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Revolutionizing Livestock Health: The Transformative Role of Infrared Thermal Imaging in Livestock Disease Diagnosis

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Abstract

Infrared Thermal Imaging has emerged as a promising tool for early disease detection and monitoring in livestock. The technique's non-invasive and real-time capabilities offer significant advantages over traditional diagnostic methods, facilitating timely intervention and improved animal welfare. It works based on the principle of capturing and analysing infrared radiation emitted by the animal's body, which is closely linked to its physiological state, health status, and thermal balance. The technology's ability to detect temperature changes associated with inflammation and disease progression makes it invaluable for detecting early signs of diseases such as mastitis, respiratory infections, lameness, and viral infections. As the technology continues to advance and becomes more accessible, it holds great potential for transforming livestock management practices, ensuring early disease detection, and ultimately enhancing animal health, welfare, and productivity in the agricultural sector. Continued research and practical application will further refine its capabilities, cementing its position as a valuable tool in modern livestock health management.

Keywords: Disease diagnosis, Infrared thermal imaging, IRT, Livestock

Introduction

Advancements in dairy farm management, including the increase in farm size and the integration of automation in livestock production, necessitate the adoption of new methods for monitoring animal health. One such method involves utilizing infrared thermal radiation, which is the radiant energy emitted by all substances due to their absolute temperature. The infrared thermal radiation falls within the electromagnetic spectrum, specifically ranging from approximately 0.1 to 100mm, encompassing both the visible and infrared spectrum.

Infrared thermography (IRT) is a non-destructive testing technology that can be effectively used to assess the superficial temperature of objects, including animals. It operates by collecting the infrared radiation emitted by the animal's surface, converting it into electrical signals, and generating a thermal image that depicts the distribution of superficial temperatures across the body. The thermal image is presented with a defined color scale, with each color representing a specific temperature range. Maintaining optimal body temperature is crucial for homeothermic animals to achieve homeostasis, and thermoregulation plays a key role in this process. Homeothermic animals actively manage their body temperature to conserve energy and minimize the costs associated with thermoregulation. When subjected to thermal changes, these animals respond through physiological mechanisms that lead to increased energy expenditure.

By employing IRT, it becomes possible to visualize the temperature distribution on the animal's surface and identify changes in peripheral blood flow, which can be indicative of various conditions such as disease, edema, and stress. This non-invasive technique proves valuable in assessing the health status of animals, as it allows for precise and trouble-free surface temperature measurements, particularly on animals with low heat capacities such as those with certain coat characteristics. The information gathered through IRT aids in detecting anomalies and monitoring the overall well-being of the animals on dairy farms. Thus, the integration of infrared thermography as a monitoring tool in dairy farming provides valuable insights into the thermal characteristics and health status of animals. By visualizing temperature distribution and detecting changes in superficial heat, IRT proves to be a valuable and non-destructive method for assessing animal health and welfare in large-scale livestock production systems.

The applications of Infrared Thermal Imaging in animal production

Any alteration in an animal's normal physiological state, such as the onset of early diseases, stress, oestrus, or pregnancy, can disrupt the thermal balance, resulting in significant changes in the animal's body surface temperature. Herein lies the potential of infrared imaging technology, as it swiftly captures temperature fluctuations between the animal's body surface and core areas, along with temperature variations between natural and pathological physiological conditions. This capability forms the foundation for early diagnosis and a range of valuable applications, including:

1. Detection of temperature fluctuations in animal surfaces and core anatomical areas.
2. Early diagnosis of animal diseases and inflammations.
3. Monitoring and detection of animal stress levels.
4. Early identification of oestrus and ovulation in animals.
5. Pregnancy diagnosis in animals.
6. Enhancing animal welfare through improved health monitoring.

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Advancing Mastitis Detection in Dairy Cows: The Potential of Thermal Imaging and Sensor Technologies

Mastitis stands as the most prevalent and economically damaging disease affecting dairy cows. Swift and accurate detection methods are urgently needed to minimize losses in the dairy industry. While various techniques have been explored, such as analyzing electrical conductivity (EC), milk color, and somatic cell count (SCC), they have proven inadequate for early mastitis detection or automatic diversion of infected milk. The current challenge lies in finding a detection method unrelated to milking, capable of identifying mastitis during the dry period, before the first calving, and during severe clinical mastitis cases where milk changes follow clinical signs.

