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Precision systems in dairy farms related to monitoring and management of some reproductive and health indicators - A review

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Abstract: Precision dairy farming (PDF) systems are developed through the use of sensor technologies, sound analysis, image analysis, and processing of results through special algorithms with continuous monitoring and analysis of data in real time - 24 hours a day, 7 days a week. The aim of this study is to analyze the use of precise monitoring systems related to certain health and reproductive indicators in dairy cows. These systems have the ability to collect, process and analyze information on motor activity, detection of cows in estrus, monitoring of rumen and body temperature, condition of limbs and hooves, as well as mastitis control. Precise monitoring systems allow farmers and consultants to make management decisions based on information, both at the level of an individual animal and for the entire herd. The information from such systems cannot be subjective, nor can it be manipulated even by chance, which makes it objective. Whether the decisions that farmers and consultants make are correct depends, however, not only on the information received, but also on their knowledge and skills.

Keywords: precise monitoring systems; dairy cows; health indicators; reproductive indicators

INTRODUCTION

The dairy cattle sector is going through a transitional phase, but in an upward trend in terms of the number of high productive cows. The number of dairy cattle with good genetic potential is increasing. Precision dairy cattle technologies allows milk producers to make timely and informed decisions, which, according to Van Asseldonk et al. (1999), leads to better productivity and profitability.

Often, when an animal shows clinical signs of stress and illness, it is already too late for preventive action. The manifestation of noticeable clinical symptoms is usually preceded by physiological reactions that are not visible to human eyes (e.g., changes in temperature and heart rate). The availability and use of precise monitoring systems can help the dairy farm manager intervene earlier and take adequate preventive actions. At present, in practice, more and more data is collected through various technological innovation systems. Some of the important benefits of permanent residency include increased efficiency, reduced costs, improved production quality, minimized adverse impacts on the environment, improved animal health and welfare (Bewley, 2010). The use of precision technology to record productive, reproductive and health indicators increasingly provides farmers with reliable information. With the correct use of this information in the production process, a reduction in financial costs and improvement in the management of large herds is achieved (Bewley, 2010; Eastwood et al., 2012; Easrwood et al., 2015).

According to Bewley (2010), integrated computerised information systems are essential for the interpretation of large amounts of data obtained through precision dairy cattle technologies.

This information can be incorporated into systems designed to facilitate decision-making on problems that require the collection of data from multiple sources. Moreover, Bewley (2010) and Eastwood et al. (2015) report that by identifying changes in physiological parameters, the farm manager can intervene earlier, while in the absence of precise technologies, decisions for each cow will be based almost entirely on the judgement and experience of the farmer.

According to Popova et al. (2024), precision livestock farming involves the use of digital technologies in order to improve production and reproduction, animal welfare and facilitate the use of resources to reduce the impact on the environment and human health through the precise control of processes.

The aim of this review is to investigate the use of precise monitoring systems related to the determination of health and reproductive indicators in dairy cows.

Systems for monitoring and reporting motion activity and heat detection of cow

The daily movement of dairy cows along with milk yield can be used as an important tool for early detection of various potential physiological or health abnormalities in dairy animals. To this purpose, Edward and Tozer (2004) use an automated system, called „Pedometer". They use the pedometer to monitor both the daily movement of dairy cows and during milking, feeding, standing and lying down, and the system detects, registers and reports changes that have occurred.

Adewuyi et al. (2006) discover 7 to 8 days early based on motor activity and 5 - 6 days early based on milk yield, disorders in premature cows such as ketosis and digestive disorders. They found a negative correlation between movement activity and plasma concentration of NEFA in dairy cows. It is reported that the pedometer can predict the appearance of lameness earlier than the manifestation of clinical signs in a herd of dairy cows such as Mazrier et al. (2006) compared pedometric activity with clinical cases of lameness. Currently, the accounting of the daily motor activity of animals is mainly used to detect cows in estrus.

In the late 80s and early 90s of the last century, researchs were carried out on the use of pedometers to detect cows in estrus (Holdsworth and Markillie, 1982; Redden et al., 1993). More recently, have become available 3D-accelerometer, which are used to detect estrus (Lovendahl and Chagunda, 2010; Valenza et al., 2012) and assisting in performing estrus synchronization. In addition to those based on automated estrus detection systems, there are others, such as a system for measuring progesterone (Friggens and Chagunda, 2005).

