Relationship between thermography image and rectal temperature in goat kids.

Estudiante:
Citlalli Mateo Díaz.

Tutor:
Antonio Morales de la Nuez.

Cotutor:
Marta González Cabrera

Curso Académico: 2022-2023

Convocatoria Ordinaria

UNIVERSIDAD DE LAS PALMAS DE GRAN CANARIA
Facultad de Veterinaria

RELATIONSHIP BETWEEN THERMOGRAPHY IMAGE AND RECTAL TEMPERATURE IN GOAT KIDS.

Citlalli Mateo Díaz

Facultad de Veterinaria (ULPGC), curso 2022- 2023

Abstract

Infrared thermography (IRT) is a non-invasive technique that uses thermal cameras to measure surface temperatures by detecting infrared radiation. The purpose of our study was to explore the applicability of IRT in goats kids by examining the correlation between body temperature measured by a conventional thermometer and IRT. We also aimed to investigate temperature variations across different areas of the goat's body and assess the impact of collection day and observer variability.

For our study, we used a single model of an infrared camera and collected samples from 11 Majorera goat kids calves over three consecutive days, with measurements conducted by three different observers. Non-parametric tests were employed to analyze the camera data, and the correlation with the measurements in the perineal area, which belongs to the same area as the rectal measurement, was concluded. To enhance future research, it is recommended to include animals with febrile conditions to establish a wider temperature range.

Regarding the temperatures measured in different body zones using IRT, correlations among these zones were observed. Notably, the observer effect was found to have the most significant impact, likely due to variations in the distance between the camera and the animal's body not being standardized.

Keywords: Thermography image, Digital thermometers, temperature, goat, IRT, Jamovi, ANOVA, non-parametric, Kruskal-Wallis, DSCF

ACKNOWLEDGMENTS

First of all, I would like to thank my tutor, Antonio Morales de la Nuez, my co-tutor, Marta González Cabrera, and my teacher, Anastasio Argüello Henríquez, for giving me the opportunity to carry out this study and for the help they have given me.

I would also like to thank my family for their support throughout my life, and for teaching me never to give up. I would especially like to thank my sister, Melodie, you don't know how strong you can be, and thank you for giving me my Niece, she has become my greatest pride.

I thank my life partner, Adrián, you have been there not only at the beginning of my career, but also before all this happened. We have lived together with many good moments and some bad ones, but always together and support each other. Now this stage of my life is coming to an end, and I know that the next one will be the best because you will be with me.

Finally, I want to thank the reason why all this started: my first pet, Rony, it is because of you that I started to love animals. You left before I could be the one to help you, but I promise I will always be there and I will give my all. Te llevo hasta la raíz.

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INTRODUCTION

Thermography, also known as infrared thermography (IRT) or thermal imaging, is a process where a thermal camera captures and creates an image of an object or living being by using infrared radiation. It relies on the principle that all objects emit infrared radiation in proportion to their temperature (Giannetto et al., 2020). Infrared thermography measures non-invasively radiated electromagnetic energy in the 3 to 12 μm wavelength range (Schaefer et al., 2004). Electromagnetic radiation can be described as a stream of photons, which are massless particles, each traveling in a wave-like pattern and moving at the speed of light, and as the electromagnetic spectrum the wavelengths, of infrared radiation, are wide-range, small changes in temperature can result in amounts of emitted photons that can be detected with great precision using IRT (Stewart et al., 2005). Generally, the images that are taken are of anatomical regions that present high vascularity, such as the orbital, nasal, and perineal regions). However, other regions such as the scapular, masseteric, sacral, umbilical, and scrotal regions may be used (Silva et al., 2023).

Infrared radiation had been described in the year 1800 by Sir William Herschel (Zambrano & Gregorio, 2019) .However, it was not until 1830 that the first detectors for this type of radiation were developed, but it was not until 1960 that it began to be commercialized (G. Gaussorgues & S. Chomet, 1993) . Around the 90s, and with the advancement of technology and information technology, cameras were allowed to evolve more quickly, causing them to be within the reach of a large part of the population (Zambrano & Gregorio, 2019) .

