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## Comparison of skin and rectal thermometry in Sokoto Gudali cattle

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### Abstract

Measuring temperature with a rectal thermometer in conscious animals can be exacting and time-consuming, especially in a herd without adequate restraint. This research compared the accuracy and reliability of non-contact infrared thermometry with the established rectal thermometry in measuring body temperature in cattle. Twenty-one apparently healthy Sokoto Gudali cattle were used for the study. Skin infrared thermometry from four sites across the body (forehead, eye, abdominal region and base of the tail) was compared with rectal thermometry (RT). The parameters were recorded at 07:00 h, 12:00 h and 18:00 h each experimental day. The recordings were carried out twice within three weeks. Environmental parameters, dry-bulb temperature (DBT), relative humidity (RH) and temperature-humidity index (THI) were determined during the study period. The result of the THI was significantly ( $p < .05$ ) increased in the afternoon ( $87.48 \pm 4.0$ ) and evening ( $83.64 \pm 1.2$ ) hours compared to the value obtained in the morning hours, indicating thermal stress. RT was significantly ( $p < .05$ ) increased in the afternoon and evening hours ( $38.56 \pm 0.5^\circ\text{C}$  and  $39.34 \pm 0.4^\circ\text{C}$ , respectively) compared to the value recorded in the morning ( $37.65 \pm 0.4^\circ\text{C}$ ). In comparison to RT, the base of the tail temperature ( $-1.917 \pm 2.0$ ) had the least mean bias difference, while the forehead temperature ( $-2.815 \pm 2.0$ ) was the farthest. In conclusion, rectal thermometry remains a valid means of obtaining the true reflection of the core body temperature. The base of the tail infrared thermometry was the closest to the rectal temperature, but may require further studies to verify its reliability and validity as an alternative to rectal thermometry in cattle.

**Keywords:** Cattle, Critical care, Infrared, Rectal temperature, Skin temperature

### Introduction

Accurate body temperature measurement is pertinent to evaluating health status in veterinary

practice, especially in diagnosing febrile conditions, assessment of physiological status during surgeries

and monitoring during anaesthesia (Sund-Levander M & Grodzinsky). Abnormal increase in body temperature indicates fever and this is commonly reported in animals during routine physical examination with the aid of conventional rectal thermometer (Kahnq & Brundage, 2020). Fluctuations in body temperature may occur during measurement due to diurnal and seasonal changes, different anatomic site of the body, clinical interventions and emergencies (such as open surgeries of large body cavities and trauma) leading to heat loss via conduction, convection, radiation, evaporation and redistribution of blood from core to periphery (Marable *et al.*, 2009; Taylor *et al.*, 2014). Core body temperature is the temperature of the deep tissues (brain, heart, viscera) of the body that must be maintained within a constant range for the optimum function of individual animal. Core body temperature is considered the gold standard, of which rectal temperature (RT) is the least invasive site of measuring core body temperature (Barnason *et al.*, 2012; Allegaert *et al.*, 2014; Kreissl & Neiger, 2015). Other invasive methods for measuring core body temperature include pulmonary artery, oesophageal and bladder measurements (Moran & Mendal, 2002; Farnell *et al.*, 2005; Dunleavy, 2010; Goudie *et al.*, 2020; Dervisevic *et al.*, 2022; Do Nascimento *et al.*, 2024). Infrared thermometry is gaining popularity in animals of various species (Jara *et al.*, 2016), it has been proven to be accessible, accurate and reliable in human (Hughes *et al.*, 1985; Osio & Carnelli, 2007). In cattle, infrared thermometry has been successfully used and variations in the temperature pattern have been reported to be as a result of different body region (Montanholi *et al.*, 2008). Moreover, infrared thermometry has been employed in various analyses concerning animal production, including responses of metabolic activities to thermal stress (do Prado Paim *et al.*, 2013) and inflammatory processes diagnosis (Hovinen *et al.*, 2008). Some studies have also reported measured infrared temperature of the eye in cattle and pig to be related with cortisol, due to altered blood flow caused in this region as a result of stressful conditions (Tan *et al.*, 2009). Previous studies have reported comparison between non-contact infrared and rectal thermometry in various animals using different sites such as rectum, ear canal, rumen and vagina. These studies have reported findings contradictory in some animals (Taylor *et al.*, 2014; Omobowale *et al.*, 2017; Kahnq & Brundage, 2019; Muhammed *et al.*, 2019; Cugmas *et al.*, 2020). One of the factors that influence the variation of skin temperature is body site available, which sometimes

