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Assessment of Rectal Temperature using Infrared Thermal Camera in Pigs

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Abstract

Objective: To develop substitute measures for assessing accurate Rectal Temperature with an Infrared Thermal Imaging Camera in pigs. **Methods:** In the experiment, three different genetic groups were used: Hampshire, crossbred (Hampshire X Niang-Megha) and Niang-Megha. Apparently healthy 90 adult pigs (1-3 years) consisting 30 numbers from different group were used for each season; namely, summer (July) and winter (December). Thermal images were taken at different anatomical body sites. Appropriate anatomical sites were selected based on close association with rectal temperature (T_{rectal}). Developed a constant correction factors (CF) as a substitute measures using selected sites and validated for assessing accurate T_{rectal}. **Findings:** Base of the Ear Temperature (T_{ear}) and Eye Temperature (T_{eye}) were highly correlated with T_{rectal}. The correction factor was developed as substitute measures for assessing rectal temperature using base of the ear and eye temperature. Accordingly, the rectal temperature was recorded ranging from 36.45 to 38.25°C with T_{ear} and 35 to 38.2°C with T_{eye} based on the developed correction factor. **Novelty:** Developed correction factors as a substitute measures for accurate assessment of rectal temperature by non-invasive techniques by measuring base of the ear and eye temperature with an infrared thermal imaging camera.

Keywords: Rectal temperature; Correction factor; Infrared thermography; Swine; Disease

1 Introduction

Body temperature and its variations are essential indications of an animal's physiological health, stress level and well-being among other physiological measures. Stress generated by elevated body temperatures is a major constraint for farm animal output [1]. Temperature measurement is an effective means to assist in diagnosis and pig health monitoring. Thus, it is important to monitor the body temperature as closely as possible for early detection and treatment of economically important diseases of pigs [2]. In conventional method of measuring body temperature, the use of a mercury column/digital thermometer is considered as the gold standard. However, this method is invasive, requires restraining and handling which is challenging in backyard farming system as well as in wild animals and it often causes stress to the animals. In recent years, the livestock industry has adopted infrared thermography widely to enhance animal health, welfare, and productivity as well as to monitor the condition of the animals on a daily basis, increase cost-effectiveness, and boost production efficiency[(3)]. An advantage of using thermal imaging is its high resolution, non-invasive and ability to contrast variation in body surface temperature[(4)]. This technology successfully studied for research in laboratory, companion and large farm animals[(5)]. In veterinary medicine, the technology was mainly accepted based on its capability to measure changes in animal surface temperature which may be associated with underlying physiological[(6)] and behavioural processes and mechanisms[(7–9)]. This technology has also been successfully studied different important diseases such as lameness in cattle[(10,11)] identify sick or stressed pigs[(12)], heat stress in sheep[(13)]. It has been used to detect non-diseased conditions including pregnancy and reproduction[(14,15)].However, only a few studies have investigated the use of infrared thermography as a tool to monitor temperature as an alternative to rectal temperature in pigs. According to recent researchers, the orbital, base of the ear, inner thigh, udder and abdomen are the reliable locations to use infrared thermography to determine the core body temperature in pigs[(16–20)].However, Farrar et al[(18)] stated that infrared thermometry tended to underestimate rectal temperatures at lower values, and overestimate rectal temperatures at higher values by approximately (±) 0.8 °F of rectal temperature. Only few studies investigate the correlation between body surface temperature and rectal temperature. The study by Schmid et al[(20)] highlighted that temperatures assessed with the camera, found that inner thigh and abdomen correlated most closely to core temperature. A study in sheep showed that the forehead and eye IRT temperatures had the highest correlation with rectal temperature[(13)]. The correlation between the ear and body temperature seems highly dependent on where the skin temperature is measured, as ear flap is an important thermoregulatory area, while other areas such as the ear base and ear canal area may be considered as thermal windows. Some studies found a much higher correlation between the body and skin temperature of the ear base compared to the ear tip[(21,22)]. In the study by Barbieri et al[(19)], a significant correlation between rectal and eye temperatures was found in weaners pig. However, Magnani et al[(23)], observed a low correlation coefficient between the eye and body temperature in response to a stressor in pigs.

