Technology to Improve Transition Cow Health and Reproductive Performance

Ricardo C. Chebel[1,2*], Anderson Veronese[1], Manuel Agustin Silva[1]
[1]Department of Large Animal Clinical Sciences, University of Florida, Gainesville 32068
[2]Department of Clinical Sciences, University of Florida, Gainesville 32068

TAKE HOME MESSAGE

Automated systems for monitoring livestock may produce a plethora of data for producers and consultants that were rarely obtained as early as 10 years ago. As with other technologies, one should be cautious not to seek a problem to apply a new tool, but instead seek a new tool to solve an existing problem.

- Automated health monitoring systems have the potential to expedite the diagnosis of metabolic diseases (e.g. sub-clinical ketosis) compared with clinical evaluation alone or cow-side tests at predetermined intervals from calving. Questions remain, however, about the advantages of such earlier diagnosis to the health and performance of the cow.
- Treatment of cows identified by health monitoring systems as abnormal with supportive therapy (e.g. fluids, glucose precursors, anti-inflammatory), despite no other clinical symptoms, needs to be evaluated as a strategy to minimize future clinical disease and production losses in light of additional costs due to treatment cost and labor demands.
- Herds with poor estrus detection efficiency and accuracy are the herds that could potentially gain the most with the incorporation of automated estrus detection systems into their reproductive management.
- Genetic selection for cattle with greater reproductive aptitude appears to have changed physiological responses during the estrous cycle to the point of altering phenotypes associated with estrus (e.g. acceptance of mount, walking/activity, rumination, etc.), which may facilitate detection of estrus.

INTRODUCTION

Dairy producers have an evident need to monitor individual cows and groups of cows in order to adjust management (e.g. feeding, comfort, heat abatement), to identify ill cows and cows at risk for disease, and for reproductive management. The quest for automated monitoring systems is not new. One of the most basic and oldest monitoring strategies is to measure daily milk yield and deviations from the expected lactation curve. This is a logical strategy because several physiological and pathological conditions are associated with changes in pattern of milk yield and while monitoring individual milk yield dairymen may determine the profitability of a specific cow. Other automated monitoring systems evaluate somatic cell count, body weight, locomotion score, body condition score, betahydroxybutyrate concentration in milk, feed intake, feeding time, rumination time, lying time, temperature (skin, vagina, rumen), among other characteristics. Although several of these systems are mainly used in research settings, more herds are buying into technologies that promise to aid in more precise and consistent management of individual cows and groups of cows. The reality is, however, that such systems will only positively impact dairies when the data produced by the systems are translated into a clear language that allows for prompt proactive measures to solve problems or to make decisions (e.g. to breed or not a cow). In this manuscript, we will mainly discuss the use of automated systems that monitor chewing time (a.k.a. rumination), activity, and lying time with the intent of early diagnosis of periparturient diseases and improved transition cow health and reproductive performance. This manuscript is not an exhaustive review of automated monitoring systems currently available.

Automated Health Monitoring Systems

Cows are predisposed to health disorders during the transition period (3 weeks prepartum to 3 weeks postpartum) because of physiologic and management changes. It is commonly accepted that the variability in feed intake during the last weeks of gestation is one of the predisposing factors for health disorders and poor performance (Huzzey et al., 2007). An important misconception must be noted. Determining that a group of cows (e.g. cows diagnosed with metritis postpartum) has reduced average daily dry matter intake (**DMI**) than another group of cows (e.g. healthy postpartum cows) does not necessarily mean that prepartum DMI may be used as a diagnostic tool for a specific disease. A test is only suitable as a diagnostic tool once its sensitivity and specificity are determined in comparison to a 'gold standard' test. Nonetheless, monitoring DMI of individual cows could represent a major advantage if it resulted in interventions that prevented or minimized variability in DMI peripartum and prevented health disorders. Aside from tie stall herds, however, it is not possible to evaluate individual DMI in commercial herds. In commercial freestall, loose housing, and open lot herds some have suggested that cud chewing time (interval from regurgitation to swallowing), also known as rumination time, and feeding time (the amount of time a cow spends in the feed bunk) may be used as proxies for feed intake. Schirmann et al. (2012) demonstrated that, within a 2 h period, the relationship between cud chewing and DMI is negative. This may be explained by the fact that monitoring systems differentiate the sounds produced during regurgitation, mastication, and swallowing from the sounds produced during ingestion of feed and that cows cannot perform both activities at the same time (Hedlund and Rolls, 1977). There was, however, a positive correlation between DMI recorded 4 h before the recorded rumination to which it was compared (Schirmann et al., 2012). Additionally, Schirmann et al. (2013) demonstrated a parallel decrease in DMI and rumination from 48 to 24 h before calving, suggesting that changes in DMI due to physiological or pathological conditions are followed by changes in rumination time. Interestingly, while DMI increased by nearly 50% from 24 h before calving to the day of calving, rumination time decreased further within this period by nearly 20%, only returning to pre-calving levels by 48 h after calving (Schirmann et al., 2013). This demonstrates that while rumination time serves as a proxy to DMI, changes in rumination time have a lag of approximately 4 to 6 h compared with changes in DMI.