could be challenging due to difficulty in restraining and handling conscious untamed farm animals, especially the temperamental ones. Therefore, validation of consistency and agreement between noncontact infrared thermometry and conventional rectal thermometry must be verified in local breed of cattle like Sokoto Gudali. Hence, this study compares the accuracy of a non-contact infrared thermometer with digital clinical thermometer (rectal) in 21 apparently healthy cattle.

## Materials and Methods

### *Ethical consideration*

The experiment was conducted in accordance with the current guidelines set forth for the ethical care of animals by the Animal Care and Use Ethics Committee at the University of Ibadan, ensuring adherence to ethical standards throughout the study. The study did not require approval number since the study was not invasive.

### *Experimental location of animals and management*

The study was carried in the University of Ibadan, Faculty of Veterinary Medicine farm. Twenty-one apparently healthy cattle were used for the experiment, comprising of 17 females and 4 males, weighing averagely 300 kg. They were housed in the Animal Pen of the faculty of Veterinary Medicine, University of Ibadan. The animals had access to feed and water throughout the experimental period. On each day of the experiment the animals were not grazed, feed was made available so they can be kept for ease of parameters collection.

### *Experimental design*

The parameters [skin (forehead, eye, abdomen and coronary band) and rectal temperatures] were recorded at 07:00, 12:00 and 18:00 h (GMT +1) using an infrared and digital thermometers. The study period covered a period of three weeks; the parameters were measured twice with one week interval during the hot-humid period. The digital thermometer with a 5- cm probe (range 32.0 to 43.9°C; accuracy  $\pm 0.2^\circ\text{C}$ ) and Rycom<sup>®</sup> infrared thermometer (model AR330, Nanjing, Jiangsu, China) range  $-50.0$  to  $100^\circ\text{C}$ ;  $\pm 1^\circ\text{C}$ ) were used for the recordings.

### *Measurement of environmental parameters*

The dry-bulb temperature (DBT) and relative humidity (RH) were recorded on each day of the experiment at 07:00 h, 12:00 h and 18:00 h, using a digital temperature and humidity recorder (Haryana,

India), temperature-humidity index (THI) was determined using the formula by Yan *et al.* (2021):

$$\text{THI} = (1.8 \times \text{Tdb} + 32) - (0.55 - 0.0055 \times \text{RH}) \times (1.8 \times \text{Tdb} - 26)$$

Where, Tdb = dry-bulb temperature (°C)

RH = relative humidity

#### Measurement of rectal and skin temperature

Measurements of rectal temperature (RT) and body surface temperatures (BSTs) were recorded twice at 07:00h, 12:00h and 18:00h, respectively, with one week interval. Two personnel took the RT and BST measurements simultaneously. Briefly, each cattle was restrained lightly and RT was recorded with a standard digital clinical thermometer (Krusser Thermometer®, Amazon, Berlin, Germany) within 2 minutes.

