INVESTIGATION OF AUTOMATED ACTIVITY MONITORING SYSTEMS FOR REPRODUCTION IN DAIRY CATTLE

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ABSTRACT

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This thesis is an investigation of the reproductive performance of dairy herds managed using automated activity monitoring systems for heat detection (AHD) in comparison to herds using timed artificial insemination programs (TAI). Two approaches were taken: a randomized clinical trial and a retrospective cross-sectional study.

In the field trial, pregnancy risk (PR) was not different between the AHD (14.6%) and TAI program (15.9%). Overall, time to pregnancy, time to 1st service and time to 2nd service were not different between breeding programs.

In the observational study, annual herd-summary reproductive performance in farms using AHD and TAI were not different. Finally, a retrospective analysis in herds that were using AHD for more than one year compared the years before and after adoption of the system. A significant increase of PR and insemination risk was found. In conclusion, AHD systems had comparable reproductive performance to TAI-based programs.

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CHAPTER ONE

INTRODUCTION, LITERATURE REVIEW, AND RESEARCH OBJECTIVES

INTRODUCTION

Dairy herd profitability is highly dependent on reproductive performance, since the latter directly affects both milk production and the number of pregnant animals necessary to maintain herd size. Several parameters can be used to assess reproductive efficiency. Ferguson and Galligan (2000) emphasize the use of pregnancy rate as the single most important variable. If pregnancy rate is not known, it can be estimated by multiplying conception rate and heat detection rate (HDR).

In the past, good reproductive performance was invariably linked with the efficiency of estrus detection. The practice of visual heat detection is time consuming and, because it is a repetitive action that should be performed routinely, it is quite often not done as intensively as required. Therefore, large variations in rates of heat detection are found in dairy herds (Diskin and Sreenan, 2000), thus affecting profitability.

With the implementation of timed artificial insemination (TAI) programs, provided by hormonal manipulations of the estrus cycle, prediction of the time of ovulation was possible. Consequently, determination of the appropriate timing of artificial insemination (AI) was no longer dependent on estrus detection. Moreover, good reproductive performance can be achieved with TAI programs, which has caused an increase in their popularity. However, the growing concern from consumers and producers about animal welfare leads to perceptions against the use of hormone treatments and injections in dairy cattle and have put some research focus on alternatives to TAI programs.

Heat detection using activity monitoring is a relatively old technology, but interest from dairy producers in modern activity-based systems has been growing. However, the comparison of reproductive performance between automated activity monitoring systems for heat detection and TAI programs has not yet been performed under North American conditions, and it is the main focus of this thesis.

LITERATURE REVIEW

This review of the literature focuses on a critical appraisal of the principles and application of activity monitoring systems for heat detection in dairy cattle. Much of the knowledge gained about the function of automated heat detection systems came through interactions with industry personnel. As Senger (1994) pointed out "…technology transfer does not always involve carefully documented scientific reports." If one accepts this approach, it is hard to judge whether a new technology was properly evaluated or not. For instance, the initial costs in activity monitoring systems are high, and dairy consultants and producers must know in what situations there may be a benefit when adopting automated heat detection systems.

Estrus signs

The estrous cycle can be divided into estrus, metestrus, diestrus and proestrus (Senger, 2005). The estrus period is characterized by sexual receptiveness and is distinguishable from the other stages due to specific behavioural signs (Senger, 2005).

A number of authors have described the behaviours expressed by dairy cattle when in estrus (Williamson et al., 1972; Hurnik et al., 1975; Walton and King, 1986; Van Vliet and Van Eerdenburg, 1996; Lyimo et al., 2000; Senger, 2005). The following are the most commonly reported behavioural characteristics:

- Standing to be mounted
- Mounting other cows
- Rubbed rump and tail-head
- Chin resting
- Restlessness
- Increase in agonistic interactions (e.g. head to head fights)
- Sniffing of the vagina of herd-mates
- Flehmen reaction (wrinkling of the nose and curling of the lip)

When producers practice visual detection of heats, standing to be mounted is likely the most reliable indicator of estrus. Inseminations based on the observation of standing to be mounted often achieve a greater conception risk when compared to animals displaying only secondary signs (Reimers et al., 1985). Reimers et al. (1985) conducted a large observational study of dairy herds in seven states in the northeastern United States, to determine whether inseminations based on standing to be mounted, when compared to other behavioural changes, led to a difference in reproductive performance. The cows that were bred based on observation of a standing heat (n = 2696; CR = 51.3%) had a 5.6% higher conception rate when compared to the cows bred based on different estrus signs but not standing to be mounted (n = 1174; CR = 45.7%).

Despite the greater reproductive performance when breeding cows based on standing to be mounted, there are several variables that influence the reliability of this sign. A principal limitation is the variability in the reported number of animals showing such behaviour. Hurnik et al. (1975) showed that 90% of the cows observed in estrus demonstrated standing heat. On the other hand, Lyimo et al. (1999) observed that 53% of the cows had standing to be mounted behaviour, whereas Van Vliet and Van Eerdenburg (1996) detected this behaviour in only 37% of the estrus periods. While all three studies were conducted in free stall herds, reflecting a similar environment, they used different observational periods and methods for definition of a true estrus. Hurnik et al. (1975) used intensive 24-hour video surveillance to identify sexual behaviour in the cows, defining estrus as the period that the animal made no attempt to escape while being mounted. Not surprisingly, they reported the greatest proportion of the cows showing standing heat. Lyimo et al. (1999) used 30-minute observation periods every 3 hours, and estrus was defined based on a scoring scale of estrus signs. Van Vliet and Van Eerdenburg (1996) used a 30-minute observation period every 2 hours, with the characterization of an estrus occurrence based on milk progesterone assays. Both of the referred studies detected a lower proportion of cows in standing heat. Despite the differences in definitions of a true estrus among studies, the observation of standing behaviour is highly dependent on the time allotted to observation. It is therefore not surprising to see low heat detection rates under commercial farm conditions, with multiple demands on managers' time, and when no specific time is allotted towards observation of estrus behaviour.

In addition, the assessments of all behavioural signs exhibited by a cow in estrus are dependent on the reactions of other cows in the group and the person observing and deciding whether or not to inseminate the animal, which inevitably introduces subjectivity. Reimers et al. (1985) found that errors associated with visual observation of estrus varied from 5.1% to 60% depending on the herd. Similarly, Smith (1982) showed that a dairy herd relying on visual heat detection had about 30% of the cows inseminated when they were not in estrus, resulting in poor conception rates.

Electronic heat detection aids

To reduce reproductive losses caused by erroneous or poor heat detection rates by visual observation, alternatives have been developed. While manipulation of the estrus cycle with estrus synchronization and timed artificial insemination programs can largely overcome the need for heat detection, these methods may meet objections based on perceptions, preferences, or logistics. Thus, electronic estrus detection aids are still an option, and would have to be more effective than simple but marginal facilitators of detection, such as tail paint. Senger (1994) proposed a standard model of an electronic system for detection of estrus, with the following characteristics:

1 – The system must allow, through electronic, chemical, or visual means, continuous surveillance of quantifiable behavioural or physiological changes occurring during estrus.

2 – The technology should provide automatic animal identification, capable of storing information related to the estrus event for future data retrieval. This identification should be permanent, allowing for monitoring throughout the animal's lifetime.

3 – The system should be cost-effective with minimal human intervention.

4 – Lastly, the monitoring device should measure a parameter that is highly correlated with the time of ovulation, ensuring high specificity.

There are currently two methods commercially available that possess the above-mentioned characteristics: heat mount detectors, and automated activity monitoring systems. These will be described in more detail, with emphasis on automated heat detection systems.

Heat mount detectors

Heat mount detectors are pressure-sensors placed on the cow's rump, and are stimulated each time the cow is mounted. The electrical stimulus is transmitted via a radiotelemetry to a central transponder, which collects data on the frequency of mounts over time and the duration of each mount. Estrus is signalled when a minimum of three successive mounts lasting 2 seconds or longer occurs within a 4-hour period (Rorie et al., 2002).

Animals reared in different management systems may exhibit varying intensities of estrus behaviour (Xu et al., 1998; Palmer et al., 2010). This affects the accuracy and efficiency of a system for detecting heat. Xu et al. (1998) evaluated the HeatWatch® system, a commercial automated heat mount detector, in a pasture-based Friesian herd, and demonstrated that the system identified 91.2% of the periods of estrus. These periods had a mean duration of 9.7 hours (h) with 13.6 mounts per period. At-Taras and Spahr (2001), using non-synchronized cows fitted with HeatWatch® in a free stall barn found that the total mounting activity averaged 5.8 ± 0.78 h with 6.7 mounts per heat. Recently, Palmer et al. (2010) compared estrus characteristics between Holstein-Friesian cows housed in a free stall or on pasture. Again, estrus was measured with HeatWatch®, and a higher incidence of sub-estrus events (i.e. characterized by the loss of some tail paint or one to two mounts greater than 1 second within 4 hours recorded by the HeatWatch® system) and a lower percentage of cows demonstrating standing heat were detected among those cows housed in free stall barn. All these papers point out that the environment has an effect on the expression of estrus. Possibly, technologies based on the measurement of other estrus signs, such as restlessness, would help minimize environmental effects. Lopez et al. (2004) observed that high producing primiparous and multiparous Holstein cows (≥ 39.5 kg/day), had a shorter duration of estrus (6.2 h) measured by HeatWatch® when compared to lower producing cows (10.9 h). Also, the same study showed a reduction in the number of standing events between high (6.3) and low producing cows (8.8). This suggests that cow productivity affects expression of estrus and may also affect heat mount detectors' efficiency.

Development of activity monitoring systems

The increase in physical activity during estrus in dairy cows was first described by Farris (1954) in a study on 13 Guernsey cows. Later, Kiddy (1977) evaluated the mean variation in physical activity of dairy cows in estrus using pedometers for human use. The devices were covered with a plastic case and attached to the cow's rear ankle using a strap. The study collected data on 87 estrous periods observed in 40 Holstein cows in a free stall barn, in which the average increase in movements during estrus was 393% compared to activity during non-estrus periods. These two studies were the basis for the development of activity systems for heat detection.

To define the increase in activity associated with estrus, one must first define a reference period, and then use this baseline information to detect a meaningful deviation in motion. In the literature, a number of reference periods have been used (Kiddy, 1977; Lewis and Newman, 1984; Schlünsen et al., 1987; Schofield et al., 1991). This review will focus on what has been used in commercial systems.

Heatime® (SCR Engineers, Natanya, Israel) is an activity monitoring system. It calculates the mean activity of rolling seven day periods, which is used as the reference period and is compared to the same time interval of the current day. In other words, the activity pattern for Day 8 is compared to the mean activity of Days 1 through 7, which is further divided into time intervals (Bar, 2010). Afimilk®, another activity monitoring system, uses the mean value of the previous 10 days (Galon, 2010). This reference period is included in the calculation for the heat-alarm detection of each commercial tag.

Another point of consideration with regards to activity systems is the methodology used to measure activity. Some activity systems are based on a mercury-switch technology. Depending on the animals' movement, the mercury tilt is switched on and off (Firk et al., 2002), and a step counter component is linked to that. This system is probably obsolete, when compared to newer technologies using accelerometers. These are commonly used in electronically devices such as iPods, smart phones, GPS, etc, and are based on gravitational forces (i.e. "G-forces").

In addition to the reference period and methodology for activity data collection, the data processing unit also incorporates an algorithm used in the "translation" of the data obtained from the tag. After the activity tag is read, the data are transmitted to the computer for processing. Firk et al. (2002) describe the different approaches used to analyze activity data, named serial data analysis, and present a summary of the possible methods of analysis (divided into univariate and multivariate approaches). The commercial systems employed currently compare the current activity level with some form of running mean or standard deviation (running variance), as determined by the reference period for each cow, and the animal is detected in heat if this ratio exceeds a preset threshold (Eradus et al., 1992). For the

Afimilk® system, a heat alarm is given when the current activity level surpasses two times the mean activity of the 10 preceding days. The Heatime® collars use a five standard deviations' (SD) increase in activity for inclusion on the heat list.

Factors affecting the determination of estrus by activity monitoring systems

A few studies have evaluated how some cow-level factors and a few herd management factors might affect estrus detection based on activity. This review uses the term 'activity estrus' to refer to estrus detected by activity monitoring systems.

Arney et al. (1994) evaluated the effects of milk yield, parity, lactation stage and nutrition on walking activity. There was no association between milk production, or cow age or parity with activity estrus, but activity decreased with stage of lactation. More recently, López-Gatius et al. (2005) found both milk production and parity number to be significantly associated with walking activity. The study reported that for each increase in 1 kg in milk yield and with each additional parity number, walking activity at estrus was reduced by 1.6% and 21.4%, respectively.

Müller and Schrader (2005) investigated the consistency of activity across 2 successive lactations in 35 Holstein-Friesian cows housed in a free stall barn. The findings showed consistency in activity behaviour across lactations and this was not influenced by week of lactation, parity, or environmental conditions (light and ambient temperature). Throughout the study, no animals were added to the study group, therefore maintaining a constant social structure, reducing any antagonistic interactions and their effect on overall activity. However, activity was only measured from 105 days in milk onwards, missing possible differences in activity at an earlier stage in lactation, when metabolic status may differ significantly. Further controlled studies are needed to investigate these associations and to explore at what level these variables might impact heat detection rates.

Arney et al. (1994) also evaluated the effect of energy intake on activity estrus by allocating 18 Holstein-Friesian cows to high and low energy intake groups. The activity level during estrus was not different between the two groups. Løvendahl and Chagunda (2010) found that cows in a low body condition score (the cut-point was not provided) had a longer interval from calving to first activity estrus, and the correlation between BCS and estrus activity from 90 to 120 DIM was positive, even though it was low ($r = 0.08$; $P < 0.05$).

Hurnik et al. (1975) demonstrated that when more than one animal was in estrus at the same time, the number of mounting events increased considerably, from 11.2 to 52.6 mounts per estrus when 3 animals were in heat simultaneously. The same pattern would be expected when measuring walking activity during estrus. Roelofs et al. (2005) demonstrated that the number of animals in estrus resulted in an increased number of steps taken during estrus. Though this increase was not significant, the overall detection rate of estrus by pedometers was significantly higher when more than one animal was in estrus (67% when only one animal was in heat versus 85% and 95% when two or more than two animals were in estrus simultaneously, respectively). More social interactions would likely occur as more cows are in estrus at once, increasing their activity and therefore the probability of heat detection.

Lameness affecting activity estrus

Espejo et al. (2005) found an average of 24.6% lame cows in free stall herds in Minnesota, demonstrating the high prevalence of this condition in dairy herds. Several studies have shown that lameness negatively affects both the daily time budget (Cook et al., 2004; Gomez and Cook, 2010) and reproductive performance in dairy cows (Melendez et al., 2003; Hernandez et al., 2005). Chapinal et al. (2009) demonstrated that cows with sole ulcers had a higher lying time when compared to cows without ulcers, though this did not affect walking speed. Holman et al. (2011) found a significant reduction in the sensitivity of a neck and leg activity system in detecting true estrus in lame cows in a small clinical trial. Further research on the topic with direct quantification of the effect of lameness on activity during estrus is needed.

Genetic variations related to activity estrus

Løvendahl and Chagunda (2010) demonstrated differences in activity estrus between 3 breeds of dairy cows. Jersey cows had significantly shorter duration (mean of 6.3 h) and strength (2.59 folds of increase) of activity estrus compared to animals of the same age of Holstein (mean of 7.2 h and 2.8 folds of increase) and Danish Red (mean of 7.3 h and 2.87 folds of increase) breeds.

Heat detection intensity and accuracy with activity systems

Several studies have evaluated the efficiency and accuracy of different activity systems. However, direct comparisons among studies and extrapolation of their results to commercially available automated monitoring systems are difficult for a variety of reasons. First, there is a substantial difference in threshold values (i.e. the deviation in activity to signal estrus) among studies, making direct comparisons unrealistic. Second, there are differences among definitions of a real estrus, varying from progesterone concentrations in serum or milk (considered the gold standard), to a combination of visual estrus signs or the estimation of the possible estrus periods occurring throughout the study period. Different environmental conditions may also contribute to the discrepancies observed between studies, such as rearing conditions and ambient temperature.

To illustrate such discrepancies, while Peralta et al. (2005) reported an efficiency of only 37% (212/570) using ALPRO® (DeLaval) in a large free stall Holstein herd during summer, At-Taras and Spahr (2001), also evaluating cows in free stall conditions, found estrus detection efficiency to range from 79% to 87%. The first study calculated system efficiency based on the number of possible estrus periods that could have occurred during the study period, considering a 21-day cycle. Meanwhile, the second study used a combination of estrus signs to define if a true estrus had happened. The differences might be due to distinct definitions of a real estrus and Peralta et al. (2005) evaluating cows only during heat stress.

To avoid these limitations, only studies that reported the number of correct, false and missing heat alerts are summarized in Table 1.1. Using the numbers reported in these studies, the sensitivity (i.e. efficiency) of the activity system used in detecting heats was computed using the following formula (Dohoo et al., 2009):

Sensitivity = (number of cows that were identified as being in estrus by the activity system) / [total number of cows in true estrus (as defined in the study)] x 100

One point that merits further attention in Table 1.1 is that the studies performed by Roelofs et al. (2005) and Yoshioka et al. (2010) clearly demonstrate how the sensitivity of the activity system varies according to the thresholds used. Figure 1.1 is an illustration of a typical activity curve of a cow in estrus.

Silent heats in activity monitoring systems

Another variable that may influence the efficiency of estrus detection with activity monitors are "silent ovulations" not preceded by a sufficient increase in walking activity to signal a heat. Only one study was found exploring the possible association between silent ovulations and activity estrus (Ranasinghe et al., 2010). This study used 161 Holstein-Friesian cows in a free stall equipped with Afimilk® pedometers to analyse cow-level factors that may be associated with the occurrence of silent ovulations. Parity, season of ovulation (temperature range was -9.6˚ to 19.9˚ C) and postpartum diseases were not found to be risk factors for silent ovulations. Conversely, milk yield was significantly associated with an increase in silent ovulation for the second to fourth ovulations postpartum in high producing dairy cows. Considering that the voluntary waiting period usually lasts 50 days, the most relevant frequencies of silent ovulations would be the third and fourth estrus periods. In the study, the frequencies of silent ovulations for these estrus cycles were 21.3% and 10.5% respectively. Palmer et al. (2010) found an average incidence of 35% of apparent silent ovulations in Holstein-Friesian cows housed in a free stall using the HeatWatch® system.

