DOI: 10.1590/1809-6891v24e-73559E

Ciência Animal Brasileira
Brazilian Animal Science

e-ISSN 1809-6891

Section: Animal science
Research article

Seasonality effect on the physiological and productive responses of crossbred dairy cows to the equatorial Amazon climate

Efeito da sazonalidade sobre as respostas fisiológicas e produtivas de vacas leiteiras mestiças ao clima amazônico equatorial

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Abstract
The objective of this study was to evaluate the seasonal effect of months of the year upon the physiological and productive responses of crossbred dairy cows raised in an Amazonian climate. Twenty lactating cows were evaluated, fed on *Brachiaria decumbens* pasture, with free access to water and mineral supplementation. Data from climate variables air temperature (AT), relative humidity (RH), rainfall (RA) and temperature and humidity index (THI) were recorded dur ing the months of January to April 2019. The physiological data collected were: respiratory rate (RR, mov/min), heart rate (HR, beats/min), rectal temperature (RT, ºC), udder surface temperature (UST, ºC), body surface temperature (BST, ºC), dorsum surface temperature (DST, ºC), front surface temperature (FST, ºC) and rear shin temperature (RST). Milk production (MP) was also measured. There was a significant difference (P<0.05) of RST and RR with values ranging from 34.8 to 35.5°C and 32.0 to 36.2 mov/min, respectively. There were no significant difference (P>0.05) for BST, and the values for MP and THI were 3.8; 3.8; 4.6; 4.1 kg and 77.7; 79.7; 80.6; 80.1, respectively. It was concluded that there was a seasonal effect of the months of the year evaluated on the respiratory rate of animals, however, it did not change the MP and the THI. The Amazon environment is conducive to causing thermal stress in lactating cows raised on pasture, requiring the use of shading to facilitate the ability of these animals to dissipate heat.
Keywords: animal performance; thermal stress; milking; room temperature

Resumo
O objetivo desse estudo foi avaliar os efeitos sazonais dos meses do ano sobre as respostas fisiológicas e produtivas de vacas leiteiras mestiças criadas em clima amazônico. Foram avaliadas 20 vacas lactantes, alimentadas com pasto de *Brachiaria decumbens*, com acesso livre a água e suplementação mineral. Foram registrados dados das variáveis climáticas temperatura do ar (TA), umidade relativa do ar (UR), precipitação pluviométrica (PP) e índice de temperatura e Umidade (ITU) durante os meses de janeiro a abril de 2019. Os dados fisiológicos coletados foram: frequência respiratória (FR, mov/min), frequência cardíaca (FC, bat./min), temperatura retal (TR, ºC), temperatura superficial do úbere (TSU, ºC), temperatura superfície corporal (TSC, ºC), temperatura superficial do dorso (TSD, ºC), temperatura superficial da fronte (TSF, ºC) e temperatura superficial da canela (TSCA, °C). Também foi mensurada a produção de leite (PL, kg). Houve diferença significativa (P<0,05) da TSCA e FR com valores variando de 34,8 a 35,5°C e 32,0 a 36,2 mov/min, respectivamente. Não houve diferença significativa (P>0,05) para TSC e os valores observados para PL e ITU foram 3,8; 3,8; 4,6; 4,1 kg e 77,7; 79,7; 80,6; 80,1, respectivamente. Houve efeito sazonal dos meses avaliados sobre a taxa respiratória dos animais, no entanto, isso não alterou a PL nem o ITU. O ambiente amazônico é propício a causar estresse térmico em vacas lactantes mantidas a pasto, sendo necessário o uso de sombreamento para facilitar a capacidade de dissipação de calor corporal desses animais.
Palavras-chave: desempenho animal; estresse térmico; ordenha; temperatura ambiente.

1. Introduction

The stress inflicted by environmental climate change confers significant variations correlated to animal welfare and productivity. Thus, it is essential to be concerned with the environment in which the animal lives, since production animals may not express their full potential due to the imposed environmental thermal stress [1]. In regions with a tropical climate, such as the Amazon, environmental factors such as high temperature, solar

Received: July 29, 2022. Accepted: November 4, 2022. Published: February 2, 2023.

https://revistas.ufg.br/vet/index

radiation and relative air humidity must be considered to ensure comfort to the animals, since these factors are among the main causes that limit the cattle production(2).