Measurements of the body surface (forehead, eye, abdomen and base of the tail) temperatures were performed by a non-contact infrared thermometer (Model: JXB-181, Guangzhou Jinxinbao Electronic Co., Ltd, China). The distance of the cattle's skin from the camera was < 0.5 cm for each temperature measurement, and the camera was positioned at an angle of 90° (Chan *et al.*, 2004). The landmarks for the infrared measurement for each of the body parts were as follows:

- (i) Forehead: os frontale (frontal bone) (Peng *et al.*, 2019).
- (ii) Abdomen: area of skin covering muscles between the caudal border of the scapula and the vertical line defined by tuber coxae, excluding the area of m. pectoralis transversus (Domino *et al.*, 2020).
- (iii) Eye: area around the posterior border of the eyelid and the caruncula lacrimalis (Bartolome *et al.*, 2013).
- (iv) Base of the tail: area under the base of the tail, area between the coccyx and tuber ischii in the caudal region (Song *et al.*, 2019).

#### Statistical analyses

GraphPad Prism, version 8.02 for Windows (GraphPad Software, San Diego, CA, USA, www.graphpad.com.) was used for the analyses. Data were expressed as mean ± standard deviation of the

mean (Mean ± SD). The data were normally distributed (Kolmogorov-Smirnov test). Since the data were parametric, one-way analysis of variance (ANOVA) was used for the analysis followed by Tukey's post-hoc test to compare mean values. The relationship between thermal environmental parameters, RT and BST were evaluated by Pearson's correlation (r) analysis. The level of agreement between the RT and body surface temperature (BST) values was determined by a Bland-Altman plot. Receiver operating characteristic (ROC) analysis was used to evaluate the accuracy of the BST measurements. The area under the curve (AUC) value indicates the accuracy of the measurements. Values of  $p < 0.05$  were considered significant.

#### Results

Table 1 shows the environmental parameters during the experimental period. The DBT rose from  $24.80 \pm 1.0^\circ\text{C}$  in the morning hours to  $36.15 \pm 4.6^\circ\text{C}$  in the afternoon hours. The DBT values were not significantly different across the day ( $p < .05$ ). The value of the RH recorded during the experiment was higher in the early morning hour ( $80.5 \pm 0.7\%$ ) compared to the values obtained in the afternoon ( $56.5 \pm 10.6\%$ ) and evening ( $58.5 \pm 7.8\%$ ) hours, respectively, though not significantly ( $p < .05$ ) different. The THI values recorded in the afternoon ( $87.48 \pm 4.0$ ) and evening ( $83.64 \pm 1.2$ ) were significantly ( $p < .05$ ) higher than the value recorded in the morning ( $66.47 \pm 0.8$ ).

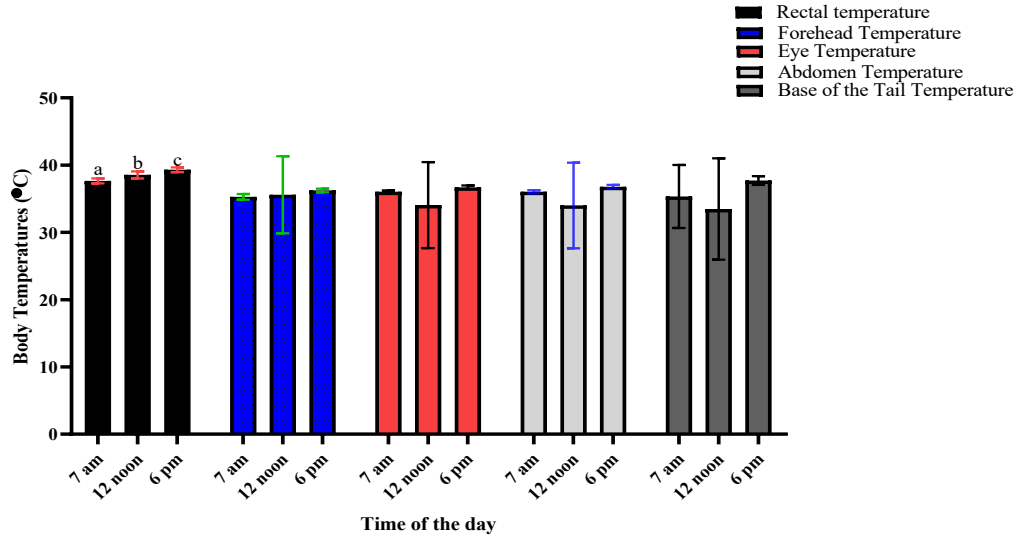
The diurnal fluctuation of body temperatures is shown in Figure 1. The RT values increased significantly ( $p < .05$ ) from  $37.65 \pm 0.4^\circ\text{C}$  in the morning hours to  $39.34 \pm 0.4^\circ\text{C}$  in the evening. The skin temperatures (forehead, eye, abdomen and base of the tail) were not significantly ( $p < .05$ ) different through the hours of the day. The values recorded in the afternoon for eye ( $35.15 \pm 5.6^\circ\text{C}$ ), abdomen ( $35.07 \pm 5.6^\circ\text{C}$ ) and base of the tail ( $34.93 \pm 6.7^\circ\text{C}$ ) were lower than the values obtained in the morning ( $36.10 \pm 0.2$ ,  $36.03 \pm 0.3$ ,  $35.73 \pm 4.0^\circ\text{C}$ ) and evening ( $36.70 \pm 0.3$ ,  $36.75 \pm 0.3$ ,  $37.71 \pm 0.6^\circ\text{C}$ ) hours, respectively.

