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USING INFRARED THERMOGRAPHIC TECHNIQUE AS AN ALTERNATIVE TO CONVENTIONAL RECTAL THERMOMETER IN SHEEP

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ABSTRACT:

This research was established to assess the precision of the infrared (IR) camera and thermometer in measuring different body regions of sheep. This study was undertaken in the animal farm at the College of Agricultural Engineering Sciences, University of Duhok, Kurdistan Region of Iraq. The temperature was measured from the rectum using a digital thermometer. At the same time, the peripheral temperatures were measured from the ears, muzzle (MUZ), inner thigh (IT), inguinal region (ING), rectum, vulva, and five areas of the eyes, including nasal conjunctiva (NC), nasal limbus (NL), center cornea (CC), temporal limbus (TL), and temporal conjunctiva (TC) using IR thermometer and IR camera. The temperatures obtained from the IR thermometer were higher than those obtained from the digital thermometer. only NC temperature was found to be significantly ($P<0.05$) higher than other eye regions, and rectal and vulva temperatures. IR thermal camera showed no significant differences in the eyes' NL, CC, TL, and TC regions compared to rectum and vulva temperatures using the digital thermometer. The muzzle temperature was significantly ($P<0.05$) lower than all other body parts. In addition, the inner thigh, inguinal region, and ear temperatures were significantly ($P<0.05$) higher than rectum and vulva temperatures. The rectum and vulva temperatures obtained from the IR thermometer were significantly higher ($P<0.05$) than thermal camera and digital thermometer temperatures. In conclusion, thermal cameras as a non-invasive and accurate method can be an alternative temperature measuring method.

KEYWORDS: Infrared, Eye Temperature, Thermal Imaging, Sheep, Rectum.

1. INTRODUCTION

In veterinary medicine, one of the major routine tests performed as a physical examination of animals is measuring their body temperature (Goodwin, 1998). In farm animals, such as sheep and goats, it is a possible indicator of early disease detection (Fuchs *et al*., 2019). Animals' body temperature increases when they suffer stress or diseases; for example, foot and mouth disease and mastitis (Arfuso *et al*., 2022), as well as during some painful husbandry procedures like ear tagging (Zebaria *et al*., 2021).

As a standard practice of measuring the temperature of the animal's body, rectal thermometers are used, mainly because it is inexpensive. However, it has some limitations as it is an invasive method and needs to restrain animals so the animals might be stressed and the readings might be abnormal (Soerensen and Pedersen, 2015). In addition, diseases can be transmitted through this method of rectal thermometry when measuring the temperature of larger groups of animals (Katsoulos *et al*., 2016).

Over the last two decades, the infrared thermal imaging (IRT) technique as a new and non-invasive method has been widely used in research regarding farm animals such as sheep and cattle (Knízková *et al*., 2007; George *et al*., 2014). The purpose of IRT is to early detection of stress, and heat stress and minimize the errors in temperature measurement as it is a non-invasive method (Cai *et al*., 2023). When an animal is in a stressful state, the hypothalamus pituitary adrenal axis is activated to stimulate the release of adrenal steroids and catecholamines; thus, an animal's heat can be lost and is detected by the decreasing surface temperatures (Proctor and Carder, 2016; McManus *et al*., 2016; Weaver *et al*., 2021).

Since the surface temperature of an animal changes during abnormal environments such as illness, and stress; the core body and the infection site temperatures are increased while the peripheral temperature is decreased (Hussein and Al-Naqshabendy, 2024a).

That is mainly because of the vasoconstriction of the surface blood vessels and vasodilation of the infected region of the body (Molony *et al*., 2012). Therefore, this method may accurately detect changes in the thermal status of an animal's body while reducing labor costs and fewer errors (Cai *et al*., 2023). The researchers used different body regions to measure surface temperature, including eyes, ears, nostrils, udder, hooves, and neck (McManus *et al*., 2016). This method has been used to measure positive, and negative emotions and pain caused by diseases like mastitis and foot rot in sheep and goats (McLennan *et al*., 2016; Hussein and Al-Naqshabendy, 2023, 2024a). There is little information regarding the correlation and variation in the temperature of the animal's body between rectal thermometers and IRT using infrared (IR) cameras and thermometers (Ibáñez *et al*., 2023). Therefore, the main purpose of this research was to assess the precision of the IR cameras and thermometers in measuring different body regions of sheep.

