattle has a shorter haircoat, thicker, more numerous fur per unit area and very well settled against skin, besides a bright surface; this trait is one of the genetic characteristic that explain superior thermotolerance of Zebu cattle in warm climates (Hansen, 2004).

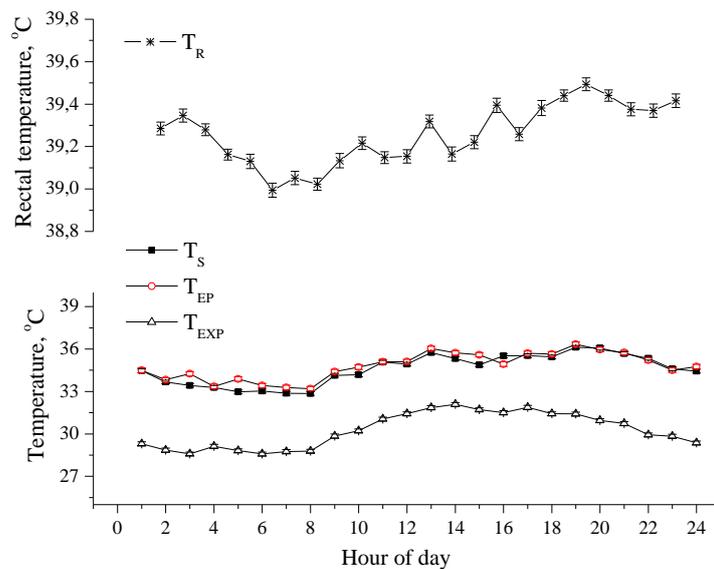


Figure 2: Least square means (\pm SEM) of rectal temperature (T_R), coat surface (T_S), skin (T_{EP}) and expired air (T_{EXP}) during 24 hour.

Average metabolic heat production of $158.43 \pm 13.97 \text{ W m}^{-2}$ was observed; highest ($174.62 \pm 2.63 \text{ W m}^{-2}$) value occurred at 11:00 h during the morning; thenceforth, it was gradually decreasing, and start to increase one hour after feeding time (Figure 3). From 12:00 to 16:00 and 00:00 to 06:00, minimal values were noted. According to our results, values presented for metabolism of Nellore cattle were lower than Jersey ($\mu = 180 \text{ W m}^{-2}$) and Holstein ($\mu = 185 \text{ W m}^{-2}$) cows bred in tropical environment (Unpublished data), especially if we compare the specific metabolic rate (W.kg^{-1}), being the main aspect discussed about thermotolerance of Zebu in tropical environments. Previous investigation has been confirmed the lower metabolism of *Bos indicus* in comparison with European breeds (Singh and Bhattacharyya, 1985; Reid et al., 1991) In no time over the 24 hours, sensible heat ways (Long wave radiation and convection) was not sufficient to dissipate heat generate by metabolism. For example, from 10:00 to 14:00, heat transfer by long wave radiation and surface convection corresponded to less than 40% of metabolism. At this time, the rest of heat was dissipated by cutaneous evaporation and, in a minor percentage, from respiratory tract. On average, the q_{er} was $2.86 \pm 0.82 \text{ W m}^{-2}$, corresponding to 1.8% of the heat generated by the metabolism. According to Hansen (2004) and de Melo Costa et al. (2017) this occurrence can be indicative of superior thermoability of bovine breeds adapted to tropical environment. It is interestingly to point out the stability of the sweating pattern over the 24 hours; even at night, cutaneous evaporation accounted approximately 36 % of the metabolism. This could be explained by a type of “continuous discharge of sweat” with low intensity (Johnson, 1975), which should represent lower energetic cost. Skin temperature is the primary driving force for sweating (Silva and Maia, 2011; Gebremedhin et al., 2008); in the present study, there was a small variation of T_{skin} over the day ($32 - 35 \text{ }^\circ\text{C}$), possibly, maintaining sweating activity relatively stable. The lower thermal resistance of the tissue of *Bos indicus* breeds (Finch, 1985) should play a large role in maintaining heat flow constant from the body core to the skin. This can be an advantage at times of high thermal load, but a problem in low temperatures, especially under open field when associated with wind and precipitation.

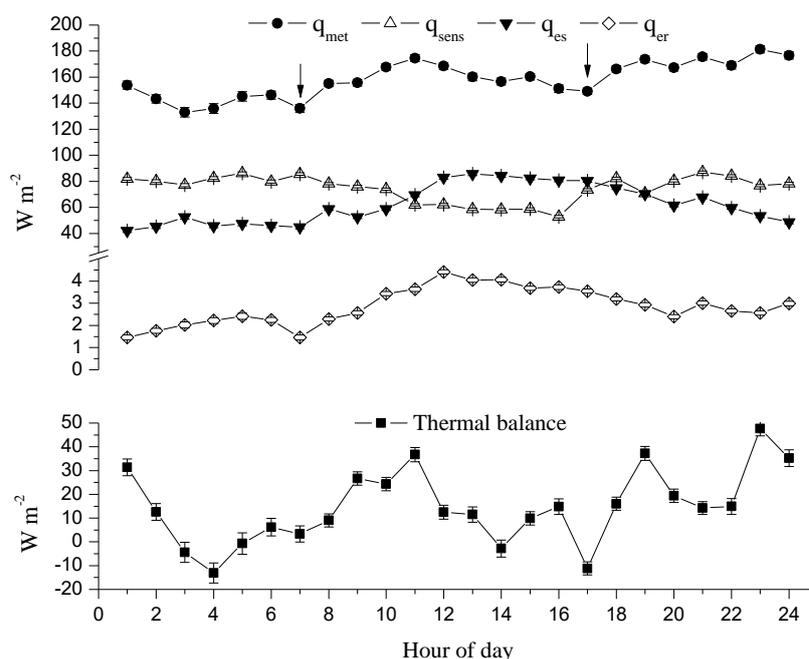


Figure 3: Least square means (\pm SEM) of metabolic heat production (q_{met}), heat loss by cutaneous evaporation (q_{es}), heat loss by respiratory tract (q_{er}), sensible heat flux (q_{sens}) and the thermal balance of Nellore cattle. The arrows show the feed time.

Conclusions

Under tropical condition, from 21 to 30 $^\circ\text{C}$, thermoregulatory responses of Nellore cattle remain stable over the 24 hours when protected from direct solar radiation and rain overnight, which seems to be a good indicative of lower energetics costs for homeothermic maintenance.

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