**Table 1:** Environmental parameters during the study period

Parameters	7:00	12:00	6:00	$p = \text{value}$
DBT (°C)	$24.80 \pm 1.0$	$36.15 \pm 4.6$	$32.95 \pm 1.9$	0.063
RH (%)	$80.5 \pm 0.7$	$56.5 \pm 10.6$	$58.5 \pm 7.8$	0.087
THI	$66.47 \pm 0.8^a$	$87.48 \pm 4.0^b$	$83.64 \pm 1.2^b$	0.007

<sup>a, b</sup> = Values with different superscript letters along the same row are significantly ( $p < 0.05$ ) different.

Note: DBT = dry-bulb temperature, RH = relative humidity, THI = temperature-humidity index



**Figure 1:** Diurnal fluctuations in rectal and skin temperatures of cattle (n = 21) Different superscript letters <sup>a,b,c</sup> indicate significant ( $p < 0.05$ ) difference in the times of measurements.

**Table 2:** Correlation of environmental parameters with body temperatures in cattle (n = 21)

Parameters	Coefficient of Correlation (r)
Dry-bulb temperature and rectal temperature	0.7275*
Dry-bulb temperature and forehead temperature	0.5514*
Dry-bulb temperature and eye temperature	-0.3955 <sup>ns</sup>
Dry-bulb temperature and abdomen temperature	-0.3515 <sup>ns</sup>
Dry-bulb temperature and base of the tail temperature	-0.0366 <sup>ns</sup>
Relative humidity and rectal temperature	-0.8502**
Relative humidity and forehead temperature	-0.7074*
Relative humidity and eye temperature	0.2034 <sup>ns</sup>
Relative humidity and abdomen temperature	0.1568 <sup>ns</sup>
Relative humidity and base of the tail temperature	-0.1644 <sup>ns</sup>
THI and rectal temperature	0.7951*
THI and forehead temperature	0.6354*
THI and eye temperature	-0.2975 <sup>ns</sup>
THI and abdomen temperature	-0.2520 <sup>ns</sup>
THI and base of the tail temperature	0.0678 <sup>ns</sup>

\*\* =  $P < 0.01$ , \* =  $P < 0.05$ , <sup>ns</sup> =  $P > 0.05$

Table 2 shows the relationships between body temperatures and environmental parameters. Rectal temperature and forehead temperatures were significantly ( $p < .05$ ) and positively correlated with DBT (0.7275 and 0.5514, respectively) and THI (0.7951 and 0.6354, respectively), while relationship between rectal and forehead with RH were significant ( $p < .05$ ) but negatively correlated (-0.8502 and -0.7074, respectively). The relationships of the other skin (eye, abdomen and base of the tail) temperatures with the environmental parameters were not significant.