In scientific research, thermography has emerged as a valuable tool for studying the world of mechanics, for example, increased friction develops heat and causes wear which can lead to material failure (Faust et al., 2014) . It is also used in the location of defects in electrical installations, in surveillance at night or low visibility conditions, in the detection of energy losses, among other functions that it presents (Bilbao & Gravía, 2012). As for human medicine, infrared (IRT) has been used as a non-invasive diagnostic method to measure physiological or pathological changes in skin temperature (Schaefer et al., 2004), such as breast cancer, arthritis, vascular disorders, and soft tissue injuries, among others (Bilbao & Gravía, 2012). In the same way, in animal medicine, IRT is being used to detect any disease that causes pyrexia or localized inflammation (Rekant et al., 2016), such as its use in livestock for the detection of mastitis, lameness (Stewart et al., 2005), detect temperature changes in animals infected with Bovine Viral Diarrhea Virus (Schaefer et al., 2004), it can be used as a complementary method for the diagnosis of feline fibrosarcoma (Tolón et al., 2008) . It is capable of detecting animals at risk of bovine respiratory disease complex (BRD), and also identifying true positive and true negative animals (Schaefer et al., 2012) , among other uses that it presents.

OBJECTIVES

The main objective of the present study is to investigate the utility of using IRT at the farm level as a tool to control goat body temperature in the frame of animal welfare. This main objective is divided in short objectives.

1. To investigate the correlation between body temperature measured by thermometer and IRT.
2. To observe if there are temperature differences between different areas of the animal's body.
3. To evaluate the effects of the day of collection and operators.

MATERIAL AND METHODS

Sampling was carried out at the Granja de la Facultad de Veterinaria de la Universidad de Las Palmas de Gran Canaria, which is located in the Campus Universitario Cardones de Arucas, in the city of Las Palmas on the island of Gran Canaria in Spain. The days chosen for sampling were 21, 22, and 23 February 2023, whose temperatures and relative humidity, collected by the Meteoblue.com website, which is a free website initially developed at the University of Basel, Switzerland, in 2002, produces meteorological data at any point on Earth, and can be stored for a period of one year.

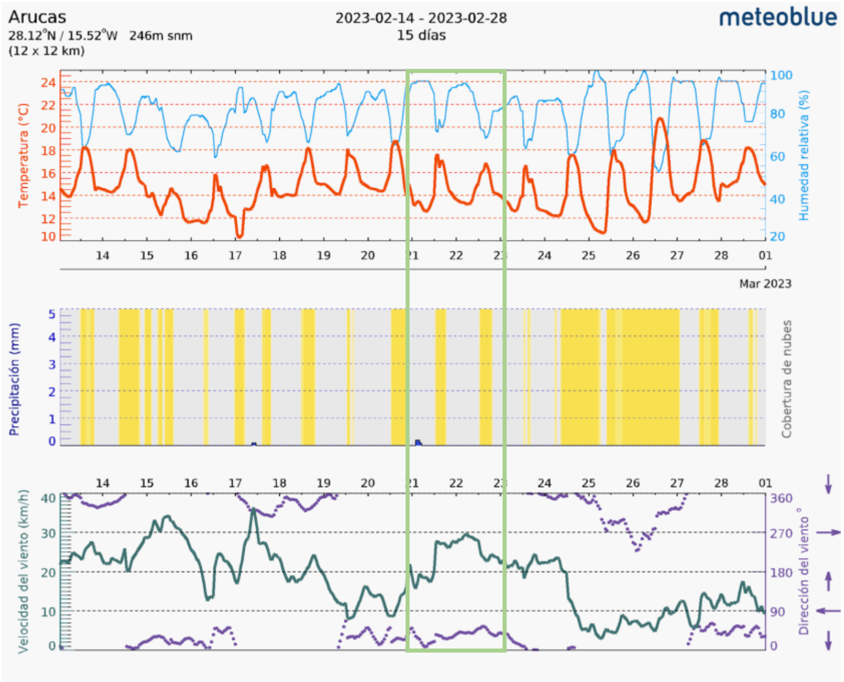

Figure 1: Temperature and relative humidity for the 3 consecutive days according to Meteoblue