According to Saint-Dizier and Chasant-Maillard (2015), in practice, four monitoring systems are available to determine calving times: inclinometers and accelerometers detecting tail raising and changes in animal activity; abdominal belts to monitor uterine contractions; vaginal devices determining vaginal temperature and allantochorionic expulsion, but all of them are still of limited use.

Another monitoring system available on the market is the electronic ear tag, which contains an accelerometer collecting data on the motor activity of dairy cows. This system has been developed as a real-time monitoring tool providing localization of animals (Wolfger et al., 2016), data for locomotion activity and rumination.

Estrus detection system can be combined with a system to optimise insemination time (Steeneveld et al., 2012).

Aungier et al. (2012) conduct research, which includes dairy cows (pasture farming), monitored during the breeding season via a neck-mounted activity monitor Heatime. In this study, they set themselves the goal of establishing both the relationship between the physical activity index created for each cow by the monitoring systems and the identification of the pre-ovulatory follicular phase, as well as the influence of various production factors on health and the relationship between physical activity and behavior during estrus. According to the authors, advances in the development of precise automatic monitoring of the pre-ovulatory follicular phase will help determine the timing of insemination and thus improve the degree of fertilization.

LeRoy et al. (2018) conduct a survey, with which they set their goal to evaluate the ability of an automatic motion monitoring device to determine estrus and the time of first insemination, the accuracy of this device and the optimal time interval between the notification of estrus by the device and the time of insemination. The study was conducted on four dairy farms with various automatic systems for monitoring the movement and activity of cows over a year. The results of the activity monitoring show that more than 80% of cows must be inseminated for the first time between 55 and 80 day from the beginning of lactation. Timely detection and treatment of purulent vaginal discharge, lack of ovulation or laminitis will improve the results of the use of automatic monitoring systems in determining estrus. However, due to the large differences in this study with another one, the authors considered that further research is needed to confirm the optimal time for first insemination, especially in first-calves, as well as the factors that influence it. The authors found, insemination based on the results of automatic monitoring systems once a day is acceptable for cows in the second, third and more lactation, while for heifers at least twice observations and reports daily for activity are required, and only then switching to insemination.

The observation and follow-up of the cow during the advanced stage of pregnancy (last trimester) to start the calving process is an important aspect of managing a dairy farm. This make it possible to organize the presence of a companion during calving in a timely manner, which is a prerequisite to avoid or quickly resolve any unfavorable situation for both the cow and the calf. Although the expected calving date is known, farmers should still regularly check the animals to determine when calving begin. Sensor monitoring system predicts the moment of calving, which helps farmers to efficiently organize this process (Hogeveen, 2017; Rutten et al., 2017).

Dystocia (misalignment of the fetus) and stillborn calves are common problems on dairy cattle farms, leading to an increase in the cost of veterinary care and treatment. Team of researchers (Krieger et al., 2018) determine the onset of calving using a triaxial accelerometer, fixed at the top of the tail by analyzing the pattern of movement of the tail of the calving cow. They developed an algorithm for detecting the frequency and duration of the queue raising and a function for decision-making and alarm when the threshold values of the studied indicators are exceeded. According to the authors, the precise monitoring system developed by them (Accelerometer) gives good results for predicting the timing of the upcoming calving.

Titler et al. (2015) conduct research, in which they aim to assess the effect of the upcoming calving on the behavioral activity of the cows (number of steps, time in standing position, time lying down, etc.) four days before calving, using electronic data loggers. During the study, the authors established a certain pattern of behavior of cows that predicted the onset of calving 6 hours in advance. According to the authors, electronic data loggers can be successfully used around the clock and in real time to determine the beginning of calving. This would make it easier the development and implementation of a precise program for calving process management in order to reduce calving-related losses (dead fetus, complications due to late or no help in calving, etc.). The appropriate time to place the electronic data loggers according to the expected calving date and activity index should be fine-tuned, taking into account the management and logistics of each individual farm.

