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Heat Stress and Body Temperature in Brown Swiss Cows Raised in Semi-Arid Climate of Ceará State, Brazil

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ABSTRACT

***Background*:** In tropical countries like Brazil, air temperature and relative humidity have a significant effect on animal physiology; there is a great impact of solar radiation on physiological parameters, especially on body temperature. This study evaluated the occurrence of heat stress in Brown Swiss cows in a tropical semi-arid climate, and checked for the correlation between internal body temperatures [rectal temperature (RT) and vaginal temperature (VT)] with surface temperature (ST) to determine if these variables are associated.

***Materials, Methods & Results*:** Twenty-eight Brown Swiss cows at three stages of the lactation cycle were used in this study: 10 nonpregant lactating (NPL) cows, 8 dry pregnant (DP) cows, and 10 pregnant lactating (PL) cows. These animals were between the second and third calving, weighed between 346 and 720 kg, and had ages between 2 and 13 years. During the experimental period, air temperature and relative humidity (RH) at the experimental site were measured using a digital thermo-hygrometer. The temperature and humidity index (THI) was calculated according to methodology described by Thom (1958), and was used as an environmental comfort parameter. For the evaluation of RT and VT, two digital clinical thermometers, one inserted in the vagina and the other in the rectum, were used simultaneously to minimize stress. Surface temperature (ST) was assessed using a digital infrared laser thermometer at a distance of 50 cm from the animal. Surface temperature was measured in the forehead (FST), thorax (TST), flank (FLST), and legs (LST). During the study period, the ambient temperature (AT) was significantly higher outside (in the sun) than inside of the facilities (in the shade) ($P < 0.05$). RH was inversely proportional to AT, and was significantly higher inside than outside the facilities ($P < 0.05$). Like AT, THI was significantly higher outside (in the sun) than inside the facilities (in the shade), with significant differences between these locations ($P < 0.05$). The amplitudes of the differences between the locations were as follows: 3.8°C for AT, 6.2% for RH, and 2.6 for THI. Mean values of rectal and vaginal temperatures were not significantly different from each other independent of lactation cycle stage, and were almost always significantly higher than the measured surface temperatures ($P < 0.05$). The maximum values obtained for each lactation cycle stage in this study were higher when compared to the mean values, showing that they are more representative of the occurrence of heat stress. Correlations between internal temperatures (RT and VT) and surface temperatures (TSF, TST, TSFL, and TSP) were weak and non-significant. ST values exhibited mostly weak, non-significant correlations, with the exception of FST with FLST and LST, which had moderate, significant correlations, as shown by the following coefficient factors: FST x FLST, 0.34; LST x FST, 0.415; and LST x FLST, 0.37.

***Discussion*:** A temperature of 34°C with RH ranging from 46% to 80% (i.e., a THI between 83 and 89) has been reported to have a significant thermal impact on dairy Brown Swiss cows; the THI values found in the present experiment were close to those. Body temperatures exhibited significant variations depending on the lactation cycle stage of the cows. Lactation concomitant with pregnancy significantly increases internal temperatures (RT and VT) in DP and NPL cows. This finding may be explained by the fact that pregnancy concomitant with lactation accelerates the metabolism, which results in higher food intake and increased production of body heat with consequent increase in internal body temperature. The maximum values of internal body temperatures (RT and TV) at all stages of the lactation cycle were higher than their corresponding average values, which indicates that some cows exhibited, at given moments, hyperthermia.

Keywords: body temperature, heat stress, environment, ruminant.

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INTRODUCTION

The skin plays a key role in body heat dissipation, since there is a constant exchange of heat between the body and the environment. Body temperature is dependent not only on environmental factors such as temperature and humidity, but also on physiological characteristics such as vascularization and evaporation of sweat [29]. Thus, the external surface of the body constitutes a boundary between the body and the environment, and allows the conduction of heat from the internal medium of the body to the body surface, where it can be transferred to the environment [29].

Strong and significant correlation between vaginal temperature (VT) and rectal temperature (RT) have been found in cows at different reproductive stages as observed in pregnant cows [11], cyclic cows [19], and beef heifers, which indicates that such correlation can be used to evaluate animals with hyperthermia due to a disease or occurrence of heat stress [5].

The body surface temperature is an indicator of heat absorption by the animal during thermogenesis and heat loss during thermolysis, which may influence the internal body temperatures in cows at different reproductive and productive status [20,21]; in this context, it remains unknown whether surface temperature (ST) correlates with VT and RT.

Thus, this study aimed to evaluate the occurrence of heat stress in Brown Swiss cows reared in northeastern Brazil and, also, determine whether internal body temperatures (RT and VT) correlate with ST.