At present, the correction factor (CF) as a substitute measures for accurate assessment of body temperature utilising infrared thermography as an alternative to rectal temperature has not yet been developed. Therefore, the objective of the present study was to select suitable sites based on the correlation between T_{rectal} and body surface temperature at different body sites and develop CF to assess accurate body temperature using infrared thermal imaging camera (T_{camera}) in pigs as an alternative to rectal temperature.

2 Methodology

The experimental procedures were reviewed and approved by the Institutional Animal Ethics Committee (IAEC), ICAR-RC for NEH Region, Meghalaya. The animals were humanely treated during our study.

2.1 Study location

The experiment was conducted in Pig Breeding Farm, Division of Livestock Production of the Institute (2019-20). It is located at 24° 58' N to 26° 07' N latitudes and 89° 48' E to 92° 51' E longitudes with an altitude of 1010 meter above sea level.

2.2 Animals and experimental design

An experiment was conducted separately for summer (July) and winter (December) in three different genetic groups viz, Hampshire, crossbred (Hampshire x Niang Megha) and Niang Megha (indigenous). In each season, a total of 90 pigs were taken for the study, with each genetic group consisting 30 numbers of apparently healthy adult pigs between 1-3 years. These pigs were reared under pen system of housing and provided with uniform managemental practices. Regular vaccination and deworming were carried out as per the standard procedures. Thermal images were taken twice daily between 9-11AM and 3-5PM for 6 days for each pig, With an environmental temperature range of 22 to 26°C in summer and 19 to 22°C in winter. All thermal images were captured using a thermal imager - Testo 875i (Testo India Pvt. Ltd. Pune, India). The emissivity of 0.95 was taken as standard emissivity of pig body surface in the study. The measurement of the body surface temperature was taken on five different anatomical sites viz, tip of the snout, eye, back temperature at lumbar region, base of the ear on the neck and inner thigh above the hock joint. Rectal temperature was measured in the rectum using Digital Thermometer (DT) with proper restraining of pigs to avoid stress. The thermographic images were analyzed using the software IRSoft Version 3.6 Testo (Testo India Pvt. Ltd. Pune, India). This software enabled to measure the temperature of specifically selected sites by simply defining them within each image and represented in Figure 1. The rectal temperatures were compared with the body surface temperatures.

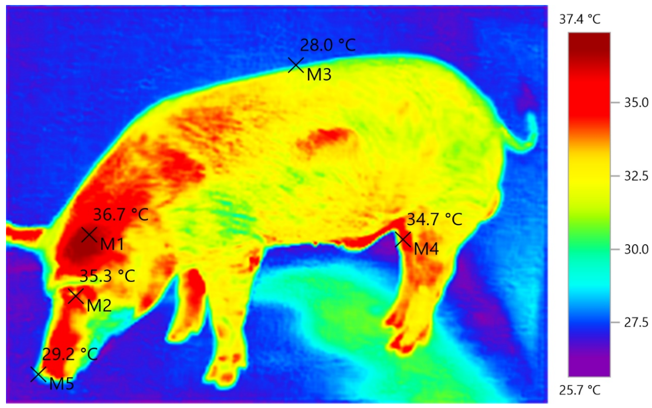

Fig 1. Overall view of thermal image of temperature gradations over different anatomical sites; (M1) base of the ear, (M2) eye, (M3) back, (M4) inner thigh and (M5) snout. Representative figure in the month of July (summer) in crossbred pig.