The thermal comfort indices are indicative for animal welfare and the physiological responses to thermal stress most used for the development of indices are body temperature, respiratory and heart rate, which allow a more accurate assessment of the situation of the environment [3]. The climate control and environmental management strategies according to Cerutti et al.[4] can also be established to minimize the effects of thermal stress on lactating cows, aiming to increase, especially in tropical regions, the thermal comfort of animals and to contribute to economic gains in milk production.

For Zero and Mello[5] the thermal stress conditions caused by high temperatures and relative humidity results in a decrease in milk production, reproductive efficiency, thermal stress, and when in more severe conditions, it can lead to the death of animals; however, in herds composed by crossbred cows, the impacts are smaller, as they are animals adapted to tropical regions and, in general, are a good option on pasture. Zebu breeds have greater rusticity and lower metabolic rate, which make them withstand greater variations in the environment and management systems, in addition to having lower production costs when compared to systems using animals of European breeds[6].

According to Pinheiro et al.[7], milk production is correlated with the environmental conditions in which the animals are kept and with the ability of these animals to maintain their body temperature within limits considered normal, in their thermoneutral range, where they do not need to divert nutrients intended for production to maintain their body temperature.

The northern region of Brazil presents edaphoclimatic diversity and variations in air and soil temperature between the months of the year, with consequent seasonal variations in forage growth rates. Despite not related to the intrinsic quality of the milk, the quantities and seasonality of production are criteria widely considered for the payment of the product. Dairies are interested in capturing milk from producers who supply large daily quantities of milk and who present a small seasonal variation in production, providing better planning by the industry and minimizing the idleness of the industrial park at certain times of the year.

Studies that associate seasonal variations as the months of year and the hot and humid environment of the tropical climate with the physiological and productive responses of crossbred dairy cows raised on pasture in the Western Amazon are scarce. In this context, the objective was to evaluate the effects of monthly climatic variables on the physiological and productive indices of crossbred dairy cows kept on pasture in an equatorial Amazonian climate.

2. Material and methods

This study was approved by the Ethics Committee on the Use of Animals (CEUA) of the Federal Institute of Education, Science and Technology of Acre, under protocol no. 008/2019. The experiment was conducted from January to April 2019, on a rural property, located in the dairy basin of the municipality of Sena Madureira, Acre, with an average area of 39 ha, a family-based production and low technological level.

The region is located in the Southwest of the Amazon, 150 m above sea level, at a latitude of 09°03'57"S and longitude 68°39'25"W, it has a tropical climate type according to the Köppen classification, temperatures ranging from 20°C to 33°C, annual rainfall above 1,600 mm, the rainy season occurs from November to April, and a less rainy season from June to September[9].

This study used twenty crossbred multiparous (3-4 lactations) 3/4 to 5/8 Holstein x Gyr cows (500±25 kg) with 45±25 days in milk, production 5.4±3.3 kg/ day and age 72±5.5 months, maintained in an extensive grazing system with *Brachiaria decumbens* pasture. The cows, regardless of production level, grazed in paddocks, with free access to water, no shade, low mineral and vitamin supplementation and did not receive balanced or concentrated ration.

Before the beginning of each milking, the animals would stay in a waiting area with no cover available (outdoors) with natural ventilation. There was no modification in the milking management, to avoid stress conditions. The animals were milked mechanically, by a system “bucket at the foot”, once a day, without the calf around, between 5:30 and 7:30 am. Milkers did not diagnose clinical mastitis (cup test), pre and/or post-dipping. The milking facilities had a rough cement floor and a roof with a ceiling height of 5m and zinc tiles. The milk production of each animal was quantified through the dairy control carried out fortnightly, the average production was measured based on two monthly weighing sessions.

The physiological and climatic parameters evaluated were measured four times a month, with intervals of 10 days. The measurements of air temperature (AT, °C) and relative humidity (RH, %) were recorded by HOBO® data logger, model U12-012 (Onset, Brazil) with intervals of 30 minutes. The averages of maximum air temperature (Tmax, °C), minimum air temperature (Tmin, °C) and RH, %, measured in the milking parlor during the experimental period were 26.8°C, 25.9°C and 93.8%, respectively, in order to calculate the temperature and humidity index (THI) according to the mathematical equation proposed by [9].

$$THI = (0.8 \times T + (RH / T - 14.4) + 46.4$$

Where: THI = temperature and humidity index;

RH = relative humidity (%); T = average air temperature (°C).

