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The Detection of Rectal Temperature in Dairy Cattle by Using Infrared Digital Laser Thermometer

Detecção da Temperatura Retal em Bovinos Leiteiros Usando Termômetro Digital a Laser Infravermelho

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Abstract

Heat stress in dairy cattle can jeopardize several physiological functions, including milk production, reproduction and immune function. The objectives of this study were to correlate body surface temperature (BST) and rectal temperature (RT) of dairy cows by using an infrared digital laser thermometer as well as to determine the ideal emissivity. Ten dairy cows were maintained under a covered area for three consecutive days. BST and RT measurements were taken at 8 am, 01 pm and 04 pm every day. Thermal readings were carried out at four distinct anatomic locations: the face, ribcage, rump, and mammary gland at 0.95 and 0.50 emissivity. The temperatures and anatomic locations of thermal measurements were evaluated by ANOVA and the means were compared using the Tukey Test at 5%. Emissivity at 0.50 did not establish a significant (P>0.05) correlation between BST and RT, while a significant correlation (P<0.05) was obtained at 0.95 emissivity. Therefore, emissivity at 0.95 was used to assess the variables. The following equation was established: RT = 0.143 x BST + 33.534, which was found to be significant with a determination coefficient of 82%. The results of this study suggest that the utilization of infrared digital laser thermometer with emissivity of 0.95 directed at the middle region of the ribcage can be efficient to estimate the rectal temperature of dairy cows.

Keywords: Animal Well-Fare. Emissivity. Heat Stress. Thermoregulation.

Resumo

O estresse calórico em bovinos de leite pode comprometer diversas funções fisiológicas, incluindo produção de leite, reprodução e função imunológica. Os objetivos deste estudo foram correlacionar a temperatura da superfície corporal (TSC) e a temperatura retal (TR) de vacas leiteiras usando um termômetro digital a laser infravermelho, bem como determinar a emissividade ideal. Dez vacas leiteiras foram mantidas em área coberta por três dias consecutivos. As medidas de TSC e TR foram realizadas às 8h, 13h e 16h, todos os dias. As leituras térmicas foram feitas em quatro localizações anatômicas distintas: face, caixa torácica, garupa e glândula mamária nas emissividades de 0,95 e 0,50. As temperaturas e localizações anatômicas das medidas térmicas foram avaliadas por ANOVA e as médias foram comparadas usando o Teste Tukey a 5%. Emissividade em 0,50 não estabeleceu correlação significativa (P>0,05) entre TSC e TR, enquanto uma correlação significativa (P<0,05) foi obtida na emissividade 0,95. Portanto, a emissividade de 0,95 foi utilizada para avaliar as variáveis. Foi estabelecida a seguinte equação: RT = 0,143 x BST + 33,534, que se mostrou significativa com coeficiente de determinação de 82%. Os resultados deste estudo sugerem que a utilização de termômetro digital a laser infravermelho com emissividade de 0,95 direcionada para a região média da caixa torácica pode ser eficiente para estimar a temperatura retal de vacas leiteiras.

Palavras-chave: *Bem-Estar Animal. Emissividade. Estresse Calórico. Termorregulação.*

1 Introduction

The effects of high environmental temperature on farm animals, previously considered limited to tropical areas, were extended to the temperate climate areas in response to the rise of global temperature (POLSKY; VON KEYSERLINGK, 2017). Thermal comfort and animal welfare are essential conditions for the production, productivity, and profitability of livestock exploitation (CRUZ *et al*., 201; LEME *et al*., 2005). St-pierre *et al.* (2003); Liu *et al.* (2019) estimated annual losses of $ 897 million by the US dairy industry, due to reduction in milk production and animal reproduction. This is a concern, especially for dairy cattle, considering that most of the territorial Brazil is in the tropical region, with a predominance of high temperatures and a high incidence of solar radiation (AZEVEDO *et al*., 2005).

Heat stress in dairy cattle can jeopardize a variety of physiological functions, including milk production, reproduction and immune function. Most of the negative effects of heat stress on animal performance are consequences of physiological adaptations or the animal's difficulty maintaining its homeothermy (DIKMEN *et al*., 2013).

Among physiological parameters, body temperature and its fluctuations are key indicators of animal health and welfare (GODYŃ *et al*., 2019). Rectal temperature is an indicator of deep body temperature and there are several methods to evaluate temperature differences by obtaining samples from various body anatomic locations, to understand how temperature varies in different parts / organs and how they change in response to physiological, behavioral, and environmental parameters (MCCAFFERTY *et al*., 2015).

