Research Article

Heat Detection of Gilts Using Digital Infrared Thermal Imaging Camera

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Abstract | The body temperature of livestock animals can be the main parameter for measuring their health and well-being, such as proestrus, estrus, and pregnancy. The control of estrus and ovulation has become the main topic for a batch of flow management, and the failure to detect estrus accurately has the greatest impact on labor rate and little size. Digital infrared thermal imaging (DITI) technology can easily recognize and detect animals' temperature changes, which would be useful in farm animal production. This study investigates the possibility of replacing a contact thermometer with a non-contact thermometer and digital infrared thermal imaging camera (DITI) to detect the estrus of gilts. Seven gilts (129.21±2.51kg) were considered for this experiment. Each gilt was fed 5 ml of synthetic progesterone for 18 days, and the anus temperature was measured using the contact thermometer, non-contact infrared thermometer, and DITI camera FLIR E76. The temperature of the vulva during proestrus and estrus was measured using a DITI camera FLIR E76. As a result, there was no significant difference ($p>0.05$) in the anus temperature using the thermometer, non-contact infrared thermometer, and DITI camera FLIR E76. Moreover, the average vulva temperature during estrus was 34.5°C and proestrus was 33.7°C with a difference of 0.8°C. The temperature range and the value differences between proestrus and estrus suggested that the DITI camera could be a new technology for heat detection in gilts.

Keywords | Temperature, Proestrus, Estrus, Thermal camera

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INTRODUCTION

The sound health of livestock animals is essential for high productivity and good economic returns. The body temperature of farm animals is a very important parameter for ensuring their physiological health and well-being. For example, various physiological changes such as proestrus, estrus, pregnancy, breastfeeding, parturition, etc., can affect the body temperature (Neethirajan, 2017). The skin's surface works as a heat-radiating cooling system, allowing thermal imaging to quantify temperature gradients accurately. Changes in blood flow and tissue angiogenesis can affect the skin's surface temperature under physiological circumstances. Moreover, body temperature is an important parameter when assessing animal health (Süli et al., 2017). Information on body temperature is very useful in diagnosing and treating diseases in animals. It enables the early detection of infected animals and the investigation of the disease's scope and severity. With the correct recognition and rational use of physiological indicators of changes in body temperature in pigs, early detection, diagnosis, and treatment of several pig diseases are possible. (Zhang et al., 2019).

In recent years, the control of estrus and ovulation has become the main topic for a batch of flow management, which requires a pool of females service-ready for Artificial Insemination at set times. Additionally, the swine industry needs to develop new technologies that can maintain estrus and ovulation. Failure to detect estrus accurately has the greatest impact on labor rate and little size (De Rensis and Kirkwood, 2016; Kraeling and Webel, 2015). By measuring body temperature, it can accurately identify the sow's estrus, so that it can be fertilized in timely breeding to improve the reproductive rate of sows. Temperature changes in pregnant sows are monitored in real-time, which serves to determine their health. Depending on body temperature, it is possible to increase the birth rate of sows by organizing appropriate breeding tasks (Polit, 2018).

Infrared thermography (IRT) is a non-destructive examination method for determining an object's symmetric and asymmetric surface temperatures. Infrared cameras collect infrared radiation produced from the surface and convert it to electrical impulses, resulting in thermal pictures that depict the body's surface temperature distribution (Irenilza et al., 2020). Furthermore, infrared thermometry (IRTM) is a non-contact temperature measuring technique with various benefits over other temperature monitoring techniques used in veterinary medicine. Even though handling the patient is unnecessary, with infrared (IR) temperature monitoring, the danger of infection is greatly reduced. This is helpful in animals since handling and constraint cause stress, which affects core and surface temperatures. (Soerensen and Pedersen, 2015). Infrared thermography (IRT) can be used for rapid screening of foot lesions in sheep (Talukder et al., 2015). In Veterinary medicine, IRT has been successfully used in many applications such as foot and mouth disease (Rainwater-Lovett et al., 2008), clinical mastitis (Hovinen et al., 2008, Polat et al., 2010, Martins et al., 2013), bovine respiratory disease (Schaefer et al., 2007; Schaefer et al., 2012), and to test for detection of oestrus in dairy cows (Talukder et al., 2014b). Changes in the surface thermal image of a normal horse can be used to detect claudication or inflammation. Thermal imaging has been used to diagnose inflammation as well as to evaluate several other clinical syndromes (Figueiredo et al., 2013). Therefore, DITI can easily recognize and detect temperature changes and can be used as a means to detect and monitor normal and abnormal physiological phenomena (Sykes et al., 2012). In livestock, DITI has been used for assessing fertility in rams and bulls, monitoring heat in dairy cattle, diagnosing leg and foot problems in horses and cattle, characterizing the responses of cattle to freeze branding and hot-iron, and evaluating thermal comfort in poultry (Bowers et al., 2009).