The animals used for this work were goat kids of approximately 2 months of age, of the Majorera breed, *Capra aegagrus hircus*. The Majorero goat is a breed of goat native to the island of Fuerteventura and Gran Canaria, in the Canary archipelago. It is widely spread throughout the archipelago, with a larger census on the islands of Fuerteventura and Gran Canaria. A total of 11 animals were used for the work, 4 males and 7 females.

These measurements were taken using the RS PROT DT - 870 (Figure 2) thermographic camera, which has a focal length of 7.5 mm, a temperature range of 20 °C to 380 °C (-4 °F to 716 °F), an accuracy of ±2 °C (±36 °F) or ±2 % of reading (temperature environment 10 °C to 35 °C, object temperature >0 ºC) and a sensitivity of <0.1 ºC + 30 C(+86°F)/100mK.The temperature is then taken by means of a convex thermometer (Figure 3) in the anal area.

Figure 2: Thermal imaging camera PRO RS-870 with WIFI

Figure 3: Digital thermometers.

The areas chosen for temperature acquisition by IRT were the body animal, the head, the eye (Eye), the mouth (Mouth), the head, and the perineum. The maximum (Body max), minimum (Body min), and median (Body median) temperature of the animal's body, the maximum (Head max), minimum (Head min) and median (Head median) temperature of the head and the maximum (Perineum max), minimum (Perineum min) and median (Perineum median) temperature of the perineum were recorded, taking into account that the minimum temperature in the case of the animal's body was the temperature of objects close to the animal. The temperatures were taken on the 3 days by different people, with 3 repetitions per animal. The anal temperature was taken only in two repetitions, as no differences were found between each recording.

Figure 4: Full body photograph

Figure 5: Photograph of temperature uptake in the eye.

Figure 6: Photograph of head temperature capture

Figure 7: Photograph of mouth temperature capture.

The information obtained by the RS PROT DT - 870 Thermographic Camera was transmitted, as it has a Bluetooth instant sharing function, to a smartphone in order to keep the information and perform a quick analysis.

The results obtained were collected in a spreadsheet, where the animal's ear tag number, the person who took it, and the different zones with their respective measurements were indicated.

Using this data and using the Jamovi programme, which is a free application that uses an advanced spreadsheet to perform complex statistical calculations, as well as advanced tests that can be implemented using R, we will obtain tables to organize, summarize and represent the data collected. It also includes the option of installing additional modules to perform more specific tasks, such as Bayesian models or visual analysis, among others (Navarro & Foxcroft, n.d.) .

To be able to obtain conclusions and get relevant information about the data, the following set of statistics observations and tests were used:

1. Basic descriptive statistics observations: median, minimum value and maximum value were used.
2. Shapiro-Wilk test (Shapiro & Wilk, 1965) .A test is used to test the null hypothesis that a sample came from a normal distribution. A significance level of 0.05 and an alternative hypothesis that the distribution is not normal were used. Therefore, if the p-value is lower than the chosen alpha level, the null hypothesis is rejected and there is evidence that the data analyzed are not normally distributed. On the other hand, if the p-value is greater than the chosen alpha level, the null hypothesis cannot be rejected, so the data are from a normally distributed population.
3. Kruskal-Wallis test, also known as H-test (Kruskal & Wallis, 1952). It's a non-parametric test, used when the assumptions of one-factor analysis of variance are not met. Since it is a non-parametric test it is not necessary for the data to have a normal distribution, the only requirement is that the data be ordinal in scale. The Kruskal-Wallis test will use the samples to determine whether or not there is a statistically significant difference between the medians of the independent groups. Therefore, to know if there is a significant difference, the p-value will be assessed, and if the p-value is greater than 0.05, the null hypothesis is maintained, and if the p-value is less than 0.05, the null hypothesis is rejected.
4. Dwass-Steel-Critchlow-Fligner (DSCF) (Kruskal & Wallis, 1952) test. A test to find out which of the pairs differ in the Kruskal-Wallis test, when the hypothesis is invalidated. It's a two-sided nonparametric procedure. To compare the medians of all pairs of the different levels for factors with significance, the null hypothesis is

