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Research Article

Development of Infrared Temperature Sensor for Use among Sow Herds

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Abstract

Presently, digital technology has become an important contributor to the developing concept of smart agricultural tools, especially with sensor monitoring to health status. In the livestock industry, the body temperature of farm animals must be monitored to prevent the occurrence or progression of any disease amongst the herds. In our device called the Inspect, we have employed infrared sensors to detect the fever status of sows. Systemic architecture and data flow systems have also been designed for workers to use on large-scale pig farms. The body temperature of 100 gestating sows was determined with the use of a standard thermometer (inserted into the rectum), while our device known as the Inspect was used on each part of the body of the sows. The valva or anus was found to be that location because of the high correlation that was observed between the two measurements (R = 0.78). Moreover, regular and systematic inspections were employed for a full year in 2019 on commercial pig farms that were home to at least 300 sows. The pig production values of 2018 and 2019 were compared before and after employing the Inspect. The results indicated that the production indexes of the after period (2019) were better than those of the before period (2018), especially in terms of the health status of the animals with regard to mg/PCU. Accordingly, the after period recorded mg/PCU values that were less than the before period. Consequently, it was determined that this system could detect abnormal signs in livestock before they could become a bigger problem or result in an outbreak of a disease. However, this system should be further developed and integrated with the use of artificial intelligence or AI for beneficial applications of 'smart agriculture' in the future.

Keywords: *Infrared Temperature Sensor; Inspect; Sow; Body Temperature*

Abbreviations

PWM: Pre-Weaning Mortality; AI: Active Ingredient; PCU: Population Correlation Unit; AW: Average Weight at Treatment; mg: Milligram

Introduction

The swine industry continues to develop resulting in increased pig populations on farms. Consequently, it has become difficult to manage and monitor the health status of pigs. When swine farms transition into large holder pig farms, the operators of these swine farms must invest in a range of systematic advancements to improve upon management and to help them survey the health status of the pigs. For example, necessary investments related to cost production enhancements should include those associated with labor costs, feed costs, facilities costs of farm operations and also the cost of monitoring the health status of the animals or robust disease surveillance systems [1]. Large swine farms have to control disease outbreaks because they can lead to high losses in production, which could impact large-scale farms far more than median or small holder pig farms. Thus, the operators of these pig farms need to prevent disease outbreaks and to continuously survey the threat of diseases upon their farms [2].

The first abnormal signs of potential infection by an agent is that a pig will have a fever or show a temperature change [3]. Therefore, body temperature can be a good indicator in the monitoring of the health status of these animals and in the monitoring of a potential outbreak of disease on a farm before it becomes a full blown event. This type of monitoring is commonly referred to as syndromic surveillance. The Participatory One Health Disease Detection (PODD) System involves the concept of initially monitoring the health of a single participant who can be assumed to represent all stakeholders along the chain of epidemiology. This is implemented by a user or reporter through the use of an application on a mobile phone [4]. However, it can be very difficult to monitor the body temperature of a pig within a large farm. In the pig industry, farms are home to many pigs so it is difficult to monitor the body temperature of each pig by rectal temperature measurement. Rectal temperature measurement is commonly used to measure the temperature of farm animals because it is considered an extremely accurate form of monitoring an animals' temperature [5]. However, rectal temperature measurement also contributes to a high risk of spreading disease agents to other pigs. This is because healthy pigs can become infected by the agent that can remain on the surface of this tool [6]. Thus, the use of contact thermometers may be responsible for spreading infection on livestock farms.