The pig anus temperature can be said to be the temperature measurement area that best represents the pig body temperature. And pig body temperature is mainly measured by inserting a thermometer directly into the anus. However, traditional temperature monitoring methods based on core organs (heart, intestine, and brain) and rectal tubes, on the other hand, have a number of drawbacks, including a wide range of temperature measurement variations and the risk of disease transmission via equipment or device, all of which cause discomfort and waste consumables (Neethirajan, 2017; Lin et al., 2019). Therefore, recently, attempts have been made to easily measure the body temperature of pigs through a non-contact method. Pig body temperature can also determine a pig's physiological condition. Recently, an attempt has been made to measure the temperature using a non-contact digital infrared thermal imaging camera (DITI) and to detect the physiological condition of pigs through the temperature measurement results. Therefore, the goal of this study was to investigate the possibility of replacing a contact thermometer with a non-contact thermometer and digital infrared thermal imaging camera (DITI), and the detection of estrus using a DITI camera in gilts.

MATERIAL AND METHODS

Animal and housing

The experiments on the heat detection of gilt using digital infrared thermal imaging cameras were performed for 30 days in winter from 20 December 2021 to 19 January 2022 at the Sunchon National University Experimental Farm, South Korea. The experimental group comprised a total of 7 gilts of around 8 months of age (129.21±2.51kg). The females were crossbred [(Landrace White x Yorkshire) x (Duroc)], Individually housed in 2 x 0.60 meter stalls with temperature and humidity control. The diet used in the study was designed to match NRC's nutritional recommendations (1998) (Table 1). Throughout the study, the pigs had unlimited access to feed and water. The gilts were orally administered with synthetic progesterone daily for 18 days for estrus synchronization. After 24 hours, each

Table 1: Composition (%) of the experimental diet

Ingredient		Gilts
Yellow Corn		55.00
Rice Bran		3.00
Unpolished rice		5.00
Rapeseed oil meal		3.00
Soybean meal		18.16
[1]DDGS		6.00
Meat and bone meal		1.60
Beef tallow		3.16
Molasses		2.50
Salt		0.30
Limestone		1.00
Calcium phosphate		0.20
[2]Vitamin-mineral, premix		0.20
Choline chloride (50%)		0.05
Amino acid additive		0.88
Total		100.00
Chemical composition (%)		
Crude protein		16.00
Crude fat		3.50
Crude fiber		9.00
Crude ash		10.00
Calcium		0.55
Phosphorous		1.50
Lysine		0.50
Digestible crude protein (DCP)		11.00
Digestible energy (DE)	Kcal/Kg	3 200

[1]Distillers Dried Grains and Soluble; [2]Each kilogram contains vitamin (V) A 6000 IU; VD3 800 IU; VE 20 IU; VK3 2mg; VB1 2mg; VB2 4mg; VB6 2mg; VB12 1mg; pantothenic acid 11mg; niacin 10mg; biotin 0.02mg; copper 21mg; iron 100mg; zinc 60mg; manganese 90mg; iodine 1.0mg; cobalt 0.3 mg; selenium 0.3mg.

gilt was injected with PMSG (Pregnant Mare's Serum Gonadotropin) to induce ovulation in livestock before artificial insemination. After injecting PMSG for 72 hours, each gilt also got hCG (human Chorionic Gonadotropin) for progesterone production, which helps prepare the uterus lining for implantation. The first artificial insemination was performed after 36 hours of hCG injection, and the second artificial insemination was performed after 12 hours of the first insemination. Day 1 was defined as the day when gilts were orally given progesterone hormone. The electronic ventilation system's thermostats controlled the room temperature, and the temperature was recorded whenever thermal imaging was carried out.