Despite the fact that rumination does not precisely reflect DMI of a cow, several studies have demonstrated that cows that develop postpartum metabolic (e.g. sub-clinical hypocalcemia, sub-clinical ketosis) and infectious (e.g. metritis and mastitis) diseases, and retained placenta, displacement of abomasum, and indigestion have altered rumination patterns pre- and post-partum compared with healthy cows (Kaufman et al., 2016; Liboreiro et al., 2015; Stangaferro et al., 2016a,b,c). Despite significant differences in average pre- and post-partum rumination between populations of ill and healthy cows, the use of rumination as the sole diagnostic tool for such diseases needs further evaluation. Stangaferro et al. (2016a,b,c) demonstrated that the use of health index produced by the Data Flow II software (SCR Ltd., Netanya, Israel), an arbitrary numerical value generated according to the recovery of rumination and activity post-partum and days in milk of the cow, as a diagnostic tool resulted in sensitivities (percentage of sick cows diagnosed as sick) between 86 and 100% for metabolic diseases, 55 to 89% for clinical mastitis, and 49 to 78% for metritis. The specificity of using the health index (percentage of healthy cows diagnosed as healthy) as a diagnostic tool for post-partum disease (displaced abomasum, ketosis, indigestion, mastitis, and metritis) was 98% (Stangaferro et al., 2016c). These are very promising results and strongly suggest that herds that have sub-par transition cow monitoring by herd personnel or no other means of evaluating performance (e.g. individual daily milk yield, milk yield deviation, etc.) could benefit significantly from automated rumination/activity monitoring systems.

In a recent experiment conducted in Florida, 610 cows (control = 317, collar monitored (**CM**) = 293) were fitted with Heat Detection Long Distance Rumination collars (SCR Ltd., Netanya, Israel) from approximately 60 d pre-partum to 80 d post-partum. All cows were monitored by herd personnel who used daily milk yield and milk yield deviations as indicators of health status and examined the cows at 4, 7, 10, and 14 d relative to calving for metritis. For CM cows, in addition to routine monitoring by herd personnel, health index < 80, negative 3 d rumination (difference between today's rumination from the average of the previous 3 d), and rumination ≤ 200 min/d were also used as indicators of health disorder. Thus, CM cows presenting health index < 80, negative 3 d rumination, and rumination ≤ 200 min/d were presented to herd personnel for further examination. Disease diagnosis and treatment were performed by herd personnel using guidelines defined by the veterinarians from the Food Animal Reproduction Medicine Service from the University of Florida. A similar (*P* =0.61) percentage of CM (55.9%) and control

(53.9%) cows had altered rumination pattern during the first 80 d postpartum. Despite the fact that the percentages of cows diagnosed with postpartum health disorders (retained placenta, metritis, ketosis, milk fever, displacement of abomasum, mastitis, indigestion) did not differ between the two treatments, a larger ($P < 0.02$) percentage of CM cows were treated with supportive therapy compared with control cows (61.1 vs. 52.1%). Ultimately, milk yield in the first 80 d postpartum (control = 42.7 ± 0.5, CM = 41.8 ± 0.6 kg/d; $P = 0.31$), culling within the first 60 d postpartum (control = 5.3%, CM = 6.8%; $P = 0.45$), and percentage of cows pregnant to the first postpartum service (control = 36.2%, CM = 33.8%; $P = 0.56$) did not differ between treatments. This experiment suggests that in herds with aggressive monitoring of postpartum cows the addition of automated rumination/activity monitoring may not improve transition cow health and performance, despite increasing the percentage of cows treated with supportive therapy. This experiment was conducted in one dairy and the external validity of our results needs to be validated by other experiments with similar design but in different conditions.

In general, alterations in rumination preceded the diagnosis of ketosis, displacement of abomasum, and metritis by herd personnel. Additional experiments are needed to evaluate the benefit of aggressively treating cows at the first signs of rumination/activity alteration to reduce the incidence of diseases and improve performance.

