Computerized Heat Detection

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Take Home Messages

- In dairy cows, the average duration of estrus is 7.1 h with 8.5 mounts and in dairy heifers estrus lasts 10.3 h with 16.3 mounts. However, there is considerable variation in both duration of estrus and number of mounts.
- The onset of estrus is evenly distributed throughout the day. Ovulation occurs about 27 h after the onset of standing estrus.
- Conception rates are highest when cows are inseminated from 5 to 16 h after the first mount.
- The efficiency of visual detection of estrus is $\leq$ 50% in most dairy herds and 5 to 30% of inseminations occur in cows that are not in estrus.
- Walking activity increases around the time of estrus and can be measured with a pedometer. Pedometers will detect 70 to 80% of cows that are in estrus.
- Pressure-sensing devices can provide efficient and accurate monitoring of mounting activity in cattle.

Introduction

A critical factor affecting fertility in artificial insemination (AI) programs is the timing of insemination. Pregnancy will only occur when cattle are inseminated within approximately a 24-h interval every 3 wk (with a 12-h window to achieve maximal fertility). The most common approach is to breed cattle a few hours after they are detected in estrus (principally by observation of mounting behaviour). Therefore, failure to detect estrus in a timely and accurate manner greatly limits reproductive performance in dairy herds using AI (Nebel et al., 2000). It is generally agreed that the efficiency of estrus detection is $\leq$ 50% in most dairy herds (Senger, 1994). Indicators of poor estrus detection include few estrus periods observed before first service, excessive intervals both from the end of the voluntary waiting period to first service and between services, and a high incidence of nonpregnant, cycling cows at the time of pregnancy diagnosis (35 to 45 d after AI). Furthermore, studies utilizing milk or blood progesterone assays indicated that 5 to 30% of inseminations occur in cows that are not in estrus (Senger, 1994). It was estimated that failure to detect estrus or incorrect diagnosis of estrus results in losses exceeding US$300 million annually to the dairy industry in the United States (Senger, 1994).

The purpose of this article is to briefly review pertinent information regarding estrus and the estrous cycle, timing of AI, estrus detection, and computerized methods of detecting estrus (including pedometers and pressure-sensing radiotelemetric devices).

■ Estrus and the Estrous Cycle

It is well known that the estrus cycle in cattle averages 21 d, with the majority of the cycles ranging from 17 to 24 d. The duration of estrus varies greatly among herd-mates as well as among different studies. In one study with lactating dairy cows (Dransfield et al., 1998), duration of estrus (defined as the interval from the first to the last standing event as detected by pressure-sensing radiotelemetric devices) was 7.1±5.4 h (mean±SD; range, 33 min to 35.8 h; n=2055 estrus periods), with 8.5±6.6 mounts per estrus period. Using similar equipment, the duration of estrus in dairy cows (n=89) on pasture was 8.6±4.3 h (range, 1.0-21.3 h; Xu et al., 1998). In dairy heifers, the duration of estrus was 10.3±5.9 and 12.8±6 h in Holstein and Jersey heifers, respectively, and the number of mounts per estrus period was 16.3±11.6 and 28.0±17.9 (Nebel et al., 1998). Differences in age, herd size, management, methods and frequency of detecting estrus, and definition of onset of estrus may account for much of the variation among studies in the duration of estrus and the number of mounts (Nebel et al., 2000).

There are several environmental factors that can affect estrous mounting activity. A dirt surface and more than one cow in estrus enhance estrous activity in cows (Xu et al., 1998). Conversely, it is well known that slippery floors, lameness, inclement weather, feeding, and milking can all inhibit estrous activity. Regarding diurnal effects, the onset of standing behaviour (when determined precisely) is evenly distributed throughout the day (Nebel et al., 2000).

