Managing Robot Herds to Optimize Health and Welfare

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Take Home Messages

- Make good use of individualized management opportunities such as milking frequency and supplemental feeding. Milk early lactation cows more often and supplement them with appropriate feed to optimize their production and health. Before dry-off, use automatic step-down settings for milking frequency to reduce milk leakage and udder pressure.
- Keep your cows healthy so they are willing and able to voluntarily visit the robot for milking; otherwise, you may have to spend time fetching cows.
- Robotic milking systems and their associated health monitoring systems collect a lot of data and create numerous reports. Use these to help make informed decisions about your cows, but do not completely reply on this information to replace time spent in the barn.

Introduction

Milking with single-box automated (robotic) milking systems (AMS) has revolutionized the way we can manage and milk dairy cows. As of 2014, nearly 30,000 farms globally were using AMS (Barkema et al., 2015) and this number continues to grow. In Canada, current estimates would indicate that ~10% of herds now use AMS.

Benefits of AMS adoption for dairy producers include reduced stress and labour requirements and greater time flexibility (Tse et al., 2018). The reduction in labour and modification of how time is spent in the barn is helping smaller family farms and those wishing to grow remain functional without hiring outside labour. From a cow health and welfare perspective, AMS give cows more freedom to control how they spend their time and to perform desired behaviours. In a recent survey, 66% of Canadian producers reported that after transitioning to AMS they changed their health management strategy, and 80% of producers found illness detection to be easier than

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before because of the AMS and the associated health monitoring software (Tse et al., 2017). Those researchers also reported little to no perceived change in rates of lameness and culling, and most producers thought rates of mastitis were similar or lower than before and conception rates were higher. Therefore, Canadian AMS producers generally feel successful about their transition to AMS and new health management systems (Tse et al., 2017).

Managing cow health and welfare with AMS requires adaptation of conventional management techniques and consideration of new strategies. In this paper we discuss specific health and welfare management related to milking with AMS, including:

- Managing the voluntary nature of milking in AMS
- Managing cows individually to improve metabolic and udder health
- Controlling lameness and its negative effects on productivity

We also discuss health and behaviour monitoring equipment associated with AMS. Producers must also learn to interpret these data correctly, and management skills must become more technology-based as dairy producers spend more time viewing data when making management decisions.

Cows Choose When to be Milked

Ideally, cows voluntarily visit the AMS for milking and do so at an appropriate frequency each day. Among intensive AMS barns, producers have different management strategies to enhance productivity; some aim for 3.0 milkings/day or more, while others target 2.0–2.5 milkings per day to increase milk yield per milking. This is not always easy to accomplish because of many factors, but all can be managed to improve cow motivation and ability to visit the AMS.

Each AMS unit can milk 50 to 60 cows (Jacobs and Siegford, 2012), and will be the most efficient if the robot is not overstocked with too many cows. The number of cows per robot is negatively related to milking frequency, i.e., as farms increased stocking density from 34 to 71 cows per robot, milking frequency per cow declined (Deming et al., 2013; King et al., 2016). However, at higher milking frequencies at a farm level (3.0 times/day vs. 2.0 times/day), Tremblay et al. (2016) found an inverse relationship such that more cows per robot was associated with greater milk production per cow. Greater feed bunk space has also been associated with greater milk production in AMS (Deming et al., 2013). Even though there may be less synchrony of feeding activity in robot barns, cows still want to lie down simultaneously overnight (Munksgaard et al., 2011), so it is still necessary to maintain lower stocking density in lying areas (e.g., 1:1 cows:stall) compared with the feed bunk. Greater stall stocking density has also been linked to greater lameness prevalence in AMS herds (King et al., 2016; Westin et al., 2016).

The voluntary nature of milking in AMS provides more behavioural freedom for cows, but this also creates challenges for managing milking intervals and udder health. In AMS, cows can make more choices about their daily routine and time budget (Jacobs and Siegford, 2012) and, particularly with free cow traffic, cows can move throughout the barn freely. It is plausible that this behavioural freedom improves cow health and welfare in AMS because cows can make decisions according to their individual needs.