Precision monitoring technologies in dairy cattle breeding are traditionally used to generate alarm signals related to the occurrence of health problems, the appearance of estrus, can be successfully used to report the change in the behavior of cows before calving. Precision monitoring technologies in dairy cattle breeding are traditionally used to generate alarm signals related to the occurrence of health problems, the appearance of estrus, can be successfully used to report the change in the behavior of cows before calving. In the absence of one of the components of this electronic network, the accuracy of the information provided significantly decreases. Therefore, according to Borchers et al. (2017), future studies should focus on setting appropriate time slots to ensure that farmers can make meaningful management decisions.

Observation of cows before calving is an important moment in the technological process due to the possibility of health problems, which requires timely intervention to mitigate adverse effects on both the cow and the calf. Since farmers have little time to monitor each cow, the presence of a sensor monitoring system supports and facilitates their daily activities (Hogeveen, 2017).

Crociati et al. (2020), investigate the net return from the implementation of a system for remote monitoring of calvings and the obstetric and neonatal care provided in a model dairy cattle farm over a 7-year period and a total of 680 calvings. The authors found that the use of this monitoring electronic system leads to an improvement in farm productivity, expressed in net return from €37 to €90 per cow per year. Of course, an electronic monitoring device alone cannot increase profits or reduce costs. It must be supported by adequate management decisions and the provision of qualified assistance and supervision by workers during the calving of cows. Optimising the presence of staff in the calving area at the right time leads to rapid calving, providing timely assistance to newborn calves and feeding them with colostrum within the first hours of their life, which in turn reduces mortality in calves and increases production indicators.

Rumen monitoring systems

In order to identify cases of health problems, such as subacute acidosis, ketosis and tympania of the rumen need to be measured and monitored pH of the rumen, temperature and the rumination using various automatic recording devices (Singh and Chopra 2007).

The development of technology allows for continuous monitoring of pH and temperature in the rumen. The correlation of these two indicators serves as a diagnostic marker in the occurrence of subacute rumen acidosis. The most widely used is the use of a bolus containing a temperature sensor, processor and transmitter to measure temperature (Ipema et al., 2008). The temperature of the rumen is measured every minute and stored in an internal buffer. Pressure changes are used to determine rumen movements. Therefore, by determining the pressure in the rumen, the occurrence of tympania can be determined. Although not very well studied, boluses would be a useful tool for establishing a precise relationship between the pressure inside the rumen and the appearance of tympania (Agrawal et al., 2023).

Monitoring of pH of the rumen can be used as a tool to achieve optimal health and obtain maximum production from dairy cows. The value of pH in all parts of the rumen must be within the limits of 6.3 to 6.7, in order to maintain optimal physiological conditions for fermentation. The measurement of pH of the rumen is a reliable and accurate diagnostic test for the presence of health problems such as rumen acidosis. Reducing the values of pH of the rumen has feedback on rumen temperature (Phillips et al., 2010).

Another indicator of herd health is the percentage of animals that survive at any time, because the pH of the rumen is influenced by the time the cows spend in rumination (Owens et al., 1998). Continuous monitoring of the ruminations makes it possible to accurately detect subacute acidosis when detecting deviations characterized by reduced intensity and number (Phillips et al., 2010). Some consultants believe that the dairy herd is in good health when at least 40% of the cows ruminating at some point (DeVries et al., 2009).

Body temperature monitoring systems

Body temperature is the first indicator to be established, since for many diseases an increase in body temperature is an early physiological reaction. According to Maatje et al. (1987), the use of an automatic body temperature monitoring system on the dairy farm is of significant benefit, as it helps to detect cases of illness or health disorders early. In recent years, a number of intensive management programs have been established for groups of fresh cows, based on the use of thermometers to detect fever (Aalseth, 2005).

Faruq et al. (2019) develop a system for managing the health status of dairy cows (combining monitoring systems and detection systems in one application using IoT and intelligent system technology). They found that in cows for milk based on temperature and heart rate (error from 0.6 degrees Celsius and 3.5 beats per minute), this system can diagnose a manifestation of a disease with an accuracy of 90%. Authors specify, that this complex monitoring system is used and is useful mainly for research purposes, while its implementation in practice is difficult and expensive.

