

REVOLUTIONIZING ESTRUS DETECTION AND HERD HEALTH SURVEILLANCE WITH AI AND THERMAL IMAGING IN DAIRY ANIMALS

Anugraha P.J

Veterinary College and Research institute, Tirunelveli, Tamil Nadu Veterinary and Animal Sciences University

* Corresponding author's email: anugrahaj21@gmail.com

DOI: <https://doi.org/10.5281/zenodo.22674817>

Abstract

Efficient reproductive and health management is essential for sustainable dairy production, yet timely detection of estrus and early recognition of disease remain challenging under routine farm conditions. In dairy animals especially buffaloes, weak or poorly expressed estrus behaviour can result in missed opportunities for artificial insemination, delayed conception and prolonged calving intervals. The subtle physiological changes associated with disease may remain undetected until recognizable clinical signs develop. Conventional visual observation is also influenced by herd size, observation frequency, environmental conditions and the experience of farm personnel. Advances in precision livestock farming provide opportunities to complement conventional observation with continuous, non-invasive monitoring. Infrared thermography can capture surface temperature patterns, while artificial intelligence and computer vision can analyse animal identity, movement and behaviour. Integrating these information sources may help identify patterns associated with estrus, including poorly expressed estrous events, while also flagging abnormal thermal or behavioural changes that could indicate an underlying health problem. Such a system could serve as an early-warning tool for both reproductive and herd health management. Real-time digital alerts could assist farmers and veterinarians in prioritizing animals for reproductive intervention or clinical examination. Environmental influences, individual variation, image quality, algorithmic reliability and field validation remain important considerations. The integration of thermal imaging, behavioural monitoring with artificial intelligence represents a promising approach towards objective, non-invasive and data-assisted reproductive and health surveillance in dairy herds.

Introduction

The productivity and profitability of a dairy farm depend on efficient reproductive management and maintenance of good animal health. Reproductive efficiency is particularly important because timely breeding influences calving intervals, lactation cycles, replacement of animals, and the productive life of dairy cows. Failure to detect estrus at the appropriate time can lead to missed breeding opportunities, prolonged calving intervals, increased services per conception, and economic losses. Early recognition of diseases such as mastitis, lameness, respiratory disorders, and reproductive problems is essential to minimize reductions in milk production, fertility, animal welfare, and increased treatment costs. Therefore, continuous monitoring of reproductive and health status is essential for efficient dairy-farm management. Estrus detection remains a major challenge in dairy cattle. Traditionally, farmers rely on visual signs such as standing to be mounted, mounting behaviour, increased activity, restlessness, vocalization, mucus discharge, and changes in feeding or lying behaviour. Although useful and inexpensive, visual observation requires considerable time, regular supervision, and experience. Estrus expression also varies between animals and may be less pronounced in high-producing

cows or under intensive housing conditions, resulting in undetected silent or weak estrus. Conventional methods such as rectal palpation, ultrasonography, and hormonal assays can provide reliable reproductive information but require skilled personnel, specialized equipment, repeated examinations, or additional costs. To overcome these limitations, automated technologies including activity monitors, pedometers, accelerometers, rumination sensors, pressure-sensitive systems, and automated feeding or weighing systems have been introduced. These systems enable continuous monitoring of behavioural and physiological changes, but individual technologies generally focus on specific parameters and may require wearable devices, additional infrastructure, maintenance, or animal-specific sensors. Behavioural changes can be influenced by environmental conditions, housing, social interactions, and disease. Health surveillance presents a similar challenge, as obvious signs such as reduced appetite, altered gait, nasal discharge, udder abnormalities, or behavioural changes may appear only after disease has progressed. Continuous individual monitoring is labour-intensive, particularly in larger herds, highlighting the need for automated systems capable of detecting subtle deviations from an animal's normal condition. Reliable individual animal identification is also essential so that information from cameras and sensors can be accurately linked to the correct animal. While ear tags, collars, branding, tattoos, and RFID systems provide identification, they may require physical tags or additional infrastructure. Computer vision provides an alternative by enabling animals to be recognized and tracked through visual characteristics and identification markers, allowing reproductive, behavioural, thermal, and health information to be accumulated as individual records. Recent advances in artificial intelligence, computer vision, and infrared thermography (IRT) provide an opportunity to integrate these aspects into a unified dairy-monitoring system. IRT enables

non-contact assessment of surface temperature and can identify thermal changes associated with reproductive activity, inflammation, fever, mastitis, respiratory disease, and locomotor disorders. AI-based object-detection models such as YOLO (You Only Look Once) can facilitate real-time detection and localization of animals and relevant anatomical regions, while tracking technologies maintain individual animal identity. Combining thermal information with activity and behavioural parameters may improve the identification of reproductive and health-related changes compared with reliance on a single indicator. A farmer-friendly, real-time platform integrating AI, IRT, animal identification, activity and behaviour monitoring, and automated alerts could therefore provide a practical foundation for smart dairy farming. Such a system could continuously monitor individual animals, detect reproductive and health abnormalities, maintain animal-specific records, and deliver alerts through a mobile application. This approach has the potential to improve reproductive efficiency, enable earlier veterinary intervention, reduce production losses, and support precise and sustainable dairy-farm management.