Instead of free cow traffic, producers may choose to use directed/guided traffic to force cows through the AMS. There are no differences in milk yield or cow stress between traffic designs, but free traffic is much more conducive to good rumen health and feeding behaviour (Bach et al., 2009). Free cow traffic also has lower waiting times, especially for low-ranking cows, who must spend more time waiting to be milked and are milked less often and at less preferred times of the day (Jago et al., 2003). Particularly in partially-directed and forced traffic systems, low-ranking cows wait longer in front of the AMS (Lexer et al., 2009) and spend less time chewing while feeding compared with dominant cows (Melin et al., 2007). To better accommodate lower-ranking cows, a free cow traffic barn design with a split entry holding pen near the AMS (Rodenburg, 2017) can be used, increasing the cows' chances to milk when needed and reducing their wait times.

▪ Ketosis and Metabolic Health

Having a customized supplemental feeding regimen for each cow can help combat negative energy balance in early lactation; this can help manage the cow's body condition score (BCS) and prevent health problems. For example, loss of BCS during early lactation has been associated with greater risk of subclinical ketosis (SCK; Kaufman et al., 2016) and hoof horn lesions; we know that claw horn disease is related to body condition and the thickness of the hoof's digital cushion (Bicalho et al., 2009). In Canadian AMS herds, cows with SCK or hoof disorders were offered less supplemental feed than healthy cows, and they had lower milk yield, rumination time, milking frequency, and refusal frequency (King et al., 2017a; King et al., 2018). Therefore, managing energy balance and BCS is crucial to maintain metabolic and hoof health, but more research is needed to effectively target proper feed supplementation in AMS.

Feed supplementation (and higher milking frequencies) for early and peak lactation cows may also have negative consequences for cow health. Tatone et al. (2017) found that AMS herds had higher within-herd prevalence of SCK (26%; as measured through milk ketone levels) than did conventional herds (21%). The higher prevalence may be the result of increased frequency of milking during early lactation or inadequate supplemental feeding of concentrates in the AMS. This study also found that multiparous cows in AMS had a higher risk of SCK at their first milk test compared with those in conventional herds, but there was no difference in risk for primiparous cows. The authors explained this to be related to transition cow management before calving, and that primiparous cows are reared similarly in AMS and non-AMS herds, but that the differences lie in management of cows between lactations. Therefore, the extent to which negative energy balance affects AMS herds requires more research, but it is crucial to maintain the right balance between feed consumption at the feed bunk and in the AMS (Hare et al., 2018).

The amount of supplemental feed offered to cows in the AMS is usually based on their milk production, parity and stage of lactation, and can be manipulated to optimize milking frequency. However, there is the risk of feeding too much concentrate per visit and over-satiating cows. Furthermore, feeding additional concentrate in the AMS does not necessarily increase voluntary milk visits of cows provided the same mixed ration (Bach et al., 2007). Increasing concentrate provision can reduce overall dry matter intake (DMI), because cows may eat less of their partial mixed ration (PMR) in the feed bunk (Bach et al., 2007; Hare et al., 2018). This may put cows at greater risk for rumen health problems, such as acidosis, because decreasing intake at the bunk would subsequently decrease intake of physically effective neutral detergent fibre. In a recent study, cows fed a lower-forage PMR tended to have a lower minimum ruminal pH, and therefore, a higher risk of ruminal acidosis compared with cows fed a higher-forage PMR (Menajovsky et al., 2018). Therefore, it is critical that PMR intake is balanced with supplemental concentrate allowance in the AMS.

▪ Lameness and Cow Comfort

Key factors for good health and welfare in AMS are minimizing lameness and keeping cows comfortable. In a study of AMS farms in Alberta and Ontario, 26% of cows were clinically lame (score of 3+ out of 5; Figure 1a), whereas 2.2% of cows were severely lame (score or 4+ out of 5; King et al., 2016). Not only do lame cows in AMS produce less milk (-1.6 kg/d; Figure 1b), they milk 0.3 times/day less often (Figure 1b) and are 2.2x more likely to be fetched for milking (King et al., 2017b). At a farm level, milk yield per AMS and milk yield per cow both declined with increasing lameness prevalence in AMS herds (King et al., 2016).

