USING DIGITAL TECHNOLOGY TO OPTIMIZE HEALTH AND REPRODUCTIVE MANAGEMENT

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TAKE HOME MESSAGES

- Digital technologies are not the future, but the present of the dairy industry. Their penetration in dairy herds will increase as data generated produce actionable interventions that increase efficiency.
- Detection of estrus is the most studied and obvious application of such technologies.
- Whether automated systems can improve reproductive performance depends on the herd's current reproductive performance and the herd's reproductive management philosophy (heavy use of exogenous hormones vs. heavy reliance on insemination in estrus).
- In herds with intense health-screening strategies, adding automated devices to the health-screening program may not improve survival, reproduction, and production.
- Integration of data generated by automated systems and data already available on-farm is a formidable avenue through which it would be possible to tailor reproductive management and therapeutic interventions according to the cows' needs.

INTRODUCTION

Potential application of automated devices that track changes in physical activity associated with estrus for management of reproduction in cattle was first reported in the 1970's (Kiddy, 1977). Automated monitoring has become a reality in today's dairy industry. Somatic cell count, body weight, locomotion score, body condition score, beta-hydroxybutyrate concentration (in milk), feed intake, feeding time, rumination time, lying time and temperature (skin, vagina, or rumen), among other responses, can be measured real-time. This information will likely revolutionize dairy management, as long as it can be translated into clear language that allows for prompt, proactive measures to solve challenges or make decisions. The most obvious and optimized use of such technologies is for the identification of cows in estrus. Limitations to the use of these data for prediction of health disorders and management deficiencies, however, include the lack of clear understanding of the meaning of certain changes for these responses as well as what to do when alterations are detected. In this presentation, a few of the research studies that have used these digital technologies in the management of reproduction and peripartum period will be discussed. This is not an all-encompassing review of this fast-changing subject.

REPRODUCTIVE MANAGEMENT

Reproductive performance is a key component of economic success in dairy herds as it impacts average milk yield, income over feed cost, and culling decisions (Giordano et al., 2012; Galvão et al., 2013). According to census data compiled by the U.S. Department of Agriculture, 71 and 53% of surveyed dairy operations use estrous detection for first and subsequent services, respectively (USDA, 2016). Despite the substantial advancement observed in the past two decades of programs for synchronization of ovulation and timed AI, refining efforts to detect estrus remains a major priority for dairy operations. Financial analyses using stochastic dynamic Monte-Carlo simulation models indicated that improving estrus-detection efficiency from 40 to 60% and accuracy from 85 to 95% increased profit per cow by US$ 83/year to $94/year when milk prices ranged from US$ 0.33 and 0.44/kg (Galvão et al., 2013). Furthermore, improving estrus-detection efficiency and accuracy increases the profitability in dairy herds in which ovulation synchronization and timed AI are used (Giordano et al., 2012). Developing strategies to enhance estrus-detection programs becomes exceedingly important given its widespread utilization.

Currently available automated-monitoring devices (**AMD**) monitor changes in activity and rumination patterns, among other behaviors, compared with the individual's baseline values in order to estimate the onset of estrus and determine the ideal time for insemination (Fricke et al., 2014a). Automated estrus-detection systems have become more accessible to dairy producers, but penetration in U.S. dairy herds remains less than 10% (Denis-Robichaud et al., 2016; USDA, 2016). Expected changes in reproductive performance and profitability following implementation of AMD are highly dependent on herd's current performance. Therefore, it is critical to compare fertility outcomes in cows managed with specific AMD with that of cows managed with timed AI programs, detecting estrus based on mounting devices (i.e., tail paint or chalk and estrus-detection patches), and different combinations of these methods.

Several experiments have compared reproductive management using AMD versus strict fixed time AI for first service. By design, the rate of first insemination is faster for cows subjected to insemination at detected estrus with AMD, but by a predetermined days in milk, all cows are inseminated as is expected when fixed time AI protocols are implemented (Denis-Robichaud et al., 2018; Fricke et al., 2014b; Stevenson et al., 2014). As for the effect of AMD on pregnancy outcomes, some reports suggest that management of first service with AMD improve hazard of pregnancy (Stevenson et al., 2014), others have detected no differences (Fricke et al., 2014b). Denis-Robichaud et al. (2018), in fact, detected an interaction between herd and reproductive protocol, suggesting that in herds with optimum compliance with scheduled treatment injections, use of 100% fixed time AI for first service may be advantageous.