That is why there is a need to develop a non-contact thermometer that could measure the animals' temperatures easily and quickly and without direct contact with the animals [7]. Many researchers have reported that infrared technology can be used in non-contact thermometers to measure the temperature of animals [8-10]. The concept of infrared thermometry (IRTM) involves the use of non-contact thermometers that can reduce or eliminate the need for direct contact between the thermometer and the animal, which is known to contribute to disease outbreaks among livestock. The implementation of IRTM can reduce the levels of stress animals incur as a result of the excessive amounts of handling and restraint that are often necessary on pig farms. Notably, these increased levels of stress can have an effect on both core and surface temperatures [11]. However, our device makes it easier to monitor an animal's body temperature and it can contribute to the creation of a more comprehensive automated monitoring system. IRTM offers many benefits, but there are still a number of weak points associated with it. Notably, there is a relationship between surface temperature and ambient temperature. Thus, the accuracy of the body temperature value can be influenced by incidental contact with some areas of the skin from which hair may be growing, which can influence the accuracy of the measurement recorded by IRTM [12]. Moreover, body temperature measurements obtained from pigs will be very useful if a system is established that can make on-site assessments and then remotely report to vets who are assisting in the monitoring of the potential for disease outbreaks on farms.

Objective of the Study

The objective of this study was to develop an infrared temperature sensor that does not involve contact with the animal and also to combine it with an automatic wireless transmission system that can be used on sows.

Materials and Methods

Test animals and farms

The body temperatures of one hundred gestating sows (large white x land race), who displayed a variety of parity (parity 0-6 pass), were measured by inserting a thermometer into their rectums (by livestock digital thermometer SKU8278 obtained from the USA). Furthermore, each part of each sow's body was checked for body temperature in the mornings (07.00 - 08.00 am.) every day for 7 days using a temperature sensor developed by our team, which we call the Inspect. Body temperature measurements of the animal's forehead, shoulders, hips and anus/vulva were conducted. The experimental sows were then cared for by farm management systems that considered both feeding and management routines.

Area and type of farm

This study was performed at a commercial farm (home to at least 300 sows) in Lamphun Province in June of 2018. The animal housing unit was comprised of an open system that continually measured the environmental temperature. Data were recorded at the farm to establish a baseline of data. In 2019, we investigated the same pig farm that was home to 300 sows, where our device known as the Inspect was used to survey the animals and detect any illnesses in the pigs, especially with regard to the fever status of the animal population. Moreover, the body temperatures of the sows were accessed to recover the status of fever of the animals. At the end of 2019, pig production on the farm was summarized and compared with the findings for pig production in 2018.

Systemic architecture and data flow

Temperature measurement

Body temperatures of the animals were measured with the Inspect. Importantly, the Inspect was created and designed for farm workers because it is easy to use to measure the body temperatures of farm animals. The device incorporates an infrared sensor (MLX90614 module from Melexis, Italy). Its specifications include the following: a temperature range of -40°C - 85°C with a ± 0.5°C margin of error in terms of accuracy. Moreover, the device also incorporates a four-digital tube module that can be used to record the ID of each sow. It also derives power from a power supply module AMS1117 that uses a 9-volt battery. The circuitry of the system is shown in figure 1.

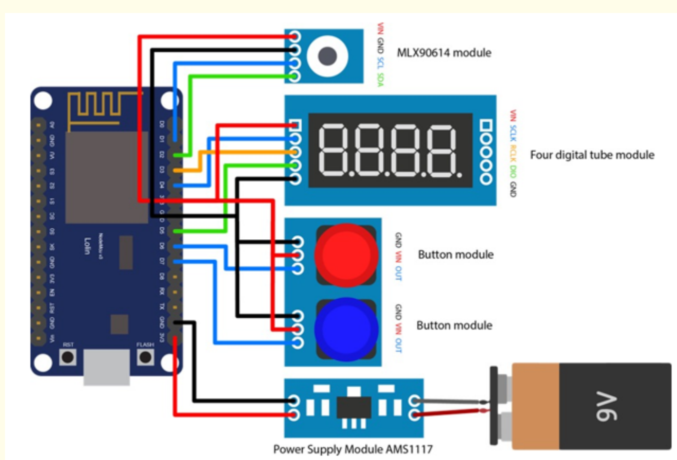

Figure 1: *Circuitry of the Inspect used to measure the body temperature of sows.*

Systemic architecture

Eight steps were employed for systemic architecture (Figure 2); 1) body temperature of the sow was measured by the Inspect (infrared sensor; MLX90614 module), 2) the body temperature signal was converted to digital signal data as NodeMCU or ESP-12, 3) the signal data was sent to the internet by a Wi-Fi access point, 4) the signal data was then sent to a PHP Server by HTTP request, 5) an API from the PHP server received the temperature data for analysis, 6) the temperature data was stored in MySQL, 7) the temperature data was categorized according to the degree of body temperature and the notification would then be sent to a veterinarian via a LINE notification if a sow had either a high or low temperature following determination of the animal's actual body temperature, and 8) The report would then be referred to as API from the PHP server for the data of MySQL to be displayed on the official website.