Walking activity related to ovulation

Estradiol is the hormone responsible for the manifestation of estrus behaviour (Senger, 2005). Shemesh et al. (1972) demonstrated that during estrus the estradiol concentration reached its peak 4 hours before the cow accepted mounting activity by a bull. This increase and subsequent steep decline of estradiol (Shemesh et al., 1972; Dieleman et al., 1986) precedes the LH surge and, consequently, ovulation. Only one study was found correlating the peak of estradiol to walking activity. Lyimo et al. (1996) found that the peak of walking activity occurred 8 hours after the peak in estradiol concentrations. However, on closer inspection, this study may have failed to correctly analyze the pedometer data because only the raw count of steps was used in the analysis. It is well documented that cows' activity follows a circadian rhythm (Farris, 1954; Koelsch et al., 1994; Lovendahl and Chagunda, 2010). Therefore, raw activity data should not have been used, because deviation in activity needs to be compared to the same time interval of the day it was measured. While it is possible that some time lag between the peak of estradiol to activity estrus detection occurs, this should be less than 8 hours.

As previously discussed, heat detection rates and accuracy are greatly influenced by activity thresholds (i.e. the deviation in activity) used. However, there is more consistency in the interval from the onset of activity estrus to ovulation. Table 1.2 summarizes three studies in which time of ovulation relative to increase of activity was evaluated. Time from onset of the increased activity was in the range of 29 to 33 hours. Yoshioka et al. (2010) demonstrated that, from the onset of increased activity (i.e. above the threshold) to standing heat behavior, the interval was only 1 hour. Moreover, by using activity thresholds varying from 150% to 300% of the mean average activity from diestrus period, the interval from onset of increased activity to ovulation decreased by approximately 1 hour.

Figure 1.2 is a schematic representation from several studies to illustrate the relationship of activity with ovulation, and periods characterized by optimum AI.

Reproductive performance between automated activity monitoring systems versus other reproductive management protocols

Some studies have addressed differences in efficiency and accuracy between heat detection aids (Williams et al., 1981; Xu et al., 1998; Cavalieri et al., 2003). Very few studies have compared reproductive performance (i.e. pregnancy and conception risk) between activity monitoring systems and other methods of heat detection. Peralta et al. (2005) found no differences in conception risks between inseminations based on an activity system (ALPRO®, DeLaval) to HeatWatch®, or visual observation of estrus in a large dairy herd during summer. Galon (2010) compared reproductive management with a timed AI protocol (OvSynch) to an activity system (Afimilk®) in two Israeli dairy herds (n = 66 cows in the OvSynch group versus 69 in the control group), and found no differences in first service conception risk and days open between treatment groups. One must note that environmental conditions in Israel are substantially different from North America, and cows are housed in loose-housing with enough space to freely express estrus, and in dirt-floor pens (Galon, 2010). Moreover, the voluntary waiting period in the study herds was 80 days and considering that the typical North American free stall herd uses a VWP of 50-60 days, it is possible that the results of such trial may not realistically apply to herds in Canada and USA.

Activity monitoring systems on the neck versus on the leg

Kiddy (1977) described the first potential use of pedometers as an aid for heat detection, but indicated that the movement of the hind legs might not be well correlated with progressive movement. Interestingly, the patent of the first U.S. electronic estrus detection system for dairy cows was actually based on the invention of a motion detector and a digital counter applied in conjunction with an animal identification system attached to the cows' neck strap (US Patent 4,247,758) (Rodrian, 1981). Therefore, the system would actually measure body movements, as opposed to steps.

Eradus (1992) compared heat detection accuracy using a mercury switch based pedometer on the foreleg and on the neck, and found more false positive alerts when the activity system was on the neck. Sakaguchi et al. (2007) compared sensitivity and positive predictive value of a commercial Japanese pedometer attached to the neck or hind legs using 6 Holstein heifers in an open paddock. This study tested different activity thresholds and reference periods. Depending on these variables, there were times that the activity system on the leg performed better than the neck and vice versa, but there was a tendency of the leg system to perform better most times. Løvendahl and Chagunda (2010), using a modified algorithm on ALPRO® system (neck collar) and different thresholds, found detection rates between the ranges of 56.4% to 84.2%. However, the most interesting part of this work was the low error rate (false positives) associated with the algorithm, which ranged from 0.38% to 3.85%. This work has shown that by including smoothed deviations of the activity data in the heat detection function, this could account for most of the noise (i.e. error) associated with activity being measured on the neck, resulting in high positive predictive values. Holman et al. (2011) compared sensitivity and positive predictive values of two commercial systems (Afimilk® system; leg tag and Heatime® collars; neck tag) in detecting estrus periods. The sensitivity did not differ between systems, but the Heatime® collars had a significantly higher positive predictive value when compared to Afimilk® tags (93.5% and 73.5%, respectively).

With the advances in technology used in activity systems and knowing that the tag attached to the leg is measuring motion and not necessarily only step, the correct terminology to define such systems would be activity monitoring system for heat detection. The term ‘pedometer’ refers to the location of attachment of the tag, on the hind or forelegs.

Possible improvements in activity monitoring systems

For several years researchers have been trying to improve estrus detection and more recently, detection of ovulation using precision technologies, such as vaginal mucus resistance and temperature, daily milk yield, body and milk temperature, heart rate (Lewis and Newman, 1984; Firk et al., 2002; Fisher et al., 2008; Hockey et al., 2010). It is beyond the scope of this review to discuss these methods, but lying behaviour and rumination time have been recently implemented into newer activity systems. Heatime®, SCR has a new activity tag which also provides rumination data while Afikim® has introduced a measurement for lying behavior. However, such variables have yet to be used in conjunction with walking activity to improve heat detection rates, despite the availability of some data to support such applications (Brehme et al., 2008; Brizuela, 2010; Jónsson et al., 2011). Firk et al. (2002) states that by using a combination of measures in the formulation of estrus detection algorithms, heat detection rates greater than 90% would be likely achievable, while reducing the percentage of error rates. Additionally, the combination of more variables in the heat detection algorithm might help detect silent ovulations.

RESEARCH OBJECTIVES

1. To compare cow level and herd level reproductive performance between an automated activity monitoring system and systematic timed insemination programs under field conditions using a cluster randomized trial

2. To compare herd reproductive performance between the year before and the year after implementation of an automated activity monitoring system in Canadian dairy herds using a cross-sectional study

3. To compare herd reproductive performance in Canadian dairy herds managing reproduction with an automated activity monitoring system relative to other reproductive programs using a cross-sectional study

4. To describe factors associated with a farmer's decision on implementation of an automated activity monitoring system and reproductive practices associated with use of this technology using a mail questionnaire

Table 1.1 Sensitivity of activity monitoring systems for heat detection according to different thresholds

Pedometer used	Activity threshold[1]	Sensitivity	Method used to define a true estrus	Use of estrus synchronization (Yes or No)	Breed	Rearing conditions	Reference
Heat-Seeker® TX, Bou-matic	Proprietary activity threshold	81.4% (35/43)	Milk progesterone (< 2ng/ml)	Yes	?	Pasture	Cavalieri et al. (2003)
Human modified pedometer	?	76% (69/91)	Serum progesterone (cut-point not defined) and rectal palpation of the ovaries	No	Holstein	Pasture	Peter and Bosu (1986)
Gyuho, Comtec, Japan	Deviation greater than 150% of average activity	100% (20/20)	Pressure-sensing radiotelemetric device	No	Japanese black cows	Free-stall with concrete floor	Yoshioka et al. (2010)
Gyuho, Comtec, Japan	Deviation greater than 300% of average activity	95% (19/20)	Pressure-sensing radiotelemetric device	No	Japanese black cows	Free-stall with concrete floor	Yoshioka et al. (2010)
Nedap Agri B. V., The Netherlands	2 standard deviations of average activity	87.3% (55/63)	Ultrasound to detect ovulation	Mixed[2]	Holstein-Friesian	Free-stall with slatted floor	Roelofs et al. (2005)
Nedap Agri B. V., The Netherlands	3.5 standard deviations of average activity	79.3% (50/63)	Ultrasound to detect ovulation	Mixed[2]	Holstein-Friesian	Free-stall with slatted floor	Roelofs et al. (2005)

[1] For complete threshold formulae calculation, refer to the reference

[2] Estrus was induced using 15 mg of prostaglandin $F_{2\alpha}$ in 23 animals and 40 animals had natural cycles

Table 1.2 Time of onset and end of activity estrus relative to ovulation

Pedometer used	Activity threshold[1]	Onset to ovulation[2] (average hours ± SE)	End to ovulation[3] (average hours ± SE)	Estrus duration (h)	Breed	Rearing conditions	Reference
Nedap Agri B. V., The Netherlands	3 standard deviations of average activity	29.3 ± 3.9	19.4 ± 4.4	10.0 ± 4.2	Holstein-Friesian	Free-stall with slatted floor	Roelofs et al. (2005)
Gyuho, Comtec, Japan	Deviation greater than 200% of average activity	30.2 ± 0.6	15.3 ± 0.9	15.8 ± 0.9	Japanese black cows	Free-stall with concrete floor	Yoshioka et al. (2010)
Rescounter II®, Westfalia-Surge	2 standard deviations of average activity	33.4 ± 1.24*	17.3 ± 1.8*	?	Holstein-Friesian (seasonal calvings)	Open grazing areas	Hockey et al. (2009)

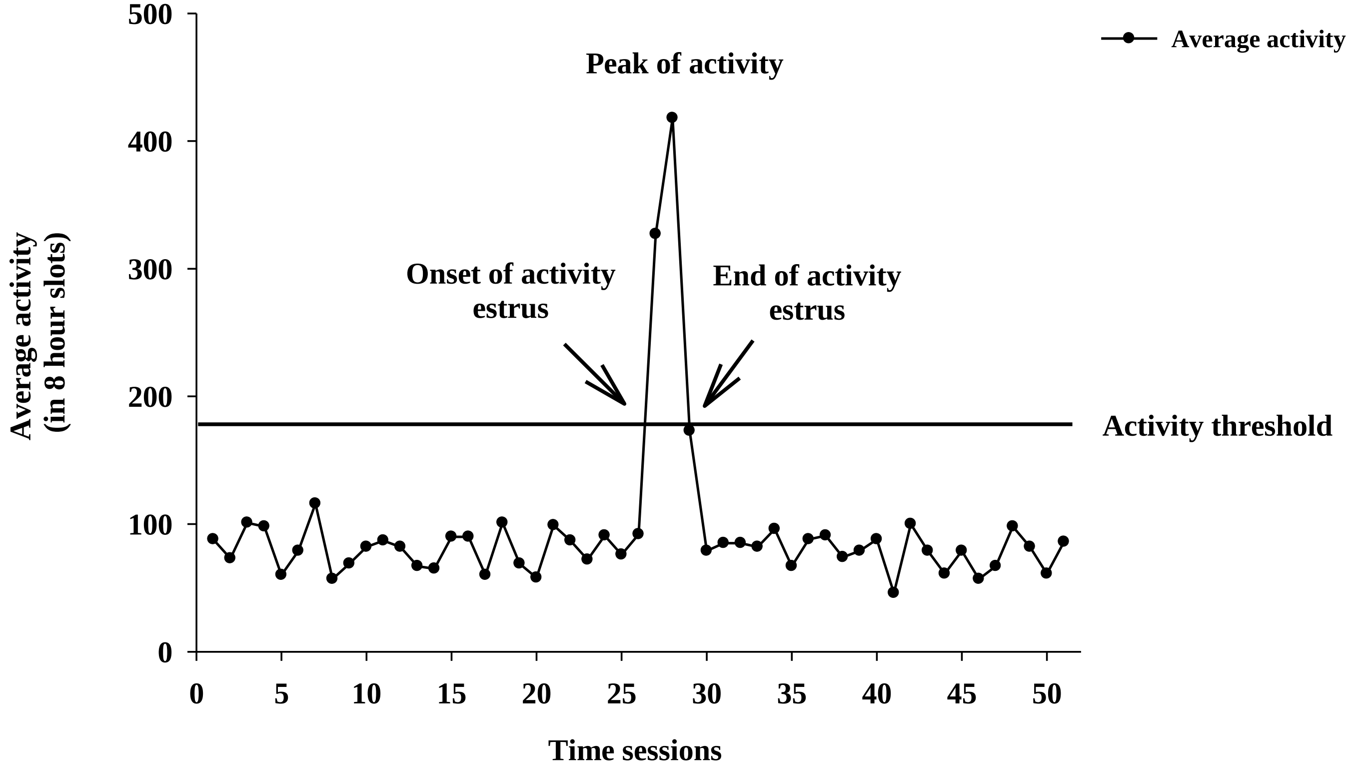
[1] For complete threshold formulae calculation, refer to the reference

[2] Time from onset of increased activity estrus to ovulation

[3] Time from end of increased activity estrus to ovulation

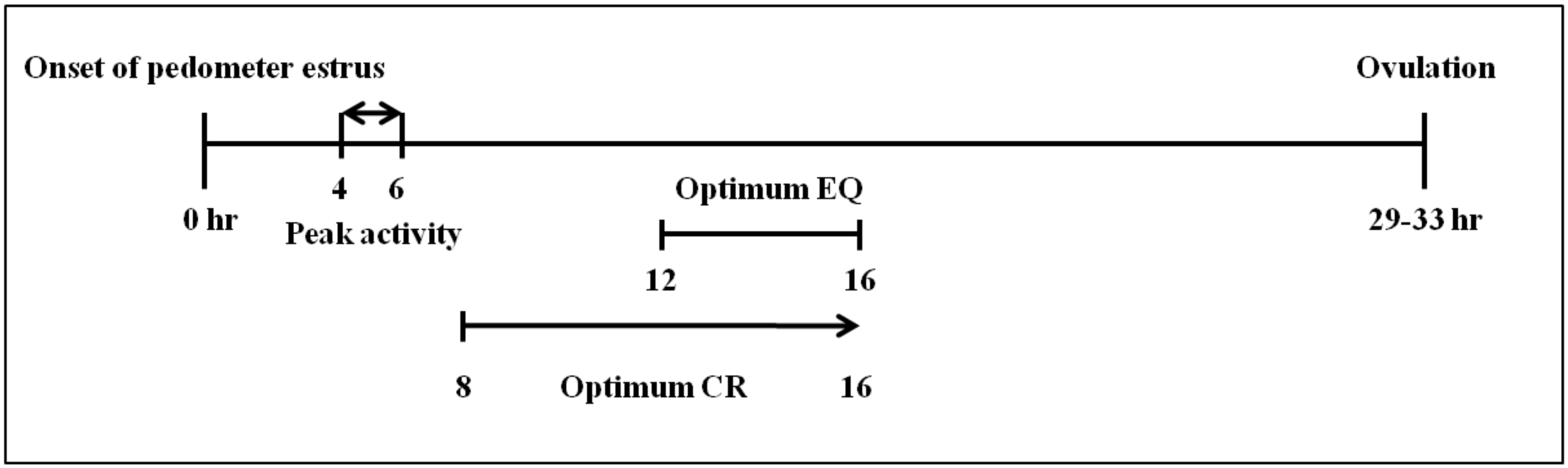
* Standard error was estimated using the following calculation: Standard deviation/sqrt(n), where n was 100 ovulations

Figure 1.1 Schematic illustration of an optimal estrus activity curve



Note: Activity data were obtained from AfiMilk® software from a commercial dairy in Ontario, in which average activity was extracted from 17 consecutive days and divided into 3 time slots of 8 hours per day. Threshold value was calculated using the ratio of the session of increase in activity to the mean of the 8 previous days from the same day-time interval. Estrus was assumed to have occurred after a 2 fold increase in activity. This may not represent the actual estrus threshold alert for this individual cow.

Figure 1.2 Schematic illustration of the interval of onset of estrus activity (i.e. time that a heat signal is given by the system) and optimum intervals for artificial insemination



EQ – Embryo quality

CR – Conception risk

References used to build the illustration: Bar (2010); Hockey et al. (2009); Maatje et al. (1997); Roelofs et al. (2005); Roelofs et al. (2006); Yoshioka et al. (2010)

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CHAPTER TWO

REPRODUCTIVE PERFORMANCE WITH AN AUTOMATED ACTIVITY MONITORING SYSTEM VERSUS A SYNCHRONIZED BREEDING PROGRAM

INTRODUCTION

Improving economic and reproductive efficiency in a dairy herd relies on a reproductive management strategy that can accurately identify cows in heat (Heersche Jr. and Nebel, 1994; Senger, 1994) or a program that can efficiently inseminate animals at the ideal time relative to ovulation (Gwazdauskas et al., 1986; Maatje et al., 1997). The first and most popular method of synchronization of ovulation for dairy cattle using GnRH and $PGF_{2\alpha}$ (OvSynch) was published more than 15 years ago (Pursley et al., 1995). Since then, most research efforts have been on the development of hormone-based artificial insemination (AI) protocols. Technology is now applied in precision dairy management tools. Reproduction is one area that has benefited from such advances with newer activity monitoring systems for estrus detection being developed.

Senger (1994) described the principles of an ideal estrus detection system. Accuracy in detection of estrus periods while requiring minimal labour and with appropriate indication of the optimum time of AI relative to ovulation are the primary factors to look for in an automated system. Additionally, constant surveillance for the lifetime of the animal optimizes this technology. Activity monitoring systems and radio-frequency monitors for detection of mounting activity are among the tools approximating the proposed ideal system which are currently available to the dairy producer.