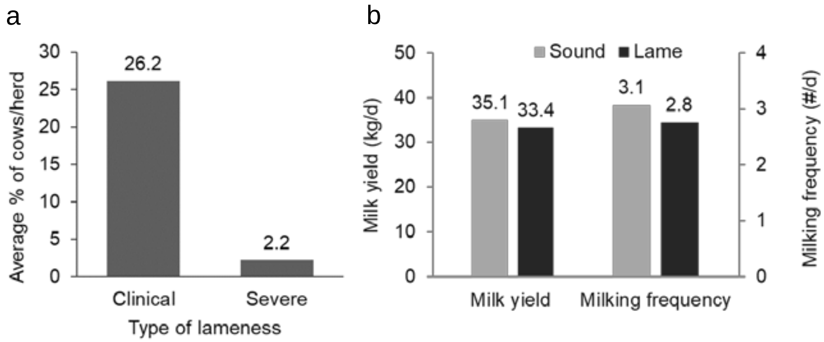

Figure 1. a) Prevalence of clinical (3+ out of 5) and severe (4+ out of 5) lameness and b) the impact of clinical lameness (3+ out of 5) in AMS on milk yield and milking frequency.

In AMS herds, cow-level risk factors for lameness include greater parity and lower BCS; cows with BCS = 3 and BCS ≤ 2.5 were 1.4 and 1.6 times, respectively, more likely to be lame compared with cows of BCS ≥ 3.5 (King et al., 2017b). Herd-level risk factors for lameness include obstructed lunge space, narrow stalls, and narrow feed alleys. Sand-based stalls tend to lower the probability of lameness (Westin et al., 2016). Severe lameness prevalence in AMS has been associated with higher stocking density in stalls and with higher curbs at the back of stalls (King et al., 2016); ideally, cows should not be overcrowded (i.e., no more than 1:1 cows:stalls) and curbs should be no more than 20 cm (8 inches) high. Bedding should be kept clean and dry, and maintained at an adequate depth (deep bedding or minimum 1-2 inches on mattresses) to encourage cows to rest. Excessive standing time, particularly perching in lying stalls, has been associated with a greater hoof problems and lameness prevalence. Separate sick and lame cows from the rest of the herd and provide them with comfortable bedding (ex. bedding pack) and easy access to the milking area. Holding areas and multiple access points to enter each robot are great ways to improve access for sick and low-ranking animals.

Producers with AMS often install automatic alley scrapers to avoid driving through manure alleys multiple times per day. King et al. (2016) reported that scraping alleys more frequently was related to lower lameness prevalence and fewer fetched cows, but the optimal alley scraping frequency for AMS herds is unknown. Running footbaths in AMS herds is another challenge. Unless cows are manually directed, not all cows in a herd will pass through specific areas of the barn at similar frequencies; thus, some cows may seldomly walk through the footbath.

■ Mastitis and Udder Health

Relying on cows to voluntarily visit the AMS unit creates vast variation in milking intervals (i.e., the time interval between two milking events). Because AMS can refuse cows who return too quickly since their last milking, it is more of a concern when cows come to the AMS too infrequently, thereby having longer milk intervals and increasing labour needed to fetch cows for milking.

Long milk intervals cause milk accumulation and changes in udder tissue, such that connections between cells become leaky, which changes milk composition and impairs secretion. Reduced milking frequency and increased milk leakage have been associated with higher somatic cell count and risk of intra-mammary infection (IMI; Hovinen and Pyörälä, 2011).

With AMS, producers can also taper milking frequency for late-lactation cows to reduce the physiological stress of dry-off. Reducing milking frequency should reduce milk yield before dry-off and milk leakage after dry-off, resulting in a reduced risk of IMI during the dry period and next lactation. Gradual milking cessation by skipping every second milking over five to seven days has successfully lowered milk yield (Zobel et al., 2013; Gott et al., 2016) and milk leakage (Zobel et al., 2013). Gott et al. (2016) found no difference in milk leakage or IMI after dry-off between gradual and abrupt dry-off, but they did see differences between first lactation and older cows; gradual dry-off was beneficial to cows ending their first lactation but was harmful to the udder health of multiparous cows. Therefore, there may be differences in optimal dry-off strategies for cows based on their parity. Most AMS software includes customizable dry-off management and step-down features; however, research is lacking in this area and we do not know if producers use and benefit from this option. Field observations indicate there is large variation in use among farms.

Keeping cows clean is imperative for maintaining udder health. Less frequent scraping of the barn alleys has been associated with poorer hygiene of the upper legs and flank, udder, and lower legs (DeVries et al., 2012). In that study, poor udder hygiene was also associated with poor stall hygiene. Poor hygiene, particularly of the udder, is associated with increased risk of mastitis and high SCC.

In Canadian AMS herds, cows with mastitis had lower milk yield, milking frequency, rumination time, activity, and milk temperature compared with healthy cows, and those measures all declined in the seven to 14 days before diagnosis and treatment (Figure 2; King et al., 2018). The cows with mastitis also had higher milk conductivity than healthy cows, showing that those data can be useful to earlier identify health disorders like mastitis.