Studies have discovered that while a cow's overall body temperature remains consistent regardless of infection status, the udder temperature notably increases in mastitis cases. Cows with sub-clinical mastitis exhibited an average udder temperature 2.4°C higher than the general body temperature, while those with clinical mastitis showed temperature increases of 1-1.5°C. When using thermal imaging and SCCs together, mastitis detection has been observed as rapidly as 4 hours post-challenge with a controlled E. coli infusion. However, a potential drawback in using thermal imaging is the lack of reference material. To ensure meaningful comparisons, establishing a robust database with baseline values for each herd or flock is essential. Additionally, coupling thermal imaging with other mastitis indicators, such as SCC, is crucial to enhance diagnosis reliability.

Tackling Lameness in Livestock: The Role of Thermal Imaging in Identification and Diagnosis

Lameness poses a significant health challenge for livestock farmers, impacting cattle, sheep, and pigs alike. This condition can arise from various causes, making it difficult to pinpoint, often requiring veterinary investigation. Lameness is generally caused by infections (e.g., abscesses, foot rot) or injuries (such as muscular injuries from kicks). Both of these issues can be identified by detecting increased local temperature using a thermal imaging camera. While most scientific research focuses on cattle, the concepts can be applied to sheep and pigs as well.

Studies have revealed that different parts of a cow's foot exhibit varying temperatures under normal conditions. For instance, the central and inter-digital areas of the hind foot consistently have higher temperatures compared to other regions. It is crucial to consider these differences to ensure accurate data and prevent false positives and unnecessary treatment. When comparing cows affected by foot disease to healthy animals, lame cows consistently exhibit higher foot temperatures in all regions.

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Moreover, thermal imaging has been investigated in diagnosing horn lesions in dairy cows, particularly in relation to lifting and cleaning the foot. It has been noted that dirt can impact the reliability of thermal imaging, as it impairs the foot's surface ability to radiate and conduct heat. However, cleaning the cow's legs has a cooling effect, which may also affect the results. By leveraging thermal imaging technology, livestock farmers can gain valuable insights into early signs of lameness, enabling timely intervention and treatment. Despite the challenges related to dirt and cleaning, the potential benefits of thermal imaging in managing lameness make it a promising tool for improving overall herd health and reducing economic losses in the livestock industry.

Thermal imaging has also been applied to detect lameness in pigs. The camera demonstrated sufficient sensitivity in detecting some patterns associated with lameness. However, several confounding factors surfaced, including limb conformation, physical activity, and parity. Limb temperature was found to fluctuate based on the time of day and relative to feeding, emphasizing the importance of consistency in measurement and the necessity for robust baseline data for accurate comparison.

As research progresses, understanding the impact of environmental factors, like dirt and daily variations, on thermal imaging results becomes vital in enhancing its applicability for livestock health assessment. By finding the optimal threshold for detecting lesions in the presence of dirt and considering other influential factors, thermal imaging can become a valuable tool for early lameness detection, enabling timely intervention and improved management practices for livestock welfare.

Thermal Imaging: A Cutting-Edge Diagnostic Tool for Infectious Diseases in Livestock

Thermal imaging has emerged as a valuable diagnostic tool in the detection of infectious diseases in livestock, leveraging inflammation, characterized by heat and swelling, as the primary indicator. Its applications have showcased remarkable potential in early disease identification and improved efficiency compared to traditional methods.

In calves with respiratory disease, thermal imaging cameras identified animals in the early stages of illness up to a week before clinical symptoms appeared. By using thermal imaging, diagnosis accuracy was enhanced, surpassing the industry standard practice of clinical scoring by 4-6 days before the onset of clinical symptoms. Similarly, the technology proved effective in diagnosing bluetongue virus (BTV) in sheep, distinguishing between low-grade fever and clinically normal sheep with a sensitivity of 85% and specificity of 97%. Continuous monitoring of sentinel animals through thermal imaging was suggested to reduce BTV outbreaks.