Marques et al. (2020) evaluated the effect of adding information of an AMD device to the reproductive management of lactating dairy cows, compared with detection of estrus by visual means or Estrotect tail patches (Rockway Inc., Spring Valley, WI) and timed AI. Use of AMD only marginally increased the hazard of first and second services. Michaelis et al. (2014) demonstrated that in a commercial German herd, the rate of estrus detection during the first 21 days after the end of voluntary waiting period was not different between AMD and visual observation, but AMD increased estrus-detection rates in the first 42 and 63 days after the end of the voluntary waiting period. Improvements in efficiency of detection of estrus when using AMD are largely dependent on the herd's efficiency of detection of estrus without the AMD. Thus, one must consider the current hazard of services in each specific herd before deciding to adopt such systems.

Use of AMD increased the risk of pregnancy to first service in cows with above median milk yield, but not in cows with below median milk yield, and increased the risk of pregnancy to second service regardless of milk yield (Marques et al., 2020). Improvements in pregnancy to first and second services were likely a consequence of improvements in the accuracy of detected estrus and timely insemination resulting in better synchrony between insemination and ovulation. In research conditions in which automated mounting devices (Valenza et al., 2012) or temporal progesterone changes (Nelson et al., 2017) were used as the gold standard for characterization of estrus, the AMD resulted in test characteristics (sensitivity, specificity, predicted value positive, predicted value negative) $\geq$ 85%. Furthermore, Nelson et al. (2017) demonstrated that AMD were more precise at determining ovulation, diagnosed by ultrasonography, than a complex visual estrus-detection scoring system. Thus, in situations in which accuracy and timing of insemination based on visual detection of estrus are inappropriate, addition of AMD may prove beneficial to pregnancy per service.

Surprisingly, the positive effects of AMD on pregnancy risk reported by Marques et al. (2020) were observed in cows receiving AI and embryo transfer (**ET**). In fact, the magnitude of improvement in pregnancy per service with the AMD [(AMD - control)/control] was greater for cows receiving ET (first service = 51.4%, second service = 34.5%) than cows receiving AI (first service = 16.7%, second service = 18.2%). Ferraz et al. (2016) demonstrated that asynchrony of the estrous cycle and embryo development was negatively associated with pregnancy per ET. Recipients receiving embryos on days 6 and 9 of the estrus-cycle had 10% lower pregnancy per ET than recipients receiving embryos on days 7 and 8 (Ferraz et al., 2016). Thus, the authors speculated that the improved estrus-detection accuracy resulting from the use of AMD may have improved the synchrony of the estrous cycle of recipients and the stage of development of embryos, which may have led to greater improvements in pregnancy per service.

An area that has been minimally explored thus far is how data from AMD may be used to predict reproductive outcomes and the appropriate reproductive management according to a cow's needs. We recently determined that characteristics of estrus detected ≤ 41 days in milk is associated with the hazard of pregnancy. Cows with low rumination nadir at estrus recorded ≤ 41 days in milk had median interval from calving to pregnancy of 109 days, whereas those with high rumination nadir at estrus recorded ≤ 41 days in milk had median interval from calving to pregnancy of 130 days. Similarly, cows with high heat index at estrus recorded ≤ 41 days in milk had median interval from calving to pregnancy of 112 days, whereas those with high heat index at estrus recorded ≤ days in milk had median interval from calving to pregnancy of 133 days. If this is repeatable in other herds, it may be possible to use this information to determine to which reproductive management program cows should be assigned according to their needs.

POSTPARTUM COW MONITORING

Major leaps in our understanding of peripartum cow health and management were made during the past 30 years. Despite a large body of research investigating management and nutritional strategies to improve the health and performance of peripartum cows, the morbidity during the postpartum period in U.S. dairy herds is approximately 45% and the risk of pregnancy to first postpartum service is less than 40% (Pinedo et al., 2020). The transition from the non-lactating, pregnant state to the lactating state is marked by several hormonal, metabolic, and behavioral changes. To address these changes and prepare the cow for the new lactation, different diets are fed from dry off to approximately 21 days before calving, and from 21 days before expected calving through to calving (Drackley, 1999; Grummer, 1995). The goals of transition cow management and health-screening programs of postpartum cows are to reduce morbidity, expedite the diagnosis and treatment of health disorders, reduce the percentage of cows that leave the herd (dead or sold) by 60 days in milk, maximize peak milk yield, and prepare the cow to establish pregnancy to the first service.