Estrus behaviour is triggered by an increase in estrogen concentrations in the blood (usually due to the presence of a preovulatory follicle) and low concentrations of progesterone in the blood. Increased concentrations of progesterone will inhibit estrous behaviour. Similarly, stress will delay, shorten or completely inhibit estrous behaviour and may also delay or prevent ovulation (Allrich, 1994), emphasizing the importance of minimizing stress.

In one study (Walker et al., 1996), the interval from the onset of mounting activity to ovulation was 27.6$\pm$5.4 h. This interval was not significantly different between cows with spontaneous estrus compared to those with estrus induced by prostaglandin treatment.

The primary (and most reliable) sign of estrus is that the cow remains standing while mounted. Secondary signs of estrus include attempts to mount other cows (including chin resting and following), restlessness, bellowing, a red, swollen vulva, and vulvar mucus discharge.

Although the first ovulation after calving in dairy cows is often not preceded by estrous behaviour (silent estrus), subsequent ovulations are usually accompanied by at least a few mounts. Furthermore, erratic estrous activity (including prolonged estrous periods and short intervals between successive estrous periods) may be associated with cystic ovarian disease. Finally, a low percentage of cows may display standing estrus during pregnancy.

▪ Timing of AI

There is a limited window of opportunity (approximately 24 h every 3 wk) for insemination to result in pregnancy. The biological events that dictate the timing of AI (Nebel et al., 2000) are the functional viable life of the sperm and ova (approximately 24-30 and 6-10 h, respectively) and the time required for the sperm to be transported from the site of insemination to the site of fertilization (approximately 4-8 h). Early insemination results in low fertilization rates and good embryo quality whereas late insemination results in high fertilization rates but poor embryo quality (Saacke et al., 2000). Therefore, the optimal time for AI appears to be between these two extremes, resulting in a compromise of fertilization rates and embryo quality.

Ovulation occurs about 27 h after the onset of standing estrus (Walker et al., 1996). In a study (Dransfield et al., 1998) that used electronic transmitters to detect mounting activity (17 herds, 2661 inseminations), conception rates were highest when cows were inseminated from 5 to 16 h after the first mount. Similarly, in a study that used pedometers and visual signs of estrus, the optimal time for AI was estimated to be 11.8 h from the onset of estrus (Maatje et al., 1997). However, if observations for estrus are only conducted twice-daily, it is recommended that AI should be performed within 6 h of the first detection of estrus (Nebel et al., 2000).

Estrus Detection

The traditional method of detecting estrus is to observe the cattle for mounting activity; the primary (and most reliable) sign of estrus is that the cow remains standing while mounted. In addition, secondary (and therefore less reliable) evidence of estrus includes attempts to mount other cows, restlessness, bellowing, a red, swollen vulva, and vulvar mucus discharge. Numerous estrus detection aids have been used, including sterilized males or hormone-treated steers or cows (often equipped with Chin-Ball markers), and the tail-head application of non-electronic indicators of mounting activity, paint, or chalk. The general experience is that observation of standing estrus is the most reliable method and that estrus detection aids are truly aids and do not eliminate the need for visual observation.

Senger (1994) stated that ideal technologies for detection of estrus should include:

- continuous (24 h/d) surveillance
- accurate and automatic identification of cows in estrus
- operation for the productive lifetime of the cow
- minimal labour requirements
- highly accurate identification of events that are highly correlated with ovulation

Unfortunately, none of the technologies that are currently available meet all of these criteria. The use of computerized heat detection technologies, including pedometry and pressure-sensing radiotelemetric devices, will be reviewed.

