Emerging technologies in dairy medicine

Luciano S. Caixeta, DVM, PhD; Elise Shepley, MSc, PhD
Department of Veterinary Population Medicine, College of Veterinary Medicine,
University of Minnesota, St. Paul, MN 55108

Abstract

Technology is often adopted in dairy farming for one – or many – of the following reasons: to increase farm efficiency, improve farm profitability, assist in decision-making, improve animal welfare and, in some cases, increase producer happiness. As the use of technologies increases in dairy farming, dairy practitioners, who are regarded as the most reliable source of information by producers, must learn about the innovations available in the market in order to assist dairy producers when adopting these emerging technologies. More importantly, dairy producers and practitioners should leverage the large amount of data generated by these innovations to develop management actions to improve animal health, performance and welfare. This review focuses on presenting some of the emerging technologies used for the management and monitoring of lactating dairy cows, and how these technologies can be used by dairy practitioners to add value to the services they offer while increasing farm efficiency and animal welfare.

Key words: monitoring, precision dairy, activity, rumination, estrus detection

Introduction

Dairy farming, and consequently dairy production medicine, evolved at a fast pace in the last few decades with a rapid increase in adoption of precision dairy technologies. Nonetheless, dairy producers continue to search for innovations to improve the management of individual and groups of cows, increase milk yields, reduce overall costs and improve whole farm management and efficiency.[1] In this scenario, the development of user-friendly precision dairy innovations that can bring a relative advantage by comparison to current practices and are compatible with other technologies already in place in dairy farms plays an important role in the evolution of dairy farming and production medicine.[2] Already we can see the dairy community's commitment to innovations working toward fulfilling this role in driving the dairy industry forward, resulting in an increase in the number of technologies available on the market to monitor physiological, behavioral, management and production changes in individual and groups of cows.

The use of wearable sensors (e.g., pedometers, collars or ear tags) capable of measuring a dairy cow's activity and rumination for the detection of transition cow disease[3,4] and the detection of estrus[5] are among the most common precision dairy technologies encountered on dairy farms. Hence, these technologies are the most investigated by researchers with encouraging results being reported by several research groups. For instance, monitoring rumination and activity behavior have been shown to detect transition cow diseases such as mastitis, ketosis, displaced abomasum, metritis and retained placenta earlier than trained personnel.[6-8] In addition, the use of wearables sensors for the monitoring of activity and detection of estrus during the voluntary waiting period or following insemination have been important in the development of effective reproductive programs that do not depend on the enrollment of the majority of the cows in fertility programs using exogenous hormones.[9] As producer demand and industry needs continue to drive innovation further, so too does the adoption of other existing forms of precision dairy innovation beyond these more common wearable sensors and the push to develop new technologies.

The increase in the adoption of precision dairy farming technologies by dairy producers presents dairy practitioners with a great opportunity to contribute to the improvement of farm efficiency and animal welfare. The adoption of innovations that can provide real-time insight into cow health and performance is a powerful tool to support decision making, especially when used in combination with clinical observations.[10] These emerging technologies have the potential to take away the subjectivity of decision making, decreasing the frequency of protocol deviation and enabling the implementation of optimized protocols for the treatment and prevention of clinical diseases. Moreover, the adoption of emerging technologies has the potential to reduce the use of antimicrobials and exogenous reproductive hormones and instead enable the utilization of different management strategies for specific groups of cows. Lastly, the adoption of emerging technologies can improve animal performance as well as farm efficiency and sustainability while improving animal welfare. It is important to highlight that the commitment to implementing strategies to improve animal welfare is a powerful instrument to ease the public's perception of the dairy industry.[11]

Emerging technologies in dairy production medicine

There are many different innovations currently present in dairy farms. Rumination and activity monitoring systems are among the most popular innovations used by dairy businesses across the United States. Traditionally, rumination behavior has been measured by neck-mounted collars equipped with microphones or ear-tags equipped with accelerometers. Recently, however, reticuloruminal boluses capable of measuring rumination behavior have also been introduced to the market. Some of these devices are multifunction, having the capability to also measure activity, body temperature and, in some cases, rumen pH. As previously discussed, technologies capable of measuring rumination and activity behavior can be used to monitor cow health and welfare as well as reproductive management. Systems capable of measuring body temperature or respiratory rate of dairy cows can be used to monitor heat stress in groups of cows, whereas systems measuring rumen pH are useful tools to monitor the nutritional management of individual animals or groups of cows.

