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Detection of heat stress in boer goats using infrared thermography and different methodologies

Detecção de estresse térmico em caprinos boer utilizando termografia infravermelha e diferentes metodologias

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ABSTRACT: The objective of this research was to measure the surface temperature of goats by means of thermography, as well as to analyze if there is a difference between the amount of points collected to evaluate the average surface temperature. The research was carried out in a climatic chamber, evaluating the body surface temperature of goats using different methodologies at different air temperatures. The experimental design used was completely randomized with a 3x4 factorial scheme (three temperatures and four points of surface temperature collection) with six replications. The data obtained were evaluated using the Statistical Analysis System by applying the analysis of variance and Tukey test for the significant variables. However, it is concluded that there is no difference between the analysis of the average surface temperature in 3 or 8 points of the body, being proposed the analysis in 4 points, being forehead, side, neck and shin, considering that they are the places where it occurs more intense cutaneous evaporation in goats.

KEYWORDS: climatic chamber; surface temperature; thermoregulation.

RESUMO: O objetivo da pesquisa foi medir a temperatura superficial de caprinos por meio de termografia, bem como analisar se há diferença na quantidade de pontos coletados para avaliação da temperatura média superficial. A pesquisa foi realizada em câmara climática, avaliando a temperatura superficial corporal de caprinos por meio de diferentes metodologias em diferentes temperaturas. O delineamento experimental utilizado foi inteiramente casualizado com esquema fatorial 3x4 (três temperaturas e quatro pontos de coleta de temperatura superficial) com seis repetições. Os dados obtidos foram avaliados pelo Sistema de Análise Estatística aplicando-se a análise de variância e teste de Tukey para as variáveis significativas. Contudo, conclui-se que não há diferença entre a análise da temperatura média da superfície em 3 ou 8 pontos do corpo, sendo proposta a análise em 4 pontos, sendo testa, lateral, pescoço e canela, considerando que são os locais onde ocorre evaporação cutânea mais intensa em caprinos.

PALAVRAS-CHAVE: câmara climática; temperatura superficial; termorregulação.

INTRODUCTION

Infrared thermography (TIV) is a modern, safe and non-invasive technique for visualizing the thermal profile of animals. The use of the conversion of thermal radiation into images with detailed animal body temperature assists in the assessment of the animals' thermal stress by detecting minimal variations in body temperature accurately, thus making diagnoses increasingly efficient (Menegassi *et al.*, 2015; Ferreira *et al.*, 2016).

This technique is used for several areas, in the detection of estrus in goats (Façanha *et al.*, 2018), in the monitoring of the breast development of cows, goats, sheep and mares (Chacur *et al.*, 2018), in the detection of changes in temperature associated with inflammatory processes in which tissue damage leads to an increase in blood flow and, consequently, an increase in local temperature (Wood *et al.*, 2015), among others.

Thermography is commonly used in the evaluation of thermal stress in animals (Marques *et al.*, 2018), since it helps to understand body thermoregulation due to changes in surface temperature and the impact of environmental conditions on animal thermal comfort (Nääs *et al.*, 2014).

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In order to evaluate the effect of thermal stress by means of surface temperature, several methodologies for data collection can be found in the literature, which evaluate only 3 different points in the animals' bodies (Silva, 2010), some evaluate in 6 points (Souza *et al.*, 2008), others in 7 points (Souza *et al.*, 2014) and even in 8 different points (Furtado *et al.*, 2014), in order to provide the analysis with the greatest number of points, with the greatest number of points.

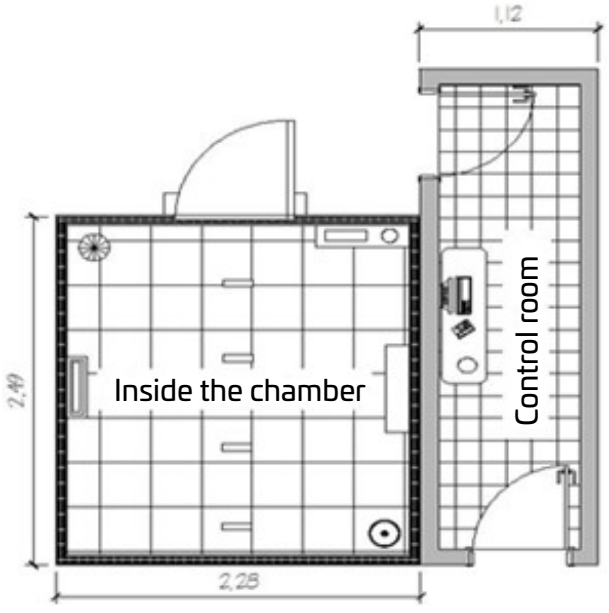
Thus, the objective of this research was to measure, with the use of infrared thermography, the physiological variations of the surface temperatures of Boer goats stored at different temperatures in a climatic chamber, as well as to observe if there is a difference between the amount of points collected for the evaluation of the surface temperature average.

