REVIEW ARTICLE

Bihevioral activity data for improving production of dairy cattle

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Summary
Monitoring and timely control of physiological processes in cows directly affect production and reproduction. Intensive farming has driven the development of monitoring systems for precise herd management. These systems vary in terms of sensor type, functionality, purpose, and the quality of processed data. Sensors enable monitoring of key activities like illness and estrus detection, rumination, feeding, group behavior, and calving prediction. The widespread use of pedometers has enabled research, improving data control and breeding programs. Besides reproductive and production data, selection requires genetic information. Integrating pedometer and genetic data supports innovative concepts that boost production efficiency and sustainability.

Key words: sensors, pedometers, dairy cattle, reproduction, production,

Introduction

Dairy production involves a range of technological processes that connect humans, cattle, and complex automated systems. Production parameters such as milk yield, fat and protein content, as well as the reproduction rate depend on the individual cow performance. Optimal nutrition, veterinary care, quality of housing conditions, and effective management are essential for maintaining productivity. In addition to providing optimal production conditions, monitoring animal behavior becomes more important factor in intensive farming systems. In these systems, cows undergo various physiological processes that must be promptly recognized and managed, posing significant challenges. The development of cow monitoring systems has enhanced efficiency in managing production and reproductive data. These systems vary in terms of group or individual approaches, as well as the purpose of the devices depending on targeted traits. Automated monitoring models consist of one or multiple devices, a data storage system, and software for interpreting the results. Devices can be designed as leg or neck collars, or ear or neck sensors, although applications to other body parts also exist but are less common. The advantages of these systems are numerous including individual or group monitoring, objective estrus detection and disease identification, improved synchronization of insemination, as well as the availability and storage of large amounts of data. Monitoring cow activity through tracking systems provides detailed insights into individual variability in traits measurable through these technologies. This variability can be the result of various factors, including genetic differences among animals, environmental influences, or their interaction. In addition to monitoring bihevioral activity variation, studying the genetic structure of these traits raised interest in scientific research. Breeding programs are based on genetic parameters such as heritability and genetic correlations mainly for economically important traits (Oliveira Junior et al., 2021). Identifying specific genomic sequences associated with bihevioral activity traits represents a novel approach in modern livestock breeding, enabling the long-term optimization of production systems.

Systems for monitoring and tracking cows

Monitoring and tracking systems include technological solutions that provide continuous access to information on cow health, nutrition, reproduction, and overall status. Current tracking systems usually include: 1) individual sensors or a combination of sensors placed on each cow, including magnetometers, accelerometers, gyroscopes, compasses, pressure sensors, microphones, and global positioning systems (GPS); 2) devices for processing, storing, and distributing data collected by the sensors; 3) models or combinations of models that interpret animal behavior based on raw sensor data (Rahman et al., 2018). These monitoring systems have the ability to accurately track all processes related to production and reproduction. Nowadays, various sensors are available for classifying animal behavior, such as walking, ruminating, grazing, and resting (Neethirajan, 2020). The use of wearable sensors for cattle behavior is becoming an increasingly important tool in farm management and recently in breeding programs. Unlike traditional herd-based approaches, these technologies enable a stronger focus on improving individual welfare and efficiency (Rahman et al., 2018). Sensors are linked to the animal's identification number (ID) allowing collected data to be archived and analyzed in herd management software. Sensors can track various activites including detecting sick cows and estrus, monitoring rumination and feeding, analyzing group behavior, and predicting the onset of calving (Marques et al., 2024). Sensors can be placed on different parts of the animals, while the relevance and quality of the data depend on sensor type, control conditions, and manufacturer (Rahman et al., 2018). A study by Holman et al. (2011) suggests that activity monitoring devices placed on the leg can detect estrus more reliably than those mounted on neck collars. However, in grazing conditions, neck-mounted sensors have been shown to effectivelly identify estrus. Accelerometers are among the key devices used for monitoring cow activity. These sensors belong to the category of microelectromechanical (MEMS) systems and measure movement-based activity (Neethirajan and Kemp, 2021). One example is the SensOoR 3D accelerometer (Agis Innovations), which was developed to be attached to ear tags on cattle, allowing precise tracking of their activities. The sensor measures movements along three axes, enabling monitoring of head position and movement (Martiskainen et al., 2009). The system processes sensor data and classifies behavior into four categories: resting, activity, eating, and ruminating. This classification system is based on recognizing specific movement patterns, providing insights into the activity and behavior of animals, allowing more efficient monitoring and management (Bikker et al., 2014). According to the results of Bikker et al. (2014), it can be concluded that ear-mounted sensors can provide relevant data on rumination and resting patterns in dairy cows housed in free-stall barns. Ear sensors have microphones that can track the sounds of chewing and swallowing. Movements from the facial and neck muscles are transferred to the ears, allowing the sensors to detect micro-movements through algorithms designed to recognize rumination patterns. Additionally, these sensors show potential for monitoring feeding behavior in intensive commercial systems, though further research is needed to validate their effectiveness (Bikker et al., 2014). In addition to being attached to the ears, different types of accelerometers can be placed on the neck or legs, where they effectively track behavior with high sensitivity (Morrone et al., 2022). Cow activity and behavior can also be monitored using video and infrared cameras, which rely on temperature-sensing technology (Perez Marquez et al., 2019). However, a major challenge for monitoring systems in intensive cattle farms is the limited space available for movement, which reduces the effectiveness of pedometry (Palmer et al., 2010). Data sets generated through precision livestock farming, incorporating activity monitoring systems such as pedometers, accelerometers, thermal cameras, and video surveillance in combination with the development of data science, are crucial for demonstrating animal welfare and improving genomic breeding values (Brito et al., 2020).