Automated lameness detection systems traditionally used wearable motion sensors for the detection of lameness in research and commercial dairy farms.[12,13] These systems, however, rely on the detection of substantial alterations in gait and physical activity that does not occur until more advanced stages of the disorder. In recent years, algorithms created using deep learning programs have been applied to image and videos for the early identification of lameness events. It has been reported that these systems can identify lameness events with high

accuracy, up to 96%, when continuously monitoring a dairy cow's locomotion prior to the lameness event.[14] The application of machine learning algorithms has also been proposed as a more efficient and accurate method to assess body condition score of dairy cows.[15,16] An automated system to assess body condition score in dairy cows would have the potential to generate more consistent and objective data without the need for trained personnel. Finally, machine video technology has been used to predict and monitor feed intake of individual cows[17] as well as to monitor feed availability and feed bunk management. Emerging technologies capable of accurately determining feed intake and feeding behavior can be extremely important for the improvement of nutritional management and, consequently, farm efficiency. Overall, due to their non-invasive nature, relatively low cost of installation, and capacity to produce continuous, reliable data, machine video technology, especially when integrated with other management and performance information, has an enormous potential in the dairy industry.

Innovations are also encountered in milking systems. Automatic milking systems – i.e., robots – are one the most well-known precision dairy technologies. The adoption of this technology in the U.S. and Europe has increased in the last several years,[18] driven in large part by labor concerns and unavailability of inexpensive and specialized labor. Since trained personnel are not constantly assessing milk appearance for the detection of clinical and subclinical mastitis, as is normally the case when milking manually, automatic milking systems rely on in-line sensors for udder health surveillance. In fully automated systems, somatic cell count and milk conductivity are assessed every milking for the detection of intramammary infections and clinical mastitis cases.[19] Similar in-line sensors can also be encountered in more traditional milking parlors. In addition, benchtop instruments for the measurement of differential somatic cell count are also available. Despite the poor accuracy of this technology to detect intramammary infections,[20] it can still be used to monitor udder health.

All these emerging technologies generate an overwhelming amount of data that cannot be easily managed and interpreted, hence the development of integrated, cloud-based networks using artificial intelligence and machine learning techniques. These integrated networks have been created to combine the complex data from different sensor and farm management records into actionable items that can be used to improve animal husbandry and farm efficiency. As these emerging technologies and the integration of data streams evolve, companies integrating these data will continue to deliver simpler and more customized reports to stakeholders, who will have a better understanding of the value of this information. In the future, terms like "artificial intelligence" and "machine" are likely to become part of the progressive dairy practitioner's vocabulary.

Emerging technologies meet dairy medicine

These following 2 sections will describe areas where emerging technologies are currently being used to optimize management as well as animal health and welfare on commercial dairy farms. This does not mean that these are the only emerging technologies commonly used in dairy production medicine. Other emerging technologies not discussed in this review (e.g., biotechnology) are also being used very effectively by today's dairy industry.

Automated health monitoring systems and disease detection

Rumination has long been recognized as an indicator of dairy cattle health and wellbeing. The development of different automated health monitoring systems capable of continuously monitoring rumination and activity behavior in real-time enables the collection and use of this information by commercial farms. Previous reports have demonstrated that differences in rumination and activity behavior pattern are observed approximately 5 days earlier than the clinical diagnosis of mastitis by farm personnel.[6] Similar results were also reported when using automated health monitoring systems for the detection of metabolic disorders[7] and metritis.[8] In addition, others have also reported that cows with decreased rumination and activity time before calving are also associated with disease development in early lactation.[3,4,21] Although current technologies still do not accurately determine the specific disease that will occur based only on the patterns of rumination and activity, the early detection of cows at risk for disease development allows for better allocation of farm input, such as personnel and treatments efforts, as well as for the development of management strategies for the prevention of transition cow disorders.[22,23] More importantly, it has been reported that the implementation of monitoring programs using alerts generated by automated health monitoring systems and milk yield information to identify cows suffering from health disorders during the transition period did not impact milk production, reproductive performance or herd removal patterns.[24] These results indicates that the health monitoring strategies based on alerts generated by automated health monitoring systems are a reasonable alternative to traditional monitoring programs for the identification of cows that are at risk to develop diseases and disorders in early lactation.