In addition to being used for monitoring individuals and assisting in the diagnosis of diseases, some have suggested that the variability in behaviors in groups of cows could suggest errors in management (dietary or environmental). Because of the dynamics of groups of peripartum cows, it is important to understand the factors that affect the variability in rumination/activity/lying behavior of periparturient cows. In a recent study (n = 310) conducted in one NW Wisconsin herd, we monitored rumination and activity (HDLR tags, SCR Ltd., Netanya, Israel) from -21 to 21 d relative to calving and lying behavior (HOBO,) from -11 to 11 d relative to calving. Nulliparous and parous cows were housed in separate pens during the prepartum, but nulliparous and parous cows were commingled in the postpartum. Data referent to the individual [day relative to calving, parity (nulliparous, primiparous, multiparous), body condition and locomotion scores, calving related events, calf sex, acute phase protein concentration, occurrence of postpartum health disorders], to environmental conditions (stocking density in the prepartum pens only, and temperature humidity index pre and postpartum), and to the diet (chemical composition, particle size, and peNDF) were recorded. Environmental conditions were recorded daily. Total mixed ration was sampled twice per week (Monday and Friday) and the average for the week was used for the statistical analysis. During the prepartum period, cow explained 64.2% (parous) to 82.6% (nulliparous) of the variability in daily rumination time, 55.6% (parous) to 69.6% (nulliparous) of the variability in daily activity, and 40.8% (nulliparous) to 68.3% (parous) of the variability in daily lying time. Environmental conditions such as stocking density and percentage of time during the day (evaluated in 30 min intervals) with THI > 68 explained from 0.3 to 11.4% of the variability in rumination time, activity, and lying time during the prepartum period. Crude protein and ether extract content of the TMR and peNDF explained from 0.2 to 4.9% of the variability in rumination time, activity, and lying time during the prepartum period. During the postpartum period, cow explained 52%, 66.3%, and 39.5% of the variability in rumination time, activity, and lying time, respectively. Percentage of time during the day with THI > 68 explained from 6.3 to 13.9% of the variability in rumination time, activity, and lying time during the prepartum period. Crude protein, ether extract, and peNDF content of the diet explained from 0.7 to 5.0% of the variability in rumination time, activity, and lying time during the prepartum period. The within and between animal variation in rumination and activity recorded from -21 to 21 d relative to calving and lying time from -11 to 11 d relative to calving are depicted in figures 1, 2, and 3, respectively.

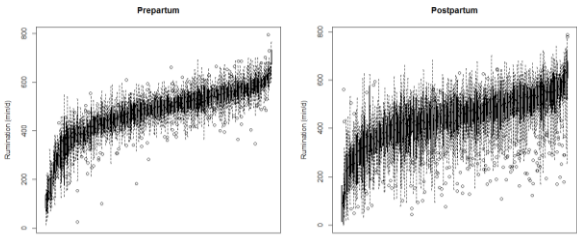

Figure 1. Within and between animal variation in daily rumination time during the prepartum and postpartum periods.

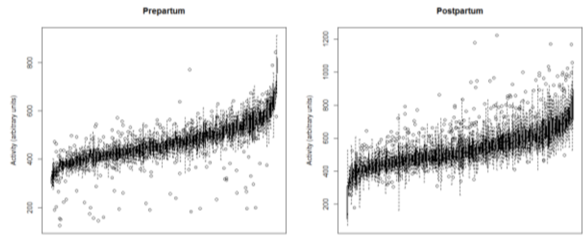

Figure 2. Within and between animal variation in daily activity during the prepartum and post-partum periods.

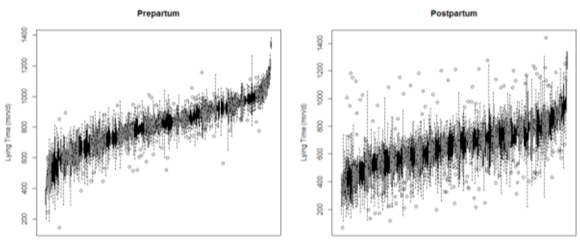

Figure 3. Within and between animal variation in daily lying time during the prepartum and postpartum periods.

These preliminary data suggest that, within a well-managed herd without exceptional circumstances, changes in behaviors in groups of periparturient cows over time are likely better explained by differences in individuals within the group than small changes in environmental and dietary conditions.

Automated Estrus Detection System and Reproductive Efficiency

A multitude of automated estrus detection monitoring (**AEDM**) systems is available in the USA market and each one has its nuances (Fricke et al., 2014a). In general, AEDM systems determine the occurrence of estrus according to changes in patterns of behaviors such as steps/walking, activity, and rumination.

Figure 4 depicts the activity and rumination graphs generated by the Data Flow II software (SCR Inc., Netanya, Israel), one of the commercially available AEDM systems. The AEDM system in question continuously monitor activity and rumination, recording activity and rumination in 2-h time periods. Through a mathematical algorithm, the software calculates the momentary deviation of the activity/rumination from the average activity/rumination in the same time period during the previous 7 days. As seem in figure 4, deviations in activity/rumination from the cow's normal pattern are identified as estrus (depicted by the cow mounting symbol).