MATERIALS AND METHODS

Location of the experiment

This study was conducted at the Experimental Farm Vale do Curu (FEVC), which belongs to the Federal University of Ceará (UFC), in the municipality of Pentecoste, state of Ceará, Brazil. FEVC is located in an area with semi-arid climate, between 3º45' and 3º50' south latitude and 39º15' and 39º30' west longitude, has an average altitude of 47 m, and an average rainfall of 818 mm. The climate in that area is classified by the Köppen method as BSw'h', semi-arid with irregular rainfall. This study took place during the hottest period of the year (dry period), in the months of September, October, and November 2015.

Animals

Brown Swiss cows (n = 28) at three stages of the lactation cycle were used in this study: 10 nonpregant lactating (NPL) cows, 8 dry pregnant (DP) cows, and 10 pregnant lactating (PL) cows. These animals were between the second and third calvings, weighed between 346 and 720 kg, and had ages between 2 and 13 years.

The cows were maintained in semi-intensive system: in the morning, they were fed natural pasture, which was complemented with concentrated feed after returning from the field; in the afternoon, they were fed elephant grass (*Pennisetum purpureum*) supplemented with concentrated feed based on corn, soybeans, and wheat.

All animals received diets that met their energy requirements for pregnancy and lactation according to the guidelines of the National Research Council (NRC, 2001) for adult animals. The animals were maintained in stalls according to their lactation cycle stage, where they received mineral salt and water *ad libitum*.

Evaluation of environmental variables

During the experimental period, air temperature (AT) and relative humidity (RH) at the experiment site were measured using a digital thermohygrometer[1]. Environmental comfort was estimated using the temperature-humidity index (THI), which was calculated according to methodology described by Thom [31], using the formula THI = 0.8 x T + (RH/100) x (T -14.4) + 46.4, where T = air temperature (°C) and RH = relative humidity (%).

Evaluation of physiological variables

The rectal temperature (RT), vaginal temperature (VT) and surface temperature (ST) of the cows were measured after returning from pasture. The animals were evaluated during the second milking, in the afternoon, at 1:00 p.m., when the ambient temperature (AT) reached its maximum value. DP cows were placed in a squeeze chute to minimize stress. Lactating cows remained in the barn to be milked and, after milking, body temperatures were assessed.

For the assessment of RT and VT, two digital clinical thermometers (TS-101PM)[2], one inserted in the vagina and the other in the rectum, were used simultaneously to minimize the stress caused by internal body temperature measurement. The thermometer was inserted 7 cm into the rectum and vagina.

Surface temperature (ST) was assessed using a digital infrared laser thermometer (DT-8867H)[3] at a distance of 50 cm from the animal. ST was measured on the forehead (FST), thorax (TST), flank (FLST), and legs (LST). Environmental and physiological data were collected at the same time, once a week, from September to November 2015, totaling 10 data collection sessions.

Statistical analysis

Statistical analyses were performed using SYSTAT 13 software (USA). The experiment was conducted with a completely randomized design, and data were tested for normality using the Shapiro-Wilk test. Once the homoscedasticity of the data was verified, the means were compared using the Tukey's test at a significance level of 5%. The correlations between the temperatures were checked using Pearson correlation at a significance level of 5%.

RESULTS

Climatic data and temperature-humidity index (THI) values are shown in Table 1. During the study period, the ambient temperature (AT) was significantly higher outside (in the sun) than inside the facilities (in the shade) [$P < 0.05$], while the relative humidity (RH) was inversely proportional to AT values, and was significantly higher inside than outside the facilities ($P < 0.05$).

Like AT, THI was significantly higher outside (in the sun) than inside the facilities (in the shade), with significant differences between these locations ($P < 0.05$). The amplitudes of the differences between these locations were as follows: 3.8°C for AT, 6.2% for RH, and 2.6 for THI.

Data on body temperatures obtained in this study (Table 2) show that the mean values of internal (RT and VT) and surface (FST, TST, FLTS, and LTS) temperatures of pregnant lactating (PL) cows were higher than those found for nonpregnant lactating (NPL) and dry pregnant (DP) cows, except for the mean surface temperature (Mean ST). Mean ST in PL cows was lower than in DP cows and higher than in NPL cows, with no significant difference between the values ($P < 0.05$).

Mean values of rectal and vaginal temperatures did not differ significantly from each other independent of the lactation cycle stage, and were almost always significantly higher than the measured surface temperatures ($P < 0.05$). Surface temperatures varied little and exhibited no significant statistical difference ($P > 0.05$) between the evaluated body areas (Table 2). The maximum values obtained in this study for each lactation cycle stage were higher than their respective mean values, showing that they are more representative of the occurrence of heat stress. Table 3 presents the results of Pearson correlations between body temperature values. RT and VT exhibited a strong positive correlation ($r = 0.812$; $P < 0.05$). Correlations between internal (RT and VT) and surface temperatures (TSF, TST, TSFL, and TSP) were weak and non-significant. Surface temperature values exhibited mostly weak, non-significant correlations, with the exception of FST with FLST and LST, which had moderate, significant correlations, as demonstrated by the following coefficient factors: FST x FLST, 0.34; LST x FST, 0.415; and LST x FLST, 0.37.