Targeted reproductive management

In recent years, the concept of targeted reproductive management has been investigated by different research groups. Targeted reproductive management consists of allocating different breeding strategies based on biological, management and performance information for each individual or groups of cows.[25] In this context, automated estrus detection systems play an important role. Automated estrus detection systems have been traditionally used to determine when cows should be inseminated.[26] However, scientific results indicate that dairy cows that express estrus at least once during the voluntary waiting period[27,28] and cows expressing higher intensity estrus[29] are more likely to become pregnant. Leveraging this knowledge, targeted reproductive management strategies are designed to prioritize artificial insemination following estrus detection. Recent results indicate that, when administration of exogenous hormones is withheld only from animals that are already cycling at the end of the voluntary waiting period and insemination of cows occurs following estrus detection, the overall reproductive performance is similar to reproductive management strategies relying heavily on the administration of exogenous hormones and timed artificial insemination.[9] As a consequence, these alternative strategies will not only decrease the need for trained personnel and protocol compliance, but, more importantly, will decrease the use of exogenous hormones on dairy farms. Therefore, targeted reproductive management presents itself as an effective alternative strategy that continues to allow farms to have good reproductive performance while adapting to consumer-driven requirements.

Other benefits of emerging technologies on dairy farming

One of the greatest improvements to animal welfare when using emerging technologies is the decrease in the lock-up time of cows considered to be healthy. Contrary to herds using transition cow monitoring management programs, which rely on locking up all cows in head gates at the feed bunk to be screened by trained personnel, dairy herds using automated health monitoring systems can use this technology to screen animals based on physiological and production measurements captured by the monitoring systems. In these herds, only cows that need attention from farm personnel are sorted to be locked up while the vast majority of the herd are left undisturbed. As a result, some herds have reported that this strategy has assisted with the identification of disease events earlier, increased milk production (on average 5 lbs [2.3 kg] of milk per cow in the herd), lowered the use of antimicrobials, and decreased labor needs.[30,31] Another benefit of the use of emerging technologies is to remove the subjectivity of decision making, decreasing the frequency of protocol deviations and increasing compliance to designed protocols. Moreover, the consistency and objective evaluation of the automated monitoring systems contribute to the maintenance of the same standards when evaluating a group of cows, even when relief personnel is conducting the task.

Conclusion

The popularization of innovations currently available in the dairy industry and the development of newer technology will likely have an impact on dairy production medicine and will represent an area of opportunity for progressive dairy practitioners in the future. Taking advantage of the overwhelming amount of data generated by precision dairy technologies to establish actionable items to improve the performance, health and welfare of dairy cows will contribute to the improvement of farm efficiency and sustainability.

References

1. Wathes CM, Kristensen HH, Aerts JM, Berckmans D. Is precision livestock farming an engineer's daydream or nightmare, an animal's friend or foe, and a farmer's panacea or pitfall? *Comput Electron Agric*. 64, 2–10 (2008).

2. Stone AE. Symposium review: The most important factors affecting adoption of precision dairy monitoring technologies. *J Dairy Sci* 103, 5740–5745 (2020).

3. Soriani N, Trevisi E, Calamari L. Relationships between rumination time, metabolic conditions, and health status in dairy cows during the transition period. *J Anim Sci*. 90, 4544–4554 (2012).

4. Calamari L, et al. Rumination time around calving: An early signal to detect cows at greater risk of disease. *J Dairy Sci*. 97, 3635–3647 (2014).

5. Mayo LM, et al. Automated estrous detection using multiple commercial precision dairy monitoring technologies in synchronized dairy cows. *J Dairy Sci*. 102, 2645–2656 (2019).

6. Stangaferro ML, Wijma R, Caixeta LS, Al-Abri MA, Giordano JO. Use of rumination and activity monitoring for the identification of dairy cows with health disorders: Part II. Mastitis. *J Dairy Sci*. 99, 7411–7421 (2016).

7. Stangaferro ML, Wijma R, Caixeta LS, Al-Abri MA, Giordano JO. Use of rumination and activity monitoring for the identification of dairy cows with health disorders: Part I. Metabolic and digestive disorders. *J Dairy Sci*. 99, 7395–7410 (2016).

8. Stangaferro ML, Wijma R, Caixeta LS, Al-Abri MA, Giordano JO. Use of rumination and activity monitoring for the identification of dairy cows with health disorders: Part III. Metritis. *J Dairy Sci*. 99, 7422–7433 (2016).

9. Rial C, Laplacette A, Giordano JO. Effect of a targeted reproductive management program designed to prioritize insemination at detected estrus and optimize time to insemination on the reproductive performance of lactating dairy cows. *J Dairy Sci*. S0022-0302(22)00478–7 (2022) doi:10.3168/jds.2022-22082.