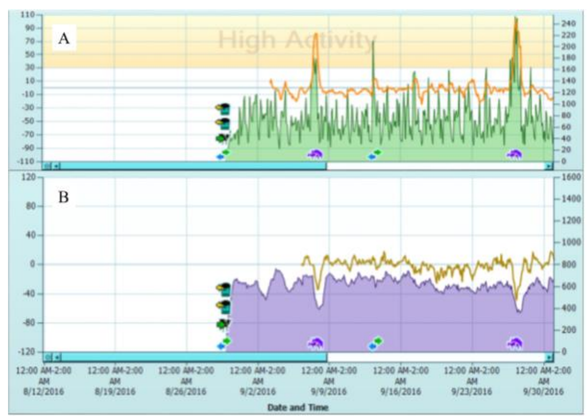

Figure 4. Activity data (green bars) and deviation (brown line; panel A) and rumination data (purple bars) and deviation (brown line; panel B). Data Flow II (SCR Ltd., Netanya, Israel).

The AEDM systems most commonly used in commercial dairy farms detect the occurrence of estrus based on secondary signs of estrus. Nonetheless, sensitivity and specificity of such systems compared with ovulation determined by ultrasonography or visual observation of mounting activity are > 90% (Dolecheck et al., 2016a; Valenza et al., 2012). Valenza et al. (2012) demonstrated a high level of agreement between an AEDM system based on changes in activity (SCR Engineers Ltd., Netanya, Israel) and a mounting detector (Kamar heatmount detector, Kamar Inc., Steamboat Springs, CO). Furthermore, standing to be mounted, the principal characteristic of bovine in estrus, was positively associated with duration of estrus and peak of activity measured by an AEDM system (Silper et al., 2015).

The advantages of using such AEDM systems for reproductive management of lactating cows, however, is likely dependent on current reproductive performance of the herd. Several experiments have evaluated the reproductive performance of lactating cows managed primarily to be inseminated in estrus detected by AEDM systems compared with cows inseminated at fixed time. Stevenson et al. (2014) demonstrated that a reproductive strategy based on AI in estrus detected by an AEDM system resulted in shorter interval from calving to establishment of pregnancy (80 vs. 90 d) than a reproductive strategy based on fixed time AI following the Presynch-Ovsynch protocol. In this experiment, however, the voluntary waiting period for cows inseminated in estrus detected by an AEDM system was 40 d postpartum, whereas the voluntary waiting period of cows inseminated at fixed time was 71 d postpartum (Stevenson et al., 2014). Fricke et al. (2014b) did not observe differences in interval from calving to establishment of pregnancy when cows were submitted to fixed time AI at 79 d postpartum compared with cows inseminated at estrus detected by an AEDM system starting at 52 d postpartum, with cows not detected in estrus submitted to fixed time AI by 79 d postpartum. In another experiment in Canada, Burnett et al. (2017) demonstrated that the pregnancy per AI (P/AI) of cows inseminated in estrus detected by AEDM system was dependent on cyclic status of the cow. In this experiment, P/AI of cyclic cows inseminated in estrus detected by AEDM system and inseminated at fixed time (Presynch-Ovsynch) were 33.9 and 34.2%, respectively, whereas the P/AI of anovular cows inseminated in estrus detected by AEDM system and fixed time were 16.4 and 29.7%, respectively. In this experiment, interval from calving to establishment of pregnancy was largest for cows that were anovular at 50 d postpartum and were primarily managed to be inseminated in estrus detected by the AEDM system (Brunett et al., 2017). In an ongoing experiment in one Florida herd, cows receiving first and second AI (29.1 and 27.7%, respectively) or embryo transfer (22.4 and 23.54%, respectively) following detection of estrus by visual observation have had reduced P/AI compared with cows receiving AI (33.8 and 35.3%, respectively) or embryo transfer (35.4 and 37.5%, respectively) following detection of estrus by an AEDM system. In this experiment, the median interval from calving to establishment of pregnancy has been 142 and 116 d for cows serviced following detection of estrus by visual means or by an AEDM system, respectively. These are just a few experiments that exemplify how the benefits of AEDM systems over fixed time AI programs or visual estrus detection are highly dependent on the current reproductive strategy and performance of the herd in question.

