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Assessment of the physiological changes of dairy cows using infrared thermography

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Abstract

Infrared thermography (IRT) is a non-contact method of measuring temperature that offers several benefits over conventional techniques used in veterinary medicine. One of its key advantages is the ability to minimise the risk of transmitting infection, as there is no need for direct contact with the animal. This is particularly beneficial in veterinary fields, where physical handling and restraint can induce stress, leading to fluctuations in both core and surface temperatures. In recent years, thermographic imaging has gained recognition as a valuable tool in veterinary diagnostics and research (Giannetto *et al.*, 2021).

This review aims to examine and analyze existing research on the application of infrared thermography (IRT) in cattle health management. Currently, the most commonly used methods for assessing cattle health on farms rely on invasive techniques, such as analyzing milk, tissue, or blood samples (Zhang *et al.*, 2020) and implanting contact sensors in the vagina or rectum (Chung *et al.*, 2020; Gray *et al.*, 2018). However, these invasive approaches often induce stress in animals, which can compromise the reliability of the results. Additionally, they require significant time and resources to obtain the necessary parameters, making them less efficient for large-scale or routine health monitoring.

Researchers are actively developing non-contact methods to enhance animal welfare, with infrared thermography (IRT) emerging as a promising solution. IRT is a passive, remote, and noninvasive thermal visualization technology that captures images displaying the surface temperature distribution of animals (Knizkova *et al.*, 2007). When an animal experiences illness due to pathological changes, the affected area's surface temperature increases as a result of heightened circulation and metabolic activity (Alsaad *et al.*, 2014; Bagavathi *et al.*, 2026). IRT technology can accurately detect these temperature variations, making it a valuable tool for assessing cattle health. Additionally, a review of existing literature suggests that IRT has the potential to replace labor-intensive and complex destructive sampling methods.

Keywords: Infrared thermography, dairy cows, diseases, animal welfare

Introduction

Infrared thermography (IRT) is an emerging non-invasive technique that offers substantial advantages over traditional invasive methods commonly used in cattle health monitoring. Unlike conventional approaches such as milk, tissue, or blood sampling and implantation of contact sensors, which often induce stress and require extensive time and resources. IRT provides a remote, contactless means of assessing surface temperature variations linked to physiological changes in cattle (Mota-Rojas *et al.*, 2021; Sousa Pinto *et al.*, 2026) ^[21, 32].

Applications of IRT in cattle health have been diverse and include assessing thermal comfort, detecting lameness, and monitoring physiological responses like respiratory rates. For instance, thermal windows such as the orbital, nasal, vulvar, and udder regions have proven reliable for correlating surface temperatures with environmental and health parameters. The inner canthus (corner of the eye) region has also emerged as a sensitive site for detecting heat stress, showing strong correlation with respiratory rates and thermal indices across different cattle breeds (Mota-Rojas *et al.*, 2021; Singaravadivelan *et al.*, 2025; Sousa Pinto *et al.*, 2026) ^[21, 30, 32].

Furthermore, the use of IRT has gained recognition in specific diagnostic applications, such as detecting lameness by identifying abnormal temperature patterns associated with inflammation or injury (Bagavathi *et al.*, 2026) ^[2]. Although environmental and methodological factors can influence thermographic readings, controlled conditions have facilitated accurate detection of contralateral temperature differences and maximum foot temperatures indicative of lameness (Alsaad *et al.*, 2014) ^[1]. This highlights the technology's potential in improving animal welfare and management decisions without imposing additional stress.

Infrared thermography (IRT)

Infrared thermography (IRT) is a non-invasive and non-contact technology that allows the surface temperature of animals to be measured remotely by detecting the infrared radiation emitted from their bodies (Sathiyabarathi *et al.*, 2016; Lowe *et al.*, 2019) ^[27, 19]. The scientific basis of infrared radiation can be traced to 1800, when Sir William Herschel, a German-born astronomer who later became a naturalized English citizen, conducted experiments demonstrating the existence of radiation beyond the visible portion of the electromagnetic spectrum. This radiation was subsequently identified as infrared or thermal radiation.

The operating principle of IRT is based on the fact that all objects with a temperature above absolute zero (-273.15°C) emit electromagnetic radiation, including radiation within the infrared range (Poikalainen *et al.*, 2012) ^[22]. An infrared camera detects this emitted radiation and converts it into a visual thermal image known as a thermogram, which represents variations in surface temperature. These temperature differences are commonly displayed using a colour scale, with relatively warmer regions represented by colours such as white, yellow, or red and cooler areas generally appearing in shades of blue or black (Colak *et al.*, 2008).