Pedometry

In an early study of the effects of stage of the estrous cycle on physical activity, pastured cows with mechanical pedometers had 218% higher physical activity during estrus than during the interval just before or just after estrus (Farris, 1954). In a subsequent study (Kiddy, 1977), in cows in free-stall or comfort-stall barns, activity during estrus was 3.9 and 2.8 times, respectively, greater than at other stages of the cycle, indicating that the magnitude of estrus-related increases in activity were affected by housing. Furthermore, in this study, there were significant differences in activity among cows and therefore it was concluded that pedometry was most effective for predicting estrus when comparisons were made on a within-cow basis (using data previously collected for that cow) rather than on a group basis. In another study that combined visual observations and pedometry (Pennington et al., 1986), pedometry was as effective as observation periods of 30 min or 1 h, 1-3 times daily. However, pedometry was less effective than visual observation for 60-min periods, four times daily or 30-min periods, six times daily. The combination of pedometer measurements and periodic observations was more effective than either method alone, with continuous observation being the most effective method. Other findings in this study were that management activities had a greater effect than time of day on mounting behaviour and that minimizing crowding and providing good footing enhanced mounting activity.

In a review of estrus detection methods (Lehrer et al., 1992), it was stated that pedometers will detect 70 to 80% of cows that are in estrus. Current pedometry systems do not use real-time data transfer, thus requiring that activity information be retrieved by an interrogation device. Therefore, information retrieval is usually intermittent (typically at milking), reducing the effectiveness of determining the optimal time for insemination. Pedometry systems that allow identification of the onset of estrus, in addition to efficient and accurate determination of estrus, will be more useful than the current technology.

▪ Pressure-sensing Radiotelemetric Devices

A commercial system (HeatWatch™; DDx Inc., Denver, CO) has been on the market for several years. A radiotelemetric sensor attached to each cow consists of a plastic case (5.3- x 8.1-cm and 1.8 cm) containing a pressure sensor, a miniature radiowave transmitter, and a lithium battery. Each device is secured in a water-resistant pouch, attached to a 35- x 20-cm nylon mesh patch that is glued with contact-type (e.g. back tag) adhesive to the hair of the tail head region (burlap and 'peel and stick' patches are also available). When a herd-mate mounts and activates the pressure sensor for a minimum of 2 sec, a radiowave is produced, indicating sensor identification, date (month, day, and year), time (hour and minute), and duration of sensor activation. Transmitted signals are received by an antenna (within 400 m of the sensors, although distances of several km are possible with the use of repeaters) and sent to buffer (with a capacity of 2,500 mount events). The buffer is either attached to a microcomputer or to a printer. When attached to a microcomputer, the software generates both fixed reports and individual cow files. Two management list are generated: 1) Suspect estrus (cows receiving <3 standing events within a user-defined time interval); and 2) Standing estrus (cows receiving $\geq$3 standing events within a 4-h interval. In addition, the system monitors the transmitters and produces a list of transmitters that are not functioning.

In a preliminary report of the HeatWatch™ System at Virginia Tech (Bailey, 1997), it was noted that the efficiency and accuracy of the HeatWatch™ System for estrus detection were 94 and 95%, respectively (the efficiency of estrus detection was defined as the total number of estrus periods that were detected and the accuracy as the number of estrus periods detected that were true estruses). In another study reported by workers at Iowa State (Timms et al., 1997), estrus detection efficiency in dairy cows was 89% during both May to

October and November to April and accuracy was 88 and 77% for these two periods, with 68% efficiency for visual detection of estrus during May to October. In heifers, the efficiency of estrus detection was 92 and 73% for HeatWatch™ and visual detection, respectively.

In a study (Xu et al., 1998) of pastured dairy cattle in New Zealand (2 herds, 189 cows) half the cows were fitted with a HeatWatch™ transmitter and the remaining half were observed for mounting activity for 20 min intervals, twice-daily and they had their tail-head painted. Cows in the second group were defined as being in estrus if they were observed being mounted and/or if their tail-head paint was removed or obviously disrupted. The breeding season lasted for 6 wk. Estrus was confirmed on the basis of repeated measurements of milk progesterone; this was used as the 'gold standard' to determine the efficiency and accuracy of estrus detection. For the HeatWatch™ and visual observation/tail-head painted groups, the efficiency of estrus detection was 91.7 and 98.4% respectively ($P<0.05$), the accuracy was 100 and 97.6% (not significantly different) and the conception rate was 65.8 and 65.0%. It was noted that 5 of the 10 estrous periods not detected in the HeatWatch™ group were attributed to transmitters that prematurely detached from the cow. The near-perfect efficiency in the visual observation/tail-head painted group was approximately double that of visual observation per se in North American herds (approximately 50%) and the conception rate was approximately 60% higher than the 40% conception rate that is commonly reported. Perhaps pasture conditions and lower rates of milk production of these cattle are responsible for their better reproductive performance compared to North American dairy cattle.