Because most experiments comparing reproductive performance of cows managed with AEDM systems and cows principally managed with fixed time AI or visual detection of estrus can only be conducted in a few herds, experiments that simulate the economic return over investment on AEDM systems through mathematical models become very important. Rutten et al. (2014) used stochastic dynamic modeling to determine whether herds varying from 65 to 195 lactating cows would benefit from investing in AEDM systems. Authors took into consideration sensitivity and specificity of visual estrus detection vs. AEDM systems, voluntary waiting period, dry-off period, length of gestation, milk yield, milk solids content, culling rates and replacement costs, feed cost, labor cost, and cost of AEDM systems. In this experiment, authors determined that the average internal rate of return (a measurement of profitability) was 11% over the investment on an AEDM system and only when the sensitivity of visual estrus detection (percentage of cows in estrus detected in estrus by visual observation) rose to 65% was the internal rate of return neutral on the investment on AEDM systems. In another experiment, Dolecheck et al. (2016b) evaluated whether investment on an AEDM system would be profitable compared with visual observation of estrus (or combination of AEDM system and visual observation) and fixed time AI (or combination of AEDM system and fixed time AI) according to changes in cost of days open, cost of semen, cost of pregnancy diagnosis, and cost of reproductive management. Some of the assumptions of the model were that the efficiency of estrous detection by visual observation was 48.6% and that in fixed time AI programs no re-insemination in estrus would occur. Additionally, researchers assumed that the use of AEDM system would increase the efficiency of insemination to either 60 or 80%. In this experiment, the major factors determining the return over investment (change in net present value) and payback period were the initial cost of the AEDM system (tag, hardware, and software) and the efficiency of insemination once the AEDM system was adopted. In a non-peer reviewed manuscript, Giordano et al. (2015) evaluated the economic impact of investing on an AEDM system in herds with poor (30%) and average (60%) estrus detection efficiency. The life expectancy of the system (3, 5, or 7 years), initial cost of the system ($90 or $120), improvements in estrus detection rate, among other things were considered. Based on this manuscript, the most important factors determining the net value of the investment were the estrus detection rate prior to the adoption of the AEDM system, the change in estrous detection efficiency, the life time expectancy of the system, and efficiency of labor use prior to the adoption of the AEDM system.

Taken together, these data demonstrate that the adoption of AEDM system for reproductive management of lactating dairy cows is highly dependent on the current reproductive parameters of the herd (estrus detection rate and pregnancy rate), the expected improvements in reproductive parameters (in particular estrus detection rate), the initial cost of the system and the life time expectancy of the system. A good rule of thumbs seems to be that herds with estrus detection rate < 50% could certainly benefit from such systems, whereas herds with estrus detection rate > 65% may not benefit at all.

Fine Tuning Reproductive Management with the use of Automated Estrus Detection Systems

The ideal interval from onset of estrus (based on mounting behavior) to insemination with conventional semen is 4 to 12 h for lactating cows (Dransfield et al., 1998). On the other hand, Stevenson et al. (2014) used an AEDM system for estrus detection and demonstrated that among multiparous cows inseminated with conventional semen, the ideal interval from onset of estrus to AI was 0 to 12 h, whereas the ideal interval from onset of estrus to AI for primiparous cows inseminated with conventional semen was 13 to 16 h. Timing of insemination of cattle with conventional semen relative to ovulation is important to P/AI, but its effects on fertilization rate and embryo quality are opposite (Dalton et al., 2001; Saacke et al., 2008). Insemination of animals closest to onset of estrus may result in reduced fertilization rate and excellent embryo quality because insemination closest to onset of estrus would result in scarcity of sperm cells in the oviduct to fertilize the oocyte, but sperm cells available to fertilize the oocyte would be highly selected (Dalton et al., 2001; Saacke et al., 2008). Conversely, insemination of animals closest to ovulation may result in high fertilization rate and poor embryo quality because the oocyte may be too aged by the time that sperm cells are able to fertilize it and the pool of sperm cells available to fertilize the oocyte is of lesser quality (Dalton et al., 2001; Saacke et al., 2008).

In a study conducted in Texas, Sales et al. (2011) demonstrated that insemination of Jersey heifers with sex-sorted semen 6.5 h before presumptive ovulation improved P/AI compared with insemination with sex-sorted semen 12.5 h before presumptive ovulation. On the other hand, time of insemination (12.5 vs. 6.5 h before presumptive ovulation) did not affect P/AI of Jersey heifers inseminated with conventional semen. In another experiment, Sá Filho et al. (2013) demonstrated that the probability of pregnancy of Jersey heifers was lowest when they were inseminated with sex-sorted semen 12 to 16 h after onset of estrus (12 to 16 h before presumptive ovulation), based on mounting activity, and highest when heifers were inseminated between 16.1 and 24 h after onset of estrus (4 to 12 h before presumptive ovulation). In an experiment with lactating jersey cows (n = 678) from a commercial dairy herd in MN, we demonstrated that there was a quadratic effect of the interval between onset of estrus (activity threshold reached) and AI on probabilities of pregnancy at 31 ± 3 ($P = 0.07$) and 66 ± 3 ($P = 0.15$) d after AI with sex-sorted semen (Bombardelli et al., 2016). In this experiment, P/AI at 66 ± 3 d after AI with sex-sorted semen was higher for cows inseminated between 23 and 41 h after onset of estrus (< 3 h = 20.0%, 4 to 12 h = 27.1%, 13 to 22 h = 39.1%, 23 to 41 h = 45.6%, and > 42 h = 40.0%). These experiments suggest that herds that inseminate heifers and cows detected in estrus by AEDM systems with sex-sorted semen should aim to inseminate closer to ovulation. This may be accomplished by determining which animals are in estrus every 12 h and inseminating animals 12 h after the detection of estrus (AM/PM breeding).