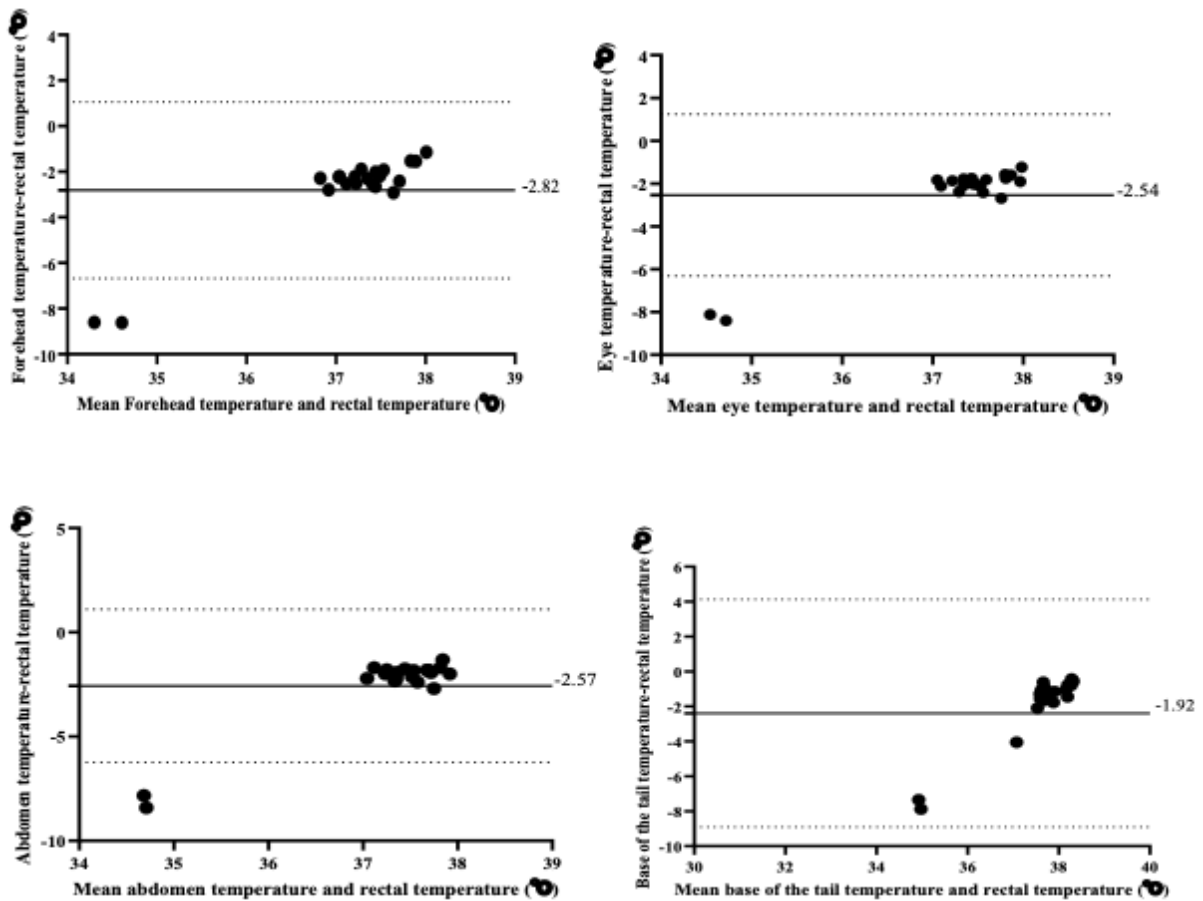
The mean differences between rectal temperature and skin (forehead, eye, abdomen and base of the

tail) temperatures of cattle are shown on Table 3, while the Bland Altman plots for comparison of the level of agreement between rectal temperature and skin temperatures are shown in Figures 2. The mean difference between rectal temperature and skin temperatures varies from  $-2.815 \pm 2.0$  (forehead) to  $-1.917 \pm 2.0$  (base of the tail) in the cattle.