HeatWatch™ transmitters were used to detect mounting activity in 17 dairy herds (range, 56-556 lactating cows/herd) in Virginia. In that study, the average conception rate was 45.3% (n=2661 AI) and was lower for cows (n=260) inseminated after only one mount compared to those (n=2401) inseminated after $\geq$2 mounts (36 vs 46%, $P<0.05$). By design, this study included a wide range in intervals from the onset of standing estrus to AI. It was concluded that conception rates were highest (approximately 50%) when cows were inseminated from 5-16 h after the first mount; however, 790 (approximately 30%) of the inseminations were performed earlier or later, with conception rates of 30% for 463 insemination performed later than 16 h after the first mount.

Depending upon how the transmitters are used, it is estimated that the number needed is approximately 15 to 20% of the number of lactating cows. If there are many animals to monitor (e.g. this technology is first being introduced in a herd with a high proportion of nonpregnant cows or if heifers are simultaneously being monitored) then more transmitters may be needed. The transmitters are expected to have a functional life of approximately 5 yr, with a battery replacement required after about 1 yr of service. Patches are generally a single-use item, with usually only one patch needed for the duration of the monitoring period on each animal. When the HeatWatch™ system was used to measure 133 estrous cycles in 71 cows, the average time required (for data retrieval) was 13 min/day, with patch application taking 7 min/cow (Timms et al., 1997). Depending on herd size, the HeatWatch™ system could reduce labour costs.

The HeatWatch ™ transmitters can be applied at various times for detection of estrus. For example, a transmitter can be attached about 15 d after calving to monitor the re-establishment of cycles. One limitation is that patches do not remain in place indefinitely; with careful application, patches will generally remain on for at least 60 d, although some 'maintenance' (e.g. re-gluing corners) will probably be needed on one or two occasions during that interval. The more typical approach is to attach a transmitter at the end of the voluntary waiting period. One option would be to inject prostaglandin at the time of transmitter attachment; if the cow is cycling, about 60% would be expected in estrus within 2-7 d after a single treatment. Furthermore, if a 'set-up' dose of prostaglandin had been given 11-14 d earlier, this proportion of cycling cows would increase to about 80%.

Achieving acceptable reproductive performance (including intercalving interval and culling rate for reproductive failure) requires that the first service occur in a timely fashion and furthermore that nonpregnant cows are identified and rebred as quickly as possible. Some regimens (e.g. Ovsynch) insure a timely first service, but rapid identification and rebreeding of nonpregnant cows can be difficult to achieve. A substantial advantage of the HeatWatch™ system is the detection of estrus in cows that failed to become pregnant (or to maintain pregnancy) and that return to estrus perhaps 17-25 d after the initial AI. With typical estrus detection, many of these cattle are not seen in estrus and are diagnosed nonpregnant, typically 35-45 d after breeding. Furthermore, even with immediate treatment, an additional interval of 3-10 d (depending on treatment and response) will elapse before these cattle are rebred and indeed some will not be rebred (if breeding is only done after detection of estrus).