The physiological parameters measured during milking were: 1) respiratory rate (RR, mov/min) was determined by means of visual assessment, observing the movements of the animal's right flank for 15 seconds, keeping the observer at a distance of two meters from the animal, multiplying by four to determine movements per minute; 2) heart rate (HR, beats/min) was measured by auscultation with the use of a stethoscope, on the left side of the animal, between the third and fifth intercostal spaces, auscultation being performed for 15 seconds and multiplied the result by four to determine the heart rate per minute; 3) rectal temperature (RT, °C) was recorded using a digital clinical thermometer, inserted approximately 5 cm into the animal's rectum until the sounder was triggered (approximately 60 seconds); 4) for body surface temperature (BST), four points on the animal's body were measured: forehead, back, hind shin and udder, respecting a distance of 30 cm from the animal's skin, using a portable digital infrared thermometer, at the beginning and the end of milking. The weighted average was calculated by assigning weight of 10% to the forehead, 70% to the back, 12% to the shin and 8% to the udder, according to the mathematical equation proposed by Pinheiro et al.[10] :

BST = 0.10 x T.forehead + 0.70 x T.dorsum + 0.12 x T.shin + 0.08 x T. udder

Where: BST = body surface temperature; T = temperature (°C).

The statistical design used was in randomized blocks with four treatments (months of the year) with twenty replications (animals) per treatment. The physiological variables were submitted to tests to verify normality and homoscedasticity, were analyzed by splitting the treatments into linear regression, quadratic regression and deviation using Fisher's test (P<0.05).

3. Results and discussion

During this study, the maximum air temperature (Tmax) was 30.3 ºC in April and the minimum (Tmin) was 24.5 ºC in January, and the relative humidity (RH) ranged from 92.1 to 94.1 % in the period from January to April, respectively, and average rainfall of 248 (mm/month) in the months evaluated.

The climatic data and THI (Table 1) presented in this study according to Bertoncelli et al.[11] proved to be unfavorable to dairy production, as the relative humidity at room temperature increases, the susceptibility of cattle to thermal stress changes. Similar results previously found under imposed high temperature and humidity by Cowley et al.[12]have shown that, under thermal stress conditions and with a THI higher than 72, lactating dairy cows exhibit several physiological state and milk yield of the cow begin to be adversely affected, and more recent analysis shows that this threshold is as low as 68 for high milking cows.

Table 1. Descriptive statistics of the climatic variables during the experimental period (January to April 2019).

Variables	Months of the year				
	Jan.	Feb	Mar.	Apr.	CV (%)
Tmax. ºC)	27.3±0.5	28.9±0.3	29.2±0.1	30.3±0.5	16.5
Tmin. (ºC)	24.5±0.1	24.7±0.7	25.8±0.2	25.0±0.5	18.6
Relative Humidity (%)	92.1±1.0	95.7±1.2	93.4±1.1	94.1±1.3	24.3
Humidity and Temperature Index	77. 7±2.1	79.7±2.5	80.6±2.6	80.1±1.3	26.1
Rainfall (mm/month)	257.0±10.5	260.2±20.8	271.3±37.5	204.5±28.9	19.8

Tmax = maximum air temperature; Tmin = minimum air temperature, CV = Coefficient of variation; Means no distinct by Fisher's test (p<0.05)

The values for RR were lower than those obtained by Barros Junior et al.[13] (49.57 to 58.10 mov/min) evaluating the thermoregulatory characteristics of lactating crossbred cows in a semi-arid region during the rainy season. The low amount of mov/min for the animals evaluated in this study may indicate that, according to the classification by Nóbrega et al.[14] , the RR remained below the frequency of 40-60 mov/min classified as low level stress.

The average RR in March and April were higher (P<0.004) than in January and February and ranged from 30.4 to 36.2 mov/min (Table 2) indicating that, possibly, the months of March and April provided a favorable microclimate to increase the RR and milk production, therefore the animals needed to expend less energy to maintain homeostasis.