Activity systems detect walking and restlessness behaviour rather than mounting activity, which can be an advantage for some free-stall dairy herds. Palmer et al. (2010) showed that cows in free-stalls had significantly higher sub-estrus behaviour and fewer standing estrus events compared to cows on pasture. Moreover, there is an indication that high producing Holstein cows have significantly lower standing activity when compared to low producing cows (Lopez et al., 2004).

To date, there is one clinical trial comparing reproductive performance between a pedometry system and OvSynch protocol performed under Israeli conditions (Galon, 2010). Considering the environment and conditions where the trial was performed, it is very probable that the interpretations may not be the same as for North American herds. Therefore, this current project takes the first step to compare herd and cow-level reproductive performances between an automated activity monitoring system and a systematic timed insemination program using free-stall Canadian dairy herds. The null-hypothesis was that the same reproductive performance will be obtained using an activity monitoring system as in a timed AI program.

MATERIALS AND METHODS

A sample of three free-stall commercial dairy herds located in Ontario, Canada participated in the study. Herd inclusion was dependent on the exclusive use of artificial insemination, and the housing of lactating cows in the breeding period in at least two separate pens with similar flooring, size, stabling, and diet. Herds A, B and C milked 495, 305 and 260 cows on average, respectively. Herd A milked 3 times/day while herds B and C milked 2 times/day.

All herds had been using a timed artificial insemination (TAI) program for the majority of AI in the lactating cows for several years before this study.

Data were collected from September 2009 until January 2011, during which each herd was enrolled for one year. All herds housed primiparous cows in separate pens from multiparous cows. At the pen level, animals were assigned either to an automated heat detection (AHD) system (Heatime®, SCR Engineers Ltd.) or to a TAI program, and a cross-over occurred after 6 months of the trial to avoid confounding treatment with parity. Animals in the Heatime group were bred based on increased activity. A heat was signaled when the weighted activity calculated using a proprietary algorithm surpassed 5 standard deviations (SD) of the average activity of the individual cow in the same time period in the past 7 days. In addition, all herds continued to breed cows based on visually detected heats in both treatment groups.

At the start of a 6 months AHD treatment period, all non-pregnant animals in the pen received an activity tag collar. As cows calved and joined the AHD group, they received a collar at calving. In herds A and C, the breeding of the multiparous cows was randomly assigned to the AHD system for the first half of the study, whereas herd B initially allocated the activity system to the first lactation animals. Herds B and C bred twice daily for heats signaled by the AHD system, whereas herd A bred cows once a day. In addition, herds B and C bred their own cows, while herd C had just over half of their animals bred by a technician. Cows that did not become pregnant in the first 6 months of the trial were carried over to the second period and therefore, their breeding program was switched. Approximately, 31 different sires were used during the study period at herd A, whereas herds B and C had 12 and 36 different sires, respectively; bulls were selected by herd owners independent of pen.

Reproductive practices were discussed at the beginning of the trial with each herd manager to ensure compliance with the protocols during the study period. Animals in herd A assigned to the TAI pen received two doses of prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) 14 days apart (Presynch 14), followed 14 days later by OvSynch 56 program (GnRH – 7 days – $PGF_{2\alpha}$ – 56 h – GnRH – 16 h – AI) for the first breeding of the lactation. Cows diagnosed not pregnant were started in the OvSynch program again. Herd B started OvSynch 56 protocol at around 62 DIM and cows diagnosed open were restarted on the same protocol. Herd C started breeding cows at around 70 DIM based on a Co-Synch 72 program (GnRH – 7 days – $PGF_{2\alpha}$ – 72 h – GnRH and AI), and 25 to 37 days after AI and 7 days prior to the veterinarian pregnancy diagnosis check, the cows received a GnRH injection. At the herd check, the open cows diagnosed with a functional corpus luteum (CL) determined by the herd veterinarian received a $PGF_{2\alpha}$ injection followed by GnRH and AI 72 hours later. Open cows diagnosed with no presence of CL were restarted on the Co-Synch 72 protocol. Table 2.1 summarizes some descriptive information on the study herds.

All breeding-eligible animals in the AHD pen had the Heatime tags attached according to the manufacturer's instruction after freshening. The neck collars were kept for at least 60 days after confirmation of pregnancy. In all three herds the cows not detected in estrus by the AHD system by 80 DIM were allowed to have hormonal treatment at the herd manager and veterinarian's discretion. In the majority of cases, the protocol used on those animals was the same synchronization program used for a cow diagnosed open in each herd. The AI following hormonal treatment was recorded as a synchronized protocol breeding. All inseminations were individually recorded as being based on the AHD system, the TAI protocol or visual observation.

On-farm records including calving, inseminations, pregnancy, do not breed and culling dates were retrieved from electronic files of DairyComp 305 (Valley Agricultural Software, Tulare, CA) every 60 days. On the same day, a backup of the Heatime software was also performed, in which graphical outputs of individual cow activity data were displayed.

Lameness scoring was performed on a pen-level basis using a 5-point scale (Sprecher et al., 1997) at the start of the study, 6 months later and at the end of the trial. Cows were observed on their way back to the stalls from the milking parlour. All animals assigned a gait score of 3 or greater were considered lame.

Data management and Statistical Analysis

Sample size calculation based on an estimated difference of 10 days to conception (SD=30d) between the AHD and TAI breeding groups, with 95% confidence and 80% power allowing for clustering effect, required a minimum of nearly 150 milking cows per treatment group (Dohoo et al., 2009). To increase external validity, 3 replicates (i.e. herds) were performed concurrently.

Individual cow data were exported from DairyComp 305 to Microsoft Excel (Microsoft Corporation, Richmond, WA). Data editing and statistical analyses were performed with SAS (Version 9.2, SAS Institute, Cary, NC).

Herd-level analysis

Using the command BREDSUM\E in DairyComp 305 (i.e. pregnancy risk analysis according to 21-day cycle eligibility criteria established by the software), all pregnancies and the total 21-day cow-periods eligible for pregnancies stratified by period of the study and parity number was retrieved for each herd. The mean-annual 21-day pregnancy risks for the TAI and AHD groups across the 3 herds were analyzed utilizing least squares means while controlling for random herd effect in a linear mixed model (MIXED procedure).

Cow-level analysis

a) Time to pregnancy

Individual cow parity group was categorized into two levels (first; second or greater), while season of calving and breeding were each categorized into 4 levels (Fall: September to November; Winter: December to February; Spring: March to May; Summer: June to August).

Because not all animals in the beginning of the study were fresh, and a cross-over was performed half-way through the study, days to pregnancy during the study period was the outcome of interest and the unit of analysis was the cow-treatment period. Therefore, cows carrying over from the first to the second period of the trial contributed to two separate periods. A thorough assessment of individual cow breeding data was performed. Due to specific farm factors, a small number of animals were not assigned to the proper breeding program according to lactation group. Thus, each cow-period was checked for the proper reproductive program, wherein animals assigned to the AHD system but not showing any records of having had a Heatime tag and/or a Heatime breeding code were assigned to the

TAI group. In the same way, cows appointed to the TAI program but with evidence of having had a Heatime tag and a Heatime breeding code were placed in the AHD group. Herd A had 92 cow-treatment periods breeding groups reassigned according to the previously described criteria, whereas herd B and C had 125 and 26 cow-periods, respectively.

Time to pregnancy during the study period (survivor function) was estimated using the Kaplan-Meier method (LIFETEST procedure). This method was used to compute crude median time to pregnancy and corresponding graphs for AHD and TAI groups. The effect of treatment on time to pregnancy was analyzed using Cox's proportional hazards regression (PHREG procedure). The Cox proportional hazards model measures the probability of pregnancy per unit time expressed as a hazard ratio.

In addition to the main effect of breeding group affecting time to pregnancy, the effect of lactation group, season of calving, period of the study (1: first half of the trial; 2: second half of the trial) were offered to the model as covariates. Using backward stepwise selection technique, all predictors of interest were offered to the model and at each step, the variable showing the smallest contribution to the model was deleted. Lactation group, calving season and period of study were not significant covariates. However, the final model demonstrated a significant interaction between herd and breeding group.

Three different approaches were taken to deal with herd clustering effect. In the first one, herd was treated as a fixed effect. As a second approach, robust standard errors of the main effect estimate were calculated using the robust variance estimator method (COVS option) in order to correct for dependence among the observations within the herds (Allison, 2010). The proportional hazards assumption of the model was assessed using the PH and RESAMPLE option, which uses a Kolmogorov-type supremum test. If a significant *p*-value is obtained, there is enough indication of poor model fit (Allison, 2010). A third approach to contend with the herd effect was using the NLMIXED procedure. This method allows for the inclusion of a disturbance term in the model leading to a correction of some or all of the bias in the estimates caused by unobserved heterogeneity (Allison, 2010). In this case, herd was treated as a random effect, but little variation in the coefficients and *p*-values was perceived when compared to the model computing robust standard errors.

b) Time to 1stAI and from 1st to 2nd AI

A similar Cox's proportional hazards model used to assess time to pregnancy was built to evaluate the overall effect of treatment on time to first service and time from first to second service during the study period. The model building process for the abovementioned outcomes was performed as for the time to pregnancy model. Survivor functions across treatment groups were estimated using the Kaplan-Meier method (LIFETEST procedure).

The Cox proportional hazards model of time to 1st service had season of calving and period of the study as significant covariates and were therefore, kept in the final model. Those same variables were used in the model assessing the effect of treatment on time from 1st to 2nd service. Due to a greater relevance, the event time in the days from 1st to 2nd service model was limited to 100 days.

Both models assessing days to first and to second AI were performed using herd as a fixed effect and a significant interaction between herd and breeding group were present. In order to check for more important differences on time from 1st to 2nd service, the time event interval was set in a herd-level basis according to average stage of pregnancy diagnosis and the end of the resynchronized program used. Therefore, herd A had the time to event set as 50 days, whereas herds B and C were set to 42 days. For all analysis, if the predictor of interest violated the proportional hazards assumption of the model, the product between the time-dependent covariate (i.e. the breeding group) and the event time (i.e. days to AI) was forced into the model (Allison, 2010).

c) Conception risks

A multiple logistic regression model was built to compare conception risks among AI based on observed heat, TAI and AHD using the GLIMMIX procedure. An identical approach to the Cox proportional hazards model building process was taken for the determination of the final multiple regression model. Using pregnancy as the binary outcome of interest, the final model included breeding code as the parameter of interest while accounting for the fixed effects of breeding season, lactation group and herd. Breeding season and parity group were not significant covariates, but were forced into the model due to a priori concern of their confounding effects. Unlike the Cox proportional hazards model, there was no interaction between breeding code and herd. Next, additional multiple logistic regression models were built to compare the conception risks between AI based on observed heat within the TAI and AHD breeding pen assignment in each herd. Again, breeding season and parity group were forced into the model.

RESULTS

A total of 1429 animals were enrolled in this study, resulting in 1985 cow-periods included in the statistical analysis. At the start of the study, cows eligible to become pregnant that were past the voluntary waiting period were enrolled in the trial. The mean days in milk (DIM) and standard error mean (SEM) at the start of the first study period was 56.5 ± 3 days and 56 ± 3 days for the second study period.

The proportion of animals classified as lame stratified by herd and period of the study is presented in Table 2.2. The prevalence of lame animals per pen was averaged, in which the first and second gait scoring assessment was summed and the proportion obtained was assigned to period 1. In the same way, period 2 was an average from the second and third gait scoring assessment.

Herd-level analysis

A total of 6165 21-day cow-periods were used for the overall pregnancy risk analysis across the 3 herds. There was no difference (P = 0.25) in the mean annual pregnancy risks between TAI program (15.9%) and AHD system (14.6%).

Cow-level analysis

a) *Time to pregnancy*

In univariable overall analysis, median time to pregnancy was not different between the AHD (122 days) and TAI (137 days) treatment groups (P = 0.19). The hazard ratios (HR) for the models dealing with herd as a fixed effect or in a cluster-adjusted robust variance method similarly showed no significant difference between programs (Table 2.3). A survival curve of time from enrollment to pregnancy is shown in Figure 2.1. The final model demonstrated a significant interaction between herd and breeding programs, such that the association of reproductive program with time to pregnancy differed between farms. The Cox proportional hazard model stratified by herd, revealed no significant difference in time to pregnancy between cows managed in the AHD system vs. TAI in herd A (median = 151 and 136 days; HR = 0.93, 95% CL = 0.75 to 1.15; P = 0.52; Figure 2.2) and herd C (median = 99 and 124 days; HR = 1.24, 95% CL = 0.97 to 1.57; P = 0.08; Figure 2.3), whereas herd B had a difference of median time to pregnancy of 119 and 146 days (HR = 1.3, 95% CL = 1.04 to 1.64; P = 0.02; Figure 2.4).

b) Time to 1st AI and 1st to 2nd AI

Similar to the time to pregnancy model, median days to first service (P = 0.3) and days from first to second service (P = 0.2) were not different between the AHD and TAI treatment groups. However, an interaction between the breeding programs and herd was significant in both models. The survival curves of days to first service and to second service are shown in Figures 2.5 and 2.6. The Cox proportional hazards model of time to first service stratified by herd revealed no significant difference between cows managed in the AHD system vs. TAI in herd A (median = 66 and 68 days; HR = 0.82, 95% CL = 0.59 to 1.14; P = 0.24) and herd B (median = 74 and 73 days; HR = 0.7, 95% CL = 0.46 to 1.06; P = 0.09), whereas herd C had a difference of median time to first service of 55 and 72 days (HR = 2.32, 95% CL = 1.53 to 3.51; $P < 0.0001$).

The Cox proportional hazards model of time from first service to second service stratified by herd was not different between cows managed in the AHD system vs. TAI in herd B (median = 35 and 42 days; HR = 3.30, 95% CL = 0.90 to 12.01; P = 0.07), whereas herd A (median = 32.5 and 29 days; HR = 0.53, 95% CL = 0.30 to 0.93; P = 0.02) and herd C (median = 25 and 35 days; HR = 1.97, 95% CL = 1.45 to 2.67; $P < 0.0001$) it was significantly different. It is important to note that in all analysis the TAI breeding program was set as the referent and the hazard ratios correspond to the AHD breeding program.

c) Conception risks

The multiple logistic regression model of probability of pregnancy at each insemination included 3015 AI (1303, 726 and 986 breedings in herds A, B and C, respectively). There was no difference (P = 0.43) in conception risks (CR) between breeding programs. Moreover, Heatime AI and TAI CR within each herd were never greater than 5% apart. Overall least squares mean CR accounting for herd, breeding season and parity are presented in Table 2.4. The multiple logistic regression models comparing conception risks by breedings that occurred based on observed heats in the cows assigned to the AHD and TAI programs within herds showed no difference (Herd A, P = 0.99; Herd B, P = 0.93; Herd C, P = 0.25). Also, when conception risks were compared to AHD versus observed heats and TAI versus observed heats within each herd, in herd A there was no difference. However, in herds B and C, observed heats that occurred in cows assigned to the TAI program had a higher conception risk (P = 0.04 on both herds) when compared to the TAI breedings. The same comparison was not significant for the observed heats happening in the cows assigned the AHD management. The proportion of TAI in the TAI pen and Heatime AI in the AHD pen within each herd and respective CR are presented in Table 2.5.

DISCUSSION

The present study differs from many previous studies because it compares the reproductive performance of commercial dairy herds managed with an AHD system relative to a TAI-based program under North American housing and management conditions. Taking into account that the comparison of the reproductive management approaches were performed under field conditions, in which expectations of pure compliance to the protocols are illusive, the results of this trial are more likely to approximate to farm level responses.

Overall, the management of cows with AHD or TAI-based programs was not associated with differences in time to pregnancy or conception risks. However, the interaction between herd and reproductive management in this trial raises the question of potential factors associated with such differences.

Differences in TAI programs

One potential explanation for this difference in reproductive performance between herds could be from the type of synchronization program adopted in each herd. As described earlier, herd A adopted a Presynch 14/OvSynch 56 protocol. It has been shown that cows receiving two injections of $PGF_{2\alpha}$ 14 days apart before the start of the TAI program have significantly higher conception rates when compared to cows starting a TAI program at random stages of the estrous cycle (Moreira et al., 2001; Vasconcelos et al., 1999; El-Zarkouny et al., 2004).

Herd B was on OvSynch, while herd C used a Co-Synch program. Geary and Whittier (1998) compared pregnancy rates of OvSynch and Co-Synch protocol across 3 regions of the United States using suckled beef cattle. OvSynch led to a higher pregnancy rate (57%) than Co-Synch (49%) (P = 0.02). Similarly, Brusveen et al. (2008) found significantly higher CR when lactating dairy cows were synchronized with OvSynch 56 compared to Co-Synch 72 or Co-Synch 48.

Differences in prevalence of lame cows across AHD and TAI pens

In the present study, herd C had a notably higher prevalence of lameness among multiparous animals, resulting in a disparity of lameness prevalence across the AHD and TAI pens (Table 2.2). An experimental study reported a significantly lowered standing to be mounted activity in lame cows compared to normal animals when in estrus (Sood and Nanda, 2006). The same study reported a considerable increase in estrus behaviour score when more than one animal was in estrus in the non-lame cows but the same did not occur with the lame animals. Roelofs et al. (2005) described a higher chance of estrus detection by a pedometer when behavioural estrus was more intense.

Garbarino et al. (2004), using a slightly modified lameness scoring system developed by Sprecher et al. (1997), revealed a detrimental effect of lameness on ovarian activity of Holstein cows. Cows classified as lame were at 3.5 times greater risk of delayed cyclicity during the first 60 days postpartum when compared to non-lame animals. However, this study did not perform a comparison of conception risks and days open between the group of lame and non-lame animals.

Due to the possible effects of lameness on fertility, it was conceivable that the difference in lameness prevalence across pens in Herd C could have confounded the effect of breeding program and the tendency of difference in reproductive performance between the TAI and AHD group for that herd. However, when the survival analysis was stratified by period of the study (i.e. by parity group), the apparent difference in time to pregnancy between the TAI and AHD programs was similar for period 1 and period 2.