The area under the curve (AUC) values, the comparison between rectal and skin temperatures is shown in Figure 3. The AUCs for rectal temperature and skin temperatures were all at the highest accuracy (AUC = 1.0, with P values of 0.0001).

**Table 3:** Differences in mean measurements of rectal and skin temperature in cattle (n = 21)

Temperature parameters	Differences (bias) between measurements	
	Mean $\pm$ SD ( $^{\circ}$ C)	95 % Limits of agreement
Rectal and forehead	-2.815 $\pm$ 2.0	-6.68 to 1.05
Rectal and eye	-2.537 $\pm$ 1.9	-6.32 to 1.24
Rectal and abdomen	-2.568 $\pm$ 1.9	-6.24 to 1.10
Rectal and base of the tail	-1.917 $\pm$ 2.0	-5.91 to 2.08

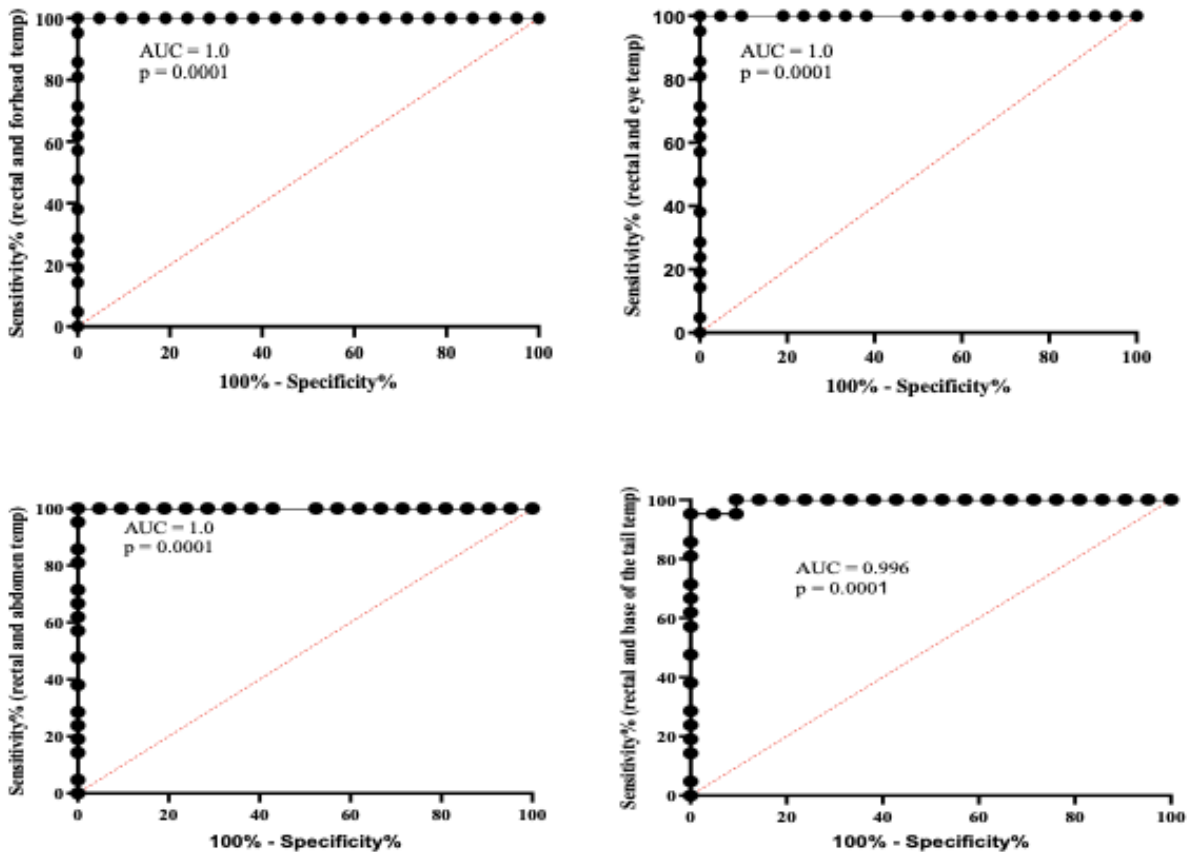


**Figure 2:** Bland-Altman plots for comparing the differences between skin temperatures (forehead, eye, abdomen and base of the tail) and rectal temperature in cattle. The thick black line at the center represents the mean difference and the dash lines represents range of agreement, bordered by the upper and lower limits of agreement

**Discussion**

Southwest Nigeria is generally known for high rainfall duration compared to the northern part of the country, with a shorter period of rain (Ibebuchi & Abu, 2023). Consequently, the southwest of Nigeria has a longer period of high humidity (Akinbode *et al.*, 2008; Layi-Adigun *et al.*, 2020), and therefore can be

very stressful in terms of the thermodynamic mechanism of heat loss. The relative humidity (RH) values recorded in this study were not significant across the day. The dry-bulb temperature (DBT) recorded during this study period was lower in the early morning compared to the values recorded in the afternoon and the evening of the experimental



**Figure 3:** Receiver operating characteristic analysis curve for the accuracy of rectal versus skin temperatures (forehead, eye, abdomen and base of the tail) cutoff. The area under the curve for forehead, eye, abdomen and base of the tail temperature are 0.1, 0.1, 0.1 and 0.996

Note: AUC = Area under the receiver operating characteristic curve. Low accuracy = 0.50-0.70, fair accuracy = 0.70-0.90, and high accuracy = > 0.90.