There was no significant effect (P>0.05) of the interaction between the studied months and the HR variable (Table 2). The values observed in this study were close to 67.1 beats/min, which were obtained by Cerutti et al.[4] when evaluating the effect of acclimatization on lactating Holstein cows in a subtropical climate region, and higher (65.4 and 60.7 beats /min) than the values reported by Moreira et al.[15] studying the interaction of the semi-arid climate in crossbred cows kept on pasture from February to November.

Table 2. Regression models during the experimental period (January to April 2019) of Respiratory Rate (RR), Heart Rate (HR), Rectum Temperature (RT) and Milk Production (MP) of pasture-raised crossbred dairy cows in the Western Amazon.

Variables	Rainy Season				EPM	Value P	
	Jan	Feb	Mar	Apr		L [1]	Q [1]
RR (mov/min)[2]	32.0	30.4	35.1	36.2	4.97	<0.004	0.208
HR (beat/min)	66.3	68.1	66.5	66.1	3.38	0.759	0.458
RT (ºC)	38.2	38.2	37.8	38.1	0.77	0.399	0.165
MP (L/cow/day)	3.8	3.8	4.6	4.1	11.1	0.081	0.203

[1]Effect of linear (L) and quadratic (Q) relative to the experimental period at 5% probability. [2] $\hat{y} = 30.83 + 0.058x$ (R^2= 69.0); EPM = Standard error of the mean.

The average results of the HR variable observed in this study were within the normal range for the bovine species, and the animals did not show an indication of thermal stress, since, according to Moreira et al.[15], only above 120 beats/min do cattle reflect excessive heat load; however, heat stress conditions do not necessarily cause an increase in HR variable. According to Cerutti et al.[4], the HR data in the scientific literature in crossbred lactating cows are most often discrepant, due to the different environmental conditions in which they were obtained, and the variation between animals: smaller animals have higher HR, a fact strictly linked to the intensity of the animal's metabolism.

The values obtained for the RT (P>0.05) showed that there was no interaction between the studied months (Table 2). It was found that all evaluated animals maintained the RT within the normal range, corroborating classification by Klein [16] that established a normal condition for dairy cattle that maintain RT between 38.0 and 39.3°C. The mean RT values in this study were lower than those obtained by Tosetto et al.[17] when evaluating the influence of climate in the city of Passo Fundo - RS on the thermal comfort of Holstein dairy cows in a semi-confinement system, indicating that the evaluated animals were not submitted no thermal stress.

Milk production did not vary significantly (P>0.05) between the studied months (Table 2). Probably the number of animals and the genetic diversity among them prevented us from detecting significant differences. The absolute means were higher in March and April (4.6 and 4.1 L/cow/day, respectively), and lower in January and February (3.8 L/cow/day). The averages of milk production differ from those observed by Souza et al.[18] when they stated that in an environment with high temperature, the animals increase sweating, RT and RR, avoiding the accumulation of heat in the body, consequently diverting energy that could be used for milk production, which would result in a reduction in animal performance.

It is believed that the low average milk production found in this study is related to the low technological level and the inadequate management adopted in the property where milking was carried out and there was no supply of concentrated animal feed. The results corroborate those found by Bertoncelli et al.[11] who stated that, in situations where nutritional management is insufficient along with high temperatures and humidity, the thermal stress of the animals increases and, consequently, food intake and milk production are suddenly reduced.

The average data found for milk production in this study were lower than those obtained by Vitor Neto and Bittar[19] (14.6 L/cow/day) when performing an analysis of thermal comfort in crossbred cows kept on pasture in a tropical climate region and did not observe reflections of thermal stress or interference of climatic variables on milk production. On the milk production, a behavior similar to those obtained by Santos et al.[20] did not observe the effect of climatic variables on the milk production of F1 Holstein x Zebu cows, thus indicating, as in this study, the animals' adaptation to the climatic conditions of the raising environment.

This way, it is possible to infer that, even in regions where there are climatic conditions of high temperature, it is possible to obtain satisfactory results in milk production, provided that investment is made in shaded areas, adequate nutritional and sanitary management, easy access to abundant quality water, thus making the environment more comfortable to the animals.