MountCount™ is a lower-cost, manual version of the HeatWatch™ transmitter unit and is produced and marketed by the same company (DDx Inc., Denver, CO). This device is attached to the cow in a manner similar to the HeatWatch™ transmitter but is completely self-contained and does not send a signal nor does it require any monitoring equipment. Each unit will last for 20 heat cycles before it is recharged and reprogrammed. Instead of sending a radio signal, each device has 3 light emitting diodes (LED) located across the rear. When a herdmate mounts for at least 2 sec, the left LED will start to blink (indicating a suspect estrus). This light will continue to blink for up to 14 h. If the cow is mounted at least twice more within 4 h of the initial mount, the middle light will start to blink, indicating standing estrus. Four hours after the third mount, the middle LED will stop blinking and the right LED will double-blink, indicating that this is an optimal time for AI (this LED will blink for a 10-h interval). To make interpretation easier, only one LED blinks at a time, and the right LED (indicating optimal time for AI) has a double-blink. At night, the LED can be seen from as far as 400 m. During the day, the LED can be seen from a distance of about 10 to 20 m, depending on light intensity and shade.

Further information regarding HeatWatch™ can be obtained from the website (www.heatwatch.com). The following prices were derived from the website in January 2001 and converted to Canadian dollars, excluding shipping and any taxes. A Windows-based dairy system (includes receiver, buffer and software) is approximately $5400 and requires a standard Windows-based microcomputer (DOS-based systems are also available). Another option is the HeatWatch Xpress™ package (approximately $3100). This system does not require a computer; a thermal printer (included) is used to print out a standing heat list (cows to be bred and the optimal time for breeding) and the suspect heat list (cows with some mounts). Portable units (that use battery and not AC power) are also available. HeatWatch™ Transmitters are $85.00 and Mount Count™ units are $92.00. Patches are approximately $5.50 and require glue (we routinely purchase back-tag cement at local suppliers as the glue supplied by the company is classified as a dangerous good and shipping costs are substantial). Peel and stick patches (not requiring glue) cost approximately $11.00.

▪ Cost-Benefits of Computerized Heat Detection

Although each operation represents a unique situation, there are general principles that are relevant for every operation. Achieving a reasonable intercalving interval without an excessive culling rate due to reproductive failure are generally required for a profitable and sustainable operation. Although much attention is focussed on conception rate (proportion of inseminated cows that are diagnosed pregnant), pregnancy rate (proportion of all cows eligible to be bred that become pregnant) is more important. Pregnancy rate is a product of the conception and estrus detection rates. Therefore, a low estrus detection rate (typically 50% of all cows in estrus are detected) inherently limits pregnancy rate, even if conception rate is acceptable.

It is important to recognize that increasing the pregnancy rate will result in improvements that will be manifest after varying intervals. For example, pregnant cows do not need further inputs associated with establishing pregnancy (treatments, estrus detection, breeding, pregnancy diagnosis); this benefit will be manifest after a short interval. Pregnant cows do not need to be culled for reproductive failure, with a reduction in culling manifest after about 4-6 mo. Increases in milk production associated with a decrease in the number of days open will be noted after a delay of several months. Furthermore, an increase in the number of cows calving will be noted after approximately 10 mo, an interval corresponding to the length of the gestation period.

Realistic Expectations

The probability of a cow becoming pregnant is affected by timing of insemination, cow fertility, semen fertility, and inseminator skill. Poor estrus detection affects time of insemination and also the number of cattle that are inseminated. Therefore, improvements in estrus detection will improve reproductive performance. However, it must be remembered that 'good management means doing a lot of little things right.' Although computerized methods of estrus detection have substantial potential for improving estrus detection and reproductive performance, they will complement good management but not replace it.

Summary

Achieving acceptable reproductive performance requires a timely first service, with nonpregnant cows quickly identified and rebred. Ovulation occurs about 27 h after the onset of standing estrus. Conception rates are highest when cows are inseminated from 5 to 16 h after the first mount. Although visual detection of estrus is the most common method used to determine time of AI, the efficiency of visual detection of estrus is $\leq$ 50% in most dairy herds and 5 to 30% of inseminations occur in cows that are not in estrus. Pedometers and pressure-sensing devices can provide efficient and accurate monitoring of mounting activity in cattle. Good estrus detection and reproductive performance require good management.

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