considered not rejected if there is no significant difference, that is p-value > 0.05, while the null hypothesis is considered rejected if there is a significant difference, that is p-value < 0.05.

RESULTS

In the Jamovi application, a first descriptive table (Table 1) was obtained, in which were obtained the median, maximum value, minimum value, and Shapiro-Wilk test results. This gave an overview of the data characteristics, and whether the data is following a normal distribution or not.

	Rectal	Body max	Body median	Body min	Head max	Head median	Head min	Eye	Mouth	Perin max	Perin median	Perin min
Med	39.4	31.8	24.4	17.0	34.4	28.4	17.3	34.5	32.5	37.3	36.8	19.3
Min	39.0	24.5	16.2	8.10	29.0	15.5	9.70	24.4	25.2	31.4	30.6	10.7
Max	39.9	38.7	33.3	20.8	36.8	35.0	20.1	37.2	35.6	38.6	38.5	23.1
Sha p	0.002	<.001	0.001	<.001	<0.001	0.007	<.001	<.001	<.001	<.001	<.001	<.001

Note. Med: Median, Min: Minimum, Max: Maximum, Sha p: Shapiro – wilk p, Perin: Perineum

Table 1. Descriptive statistics

Based on the collected data, it was determined that none of the measurements obtained using various techniques and devices followed a normal distribution. Consequently, the utilization of parametric methods, such as the Analysis of Variance (ANOVA) test, to understand the differences between the distributions of the different observation factors used, which constitutes one of the objectives of this project, was deemed infeasible.

The Kruskal-Wallis test was employed as a non-parametric alternative to investigate distribution similarities. The project aims to examine differences in three factors: test repetition, the person conducting the measurement, and the sex of the animal. Consequently, the test was executed for each dependent factor, grouped by the three aforementioned factors.
According to the findings presented in Table 2, no significant differences were observed for the repetition factor, except for the minimum perineum temperature (Perineum min).

Kruskal-Wallis	χ^2	df	p
Rectal	1.719	2	0.423
Body max	0.327	2	0.849
Body median	1.441	2	0.487
Body min	0.110	2	0.946
Head max	0.437	2	0.804
Head median	5.851	2	0.054
Head man	0.944	2	0.624
Eye	0.188	2	0.910
Mouth	4.049	2	0.132
Perineum max	3.345	2	0.188
Perineum median	0.805	2	0.669
Perineum min	6.137	2	0.046

Table 2. One-way ANOVA (Non - parametric) in repetition

To determine the different variations among repetitions, a pairwise comparison was conducted using the DSCF test. The results of this analysis are presented in Table 3, indicating a significant difference solely between replicates 1 and 3.

Pairwise comparisons – Perineum min

		W	p
1	2	1.37	0.597
1	3	3.37	0.046
2	3	2.27	0.244

Table 3. Pairwise comparisons – Perineum min

For the person grouping factors, the Kruskal-Wallis test was performed. The null hypothesis was rejected for the following dependent factors: Rectal, Body max, Body min, Hea max, Head min, Eye, Perineum min, Perineum max, and Perineum median. Therefore, there is no significant difference in the distribution of person groups for any of these factors.