Postpartum health-screening programs vary and depend on farm size, facilities, personnel, and individual cows' data available (Espadamala et al., 2016). Larger herds generally have fewer workers per cow (Reed, 2000); thus, efficient systems to monitor transition cows are imperative. During the last weeks of gestation, dry matter intake decreases progressively to a nadir on the day of calving (Perez-Báez et al., 2019), which is reflected by reduced rumination time on the days preceding calving followed by a steep increase in rumination in healthy cows (Liboreiro et al., 2015). Several researchers have demonstrated that peripartum health disorders are negatively associated with rumination time postpartum (Calamari et al., 2014; Liboreiro et al., 2015; Soriani et al., 2012; Stangaferro et al., 2016a,b,c). Among the diseases associated with reduced rumination time were sub-clinical hypocalcemia and ketosis, retained fetal membranes, metritis, displaced abomasum, indigestion, and even some cases of mastitis. In a series of publications, Stangaferro et al. (2016a,b,c) demonstrated that AMD result in high sensitivity for the diagnosis of metabolic and digestive disorders and severe cases of metritis and mastitis. It is imperative to understand that, to date, automated systems produce alerts for cows that likely have health disorders but these alerts are not pathognomonic (not specific to any disease). Thus, once an automated device generates an alert, the cow in question must be examined by an experienced veterinarian or herdsperson for the proper diagnosis of the disease.

Silva et al. (2020) evaluated whether by adding the information generated by an AMD to a health-screening protocol of postpartum cows it would be possible to improve their survival and reproductive and productive performances. In this experiment, all cows were fitted with AMD, were monitored according to daily milk yield, and were examined at 3, 6, and 9 days in milk for the diagnosis of postpartum disorders. Only one group of cows, however, was also examined when the AMD generated an alert. In this experiment, adding the information of the AMD to the monitoring of postpartum cows did not improve survival and milk yield, but surprisingly, it reduced the risk of pregnancy by 150 days in milk. The negative effect of the AMD alerts on the risk of pregnancy by 150 days in milk is likely a spurious finding because the two treatments did not differ regarding the incidence of sub-clinical and clinical diseases. Contrary to what had been hypothesized, by adding the AMD alert to the screening program, the interval from the first AMD alert to the diagnosis of disease was not reduced (Silva et al., 2020). Among cows not diagnosed with clinical disease, those for which AMD alerts were used were more likely to receive supportive therapy (oral and intra-venous fluids, transfer of rumen fluid from a healthy cow to a sick cow, vitamin B complex, etc.). The authors concluded that in herds that have intense postpartum health-screening strategies, the addition of AMD alerts may not prove beneficial to the performance of the cows. Furthermore, the authors identified that an area that should be investigated further is what to do with cows that have AMD alerts but do not present sub-clinical and clinical signs of disease.

Stangaferro et al. (2016a,c) demonstrated that the intensity of alterations in the pattern of rumination and activity may be an indicative of the severity of the disease. Alterations in the patterns of rumination around the diagnosis of disease was associated with significant milk losses compared with cows not diagnosed with diseases, whereas no differences in milk yield were observed between cows with no clinical diseases and cows with clinical disease and no alteration in rumination (Stangaferro et al., 2016a,c). Furthermore, among cows diagnosed with metritis, those with severely altered patterns of rumination and activity had greater haptoglobin concentration and were more likely to be classified as do not breed or were sold by 60 days in milk than those with minor alterations in the patterns of rumination and activity (Stangaferro et al., 2016c). Similarly, Silva et al. (2020) demonstrated that the absence of AMD alert at the diagnosis of clinical diseases was associated with performance similar to that of cows not diagnosed with clinical diseases. It is important to note that in these experiments, cows diagnosed with clinical disease, with or without AMD alerts, were treated according to the dairies' standard operation procedures. Thus, it is not possible to affirm that cows diagnosed with clinical diseases without AMD alerts do not need treatment or would perform as well as healthy cows if left untreated. This is, however, an exciting area of research because it could lead to more judicious use of anti-microbials and anti-inflammatory drugs, based on the cow's needs.

CONCLUSIONS

The plethora of data generated by digital technologies available to dairy producers is exciting, and to a certain extent, intimidating. For these systems to be used to their maximum potential, the data must be processed and generate information that is easy to understand and provide options to resolve the issue at hand. Unquestionably, the best understood use of these technologies is for the detection of estrus, but to limit their applicability to alert for cows that only need artificial insemination seems wasteful. The integration of AMD generated data with cow-data commonly recorded on farm, environmental data, and diet information it is possible to foresee situations in which we will be able to tailor the management of cows according to their needs.

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