Implementation of digital systems in dairy cattle farming

Cattle farming systems present a specific challenge for farmers, as each individual animal represents a high-value investment. Overall production efficiency is influenced by a wide range of factors, which in turn affect herd profitability (Neethirajan Kemp, 2021.). In livestock sector, behavior analysis provides valuable insights into: 1) animal health; 2) food intake and satiety status; 3) heat periods and estrus occurrence (Rahman et al., 2018). Health status of the animal is usually determined by the animal behavior patterns (Shahriar et al., 2016). Behaviors such as feeding are indicators of feed consumption. The percentage of time spent in feeding related behaviors can be useful for understanding the relationship between the amount of feed intake and the availability of pasture, as well as for assessing animal preferences and their level of satiety (Greenwood et al., 2016). The periods of heat and signs of estrus can be detected through changes in activity, where the animal becomes restless. Identifying the estrus period indicates the optimal time for artificial insemination (Rahman et al., 2018). The identification of estrus is crucial in assessing the reproductive efficiency of dairy cows (Wang et al., 2020). Incorrect estrus recognition and false positive results in estrus detection can lead to missed opportunities or inaccurately timed artificial inseminations. The outcome of such decisions is poor reproduction, causing economic losses on dairy farms (Perez Marquez et al., 2019). Estrus is influenced by a large number of factors that affect its intensity and duration, leading to variation within the herd (Reith and Hoy, 2018). The ability to monitor the timing of fertile cycles in real-time is essential for effective herd management, while precise nutritional control plays a key role in maximizing milk production (Neethirajan and Kemp, 2021). Automated activity monitoring system in estrus detection vary in the variables they analyze, incuding step count, accelerated movement, rumination frequency, and lying duration (Morrone et al., 2022). Pedometers have proven to be an effective tool for estrus detection and are considered a promising method for predicting ovulation, ultimately improving fertility rates (Wang et al., 2020). In an experiment conducted by Valenza et al. (2012), a neck-mounted device succesfully detected approximately 71% of pre-ovulatory phases, missing a total of 13% of recorded ovulations. Using the same devices, Aungier et al. (2012) detected 72% of pre-ovulatory follicular phases, with the remaining results classified as false positives. Cows are higly sensitive animals, and in intensive farming systems, diseases often arise that negatively impact production. Another significant issue in dairy cattle farming is lameness, which is widely recognized as a major concern. Clinical lameness leads to financial losses for farmers due to reduced production, delayed estrus, and various indirect costs. Early detection and subsequent treatment shorten the time needed for complete recovery and return to production, thereby reducing financial losses for the farmer (Mazrier et al., 2006). Most cases of lameness related to the hoof, excluding trauma-induced injuries, result from subclinical laminitis, which includes conditions such as abscesses and double sole (Van Nuffel et al., 2016). Pedometers, along with other monitoring systems, are commonly used to detect lameness in dairy and beef cattle. In a study conducted by Morrone et al. (2022), seven variables were used to diagnose lameness: walking speed, beats per minute, milk yield, lactation number, milk flow rate, and milk electrical conductivity. Feeding and rumination are among the most important activities for ruminants, as these behaviors occupy most of their daily routine. Monitoring these activities provides a more accurate insight into animal health and productivity.

Conclusion

Precision livestock farming systems have developed models for monitoring and tracking animal activity. These models are capable of tracking major physiological activities and behaviors in real time. Data collected from automated devices are transmitted to specialized programs for behavior and activity interpretation. Tracking models vary in terms of sensor type, functionality, communication, and attachment method. Pedometer devices, due to their effectiveness in monitoring production and reproductive processes, have significantly contributed to advancements in livestock technology. However, a major drawback of these systems is the high initial investment cost and expensive maintenance. Modern breeding programs require not only technological solutions but also the integration of genetic data. Combining information from monitoring systems with genetic data from genotyped individuals enhances breeding selection programs, creating a more precise and efficient approach to livestock management.

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