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In poultry, thermal imaging demonstrated promising results in the detection of bumble foot, achieving an accuracy level of 87% when presented with clinical cases, compared to only 27% with visual inspection. However, its application in the detection of foot and mouth disease in cattle showed a 50-60% detection rate, suggesting that the technology may not be universally applicable or may require further optimization.

Thermal imaging has also been utilized to detect ear tag infections in lambs, with significant temperature differences observed between infected and non-infected ears before clinical symptoms emerged. Electronic ear tags were associated with a higher infection rate than conventional visual ear tags, possibly due to their greater weight and impact on animal retention rates.

1. Early Detection of Bovine Viral Diarrhoea (BVD) in Calves

In the battle against Bovine Viral Diarrhoea virus (BVDV), infrared thermal imaging (IRT) has emerged as a groundbreaking tool for early detection. Calves subjected to IRT showed remarkable results, as the technology identified body temperature changes consistent with BVD as early as the very first day of infection. Temperature proved to be the most reliable indicator of disease progression, with orbital IRT temperature readings peaking alongside abnormal clinical scores, indicating the most severe clinical signs of the disease.

The true power of IRT lies in its ability to measure the rate of change in temperature at a specific anatomical site. By doing so, it enabled the detection of BVDV-infected calves before other diagnostic tests yielded positive results or clinical signs of the disease were evident. This early detection is crucial in effectively managing BVD outbreaks. IRT serves as a highly effective screening tool for cattle herds, identifying BVDV-infected animals up to 1 week before the onset of viral shedding.

2. Infrared Thermal Imaging aids in Bovine Respiratory Disease Complex Management

Bovine Respiratory Disease Complex (BRDC) poses a significant challenge to cattle health, with multiple factors contributing to its pathogenesis. Successful treatment hinges on early disease recognition and timely intervention. In this regard, infrared thermal imaging (IRT) of the eye has emerged as a powerful tool in identifying cattle with BRDC several days before clinical signs appear, comparable to more invasive methods like rectal temperature and serial blood tests. The integration of IRT with radio frequency identification (RFID) tags, applied to each animal and linked to a remote computer, further enhances early BRDC detection. As cattle approach the water station in the pen, the IRT camera activates automatically, obviating the need for individual animal capture and restraint. This streamlined approach makes IRT an appealing alternative to traditional testing methods, such as rectal temperature monitoring or blood sampling.

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The benefits of this innovative system are twofold. First, it enables producers and veterinarians to swiftly isolate and treat cattle for BRDC during the early stages of the disease, significantly increasing the probability of treatment success. Second, early detection and intervention effectively minimize the transmission of the disease within the herd, preventing further spread. The incorporation of IRT and RFID technology represents a major advancement in BRDC management, as it optimizes disease monitoring, reduces stress on cattle, and enhances treatment outcomes. By leveraging this non-invasive and efficient approach, livestock farmers can proactively safeguard herd health and bolster the overall productivity and welfare of their cattle.

3. Advancing Foot and Mouth Disease Detection: The Potential of Infrared Thermal Imaging in Outbreak Management

Foot and Mouth Disease (FMD) remains a significant concern in cattle and pigs, necessitating swift and accurate detection methods for effective outbreak control. Experimental inoculation of cattle with FMD virus has shown that infrared thermal imaging (IRT), in combination with traditional rapid diagnostic tests, can be a valuable tool in identifying FMDV-infected cattle during an outbreak. The early identification of infected animals facilitates prompt disease control, hastens eradication efforts, and expedites recovery. IRT's role as a pen-side screening tool allows for on-site testing of animals suspected of FMDV infection, complementing the time-consuming and labor-intensive gold standard FMDV testing protocol involving virus isolation and PCR assay confirmation. Following the establishment of standard operating protocols, IRT and pen-side diagnostic tests could be utilized for early detection of FMDV-infected animals, aiding in quarantine measures or pre-emptive culling.