Infrared thermography

The anus temperature of gilts was directly measured using a thermometer (model, MT200, PR Korea). In order to measure the gilt anal temperature in a non-contact manner, a Korean non-contact (NC) infrared thermometer and a digital infrared thermal imaging camera FLIR E76 (FLIR Systems Inc. Boston, MA, USA) were used. The measurement distance between the non-contact thermometer and the pig anus was 30 cm, and the temperature was measured for 7 days using 7 heads of gilts. The experimental gilts were raised in a house with a temperature of 24°C and humidity of 40%. The anus temperature of gilts was measured following the administration of progesterone hormone (5ml per head), and the individual gilt was considered as replication. The vulva and anus temperature of the pig were recorded using infrared thermal cameras (Advanced Thermal Imaging Camera FLIR E76 with the emissivity set at 0.95). Anus temperature was measured with a MT200 high-performance digital thermometer at the time of imaging. From day 1 to day 18, gilts were monitored one time a day at 10:00 am by using different infrared thermal imaging cameras. After getting an oral daily dose of synthetic progesterone for 18 days, gilts were monitored after every 6 hours at 04:00 AM, 10:00 AM, 04:00 PM, and 10:00 pm from day 19 to day 22 during the proestrus period. The period from day 23 to 26 was considered estrus period. The body temperature of the gilts was measured using the Advanced Thermal Imaging Camera (FLIR E76) taken at a distance of 1 m from the gilts. Thermal images were recorded from December 2021 to January 2022, with average room temperatures ranging from 10.7°C to 24.6°C, respectively. Maximum (MAX), minimum (MIN), and average (AVG) temperatures were determined using vulva and anus thermal images from designated areas of interest (Figure 1).

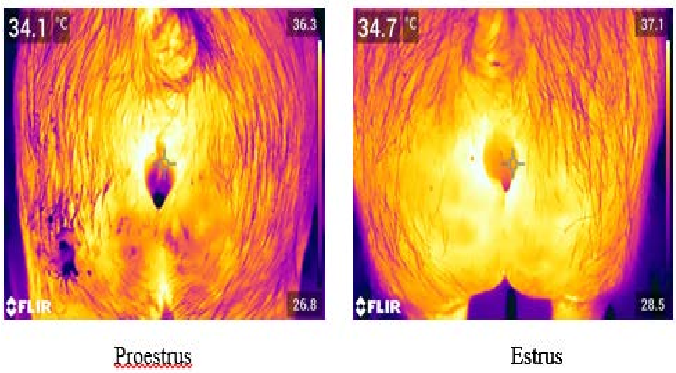

Figure 1: The circle defined the region of interest from which anus and vulva thermal measurements in gilts were determined. The maximum, minimum, and average temperature values of representative gilts in estrus are shown for the thermal image above

Statistical analysis

All data were submitted to one-way analysis (ANOVA) using the Statistical software IBM SPSS statistics 21 to determine differences between proestrus and estrus in thermal signatures. The data are presented as standard error means, and the probability values of $p<0.05$ were considered significant.

Table 2: Detection of anus temperature (°C) of pigs using thermometer, non-contact infrared thermometer, and FLIR imaging camera

Body part	Thermometer	NC-Thermo.[2]	FLIR[1]	SEM	*p*-Value
Anus	37.5	37.9	37.3	0.12	0.155

SEM, standard error means n=7

[1] Advanced Thermal Imaging Camera FLIR E76

[2] Non-contact (NC) infrared thermometer

Table 3: Temperature (°C) of Anus and Vulva taken by FLIR camera during first 18 days

Thermal Camera	Anus	Vulva	SEM	*p*-Value
FLIR[1]	35.1	35.2	0.146	0.775

P-value for different ($p < 0.05$)

SEM, standard error means n=7

[1] Advanced Thermal Imaging Camera FLIR E76

Table 4: Vulva Temperature (°C) of gilts taken by FLIR camera during the proestrus and estrus period

Thermal Camera	Temperature	Proestrus	Estrus	SEM	*p*-value
FLIR[1]	MIN	26.5[a]	29.4[b]	0.547	<0.0001
	MAX	35.8[a]	36.9[b]	0.168	<0.0001
	AVG	33.7	34.5	0.216	0.061

[a,b] means that number in the same row with different superscripts are significantly different ($p < 0.05$) with the gilt's vulva regardless of stage of pro-estrus and estrus.

SEM, standard error means n=7

[1] Advanced Thermal Imaging Camera FLIR E76

MIN: minimum temperature, MAX: maximum temperature, AVG: average temperature

RESULTS AND DISCUSSION

The anus temperature of gilts measured using a thermometer, non-contact infrared thermometer, and FLIR E76 is presented in Table 2. As shown in Table 2, the anus temperature of gilts using FLIR had no differences with the thermometer, non-contact infrared thermometer, and a digital infrared thermal camera (FLIR E76). No significant differences were observed in the temperature measurements with DITI camera FLIR E76 with an ordinary thermometer. Therefore, we considered DITI camera (FLIR E76) as the smart tool for the rest of the trail. In the study by Petry et al. (2017), infrared imaging (IR) technology can be used as precise. Swine and other animals, including wildlife, can monitor their core body temperature with a non-contact alternative.