period. At higher DBT and lower RH, the cattle were able to lose heat easily to the environment with less stress. But the values of THI recorded in this study in the afternoon and evening periods indicated that the cattle were exposed to thermal stress, especially in the afternoon and evening hours. The finding indicates that the afternoon and evening period was stressful to the cattle and could result in deleterious effects in the animals' well-being and eventually production parameters.

Body temperature measurement is used as an index of the health status of humans and animals. The result of the rectal temperature (RT) in this study shows that the parameter fluctuated throughout the day. The value of RT in the early morning was significantly lower than the values obtained in the afternoon and evening periods. This result showed that rectal temperature increased as the air temperature increased during the day. It is of interest to note,

however, that the value of RT obtained in the evening hour was significantly higher than the value recorded in the afternoon hour, though the THI was highest in the afternoon hour; this may be as a result of heat radiation from the cattle surroundings. Despite the fluctuations in the environmental heat sources, the RT values obtained in the current study were largely within the established normal range (36.7 – 39.2°C) for cattle in Nigeria.

Skin temperature is also referred to as peripheral temperature, which is largely reported to be greatly influenced by environmental parameters (Romanovsky, 2014; Bakony *et al.*, 2023). The results of the different regions of the body (forehead, eye, abdomen and the base of the tail) recorded in this study, though, were not significantly different across the day, still reflected the significant influence of the fluctuations in the environmental parameters. Of note were the afternoon hours recordings, which

were lower when compared to the evening hours values.

Invasive RT measurement over the years has been used as a gold standard for the measurement of core body temperature in animals (Balhara *et al.*, 2024; Zhao *et al.*, 2024). It has limitations in situations where direct contact with animals is largely restricted and in cases of time constrain in situations where a large number of animals are to be handled, and may contribute to the thermal stress experienced by the animals (Smith *et al.*, 2023). The use of infrared thermometers to measure skin temperature is increasingly becoming common; it is fast and easy to record (Balhara *et al.*, 2024; Korelidou *et al.*, 2024).