Considering that the use of AEDM systems may result in greater efficiency and accuracy of estrus detection, its use for detection of estrus and insemination in cherry peaking herds (herds that use Presynch-Ovsynch for first postpartum AI and inseminate cows in estrus before enrollment into the Ovsynch protocol) may result in a larger proportion of anovular cows being presented for ovulation synchronization protocols and fixed time AI compared with herds that either do not cherry peak and herds with inefficient estrus detection. This may present an opportunity to more aggressively use intravaginal progesterone inserts in cows submitted to the ovulation synchronization protocol since according to Bisinotto et al. (2015) cows without a CL at the onset of the ovulation synchronization protocol benefit the most from progesterone insert. This would reduce the cost of the reproductive management by reducing the number of cows that are treated with progesterone insert while maximizing the gains in fertility from the use of the progesterone vaginal insert.

Exploring Differences in Estrus Behaviors of Cows differing in Genetic Potential for Reproductive Success

Estrous behavior characteristics appear to be important for accurate visual estrus detection by farm personnel and for P/AI. In an experiment conducted in one herd in Florida, cows (n = 610) were fitted with AEDM system to characterize estrus behavior (duration of estrus, rumination nadir, activity peak, and heat index – a composite that takes into account changes in activity and rumination at the time of estrus compared with the previous 7 d). Reproductive management, however, was based on visual observation of estrus signs and activation of mounting patch by farm personnel, thrice daily. Efficient estrus detection was characterized by visualization of estrous signs (e.g. standing to be mounted and/or activation of a mounting patch) between -2 and 24 h after onset of estrus determined by the AEDM system. Duration of estrus was positively associated with the probability of accurate estrus detection; whereas, the association between rumination nadir at estrus and probability of accurate estrus detection was quadratic (Figure 5). The associations between activity peak and probability of accurate estrus detection and between heat index and probability of accurate estrus detection were quadratic (Figure 5). According to this dataset, the probability of farm personnel detecting cows on the bottom 10th percentile for duration of estrus ($\leq$ 10 h) and heat index ($\leq$ 80) in estrus was 0.21, whereas the probability of farm personnel detecting cows on the top 10th percentile for duration of estrus ($\geq$ 22 h) and heat index (100) in estrus was 0.90. Consequently, the interval from calving to first postpartum AI was shorter for cows on the top 10th percentile than cows on the bottom 10th percentile (64.1 ± 2.1 vs. 77.8 ± 3.6 d). Additionally, heat index was positively associated with P/AI (Figure 6). Madureira et al. (2015) demonstrated that cows with low heat index (35 to 89 arbitrary units) had reduced concentrations of estradiol (8.2 ± 0.1 vs 9.4 ± 0.3 pg/mL) than cows with high heat index (90 to 100 arbitrary units). These preliminary results demonstrate the importance of the estrous behavior phenotypes for improved dairy cow fertility and that such variability in estrus behavior may be explained by physiological differences among cows.

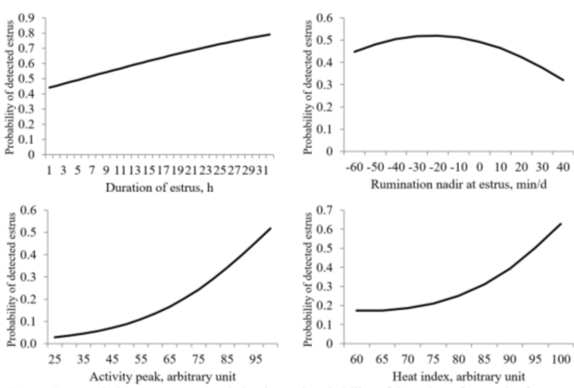

Figure 5. Association among estrous behavior and probability of detection of estrus by farm personnel (thrice daily visual observation). Ranges of variables depicted on the graphs (x axis) were observed in the study population (n = 610).