MATERIAL AND METHODS

Six goats male Boer (3/4 Boer + PRSPRD), with an average weight of 25 kg and 5 months old, were housed in a climatic chamber (Figure. 1) and separated individually in metal cages, with dimensions of 1.30 × 0.55 m, provided with a feeder, drinker and a feces and urine collection system.

The surface temperatures were collected using a FLUKE thermographic camera, obtaining the thermal profile of the animals, the thermographic photos were taken individually at a distance of two meters from the animal, and the infrared radiation was transformed into a thermal map of the body surface of the animal.

The animals were submitted to three different temperatures, 25.7, 29.4 and 33.4 °C, the first being within the ideal thermal comfort zone for the species; the second temperature in the limit zone between thermal comfort and thermal stress and the third above the thermal comfort zone. The humidity and wind speed were 67.6 % and 1m.s^{-1}, respectively.



Source: Miranda *et al.* (2018).

Figure 1. Illustration of the climatic chamber for simulating stressful conditions.

During the experimental procedure, a period of five days of adaptation to the controlled environment, management and feeding and 10 days of data collection were adopted. Between the end of one temperature and the beginning of the next, the animals were offered a period of five days to restore their physiological functions.

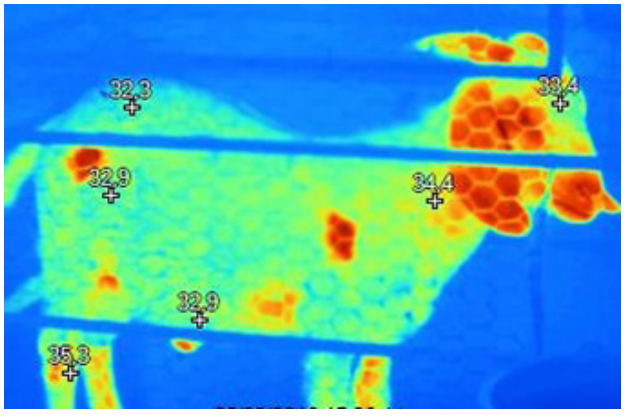
The animals were submitted to a thermal program of 8/16 (8 h at test temperature and 16 h at room temperature), where the daily preparation of the chamber consisted of turning it on at 7 h, allowing a time of 1 h to stabilize the internal temperature. After this stabilization, the period of 8 h at an experimental temperature began, with the animals remaining for 8 h uninterrupted in the closed chamber. Subsequently, the chamber was turned off and opened in order to start the period of 16 continuous hours at room temperature, simulating the conditions of the Brazilian semi-arid region, where there is approximately 8 hours of thermal stress and 16 hours of room temperature.

The thermograms obtained by digitization were processed using the SmartView® software, thus allowing a detailed analysis of the temperature field, where particulars points of the image were observed and local temperatures were selected, in order to compare the existing methodologies for calculating the estimate of the average surface temperature of goats.

The thermographic photos were analyzed based on the methodologies of average surface temperature (AST) proposed by four authors, Silva (2010), Souza *et al.* (2008), Souza *et al.* (2014), Furtado *et al.* (2014).

The methodology proposed by Silva (2010) adopts the AST to obtain data from only 3 points (forehead, side and shin). While Souza *et al.* (2008) recommends obtaining the SST from the arithmetic mean of 6 points (forehead, side, shin, neck, belly and loin) (Figure 2).

Souza *et al.* (2014) recommend obtaining SST from 7 points (forehead, side, shin, neck, belly, loin and thigh). Furtado *et al.* (2014) in turn recommend the use of 8 points (forehead, side, shin, neck, belly, loin, thigh and testicles) (Figure 3).