Frequency of AI

Herds B and C bred based on the AHD system twice a day which may have improved the timing of AI relative to the onset of increased activity. Conversely, once a day AI may have contributed to the lack of difference in time to pregnancy between the two breeding programs in herd A.

High heat detection accuracy (83%) with a fairly precise prediction of time of ovulation was obtained in a study done in the Netherlands using Holstein-Friesian cows equipped with pedometers and housed in a free stall with a slatted floor (Roelofs et al., 2005). The interval from beginning of the pedometer estrus (i.e. time that the estrus activity surpassed the system threshold) to ovulation was on average 29.3 hours, and no difference was seen between primiparous and multiparous animals (Roelofs et al., 2005), while the highest percentage of good quality embryos was obtained when AI occurred 12 to 16 hours before ovulation (Roelofs et al., 2006).

In a study in Australia, where cows were in open grazed areas, the mean interval from onset of pedometer estrus to ovulation was 33.4 hours (Hockey et al., 2009; Hockey et al., 2010). Yoshioka et al. (2010) also investigated the time of ovulation relative to the onset of pedometer estrus in Japanese black cows housed in loose-housing barn. The mean interval from the onset of pedometer estrus to ovulation was 30.2 hours.

It is important to note that the studies performed in the Netherlands and Australia used a low activity alert threshold. The Australian trial defined a heat as being an increase of 2 SD of the activity recorded in 2 hour intervals for the corresponding periods at the same times of the day in the previous 10 days (Hockey et al., 2009; Hockey et al., 2010). The definition of heat onset with the system used in the present study was an increase of 5 SD of the 7 preceding days mean activity. Therefore, it is understandable that when a higher activity threshold is used, the expected time from onset of estrus (according to the activity monitor) to ovulation may be reduced. Moreover, the system employed in this study has shown optimum probability of pregnancy when cows were inseminated 0 to16 hours after the peak of the estrus activity (Bar, 2010). Therefore, a greater number of breedings may fall on the aforementioned interval if AI happens twice a day rather than once a day, even though a heat alert is signaled based on the onset of increased activity and not the peak. Unfortunately, the present study did not evaluate the timing of insemination relative to the onset or peak of increased activity.

Differences in proportions of AI based on observed heats

Herds A and C had over 40% of the total AI in the TAI pen based on observed heats. When the model was stratified by herd, there was no statistical difference in conception risks between the TAI and AI based on observed heats for herd A, but the same comparison was significantly higher for AI based on observed heats in herds B and C. Therefore, selective insemination based on obvious signs of estrus could possibly have distorted the performance of TAI in all herds.

CONCLUSION

In this study, overall herd and cow-level reproductive performance was not different between the TAI and AHD-based reproduction management systems. An interaction between breeding program and herd demonstrated that automated activity systems performed equally or better than a TAI program in a situation in which a considerable minority of AI was based on observed estrus. However, this study was not able to elucidate the herd or cow level factors that affect the relative performance of the automated activity system. Further research is needed to better understand the variables that influence herd reproductive performance when adopting automated estrus detection systems. The results of this study suggest that AHD systems may yield reproductive performance comparable to a TAI-based program under field conditions, but that relative performance may vary moderately between herds.

Table 2.1 Descriptive information on the study herds

Descriptive parameters	**Herd A**	**Herd B**	**Herd C**
Average number of milking cows during the study	495	305	260
Milking frequency per day	3	2	2
Herd average 305 ME[1] production	14273	9068	11108
Study dates	September 2009 to September 2010	October 2009 to November 2010	November 2009 to December 2010
Number of times per day AI[2] was performed based on heat alerts	Once	Twice	Twice
VWP[3]	50	45	50
Timed-AI[2] program used	Presynch 14/OvSynch 56	OvSynch 56	Co-Synch 72
Mean and SEM[4] of DIM[5] to start of the timed-AI[2] program (time of 1st GnRH)	66 ± 1	72 ± 1.5	73 ± 1
Stage of pregnancy diagnosis	38 to 45 days post AI	27 to 41 days post AI	28 to 42 days post AI

[1] 305-d mature-equivalent milk
[2] Artificial insemination
[3] Voluntary waiting period
[4] Standard error mean
[5] Days in milk

Table 2.2 Prevalence of lame cows in the AHD and TAI pen according to the period of trial, in a study comparing reproductive performance between an AHD[1] system and TAI[2] program

Herd	Period	Pen	Prevalence (%)
A	1	AHD [1]	7
		TAI [2]	6
	2	AHD [1]	15
		TAI [2]	17
B	1	AHD [1]	25
		TAI [2]	28
	2	AHD [1]	28
		TAI [2]	32
C	1	AHD [1]	33
		TAI [2]	17
	2	AHD [1]	13
		TA I[2]	45

[1] Automated heat detection
[2] Timed artificial insemination

Table 2.3 Comparison of the Cox proportional hazards model with herd as a fixed effect or in a cluster-adjusted robust variance estimation, in a study comparing reproductive performance between an AHD[1] system and TAI[2] program

Method	**Hazard Ratio**	**95% CI**	***P*-value**
Fixed effect	1.13	0.99-1.28	0.08
Robust variance estimation	1.13	0.94-1.37	0.19

[1] Automated heat detection
[2] Timed artificial insemination

Table 2.4 Overall mean conception risks by breeding code based on the final multiple logistic regression model (n=3015),in a study comparing reproductive performance between an AHD[1] system and TAI[2] program

Breeding code	**Mean (%)**	**95% CI**
AHD [1]	31	0.28-0.34
TAI [2]	30	0.28-0.33
Observed [3]	33	0.30-0.36

[1] Automated heat detection
[2] Timed artificial insemination
[3] Observed heat

Table 2.5 Proportion of artificial inseminations in accordance to the breeding program assigned as AHD[1] or TAI[2] and breedings based on observed heats and conception risks, in a study comparing reproductive performance between an AHD[1] system and TAI[2] program

Herd	Pen	Proportion of AI[3] to the assigned protocol (%)	Mean CR[4] (%) and (95% CI)	Proportion of AI[3] based on observed heats (%)	Mean CR[4] (%) and (95% CI)
A	AHD[1]	69	27 (0.23 – 0.32)	15	26 (0.18 – 0.37)
	TAI[2]	49	30 (0.26 – 0.35)	48	26 (0.22 – 0.31)
B	AHD[1]	63	39 (0.33 – 0.46)	11	46 (0.30 – 0.63)
	TAI[2]	72	36 (0.30 – 0.41)	26	47 (0.38 – 0.57)
C	AHD[1]	61	27 (0.23 – 0.33)	12	25.5 (0.16 – 0.38)
	TAI[2]	55	24.5 (0.20 – 0.30)	44	33 (0.27 – 0.40)

[1] Automated heat detection
[2] Timed artificial insemination
[3] Artificial insemination
[4] Conception risk

Figure 2.1 Survival curves for time to pregnancy during the study period for 1985 cow-periods. The black line represents the timed artificial insemination (TAI) breedings and the red line represents breedings based on the automated heat detection (AHD) system. Median time to pregnancy (95% CI) was 122 (110-139), 137 (122-152) days for AHD and TAI, respectively.

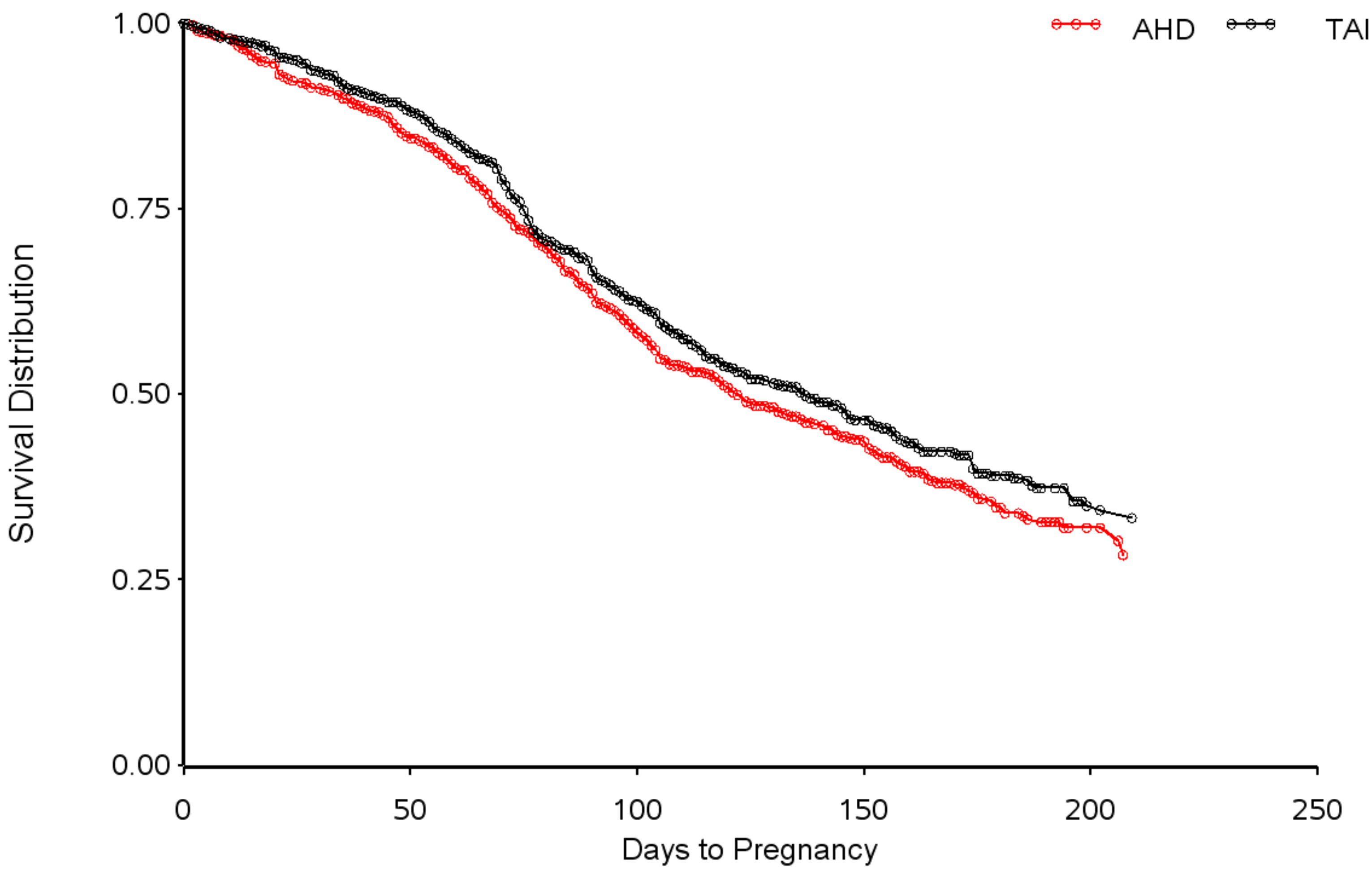


Figure 2.2 Survival curves for time to pregnancy during the study period for herd A (n = 808 cow-periods). The black line represents the timed artificial insemination (TAI) breedings and the red line represents breedings based on the automated heat detection (AHD) system. Median time to pregnancy (95% CI) was 151 (124-189), 136 (114-162) days for AHD and TAI, respectively.

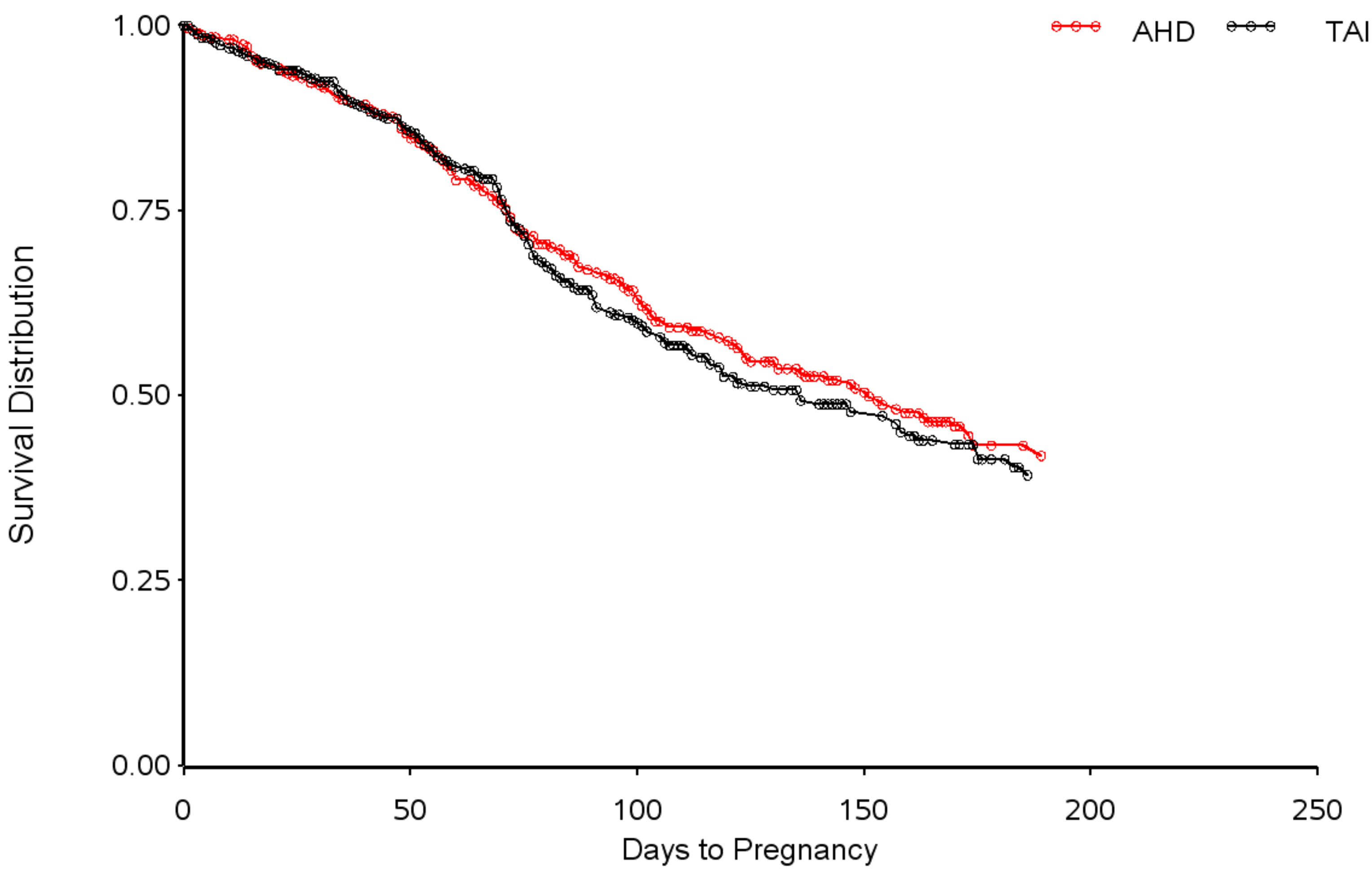


Figure 2.3 Survival curves for time to pregnancy during the study period for herd C (n = 548 cow-periods). The black line represents the timed artificial insemination (TAI) breedings and the red line represents breedings based on the automated heat detection (AHD) system. Median time to pregnancy (95% CI) was 99 (87-122), 124 (108-147) days for AHD and TAI, respectively.

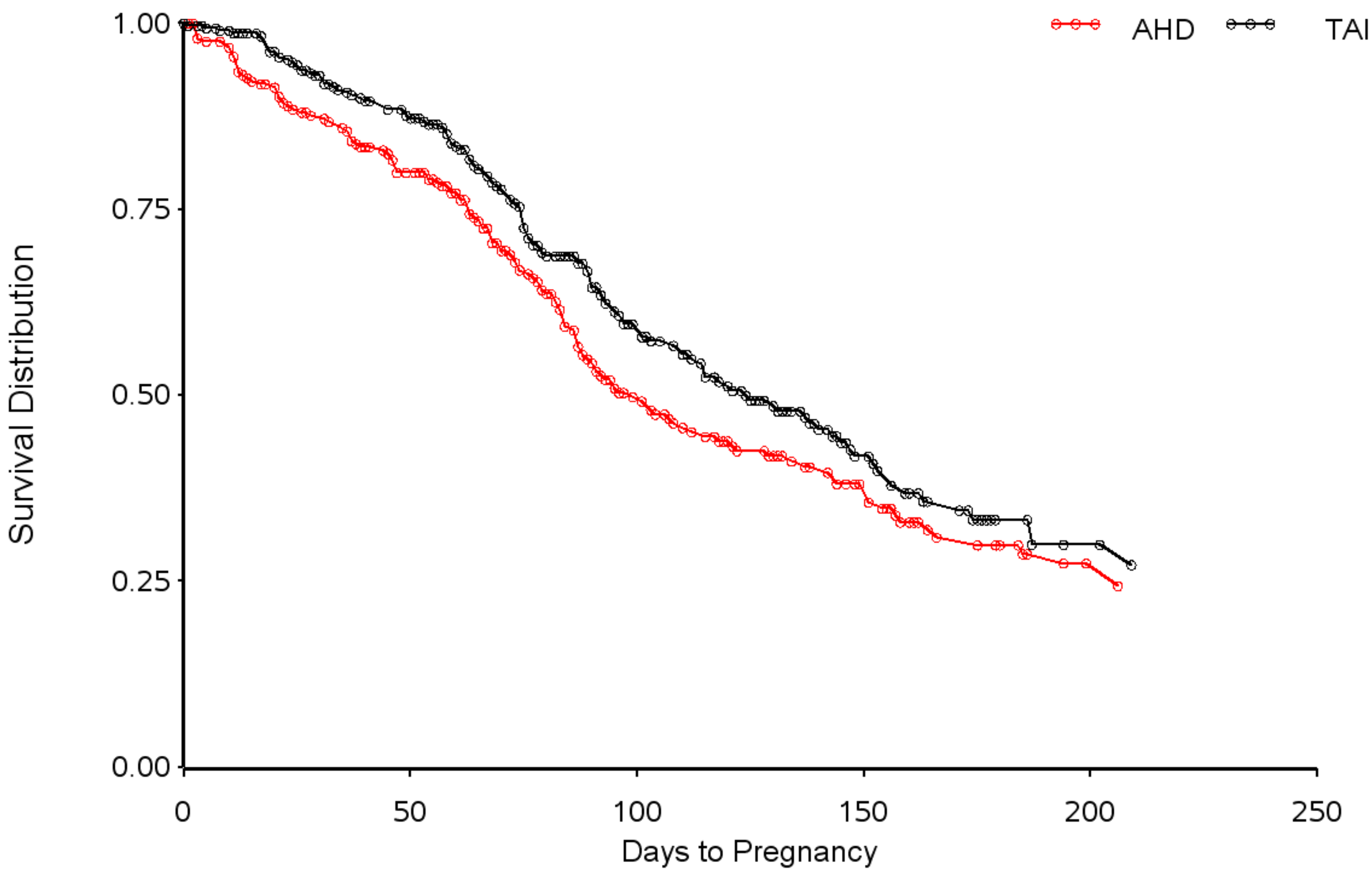


Figure 2.4 Survival curves for time to pregnancy during the study period for herd B (n = 629 cow-periods). The black line represents the timed artificial insemination (TAI) breedings and the red line represents breedings based on the automated heat detection (AHD) system. Median time to pregnancy (95% CI) was 119 (105-139), 146 (125-174) days for AHD and TAI, respectively.