2.3 Statistical analysis

All statistical analysis was performed using SPSS statistical software (SPSS 14, 2006). The data obtained from the selected anatomical sites and T_{rectal} of three different genetic groups were subjected to multivariate analysis to find out the significant level. The values were compared among the sites, genetic groups and seasons. For each site, the average T_{rectal} and body surface temperature was calculated. The correlation between T_{rectal} and body surface temperature of the selected sites in both summer and winter were calculated using correlation coefficient. Suitable sites were selected, based on the correlation between T_{rectal} and body surface temperature of different sites of the body. Accordingly, constant correction factors (CF) was established to assess the rectal temperaturein pigs using infrared thermography camera. Further, the CF was validated by conducting an experiment for 6 days with the same animals, breeds and seasons and predicted the rectal temperature on the identified sites.

3 Results and discussion

The rectal temperature of domestic animal remains relatively constant but body surface temperature varies according to the environmental temperature. However, few anatomical sites maintain temperature close to the body temperature. This study aimed to identify suitable anatomical sites and develop CF for accurate body temperature assessment utilizing infrared thermal imaging camera as an alternative to rectal temperature. The baseline rectal temperatures in our study ranged from 36.19°C to 38.8°C for all the pigs evaluated. The average rectal temperature and body surface temperature from various anatomical sites of an experimental animals at different seasons are given in Table 1. Rectal temperature did not show significant differences between the seasons or among the genetic groups in the study. However, the body surface temperature obtained with T_{camera} give significantly ($p<0.01$) lower readings compared to the rectal temperature. Similar finding was reported in various studies earlier[4,18,19,24,25]. The temperature recorded by T_{camera} at base of the ear, inner thigh and eye were found to be significantly ($p<0.01$) higher among other parts of the body in the study confirmed earlier work[17,20].Higher surface temperature at these sites could be due to the thinner skin and lower subcutaneous fat thickness resulting in greater heat dissipation from these sites. Barbieri et al[19], suggested eye could be used to estimate core body temperature in farm condition. Similar to what was previously reported[17], the surface temperature of the snout and back had the coolest temperature. The presence of thick layer of fat and higher hair density on the back which acts as insulation and presence of moisture in the snout area causing cooling evaporation could be the reason for lower temperature at these sites. Also, temperature differed significantly ($p<0.01$) between summer and winter season in the surface temperature of snout and back. This is because ambient temperature affects body surface temperature. Therefore, in order to interpret temperature results clearly, external environmental and physical parameters must be controlled in the design of experiments. These factors can have a negative impact on infrared thermography data gathered in the field[26].

Some studies investigated the correlation between rectal temperature and body surface temperature measured by infrared thermography. As previously reported, thermal temperature of base of the ear, inner thigh and eye regions showed positive

Table 1. Rectal temperature (°C) using digital thermometer and body surface temperature (°C) using infrared thermal imaging camera (mean ± SE)

Sites	Summer (July)			Winter (December)		
	Hampshire N=30	Crossbred N=30	Indigenous N=30	Hampshire N=30	Crossbred N=30	Indigenous N=30
Rectal temperature	37.8 ± 0.12^{aA}	37.5 ± 0.14^{aA}	37.7 ± 0.12^{aA}	37.17 ± 0.11^{aA}	37.19 ± 0.13^{aA}	37.59 ± 0.10^{aA}
Base of the ear	33.75 ± 0.11^{bB}	34.25 ± 0.13^{bB}	34.9 ± 0.24^{bB}	32.35 ± 0.21^{bB}	32.94 ± 0.13^{bB}	32.66 ± 0.2^{bB}
Inner thigh	32.75 ± 0.23^{cB}	33.25 ± 0.15^{cB}	32.3 ± 0.22^{cB}	31.57 ± 0.14^{cB}	32.10 ± 0.31^{cB}	31.54 ± 0.16^{cB}
Eye	32.9 ± 0.16^{dB}	33.85 ± 0.11^{dB}	32.8 ± 0.21^{dB}	32.24 ± 0.31^{dB}	32.87 ± 0.14^{dB}	32.68 ± 0.21^{dB}
Snout	26.5 ± 0.05^{eC}	27.7 ± 0.07^{eC}	27.9 ± 0.02^{eC}	21.72 ± 0.04^{fC}	22.04 ± 0.06^{fC}	21.85 ± 0.01^{fC}
Back	27.4 ± 0.07^{gC}	28.2 ± 0.04^{gC}	28.8 ± 0.08^{gC}	21.84 ± 0.06^{hC}	22.11 ± 0.03^{hC}	21.53 ± 0.02^{hC}