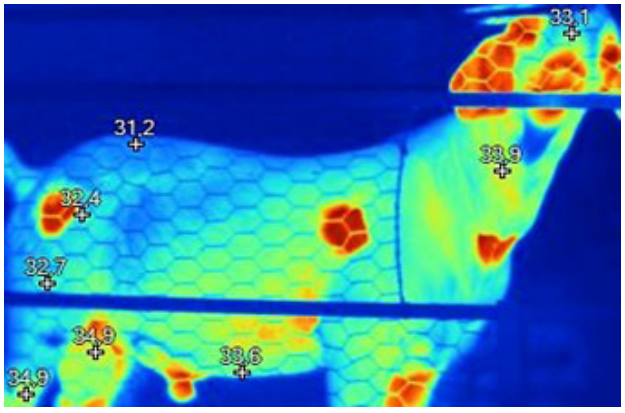
Source: author's collection.

Figure 2. Thermographic photo for analysis of SST according to the methodology of Souza *et al.* (2008).

The experimental design used was completely randomized with a 3x4 factorial scheme (three temperatures and four points of surface temperature collection) with six replications. The data obtained were evaluated using analysis of variance (ANOVA), the means compared by Tukey's test at 5% probability using the GLM (General Linear Model) procedure of the statistical package Statistical Analysis System (SAS, 2001).

RESULTS

In the analysis of the methodology by Silva (2010), it was observed that there was a statistically significant difference between the temperatures, presenting higher values at the highest temperature, with the side the most affected by the temperature rise, followed by the forehead and shin showing variations in the temperature lower for the highest temperature of 7.13, 6.92 and 6.84 °C, respectively, however there were no significant differences between the points collected (Table 1).



Source: author's collection.

Figure 3. Thermographic photo for analysis of AST according to the methodology of Furtado *et al.* (2014).

The same was observed in the analysis of the methodology by Souza *et al.* (2008), where the side was the place most affected by the rise in ambient temperature, followed by the forehead, shin and neck (Table 2).

With the analysis of the methodology by Souza *et al.* (2014), the same increase in the values of the points collected can be observed with the increase of the ambient temperature, however in this methodology the thigh was the variable with the least variation, presenting 3.79 °C between the lowest and the highest air temperature (Table 3).

While in the methodology of Furtado *et al.* (2014) it was observed that the variable with the least variation was the testicles, presenting 2.31 °C between the lowest and the highest air temperature (Table 4).

Different methodologies for estimating the average surface temperature (AST), proposed by Silva (2010), Souza *et al.* (2008), Souza *et al.* (2014) and Furtado *et al.* (2014), however in this evaluation it was observed that there is no statistically significant difference between the methodologies evaluated, with only a progressive increase in the average surface temperatures as the ambient temperature rises (Table 5).

DISCUSSION

The elevation of the surface temperature directly proportional to the ambient temperature observed in the methodological analyzes, indicates that the animals activated their thermal control mechanisms in order to maximize the heat dissipation with a view to maintaining homeothermia (Vieira *et al.*, 2016), corroborating with the research developed by Silva

Table 1. Averages and standard deviation of the average surface temperatures (AST) of Boer goats collected by the methodology of Silva (2010).

Variables	Temperatures (°C)			P Value
	25,7	29,4	33,4	
Forehead	27,35±0,66c	31,17±0,44b	34,27±0,59a	<.0001
Side	26,95±1,82c	30,88±1,12b	34,08±1,27a	<.0001
Shin	26,48±0,52c	31,73±0,71b	33,32±0,86a	<.0001

Different letters in the column differ by the Tukey test at the 5% probability level.

Table 2. Means and standard deviation of the average surface temperatures (AST) of Boer goats collected by the methodology of Souza *et al.* (2008).

Variable	Temperature (°C)			P Value
	25,7	29,4	33,4	
Forehead	27,35±0,66c	31,17±0,44b	34,27±0,59ª	<.0001
Side	26,95±1,82c	30,88±1,12b	34,08±1,27ª	<.0001
Shin	26,48±0,52c	31,73±0,71b	33,32±0,86ª	<.0001
Neck	28,37±1,39c	31,27±0,99b	33,95±2,06a	<.0001
Belly	27,62±1,22c	30,80±0,57b	33,82±0,75a	<.0001
Loin	30,05±0,82c	33,08±0,61b	35,48±0,29a	<.0001

Different letters in the column differ by the Tukey test at the 5% probability level.

