# The use of infrared thermography in the bio-surveillance of pigs

Present and emerging diseases of livestock are a major threat to animal and human health and to food security. Diseases of livestock can have devastating financial consequences, not just for farmers but also for the consumer in terms of food shortages and increased prices.

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African swine fever (ASF) has had an enormous impact on herds throughout Europe and Asia.

Probably the biggest impact has been in China where in 2018 it resulted in the death of 50% of the Chinese herd nationally, and a re-emergence of the virus in 2021 resulted in a 20% reduction in the northern Chinese herd.

In North America and Europe perhaps the most serious infectious disease is porcine epidemic diarrhoea (PED). Between 2013 and 2015 the PED virus spread rapidly though North America resulting in an estimated death of seven million pigs.

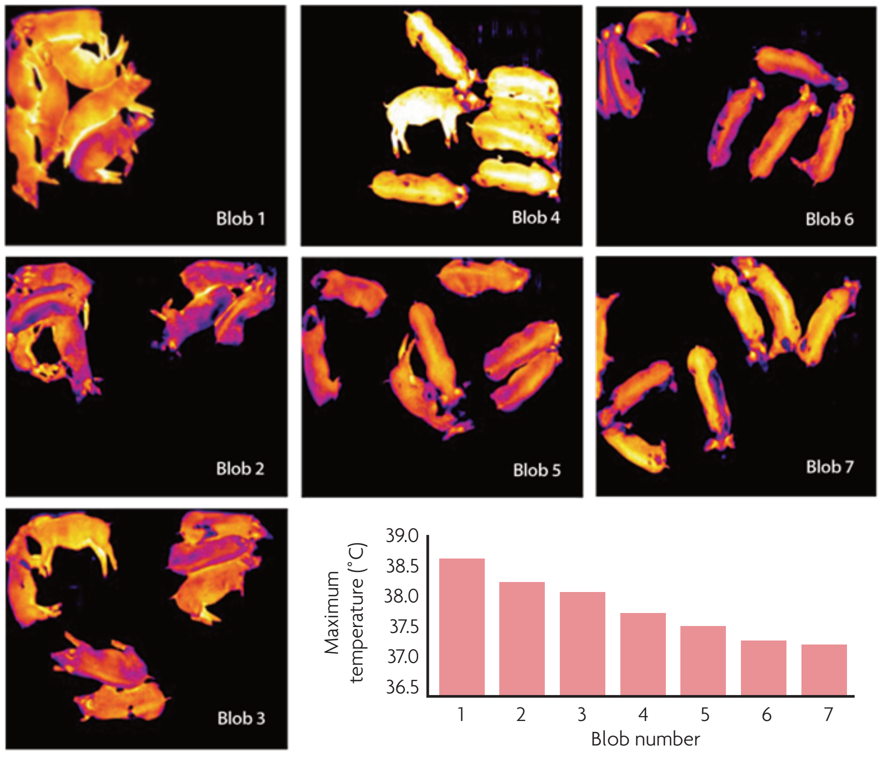


**Fig. 1. Infrared images of clustering behaviour and the effect of group size on radiated temperature measurements.**

## Impact of zoonotic diseases on industry and human health

Another major disease of pigs is Porcine Reproductive and Respiratory Syndrome (PRRS), which is estimated to be the most economically costly disease affecting the US swine industry, with an estimated annual loss to the industry of $664 million.

Zoonotic diseases of livestock can also have very serious health impacts on humans. In 2009 the world was hit with the swine flu virus (H1N1) pandemic, first detected in the USA.

In the first year of the swine flu pandemic the Centre for Disease Control (CDC) estimated 12,469 deaths from 274,304 hospitalisations and between 43-83 million infections.

Worldwide, the CDC estimated 151,700-575,400 people died from H1N1. All of these major diseases of swine are caused by viruses and all exhibit a febrile (fever) response to infection. It is clear that bio-surveillance of pigs is critical for disease detection and treatment.

In most intensive housing environments, it is impossible for stock persons to efficiently monitor many thousands of pigs. In these situations, technology can provide the answer to close monitoring and bio-surveillance.

## Infrared thermography

Infrared thermography (IRT) is a technology that has been around for a few decades in research environments and is only now beginning to emerge in commercial applications, this delay has mainly been due to the absence of small, inexpensive infrared cameras that can be placed and function within the harsh environment of pig buildings.

The thermal imaging cameras detect radiation in the long-infrared range (approximately 9,000-14,000nm) of the electromagnetic spectrum and maps the temperature of each of the camera's pixels to produce a thermogram, i.e. a temperature map of the surface of an object.

Clearly, the way forward in the development of infrared thermography for bio-surveillance has been in the automation of the technology, from image-capture to image analysis to data analysis and reporting.

Automated image-capture systems have been developed for individual animals coupled to an automated feeding system, and for group housing.

These systems are totally non-invasive, they do not require handling of animals or even the presence of humans in the barn and thereby completely avoid a confounding stress response. They also