2. MATERIALS AND METHODS

Animals and Study Area:

This study was undertaken in the Animal Farm of the College of Agricultural Engineering Sciences, University of Duhok,

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Kurdistan Region of Iraq in July and August, 2024. Twenty healthy, 10 Awassi and 10 Karadi ewes, aged 2 – 4 years, participated in this experiment.

Temperature Data Collection:

The focal sampling was used to collect temperature data individually. Data were collected twice in a week from 9 to 11 a.m. Each animal was restrained and kept still for five minutes to eliminate the stress that might be caused by restraining. After that, the temperature was measured from the rectum using a digital thermometer. At the same time, the peripheral temperatures were measured from the ears, muzzle, inner thigh, inguinal region, rectum, vulva, and five areas of the eyes, including nasal conjunctiva (NC), nasal limbus (NL), center cornea (CC), temporal limbus (TL) and temporal conjunctiva (TC) using IR thermometer and IR camera (FLIR E4). The IR data were measured from a distance of 0.5 m, except for the eye areas, which were collected from a distance of 0.2 m.

Data Analysis:

All the collected temperature data were saved in the new Excel spreadsheet. Then, they were analyzed using the GenStat Software Program (17th edition, VSN International). Data were checked for normality; thus, boxplots confirmed by the Shapiro-Wilk normality test revealed that the temperature data were normally distributed. Thus, they were analyzed using a one-way ANOVA test followed by Fisher's Unprotected LSD test for post hoc comparisons. The Pearson correlation test was used to find the correlation between the temperatures. Unless otherwise stated, data were set as mean ± standard error of the mean, and all the comparisons were stated as significant at $P<0.05$.

3. RESULTS

Eye Temperature:

There were significant differences ($P<0.05$) found between the five selected areas of the eyes measured with the IR thermometer in comparison to rectum and vulva temperatures measured with the digital thermometer. The temperatures obtained from the IR thermometer were higher than those obtained from the digital thermometer collected from the rectum and vulva (Figure 1). The average temperature for NC, NL, CC, TL, TC, rectum, and vulva were 41.9 ± 0.2, 41.7 ± 0.1, 41.2 ± 0.1, 41.3 ± 0.2, 41.1 ± 0.2, 39.7 ± 0.1, and 39.5 ± 0.1 °C, respectively.

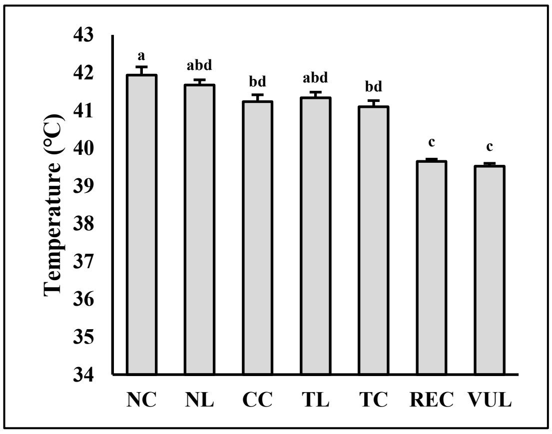

Figure 1: Comparison between five eye areas using an IR thermometer with rectal and vulva temperature. Note: different letters mean significant differences.

According to Figure 2, only NC temperature was found to be significantly ($P<0.05$) higher than other eye regions, and rectal and vulva temperatures. IR thermal camera showed no significant differences in the eyes' NL, CC, TL, and TC regions compared to rectum and vulva temperatures using the digital thermometer (Figure 2). The average temperatures for NC, NL, CC, TL, TC, rectum, and vulva were 40.4 ± 0.1, 39.6 ± 0.2, 39.8 ± 0.1, 39.8 ± 0.1, 39.4 ± 0.2, 39.7 ± 0.1, and 39.5 ± 0.1 °C, respectively.