Table 1. Means ± standard errors of climatic parameters: air temperature (AT), relative humidity (RH) and temperature and humidity index (THI) during the hot and dry period, in semi-arid climate in the state of Ceará, Brazil.

Location	Climatic variables		
	AT (°C)	RH (%)	THI
Outside the facility (in the sun)	40.3 ± 0.9^a	25.3 ± 2.1^a	85. ± 0.8^a
Inside the facility (in the shade)	36.5 ± 0.5^b	31.5 ± 1.7^b	82.5 ± 0.5^b
	Df= 3.8	Df= 6.2	Df= 2.6

Different lowercase letters (a, b) indicate significant differences between values inside and outside the facility, ($P < 0.05$). Df = difference between values in the sun and in the shade.

Table 2. Means and standard errors and maximum values of body temperature of Brown Swiss cows at different reproductive and productive status, during the hot and dry period, in semi-arid climate in the state of Ceará, Brazil.

Physiological Status	Body Temperature						
	RT	VT	FST	TST	FLST	LST	Mean ST
NPL	38.9 ± 0.03(A,a)	38.8 ± 0.02(A,a)	35.3 ± 0.08(B,a)	35.5 ± 0.08(B,a)	35.7 ± 0.07(B,a)	35.5 ± 0.08(B,a)	35.5 ± 0.08(B,a)
Max	39.7	39.7	38.7	37.6	38.3	38.1	37.7
PL	39.1 ± 0.05(A,b)	39.0 ± 0.04(A,b)	35.8 ± 0.1(B,a)	35.7 ± 0.01(B,a)	36.0 ± 0.1(B,b)	35.6 ± 0.1(B,a)	35.8 ± 0.09(B,b)
Max	40.2	40.1	39.3	37.5	38.7	37.9	39.5
DP	38.9 ± 0.03(A,a)	38.8 ±0.03(A,a)	36.3 ± 0.1(B,b)	37.5 ± 0.1(B,a)	35.8 ± 0.1(B,a)	35.8 ± 0.1(B,a)	35.9 ± 0.1(B,a)
Max	39.6	39.8	39.0	38.6	39.5	38.4	38.6

The variables FST (surface temperature of the forehead), TST (surface temperature of the thorax), FLST (surface temperature of the flank) and LST (surface temperature of the leg) and Mean ST (mean surface temperature), with significance level of $P < 0.05$. Different uppercase letters (A, B) indicate significant differences between body temperature ($P < 0.05$) and different lowercase letters (a, b) indicate significant differences between physiological status ($P < 0.05$).

Table 3. Correlations between variables of internal and surface temperature of cows during the hot and dry period, in semi-arid climate in the state of Ceará, Brazil.

Variable	FST	TST	FLST	LTS	RT	VT	Mean ST
FST	1	-	-	-	-	-	-
TST	-0.008**	1	-	-	-	-	-
FLST	0.342*	-0.056**	1	-	-	-	-
LST	0.415*	-0.003**	0.374*	1	-	-	-
RT	0.026**	0.057**	0.112*	0.095**	1	-	-
VT	0.036**	0.06**	0.061**	0.087**	0.812*	1	-
Mean ST	0.114*	0.696*	0.111*	0.11*	0.036**	0.053**	1

The variables FST (surface temperature of the forehead), TST (surface temperature of the thorax), FLST (surface temperature of the flank) and LST (surface temperature of the leg) and Mean ST (mean surface temperature), with significance level of $P < 0.05$. *significant; **non-significant.

DISCUSSION

Among the European cattle breeds, the Brown Swiss is one of the most tolerant to heat, with a black skin that absorbs ultraviolet radiation well, and a clear hair that reflects infrared radiation well, characteristics necessary for a good tolerance to heat [14,26]. In this context, this breed was chosen to check for correlations between body temperatures (RT, VT, and ST) because it has a homogeneous coating and morphological characteristics that favor adaptation to hot climates.

Temperature and relative humidity exhibited high values both in the sun and in the shade; these parameters affect the temperature-humidity index (THI), which was used to evaluate the environmental comfort and whose values were similar to those previously obtained in the same region [6].

The THI values determined under the environmental conditions present during this study are considered severe to European cattle breed as these values are beyond the thermal comfort zone of these animals [21].