Table 3. Means and standard deviation of the average surface temperatures (AST) of Boer goats collected by the methodology of Souza *et al.* (2014).

Variables	Temperatures (°C)			P value
	25,7	29,4	33,4	
Forehead	27,35±0,66c	31,17±0,44b	34,27±0,59ª	<.0001
Side	26,95±1,82c	30,88±1,12b	34,08±1,27ª	<.0001
Shin	26,48±0,52c	31,73±0,71b	33,32±0,86ª	<.0001
Neck	28,37±1,39c	31,27±0,99b	33,95±2,06ª	<.0001
Belly	27,62±1,22c	30,80±0,57b	33,82±0,75ª	<.0001
Loin	30,05±0,82c	33,08±0,61b	35,48±0,29a	<.0001
Thigh	31,91±0,53c	33,55±1,14b	35,70±0,40a	<.0001

Different letters in the column differ by the Tukey test at the 5% probability level.

Table 4. Averages and standard deviation of the average surface temperature (AST) of Boer goats collected by the methodology of Souza *et al.* (2014).

Variables	Temperatures (°C)			P value
	25,7	29,4	33,4	
Forehead	27,35±0,66c	31,17±0,44b	34,27±0,59ª	<.0001
Side	26,95±1,82c	30,88±1,12b	34,08±1,27ª	<.0001
Shin	26,48±0,52c	31,73±0,71b	33,32±0,86ª	<.0001
Neck	28,37±1,39c	31,27±0,99b	33,95±2,06ª	<.0001
Belly	27,62±1,22c	30,80±0,57b	33,82±0,75ª	<.0001
Loin	30,05±0,82c	33,08±0,61b	35,48±0,29ª	<.0001
Thigh	31,91±0,53c	33,55±1,14b	35,70±0,40ª	<.0001
Testicles	33,47±0,75c	34,65±0,92b	35,78±0,69ª	<.0001

Different letters in the column differ by the Tukey test at the 5% probability level.

Table 5. Means and standard deviation of the mean surface temperature (ST) of Boer goats.

Temperature (°C)	Surface temperature (°C)
25,7	28,04±1,03c
29,4	31,69±0,50b
33,4	34,24±0,63a
Evaluated methodologies	
SILVA (2010)	30,70±3,03a
SOUZA *et al.* (2008)	31,16±2,75a
SOUZA *et al.* (2014)	31,52±2,56a
FURTADO *et al.* (2014)	31,91±2,36a
P Value	
Temperature	<.0001
Points	<.0001
Temperature*Points	0,0966

Different letters in the column differ by the Tukey test at the 5% probability level.

et al. (2013) and Lima Junior *et al.* (2018) who found a greater change in surface temperature with a greater air temperature.

The increase in surface temperature as a mechanism for maintaining homeothermia has been reported by Lucena *et al.* (2013), Paulo *et al.* (2015), Fonseca *et al.* (2016); Ribeiro *et al.* (2018) and Vasconcelos *et al.* (2019), with goats in the semi-arid region.

Regarding the smallest variation in the temperature of the testicles between the lowest and highest air temperature observed in the methodology of Furtado *et al.* (2014), can be explained by the fact that high ambient temperatures interfere with the maturation of sperm, as well as decrease sperm concentration, progressive motility, sperm vigor and the percentage of normal sperm, thus allowing the testicles to perform the function correctly. of spermatogenesis, the testicular temperature decreases through the cremaster muscle, reducing the testicular temperature by about 2.0 to 6.0 °C in relation to body temperature (Ferraz *et al.*, 2016).

Therefore, it is proved that there is no influence of the number of points evaluated in the estimate of average surface temperature of goats, so this analysis can be performed satisfactorily by collecting only three points, being they forehead, side and shin described by the methodology of Silva (2010).

CONCLUSION

Thus, it is concluded that there is no difference between the analysis of the average surface temperature in 3 or 8 points of the body, being proposed the analysis in 4 points, forehead, side, shin and neck, considering that they are the places where cutaneous evaporation occurs more intense in goats.

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