Hoof disease monitoring and control systems

One of the serious problems in dairy cattle breeding is protecting animals from the appearance of lameness (von Keyserlingk and Weary, 2017). Due to the widespread lameness and the difficult and prolonged treatment, it remains one of the most important animal welfare issues, health and economic consequences for dairy cattle worldwide (Huxley, 2013). Detection and assessment of locomotion score through visual observation is very time-consuming, requires well-trained staff and financial costs (Vasseur et al., 2015), rarely used on farms (M.de Vries et al., 2014; Otten et al., 2019). Creating a model for remote forecasting and detection of lameness without the need for constant on-site monitoring on the farm is the goal of many scientific studies.

Large volumes of data are used in modern dairy cattle breeding (Kamilaris et al., 2019), but some of this data remains underutilized.

As the volume and complexity of information collected from dairy farms grows rapidly, the introduction of precision monitoring systems into practice is becoming increasingly necessary (Morota et al., 2018). At the same time, Pietersma et al. (2003) consider that in the case of small databases, the use of the „decision tree“ is useful and enough to get good results.

Thorup et al. (2015) investigated behavioral changes in dairy cows due to the degree of lameness and farming using an accelerometer attached to the legs. They found that through this device the first signals of the appearance of laminitis can be reliably reported, and future research in this direction will be very useful.

Alsaaod et al. (2015) conducted a study aimed at developing and validating a new algorithm for monitoring locomotor behavior based on data from a 3-dimensional accelerometer, collected from free-range dairy cows, and comparing it with the results of video surveillance devices. They conducted a study aimed at developing and validating a new algorithm for monitoring locomotor behavior based on data from a 3-dimensional accelerometer collected from free-range dairy cows, and comparing it with the results of video surveillance devices. The results of this study suggest that the newly developed algorithm for pedometers can be successfully used in determining the following behavioral characteristics – lying time, time at which cows stand upright, time of movement, number of standing up and duration of standing. The authors consider, that further research is needed to investigate in more detail the normal locomotor behaviour (with a focus on walking) of healthy dairy cows and to assess the ability to detect lameness early.

Taneja et al. (2020) using long-range pedometers, specially designed for use in dairy cows, they monitor the activity of each cow in a herd of 150 animals. Accelerometric data is aggregated and forms time series of behavioral activities that are further analyzed. According to the hybrid model used by the authors, initially each cow was classified as active, normal or dormant, and subsequently assigned to the group of cows with laminitis or cows without laminitis. Information about the presence of laminitis in an animal is sent as a notification to the farmer‘s mobile device. This pedometer model announces the appearance of lameness 3 days before it is visually detected by the farmer, and the accuracy of the results is not less than 87%. In this way, the problem animal can be treated immediately in order to avoid more serious losses.

A group of authors develop 3D video system for detecting lameness in dairy cows, which uses reading in changing the height of the hips by automatically determining the curvature of the spine and hips using the shape and curvature index. They determine threshold for the onset of early stage lameness and using a linear model achieve accuracy of judgement by 95.7% (Jabbar et al., 2017). Other authors (Warner et al., 2020) explore the possibility of developing flexible and appropriate approach, with which he can remotely to identify herds with a high risk of lameness through an automated computerized system.

Detecting problems with the limbs and the appearance of laminitis In dairy cows, with the help of accelerometers, the purpose of a number of studies is to investigate the behavioral changes in the animal‘s bedtime and wake-up. Most of these studies show good results and efficacy in detecting the initial manifestations of lameness, but mainly under experimental conditions. The widespread implementation of such devices and systems in real practice still upcoming (O'Leary, et al., 2020).

CONCLUSION

Precision systems monitoring enable farmers and consultants to make management decisions based on information, obtained from modern monitoring systems, both at the level of an individual animal and for the whole herd. Information from such systems cannot be subjective in nature, not to be manipulated even by accident, and this makes it objective. The decisions made by farmers and consultants are correct or incorrect, depends not only on the information received, but also on their knowledge and skills. The availability of reliable information and correctly made decisions make farmers competitive. This is where the need arises from upskilling and lifelong learning.

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