A low-cost radiometric method used to measure temperatures at a distance was based on sensors that recorded the radiation released by a body having its emissivity as a parameter. Emissivity is a dimensionless number between zero and 1 relative to the ratio of radiant energies emitted by two bodies of the same dimension, wavelength range, geometric shape, focus conditions, and temperature, being the numerator any surface and the denominator a blackbody (SILVA, 2014). The term blackbody implies a structure that does not reflect radiation. At the same temperature, blackbodies emit the same amount of radiation for all wavelengths (SILVA, 2014). Therefore, if the emissivity of a body is known and the amount of radiation emitted at a given wavelength range *(E)* is measured, it is possible to estimate the surface temperature (SILVA, 2014). Consequently, the use of infrared thermometers would greatly facilitate the estimation of body temperatures under field conditions.

Studies have used infrared thermography to demonstrate that increased foot temperature is associated with lameness and foot lesions (NIKKHAH *et al*., 2005; STOKES *et al*., 2012). Lin *et al.* (2018) have evaluated the surface environmental temperature adjusted of the cows' hind feet adjusted to the surface temperature aiming at verifying it the differences among the cows' hind feet would enhance the lameness detection. These authors have concluded that the results of infrared thermometry demonstrated an association between elevated foot temperature and lameness, but further improvements to this detection technique will be required before it can be implemented as a management tool for detecting cows that may benefit from this technology.

Studies that assess the cattle's rectal temperature, without the discomfort caused by rectal introduction of thermometers, will greatly contribute to the animal's welfare and allow for the evaluation of the heat stress level that is suffered by the animal, indicating the need for environmental corrective measures. This study evaluated the temperature of irradiated surfaces of several anatomic regions of dairy cattle using infrared digital thermometry and compared these results with rectal temperature and determined the best correlation obtained at 0.95 and 0.50 emissivity.

2 Material and Methods

2.1 Study location and animals

The experiment was carried out at Fazenda Realeza, city of Araputanga, Mato Grosso, Brazil. Ten crossbred (5/8 Holstein x 3/8 Gir) dairy cows, with an average production of 15 liters of milk / cow / day were used. All animals were supplemented with corn silage and concentrate with 20% crude protein (CP) being provided 1 kg for every 3.0 kg of milk produced, with *ad libitum* access to water. All cows were evaluated three times a day: at 8 am, 01 pm and 04 pm, for three days, to determine the rectal temperature (RT) and the body surface temperature (BST) during three consecutive days.

2.2 Temperature determinations

BST evaluation was performed at specific anatomic locations: 1) left masseter muscle of the face; 2) left rib, between the 7th and 9th intercostal space; 3) middle left rump, between the ischium and ileum bones, and 4) at the middle region of the left mammary gland (between the anterior and posterior quarters). Thermal measurements were taken at emissivity of 0.95 and 0.50.

All cows were maintained in a sheltered area and after 10 minutes, the RT was determined with the aid of a mercury clinical thermometer inserted into the rectum and maintained for one minute. The BST determination was done at the specific anatomic regions (mentioned above) using a digital infrared laser thermometer (Fluke 62 MAX, Washington, U.S.A), that was used placed approximately 50 centimeters distant from the animal, according to the manufacturer's recommendations. BST was evaluated at 0.50 and 0.95 emissivity. Additionally, environmental temperature and relative humidity were monitored concomitantly with RT and BST, by a hygrometer (Incoterm Thermo-hygrometer, São Paulo, Brazil).

2.3 Statistical analyses

The surface temperatures of the regions measured (face, ribcage, rump and mammary gland) were compared by variance analysis, relating irradiated BST with RT, the effect at the different measurement regions for three days. The thermal measurements of all cows were done at 8 am, 01 pm and 04 pm, at 0.95 and 0.5 emissivity. The averages obtained were compared by the Tukey test with a 5% probability.

Temperature evaluation at different emissivity was performed by using the paired variance analysis comparing the dependent variable (the square of the difference between the estimated surface temperature and rectal temperature) with the independent variable (the adopted emissivity). The assumptions of the residual distribution adherence of models regarding the normal distribution was evaluated by the Kolmogorov-Smirnov test, while the heteroscedasticity was calculated by the Levene test.

The animal utilization in the research was approved (protocol # 005/2019) by the Animal Use Ethics Committee (CEUA), University of Cuiabá.

3 Results and Discussion

During this study, the average rectal temperature obtained was 39.0°± 0.6 °C, with a lower rectal temperature ($P<0.05$) identified when morning temperature readings were compared to those done in afternoon (Table 1). The results herein described are similar to those presented (ROCKETT; BOSTED, 2012). Maintenance of body temperature is determined by the balance between heat loss and gain. The physiological reference of this variable is obtained by measuring the rectal temperature (DIRKSEN *et al*., 1993). These variables can be influenced by extrinsic factors, such as time of day when measurements were taken, and consequently may interfere and can result in variations of rectal temperature (BACCARI JUNIOR, 2001; CARVALHO, 1995).