There was no significant effect of the months studied for the variable FST (P=0.808) and DST (P=0.418), however, the variable RST had a significant linear increase (P=0.021). The values obtained for the RST variable in this study (Table 3) remained close (34.7ºC) to those obtained by Martello et al.[21] in Holstein cows housed in acclimatized facilities, which may indicate the absence of thermal stress in the animals evaluated in this study. However, it is believed that only the alteration of the temperature measured superficially in the fur of the animals is not enough for the detection of physiological alterations and the occurrence of thermal stress in the animals, because, according to Martello et al.[21], this variable is not homogeneous and presents variations according to the anatomical surface, as it is more subject to the influences of the external environment.

Table 3. Regression models during the experimental period (January to April 2019) of pasture-raised crossbred dairy cows in the Western Amazon.

Variables	Rainy Season				EPM	Value P	
	Jan	Feb	Mar	Apr		L[1]	Q[1]
FST (ºC)	35.9	35.9	35.8	35.9	1.06	0.694	0.808
DST (ºC)	36.7	36.6	36.4	36.6	0.50	0.418	0.082
RST (ºC)[2]	34.8	34.9	35.2	35.5	1.05	<0.021	0.533
UST (ºC)	37.5	36.9	37.2	37.6	0.52	0.517	0.724
BST (ºC)	36.4	36.3	36.2	36.4	0.50	0.952	0.246

[1]Linear (L) and quadratic (Q) order effect, relative to the experimental period, at 5% probability; [2] $\hat{y} = 3475 + 0.0007667x$ (R^2= 93.3); FST = Front Suface Temperature; DST = Dorsum Surface Temperature; RST = Rear Shin Temperature; UST = Udder Surface Temperature; BST = Body Surface Temperature; EPM = Standard error of the mean.

There was no significant difference (P>0.05) in the UST assessment in the evaluated months, indicating that the studied months did not influence the animals' UST (Table 3). The absolute values for the variable UST found in this study were higher than the 35.8°C recorded by Zotti et al.[22] who evaluated the effect of air conditioning in the waiting room on pasture-raised crossbred cows. High absolute values for the UST variable obtained in the evaluated animals may indicate inflammatory reactions of the breast tissues.

There was no significant difference (P>0.05) in the BST, demonstrating that the peripheral vasodilation performed by the animals as a form of heat loss to the environment was similar during the studied months (Table 3). The absolute values obtained for BST in this study were higher than those observed by Avila et al.[23], who evaluated the effect of climate in the city of Palmeira das Missões – RS on the physiological parameters of lactating Holstein cows. The absence of structure on the property evaluated, combined with the non-availability of trees or protection of the animals against solar radiation, contributed to the higher BST observed in the animals.

4. Conclusion

In the months between March and April, crossbred dairy cows 3/4 to 5/8 Holstein x Gyr raised on pasture with milk production 5.4±3.3 kg/ day have their respiratory rate altered, but it does not alter milk production. The Amazonic seasonality is conducive to causing initial or mild stress in lactating cows and other results could be obtained if the study used cows with different genetic groups unadapted, use of shading or in a year with atypical climatic conditions.

Conflict of interests

The authors declare no conflict of interest

Author contributions

Conceptualization: D. A. Costa and V. M. Santos. *Data curation:* G. R. Moreira and D. A. Costa. *Formal analysis:* C. L. Souza, G. R. Moreira and D. A. Costa. *Research:* D. A. Costa. *Acquisition of funding:* D. A. Costa. *Methodology:* C. L. Souza, G. R. Moreira and D. A. Costa. *Resources:* D. A. Costa. *Project management:* D. A. Costa and V. M. Santos. *Validation and Visualization:* D. A. Costa and V. M. Santos. *Supervision:* D. A. Costa and V. M. Santos. *Writing (original draft)*: D. A. Costa and V. M. Santos. *Writing (review and editing):* A. V. D. Oliveira, A. M. Queiroz, E. M. B. Reis and B. L.Rosa.

Acknowledgements

To CNPq for granting the PIBIC/CNPq scientific initiation scholarship, and to the GPEAS Research Group of the IFAC – Campus Sena Madureira.

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