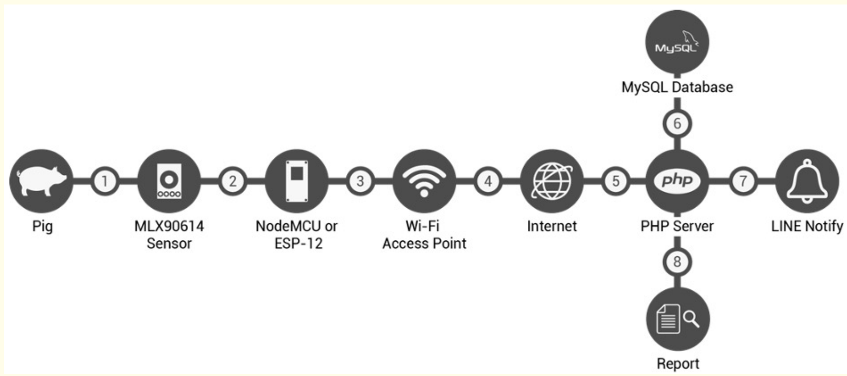

Figure 2: *Systemic architecture of the measurement system used to measure the body temperature of sows.*

Data acquisition

The body temperatures of one hundred sows were recorded in the morning for 7 days using the Inspect. On the first and the last day of the experiment, the temperature measurement of each sow was recorded in order to analyze the accuracy of the Inspect. Readings were taken on each part of the sow to be compared with the rectal temperature of the animal that was recorded with a standard thermometer. Moreover, the room temperature at that time was recorded for the purposes of comparing all relevant conditions. The amount of pig production for the farm was recorded in 2018 (before using the system) and again in 2019 (after using the system), and the results were compared. Specifically, the entire experiment was conducted on 300 sows at the finishing farm.

Statistical analysis

Room temperature was measured accordingly, while the body temperature of each sow was measured and then analyzed by descriptive analysis. Data of body temperature recorded on each part of the sow were entered into an Excel database (Microsoft Excel, 2013, Microsoft Corporation, USA) to identify any correlation with body temperature recorded by rectal measurement using a standard thermometer. Moreover, a comparison of the production indexes of sows on this farm was conducted between 2018 and 2019. The data were further compared by descriptive analysis.

Results and Discussion

Infrared sensor (the Inspect)

The box of the Inspect (Figure 3) is composed of a green button that serves as an on and off switch. The black lens represents the infrared sensor. The red button indicates the measured temperature. The green button represents the changing mode of action. Lastly, there is a four-digital display window.

