

Thermal equilibrium and methane emission of Jersey dairy cows

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Abstract: Meteorological variables have direct influences over physiological, behavioural and performance of animals. The Jersey breed shows a good potential to be managed under tropical environment conditions due to their genetic, adaptive and productive characteristics. To confirm this potential, studies on the thermal equilibrium of these animals must be coupled to methane emission. The aim of the present work was to study the thermal equilibrium of Jersey cows under tropical conditions. Twelve Jersey cows with 326.28 ± 30 kg body weight, 17.66 ± 1.8 milk yield, and $165.5 \pm$ days in milking were assigned in two latin square (LS) designs, fed twice daily under a total mixed ration of corn silage (70%) and grain (30% corn and soybean). Evaluations were performed from 08:00 to 20:00 (LS1) and from 20:00 to 08:00 h (LS2), protected from solar radiation and rain overnight. Meteorological variables (air temperature and relative humidity, short-wave radiation) and body temperatures of the cows (rectal, skin, surface and exhaled air) were recorded. Ventilation rate, respiratory rate, percentage of oxygen carbon dioxide, and methane from the exhaled air were measured by an indirect calorimetry system, using a facial mask. From these data, metabolic heat production, respiratory evaporation, sensible heat loss and methane emission were calculated. Data were analysed by the least squares method. Ambient air temperature and relative humidity ranged from 22 to 31 °C and 27 to 88 %, while short-wave radiation was higher than 600 W m^{-2} during the hottest hours of the day. The cows presented increase of body temperatures during the hottest hours of the day, correlated to a decrease of sensible heat flow and higher respiratory evaporation. The metabolic heat production was stable and higher than 200 W m^{-2} during the hottest hours and the methane emission had two apparent rise peaks after feeding times (09:00 and 18:00 h, respectively). From the data obtained, enteric methane emission of confined Jersey dairy cows bred in tropical environment is approximately 184 g per day per cow. These results can be an indicative of the potential of Jersey cows in comparison with other temperate breeds

Keywords: body temperatures, metabolism, methane, Jersey cows.

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Introduction

Meteorological variables have direct influences under physiological, behavioural and performance of animals. In tropical regions one of the main variables influencing thermal balance of animals is short-wave radiation (da Silva et al., 2010). Therefore, studies on the thermoregulation of animals based on the knowledge on the mechanisms of heat and mass exchange are fundamental, mainly related to the variation of physiological variables against diverse environmental conditions. Previously studies applied the use of indirect calorimetry technique to the study of thermal equilibrium of livestock animals under natural tropical environmental conditions, like goats (Maia et al, 2016), poultry (Nascimento et al, 2017) and beef cattle (Costa et al, 2017). Thus, studies about the thermal equilibrium of dairy cows is required, due to the relevance of milk production on Brazil's economy.

Observing the scenario of the Brazilian milk production chain, some breeds show a good potential to be managed in tropical environment conditions due to their genetic, adaptive and productive characteristics, specially the Jersey breed. Jersey cows have a natural protection against ultraviolet radiation by a pigmented epidermis and can have a better adaptation to intense radiation, in comparison with Holstein cows, which only present melanin in body regions covered by black coat, and therefore, any protection in the skin with white coat (da Silva, 2008). To confirm the potential of Jersey cows as an alternative for milk production in the tropics, it is indispensable to study the thermal equilibrium of these animals coupled to methane emission. In the last years, Brazilian government has funded several surveys aiming at estimating the contribution of different livestock production systems to greenhouse gases (GHG) dynamics, especially enteric methane emissions. The purposes of these efforts are obtain reliable baseline emissions data to find potential mitigation options.

Methane emission inventories are based on research and estimates. Therefore, the evaluation of animals under field conditions is essential to make the inventories as complete as possible, linked to the proposal of main actions to reduce the country's emissions. It is important to emphasize the inexpressive number of researches with the purpose of studying the intimate relationship between metabolism, enteric methane and thermal equilibrium. Based on these information, the aim of this work was to study the thermal equilibrium (physiological variables, metabolic heat production and heat loss by sensible and latent flows) of Jersey dairy cows during 24 hours under tropical conditions.