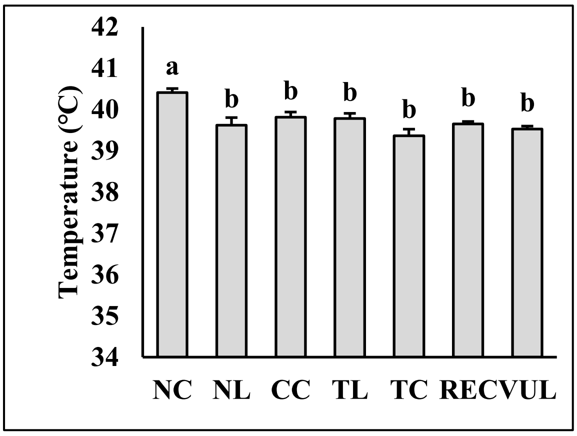

Figure 2: The temperature of five selected eye regions using an IR thermal camera in comparison to rectal and vulva temperatures using the digital thermometer. Note: different letters mean significant differences.

the average eye temperatures using an IR thermometer and IR thermal camera from all selected regions of the eye in comparison to the rectum and vulva temperatures are shown in Figure 3. The mean eye temperature of all selected areas of the eyes using an IR thermometer (41.5 ± 0.1 °C) was higher significantly than the eye temperature measured with FLIR IR thermal camera (39.8 ± 0.1 °C), and rectum (39.7 ± 0.1 °C) and vulva (39.5 ± 0.1 °C) temperatures using the digital thermometer (Figure 3).

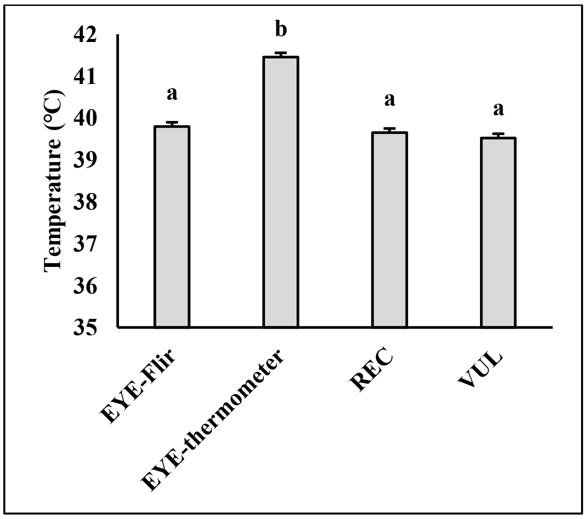

Figure 3: The mean temperature of all selected eye regions compared with rectal and vulva temperatures. Note: different letters mean significant differences. EYE-flir is the eye temperature using an IR camera, EYE-thermometer is the eye temperature using the IR thermometer, and REC and VUL are rectum and vulva temperatures, respectively.

The descriptive statistic data collected from both Karadi and Awassi breeds are shown in Table 1. The minimum temperature was 38.6 °C of TC in Karadi sheep using the FLIR thermal camera, whereas the maximum temperature was 43.6 °C in Awassi sheep using an IR thermometer.

Table 1: The descriptive statistics of the five selected regions of the eyes in both Karadi and Awassi sheep.

