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Estimation of rectal temperature of goats based on surface temperature

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Abstract
A non-invasive technique that may be able to show variations in an animal's body temperature in reaction to a thermally demanding environment is infrared thermography (IR). The aim of the research was to assess the relationship between the rectal temperature of goats and surface temperatures estimated through non-invasive techniques, specifically utilizing an infrared thermometer and thermal imaging. Goats' summer rectal and surface temperatures of 39.18± 0.04 °C and 33.17± 0.26 °C, respectively, showed the impact of temperature changes on their ability to adjust body temperature. Pearson’s coefficient of correlation (r) was calculated for each surface temperature record in order to assess the relationship between the non-invasive surface temperature readings and the rectal temperature. Notably, the ocular globe temperature (PT) exhibited a positive correlation with a coefficient of 0.581 in relation to rectal temperature, at a significance level of $p<0.05$. Regression equation for predicting rectal temperature from surface temperature of ocular globe (PT), is Rectal temperature = 37.856 + 0.107 (PT). These results provide valuable insights into the relationship between surface and rectal temperatures in goats.

Keywords: Goats, surface temperature, rectal temperature, infra-red thermography

1. Introduction
Rectal thermometry is commonly used to assess the thermal status of animals meant for commercial exploration. This method uses the animal's internal temperature as a typical measurement. The animals must usually be handled personally by the researcher in this method; the increase in rectal temperature indicates that the metabolic heat produced is not being adequately expelled by thermoregulatory processes. According to Byrne *et al.* (2017) [1], this method is time- consuming and may have an impact on animals' behaviour, which so modifies the thermoregulatory responses of the animals. McManus *et al.* (2016) [8] note that non-invasive techniques are available for assessing the animals' thermal condition. Among the techniques now in use, infrared thermography (IR) stands out for its high degree of precision and ability to avoid direct contact with subjects. This makes it a promising tool for both research development and farm animal monitoring.

2. Materials and Methods
2.1 Experimental Location
The experiments were conducted in goats maintained at the Instructional Livestock Farm Com- plex (ILFC), Pookode. Pookode, located in Wayanad district of Kerala at an altitude of 867 meters above the mean sea level and at 11°32′ 18.5’’North longitude and 11° 32′ 18.5’’ East latitude.

2.2 Experimental animals
Twelve adult Malabari does aged between one to two years with an average weight of 20.45 ± 1.12 kg were selected from the goat unit of Instructional Livestock Farm Complex (ILFC), Pookode. The goats were maintained as per the standard feeding and management practices followed at Goat Farm, ILFC, Pookode (ICAR feeding standards, 2013).

2.3 Experimental Period
The whole experiment was conducted in winter (November - January) and summer seasons (March- May). Two months from each of the seasons were selected as the study period.

2.4 Recording of animal parameters
In this study, twelve Malabari does were involved. Two groups of six animals each, MC (n = 6: Malabari Control) and MG (n = 6: Malabari Grazing), were randomly assigned to the animals. The MC animals (20.68 ± 1.51) kg were maintained in the shed, while MG animals (20.23 ± 1.83) kg were sent out for grazing between 10:00 h to 13.00 h during the experimental period. The animal parameters like rectal temperature (°C) and surface temperatures (°C) were recorded daily around13.00 h, during the study period. Four sites on the surface of the animal were measured using an infrared thermometer: the ocular globe (PT), head (HT), shoulder (ST), and hindquarter (HQ). The maximum infrared temperature (IRMax), which corresponds to the pixel with the greatest temperature recorded in the animal thermograms, was assessed in addition to the previously specified temperatures. Using an infrared thermal imaging camera (FLIR E54), thermal images of the animals were simultaneously taken at a maximum distance of 0.75 metres from them.

2.5 Statistical analysis: The data were analysed by SPSS software for correlation analysis to investigate any relationships be- tween these parameters. Simple linear regressions with a 95% confidence interval and an evaluation of the degree of elevation of Pearson's correlation coefficient were used to analyse the correlations between the PT, HT, ST, and HQ data and RT. Regression statistics were then used to further in- vestigate the possibility of relationships between surface temperature records and rectal temperature. In the end, we developed a regression equation that may be used as a tool for prediction to determine rectal temperature from surface temperature measurements.