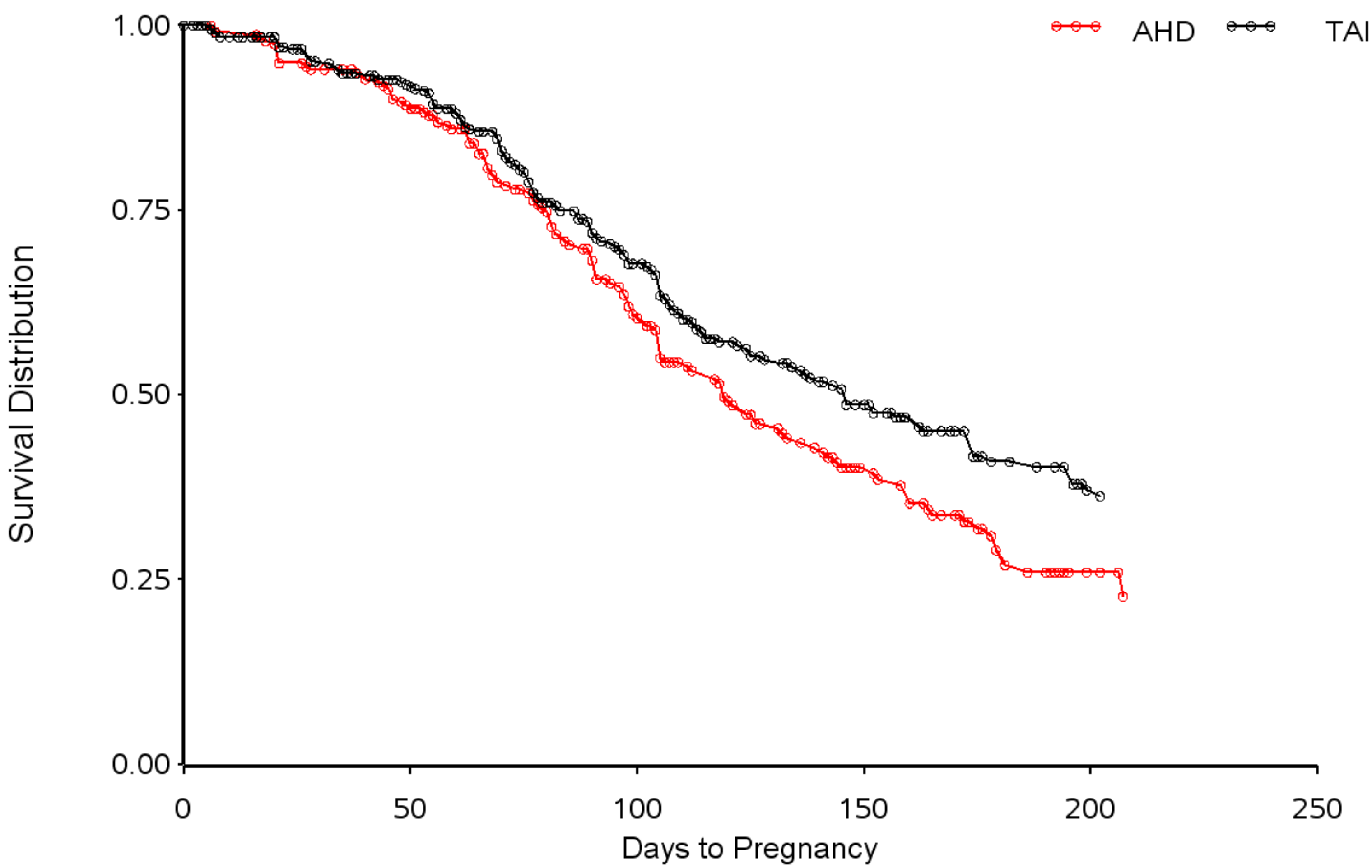


Figure 2.5 Survival curves for time to first service during the study period for 1985 cow-periods. The black line represents the timed artificial insemination (TAI) breedings and the red line represents breedings based on the automated heat detection (AHD) system. Median time to first service (95% CI) was 64 (62-68), 70 (69-71) days for AHD and TAI, respectively.

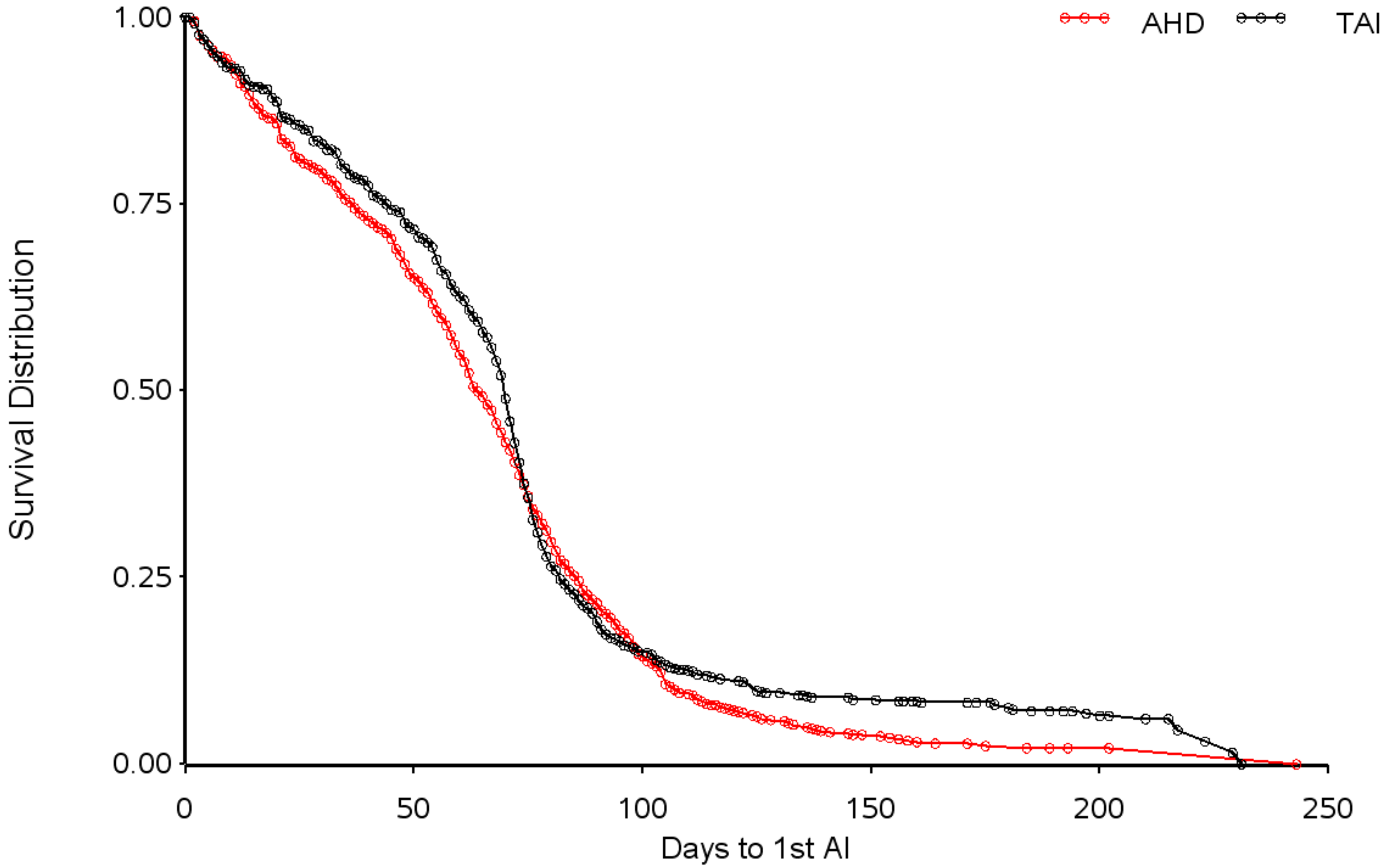
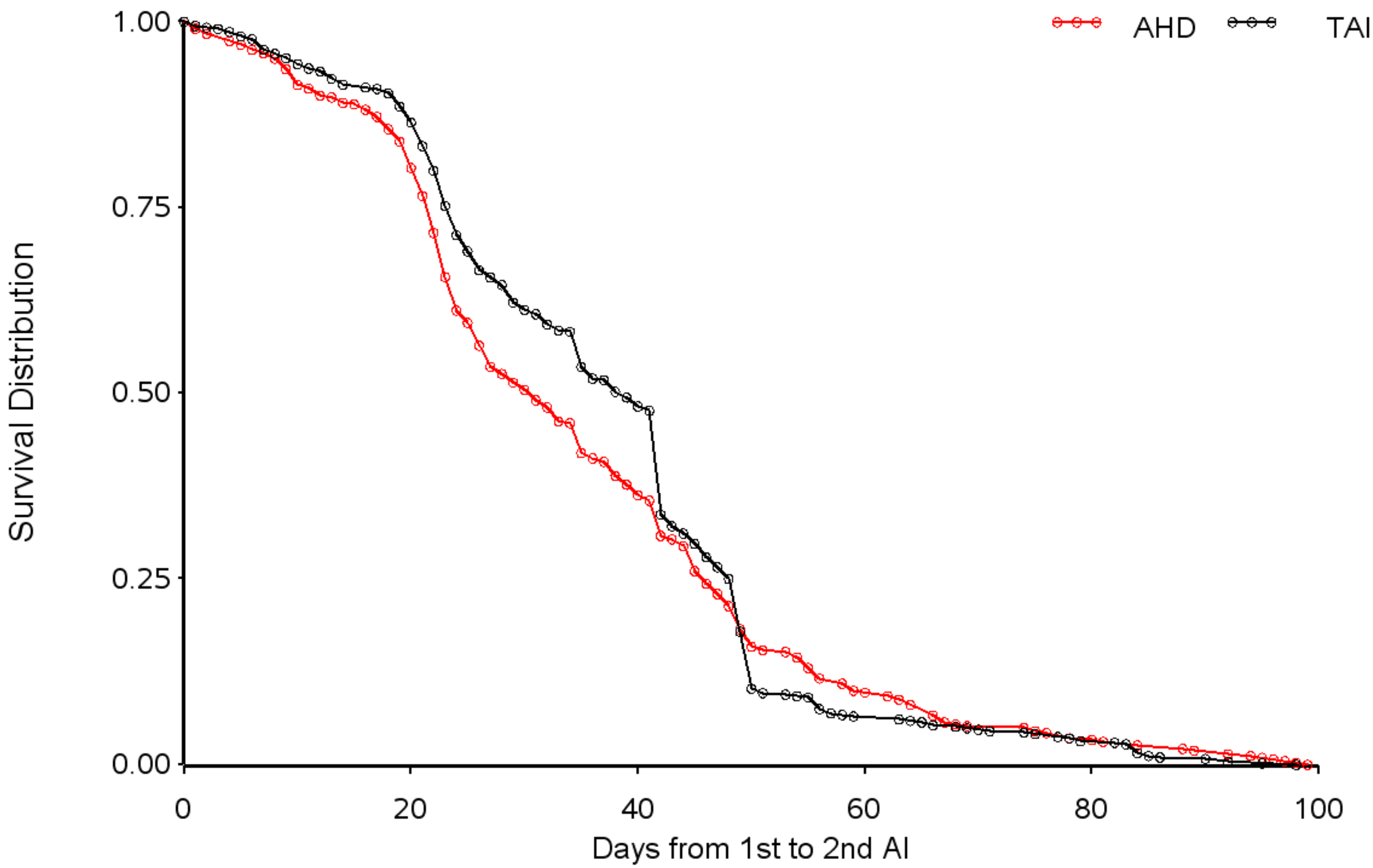


Figure 2.6 Survival curves for time from first service to second service during the study period. The black line represents the timed artificial insemination (TAI) breedings and the red line represents breedings based on the automated heat detection (AHD) system. Median time to second service (95% CI) was 31 (27-35), 39 (35-42) days for AHD and TAI, respectively.



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CHAPTER THREE

REPRODUCTIVE PERFORMANCE OF CANADIAN DAIRY HERDS USING AUTOMATED HEAT DETECTION SYSTEMS AND FACTORS RELATED TO ADOPTION

INTRODUCTION

Accurate estrus detection in dairy herds has been a long-standing and ongoing problem. Smith (1982) reported that 10 to 50% of over 450 herds participating in a study in northeast U.S. were bred when not in estrus. Senger (1994) argued that poor heat detection is the major limiting factor in efficient reproductive performance. With the advent of synchronization programs, the problem of low intensity of heat detection by observation was reduced. Timed artificial insemination (TAI) programs offered a chance to improve the pregnancy risk (PR) in herds with a poor heat detection rate. However, technology in this sector has continued to advance and estrus detection aids have been reinvented with the introduction of newer automated activity monitoring systems. It was hypothesized that these systems would improve heat detection rate, resulting in a PR comparable to that achieved in a TAI-based program. Therefore, reproductive performance was compared in herds with an automated heat detection system versus TAI-based programs under North American field conditions in a randomized controlled trial.

Gröhn and Rajala-Schultz (2000) stated that two of the difficulties in epidemiological studies involving reproductive performance are the lack of large datasets and statistical power. While experimental field trials have a high level of control of potential confounding variables, a cross-sectional study such as the one employed in this study has moderate to low level of control of extraneous variables (Dillman, 2007; Dohoo et al., 2009). However, the measurement of reproductive performance obtained by farmers when implementing new management procedures may be of more importance to adoption of new management tools by producers, than results of controlled trials. Dillon (1977) emphasized that insufficient attention has been paid to the lack of agreement between experimental and farm-level responses to interventions. The potential effect of that difference in results affects the reliability of extension work and the rate of adoption of the proposed management practice (Howard et al., 1992).

The first objective of this study was to compare annual summary herd reproductive performance before and after the implementation of an automated activity monitoring system. The second objective was to describe the current reproductive performance of Canadian dairy herds using automated heat detection (AHD) systems and, to compare the performance of these herds to a sample of herds without AHD and managing reproduction based on TAI or observation of heat.

Development of best management practices requires a deeper comprehension of farmer's perceptions and current management practices in order to make pertinent recommendations (Hoe and Ruegg, 2006). Carley and Fletcher (1986) stated that herd performance is a result of the producer's preference in adopting a variety of herd management practices. Little is known about the decision-making process of North American producers when adopting activity monitoring systems. Therefore, the third objective was to gather information about the characteristics and motivations of herds that had employed AHD systems.

MATERIALS AND METHODS

Questionnaire development and mail survey

A descriptive cross-sectional study was carried out between April and July 2010 using a mail questionnaire, which was structured based on information from the survey design literature (Dohoo et al., 2009). A purposive sample of all free-stall dairy herds (n=1750) from the provinces of British Columbia, Alberta, Saskatchewan, Manitoba and Ontario enrolled in milk recording with CanWest Dairy Herd Improvement (DHI) Association in 2010 received the questionnaire. As such, the sample size for the current study was not predetermined.

The questionnaire was designed to collect information on dairy herd characteristics and reproductive management practices with a focus on farms using automated activity monitoring systems. The survey included 39 questions, 38 of which were close-ended. Prior to implementation, the survey was pre-tested on a convenience sample of dairy producers in Ontario. Questions that were unclear or otherwise problematic were revised. A copy of the questionnaire can be found in Appendix 3.1.

In an attempt to maximize response rate, a few methods known to influence response were implemented, as described by Dillman (2007). The survey package included a cover letter, the survey booklet and a pre-paid addressed return envelope. The cover letter clearly stated the objectives of the study, confidentiality of participation and the research team involved, as well as a section advising of the eligibility for a draw for one of three prizes of $250 (CAD) if a completed questionnaire was returned prior to the deadline. Three weeks after mailing the survey package, an e-mail was sent to thank producers that had already returned the questionnaire, and to encourage those who had not done so yet. This follow-up was performed by CanWest DHI and the list of customers was not released to the researchers. University of Guelph's Research Ethics Board approved the study.

Data management and statistical analysis

Following the sample collection period, a database was built using EpiData Entry 3.1 (Odense, Denmark; available at http://www.epidata.dk/) into which every questionnaire received was entered. The database entries were checked for accuracy against a sample of the returned questionnaires, which were later exported into a single file in SAS (Version 9.2, SAS Institute, Cary, NC). Frequency distributions were calculated for the survey variables (FREQ procedure). Chi-squared tests were performed to test the association between responses (i.e. herd characteristics, practices and beliefs) and use of AHD.

All producers that indicated the use of activity monitoring systems for more than a year and that consented to the extraction of their DHI reproductive summary data were contacted via email or telephone to obtain the date (month and year) of implementation of the heat detection system. Additionally, all respondents that provided a dubious DHI identification code were contacted via e-mail to confirm the correct herd code.