In cattle, IRT has been used to monitor temperature increases at the coronary band, showing a rise in FMDV-infected cattle 24 to 48 hours before the appearance of vesicular lesions. This increase was not affected by floor temperature, making it a promising indicator of disease progression. However, it is important to note that an elevated coronary band temperature may also occur due to other inflammatory processes, necessitating the identification of a specific thermographic signature for FMDV-infected animals through ongoing research. In pigs experimentally infected with FMDV, IRT has shown a positive correlation between disease progression and temperature increases in the extremities. However, the effectiveness of IRT in identifying FMD-infected animals in a field setting, where confounding factors are less controlled than in a laboratory, remains uncertain. Nonetheless, the maximum eye temperature, determined by IRT, can be used to identify pyrexic animals, unaffected by ambient temperature and indicative of early stages of FMDV or other pyrexia-inducing viruses.

4. Advancements in Detecting Rabies, Tuberculosis, and Blue Tongue Virus in Livestock using IRT

Rabies, tuberculosis, and blue tongue virus are significant infectious diseases that pose public health concerns and impact livestock management. In recent studies, infrared thermography (IRT) has shown promise as a valuable tool in detecting and identifying animals affected by these diseases, revolutionizing early detection and disease management.

For rabies, IRT has been used to detect raccoons in the infectious stage of the disease. Experimentally infected raccoons with clinical signs of rabies exhibited significantly higher maximum nose temperatures compared to uninfected raccoons. This rise in temperature is linked to increased vascular permeability and blood flow to nasal tissues, caused by the release of chemical mediators. IRT's ability to identify abnormally increased nose temperatures in the early stages of rabies could aid in visually identifying potentially rabid animals, allowing for timely management to reduce the risk of viral transmission. However, it is essential to confirm rabies diagnosis through standard laboratory techniques, as an increased nose temperature is not specific to rabies infections. In the case of tuberculosis, traditional pre-movement testing of animals is time-consuming, requiring at least 72 hours to complete. IRT offers a potential solution by shortening screening time significantly. Cattle hyper-sensitized to *Mycobacterium bovis* or *Mycobacterium avium* showed a temperature increase associated with swelling or inflammation at the mycobacterium injection site during traditional tuberculosis testing. These findings suggest that IRT could complement or even replace traditional testing methods, expediting screening processes for tuberculosis in animals.

As for blue tongue virus, IRT demonstrated impressive sensitivity and specificity in detecting sheep with pyrexia, a common symptom of the disease. The eye temperature determined by IRT strongly correlated with rectal temperature, further validating IRT's efficacy in sheep. While IRT shows great promise for detecting blue tongue virus in sheep, further evaluation in field settings is necessary to assess its full potential.

Infrared Thermal Imaging (IRT) technology offers numerous advantages that significantly enhance livestock management and health:

1. **Non-Invasive and Safe:** IRT allows farmers to maintain a safe distance from the animals, minimizing health and safety risks associated with working closely with livestock. Additionally, the non-contact nature of IRT reduces stress on the animals, promoting better animal welfare.

2. **Efficiency and Labor Savings:** With just one person needed to operate the thermal imaging camera, IRT reduces the need for additional labor in the diagnostic process. The data can be stored or sent to the cloud for later analysis, streamlining the workflow and enhancing efficiency in livestock assessment.
3. **Early Detection of Health Issues:** One of the key benefits of IRT is its ability to detect health problems before clinical symptoms become evident. For instance, in cases of mastitis, IRT can identify changes in udder temperature even before visible symptoms occur, enabling timely intervention and treatment.
4. **Precise Problem Localization:** IRT can precisely pinpoint problem areas, such as lameness in animals. This accuracy aids in early diagnosis and targeted treatment, saving the farmer from unnecessary treatments and investigative costs.
5. **Cost Savings:** By detecting health issues early and targeting treatments more accurately, IRT helps farmers save on medical costs and reduce the use of unnecessary antibiotics. This not only saves money on medication but also reduces the risk of antibiotic resistance, promoting more responsible antibiotic use.
6. **Sustainable Farming Practices:** With the ability to reduce antibiotic usage and wasted milk, IRT promotes sustainable farming practices. By identifying health issues promptly, farmers can adopt more targeted treatments, minimizing the environmental impact of excessive medication use.