Different superscript in rows and columns indicate the significant difference ($p<0.01$). Capital letter in superscripts has been used for column wise comparison and small letter for row wise comparison, N=number of pigs.

correlation with the rectal temperature in the present study (Table 2). According to Soerensen and Pedersen[27], the skin measurement sites for highest correlation to body temperature are the ears, eyes and udder. Schmid et al[20], found that inner thigh and abdomen correlated most closely to core temperature when assessed with the camera. Stukelj et al[4], however, established three anatomical regions in healthy pigs: the ear canal, the outer ear, and the perianal region, for predicting the body temperature. Zhang et al[28], observed high association between rectal temperature and the base of the ear. Similar, Schmitt & O'Driscoll[22] in their study, rectal temperature was correlated with all infrared thermography (IRT) data and found correlations were strongest with the ear base, and weakest with the ear tip and minimum back temperature. In another study, a significant correlation between rectal and eye temperatures was observed in weaners pig[19]. Indeed, the close relation between body temperature with base of the ear and eye temperature could be due to its close proximity to the brain, also due to the low fat deposition and lesser bristle density in these regions enhancing heat dissipation[19].

Table 2. Correlation (r-value) between rectal temperature and body surface temperature measured with infrared thermal imaging camera

Sites	Summer (July)			Winter (December)		
	Hampshire	Crossbred	Indigenous	Hampshire	Crossbred	Indigenous
Rectal temperature	37.8 ± 0.12	37.5 ± 0.14	37.7 ± 0.12	37.17 ± 0.11	37.19 ± 0.13	37.59 ± 0.10
Base of the ear	0.84^{aA}	0.87^{aA}	0.84^{aA}	0.90^{aA}	0.91^{aA}	0.85^{aA}
Inner thigh	0.67^{bB}	0.7^{bB}	0.74^{bB}	0.76^{bB}	0.72^{bB}	0.7^{bB}
Eye	0.85^{cA}	0.84^{cA}	0.86^{cA}	0.87^{cA}	0.78^{cA}	0.83^{cA}
Snout	0.41	0.51	0.42	0.4	0.5	0.4
Back	0.36	0.38	0.4	0.34	0.45	0.47

Different superscript in rows and columns indicate the significant difference ($p< 0.01$). Capital letters in superscripts used for column wise comparison and small letter for row wise comparison.

In our study, two anatomical sites were selected (base of the ear and eye) for assessment of the rectal temperature based on the close relation with T_{rectal} in pigs. Prediction of body temperature using thermal image camera has been earlier reported[3]. Additionally, this technology has been used successfully to monitor piglet temperature as an alternative to rectal temperature[20] and estimate core body temperature in weaning and fattening pigs[19]. However, Farrar et al[18], stated that infrared thermometry tended to underestimate rectal temperatures at lower values, and overestimate rectal temperatures at higher values by approximately (±) 0.8 °F of rectal temperature. Thus, the aim of our work was to develop a correction factor in order to obtain the precise rectal temperature using a non-invasive technique from the appropriate anatomical sites. Therefore, in our study, we took average temperature of rectal and two selected sites of all the breeds and found out the correction factor (CF= average T_{rectal} - average T_{ear} or T_{eye}) and presented in Table 3 . Accordingly, the CF recorded for the ear and eye were 4 and 4.6 respectively. We calculate the rectal temperature for all the temperature measured with the T_{camera} and obtained rectal temperature for base of the ear by using the formula, ($T_{rectal} = T_{ear} + CF$) and eye ($T_{rectal} = T_{eye} + CF$). In view of that, the study recorded the T_{rectal} ranged from 36.45 to 38.25°C and 35 to 38.2°C in different genetic groups using T_{ear} and T_{eye} respectivelyand average values were calculated and presented in Table 4 . Thus, the highlighting factor of our study is that, the rectal temperature of pigs can be accurately assessed by non-invasive method with the used of correction factor developed in the study on the selected anatomical sites.