10. Hostiou N, et al. Impact of precision livestock farming on work and human-animal interactions on dairy farms. *Biotechnol Agron Société Environ*. 21, 268–275 (2017).

11. Rutten CJ, Velthuis AGJ, Steeneveld W, Hogeveen H. Invited review: sensors to support health management on dairy farms. *J Dairy Sci*. 96, 1928–1952 (2013).

12. Nielsen LR, Pedersen AR, Herskin MS, Munksgaard L. Quantifying walking and standing behaviour of dairy cows using a moving average based on output from an accelerometer. *Appl Anim Behav Sci*. 127, 12–19 (2010).

13. Mazrier H, Tal S, Aizinbud E, Bargai U. A field investigation of the use of the pedometer for the early detection of lameness in cattle. *Can Vet J*. 47, 883–886 (2006).

14. Kang X, Zhang XD, Liu G. Accurate detection of lameness in dairy cattle with computer vision: A new and individualized detection strategy based on the analysis of the supporting phase. *J Dairy Sci*. 103, 10628–10638 (2020).

15. Bercovich A, et al. Development of an automatic cow body condition scoring using body shape signature and Fourier descriptors. *J Dairy Sci*. 96, 8047–8059 (2013).

16. Zin TT, Seint PT, Tin P, Horii Y, Kobayashi I. Body Condition Score Estimation Based on Regression Analysis Using a 3D Camera. *Sensors* 20, 3705 (2020).

17. Saar M, et al. A machine vision system to predict individual cow feed intake of different feeds in a cowshed. *Animal 16*, 100432 (2022).

18. de Koning CJAM. Automatic Milking—Common Practice on Dairy Farms. *Proc.* First North Am. Conf. Precision Dairy Management 55–67 (Elsevier Science, 2010).

19. Nørstebø H, et al. Factors associated with milking-to-milking variability in somatic cell counts from healthy cows in an automatic milking system. *Prev Vet Med*. 172, 104786 (2019).

20. Godden SM, Royster E, Timmerman J, Rapnicki P, Green H. Evaluation of an automated milk leukocyte differential test and the California Mastitis Test for detecting intramammary infection in early- and late-lactation quarters and cows. *J Dairy Sci*. 100, 6527–6544 (2017).

21. Stevenson JS, Banuelos S, Mendonça LG. Transition dairy cow health is associated with first postpartum ovulation risk, metabolic status, milk production, rumination, and physical activity. *J Dairy Sci*. 103, 9573–9586 (2020).

22. Carraway K, Brauneis M, Engwall N, Fain J. Rumination monitoring: a management tool for early detection of metabolic disorders. in *J Dairy Sci* vol. 96 (E-Suppl.) 180 (2013).

23. von Keyserlingk MAG, Rushen J, de Passillé AM, Weary DM. Invited review: The welfare of dairy cattle — key concepts and the role of science. *J Dairy Sci*. 92, 4101–4111 (2009).

24. Perez M, Cabrera E, Giordano JO. Effect of automating health monitoring on detection of health disorders and performance of lactating dairy cows. In vol. 102(E-Suppl.) (*J Dairy Sci*, 2019).

25. Giordano JO, Sitko EM, Rial C, Pérez MM, Granados GE. Symposium review: Use of multiple biological, management, and performance data for the design of targeted reproductive management strategies for dairy cows. *J Dairy Sci*. 105, 4669–4678 (2022).

26. Nebel RL, Dransfield MG, Jobst SM, Bame JH. Automated electronic systems for the detection of oestrus and timing of AI in cattle. *Anim Reprod Sci*. 60–61, 713–723 (2000).

27. Borchardt S, et al. Association of estrous expression detected by an automated activity monitoring system within 40 days in milk and reproductive performance of lactating Holstein cows. *J Dairy Sci*. 104, 9195–9204 (2021).

28. Madureira AML, et al. Factors affecting expression of estrus measured by activity monitors and conception risk of lactating dairy cows. *J Dairy Sci.* 98, 7003–7014 (2015).

29. Tippenhauer CM, et al. Factors associated with estrous expression and subsequent fertility in lactating dairy cows using automated activity monitoring. *J Dairy Sci.* 104, 6267–6282 (2021).

30. Monitors keep healthy cows out of traffic jams. **https://hoards.com/article-31147-monitors-keep-healthy-cows-out-of-traffic-jams.html.**

31. How dairy cow monitoring systems benefit the bottom line. *Successful Farming*. **https://agriculture.com/technology/livestock/how-dairy-cow-monitoring-systems-benefit-the-bottom-line**.