Material and Methods

The study was conducted in the Paulista Agency for Agribusiness Technology (APTA), Ribeirão Preto, Brazil (21°10' S, 47°48' W, 546 m altitude). Twelve Jersey dairy cows with 326.28 ± 30 kg body weight, 17.66 ± 1.8 milk yield, and $165.5 \pm$ days in milking were assigned in two 12 x 12 Latin Square (LS) design (12 cows through 12 hours of the day): LS1 – data were collected from 8:00h to 19:00h; LS2 – data were collected from 20:00h to 7:00h. At the end of the trial all animals were evaluated in each time period. Subjects were fed a total mixed ration of corn silage (70%) and grain (30%) twice daily. Evaluations were performed from 08:00 to 20:00 (LS1) and from 20:00 to 08:00 h (LS2), protected from solar radiation and rain overnight. Air temperature (T_{Air} , °C), relative humidity (RH, %), partial vapor pressure (PV, kPa), black globe temperature in shade (T_G , °C), and under direct sunlight (T_{GSUN} , °C) were measured at regular ten-minute intervals during each trial day with a Data Logger (model HOBO, onset). A portable pyranometer (Model CMP-22, Kipp and Zonen, Delft, Netherlands) was used to measure direct and diffuse short-wave radiation ($W m^{-2}$) on a horizontal surface, in the 200 - 3,600 nm spectral range.

Physiological variables were measured using an indirect calorimetry system coupled to a facial mask adjusted to the animals' muzzles. The volumes ($L s^{-1}$) of oxygen (VO_2), carbon dioxide (VCO_2), water vapor (H_2O) and enteric methane (VCH_4) in the exhaled air of the cattle and in the atmosphere were measured. A spirometer was coupled to the system (ML 141, ADInstruments, Australia), which measured the respiratory rate (R_R , breaths min^{-1}) and ventilation (V_E , $L s^{-1}$). The system and the thermocouples were connected to a data acquisition system (PowerLab 16/32, ADInstruments, Australia), which in turn was connected to a computer that recorded continuously and simultaneously all the measurements at a rate of one observation per second.

The hair coat surface temperature (T_s , °C) was measured with a sensor (MLT 422A, ADInstruments, Australia) placed on the back of the animals just under the hair coat surface. In the same body region, another temperature sensor (MLT 422A ADInstruments, Australia) was used for the skin surface temperature (T_{EP} , °C), but in this case the skin area was previously shaved. These sensors were fixed on the animal's surface with a plastic board, positioned above of the sensors, with the aid of an elastic belt around the animal's upper body. The rectal temperature (T_R , °C) was continuously recorded by a rectal thermocouple (MLT 1404, ADInstruments, Australia). A nasal temperature sensor (MLT 415/AL, ADInstruments, Australia) was placed inside the facial mask, just in front of the animal's nostrils, to measure the exhaled air temperature (T_{EXH} , °C).

To determine thermal balance of the cows, the production of heat (metabolic heat production), the gain and the loss of heat were estimated (by sensible and latent ways). The metabolic heat production (q''_{met} , $W m^{-2}$) and the latent heat loss by respiratory system (q''_{er} , $W m^{-2}$) were calculated as proposed by daSilva and Maia (2013). The sensible heat flow (q_{sen} , $W m^{-2}$) was given by the heat loss by long wave radiation and convection (Q_{RL} and q_{conv} , $W m^{-2}$), respectively.

Data were analyzed by the least-squares method (Harvey 1960) according to Littell and Freund (1991) for data composition, frequency distribution, descriptive statistics and analyses of variance. The mathematical model used to describe study variables was:

$$Y_{ijklm} = \mu + Q_i + C_j + D_k(Q_i) + H_l(Q_i) + e_{ijk}$$

where Y_{ijklm} is the m^{th} observation of the variables; Q is the fixed effect of the i^{th} latin square ($i = 1, 2$); C is the fixed effect of the j^{th} cow ($j=1, \dots, 12$); D is the fixed effect of the k^{th} day within i^{th} latin square ($l=1, \dots, 12$); H is the fixed effect of the l^{th} hour of the day within i^{th} latin square ($l=0, \dots, 23$); e_{ijk} is the residual term, including the random error and μ is the overall mean. The statistical package used for all analyses was SAS (SAS Institute 1995).

Results and Discussion

Meteorological variables showed great amplitudes during the days (Figures 1a and 1b), which is naturally observed in tropical regions (da Silva et al., 2010). Air temperature had an amplitude of almost $10^{\circ}C$ (Figure 1a): it was higher at 15:00h ($31.91^{\circ}C \pm 0.07$) and lower at 4:00h ($22.26^{\circ}C \pm 0.06$); relative humidity was lower than 50% from 9:00h to 18:00h (Figure 1a); short-wave radiation was higher than $600 Wm^{-2}$ between 10:00h and 13:00h (Figure 1b). These data demonstrate how Jersey dairy cows will have to activate physiological mechanisms to maintain their homeostasis under different environmental conditions throughout the 24 hours of the days.