In animals, the thermal pattern detected by IRT is influenced by the distribution of superficial blood vessels and peripheral blood flow. Anatomical regions with a high density of blood vessels located close to the skin surface can exhibit measurable changes in temperature as blood circulation is altered. Because peripheral blood flow plays an important role in regulating heat transfer between the animal and its surrounding environment, changes in vascular circulation can produce corresponding variations in surface temperature that can be detected by IRT (Mota-Rojas *et al.*, 2021) ^[21]. Thus, thermal imaging provides a useful means of visualizing physiological and pathological changes associated with alterations in peripheral circulation.

Application of Infrared Thermography in temperature measurement of Livestock animals

Body temperature is a dynamic physiological parameter that varies according to an animal's health status, physiological state, and surrounding environmental conditions. Continuous or timely monitoring of these temperature fluctuations can provide important information about physiological functioning and help identify potential health abnormalities at an early stage. In dairy cattle, accurate assessment of body temperature is particularly important for supporting effective health management, reproductive management, and breeding programmes (Liu *et al.*, 2019) ^[17]. Based on anatomical location, body temperature can broadly be classified into core temperature and peripheral temperature. Core temperature reflects the thermal status of the internal body tissues,

whereas peripheral temperature represents the temperature of tissues closer to the body surface, including the skin, subcutaneous tissues, and muscles (Godyn *et al.*, 2019). Evaluation of both components can therefore contribute to a better understanding of the animal's physiological condition and overall welfare.

The development of infrared thermal imaging technology has provided an alternative approach to conventional temperature-monitoring techniques. Infrared thermography (IRT) is a non-contact and non-invasive technology that measures infrared radiation emitted from the animal's body surface and converts it into thermal images (Redaelli *et al.*, 2014) ^[25]. Since direct physical contact and restraint are generally unnecessary, IRT can reduce handling-related stress and facilitate more natural assessment of animals. Moreover, the technology is capable of identifying relatively small differences in surface temperature associated with changes in physiological and pathological conditions.

Another important advantage of IRT is its ability to overcome several practical limitations of conventional invasive methods. Measurements can be obtained rapidly with comparatively low labour requirements, making the technique suitable for repeated monitoring of individual animals or larger groups (McManus *et al.*, 2016) ^[20]. With the development of precision livestock farming and smart agricultural technologies, conventional methods such as repeated rectal temperature measurement may become less suitable for large-scale, continuous, and automated monitoring systems. In this context, IRT has emerged as a promising technology for rapid, real-time, non-invasive, and stress-free assessment of thermal responses in livestock and poultry (LokeshBabu *et al.*, 2018; Zhang *et al.*, 2020) ^[18, 36].

IRT in Disease Surveillance

An elevation in core body temperature above the physiological range is often associated with an acute immune response to conditions such as infection, tissue injury, inflammation, or disease and may ultimately result in the development of fever. In recent years, infrared thermography (IRT) has gained considerable attention as a promising non-invasive technique for the early identification and monitoring of diseases in livestock (Soroko *et al.*, 2016) ^[31]. The technique enables rapid and precise measurement of surface temperature and facilitates the identification of localized areas exhibiting abnormal thermal patterns. Consequently, early recognition of disease-associated thermal changes may facilitate prompt intervention, reduce diagnostic delays, minimize disease spread, and thereby help to limit economic losses in livestock production.

Inflammatory reactions involve several physiological changes, including increased vascular permeability, smooth muscle activity, vasodilation, enhanced leukocyte activity, and alterations in local tissue metabolism. These responses can increase blood flow and metabolic activity within affected tissues, resulting in a measurable elevation in local surface temperature (Hovinen & Pyörälä, 2011; Kotrba *et al.*, 2007) ^[14, 16]. Since IRT can detect these localized thermal alterations without physical contact with the animal, it has considerable potential for the early identification of inflammatory conditions in livestock.

The application of IRT for detecting inflammatory diseases has also been demonstrated in young animals. Shecaira *et al.* (2018) ^[29] employed infrared thermography to evaluate the umbilical region of calves and reported an association between increased navel temperature and omphalitis. Their

findings indicated that thermal changes in the navel region could provide useful information for identifying inflammatory processes. Thus, IRT represents a valuable rapid, non-invasive, and objective diagnostic and monitoring tool in veterinary medicine, with potential applications in the early detection of disease and assessment of treatment responses in livestock.

Infrared Thermography as a non-invasive diagnostic tool for early detection of digital dermatitis in dairy cows

Early identification of digital dermatitis (DD) is essential for limiting disease progression, initiating appropriate treatment at an early stage, and improving overall hoof health in dairy cattle (Alsaad *et al.*, 2014) [1]. Therefore, the development of reliable, practical, and non-invasive screening techniques is important for enabling frequent monitoring of DD at both the individual foot and cow levels. Infrared thermography (IRT) has gained attention as a potential diagnostic and screening tool because it provides a rapid, non-contact assessment of surface temperature and enables visualization of thermal patterns as colour-coded images.