3. Results and Discussion
Goats' summer rectal and surface temperatures of 39.18± 0.04 °C and 33.17± 0.26 °C, respectively, showed the impact of temperature changes on their ability to adjust body temperature. Homeothermic animals employ a range of thermoregulatory strategies to counteract heat absorption and loss relative to air temperatures above the thermoneutral zone and to keep their internal body temperatures within specific ranges in order to maintain thermal equilibrium. (McKinley *et al*., 2017) [7].

The correlations, according to the elevation of air temperature, between the physiological reaction (RT) and the temperatures (PT, ST, HT, and HQ) with a confidence interval of 95%.The current study found that PT, ST, HT, HQ, and IRMax increased ($p<0.05$) with increasing air temperature, indicating that this is caused by a decrease in the animal's capacity to dissipate heat in a sensitive way and a significant increase ($p<0.05$) in the core body representative temperature (RT) as a function of heat generation from metabolic reactions and the slight decrease of the thermal gradient between the animal and the environment. (Rizzo *et al*., 2017) [10]. Notably, the ocular globe temperature (PT) exhibited a positive correlation with a coefficient (r) of 0.581 in relation to rectal temperature, at a significance level of $p<0.05$. (Table 1.). The relationships between rectal temperature and the other body temperatures (head, shoulder and hip) are weak and not statistically significant. The correlation calculation for IRmax yielded weak correlation of 0.337.

Table 1: The relationships between rectal temperature and the other body temperatures

Rectal Temperature	Occular (PT)	Head (HT)	Shoulder (ST)	Hip (HQ)
correlation	0.581	-0.265	-0.305	-0.263
Significance (p-value)	0.037*	0.815	0.455	0.185

Measurements of the temperature of the skin and eyes have long been used as a less intrusive way to detect changes in body temperature in production animals. (Wijffels *et al*., 2021) [13]. Applications for infrared radiation monitoring include infection, reproductive status, feed efficiency, and stress. It has also been used to measure body surface and ocular temperature. (McManus *et al*., 2016) [8]. Because of direct interaction with the environment, external body surface temperatures are more changeable and lower than core temperatures (rectal, vaginal, and rumen). (Church *et al*., 2014) [2]. It is possible to forecast that skin and surface temperature locations will vary due to changes in blood flow and the structure of subcutaneous tissue. (Taylor *et al*., 2014) [12]. It is becoming more and more crucial to use infrared thermography to determine the comfort and heat stress levels of production animals. However, a number of internal and environmental factors, including race, colour, season, and weather, can affect an animal's skin temperature. (Wijffels *et al*., 2021) [13].

Since the correlation coefficient does not indicate the equality mismatch between the data values, it cannot be used alone to assess the link between two approaches. Secondly, information on the existence of a systematic difference between the approaches is not disclosed by the correlation coefficient. With the use of the regression equation and the PT's response, the RT may be precisely estimated. The RT can also be represented mathematically using the following equations. RT = 37.856 + 0.107 (PT) with statistically insignificant mean errors.

Fig 1A:

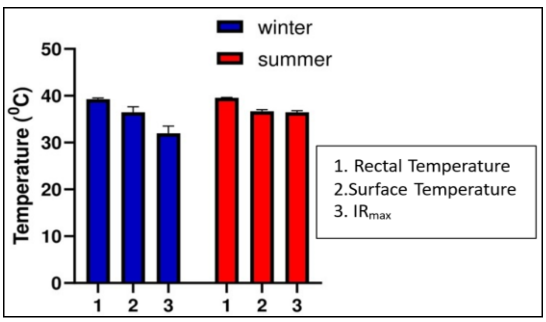

Fig 1B:

Fig 1: (A) An animal's thermograph that was assessed; and a (B) Graph showing average thermal values across the seasons

4. Conclusion

The present study shows that it is feasible to estimate goats' rectal temperatures from their surface body temperature in the ocular globe area. Our results show that this region is especially suitable for these estimations, as shown by a Pearson's correlation coefficient of 0.581. While not statistically significant, there were also moderate correlations noted in the head, shoulder and hip areas suggesting a possible localized thermoregulatory response in these regions. Additional research in these areas could shed more light on these intriguing findings.

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