The values of the rectal temperature recorded in this study were generally consistent and within a narrower range when compared to the values obtained using an infrared thermometer. The infrared thermometry values fluctuate widely as the environmental temperature fluctuates. This result is in agreement with the previous findings that body surface temperatures fluctuate largely with the changes in the environmental conditions (Omobowale *et al.*, 2017; Ake *et al.*, 2023). The finding is consistent with the effects of the thermoregulatory activities of homeotherms. Core body temperature is represented by the rectal temperature recorded by inserting a rectal thermometer into the rectum of the cattle for a while until an alarm sound is heard indicating the end of the recording. The RT is regulated by thermoregulatory system in the body, including the hypothalamus, the brain center that coordinate and integrate the information received from thermoreceptors and effectively send signals to the effector organs (Blood vessels in the skin, sweat glands and skeletal muscles) to either lose or conserve heat (Grodzinsky & Sund Levander, 2020). By this, the RT is kept relatively within a narrow range despite the fluctuations in the conditions of the environment. However, the skin temperature reflects the body temperature due to metabolic activities or changes in the environmental temperature, and consequently, the variations observed in the rectal and infrared thermometry.

Eye temperature has been previously reported to be the most reliable of the body surface temperatures and a good predictor of rectal temperature measurement (Ake *et al.*, 2023; Balhara *et al.*, 2024). The results of the study show that the value of the base of the tail temperature were much closer to the RT values than the eye temperature or any other parts of the body used in this study. This finding indicates that the base of the tail temperature is

closer and could be a better predictor of body temperature when non-invasive thermometry is used in cattle. It is therefore recommended that studies involving the use of the base of the tail infrared thermometry be carried out in other animals relative to other regions of the body.

The results of the correlation of body temperatures with environmental parameters revealed that RT and forehead temperatures were significantly correlated compared to other parts of the body. This may be an indicator of the sensitivity of the RT and forehead to changes in environmental influence. The finding is in agreement with the result obtained by Chen *et al.* (2022) that the forehead temperature was strongly correlated with the ambient temperature. This finding may be subject to further investigations to substantiate the result. The eye and base of the tail results may have been because these regions of the body are not directly exposed to the direct effect of the air temperature. Although the abdominal region is exposed directly to ambient temperature effects, the large surface area and sweating effect may reduce the value of temperature recorded in this region of the body.

The mean bias difference obtained in the skin temperatures recorded in the cattle, with the lowest mean bias difference recorded in the base of the tail temperature, indicates that infrared thermometry values may not be interpreted directly to replace rectal thermometry. The findings suggest that the base of the tail temperature was the closest to the RT rather than the eye temperature recorded in some other animal species by other studies (Bartolome *et al.*, 2013; Balhara *et al.*, 2024).

The high AUC accuracy results recorded in the cattle indicate that skin temperature may be a reliable predictor of core body temperature in the cattle, but never a replacement for rectal thermometry. This is because the skin temperature values were largely influenced by the prevailing thermal environmental conditions (Periard *et al.*, 2021).

In conclusion, the afternoon and the evening period were thermally stressful as indicated by both RT and skin temperature recorded during the period. Rectal thermometry remains a valid means of obtaining the true reflection of cattle's core body temperature. The base of the tail infrared thermometry was the closest to the rectal temperature; therefore may be the closest predictor of the body temperature values in the cattle.

Overall, the study confirms that rectal thermometry remains the gold standard for measuring core body temperature. The result of the study suggests that the

base of the tail temperature recorded with an infrared thermometer is fast, valid and closest to the rectal temperature in cattle and therefore, could serve as a reliable alternative in situations where quick, non-contact measurement is required.

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#### Conflict of Interest

The authors declare that they have no conflict of interest.

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