Cows exposed to direct sunlight in an environment where the THI exceeds 72, which is well below the values observed in the present study, are in stressful conditions, particularly if they are high producing dairy cows [18,25].

A temperature of 34°C with relative humidity ranging from 46% to 80%, i.e., a THI ranging from 83 to 89, has a significant thermal impact on dairy Brown Swiss cows [13]; the THI values found in this study (Table 1) match such a range.

Body temperatures exhibited significant variations depending on the physiological status of the cows. Lactation concomitant with pregnancy significantly increases internal temperatures (RT and VT) in dry pregnant (DP) and nonpregnant lactating (NPL) cows. This finding may be explained by the fact that pregnancy concomitant with lactation accelerates the metabolism, which results in higher food intake and increased production of body heat with consequent increase in internal body temperature.

The maximum values of internal body temperatures (RT and TV) at all stages of the lactation cycle were higher than their corresponding average values, which indicates that some cows exhibited, at given moments, hyperthermia. The maximum body temperature values are more representative of the occurrence of heat stress than mean body temperature values, which indicates that the maximum values are always more reliable [6,21]. A RT above 39.2°C is indicative of heat stress [1]. In this study, rectal and vaginal temperatures above this value (> 39.5°C) were found in maximum values; this indicates that some Brown Swiss animals have difficulty in regulating internal temperature in semi-arid climate conditions.

The results of this study confirm those reported by Silva *et al*. [29], according to which maintenance of body temperature occurs by exchange of heat with the environment. Consequently, under low ambient temperatures, the heat is dissipated to the environment in sensible form via a temperature gradient formed between animal and environment. On the other hand, when ambient temperatures are higher than body temperature, as observed in this study, heat exchange between the animal and the environment is difficult.

Accordingly, high ambient temperatures like those observed in this study (36°C to 40°C) reduce heat loss from the body to the environment because there is no favorable heat gradient for efficient thermolysis, which leads to a body temperature above normal physiological limits and results in accumulation of body heat, i.e. thermal stress. The strong correlation between RT and VT found in this study (r = 0.812) is in agreement with results from studies on pregnant cows (r = 0.90) [11], cyclic cows (r = 0.95) [19], and heifers (r = 0.92) [5]. In those studies, the authors reported RT values higher than VT values, and a strong positive correlation between these variables. The strong correlation between RT and VT occurs because the vagina and the rectum are very close to each other, and are separated only by the pelvic fascia [9].

Body surface temperatures are always lower than internal temperatures, and they may vary widely between different parts of the body surface. In this study, the difference between the internal and the surface temperature was around 3.3°C, confirming the results obtained by Yuri *et al*. [34], who measured temperatures on the rumps of Holstein cows. Silva [24] reported that temperature is not homogeneous throughout the body and varies according to anatomical region because of differences in the metabolic activity of the various tissues; this observation is valid for both internal and surface temperatures.

Although surface temperatures (ST) are an important parameter in most studies on heat stress, these are influenced by various environmental factors, such as ambient temperature, relative humidity, and wind speed, and vary greatly depending on the differences in the body surface areas. The wide temperature variation between surface areas throughout the body occurs because these zones do not share the same extent of physical contact with the environment, which may explain the weak correlations between temperatures measured on them [8,20].

In addition, the weak correlations between ST and internal temperatures (RT and VT) indicate that ST is not reliable for the assessment of heat stress. Therefore, internal temperatures are more accurate than surface temperatures to evaluate heat stress. In this context, Bianca [3] argued that a rectal temperature higher than normal physiological values is indicative of heat stress.

Several studies have used surface temperature to assess heat stress in tropical ruminants such as goats [30], sheep [27], and cattle [4]. However, those studies failed to demonstrate a correlation between internal and surface temperatures, and did not determine normal body surface temperatures for those species.

The difficulty in determining a normal range for surface temperature is probably related to the influence of environmental factors and the variation in coat color as reported by Salles *et al*. [23], who studied cattle with various coat colors in a semi-arid climate. In general, the color and the morphological characteristics of the coat in cattle directly affect the exchange of sensible heat and the loss of latent heat to the environment [14]. Therefore, the evaluation of surface temperature in various breeds of cattle in different climates must consider environmental and genetic factors besides the specific characteristics of the skin.

CONCLUSION

The semi-arid climate is not suitable for Brown Swiss cattle because air temperature and relative humidity contribute to form a hostile environment, as shown by the temperature-humidity index values found in this study.

Rectal temperature and vaginal temperature are strongly correlated and are more reliable than surface temperatures for assessing the occurrence of hyperthermia in Brown Swiss cows reared in a semi-arid climate.

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***Declaration of interest*.** The authors declare that there is no conflict of interest that could be perceived as harmful to the impartiality of the research reported.

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