IRT can therefore be used to identify abnormal thermal patterns by comparing the surface temperature of a potentially affected anatomical region with that of the corresponding contralateral region considered clinically healthy. Differences in temperature between the two symmetrical sites can help identify localized inflammatory responses and may enhance the early detection of hoof disorders such as digital dermatitis (Eddy *et al.*, 2001; Van Hoogmoed & Snyder, 2002) [7, 33]. Thus, IRT represents a promising non-invasive, rapid, and repeatable technique for monitoring hoof health and supporting early detection of inflammatory lesions in dairy cattle (Bagavathi *et al.*, 2026) [2].

Mastitis detection in dairy cattle using Infrared Thermography

Mastitis is among the most prevalent and extensively investigated diseases affecting dairy cattle, with considerable consequences for farm profitability, milk quality, and the sustainability of dairy production systems. Early and accurate identification of mastitis, particularly subclinical mastitis (SCM), remains challenging because affected animals may not exhibit obvious clinical signs. Infrared thermography (IRT) has emerged as a promising non-invasive technique for monitoring udder health by detecting variations in udder surface skin temperature (USST), which may be associated with inflammatory changes and increased somatic cell count (SCC) in milk.

Velasco-Bolaños *et al.* (2021) [34] investigated the application of thermal imaging for evaluating udder temperature in dairy cows maintained under plateau environmental conditions. Surface temperatures were recorded from the posterior, left, and right regions of the udder. The authors demonstrated that these thermal measurements were associated with mastitis status and suggested that udder surface temperature could be used as a potential indicator for the detection of subclinical mastitis. The findings highlight the ability of IRT to identify localized thermal changes associated with inflammatory processes before the appearance of prominent clinical signs.

Similarly, Satheesan *et al.* (2024) [26] reported that udder surface skin temperature (USST) provided greater diagnostic accuracy, sensitivity, and specificity for mastitis detection compared with teat apex temperature (TAT) and teat skin surface temperature (TSST). The higher USST values observed in comparison with TAT and TSST were attributed,

at least in part, to the relatively greater blood supply and vascular activity of the udder tissue. Consequently, measurements of udder temperature may provide a more sensitive representation of inflammatory changes occurring within the mammary gland.

In Sahiwal cattle, Satheesan *et al.* (2024) [26] used an SCC threshold of 250,000 cells/mL to classify animals with subclinical mastitis. Using the Youden index to identify the optimum diagnostic threshold, USST cut-off values of 37.74 °C for subclinical mastitis and 39.58°C for clinical mastitis were established. These results demonstrate the potential of USST measurement through IRT as a rapid, non-invasive approach for identifying mastitis and suggest that udder thermography could be incorporated into routine dairy herd health surveillance and early disease detection programmes.

Infrared Thermography as a non- invasive tool to detect Heat stress in Cattle

Heat stress is a major challenge in dairy production, as elevated environmental temperatures can adversely affect feed consumption, milk yield, reproductive efficiency, and overall animal welfare, thereby contributing to substantial economic losses. The severity of these effects is expected to increase with ongoing climate change, particularly in tropical and subtropical regions where dairy cattle are frequently exposed to high thermal loads (Sejian *et al.*, 2015; Polsky & von Keyserlingk, 2017) [28, 23].

Heat stress in dairy cattle can be assessed through both environmental- and animal-based indicators. Environmental measures, such as ambient temperature, relative humidity, temperature-humidity index (THI), and heat load index (HLI), are commonly used to characterize the thermal conditions experienced by animals (Herbut *et al.*, 2018) [13]. In contrast, animal-based measures including panting score (PS), rectal or body temperature, respiration rate, heart rate, dry matter intake (DMI), and alterations in behaviour provide information on the physiological and behavioural responses of individual animals to heat exposure (Gaughan *et al.*, 2002; Galán *et al.*, 2018; Wang *et al.*, 2018; Rashamol *et al.*, 2019) [9, 8, 35, 24]. Although environmental indices are valuable for estimating the risk of heat stress, they may not adequately represent the actual physiological burden experienced by individual cows. Animal-based indicators can therefore provide a more direct assessment of the animal's response to thermal stress (Liu *et al.*, 2019) [17].

Among these indicators, panting score (PS) is widely employed as a practical measure of heat stress in dairy cattle. Nevertheless, its visual assessment is subjective and may vary among observers. Infrared thermography or infrared temperature (IRT) measurement offers a non-invasive and potentially more objective approach for evaluating thermal responses in cattle (Choudhary *et al.*, 2026) [4]. By detecting changes in surface temperature at specific anatomical regions, IRT may provide useful information regarding the physiological response of cattle to heat load. However, the association between IRT measurements, panting score, and productive performance, particularly milk yield, remains insufficiently characterized.