Thermography in Estrus Detection

Infrared thermography is emerging as a promising non-invasive approach for monitoring physiological changes associated with estrus in dairy cattle. The technique detects infrared radiation emitted from the animal's body and converts it into measurable surface-temperature patterns, allowing changes to be monitored without physical handling. Recent research has demonstrated the potential of combining thermal measurements with behavioural indicators for automated estrus detection. In a commercial dairy herd, an automated system integrating skin-temperature measurement with tail movements associated with vulval exposure detected changes around the time of estrus. Skin temperature showed a tendency to increase as milk progesterone concentrations

declined, while tail movements exposing the vulva were more frequent during estrus. Temperature of vulva and muzzle increases during estrus period. Two days prior to estrus temperature drops. During estrus due to LH peak, temperature elevates. Thermal monitoring may therefore be particularly valuable when conventional behavioural signs are weak or difficult to observe. However, surface temperature is influenced by environmental conditions and other physiological factors, meaning that thermography should not be considered an independent diagnostic method. Instead, integrating thermal information with behavioural activity, individual animal identification and artificial intelligence could improve the interpretation of temperature patterns and support automated estrus alerts. This combined approach provides a scientific basis for developing intelligent monitoring systems capable of continuously screening animals and identifying those requiring further reproductive assessment.

Infrared Thermography for Early Disease Detection and Health Surveillance in Livestock

Abnormal changes in body temperature are important indicators of disease and inflammation, making temperature monitoring a valuable component of veterinary health surveillance. Infrared thermography offers a non-invasive and rapid approach for detecting changes in surface temperature and has considerable potential for the early identification of disease in livestock. In individual animal medicine, IRT can detect localized or systemic increases in temperature associated with fever and inflammation, allowing affected animals to be identified, isolated, investigated, and treated at an early stage. Research has demonstrated that IRT can be used as a screening tool at the herd level and may identify Bovine Viral Diarrhea Virus infected cattle up to one week before the onset of viral shedding. Similarly, thermal imaging of the ocular region has shown potential for detecting bovine respiratory disease complex

several days before the appearance of overt clinical signs, with performance comparable to conventional methods such as rectal temperature measurement and serial blood testing. In foot-and-mouth disease, increased temperature at the coronary band has been detected approximately 24–48 hours before the development of characteristic vesicular lesions, highlighting the potential of IRT for preclinical disease detection. Furthermore, ocular temperature measured using IRT can assist in identifying pyrexia animals and may be relatively reliable under varying environmental conditions. The technology may also have potential applications in diseases such as rabies, where thermal abnormalities of the nasal region could provide an additional screening indicator during the early stages of infection. Infrared thermography is particularly useful for detecting localized inflammatory changes associated with conditions such as mastitis and lameness. During mastitis, bacterial proliferation within mammary tissues induces vasodilation and increased blood flow to the affected area as part of the inflammatory response. This may result in localized hyperthermia, hyperemia, and swelling of the udder. IRT can detect these alterations in skin surface temperature and therefore has potential for identifying inflammatory changes during the early stages of mastitis, even before obvious clinical manifestations become apparent. Similarly, inflammatory processes associated with lameness can produce characteristic thermal changes in affected limbs and surrounding tissues. Thus, thermal imaging can serve as a valuable non-contact screening tool for the early recognition of inflammatory and infectious conditions, supporting timely intervention and improving herd health management.

Combining Artificial Intelligence and Infrared Thermography for Reproductive and Health Monitoring

The integration of artificial intelligence, infrared thermography, computer vision, automated recognition systems (ARS),

and activity monitoring provides a promising approach for continuous and non-invasive monitoring of reproductive and health status in dairy cattle. Infrared cameras can continuously capture thermal images of animals, while AI-based computer vision algorithms can detect individual animals and identify relevant anatomical regions such as the vulva, eye, muzzle, udder, and limbs. In parallel, activity and behavioural patterns can be monitored using cameras and computer-vision-based tracking. During estrus, cattle commonly exhibit characteristic behavioural changes, including increased physical activity, restlessness, increased mounting activity, standing to be mounted, chin resting, tail raising, altered lying patterns, and changes in feeding and rumination behaviour. Combining these behavioural indicators with thermal changes can improve the reliability of estrus detection compared with relying on a single parameter. Object-detection algorithms such as YOLO (You Only Look Once) can be used to detect and track animals and relevant body regions in real time. The detected animal can subsequently be linked with an automatic recognition system so that thermal measurements, activity levels, behavioural events, and reproductive observations are assigned to the correct individual animal. Continuous tracking allows the system to establish an individual baseline for each cow and identify deviations in both temperature and behaviour. For example, a simultaneous increase in vulvar or ocular temperature and an increase in locomotor activity or mounting behaviour could strengthen the probability of estrus. Conversely, persistent elevation of body-region temperature combined with reduced activity, altered feeding behaviour, or reduced rumination may indicate a possible health problem rather than reproductive activity. A real-time monitoring platform could therefore continuously collect thermal, visual, and behavioural data and process them through an AI-based decision-making system. YOLO can perform real-time animal and anatomical-region detection, automated recognition system can maintain individual