Kruskal-Wallis			
	χ^2	df	p
Rectal	10.38	2	0.006
Body max	6.70	2	0.035
Body median	1.91	2	0.385
Body min	21.82	2	< .001
Head max	18.95	2	< .001
Head median	1.43	2	0.490
Head min	30.87	2	< .001
Eye	30.66	2	< .001
Mouth	3.59	2	0.166
Perineum max	13.45	2	0.001
Perineum median	18.14	2	< .001
Perineum min	24.49	2	< .001

Table 4. One-way ANOVA (Non - parametric) in persons

Table 5 displays the results of the DSCF test conducted for the rectal temperature measurement. The findings indicate a significant difference in the distributions of Person 3 and Person 1.

Pairwise comparisons - rectal			
		W	p
Person 3	Person 1	4.669	0.003
Person 3	Person 2	2.928	0.096
Person 1	Person 2	-0.934	0.787

Table 5. Pairwise comparisons - Rectal

Table 6 presents the test results for maximum animal body temperature measured by IRT. It reveals that the only case approaching a potentially significant difference is between Person 3 and Person 2, as it falls near the confidence threshold.

Pairwise comparisons – Body max			
		W	p
Person 3	Person 1	0.835	0.825
Person 3	Person 2	3.320	0.050
Person 1	Person 2	2.886	0.103

Table 6. Pairwise comparisons – Body max

Regarding the minimum animal body temperature measured by IRT, the test results (refer to Table 7) indicate a significant difference in all cases.

Pairwise comparisons – Body min			
		W	p
Person 3	Person 1	3.52	0.034
Person 3	Person 2	6.38	< .001
Person 1	Person 2	3.48	0.037

Table 7. Pairwise comparisons – Body min

However, based on the results of the pairs tests conducted on the maximum head temperature (refer to Table 8), it is evident that the only two groups that show a significant difference are the group consisting of Person 3 and Person 2, and the group comprising Person 2 and Person 1.

Pairwise comparisons – Head max			
		W	p
Person 3	Person 1	0.218	0.987
Person 3	Person 2	5.236	< .001
Person 1	Person 2	5.399	< .001

Table 8. Pairwise comparisons – Head max

Similar to Table 8, Table 9 displays the results of the test for the minimum head temperature, and it confirms the same observation. The only significant difference is observed when comparing individuals to Person 2.

Pairwise comparisons – Head min			
		W	p
Person 3	Person 1	2.66	0.144
Person 3	Person 2	7.31	< .001
Person 1	Person 2	5.66	< .001

Table 9. Pairwise comparisons – Head min

Regarding Table 10, which presents the results obtained from the pairwise test of the eye temperature measurements using IRT, it is observed that all individuals exhibit a significant difference.

Pairwise comparisons - Eye			
		W	p
Person 3	Person 1	-3.86	0.018
Person 3	Person 2	4.30	0.007
Person 1	Person 2	7.64	< .001

Table 10. Pairwise comparisons - Eye

In the case of Table 11, representing the results of the test for the maximum temperature of the perineum measured by IRT, it is evident that only two values demonstrate a significant difference. Specifically, these values correspond to Person 3 and Person 2, as well as Person 2 and Person 1.

Pairwise comparisons – Perineum max			
		W	p
Person 3	Person 1	1.08	0.726
Person 3	Person 2	4.72	0.002
Person 1	Person 2	4.10	0.010

Table 11. Pairwise comparisons – Perineum max

Table 12, which presents the test results for the median temperature of the perineum measured by IRT, reveals that all individuals exhibit a significant difference.