Animal Breed	Eye region	Type	Minimum	Maximum	Mean	Median
Awassi	**NC**	**Flir**	39.7	40.5	40.2	40.3
	NC	**Therm**	41.2	43.6	42.2	42.2
	NL	**Flir**	38.8	40.6	39.3	39.2
	NL	**Therm**	41.7	43	42.3	42.2
	CC	**Flir**	38.7	40.4	39.5	39.3
	CC	**Therm**	40.1	42.8	41.4	41.3
	TL	**Flir**	39.1	40.1	39.7	39.7
	TL	**Therm**	40.1	42.6	41.5	41.5
	TC	**Flir**	38.7	39.8	39.2	39.2
	TC	**Therm**	40.1	42.2	41.3	41.3
Karadi	**NC**	**Flir**	39.8	41.3	40.6	40.8
	NC	**Therm**	40.2	42.7	41.7	42
	NL	**Flir**	39.2	41.6	39.9	39.7
	NL	**Therm**	40.1	42.1	41.1	41.2
	CC	**Flir**	39.5	40.9	40.2	40.2
	CC	**Therm**	40.2	42.2	41.1	41
	TL	**Flir**	38.9	41.3	39.9	39.9
	TL	**Therm**	40.2	42.2	41.2	41.1
	TC	**Flir**	38.6	41.6	39.5	39.2
	TC	**Therm**	40	42.3	40.9	40.9

Other Body Region:

The temperatures of other body regions from 2 breeds of sheep obtained by thermal camera are shown in Figure (4). The muzzle temperature was significantly (P<0.05) lower than all other body parts. Similarly, the inner thigh temperature was significantly (P<0.05) lower than all other body parts, except the muzzle.

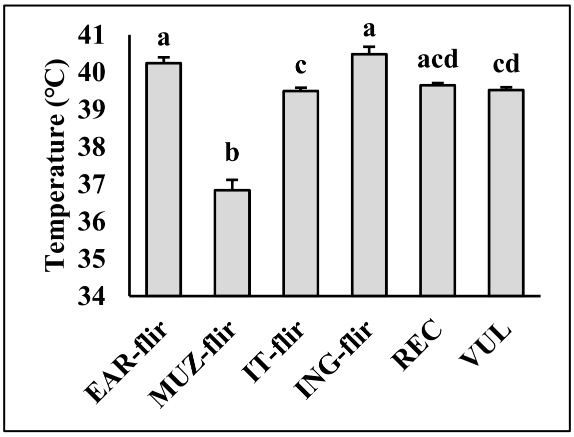

Figure 4: The temperature of body parts from both breeds obtained by thermal camera with rectum and vulva temperatures.

The temperatures of other body regions from 2 breeds of sheep obtained by IR thermometer are shown in figure (5). The muzzle temperature was significantly (P<0.05) lower than all other body parts. In addition, the inner thigh, inguinal region, and ear temperatures were significantly (P<0.05) higher than rectum and vulva temperatures.

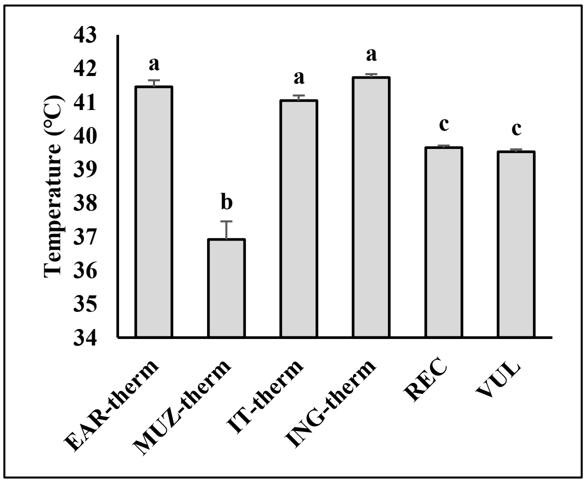

Figure 5: The temperature of body parts from both breeds obtained by IR thermometer with rectum and vulva temperatures.

The comparison between rectum temperatures from all three devices is illustrated in Figure (6). The temperature obtained from the IR thermometer was significantly (P<0.05) higher than the rectum temperature of the digital thermometer and thermal camera. The temperature of the rectum from the thermal camera, IR, and digital thermometers were 39.52 ± 0.1, 39.90 ± 0.1, and 39.65 ± 0.1, respectively.