Researchers Bang *et al.* (2022) [3] reported positive associations between IRT measurements and panting score, with Pearson correlation coefficients ranging from 0.23 to 0.50, indicating that increased surface temperatures were generally accompanied by greater panting responses. The study also demonstrated that each unit increase in HLI was associated with an approximately 0.07-unit increase in

panting score and a 0.09–0.23 °C increase in IRT, depending on the anatomical region assessed. Importantly, increases in specific IRT measurements were associated with reductions in estimated corrected milk (ECM) production. An increase of 1°C in inner vulvar temperature (IVuT), outer vulvar temperature (OVuT), and inner tail-base temperature (ITBT) was associated with decreases in ECM yield of approximately 0.75, 0.87, and 0.70 kg/cow/day, respectively. In contrast, panting score and several other IRT measurements did not

show significant associations with ECM yield. These findings indicate that although IRT measurements can serve as useful indicators of the physiological response to heat stress, IVuT, OVuT, and ITBT may have greater potential as predictors of heat-stress-associated reductions in milk production than panting score or other IRT parameters (Bang *et al.*, 2022) ^[3].

Limitations

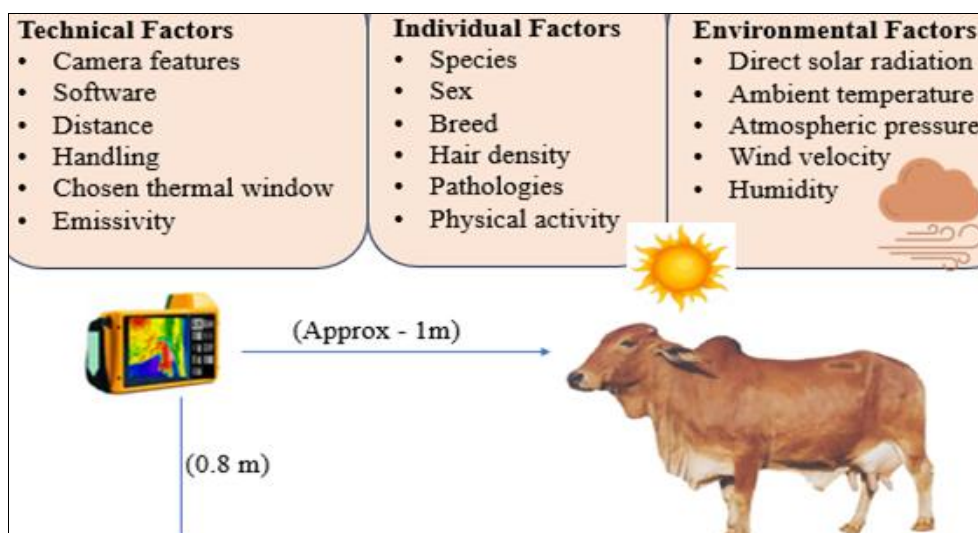


Fig 1: Limitations of Infrared Thermography

Several environmental, technical, and individual factors can influence the thermal responses of domestic animals when using infrared thermography (IRT). As a non-invasive tool that measures surface temperature fluctuations, IRT is susceptible to both extrinsic and intrinsic variables that may affect accuracy (Mota-Rojas *et al.*, 2021) ^[21].

1. Environmental Factors

Key environmental conditions that can impact thermal imaging include:

- Direct solar radiation
- Ambient temperature and humidity
- Other climatic variables
- Stockperson handling and animal management practices

2. Individual Factors

Intrinsic factors that must be accounted for include:

- Species and breed differences
- Anatomical variations
- Physical activity levels
- Systemic diseases and physiological states

3. Technical Factors

The precision of IRT readings also depends on technical parameters, such as:

- Distance between the observer and the animal
- Angle at which measurements are taken
- Selection of the appropriate thermal window

Considering these variables is essential to ensure accurate and reliable temperature measurements in livestock using IRT.

Conclusion

Achieving rapid and accurate health assessments remains a major challenge in large-scale cattle farming. Infrared

thermography (IRT) provides valuable insights by capturing thermal data from specific anatomical regions, aiding in the diagnosis of diseases, as well as assessing the physiological state and overall welfare of livestock. Based on our findings, we conclude that IRT technology plays a crucial role in enabling non-contact, automated, real-time, and continuous health monitoring in cattle. Its application significantly enhances cost efficiency, safety, and sustainability in large-scale animal husbandry, making it an essential tool for modern livestock management.

Conflict of interest

The authors declare no competing interests.

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