animal identity, tracking algorithms can quantify movement and behavioural events, and artificial intelligence models can analyse temporal patterns in temperature and activity. When predefined or learned patterns associated with estrus or abnormal health are detected, the system can generate an automated alert for the farmer or veterinarian. This approach is particularly useful because estrus is a dynamic physiological and behavioural event, and combining multiple indicators can provide a more robust assessment than observing temperature, activity, or behaviour independently. The same platform can support herd health surveillance by continuously monitoring changes in activity, feeding, rumination, lying time, locomotion, and thermal profiles. A reduction in activity or rumination accompanied by localized thermal abnormalities may provide an early indication of conditions such as mastitis, lameness, respiratory disease, or systemic inflammation. Thus, the system can function as a dual-purpose monitoring platform, identifying reproductive events while simultaneously screening for health abnormalities. Continuous individual-level monitoring also enables the development of longitudinal animal health records, allowing deviations from an animal's normal behavioural and thermal profile to be detected earlier. The proposed integration of all these represents a step towards precision livestock farming. Rather than depending on a single observation or periodic manual examination, the system can continuously observe animals, integrate multiple physiological and behavioural indicators, and provide real-time decision support. Such a multimodal approach has the potential to improve the accuracy and timeliness of estrus detection, facilitate early identification of health problems, reduce labour requirements, and enable more efficient reproductive and herd health management.

From Thermal Imaging to Real-Time Farmer Alerts: An AI-Based Smart Farming Application

The proposed AI-enabled infrared thermography system can be developed as a simple, farmer-friendly mobile application that converts complex thermal and behavioural data into easily understandable real-time alerts. Thermal cameras installed at appropriate locations in the farm can continuously capture images of individual animals, while AI-based computer vision algorithms such as YOLO detect and track animals and relevant anatomical regions. An Automatic Recognition System can associate each observation with the corresponding animal, allowing its thermal profile, activity, behaviour, estrus status, and health indicators to be monitored over time. The application can integrate thermal parameters with activity and behavioural changes, including increased locomotion, mounting activity, standing-to-be-mounted, and restlessness, changes in lying behaviour, feeding, and rumination, to improve estrus detection. At the same time, abnormal thermal patterns combined with reduced activity, altered feeding or rumination, or changes in locomotion can generate early warnings for possible health problems such as mastitis, lameness, respiratory disease, fever, or inflammation. The processed information can be displayed through a simple dashboard showing the status of each animal, with automated notifications such as “Estrus suspected,” “Health abnormality detected,” or “Animal requires examination.” Farmers could receive these alerts directly on their smartphones, enabling timely insemination, clinical examination, isolation, or veterinary intervention without requiring continuous manual observation of the herd. The application could also maintain individual animal records, including

reproductive events, previous alerts, thermal trends, and health history, thereby providing a digital herd-management platform. Such a system would make advanced AI and thermal-imaging technology accessible to farmers in a practical format and could support more efficient reproductive management, early disease detection, reduced labour requirements, and improved overall herd productivity

Conclusion

The integration of intelligent technologies into livestock production marks an important step towards smart farming, where timely information can guide everyday farm decisions. A farmer-friendly system that continuously observes animals and communicates only relevant alerts can simplify routine management while reducing dependence on constant manual observation. Recognizing reproductive changes at the appropriate time can improve breeding efficiency, while identifying subtle deviations in an animal’s normal condition can facilitate veterinary attention before a disease progresses and causes major losses. This proactive approach can help reduce treatment expenses, production losses, and disease-related setbacks while promoting better animal welfare and resource utilization. At the farm level, improved reproductive performance and healthier animals can enhance profitability; at the industry level, these gains can contribute to greater productivity, sustainability, and economic growth. Thus, the adoption of AI-driven monitoring within smart farming can bridge the gap between advanced technology and practical farm management, making modern livestock production more efficient, accessible, and sustainable for farmers.

References

- Riaz, U., Idris, M., Ahmed, M., Ali, F., & Yang, L. (2023). Infrared Thermography as a Potential Non-Invasive Tool for Estrus Detection in Cattle and Buffaloes. *Animals*, 13(8), 1425. <https://doi.org/10.3390/ani13081425>

Casas-Alvarado, A., Mota-Rojas, D., Hernández-Avalos, I., Mora-Medina, P., Olmos-Hernández, A., Verduzco-Mendoza, A., Reyes-Sotelo, B., & Martínez-Burnes, J. (2020). Advances in infrared thermography: Surgical aspects, vascular changes, and pain monitoring in veterinary medicine. *Journal of Thermal Biology*, 92, 102664. <https://doi.org/10.1016/j.jtherbio.2020.102664>

Cite this article:

Anugraha P. J. (2026). Revolutionizing estrus detection and herd health surveillance with ai and thermal imaging in dairy animals. *Vet Farm Frontier*, 03(08), 15–20. <https://doi.org/10.5281/zenodo.22674817>