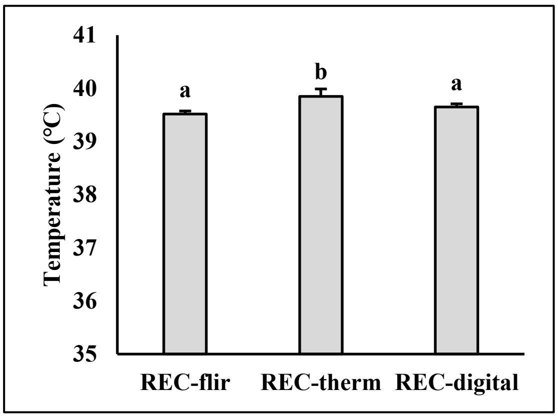

Figure 6: The comparison between rectum temperatures from all three devices.

The comparison between vulva temperatures from all three devices is illustrated in Figure (7). The temperature obtained from the IR thermometer was significantly (P<0.05) higher than the vulva temperature of both the digital thermometer and thermal camera. The temperature of the vulva from thermal camera, IR, and digital thermometers were 39.4 ± 0.1, 40.2 ± 0.1, and 39.5 ± 0.1, respectivel

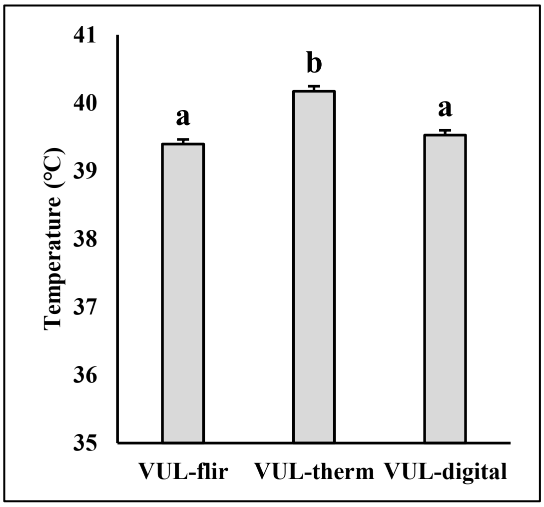

Figure 7: The comparison between vulva temperatures from all three devices.

There were significant differences between other body parts' temperatures in comparison to rectum and vulva temperatures. The muzzle temperature obtained by the FLIR thermal camera in both Karadi and Awassi sheep was significantly (P<0.05) lower than all other measured body parts' temperatures. In addition, inguinal region temperature from the FLIR thermal camera was significantly (P<0.05) higher than rectum and vulva temperatures. Data obtained from the IR thermometer were significantly (P<0.05) higher in all measured body regions than rectum and vulva temperatures (Table 2).

Table 2: The comparison of other body regions' temperatures to rectal and vulva temperatures

Animal	Device	EAR	MUZ	IT	ING	REC	VUL
Awassi	Flir	39.9acd ± 0.1	37.9b ± 0.4	39.3a ± 0.2	40.5c ± 0.2	39.6acd ± 0.1	39.5ad ± 0.1
Karadi		40.51a ± 0.2	35.8b ± 0.5	39.7a ± 0.2	40.5a ± 0.4	39.6a ± 0.1	39.5a ± 0.1
Awassi	Therm	41.4a ± 0.2	37.4b ± 0.6	41.0a ± 0.2	41.8a ± 0.1	39.6c ± 0.1	39.5c ± 0.1
Karadi		41.5a ± 0.2	36.5b ± 0.7	41.1a ± 0.2	41.7a ± 0.2	39.6c ± 0.1	39.5c ± 0.1

Data obtained from the Pearson correlation test found that the correlation between rectum temperatures measured with the FLIR thermal camera and digital thermometer was 0.98, while the correlation between the digital and IR thermometer was weak, which was 0.38. whereas for vulva temperatures, a strong correlation between FLIR thermal camera and digital thermometer was found which was 0.79, while the relation between digital and IR thermometers was 0.06.