Herd reproductive summary information was obtained from a compilation of farm records from CanWest DHI, in which annual data were extracted from each farm's data file in DairyComp 305 (Valley Agricultural Software, Tulare, CA) and exported into Microsoft Excel (Microsoft Corporation, Richmond, WA). The unique DHI herd number, annual 21-day pregnancy risk, insemination and conception risks, number of breedings and pregnancies of adult cows within each year were obtained for the years 1999 to 2010 and compiled into a single database using SAS.

For the retrospective analysis (i.e. year before versus year after implementation of the AHD), the aforementioned herd data were obtained for the year prior to employment of the automated activity monitoring system. Because direct data on conception risk (CR) were missing for 1999 to 2004, CR was estimated for all the years (i.e. 1999 to 2010) by dividing PR by insemination risk (IR). This was only performed for the dataset employed for this first study objective. The choice of the year after to be used for the comparison was established on the following criteria: herds that started using the automated system between January to June had their 'year after' starting the subsequent year, while herds that implemented the activity monitoring system between July to December had their 'year after' starting after two consecutive years.

For the second study objective (i.e. comparative analysis of farms with and without AHD), herds that started to manage reproduction based on an activity monitoring system from October to December of 2009 were not included in the comparative analysis for the year 2010. Therefore, herds that had employed activity monitoring systems for at least 15 months had their reproductive performance compared with a sample of herds that specified that more than 50% of the artificial inseminations (AI) were based on an estrus synchronization and/or a TAI program and herds that had less than half of their AI based on such programs or any other reproductive management procedure, based on the survey results.

Only herds that had their DHI herd number and province identification code on the annual herd summary data matching with the same items in the survey were included in the analysis.

Two herds had a disparity in province codes in the database for the first study objective and were, excluded from the analysis. To assure completeness of insemination and/or pregnancy records for the full year, exclusion criteria were applied to the herd summary data sets as follows: herds with fewer than 30 breedings or fewer than 10 pregnancies, herds with pregnancy risk < 2% (i.e. herds not entering all pregnancy outcome data), herds in which conception risk was < 10% or > 80% (i.e. herds mostly entering services which only resulted in pregnancy) and herds with an insemination risk < 10% (i.e. incomplete data entry) were excluded. For the second objective, a further validation step was taken. Because the total number of adult cows within a herd contributing to the 2010 DHI calculation reproductive parameters was provided for that year, the quotient of annual number of pregnancies by the number of total cows was computed. It was estimated that herds with a quotient of less than 30% and a pregnancy risk under 5% were likely to have incomplete data and were excluded. Also, herds with fewer than 50 milking animals (n = 13) were not included in the data.

Statistical analyses of pregnancy, conception and insemination risks were performed using a linear mixed model (MIXED procedure) in SAS. For the first study objective, all 3 models included the time variable (i.e. before and after implementation of the automated heat detection system) as the predictor of interest and a categorical variable containing information about the commercial system used (i.e. 5 different systems) was forced into the model, since it was considered a confounding a priori. Herd was treated as a random effect.

For the second objective, the same reproductive outcomes (i.e. PR, CR and IR) were assessed, but a number of variables from the survey (i.e. herd demographics, profile of the owners and information on management practices) were included in the model. Prior to the model building process, descriptive statistics were performed on all the variables to determine the frequency of missing observations and variation among the levels of each variable. When appropriate, categorical variables with few observations per category were collapsed into other categories. Since 96% of the herds reported Holstein as the primary breed of cows, the variable ‘breed’ was excluded from the model due to lack of variability. Subsequently, correlation between all survey explanatory variables was assessed (CORR procedure) using the Spearman’s rank correlation coefficient. No pair of explanatory variables had a high and significant correlation using $\rho \pm 0.7$ cut-off point. A manual stepwise backward elimination procedure was employed, and all variables unconditionally associated with the outcome at $P \leq 0.25$ were initially included in the model. Whenever a variable caused more than 30% change in the coefficients of the predictor of interest, the covariate was kept in the final model due to its confounding effect. In all cases, a partial F-test was used to confirm the lack of association of a variable before its removal using the REG procedure. All two-way interactions among the predictor of interest and the significant survey variables were tested in the final model.

For both study objectives and in all models, residual distributions were assessed for homoscedasticity and normality and goodness-of-fit test performed. Least squares means were obtained for the predictor of interest and any other significant variables.

RESULTS

In total, 505 questionnaires were returned, yielding a response rate of 29% (505/1750). Not all questions were fully answered by all respondents, hence some descriptive statistics were calculated with smaller sample sizes, as noted. Tables 3.1, 3.2, 3.3 and 3.4 summarize the herd characteristics, respondents' profile and the distribution of respondents by province and use of AHD systems.

Reasons for not adopting an automated heat detection system

Of the 505 returned surveys, 282 respondents (56%) did not use pedometers or similar technologies for heat detection on their operation. This subset of producers was asked to indicate the factors that influenced their decision not to use an activity monitoring system. The majority of respondents (53%; 148/279) reported satisfaction with their current herd reproductive performance as being one of the most important factors influencing their decision. Approximately 39% and 22% of the respondents reported a lack of perceived economic value (i.e. cost too high relative to benefit) and no expected improvement in herd reproductive performance if such systems were to be used on their herds as other influential factors, respectively. About 93% and 81% of these respondents did not indicate aversion to technology and unfamiliarity with available commercial systems as significant aspects in their decision to not use an automated heat detection system. Only about 30% of the respondents not using a heat detection system were considering the adoption of such a tool.

Reasons for adopting an automated heat detection system

Nearly 44% of respondents (223/505) used pedometers or similar technologies for heat detection in their herds. This subset of producers was asked to indicate the factors influencing their decision to employ such systems. The most frequently reported reason was the desire to improve herd reproductive performance (81%; 180/220). Figure 3.1 illustrates the proportion of respondents that indicated specific factors as being influential in their decision.

Factors guiding the implementation of an automated heat detection system

Respondents were asked to indicate the level of importance they placed on eight specific factors in guiding their decision to implement a heat detection system. Approximately 42% (86/203), 35% (71/201) and 27% (53/197) indicated consultation with other farmers, consultation with partners and family members, and formal investment analysis as "very important" aspects, respectively. In the same way, information from dairy farm magazines (50%; 101/201), advice from veterinarians and dairy consultants (47%; 97/206) and informal calculations to examine financial impact (41%; 82/199) were rated as "important" factors when deciding about the employment of an activity system. Figure 3.2 illustrates the fraction of the eight specific variables examined with their respective frequency ranked as 'very important', 'important' and 'not important'.

Use of automated heat detection in cows versus heifers

When the survey participant replied affirmatively to the question regarding the use of an automated heat detection system in cows and/or heifers, they were asked to describe the use of this system in both groups of animals separately. Approximately, 96% (215/223) of the respondents with AHD used the system for cows and 27% (60/223) used it for heifers. The distribution of the heat detection systems by commercial brand with respect to the group of animals employed and satisfaction is presented in Table 3.5. Roughly 42% (89/210) of respondents using an AHD system for cows indicated that less than 50% of the inseminations were based on a heat detected by the automated system. Conversely, 93% (53/57) of respondents using a heat detection system for heifers indicated that more than 50% of the inseminations were based on a heat detected by the system.

Producers also specified the relative proportion of animals which would not be bred after the voluntary waiting period if a heat was signaled by the system. Approximately 71% (146/207) indicated that less than 10% of the cows would not be bred after a heat alarm, while 22% (46/207) reported this proportion to be between 10-25%. Similarly, 84% (46/55) of producers indicated that less than 10% of the heifers would not be bred after the system indicated a heat, and 15% (8/55) reported that this occurred between 10-25% of the time. To follow up on the previous question, the reasons for not inseminating a cow or heifer after appearing on the heat list were queried. Using a ranking classification of 1 (i.e. most common reason); 2 (i.e. 2nd most common reason) and 3, out of 7 possible choices (i.e. 7th choice being "Other (please describe)" option), the top 3 reasons were as follows:

1st – "I have chosen not to re-breed the cow"; 2nd – "The cow is unhealthy"; 3rd – "The cow has already been diagnosed pregnant"

These variables were never ranked as one of the top reasons less than 22% of the time. When analyzing the same question for heifers, there was not enough variability of the frequencies. However, the choice not to inseminate a heifer because the animal was too small (55/141; 44%) was the most frequent reason given.

Table 3.6 summarizes the frequency of inseminations per day for herds using AHD systems and the typical time from the heat alarm to AI.

Comparison of the 'year prior' to 'year after' implementation of the automated heat detection system

Following all exclusion criteria as previously detailed, 44 herds remained for the analysis. Approximately, 11% of the herds employed AfiAct™ (Afimilk®), 14% CowTrakker™ (Bou-

Matic®), 16% Alpro™ (DeLaval), 25% DairyPlan C21 (GEA Farm Technologies) and 34% Heatime® (SCR Engineers Ltd.). It was assumed that from the time a herd implemented the system to the time of the survey administration, there was no change in the commercial system used within a herd.

Overall, in the comparative analysis for the 'year prior' to 'year after' employment of the automated heat detection system, there was a mean significant difference of 2.1% higher pregnancy risk (PR) ($P < 0.01$) and 7.6% higher insemination risk (IR) ($P < 0.0001$) in the year after implementation. However, in the same analysis, the estimated conception risk (ECR) showed no significant difference between the year before and the year after ($P < 0.24$). Table 3.7 displays the least square means of the reproductive parameters analyzed. In all 3 models the commercial system used was included as a covariate, but at no time was this variable significant.

Comparison of automated heat detection systems versus synchronization programs or 'other' programs

In total, 166 herds contributed to the final analysis. Approximately 21% of the herds were managing reproduction with an automated heat detection system, whereas 32% (53/166) were using a routinely scheduled estrus synchronization and/or timed AI program for more than 50% of the breedings for cows.

Reproductive management characteristics for herds using TAI

Of the 53 herds using TAI, about 53% and 34% were using OvSynch or one of its variants or prostaglandin ($PGF_{2\alpha}$) followed by heat detection for inseminations, respectively. The remaining herds indicated the use of a combination of TAI and $PGF_{2\alpha}$ with heat detection.

Reproductive management characteristics for herds using AHD

Of the 35 herds using an AHD system included in the analysis, 2 herds used Alpro™ (DeLaval) as the activity system employed, 4 herds used AfiAct™ (Afimilk®), 5 CowTrakker™ (Bou-Matic®), 9 DairyPlan C21 (GEA Farm Technologies) and 14 Heatime® (SCR Engineers Ltd.); 1 response missing. The majority of these herds (24 out of 33) were inseminating the cows twice a day, compared to 7 out of 33 that only inseminated their animals once a day, while in 2 herds breedings would occur more than two times per day; 2 responses were missing. Also, 86% of the respondents bred cows within 12 hours after an animal appeared on the heat system list (Table 3.6). Lastly, 47% (16/34) of respondents inseminated 51 to 75% of the cows based on heats signaled by the AHD system, 29% inseminated 76 to 95% of their animals based on AHD, and 24% used it for more than 95% of their milking herd.

Additionally, 47% (78/166) of the herds included in the analysis were neither using an automated heat detection system nor breeding the majority of the cows based on systematic estrus synchronization and/or timed AI programs. The questionnaire was not designed to describe specific reproductive management procedures for this third group, but it can be deduced that in these herds, less than 50% of the cows were inseminated based on estrus synchronization and/or TAI program and their inseminations were based on observed heats.

The average herd size for herds with activity systems was 168 ± 83 (mean ± SD), while herds using estrus synchronization and/or TAI and 'other' programs had a mean of 135 ± 110 and 114 ± 59, respectively.

Overall, the PR was different (*P* = 0.05) between herds with and without automated heat detection systems. However, least squares mean difference was significant between herds with activity systems and the 'other' group (by 1.9% points; *P* = 0.02), but not different when compared to herds using TAI programs (*P* = 0.41). As previously described, a number of variables relating to the herd management and owners' profile were offered to the model. One variable about the future intended duration in business was significantly associated with the outcome (*P* = 0.002), such that respondents that indicated they would expect to be in business for less than 20 years had a lower PR (15.6%) when compared to those producers that expected to be in the farming business for more than 20 years (17.8%).

The CR was not different (*P* = 0.29) among herds with and without heat detection systems, and in this case, 5 other variables remained in the final model. Both the education level of the owner and the frequency of maintenance foot trimming in the herd were significant covariates (*P* = 0.03 in both cases). The mean CR was significantly higher in those herds where the owner's highest level of education was high school (41%), compared to owners with a college education (37%; *P* = 0.009), but not different to those with undergraduate or postgraduate university education (39%; *P* = 0.33). The mean CR was significantly higher in those herds that underwent regular foot trimming once a year (42%) compared to herds that underwent foot trimming twice (37%; *P* = 0.01) or 3 times or more in a year (38%; *P* = 0.05).

Overall, the IR was significantly different (P = 0.001) among herds with and without automated heat detection systems. However, the difference was only significant when herds with activity systems and those using TAI programs were compared to farms managing reproduction based on 'other' programs (P = 0.03 and P = 0.02, respectively). Herds with activity systems and TAI programs had 6.7% and 6% points higher IR than herds with 'other' programs. Herd size had a significant impact on IR (P = 0.04), whereby herds with less than 100 cows had a mean IR of 44%, while herds with 100 to 199 cows and farms with more than 200 had a mean IR of 47% and 50%, respectively.

Least square means for all 3 reproductive parameters analyzed are presented in Table 3.8.

DISCUSSION

Using a large and random sample of free stall dairy herds on DHI, the primary objective of the current study was to describe reproductive performance using pregnancy, conception and insemination risks in herds employing automated activity monitoring systems for heat detection for at least 15 months. Specific explanatory variables related to farm management factors, owner's profile and perceptions were considered to elucidate differences in practices between herds using or not using automated heat detection systems and some of the underlying issues related to system adoption.

Reproductive performance before and after adoption of an automated heat detection system

Respondents were asked to recall the month and year of adoption of the automated heat detection system. One can argue against the reliability of the date provided by respondents.

Retrospective components in cross-sectional studies are prone to memory failure as described by Raphael (1987). The consequences of a wrong reported date would lead to loss of statistical power to detect differences in the reproductive outcomes analyzed for the year before and after adoption of the system. Memory failure was less likely to occur in this case, considering that investment in a heat detection system is costly and farmers would be more liable to recall when such an event happened. Moreover, the decision of assigning at least 6 months after the reported adoption date when selecting the 'year after' for comparison assumes that a minimum period of adaptation to a new reproductive management procedure was given.

The present data showed a significant increase in PR for the year after adoption of the automated heat detection system, such that herds before the technology implementation had a mean PR of 15% compared to 17% for the year after. However, other than the main reproductive management program used, several other aspects influence reproductive performance in a dairy herd, including nutritional, managerial, disease, environmental and genetic factors (Lucy, 2001; Schefers et al., 2010). Considering that the objective of this study was to describe population-average reproductive performance for the years before and after implementation of the system, in which herds were compared to themselves, the methods applied attained the purpose.

It was hypothesized that a greater PR would be caused by an increase in IR. Indeed, the model showed that the 'year after' implementation of the automated heat detection had a mean IR of 49.5% when the 'year prior' had a mean IR of 42%. It is known that PR can be improved by enhancing AI submission and CR, the latter being more challenging (Fricke et al., 2005; LeBlanc, 2005; Ferguson and Galligan, 2000). LeBlanc (2005) showed that an increase in IR may be sufficient to increase PR, even if the procedure causes a minor decrease in CR. Interestingly, the model showed no significant difference in mean CR after implementation of the automated heat detection system.

Reproductive performance of herds using automated heat detection system vs. synchronization programs or 'other' programs

Overall, mean PR, CR and IR were not different between herds using AHD systems and synchronization-based programs. These findings corroborate the results of our pen-level randomized trial comparing reproductive performance with an AHD system and a TAI-based program, in which PR and CR were also not significantly different, (Chapter 2).

A third group of herds were included in the analysis, in which we were not able to define the exact reproductive management used. It is implied that the majority of those herds would be inseminating cows based on visual observation of estrus. It is important to note that respondents that indicated that breedings were done by a herd bull were excluded from the analysis. AHD herds in this case had 1.9% points significantly higher PR compared to herds using 'other' programs, but no significant difference was found when compared to herds using TAI-based programs. In contrast, CR was not different among the three groups of herds. Tenhagen et al. (2004) compared performance of AI performed with OvSynch and at detected estrus in two German dairy herds. Conception risks at all services using AI at detected estrus were significantly higher in one of the herds but not statistically different in the other one. Peralta et al. (2005) compared conception risks at AI performed at detected estrus to an automated heat detection system and also found no differences. However, the study was performed during the summer in only one large herd. The findings based on field trials should be based on a larger number of replicates, whereas studies performed in single herds may be masking important herd-level covariates that are not being taken into account.

Van Vliet and Van Eerdenburg, (1996) employing 12 estrus observation periods per day of 30 minutes each demonstrated that a standing heat event was noticed on only 37% out of the total cow-heat events confirmed with a progesterone test. Accurate estrus detection is difficult for some herds (Heersche Jr. and Nebel, 1994). Not surprisingly, IR was significantly lower in herds with 'other' programs (43%) compared to herds using AHD (50%) and TAI (49%) programs. Our finding is in agreement with other studies demonstrating a high submission rate when using TAI programs (Pursley et al., 1995) or an AHD system (Galon, 2010).

It is critical to underline that reproductive performance is influenced by several other factors as previously mentioned, but the reproductive program adopted may be the major factor influencing the outcomes analyzed. A few studies have explored the associations of general management practices, housing factors, farmer's profile and dairy herd general characteristics with reproductive performance (Bewley et al., 2001; Caraviello et al., 2006; Bach et al., 2008; Schefers et al., 2010). Perhaps the difficulty lies first in the complexity of gathering reliable and complete data, and having enough numbers to allow meaningful comparisons. Schefers et al. (2010) explored a number of potential herd management variables that could be associated with conception risks and insemination rates in large dairy herds in the U.S. An increase in re-inseminations between 4 and 17 days post-AI, higher stocking densities and a shorter voluntary waiting period were related to significantly lower conception risks. Additionally, the use of resynchronization programs, greater number of cows serviced per inseminator and utilization of soakers during summer in the holding area were significantly associated with higher service rates. However, it must be pointed that the referred study had a large number of missing variables, and it was not mentioned if the missing data were considered to be random. Furthermore, interaction terms were not tested, which in turn could have led to incomplete inferences.