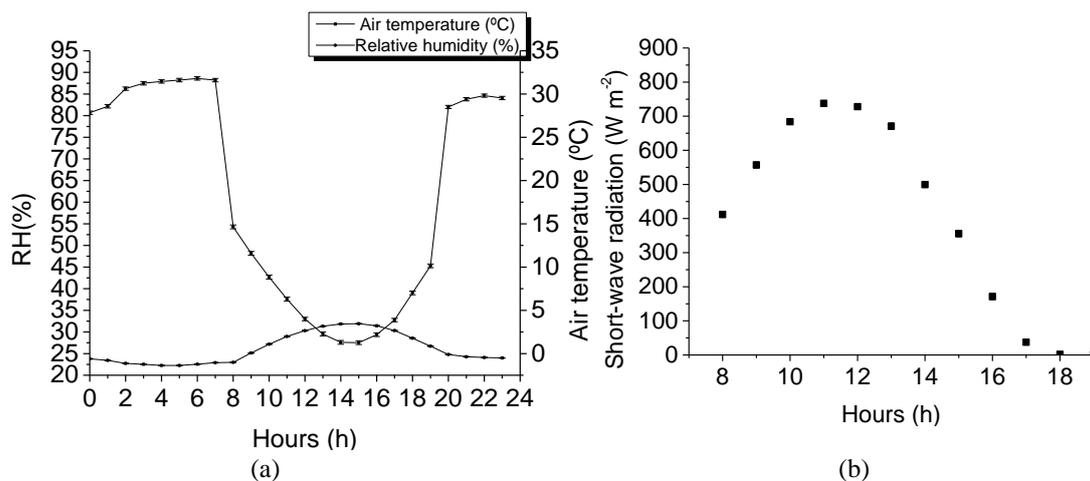


Figure 1 – Meteorological variables during the trial – (a) Air temperature and relative humidity; (b) Short-wave radiation.

Meteorological variables influenced all the measured body temperatures (T_{ep} , T_{exh} , T_s , T_r) of Jersey cows (Figure 2a). The temperatures of skin, exhaled air and body surface were higher between 9:00h and 19:00h, which coincide with the hours of the day with higher air temperature and short-wave radiation and lower relative humidity. However, the rectal temperature of the cows were higher than $39.1^{\circ}C$ from 9:00h to 23:00h, considered the core temperature in the thermoneutral zone (Yousef, 1985). Thus, Jersey dairy cows use the coolest hours of the day (from 20:00h), after the reduction of the solar radiation and the air temperature to seek their thermoregulation again. The increase in rectal temperature is accompanied by the importance of using respiratory evaporation as a mechanism of heat dissipation (Figure 2b), as reported by Aggarwal & Upadhyay (2012). Besides this, sensible heat flow (q_{sen}) has a minor importance to the thermal equilibrium of Jersey cows during the hottest hours of the day (Figure 2b), because it is observed a lower temperature differential between the air and the body surface of the animals.

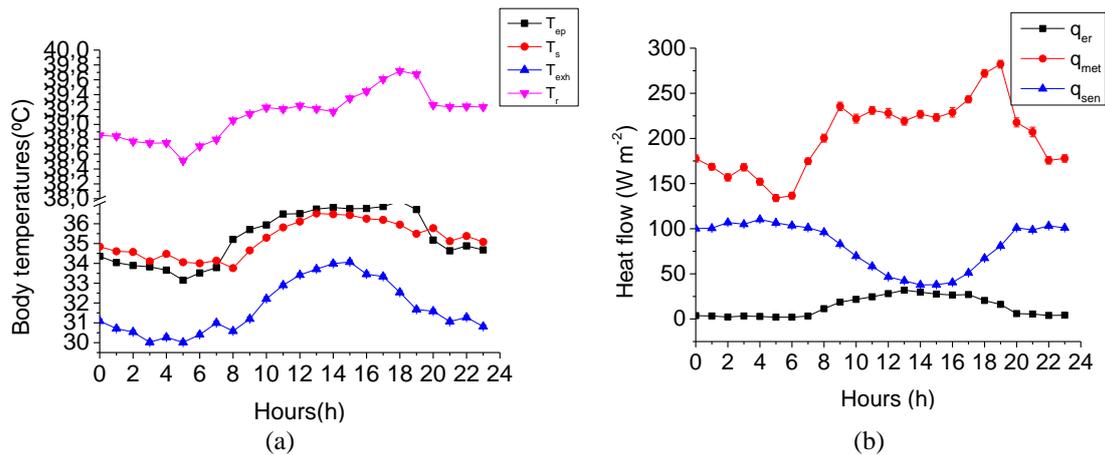


Figure 2 – Physiological variables of Jersey dairy cows under tropical conditions – a) Body temperatures (skin, T_{ep} ; surface, T_s ; exhaled air, T_{exh} ; and rectal, T_r temperatures); b) Respiratory heat loss (q_{er}), metabolic heat production (q_{met}) and sensible heat loss (q_{sen}).