Table 1 - Average values of the variables evaluated relative to the time of the day and thermal measurement using infrared digital laser thermometer with emissivity of 0.95 to determine body surface temperature in dairy cows

Variables Evaluated	**Average Values**	**Time of Measurement**		
		8 am.	**01 pm.**	**04 pm.**
Environmental temperature (C^0)	26.5 ± 5.2	21.2 ± 1.9^b	29.3 ± 4.6^a	29.0 ± 3.6^a
Relative humidity (%)	65 ± 19	86 ± 9^a	53 ± 16^b	57 ± 13^b
Rectal temperature (C^0)	39.0 ± 0.6	38.6 ± 0.3^b	39.2 ± 0.6^a	39.3 ± 0.6^a
Facial temperature (C^0)	38.0 ± 2.5^{NS}	35.2 ± 0.9^b	39.5 ± 2.2^a	39.4 ± 1.4^a
Ribcage temperature (C^0)	38.4 ± 2.8^{NS}	35.3 ± 1.1^b	40.1 ± 2.6^a	39.4 ± 1.4^a
Rump temperature (C^0)	38.7 ± 2.9^{NS}	35.4 ± 1.2^b	40.7 ± 2.4^a	40.3 ± 1.1^a
Mammary gland temp. (C^0)	39.3 ± 2.7*	36.4 ± 1.3^b	40.9 ± 2.4^a	40.7 ± 1.4^a

Footnotes: ^{NS} Not significant (P> 0.05) by Tukey test; * (P <0.05) by Tukey test. ^{a,b} Different letters in the same line represent significant difference (P <0.05) by Tukey test.
Source: Resource data.

Significant differences (P<0.05), by the Tukey test, were identified at 0.50 emissivity when the BST determined at the face, ribcage, and rump were compared relative to the rectal temperature of all animals. These results suggest that an emissivity of 0.50 was not efficient in measuring the BST during this study. Alternatively, no differences (P>0.05) were identified between the average rectal temperatures and the average temperatures of all the anatomic locations evaluated at 0.95 emissivity. Accordingly, thermal emissivity at 0.95 was used to evaluate all the results herein described (Table 1).

No statistical differences (P>0.05) were identified when the average temperatures obtained at the face (38 °C), ribcage (38.4°C), and rump (38.7 °C) were compared. Thermal mensuration at the mammary gland was discarded due to the correlation (r=0.470*, P<0.05) identified between elevated milk production and higher temperature of the irradiated surface. Consequently, the best options for thermal measurements during this study were obtained at the regions of the face, ribcage, and rump; however, the ribcage was considered as the ideal sampling location for thermal mensuration due to easy access (Table 1). The average difference between the values of the rectal temperature obtained and estimated at the body surface of the ribcage region with emissivity of 0.95 was 0.3430.062C°. These differences can be related to the color of the anatomical location evaluated, since the face, ribcage and rump of all the animals within this study were predominantly black as compared to the white-colored mammary glands. Consequently, the color of the anatomic location evaluated influenced the temperature readings.

A significant increase in BST was associated with an increase in environmental temperature taken during the afternoons. The recorded environmental, rectal, and body surface temperatures were significantly higher (P<0.05) in the afternoons (01 pm and 04 pm) when compared to those observed during the mornings (8 am). However, this relationship was inverted when the differences in relative air humidity were compared between the afternoon and morning measurements (Table 1). Similar results for environmental and rectal temperatures were described (AZÊVEDO; ALVES, 2009; FERREIRA *et al*., 2006; PERISSINOTTO *et al*., 2007).

It must be highlighted that all the temperature determinations during this experiment were performed in cows maintained within a shaded area and with the utilization of a digital infrared laser thermometer. This methodology, under these conditions, was efficient to determine the body temperature of dairy cows and may be a useful tool to evaluate heat stress in these animals, which have jeopardizing effects on milk production (PORCIONATO *et al*., 2009) and fertility (ROMAN-PONCE *et al*., 1977).

The best emissivity for temperature determinations was obtained with 0.95 at the ribcage region. Accordingly, a regression analysis was established between rectal temperature and irradiated body surface temperature (middle rib region). This resulted in the equation RT = 0.143 x BST + 33.534 (result in degrees Celsius), where RT is the rectal temperature and BST is the irradiated body surface temperature. This model was considered as significant (P<0.01), having a determination coefficient of 82% and Durbin-Watson coefficient of 2.31. The results of this experiment may be beneficial to farmers and technicians, whereby the utilization of digital infrared laser thermometry can estimate the cows' rectal temperature as well as evaluate the cattle's thermal comfort and health. With this in mind, Chung *et al.* (2010) established equations to estimate the piglets' rectal temperature using non-contact infrared thermometry and suggested that the established equations could serve as a valid alternative for the determination of rectal temperature, without inducing stress in animals.

4 Conclusions

The use of an infrared digital laser thermometer at an emissivity of 0.95 directed at the middle ribcage region of dairy cows, may be used to determine the rectal temperature in cattle. This methodology can help assess the thermal comfort of dairy cows, may facilitate management practices and reduce animal discomfort and stress due to the rectal introduction of the thermometer.

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