Table 3. Average rectal and thermal temperature of selected sites and calculated correction factor (CF)

Sites	Summer (July)			Winter (December)			Average	CF
	Hamp- shire N=30	**Cross-bred N=30**	**Indige-nous N=30**	**Hamp-shire N=30**	**Crossbred N=30**	**Indige-nous N=30**		
T_{rectal}	37.8	37.5	37.7	37.17	37.19	37.59	37.49	-
T_{ear}	33.75	34.25	34.9	32.35	32.94	32.66	33.48	***4.0**
T_{eye}	32.9	33.85	32.8	32.24	32.87	32.68	32.89	***4.6**

*Correction Factor (CF)=Average T_{rectal} – Average T_{ear} / T_{eye}

Table 4. Validation of the rectal temperature (°C) based on T_{ear} and T_{eye} using infrared thermal imaging camera (mean ± SE)

Genetic groups	Summer (July)			Winter (December)		
	T_{rectal} using DT	**T_{rectal} using T_{ear} + CF**	**T_{rectal} using T_{eye} + CF**	**T_{rectal} using DT**	**T_{rectal} using T_{ear} + CF**	**T_{rectal} using T_{eye} + CF**
Hampshire N=30	37.8±0.02	37.25±0.05	37.2±0.07	37.2±0.01	36.45±0.1	36.3±0.08
Crossbred N=30	37.3±0.03	37.85±0.02	38.2±0.07	37.5±0.02	36.9±0.06	37.1±0.05
Indigenous N=30	37.5±0.05	38.25±0.07	37±0.02	37.6±0.04	36.59±0.08	35±0.06
Average	37.53±0.15	37.78±0.29	37.47±0.37	37.43±0.12	36.65±0.13	36.13±0.16

T_{ear} = base of the ear temperature, DT=digital thermometer, T_{eye} =eye temperature, CF= correction factor, N = number of pigs, CF for T_{ear}= 4 and CF for T_{eye} = 4.6.

The overall mean differential value of T_{ear} was approximately within (±) 0.8°C of the corresponding rectal temperature. However, the T_{eye} of T_{camera} tend to be lower than rectal temperatureby 0.06°C in summer and approximately 1.3°C in winter. Thus, base of the ear and eye temperature measurements were considerably reliable indicators of rectal temperature with thermography technique using the developed CF in the present study. Indeed, the wide variation between the season can be due to the external environmental factors as it was mention earlier by Church et al [26], that external factor can have negative impact on infrared thermography. Barbieri et al [19], suggested that eye can be used as a precise, noncontact alternative to T_{rectal} measurements for monitoring core body temperature in swine. However, measuring body temperature at the eye could be difficult because of the movement of the eyelid (closing and opening). Therefore, base of the ear is considered the suitable site for measuring body temperature by infrared thermography as it is relatively easy to access and more correspond to rectal temperature in our study.

4 Conclusion

In conclusion, we have confirmed from our study that infrared thermal imaging of body surface (base of the ear and eye) with correction factors (base of the ear = 4 and eye = 4.6) could be used as an alternative method to assess T_{rectal} accurately. Using these correction factors as an alternative methods, abnormal health status of the pigs can be recorded rapidly, avoiding the stress of restraining pigs during conventional method of measuring body temperature. However, further validation is required in large number of pigs at different season for enhancing accuracy.

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