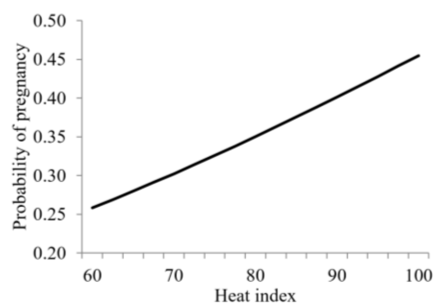

Figure 6. Association between heat index (Data Flow II, SCR Ltd., Netanya, Israel) and probability of pregnancy 75 d after first insemination.

The same cows used in the study described previously were genotyped using a medium-density SNP chip. Daughter pregnancy rate was positively associated with duration of estrus, but cow conception rate (CCR) was negatively associated with duration of estrus (Figure 7). Additionally, there was a linear negative association between DPR and rumination nadir at estrus. There was a positive association between DPR and probability of activity peak at estrus > 80, whereas there was a negative association between CCR and probability of activity peak at estrus > 80 (Figure 7). Finally, there was a tendency for DPR to be positively associated with probability of heat index > 80 (Figure 7).

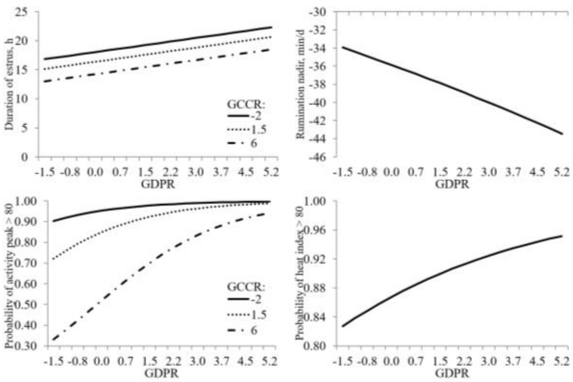

Figure 7. Association among genomic estimates for daughter pregnancy rate (**GDPR**) and cow conception rate (**GCCR**) and duration of estrus, rumination nadir at estrus, and probabilities of activity peak > 80 and heat index > 80.

These preliminary data indicate that estrous behavior characteristics associated with increased on-farm estrus detection efficiency are controlled in part by genetic components and that sufficient variation for these phenotypes exist in dairy populations to implement efficient selection programs.

CONCLUSIONS

Modern dairy operations have the opportunity to collect a massive amount of information from individuals and from groups of animals. This presents an exciting opportunity for improved management, which leading to improved health, production, and reproduction, could have a major impact on the profitability of dairy operations. The benefit of such technologies is largely dependent on their ability to easily convey a message to dairy owners and managers so that proactive solutions to the problems identified by such technologies may be adopted. According to recent data, however, it seems evident that such technologies will not necessarily increase the profitability of every dairy herd. It is fundamental to understand what the technology offers and whether or not current systems and protocols adopted by the herd are not sufficient to maximize health, productivity and reproductive efficiency.

REFERENCES

Bisinotto, R. S., I. J. Lean, W. W. Thatcher, and J. E. Santos. 2015. Meta-analysis of progesterone supplementation during timed artificial insemination programs in dairy cows. J Dairy Sci. 98:2472-2487.

Bombardelli, G. D., H. F. Soares, and R. C. Chebel. 2016. Time of insemination relative to reaching activity threshold is associated with pregnancy risk when using sex-sorted semen for lactating Jersey cows. Theriogenology 85:533-539.

Burnett, T. A., A. M. L. Madureira, B. F. Silper, A. C. C. Fernandes, and R. L. A. Cerri. 2017. Integrating an automated activity monitor into an artificial insemination program and the associated risk factors affecting reproductive performance of dairy cows. J Dairy Sci. 100:5005-5018.

Dalton, J. C., S. Nadir, J. H. Bame, M. Noftsinger, R. L. Nebel, and R. G. Saacke. 2001. Effect of time of insemination on number of accessory sperm, fertilization rate, and embryo quality in nonlactating dairy cattle. J. Dairy Sci. 84:2413-2418.

Dolecheck, K. A., W. J. Silvia, G. Heersche Jr, C. L. Wood, K. J. McQuerry, and J. M. Bewley. 2016a. A comparison of timed artificial insemination and automated activity monitoring with hormone intervention in 3 commercial dairy herds. J Dairy Sci. 99:1506-1514.

Dolecheck, K. A., G. Heersche Jr, and J. M. Bewley. 2016b. Retention payoff-based cost per day open regression equations: Application in a user-friendly decision support tool for investment analysis of automated estrus detection technologies. J Dairy Sci. 99:10182-10193.

Dransfield, M. B., R. L. Nebel, R. E. Pearson, and L. D. Warnick. 1998. Timing of insemination for dairy cows identified in estrus by a radiotelemetric estrus detection system. J. Dairy Sci. 81:1874-1882.

Fricke, P. M., P. D. Carvalho, J. O. Giordano, A. Valenza, G. Lopes Jr, and M. C. Amundson. 2014a. Expression and detection of estrus in dairy cows: the role of new technologies. Animal 8(Suppl 1):134-143.