Pairwise comparisons – Perineum median			
		W	p
Person 3	Person 1	2.85	0.108
Person 3	Person 2	5.91	< .001
Person 1	Person 2	3.33	0.048

Table 12. Pairwise comparisons – Perineum median

Table 13 demonstrates the significant difference in only two pairs when examining the minimum temperature of the perineum measured by IRT. Only cases displaying a significant difference are those associated with Person 3

Pairwise comparisons – Perineum min			
		W	p
Person 3	Person 1	6.03	< .001
Person 3	Person 2	5.85	< .001
Person 1	Person 2	-1.85	0.390

Table 13. Pairwise comparisons – Perineum min

Regarding the sex grouping factors, the results of the Kruskal-Wallis test (refer to Table 14) indicates that only the maximum body temperature of the animal and the precise eye temperature exhibit a significant difference, confirming the null hypothesis. Since there are only two groups, and the DSCF test conducts pairwise comparisons, the DSCF test was not conducted for sex, as it would be the same results as those obtained with the Kruskal-Wallis test.

To investigate why the only significant differences in the sex group were observed in the maximum body temperature and precise eye measurements, a descriptive analysis was conducted on the measurements stratified by sex. Specifically, the focus was on median, minimum, and maximum values.

The results revealed that the median temperature in males was higher compared to females. However, when examining the minimum and maximum temperatures, females exhibited higher values in comparison to males. Based on these findings, it can be inferred that while there are variations in these two specific values, there were no significant differences between sexes in the remaining measurements. Therefore, it could be concluded that the sex of the animal does not significantly impact its overall temperature.

Kruskal-Wallis

	χ^2	df	p
Rectal	2.22429	1	0.136
Body max	6.28494	1	0.012
Body median	0.10960	1	0.741
Body min	0.06315	1	0.802
Head max	0.44348	1	0.505
Head median	1.31291	1	0.252
Head min	0.00339	1	0.954
Eye	5.85718	1	0.016
Mouth	0.82080	1	0.365
Perineum max	2.91673	1	0.088
Perineum median	0.80269	1	0.370
Perineum min	0.88103	1	0.348

Table 14. One-way ANOVA (Non - parametric) in sex

Another objective of this study is to investigate the correlation between measurements obtained with a thermal camera and those obtained with a traditional thermometer. Spearman's non-parametric test was employed for this purpose, comparing all camera measurements with rectal measurements (refer to Table 15).

The results reject the test's null hypothesis, providing evidence that the measurements obtained from the thermal camera are not correlated with those obtained from the traditional thermometer.

		Rectal	Body max	Body median	Body min	Head max	Head median	Head min	Eye	Mouth	Perin max	Perin median
Body max	Spe rho	0.138										
	p-value	0.172										
Body median	Spe rho	-0.099	0.416 ***									
	p-value	0.332	<.001									
Body min	Spe rho	0.038	0.639 ***	0.573 ***								
	p-value	0.711	<.001	<.001								
Head max	Spe rho	0.178	0.466***	0.275 ***	0.521 ***							
	p-value	0.078	<.001	<.001	<.001							
Head median	Spe rho	0.120	0.300 **	0.111	0.223 *	0.388 ***						
	p-value	0.237	0.003	0.274	0.027	<.001						
Head min	Spe rho	0.121	0.477 ***	0.330 ***	0.763 ***	0.547 ***	0.161					
	p-value	0.234	<.001	<.001	<.001	<.001	0.111					
Eye	Spe rho	-0.087	0.208 *	0.070	0.282 **	0.317 **	0.064	0.407 ***				
	p-value	0.390	0.039	0.488	0.005	0.001	0.527	<.001				
Mouth	Spe rho	-0218 *	0.264 **	0.318 **	0.337 ***	0.269 **	0.110	0.231 *	0.422 ***			
	p-value	0.030	0.008	0.001	<.001	0.007	0.280	0.022	<.001			
Perin max	Spe rho	0.191	0.424 ***	0.462 ***	0.606 ***	0.458 ***	0.107	0.561 ***	0.394 ***	0.325 ***		
	p-value	0.058	<.001	<.001	<.001	<.001	0.291	<.001	<.001	<.001		
Perin median	Spe rho	0.214 *	0.354 ***	0.488 ***	0.551 ***	0.364 ***	0.040	0.375 ***	0.296 **	0.865 ***		
	p-value	0.034	<.001	<.001	<.001	<.001	0.695	<.001	0.003	<.001		
Perin min	Spe rho	0.158	0.289 **	0.355 ***	0.470 ***	0.309 **	0.153	0.363 ***	0.106	0.290 **	0.539 ***	0.571 ***
	p-value	0.118	0.004	<.001	<.001	0.002	0.130	<.001	0.296	0.004	<.001	<.001