Despite its numerous advantages, infrared thermal imaging (IRT) technology does come with certain limitations:

1. **Cost and Expertise:** The initial investment in infrared thermal imaging equipment can be expensive, making it challenging for small and medium-sized ranches with limited funds to adopt this technology. Additionally, using IRT effectively requires trained operators with a good understanding of the equipment and its settings.
2. **Environmental Factors:** The accuracy of IRT measurements can be affected by various environmental factors, such as ambient temperature, humidity, and wind. The complexity of the pasture's ecological factors may introduce errors in temperature measurements, necessitating careful parameter adjustments by technical personnel to minimize inaccuracies.
3. **Indirect Causation:** While IRT is highly sensitive in detecting temperature changes in animals, it cannot always determine the direct cause of these differences. In some cases,

further traditional diagnostic methods may be required to pinpoint the underlying issue, making IRT a complementary rather than standalone diagnostic tool.

4. **Limited Applications:** Currently, IRT technology is primarily focused on specific health issues or conditions, such as mastitis or lameness. Expanding its applications to cover a broader range of health concerns would require ongoing research and development.

Conclusion

Infrared thermal imaging offers a groundbreaking approach to enhancing animal health and welfare, ultimately leading to increased productivity and profitability for farm businesses. To ensure meaningful and accurate results, establishing a robust baseline from clinically normal animals within the herd or flock is critical. This baseline provides a reference for comparison, enabling the identification of abnormal temperature patterns associated with health problems. Additionally, factors such as environmental conditions and time of day must be carefully considered to minimize confounding effects on the thermal imaging data. Breed, age, and parity are also essential considerations as they can influence temperature variations among animals. By carefully accounting for these factors and implementing thermal imaging technology effectively, farmers can take proactive measures to address health issues early on, leading to improved animal well-being, increased productivity, and ultimately greater profitability for the farm business. As the technology continues to evolve, its widespread adoption in animal production is likely to revolutionize livestock management practices.

References

Alsaaod, C., Syring, J., and Dietrich, M. G. (2014). A field trial of infrared thermography as a non-invasive diagnostic tool for early detection of digital dermatitis in dairy cows. The Veterinary Journal 199:281–285.

Bashiruddin, J. B., Mann, J., and Finch, R. (2006). Preliminary study of the use of thermal imaging to assess surface temperatures during foot and- mouth disease virus infection in cattle, sheep and pigs. In: Report of the 2006 session of the Research Group of the Standing Technical Committee of the European Commission for the Control of Foot-and Mouth Disease. Rome: Food and Agriculture Organization of the United Nations, 304–308.

Culina, M., J. Hahne, and Vorlop, K. D. (2006). Design of an online sensor array for an early detection of udder affections in automatic milking systems. Pages 453–454 in World Congress of Agricultural Engineering for a Better World: Book of Abstracts. VDI Verlag GmbH, Bonn, Germany.

Johnson, S. R., and Dunbar, M. R. (2008). Use of infrared thermography as an alternative method to evaluate the comparative cervical test (CCT) in cattle sensitized to *Mycobacterium bovis* or *M. avium*. In: Proceedings of 112th Annual Meet US Animal Health Association, 101–102.

Lowe, G. L., Sutherland, M. A., Waas, J. R., Schaefer, A. L., Cox, N. R., and Stewart, M. (2019). Physiological and behavioral responses as indicators for early disease detection in dairy calves. *Journal of dairy science*, *102*(6), 5389–5402. https://doi.org/10.3168/jds.2018-15701.

Pérez de Diego, A. C., Sánchez-Cordón, P. J., and Pedrera, M. (2013). The use of infrared thermography as a non-invasive method for fever detection in sheep infected with bluetongue virus. Veterinary Journal, 198:182–186.

Rainwater-Lovett, K., Pacheco, J. M., and Packer, C. (2009). Detection of foot-and-mouth disease virus infected cattle using infrared thermography. Veterinary Journal, 180:317– 324.

Zheng, S., Zhou, C., Jiang, X., Huang, J., and Xu, D. (2022). Progress on Infrared Imaging Technology in Animal Production: A Review. *Sensors (Basel)*, 22 (3):705.