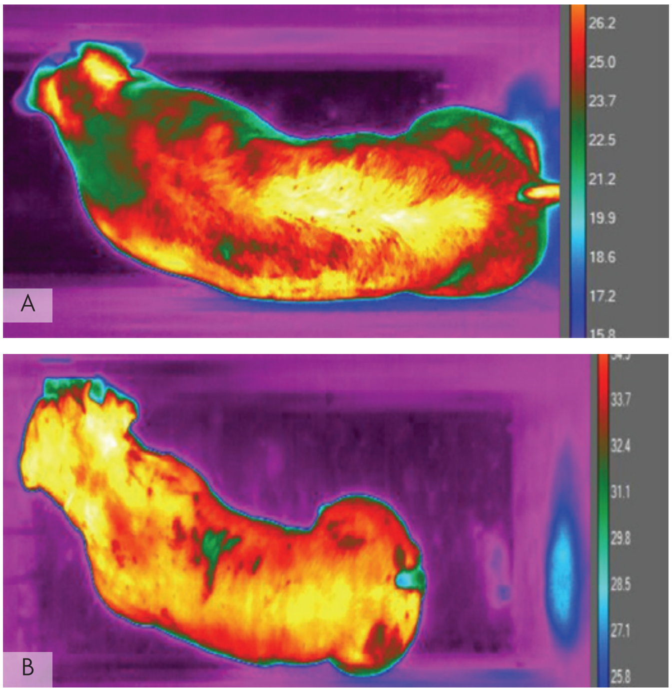


**Fig. 2. Infrared images of the dorsal surfaces of a healthy and a sick pig. A: A healthy pig with maximum radiated temperature = 31.2˚C. B: A sick pig with maximum radiated temperature = 39.9˚.**

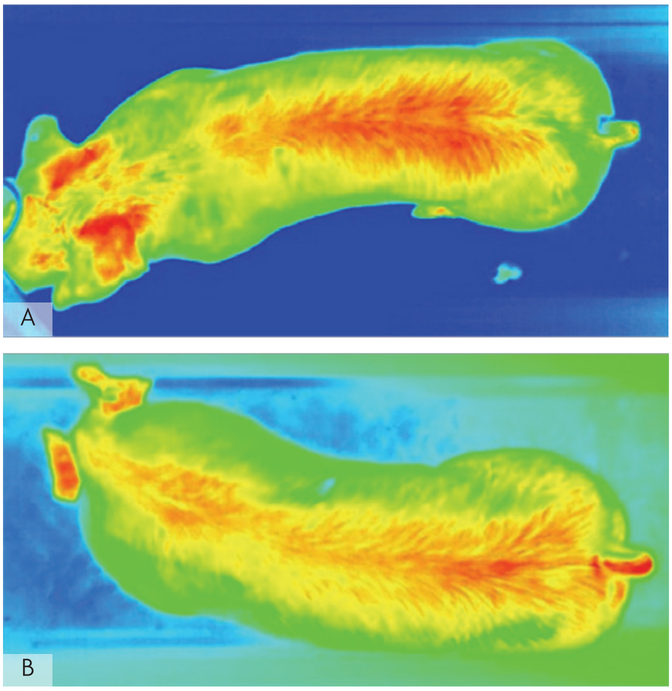


**Fig. 3. Infrared images showing tail damage due to tail-biting. A: A pig with a healthy tail. Radiated temperature = 30°C. B: Pig with a bitten tail. Radiated temperature = 38.9°C.**

permit large numbers of measurements to be made that more accurately define the animal's physiological state in relation to bio-surveillance.

## Groups of pigs

Thermal images can be collected on groups of pigs in a pen, or can be used to collect images of individual animals. Fig. 1 shows an infrared image of a group of weaner pigs taken by an overhead thermal camera that recorded images at five minute intervals.

For group imaging, the most diagnostically efficient variable is the maximum pig temperature. This is because it only requires one pig in the group to exhibit a febrile response for it to be the maximum temperature.

Group imaging allows for the quantification of clustering behaviour. Fig. 1 also shows that the average temperature of a group of pigs is highest when they cluster into a single group. Limiting temperature measurements to single clusters massively reduces the variance in temperature measurements.

Clustering activity is an important metric because this behaviour is an adaptive response to infection.

Another aspect of group imaging is that it is relatively easy to observe the growth of the group in terms of the area of the image occupied by the animals, and a suppressed growth rate may be indicative of chronic health problems.

Thus, infrared imaging can be used to obtain thermal, behavioural and physiological data simultaneously on the same animals in the same images, all of which have diagnostic relevance.

Another method is to automate the capture of images of individual animals when they visit a feed or water station. The animal is identified using half-duplex, radio frequency identification tags (RFID). When a pig enters the feeding system the RFID tag signals the image capture software to start recording.

Typically, images are recorded of the dorsal surface of the animals (Fig. 2). Note in Fig. 2 the relatively large temperature difference between a healthy (31.2˚C) and sick animal (39.9˚C).

The examples given above are all concerned with the detection of systemic diseases but IRT can also be used to detect localised injuries. Fig. 3 shows two images of pigs with uninjured and injured tails due to tail-biting.

## Relationship between animal and ambient temperature

Pigs thermoregulate to the prevailing environmental condition and it is important to account for these effects.

The relationship between animal and ambient temperature is described by either a linear or polynomial equation, which can be used to predict the animal's temperature from the environmental variable.

The difference between the animal's predicted and actual temperature is the residual temperature.

Thus, if the residual temperature is positive the animal is expending energy over that required to maintain thermal homeostasis. This is an indication of stress and disease. If the residual temperature is negative the animal is conserving heat, which may be an earlier indicator of infection because it indicates that the animal is conserving heat in order to generate an increase in core temperature or the pathogenesis of a fever.

It is for these reasons that the measurement of body surface temperature by IRT should not be taken as synonymous with taking core body temperature by other methods such as a conductive thermometer.

## Monitoring the animals, housing infrastructure and environment

Whatever system is installed in the pig barns producers are very unlikely to be able to interpret raw temperature data and therefore the system must provide the end-user with information upon which they can act.

The goal is the continuous monitoring of the animals, housing infrastructure and environment, and the integration of these data into a model capable of decision making in near real-time.

Advances in camera design, software development, automated animal ID, cloud computing, machine learning and artificial intelligence are presently converging to promote the incorporation of thermal cameras into farming practice. ■

References are available from the authors on request