Fricke, P. M., J. O. Giordano, A. Valenza, G. Lopes Jr, M. C. Amundson, and P. D. Carvalho. 2014b. Reproductive performance of lactating dairy cows managed for first service using timed artificial insemination with or without detection of estrus using an activity-monitoring system. J. Dairy Sci. 97:2771-2781.

Giordano, J. O. 2015. Use of technologies in reproductive management: Economics of automated activity monitoring systems for detection of estrus. Pages 51–66 in Proc. Western Dairy Management.

Hedlund, L., and J. Rolls. 1977. Behavior of lactating dairy cows during total confinement. J Dairy Sci. 60:1807-1812.

Huzzey, J. M., D. M. Veira, D. M. Weary, and M. A. von Keyserlingk. 2007. Prepartum behavior and dry matter intake identify dairy cows at risk for metritis. J Dairy Sci. 90:3220-3233.

Kaufman, E. I., S. J. LeBlanc, B. W. McBride, T. F. Duffield, and T. J. DeVries. 2016. Association of rumination time with subclinical ketosis in transition dairy cows. J Dairy Sci. 99:5604-5618.

Liboreiro, D. N., K. S. Machado, P. R. Silva, M. M. Maturana, T. K. Nishimura, A. P. Brandão, M. I. Endres, and R. C. Chebel. 2015. Characterization of peripartum rumination and activity of cows diagnosed with metabolic and uterine diseases. J Dairy Sci. 98:6812-6827.

Madureira, A. M., B. F. Silper, T. A. Burnett, L. Polsky, L. H. Cruppe, D. M. Veira, J. L. Vasconcelos, and R. L. Cerri. 2015. Factors affecting expression of estrus measured by activity monitors and conception risk of lactating dairy cows. J Dairy Sci. 98:7003-7014.

Rutten, C. J., W. Steeneveld, C. Inchaisri, and H. Hogeveen. 2014. An ex ante analysis on the use of activity meters for automated estrus detection: to invest or not to invest? J Dairy Sci. 97:6869-6887.

Sá Filho, M. F., M. F. Mendanha, R. V. Sala, F. J. Carvalho, L. H. C. Guimarães, and P. S. Baruselli. 2013. Use of sex-sorted sperm in lactating dairy cows upon estrus detection or following timed artificial insemination. Anim Reprod Sci. 143:19-23.

Saacke, R. G. 2008. Insemination factors related to timed AI in cattle. Theriogenology 70:479-484.

Sales, J. N., K. A. Neves, A. H. Souza, G. A. Crepaldi, R. V. Sala, M. Fosado, E. P. Campos Filho, M. de Faria, M. F. Sá Filho, and P. S. Baruselli. 2011. Timing of insemination and fertility in dairy and beef cattle receiving timed artificial insemination using sex-sorted sperm. Theriogenology 76:427-435.

Schirmann K, Chapinal N, Weary DM, Heuwieser W, von Keyserlingk MA. 2012. Rumination and its relationship to feeding and lying behavior in Holstein dairy cows. J. Dairy Sci. 95:3212-3217.

Silper, B. F., I. Robles, A. M. Madureira, T. A. Burnett, M. M. Reis, A. M. de Passillé, J. Rushen, and R. L. Cerri. 2015. Automated and visual measurements of estrous behavior and their sources of variation in Holstein heifers. I: Walking activity and behavior frequency. Theriogenology 84:312-320.

Stangaferro, M. L., R. Wijma, L. S. Caixeta, M. A. Al-Abri, and J. O. Giordano. 2016a. 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.

Stangaferro, M. L., R. Wijma, L. S. Caixeta, M. A. Al-Abri, and J. O. Giordano. 2016b. Use of rumination and activity monitoring for the identification of dairy cows with health disorders: Part II. Mastitis. J Dairy Sci. 99:7411-7421.

Stangaferro, M. L., R. Wijma, L. S. Caixeta, M. A. Al-Abri, and J. O. Giordano. 2016c. Use of rumination and activity monitoring for the identification of dairy cows with health disorders: Part III. Metritis. J Dairy Sci. 99:7422-7433.

Stevenson, J. S., S. L. Hill, R. L. Nebel, and J. M. DeJarnette. 2014. Ovulation timing and conception risk after automated activity monitoring in lactating dairy cows. J. Dairy Sci. 97:4296-4308.

Valenza, A., J. O. Giordano, G. Lopes Jr, L. Vincenti, M. C. Amundson, and P. M. Fricke. 2012 Assessment of an accelerometer system for detection of estrus and treatment with gonadotropin-releasing hormone at the time of insemination in lactating dairy cows. J Dairy Sci. 95:7115-7127.