4. DISCUSSION

The IR thermal camera was highly correlated with a digital thermometer, whereas the IR thermometer was not. Measuring both rectal and vaginal in addition to the eye temperature using IRT is crucial for animal husbandry and research as the animal is not restricted and the temperature is correctly detected.

The Pearson correlation coefficient between rectal temperatures detected by the IR camera and the digital thermometer was extremely high at 0.98. This high correlation suggests that the IR camera and the digital thermometers provide relatively close temperature readings for rectal temperature measurement. This close agreement agrees with the high accuracy predicted by digital thermometers for measuring the core body temperature (Pecoraro *et al*., 2021), and the ability of the IR camera to capture precise temperature readings as a non-invasive instrument, providing that it is correctly calibrated and used under suitable conditions. Due to their reliability, IR thermography cameras are widely used in animal research to detect diseases such as mastitis and foot rot, stress, and positive affective states such as stroking ewe's body, and to detect ovulation time in oestrus cycles (Arfuso *et al*., 2022; Ozaki *et al*., 2024; Hussein and Al-Naqshabendy, 2023, 2024b).

In contrast, the correlation between the digital and IR thermometer for measuring the rectal temperature was not strong, at 0.38. This lower correlation can indicate an inconsistency between these two types of instruments. IR thermometers are usually less reliable for measuring core body temperatures since they are not designed for core body temperature measurement (Pecoraro *et al*., 2021). This agrees with the results of Niven *et al*. (2015) and Sullivan *et al*. (2021) who stated that IR thermometers are inaccurate in clinical conditions and should not be relied on. This limitation possibly explains the weak correlation between the IR and digital thermometer.

Regarding the vulva's temperature, the correlation between the camera and the digital thermometer was high, which was 0.79. This can indicate that both instruments provide dependable measurements for vulva temperatures, even though they are not as closely correlated as the rectal temperature. However, the correlation between the digital and IR thermometer for vulva temperature was low, only 0.06. This recommends that the 2 instruments provide largely unequal readings for vaginal temperature. The IR thermometer, principally designed for superficial temperature measurements, can be affected by ambient temperature or emissivity settings, contributing to its lower correlation with digital thermometers (Crawford *et al*., 2006). The high correlation found between the IR camera and the digital thermometer for rectal and vaginal temperatures can recommend that these devices are consistent and can be used interchangeably for measuring accurate temperature.

This study measured five different regions of the sheep's eyes, all areas were found to have higher temperatures significantly than rectal and vulva temperatures using the IR thermometer, whereas only NC was higher than rectum and vulva temperatures using the IR camera. The mean eye temperature from the IR camera was similar to those of the rectum and vulva (Figure 3). This indicates that the eye temperature is a dependable region for measuring the sheep body temperature using the IRT of all the five measured regions except NC.

Future research should consider the explanations behind the lower correlation between IR thermometer and digital thermometer devices. Several factors such as calibration, environmental conditions, and the inherent limitations of IR thermometers in capturing accurate core body temperatures might be explored. Moreover, standardizing the emissivity settings and measurement protocols for IR thermometer may improve their consistency and correlation with other thermometer devices.

CONCLUSION

It can be concluded, according to the results obtained, that IR thermal camera is a suitable alternative to digital thermometers. Digital thermometers, while providing the most accurate data, can be invasive and may cause stress to the animal, particularly when used rectally. Thus, thermal cameras as a non-invasive and correct method can be an alternative measuring method. Eye and IT regions can be used to detect core body temperature in ewes.

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Author Contributions

N.J.H., contributed to the methodology, administered the project. M. O., data analysis and curation. F.M.K., formal analysis, developed software, and created visualizations. R.M.F provided essential resources and drafted the initial manuscript. R.S.H., supervised the research. All authors reviewed and approved the final version.

Ethical Statement:

All the procedures for measuring the body temperatures of studied animals were routine health procedures; thus, the animals were not mistreated or abused. Therefore, the Animal Ethics Committee of the College of Sciences, University of Zakho, Kurdistan Region of Iraq ethically approved the research methods with a code of AEC – 028.

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