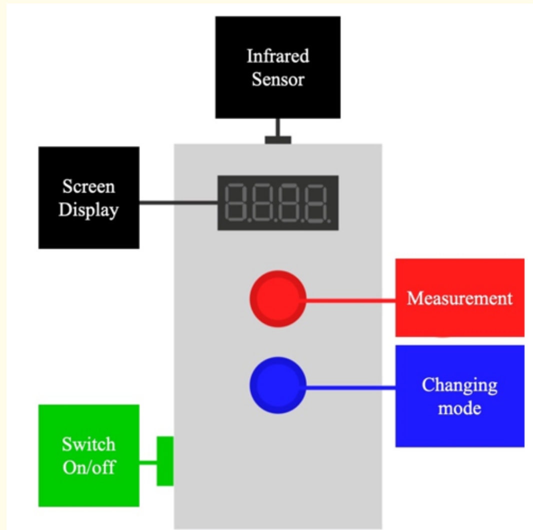

Figure 3: *Infrared sensor (The inspect).*

Presently, the body temperature measurements of pigs are usually accomplished by using a standard thermometer that is inserted into the rectum. In fact, these thermometers can be very difficult to use for the workers o these pig farms. Not only does the handling and restraint of the animal result in increased levels of stress in the pigs, but it also presents the risk of spreading infection to other animals via the equipment being used. Consequently, the use of an infrared thermometer can address these problems because its administration involves the use of non-contact temperature measurement methods, which can be much easier for workers to administer [8]. The infrared sensor of the Inspect is a method of temperature measurement that was designed and created for workers to use on pig farms. This device is not only easier to use, it also decreases the risk of spreading infection via the potential transfer of agents.

The systemic architecture of the measurement system used to measure the body temperatures of sows by infrared sensor was found to be stable. This monitoring system can be referred to as a syndromic surveillance system that can effectively monitor the fever status of sows. For the purposes of data flow, patterns of syndromic surveillance were employed to monitor clinical signs, analyze data, notify stakeholders and also to make relevant assessments after the intervention was completed (Finding Outbreaks Faster: Metrics for One Health Surveillance, 2019).

Moreover, Jang., *et al*. [5] reported that automated systems that are used to monitor pig body temperatures are a very important tools because they can help determine the health of the animal. Infrared sensors have been employed to monitor the body temperature of sows. Additionally, it has been reported that body temperature monitoring systems can be used to determine a number of other abnormalities. That is because the back temperature of the sow can be used to quickly and easily monitor the animals' potential fever status using infrared sensors. Furthermore, infrared sensors are not only more efficient but are also easier to use for workers on pig farms.

The optimal body part of the sow selected for measurement of body temperature.

The body temperatures of one hundred sows were measured both by digital thermometer and by using the Inspect. Both of the body temperature results are showed in table 1.

	Digital thermometer	Infrared sensor (Inspect)			
	Anus	**Forehead**	**Shoulder**	**Hip**	**Anus/Valva**
Anus	1				
Forehead	0.25	1			
Shoulder	0.15	0.88	1		
Hip	0.45	0.66	0.53	1	
Anus/Valva	0.78	0.53	0.37	0.55	1

Table 1: *Correlation (R) of body temperature measured using a digital thermometer and body temperature measured using the temperature sensor (the Inspect) on each part of body of the sow.*

The body temperature recorded by digital thermometer was used as the standard temperature, and it was compared with the temperature recorded at each part of the body by infrared sensor (the Inspect). As can be seen in table 1, the separation in body temperature on a digital thermometer recorded by inserting a thermometer into the anus of the animal and the body temperature of the animal recorded by infrared sensor or the Inspect via the anus/valvar was 0.78, which was considered relatively high.

Nevertheless, some problems have been identified when using an infrared thermometer on pigs. Notably, thermoregulatory ability in pigs increases with age [13] and that is why it is important to find out which part of the body of a pig is correlated with an accurate reading of body temperature measurement when using a standard thermometer. Table 1 shows that the body temperature measurement of a sow using a standard thermometer correlates with the body temperature measurement of the anus/valva of the sow when using the Inspect. In a previous study, the surface temperature of the skin (either hairy or bare skin) can interfere with certain environmental ambient factors. This occurs because the thermoregulatory response of the body that helps in maintaining a stable body temperature can be influenced, especially in adult pigs such as with fattened pigs or sows [10]. Moreover, the adult pigs of some breeds, such as the Duroc, can have a lot of hair. Therefore, a degree of accuracy of body temperature measurement is required and there is a need to find an area of the body that does not have hair growing on it such as the anus or valva. That is why the R-square value was used after comparison between the body temperature measurement using a standard thermometer inserted into the rectum of the animal and the infrared sensor of the Inspect that was used at the anus/valva. Therefore, the infrared sensor should be used to measure body temperature on or around the anus/valva area.

Production indexes of sows on the farm between 2018 and 2019

The production indexes of sows on this farm were recorded in 2018, which was considered the before period, while the production indexes of sows on this farm were recorded in 2019 which was called the after period. The Inspect was used as a measurement system for the body temperature of each sow. The production indexes of the sows on this farm between 2018 and 2019 were compared by descriptive analysis as is shown in table 2.