The present study collected information about the farmer's profile and perceptions, dairy herd characteristics and a few management practices. It was hypothesized that these variables could be indirectly associated with herd reproductive performance, therefore the statistical models considered for these effects.

The PR model showed that herds in which the producers indicated that were expecting to be in business for the long term, had significantly higher PR compared to those expecting to be in business less than 20 years. It should be pointed that among participants with lower expectation of business continuation (n = 165), approximately 4%, 11% and 15% specified their expected time in business as 5 years or less, 6 to 10 years and 11 to 12 years, either owned by them or the next generation, respectively. In the CR model, level of education of the farmer and frequency of maintenance hoof trimming were significant covariates. Herds in which the farmer's level of education was high school or college education, had a significantly higher mean CR than herds where the farmer's education was postgraduate university. The current data do not have enough information to speculate about the reasons for that finding. Similarly, herds that were performing maintenance hoof trimming once a year had significantly higher mean CR compared to those doing 2 or 3 or more trimmings per year. Perhaps herds doing more trimmings had a higher prevalence of lameness, which have been shown to impair reproduction (Sprecher et al., 1997; Garbarino et al., 2004).

Additionally, herd size was a significant covariate in the IR model, such that smaller herds (less than 100 lactating cows) had significantly lower mean IR when compared to herds with 100 to 199 cows and more than 200 cows. The majority of herds with fewer than 100 cows were in the ‘other’ reproductive program category (52.5%; 42/80), whereas those with more than 100 cows were more often managing reproduction based on synchronization programs (28%; 24/85) or an AHD system (29%; 25/85).

Factors related to adoption of activity monitoring systems

The current study did not have as an objective the analysis of association of the survey variables affecting the farmer’s decision to not use or use AHD systems. Therefore, only descriptive figures were presented. However, in the future, a multiple logistic regression model will be performed in an attempt to reveal significant associations related to the use of activity systems for reproductive management.

In an effort to bring to light some of the important reasons for adopting activity systems, the desire to improve reproductive performance was one of the major factors driving the farmer’s decision, followed by the belief of not having enough time to detect heat. We expected that the welfare concerns (i.e. frequent injections required in TAI programs) were likely to be one of the main reasons, but that was not the major factor among respondents.

CONCLUSION

This study investigated the perceptions of farmers when adopting AHD systems, and described some management practices related to the use of AHD technologies. This understanding will better enable the design of future surveys involving reproductive performance with socio-psychological characteristics.

The survey respondents were representative of the overall distribution of free-stall herds across the provinces surveyed, though is highly represented by herds that were using AHD systems. This has enabled a good description of aspects related to activity systems' adoption and how dairy herds have been using that technology. The desire to enhance reproductive performance was the main factor driving farmers' decision to adopt AHD systems. Moreover, the majority of the herds have been breeding cows twice a day based on heat alerts, and more than 80% of the respondents were breeding cows within 12 hours after the activity heat had been noticed.

Also, this project described and compared reproductive performance of Canadian dairy herds that have been using AHD technology for over 1 year. Interestingly, the cross-sectional study confirmed that AHD-based reproductive management programs can result in equivalent reproductive performance to TAI-based programs. A next step will be to conduct an economic analysis of AHD relative to other systems for management of reproduction.

Table 3.1 Demographic comparison and farmer's practices in herds using and not using automated heat detection systems

	Not using AHD[1] (#) %	Using AHD[1] (#) %	*P*-value (overall test)
Expected time in business	(280)	(217)	
≤ 20 years	31	23	0.02
> 20 years	69	77	
Education	(270)	(210)	
High school	36	36	0.92
College	44	42	
Undergraduate university	16	18	
Postgraduate university	4	4	
Age (years)	(281)	(218)	
< 30	9	15	0.13
30 to 39	19	18	
40 to 49	40	33	
50 to 59	27	31	
≥ 60	5	3	
Herd size (milking cows)	(282)	(220)	
< 99	62	37	<0.0001
100-199	32.5	43	
≥ 200	5.5	20	
Frequency of attendance of farming meetings/conferences[2]	(265)	(209)	
Never	6	3	0.43
Monthly	14	17	
Quarterly	33	34	
Twice per year	30.5	32	
Annualy	16.5	14	

[1] Automated heat detection
[2] 24 respondents that indicated "Other (please specify)" were not included on the frequency distribution and chi-squared statistics

Table 3.2 Herd characteristics and farmer's perception in herds using and not using automated heat detection systems

	Not using heat detection systems (#) %	Using heat detection systems (#) %	*P*-value (overall test)
Free-stall flooring	(282)	(219)	
Concrete	73	59	<0.001
Rubber	8	16.5	
Slatted	13	13	
Other	6	11.5	
People involved in reproduction	(278)	(219)	
1 person	31	27	0.24
2 people	50	47	
3 or more people	19	26	
AI personnel	(275)	(220)	
Owner or herdsman	61.5	54	0.15
Employee	14	21	
AI company/breeder	19	21	
Bull	5.5	4	
Problem finding good employees	(219)	(191)	
Small or not a problem	61	61	0.99
Moderate or serious problem	39	39	
Problem training employees	(213)	(191)	
Small or not a problem	82	82	0.99
Moderate or serious problem	18	18	
Problem keeping good employees	(211)	(191)	
Small or not a problem	81	80	0.8
Moderate or serious problem	19	20	

Table 3.3 Differences in use of continuing education resources in herds using and not using automated heat detection

	Not use AHD[1] (#) %	**Use AHD[1] (#) %**	***P*-value (overall test)**
Farm magazines	(281)	(219)	
No	6	2	0.03*
Yes	94	98	
Flyers / newsletters from companies	(269)	(80)	
No	18	25	0.15
Yes	82	75	
Internet	(269)	(80)	
No	35	26	0.13
Yes	65	74	
Industry meetings/conferences	(269)	(80)	
No	20	16	0.48
Yes	80	84	

[1] Automated heat detection
* Fisher's exact test

Table 3.4 Distribution of survey respondents by province and use of automated heat detection

	Not use AHD[1] **(#)** **%**	**Use AHD[1]** **(#)** **%**
Province	(282)	(220)
Alberta	24	23
British Columbia	17	14
Manitoba	5	6
Ontario	50	54
Saskatchewan	4	3

[1] Automated heat detection

Table 3.5 Proportion of heat detection systems by commercial supplier and the group of animals used, respondents' satisfaction and group of animals in which the system was first employed

	Cows (#) %	**Heifers (#) %**
System	**(214)**	**(192)**
AfiAct™ (Afimilk®)	11	0.5
Alpro™ (DeLaval)	15.5	3
CowTrakker™ (Bou-Matic®)	10	1
Heatime® (SCR Engineers Ltd.)	39	24
DairyPlan C21 (GEA Farm Technologies)	23	1.5
Not applied to that group of animals	1.5	70
Satisfaction	(203)	(58)
Very satisfied	71	79
Somewhat satisfied	25	14
Not satisfied	4	0
Group of animals in which the AHD[1] system was first[2] employed (n = 219)	86	6.5

[1] Automated heat detection system

[2] 16 respondents (7.5%) started use in cows and heifers simultaneously

Table 3.6 Frequency of breedings per a day for herds using AHD[1] systems and the typical time from the heat alarm to AI[2]

	Cows (#) %	**Heifers (#) %**
Breedings per day	(207)	(58)
Once	27	29
Twice	65	54
More than twice	8	17
Time from observation of the estrus signal from the AHD[1] system to AI[2]	(204)	(56)
< 2 hours	14	23
3 to 6 hours	25	25
7 to 12 hours	47	39
13 to 18 hours	13	11
19 to 24 hours	1	2
> 24 hours	0	0

[1] Automated heat detection
[2] Artificial insemination

Table 3.7 Differences in annual herd reproductive performance between the year before and the year after implementation of the automated heat detection system for DHI herds (n = 44)

Metrics	**Mean and 95% CI Year before**	**Mean and 95% CI Year After**	***P* - value**
PR[1]	14.9 (13.7 – 16.1)	17.0 (15.8 – 18.2)	0.01
ECR[2]	37.2 (34.1 – 40.2)	34.9 (31.9 – 37.9)	0.24
IR[3]	42.0 (38.9 – 45.1)	49.6 (46.5 – 52.7)	<0.0001

[1] Pregnancy risk

[2] Estimated conception risk

[3] Insemination risk

Table 3.8 Annual reproductive performance presented in least square means and 95% confidence interval between herds using AHD[1] or TAI[2] or "other" breeding programs for DHI herds in 2010 (n = 166), while accounting for survey variables

Metrics	Mean and 95% CI AHD	Mean and 95% CI TAI	Mean and 95% CI "Other"	*P* - value
PR[3]	18.0[a] (16.7 – 19.4)	17.3[ab] (16.1 – 18.5)	16.1[b] (15.2 – 17.0)	0.05
CR[4]	39.4 (36.3 – 42.4)	38.1 (35.4 – 41.0)	40.5 (38.3 – 42.7)	0.29
IR[5]	49.7[a] (46.0 – 53.4)	49.0[a] (45.6 – 52.4)	43.0[b] (40.2 – 45.7)	<0.001

[1] Automated heat detection

[2] Timed artificial insemination

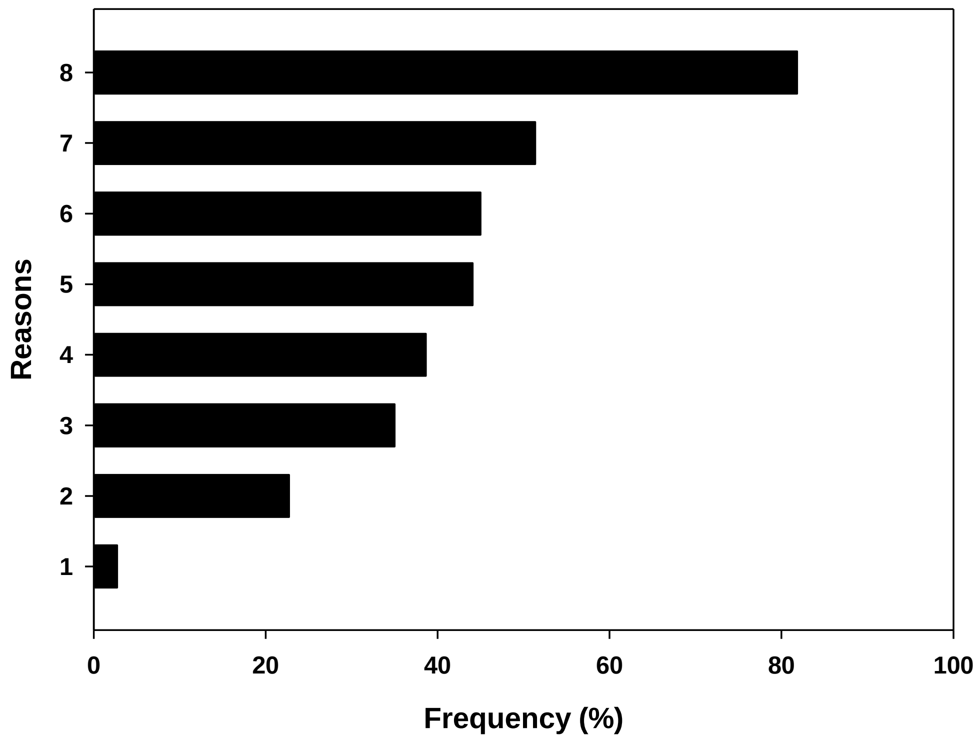
[3] Pregnancy risk; accounting for expected timing in business and hoof trimming of mid-lactation cows

[4] Conception risk; accounting for expected timing in business, producers' level of education, herd size, frequency of hoof trimming per year and hoof trimming of fresh cows

[5] Insemination risk; accounting for herd size and hoof trimming of fresh cows

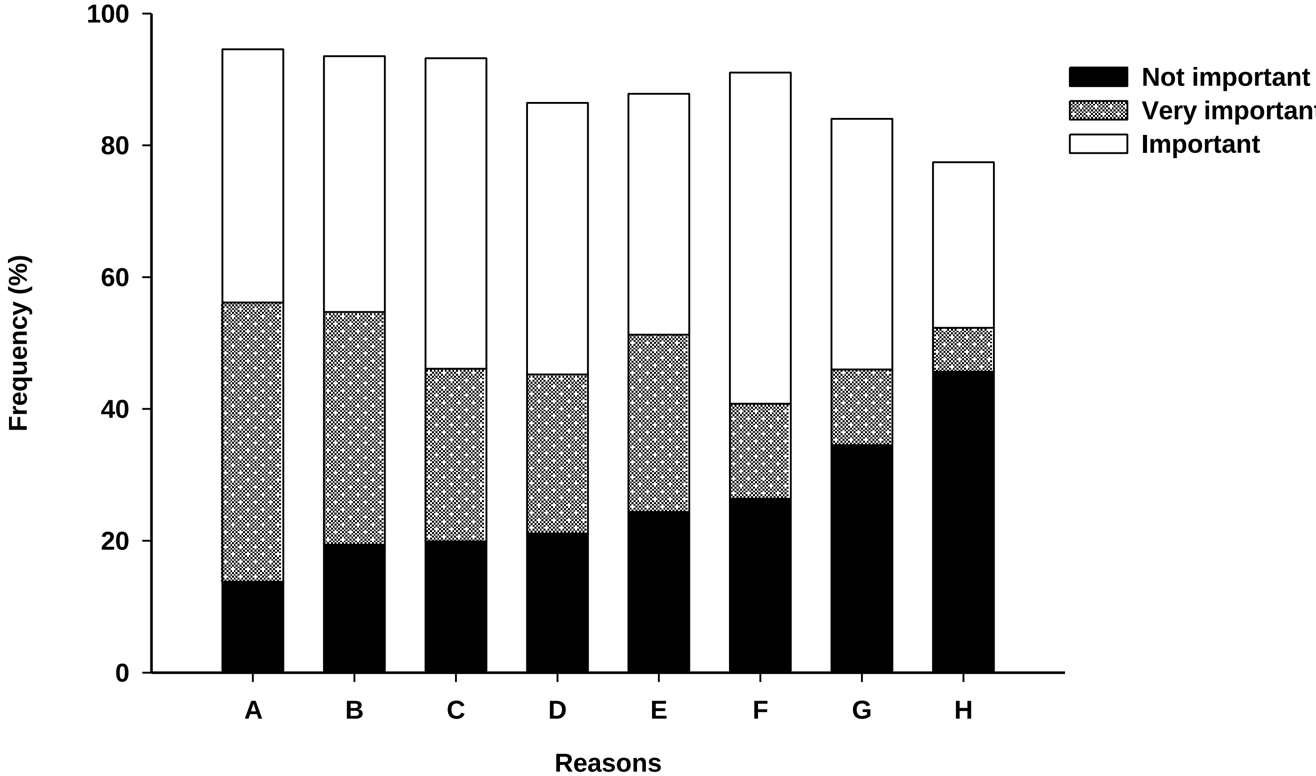
[ab] Groups without a common superscript letter differ ($P < 0.05$)

Figure 3.1 Frequency distribution of reasons to adopt an automated heat detection system



Reasons:
1 - Going organic
2 - Inability of workers to detect heat
3 - Concern about frequent needling
4 - Desire to reduce labor
5 - Desire to breed cows based on estrus behaviour
6 - Chance to monitor health along with heat
7 - Lack of time to detect heat themselves
8 - Desire to improve reproductive performance

Figure 3.2 Frequency distribution of respondents for whom specific factors were very important, important or not important in deciding to implement a heat detection system



Reasons:

A - Consultation with other farmers
B - Consultation with family members and business partners
C - Advice from veterinarians and/or dairy consultants
D - Informal calculations to examine financial impact
E - Investment analyses
F - Magazines
G - Conferences and meetings
H - Internet resources

Note: The percentage left to complete 100% frequency within each column corresponds to the fraction of instances in which the 'not applicable' choice was selected

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CHAPTER FOUR

GENERAL CONCLUSIONS

The use of automated heat detection systems in Canadian dairy herds has been increasing steadily, and this topic is often in the forefront of discussions about reproductive management program alternatives. Despite the growing interest in this technology, no field studies have been done to compare the relative reproductive performance of automated heat detection systems, relative to timed artificial insemination programs, under North American management conditions. A recently published study conducted in Israel had a similar objective. However, this study was performed on a relatively small sample of cows, and the environmental and housing conditions were very different from the North American dairy industry.

The first objective of this study was to compare both herd, and cow level reproductive performance between an AHD-based and a TAI-based program using a large pen level randomized trial. The decision to assign breeding programs by pen was made to ensure a higher level of compliance to the protocol by facilitating the farmers' routine, since they knew that cows in different pens belonged to different protocols (i.e. AHD or TAI).

Overall, the mean pregnancy risk over one year was 14.6% for the AHD group and 15.9% for the TAI group, and this was not statistically different. Similarly, median time to pregnancy during the study period was not significantly different between the two treatment groups. However, a treatment by herd interaction was present, such that time to pregnancy was different in one of the three herds, while another herd showed a tendency for the AHD system to perform better. When computing median time to first service, only one herd showed a difference between the two groups (55 days in the AHD and 72 days in the TAI group; herd C). In the analysis of time from first to second service, the responses were quite variable within the participating farms. Two herds had a significant difference in time to second service, but one herd had a shorter interval for the TAI group, while another herd had a shorter interval in the AHD group.