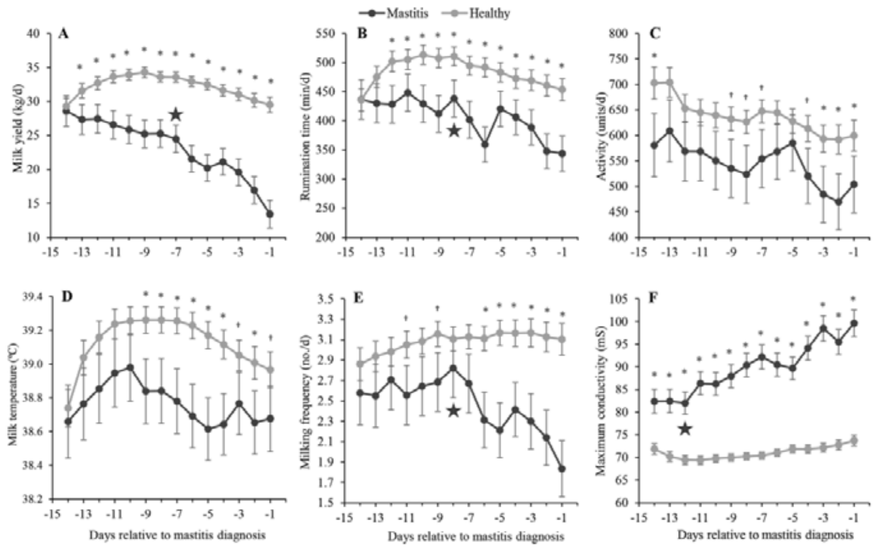

Figure 2. Data for cows with mastitis (n = 13) from d -11 to -1 relative to diagnosis of treated clinical mastitis, and for healthy cows (n = 121) given a mock diagnosis date using the mean days in milk (DIM) at diagnosis of mastitis (16 DIM). Graphs show means accounting for DIM and parity for the following variables: (A) milk yield, (B) rumination time, (C) activity, (D) milk temperature, (E) milking frequency, and (F) maximum milk conductivity. * indicates significant differences and † signifies a tendency ($P \geq 0.10$) between means for healthy and mastitis cows. ★ indicates deviation of cows with mastitis from their own baseline.

■ Automated Health Monitoring

A key feature of AMS is data collection and subsequent generation of management reports and alert lists. Data can be used to create management reports and task lists, as well as attention lists of cows with potential health problems. These reports can potentially overwhelm producers with excessive alerts (false positives), while not necessarily being sensitive enough to pick up chronic disorders (false negatives). Thus, these data must be transformed into useful, reliable information for producers. Illness detection software can include adjustable settings to personalize the sensitivity of the alert based on each farmer's management strategy, such as how willing the producer is to take risks weighted against the time needed to visually assess flagged cows that may not actually be sick.

Alerts created by AMS manufacturers are currently available on-farm, but do not always incorporate validated models and algorithms using data from validated technologies. Nonetheless, many of these alerts are already in use in the field. The same variables used in commercial health alerts have been incorporated into various detection models created and validated by researchers. Those models range in accuracy from 50 to 98% and include disorders such as displaced abomasum, ketosis, indigestion, mastitis, and metritis (Stangaferro et al., 2016; Steensels et al., 2016). Regarding lameness detection, researchers have created models with 40-89% accuracy (Van Hertem et al., 2013; Garcia et al., 2014). Many studies exclude cows with moderate severity illness, those with more than one health problem, and fresh cows, who are the most likely to become sick or lame. Therefore, there are still limitations with current prediction models regarding how to deal with cases of more than one illness, and how to detect one illness without excluding the others from analyses.

Future reports should: 1) incorporate the entire lactating herd while accounting for stage of lactation and parity of each animal, 2) evaluate deviations 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.

▪ Conclusions

This proceedings chapter highlights the challenges and opportunities of using robotic milking systems with respect to cow health and welfare. With the ability to milk and feed each cow individually in the AMS, there are associated challenges with maintaining adequate milking frequencies and managing cow health and welfare. Not only are milking and feed management important in AMS herds, bedding and hygiene must be also be well managed to maintain good hoof health, body condition, and cow comfort. Fortunately, there are many technologies and associated data to help manage cow health, provided that the data and subsequent reports are based on science and provide accurate, actionable information to producers.

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