J. Dairy Sci. 101:1–10
https://doi.org/10.3168/jds.2018-14521

Graduate Student Literature Review: Detecting health disorders using data from automatic milking systems and associated technologies[1]

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ABSTRACT

This review synthesizes a range of research findings regarding behavioral and production responses to health disorders and subsequent illness detection for herds using automatic (robotic) milking systems (AMS). We discuss the effects of health disorders on cow behavior and production, specifically those variables that are routinely recorded by AMS and associated technologies. This information is used to inform the resultant use of behavior and production variables and to summarize and critique current illness detection studies. For conventional and AMS herds separately, we examined research from the past 20 yr and those variables recorded automatically on-farm that may respond to development of illness and lameness. The main variables identified were milk yield, rumination time, activity, and body weight, in addition to frequency of successful, refused, and fetched (involuntary) milkings in AMS herds. Whether making comparisons within cow or between sick and healthy cows, consistent reductions in activity, rumination time, and milk yield are observed. Lameness, however, had obvious negative effects on milk yield but not necessarily on rumination time or activity. Finally, we discuss detection models for identifying lameness and other health disorders using routinely collected data in AMS, specifically focusing on their scientific validation and any study limitations that create a need for further research. Of the current studies that have worked toward disease detection, many data have been excluded or separated for isolated models (i.e., fresh cows, certain lactation groups, and cows with multiple illnesses or moderate cases). Thus, future studies should (1) incorporate the entire lactating herd while accounting for stage of lactation and parity of each animal; (2) evaluate the deviations that cows exhibit from their own baseline trajectories and relative to healthy contemporaries; (3) combine the use of several variables into health alerts; and (4) differentiate the probable type of health disorder. Most importantly, no model or software currently exists to integrate data and directly support decision-making, which requires further research to bridge the gap between technology and herd health management.

Key words: automatic milking, robotic milking, behavior, health management

INTRODUCTION

Rapid adoption of automatic (robotic) milking systems (**AMS**) for dairy cows is occurring worldwide. As of 2014, over 25,000 farms globally were using AMS (Barkema et al., 2015) and this number continues to grow. In Europe, this has been predominantly driven by growth in the Netherlands and Nordic countries, and in North America, Canada is the major domain of AMS use because of stable milk prices through supply management (Barkema et al., 2015). Benefits of AMS for farmers include reduced labor requirements and greater time flexibility, while cows benefit by having more freedom to control their time budgets (Jacobs and Siegford, 2012). Regarding health management, a key advantage of AMS is the availability of daily, cow-level data that are collected by AMS and associated technologies. As a result, Tse et al. (2017) reported that, after transitioning to AMS, 66% of producers changed their health management strategy and 80% of producers found illness detection to be easier than before transitioning because of the AMS and associated health-monitoring software. On the other hand, some of the main barriers preventing adoption of technology by dairy producers are that technologies are not easy to use, they provide too much information without clear recommended action, and that their performance must be evaluated by independent research (Russell and Bewley, 2013; Borchers and Bewley, 2015).

Thus, there is a need to transform behavior and production data into timely, useful, reliable, and actionable information for producers. Not only should these

Received January 30, 2018.
Accepted May 6, 2018.
[1] Submitted to the 2019 ADSA Foundation Graduate Student Literature Review Competition (Production Division, PhD) on June 5, 2018.
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data be collected by validated technologies, they must be incorporated into validated models and algorithms by combining the knowledge of field experience and science. Producers must adapt their management skills to become more technology-based as they spend more time viewing and interpreting data. Furthermore, farmers, advisors, and support staff must learn to interpret information correctly, and with this information, they can implement the proper herd management and corrective action needed to achieve success with AMS.

Therefore, this review summarizes research over the past 20 yr pertaining to the effects of health disorders on behavior and productivity of dairy cows, and the resultant use of those variables to help detect disorders. However, because such a large focus has been placed on using milk quality variables, such as electrical conductivity, SCC, and color, to detect mastitis in previous research (Hogeveen et al., 2010; Rutten et al., 2013), this review will focus on using routinely collected behavior and production measures to detect locomotion and metabolic disorders such as lameness, hoof disorders, ketosis, subclinical ketosis (**SCK**), displaced abomasum (**DA**), metritis, and pneumonia, in addition to briefly discussing mastitis detection.

Literature search criteria consisted of a web-based search through Web of Science, using the following search terms as topics: "automated milking" or "automatic milking" or "robotic milking," and "dairy cow behavior" or "dairy cow production" or "dairy cow milk yield," as well as a search regarding health management and illness detection. Inclusion criteria were that the paper must have been published in or after 2000 and must report on data collected routinely by AMS, such as milk yield, milk quality, BW, and cow activity and rumination behavior as measured by leg pedometers or neck collars.

EFFECTS OF HEALTH DISORDERS ON BEHAVIOR AND PRODUCTION

The negative effects of health disorders have been well documented for conventional herds, but less is known about these effects in AMS herds. The general outcomes associated with lameness and illness are likely similar in loose-housing systems, regardless of milking equipment; however, the individualized and voluntary nature of milking in AMS could intensify the effects of and responses to illness, given that cows are not manually brought to a milking parlor at set intervals. Therefore, we have comparatively summarized the consequences of lameness and illness in conventional and AMS herds to report overall trends, similarities, and differences.

Lameness: Associations with Behavior and Production in AMS and Conventional Herds

Table 1 shows recent findings regarding associations of lameness with behavior and productivity in conventional and AMS herds in the past 2 decades. Regarding milk yield, lameness in both conventional and AMS herds has obvious negative impacts, whether comparing lame and sound cows or looking at changes leading up to diagnosis. However, there is no clear effect on rumination time or activity (Table 1). Researchers have reported lower milk yield to be associated with lameness in conventional herds (4 to 10 kg/d lower than sound cows; Van Hertem et al., 2013) and AMS herds (1.6 kg/d lower than sound cows; Bach et al., 2007; King et al., 2017a); leading up to lameness, milk yield of lame cows declined by 4 kg in total over 14 d (Van Hertem et al., 2013). Lame cows in a conventional herd had numerically (but not statistically significant) lower milk yield compared with healthy cows (Steensels et al., 2017a) and there was no association between milk yield and gait score in an AMS herd, when the majority of cows had locomotion score of 2 or 3 out of 5 (Deming et al., 2013). Bicalho et al. (2008) conducted multiple analyses, using various study designs, to assess the impact of hoof horn lesions on milk yield in conventional herds. Because lame cows produced 3.2 kg/d more milk than control cows in the first 3 wk of lactation, those authors then controlled for that early-lactation milk yield and found that lame cows actually produced 1.0 kg/d less milk than control cows throughout lactation. The authors then matched 603 lame cows with 603 sound cows, again accounting for early-lactation milk yield, and found that lame cows produced 1.4 kg/d less milk than control cows (Bicalho et al., 2008). Thus, milk yield may be greater in cows about to become lame (1.1 kg/d more milk before cows were diagnosed with lameness), but once diagnosed, their production drops to that of an average cow (Green et al., 2002), and it is important to consider the previous milk yield and lactation potential of a cow when considering her current milk production.

Some researchers have identified associations between lameness and rumination time in conventional and AMS herds. In some studies, lame cows spent less time ruminating than healthy animals in conventional systems (−10% or approximately 40–50 min/d; Almeida et al., 2008; Van Hertem et al., 2013; Paudyal et al., 2017; Steensels et al., 2017a), whereas other researchers have observed no difference between lame and sound cows in conventional and AMS herds (Walker et al., 2008; King et al., 2017a). Before diagnosis of lameness or hoof disorders, researchers found that rumination