Production indexes	Before (2018)	After (2019)
Breeding group size; animal	597.00	694.00
%repeated	8.38	8.13
%return to service	8.93	9.01
Number of farrowing sow; animal	393.00	466.00
Total born; animal	4,061.00	5,394.00
Litter size; animal	10.33	11.58
birth weight; kg	16.10	15.80
Still birth; animal	274.00	419.00
%still birth	6.75	7.76

Mummy; animal	69.00	103.00
%mummy	1.70	1.91
Born alive; animal	3,787.00	4,872.00
Aver born alive; animal	9.64	10.45
Weaning sow; animal	373.00	477.00
Weaning pig; animal	3,352.00	4,346.00
Pig wean/sow; animal	8.99	9.11
Weaning weight; kg	2,698.00	3,538.50
Aver Weaning weight; kg	7.23	7.42
PWM; animal	435.00	380.00
%PWM	11.49	8.21
Culling; animal	53.00	61.00
%culling	26.97	26.18
Number of sow	196.50	233.00
AI of amoxicillin using (mg of sow)	3,072,000.00	3,364,000.00
PCU = population * AW	101,280.00	126,480.00
mg/PCU	30.33	26.60

Table 2: *Comparison of production indexes of sows between 2018 and 2019 (Mean values).*
Abbreviations: PWM: Pre-Weaning Mortality; AI: Active Ingredient; PCU: Population Correlation Unit;
AW: Average Weight at Treatment; mg: Milligram.

According to table 2, the production indexes of the after period were considered better than those of the before period, especially with regard to the production indexes recorded by our disease surveillance system; %PWM, and mg/PCU.

It is clear that the production indexes of the after period were better than those of the before period, especially with regard to the production indexes directly concerned with the health status of these farm animals (Table 2). Notably, the use of a sensor can help detect abnormal signs before they become problematic in the form of a disease outbreak. Undeniably, any implement that can assist in the early detection of a possible disease outbreak would be extremely beneficial. This would be referred to as a form of syndromic surveillance. Usually, the system requires a participant, identified as the reporter, who remotely sends the data as a clinical sign from the animal to a more comprehensive and sophisticated system such as the PODD system [4]. The efficacy of the surveillance system is noteworthy especially in terms of its accuracy through the use of a sensor. The sensor system has been used in surveillance systems developed by other researchers such as Hentzen., *et al*. [15], who reported that wireless temperature measurement systems can be used for the detection of fever status in sows. Furthermore, Andersen., *et al*. [16] used an ear tag temperature sensor to detect the surface temperature of sows. Moreover, many researchers have used infrared sensors to detect the body temperatures of pigs in their research work in an attempt to establish a method of early detection for an abnormal status [17-20]. A surveillance system of this type can be used in the early detection of abnormal signs obtained from animals that could significantly improve the production of these farm. However, our system can still be used as a manual method with minimal levels of training or experience needed by farm workers. Thus, going forward, a surveillance system with sensors should be further developed in terms of accuracy as an automatic method of monitoring the health status of farm animals.

Conclusion

In conclusion, body temperature can be used as an important indicator to assess the health status of pigs and to also diagnose the presence of pig diseases. Our study employed an infrared sensor for the effective detection of the health status of sows. The optimum location of the sow's body for recording temperature is the valvar or anus, which produced similar results to that of the temperature measurement established by a standard thermometer. Moreover, our system can identify normal and abnormal body temperature extremely quickly, which would mean that the outbreak of a disease would be stopped resulting in a significant decrease in losses in pig production. Non-contact infrared temperature measurement technology is an essential aspect in the development of smart agricultural tools. The development of these types of intuitive tools are part of a trend that is presently expanding to replace traditional manual temperature measurement methods. However, sophisticated sensor systems should be developed and integrated with the use of artificial intelligence or AI for the benefit of smart agricultural advancements in the future.

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Conflict of Interest

The authors declare that they have no conflicts of interest.

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