Compliance with the assigned breeding program was lower than expected in two herds, such that approximately 50% to 70% of the cows assigned to the TAI pen were bred accordingly. This raises questions regarding the reliability of the results. However, one must understand that in the real world situation, while the farmer/manager may follow a main reproductive protocol, variations will always occur. It is unrealistic to expect all producers to see a cow in good health showing estrus behaviour, and wait to breed this animal in the next cohort of cows to be synchronized. Moreover, the objective of this trial was to simulate, as much as possible, real farm conditions by allowing the herds to decide the number of breedings per day based on activity alerts and allowing the practice of AI for visually observed heats. This improved the external validity of the results obtained, allowing for a greater population level inference. Consequently, when producers and veterinarians inquire about the decision to adopt an activity system for heat detection, they will be better informed about its relative performance in commercial herds.

Another point that merits further explanation is the measurement time to the event (i.e. pregnancy and breeding) in the survival analyses. Because open cows were switching breeding programs after 6 months of the trial (cross-over), the outcome variable was time to pregnancy or time to first and second AI during the study period. Moreover, at the start of the trial, all animals eligible to become pregnant, not only fresh cows, were included in the analysis. Therefore, time to pregnancy is not necessarily equal to days from calving to the event of interest, but the interval from the start of the study period. In the majority of cases, time to pregnancy (i.e. start of study to pregnancy) will likely represent days open (i.e. calving to pregnancy). To confirm this assumption, days open were computed and the Kaplan-Meier survival time was analyzed, and the pattern of the curve was very similar to time in the study.

This research reinforces the idea that reproductive performance varies substantially among dairy herds, and even when side-by-side comparisons between reproductive programs are made, the results can be different. Certain herd-specific variables may partly explain this variability. These include: number of breedings/day, disease prevalences, stocking densities, and producer compliance for example. The number of breedings performed in a day has a direct influence on the timing of activity estrus to AI and, hence, on conception risks. Differing compliance to the synchronizing protocols might have caused a difference in performance in the study, since it is well known in the literature that this may be a limiting factor in the performance of TAI programs (Macmillan, 2010).

It is quite possible that, for larger herds (i.e. thousands of cows), the convenience of having animals inseminated one day of the week, as with TAI programs, may be advantageous. However, this is not true for every farmer, and some may cope with the routine of breeding cows every day. It is important to mention that, after the end of the trial, and as agreed at the beginning of the study, the participating herds were allowed to keep the activity system. In all cases, the farmers seemed satisfied with the performance of the AHD system. One herd bought new equipment for their milking parlour system, which came with another commercial activity system. The other two herds, obtained more activity tags and one upgraded his system to include rumination data, and is moving the former system to the heifers. Also, it was interesting to note that, while all 3 herds were using TAI programs for several years prior to this trial, none were deterred from adopting the AHD system, even though this requires breedings to be performed on a daily basis.

The second objective of this study was to retrospectively compare the reproductive performance of herds, identified through a large mail questionnaire that employed AHD systems, between the year before and the year after the implementation of the technology. On average, after the adoption of the activity system, the herds had an increase in PR and IR, while the ECR remained largely unchanged over time. It is inferred that the rise in PR was driven by the increase of 7% in insemination risk.

For the third objective, a comparison between herds managing the majority of the herd with an AHD system or TAI program was performed and all reproductive parameters analyzed (i.e. PR, CR and IR) showed no difference between breeding programs. In conclusion, our randomized trial and observational study demonstrated that overall, AHD-based programs yielded comparable reproductive performance to TAI-based protocols. The next uncertainty that requires investigation is the cost of a pregnancy based on AHD systems compared to TAI programs.

As a fourth component of this project, the demographics, attitudes, and reproductive practices associated with herds using AHD systems were evaluated with a questionnaire. The majority of the herds started to use activity systems on cows, and a smaller proportion were using for heifers. The majority of the activity systems on the market are integrated into the parlour system, which may limit their use for heifers. Most herds were breeding twice a day and the interval from the heat alarm to AI most frequently indicated was 7 to 12 hours, which is in agreement with the optimal interval for conception risks proposed by the literature. No herds indicated that AI would occur after 24 hours of the heat alarm.

A qualitative approach was taken to investigate the rationale behind the decision to adopt an AHD system, using a mail-out questionnaire. It was initially hypothesized that the top reason for such a decision would be a concern about frequent hormone injections. With a growing appreciation for animal welfare, and consumers' concern about hormone injections used for livestock reproduction and perceived concerns for food safety, producers have been looking for alternatives to TAI programs. However, the greater proportion of respondents indicated that their decision to adopt an AHD system was based on a desire to improve reproductive performance Even though the concern about frequent hormone injections was not the top reason, it was still an important factor driving the decision to adopt AHD systems.

The sample of herds not using AHD systems was queried about the reasons to not use activity systems for heat detection. It may sound odd to answer why something has not been applied or done, but the objective of the question was to highlight what was less related to producers' assessment when deciding to not use activity systems. Moreover, that could help break the myth that producers have an aversion to technology. Indeed, more than 80% of respondents never picked aversion to technology as an important factor.

Other than heat detection, activity systems are incorporating other components able to monitor health as well (i.e. lameness, and possibly metabolic diseases), which influences expectations of how dairy herds may be managed in the future.

REFERENCE

Macmillan, K. L. 2010. Recent advances in the synchronization of estrus and ovulation in dairy cows. J. Reprod. Dev. 56 Suppl:S42-47.

APPENDIX

Q1. Which of the following categories best describes the primary housing facility for your milking cows? (Please check the ONE box that matches your answer.)

- ☐ Bedded pack
- ☐ Existing building(s) converted to free stall
- ☐ Modern free stall barn
- ☐ Tie stall or stanchion barn

If you answered "Tie stall or stanchion barn", please do not consider the following questions. Thanks for your consideration! It is not necessary to return this survey.

Q2. Do you use an electronic activity monitor system (such as pedometers or similar technology) for heat detection in your operation?

- ☐ Yes ⇨ Go to question **5**
- ☐ No

If you answered "No", please continue answering the following questions.

Q3. Which of the following factors influenced your decision NOT to make use of an automated activity monitoring system for heat detection in your herd? (Please check all that apply.)

- ☐ Not familiar with the technologies that are available
- ☐ Too difficult or complex to use
- ☐ Dislike technology or computers
- ☐ Lack of perceived economic value (cost too high relative to benefit)
- ☐ Poor integration with other farm software (e.g. Dairy Comp 305)
- ☐ Satisfied with current herd reproductive performance
- ☐ Do not think that it would improve herd reproductive performance
- ☐ Other (please specify) ____

Q4. Are you currently considering the adoption of an automated electronic system for heat detection?

- ☐ Yes
- ☐ No

Q5. Do you use any other automated dairy farming technology in your herd?

- ☐ Yes
- ☐ No

Q6. If "Yes", which one(s)? (Please check all that apply.)

- ☐ Robotic milking
- ☐ Automatic calf feeder
- ☐ Other (specify) ________________________________

Q7. How long do you expect your dairy farm will be in business, either owned by you or the next generation?

- ☐ 5 years or less
- ☐ 6 – 10 years
- ☐ 11 – 20 years
- ☐ More than 20 years

Q8. What is the highest level of education that you have completed? (Please check the ONE box that matches your answer.)

- ☐ High school
- ☐ College
- ☐ Undergraduate university
- ☐ Postgraduate university

Q9. What is your age?

- ☐ < 30 years
- ☐ 30 to 39 years
- ☐ 40 to 49 years
- ☐ 50 to 59 years
- ☐ 60 years or older

DAIRY HERD CHARACTERISTICS

Q10. Which of the following categories best describe your dairy herd size – the typical <u>number of milking cows</u> in the last year? (Please check the ONE box that matches your answer.)

- ☐ < 50 cows
- ☐ 50 – 99 cows
- ☐ 100 – 199 cows
- ☐ 200 – 299 cows
- ☐ 300 – 399 cows
- ☐ > 400 cows

Q11. Which of the following categories best describe the typical number of <u>heifers (12 to 24 months old)</u> on your operation in the last year?

- ☐ < 50 heifers
- ☐ 50 – 99 heifers
- ☐ 100 – 199 heifers
- ☐ 200 – 299 heifers
- ☐ 300 – 399 heifers
- ☐ > 400 heifers

If your heifers are NOT raised on your farm please check this box ☐

Q12. Which <u>one</u> category best describes the type of flooring in the free stall alleys?

- ☐ Concrete
- ☐ Rubber
- ☐ Slatted
- ☐ Other (specify) ____________________

Q13. Which <u>one</u> breed of dairy cows best describe the majority of your herd?

- ☐ Holstein
- ☐ Jersey
- ☐ Other (specify) ____________________

Q14. Where is your operation located?

- ☐ Alberta
- ☐ British Columbia
- ☐ Manitoba
- ☐ Saskatchewan
- ☐ Ontario
- ☐ Other (specify) ____________________

Q15. Which of the following continuing education resources do you use? (Please check all that apply.)

- ☐ Printed farm magazines (Example: Hoard's Dairyman, etc.)
- ☐ Printed flyers or newsletters from companies
- ☐ Internet resources
- ☐ Industry conferences or meetings
- ☐ Other (specify) ____________________

Q16. How often do you attend farming conferences or meetings? (Please check the ONE box that matches your answer.)

- ☐ Never
- ☐ Monthly
- ☐ Quarterly
- ☐ Twice per year
- ☐ Annually
- ☐ Other (specify) ____________________

REPRODUCTION MANAGEMENT AND PRACTICES

Q17. How many people are involved in management of reproduction (i.e. heat detection and breeding) in your operation?

- ☐ 1 person
- ☐ 2 people
- ☐ 3 people
- ☐ 4 or more people

Q18. Who does most of the artificial inseminations in your herd? (Please check the ONE box that matches your answer.)

- ☐ Owner
- ☐ Herdsman
- ☐ Employee
- ☐ AI company or hired breeder

Q19. To what extent are the following aspects of employee management a problem in your operation? (Please check the ONE box that matches your answer PER ROW.)

	Not a Problem	Small Problem	Moderate Problem	Serious Problem
Finding Good Employees				
Training Employees				
Keeping Good Employees				

Q20. Do you use a systematic estrus synchronization (e.g. prostaglandin injections followed by heat detection) and/or timed AI (e.g. Ovsynch) program? This means that >50% of inseminations are done with a routinely scheduled program that cows are automatically enrolled in.

- ☐ Yes
- ☐ No ⇨ Go to question **23**

Q21. If "Yes", which type of program do you use for most inseminations? (Please check the ONE box that matches your answer PER COLUMN.)

For Cows	For Heifers
☐ Timed AI (Ovsynch or one of its varieties)	☐ Timed AI (Ovsynch or one of its varieties)
☐ Prostaglandin and heat detection	☐ Prostaglandin and heat detection
☐ I do not use for cows	☐ I do not use for heifers

Q22. For what purpose do you use estrus synchronization and/or timed AI? (Please check all that apply PER COLUMN.)

For Cows	For Heifers
☐ I do not use for cows	☐ I do not use for heifers
☐ First insemination	☐ First insemination
☐ In cows diagnosed not pregnant	☐ In heifers diagnosed not pregnant
☐ Breeding anestrous or anovular cows	☐ Breeding anestrous or anovular heifers
☐ In "problem" cows (no observed heats, repeated services, long days open.)	☐ In "problem" heifers (no observed heats, repeated services, long days open.)

Q23. Which of the following categories best describe your hoof care program?

☐ Treatment of animals with sore feet only
☐ Maintenance trimming
☐ Maintenance trimming and treatment of lame animals
☐ Other (specify) ________________________________

Q24. If maintenance trimming is used (if not, skip to question 26), which animals are trimmed? (Please check all that apply.)

☐ Heifers
☐ Fresh cows
☐ Mid-lactation cows
☐ Late lactation cows
☐ Dry cows

Q25. How frequently does maintenance trimming take place in your herd?

☐ Less than 1 time per year
☐ 1 time per year
☐ 2 times per year
☐ 3 times or more in a year

Q26. Are you willing to let us access your CanWest DHI records once to extract production and reproduction data? Your individual farm will never be identified in analysis or reports.

- ☐ Yes
- ☐ No

If you answered "Yes", please provide your:

DHI Herd number ___________________________

DHI PIN number ____________________________

In case you do not remember these numbers, please phone CanWest DHI now and ask for it – Toll free: 1-800-549-4373. Moreover, by providing your DHI Herd and PIN number you can be selected for one of the $250 prizes! Go to page 12 to enter your name.

If your herd does not have an automated activity monitor, please fold the questionnaire and mail out with the enclosed pre-paid envelope. Thanks for your participation!

For herds with automated activity monitors
PLEASE CONTINUE and answer the questions below.

Q27. For which group of animals was the electronic estrus detector <u>first</u> employed in your herd?

- ☐ Heifers
- ☐ Cows

Q28. How long have you been using activity monitors for heat detection? (Please check the ONE box that matches your answer PER COLUMN.)

For Cows	For Heifers
☐ I do not use for cows	☐ I do not use for heifers
☐ 6 months or less	☐ 6 months or less
☐ 7 – 12 months	☐ 7 – 12 months
☐ 1 to 2 years	☐ 1 to 2 years
☐ More than 2 years	☐ More than 2 years

Q29. Which activity monitoring system do you currently use in your herd?

For Cows	For Heifers
☐ AfiAct™ (Afikim)	☐ AfiAct™ (Afikim)
☐ ALPRO™ (DeLaval)	☐ ALPRO™ (DeLaval)
☐ CowTrakker™ (Bou-Matic)	☐ CowTrakker™ (Bou-Matic)
☐ Heatime™ (SCR)	☐ Heatime™ (SCR)
☐ Other (specify) ________________	☐ Other (specify) ________________

Q30. How satisfied are you with the current automated heat detection system in your herd?

☐ Very Satisfied
☐ Somewhat Satisfied
☐ Not Satisfied

Q31. Please provide comments of what you most like or dislike about the current heat detection system that you have in your herd.

____
____
____
____

Q32. Which of the following factors influenced your decision to adopt an automated heat detection system? (Please check all that apply.)

☐ Desire to reduce the need for labour
☐ Desire to improve herd reproductive performance
☐ Lack of time to detect heat myself
☐ Inability to have employees detect heat
☐ Going organic
☐ Desire to breed cows based on estrus behaviour
☐ Concern about frequent hormone injections in timed insemination programs
☐ Possibility to monitor animal health along with heat
☐ Other (specify) ____

Q33. When implementing the automated heat detection system, which of the following factors were important in guiding your decision? (Please check the ONE box for each row.)

	Not Important	Important	Very Important	Not Applicable
Advice from consultants/ veterinarians				
Conferences/meetings				
Consultation with business partners/family members				
Consultation with other farmers				
Formal decision making techniques (investment analyses, etc.)				
Informal calculations to examine financial impact				
Internet resources				
Printed magazines/publications				

Instruction:

For this last section, you will be asked questions related to your current breeding management based on your automated heat detection system. If you only use your automated heat detection system for milking cows or heifers, just ignore one of the columns. If you use for both groups of animals, please answer both columns.

Q34. How many times per day do you check the heat detection list or report on the automated system?

For Cows	For Heifers
☐ Once a day ☐ Twice a day ☐ Three times a day ☐ Four times or more per day	☐ Once a day ☐ Twice a day ☐ Three times a day ☐ Four times or more per day

Q35. How many times per day do you inseminate for heats detected by the automated system?

For Cows	For Heifers
☐ Once a day	☐ Once a day
☐ Twice a day	☐ Twice a day
☐ Three times a day	☐ Three times a day
☐ Four times or more per day	☐ Four times or more per day

Q36. What is the <u>typical</u> time from first seeing an animal appear on the heat list in the activity monitoring system until insemination?

For Cows	For Heifers
☐ Less or equal to 2 hours	☐ Less or equal to 2 hours
☐ 3 – 6 hours	☐ 3 – 6 hours
☐ 7 – 12 hours	☐ 7 – 12 hours
☐ 13 – 18 hours	☐ 13 – 18 hours
☐ 19 – 24 hours	☐ 19 – 24 hours
☐ > 24 hours	☐ > 24 hours

Q37. What proportion of inseminations is based on detection by the automated system?

For Cows	For Heifers
☐ Less than 25%	☐ Less than 25%
☐ 25 – 50%	☐ 25 – 50%
☐ 51 – 75%	☐ 51 – 75%
☐ 76 – 95%	☐ 76 – 95%
☐ >95%	☐ >95%

Q38. If the automated system indicates that an animal is in heat after your voluntary waiting period (i.e. time from calving to first insemination), what proportion of the time do you choose NOT to breed the animal?

For Cows	For Heifers
☐ Less than 10%	☐ Less than 10%
☐ 10 - 25%	☐ 10 - 25%
☐ 26 - 50%	☐ 26 - 50%
☐ > 50%	☐ > 50%

Q39. When you choose NOT to inseminate an animal that appears on the heat list of the automated system, please rank the top 3 reasons by writing 1 next the most common reason, 2 for the 2nd most common reason, and 3 for the 3rd most common reason.

For Cows		For Heifers	
	On observation, the cow does not appear to be in heat		On observation, the heifer does not appear to be in heat
	The cow is already inseminated but does not have a confirmed pregnancy		The heifer is already inseminated but does not have a confirmed pregnancy
	The cow has already been diagnosed pregnant		The heifer has already been diagnosed pregnant
	The cow is unhealthy		The heifer is unhealthy
	I have chosen not to re-breed the cow		I have chosen not to breed or re-breed the heifer
	The cow's production is high enough that I wish to delay breeding		The heifer is too small
	Other reason (please describe) ______ ______		Other reason (please describe) ______ ______

Thank you for your time and cooperation in helping with this study. If you have any additional comments, please note them in the box below. For any questions about this survey, please contact Rafael Neves, Population Medicine, University of Guelph, N1G 2W1. Phone: 519 824 4120 ext. 54775 or e-mail: rneves@uoguelph.ca

Comments:

If you have completed the survey and would like to be entered in a draw to win one of 3 prizes of $250, please provide your name and contact information below. It is completely optional and this information will not be associated with your replies. Your personal information will be destroyed immediately after the draw.

Name: ______________________________

Address: ______________________________

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Phone or e-mail: ______________________________