The temperature of the anus and vulva measured by using FLIR is presented in Table 3. As shown in Table 3, the temperature of the anus and vulva taken by FLIR camera has no significant different ($p>0.05$). This study enabled us to assess differentiated gilts' thermal imaging during the proestrus and estrus period. Blood flow to the vulva via the internal pudendal artery increases during estrus due to increased circulating estradiol from growing follicles. This increase in blood flow also raises the vulva's surface temperature. Anatomically, the vulva of the gilt is more conspicuous than that of other livestock species, and it is not blocked by the tail, making changes in surface area temperature gradients easy to detect. (Frandson et al., 2003).

Table 4 shows the vulva temperature taken by the FLIR camera during the proestrus and estrus period. The MIN and MAX temperature of gilts during the proestrus period is significantly lower ($p < 0.05$) than during estrus. The AVG temperature of vulva is not significantly different ($p > 0.05$).

Studies using infrared technology for estrus detection and estimating ovulation time in dairy cows have shown mixed results. In 2012, a study conducted by Talukder et al. (2014) showed whether infrared thermography temperature monitoring could be used to identify estrus and estimate ovulation time in dairy cows. In that study, the results revealed that out of 20 cows, only 12 cows were ovulated, seven cows weren't ovulated, and one cow developed cystic ovarian disease based on the temperature prediction detected by infrared thermography. In another study, 12 sows of two parities were considered in the winter season while the temperature was the indicator for ovulation (Jeong et al., 2016). The vulva and rectum temperature measurement was conducted after the pig got 5 ml regumate (estrus synchronization agent) for 15 days. At the same time, vulva and rectal temperatures were higher than on other days. The mean vulva and rectal temperature of heated sows was 38.8 °C, while that of unheated sows was 38.7 °C.

The vulva and rectum thermal temperature detection differences might have been caused by the house's ambient temperature and environment. Environment conditions such as airflow and temperature can affect the accuracy of thermal images. The suggested ideal temperature for obtaining thermal images of the skin surface is approximately 20-30°C (Love et al., 1976; Turner et al., 1986). Regardless of the fact that ambient temperature remained in the acceptable range (less than 25.8 °C), there was a greater difference between estrus and diestrus at an ambient temperature below 20 °C. At 21.4 °C, changes in vulva thermal temperature between estrus and diestrus were identified, but not at an ambient temperature of 12.1 °C, according to Jones et al. (2005). The reason for the failure to distinguish estrus from diestrus at this temperature range is unknown; possibly, the quantity of heat generated by the body is reduced at this temperature range. At ambient temperatures below 10 °C, the greatest variations in vulva thermal gradients were detected. These findings conclude that the most significant barrier to reliable thermal gradient measurements in the environment. Thermal gradients are affected by various factors, including ambient temperature, air movement, moisture, and debris (Cravello et al., 2008). Another study on estrus detection in Chinchilla lanigera using FLIR C2 thermal imaging camera showed a clear difference with and without a confirmed estrus of *Chinchilla lanigera*. The temperature of the external genital region rises dramatically during estrus, obviously due to genital congestion. This finding may be utilized to non-invasively diagnose estrus, which is crucial because this species lacks conventional estrous behavior (Polit et al., 2018).

CONCLUSION

In light of the findings, the anus of gilts can be the temperature measurement area that best represents the pig body temperature. There was no difference in the temperature measurement using a thermal imaging camera from the temperature measured directly with a thermometer. Moreover, when a sow exhibits estrus, the vulva temperature rises compared to the non-estrus state. A significant difference was observed in the vulva temperature of gilts during proestrus and estrus using the thermal imaging camera, with a difference of temperature rises by 0.8°C in estrus compared to proestrus. The temperature range and the value differences between proestrus and estrus suggested that the DITI camera could be a new technology for heat detection in gilts. It is recommended to use digital infrared thermal imaging technology in the swine industry to detect heat with its effectiveness.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article.

NOVELTY STATEMENT

Previous research has never been done on using digital infrared thermal camera FLIR E76 for heat dection on gilts. This study found a possible way of using this technology in the swine smart farming.

AUTHORS CONTRIBUTION

The authors contributed equally to the manuscript.

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