However, metabolic heat production (q_{met}) was lower at 5:00h and higher at 19:00h (Figure 2b), because it has a direct influence of the circadian physiological rhythm of the animals. Also, during the hottest hours of the day (from 9:00h to 21:00h) the cows were able to maintain their metabolic production higher than $200 W m^{-2}$, which is higher to the average reported by Costa et al. (2017) for Nellore cattle and higher than the metabolic heat production by Holstein cows (ranging from 162 to $209 W m^{-2}$) during heat stress (from 21 to 38°C) reported by Kibler and Brody (1956).

Methane emission had two apparent rise peaks (Figure 3), occurring after feeding times (09:00 and 18:00 h); maximum value observed was $12.47 g h^{-1}$. From the data obtained in the present investigation, enteric methane emission of confined Jersey dairy cows bred in tropical environment is approximately $184 g day^{-1} cow^{-1}$. Data reported by a literature review by Boadi et al. (2004) reports an average of $453 g CH_4 day^{-1} cow^{-1}$ for dairy cows. The literature provides evidence that enteric fermentation can vary widely depending on factors such as type of the animal, the amount and type of feed, environment, addition of dietary fat, feed additives and body weight of the animal (Moss et al. 2000), and this indicates other studies about the emission by Jersey cows are necessary, considering mainly diets fed by these animals correlated to tropical conditions.

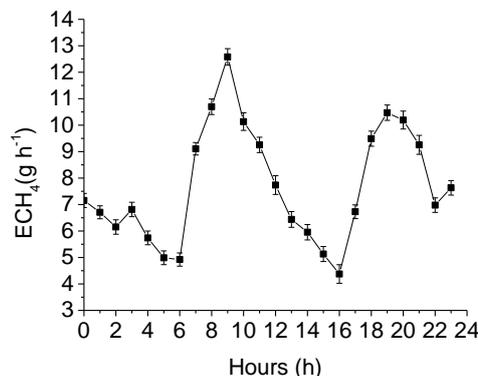


Figure 3 – Enteric methane emission by Jersey dairy cows under tropical conditions.

The respiratory variables of Jersey cows (Ventilation and Respiratory Rate) showed a little variation during the changes of meteorological variables throughout the 24-hours period of the day (figures 4a and 4b). Respiratory rate ranged between 30 and 40 $breaths min^{-1}$, which is lower compared to the data observed by Maia et al. (2005), for Holstein cows in tropical conditions, for temperatures between 22°C and 32°C. Holstein cows increase considerably the respiratory rate, describing the importance of respiratory heat loss under stress conditions to this breed. But the increase, although small, is in accordance to the described by Whittow (2013), where Jersey cows increase RR not only because of the high air temperature and solar radiation, being a reflection of a higher body temperature (rectal and surface).

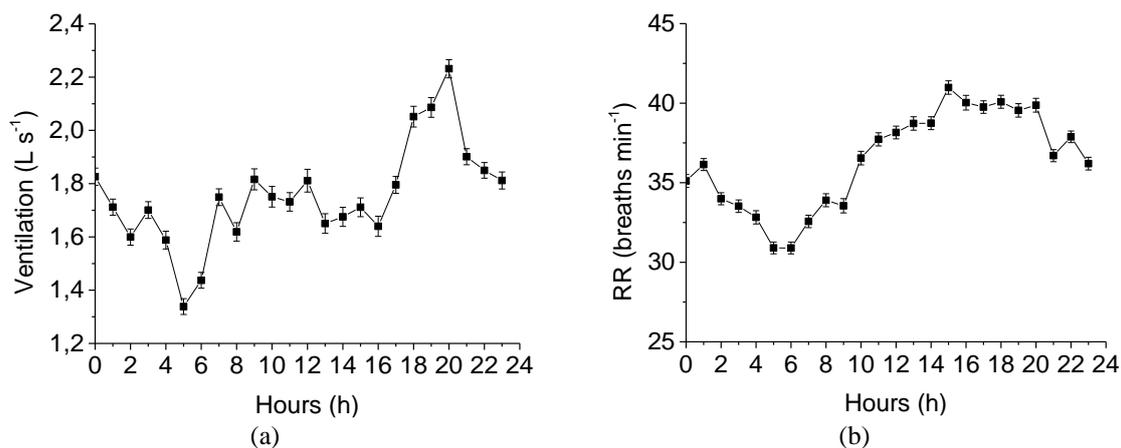


Figure 4 – Respiratory variables of of Jersey dairy cows under tropical conditions – a) Ventilation; b) Respiratory rate.

Conclusions

The Jersey breed shows a high potential to be used and better exploited in tropical environments, since it maintains the metabolic heat production and presents less emission of methane and respiratory evaporation compared to other temperate breeds, such as Holstein cows.

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