Note. *p<.05, **p<.01, ***p<.001, Spe rho: Spearman's rho, Perin: Perineum

Table 15. Correlation Matrix

DISCUSSION

One point of concern was whether repeatability would have a negative impact on the obtained samples. However, the results revealed the opposite. Through the Kruskal-Wallis test, it was demonstrated that multiple repetitions of the same sample did not have a negative effect. Instead, they provided increased reliability to the sample.

As shown in Table 2, no significant differences were observed except in the case of repetition 1 and repetition 3 for the minimum temperature of the perineum. This difference was further confirmed by the DSCF test. The variation may also be attributed to the distance of the camera from the object. It is possible that in certain photographs, the minimum temperature recorded corresponded not only to the animal but also to the surrounding environment.

One of the groups of factors that was observed to present a greater number of significant differences with respect to the temperatures taken with the camera, this group of factors corresponds to the people who took the temperatures. It was hypothesized that these temperature variations could be attributed to differences in ambient temperature on the days when the measurements were taken. However, upon analysis, it was observed that the temperatures recorded on the 22nd and 23rd days were similar, while only the 21st day displayed a distinct temperature reading.

Considering that the temperature measurements on the 21st day were conducted by person 1, it would be expected that significant differences would only arise in the DSCF test for groups compared to person 1. However, the results obtained from the DSCF tables, which reflect temperatures exhibiting significant differences, indicate differences not only for person 1 but also for person 2 and person 3, at comparable levels. This finding suggests that the temperature on the day of the test may not be the primary factor influencing the observed differences.

Although there are studies that confirm that the time at which the temperature was taken could have a significant effect, with the temperature being higher in the morning shift and lower in the afternoon shift (Roberto et al., 2014).

In another study, a high level of agreement was observed between the results obtained by two examiners. However, in cases where greater differences were noted because they used 5 different models of thermal imaging camera. This discrepancy can be attributed to the lack of a universally agreed rainbow palette, which leads to variations in the thermograms generated by different software provided by manufacturers (Howell et al., 2020)

Considering this, another potential factor contributing to temperature differences in the current study could be the variable distance between the camera and the subject at the time of photographing. Figure 8 and Figure 9 demonstrate different distances, which could notably affect the maximum and minimum temperature readings. The absence of a fixed distance during data captures likely resulted in varying temperatures being recorded.

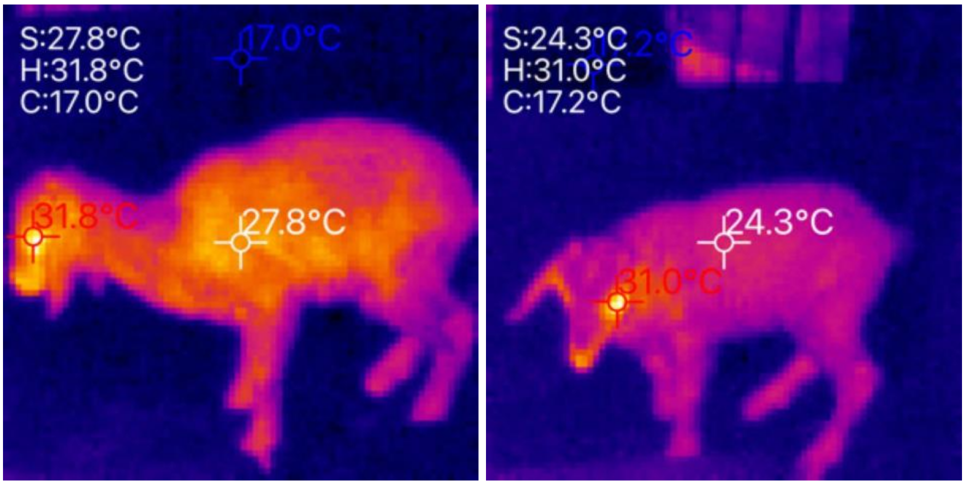

Figure 8 and 9: Full body photography made with IRT

In the context of the sex factor, the Kruskal-Wallis test was conducted to assess its impact on temperature variations. After performing statistical analysis, it was determined that the observed significant differences in the two measured temperatures were not substantial enough to conclude that sex is a significant factor influencing individual temperature variations. However, it is worth noting that other studies conducted on mice have reported that females tend to exhibit increased surface temperatures, particularly in the head and back regions, when subjected to stress due to temporary deprivation of breeding behavior (Faraji & Metz, 2020). This phenomenon could be attributed to higher levels of anxiety and risk assessment in females (Lever C. et al., 2006).

In situations of stress, it is observed that the surface temperature of the head and back in females increases significantly compared to males, while males exhibit a higher temperature increase in the tail (Vianna & Carrive, 2005) .

The results of the study indicate that there is a correlation between rectal temperature measured with a thermometer and the temperatures obtained from the mouth and mean perineal area using infrared thermography (IRT). This correlation can be understood considering that rectal and perineal temperatures are measured in similar areas of the animal's body.

This finding aligns with previous research conducted by (Montanholi et al., 2008), which demonstrated that temperatures could vary throughout the day and heat distribution can be concentrated in different regions of the body. By considering the similarities in temperature patterns and distribution in the rectal and perineal areas, it is reasonable to observe a correlation between rectal temperature measured by a thermometer and mean perineal temperature measured using IRT.

This would also answer the reason why other zones do not correlate with the rectal measurement: as they are measured in different zones in the same time range, the expected temperature values do not correspond.

Furthermore, it is worth noting that the temperature range in this study was relatively narrow. The difference observed between rectal temperature measured by a conventional thermometer and the maximum and minimum temperatures was only 0.9ºC. If the animals had exhibited pyrexia, it would have resulted in a larger temperature range, increasing the likelihood of finding stronger correlations between the measured temperatures.

Indeed, in other studies that perform temperature analysis with IRT on cattle (Hurnik et al., 1985) , the measured temperature values are also comparable with those of other studies using temperature transmitting implants in the pararectal area (Simmons et al., 1965). This suggests that IRT can provide reliable temperature measurements in line with established techniques.

Furthermore, it is notable that the temperatures measured with IRT demonstrate correlations among themselves, with the exception of the mean head temperature.

CONCLUSION

In this study, surface temperatures were measured in various areas of goats using an infrared camera, while rectal temperatures were measured using a digital thermometer. The results showed a correlation between rectal temperature and the temperature of the perineal area, which can be attributed to the proximity of these measurement sites. To enhance future studies, it would be beneficial to include samples from animals with higher temperature variability.

The observed correlation among temperatures measured in different zones using the infrared camera, except for the median temperature of the animal's head, may be explained by the natural temperature fluctuations that occur throughout the day. Animal body temperature can vary depending on the time of day, resulting in differences in temperature readings.

In terms of collection days, minimal differences were observed, suggesting that the selected sampling days did not significantly influence the temperature of the animal. However, the most notable differences were attributed to the observer effect, which may be due to the variability of the distance between the camera and the animal during data collection. Therefore, it is important to take into account and standardize the distance in future research to minimize the observer effect.

In addition, to better distinguish between collection day and observer effects, it would be beneficial to conduct repetition with different individuals. This approach would allow more detailed analysis to determine whether significant differences are mainly influenced by the specific day of collection or by the individual observer.

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