Components of a Successful Heat Detection Program

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Take Home Message

- Visual heat detection programs have failed to identify the majority of cows in heat. The obvious difficulty in successfully identifying all periods of estrus is their brevity and obscurity.
- The expression of estrus in cycling cows requires good nutrition, excellent cow comfort, the best hoof health possible, consistency of procedures by all involved, and attention to details.
- The equal distribution of the onset of standing activity during the day combined with the average estrus duration of 7 hours dictate that observations should occur three to four times daily, approximately six to eight hours apart.
- The ultimate goal of the heat detection program should be to predict the time of ovulation, thus allowing for insemination that will maximize the opportunity for conception.

Introduction

Without a doubt the number one reason for extended calving intervals is poor heat detection efficiency. It is apparent that visual heat detection programs have failed to identify the majority of the cows in estrus. Periodic visual observation has been the dominant method used to identify cows expressing outward signs of estrus. Less than 50% of the expected estrus periods are identified and the best managers observe two-thirds to three-quarters of the cows that should express estrus. The obvious difficulty in successfully identifying all periods of estrus is their brevity and obscurity. For example, when the duration of estrus is 7 hours and contains 8 standing events each lasting 4 seconds, then the actual period of estrus represents only 1.4% of the entire 21-day estrous cycle, and the duration of actual standing behavior represents 0.001% of the total duration of estrus. Inadequate or lack of estrus detection is well documented and is the source of economic loss and frustration for dairy producers and consultants who advise producers in the area of reproductive management.

▪ Characteristics of Estrus

The expression of estrus behavior is brought about by high systemic concentrations of estradiol-17β produced by the pre-ovulatory follicle which stimulates behavior coincident with the ovulatory surge of luteinizing hormone. A cow "standing" to be mounted is the most definitive behavioral expression of estrus. Secondary signs of estrus include attempting to mount other cows, clear mucous discharge from the vulva, swelling and reddening of the vulva from increased blood flow, bellowing, restlessness, trailing other cows, chin resting, sniffing the genitalia of other cows, and lip curling. These signs may occur before, during, or after estrus and are not related to the time of ovulation. These signs should be used as clues that a cow is near estrus so that they can be observed more intensely for "standing" behavior (Allrich, 1994).

A number of environmental conditions either stimulate or restrict interactions among cows and influence whether they express signs of estrus (Stevenson, 2001). Season of the year is one the largest factors that influences the expression but not duration of standing behavior (Nebel et al., 2000). Cows that are eating or are crowded in holding pens or alleys do less mounting. Cows also show less mounting activity when housed on slippery alleys, frozen ground, or any surface that makes walking tenuous (Britt et al., 1986). Cows that have foot problems express less mounting activity regardless of whether the problem is structural, subclinical, or clinical (Leonard et al., 1994).

The primary behavioral signal for sexual receptivity in the bovine is standing to be mounted by herdmates. In 1992, the first remote sensing system to identify mounting activity was installed at the University Dairy located on the Virginia Tech campus and we assisted DDx Inc. (Denver, CO) with the development, evaluation, refinement and commercialization of a system to assist with the detection of estrus in the bovine that was later registered as "HeatWatch". The HeatWatch estrus detection system was the first system that had continuous 24-hour surveillance to monitor standing events associated with estrus.

Data recorded by the HeatWatch system on individual cows is transmitted to a computer and includes identification, date (month, day, and year), time (hour and minute), and duration of each standing event. Transmitted signals are sent to a microcomputer via a fixed radio antenna. The HeatWatch software generates both fixed management reports and individual cow files that can be viewed, printed or sorted by each cow into individual periods of estrus activity. The HeatWatch software classifies a standing estrus as a cow having three standing events in any 4-hour period; fewer standing events are noted as a suspect estrus, and visual observation for secondary signs of estrus prior to the decision to inseminate is recommended.

Length of the Estrous Cycle

The biological variation for the duration of estrous cycles measured by activity monitored by the HeatWatch system located at the Virginia Tech Dairy Center was 18 to 26 days with a mean cycle length for heifers of 20 days, Jersey cows 21 days, and 22 days for Holstein cows (Figure 1). Extended cycles of 27 to 36 days occurred in 17% of all cycles in Holstein cows; whereas, Jersey cows had 9% of all cycles between 27 to 36 days and extended cycles were only 7% of the cycles recorded for heifers. The frequency of short cycles was 9% for Holstein cows, 13% for Jersey cows and 6% for heifers. Cycles of 20 to 23 days in length were 54% of all cycles recorded for Holstein cows, while 25% of the cycles were either less than 18 days or 27 to 36 days. This becomes important when constructing heat expecting list of cows that were inseminated approximately three weeks prior. A weekly rolling list that includes cows from 18 to 24 days for small herds or a daily list for large herds will assist in identifying the individuals with the greatest chance of expressing estrus because 50 to 70% of the cows on an expectancy list will usually return to estrus.

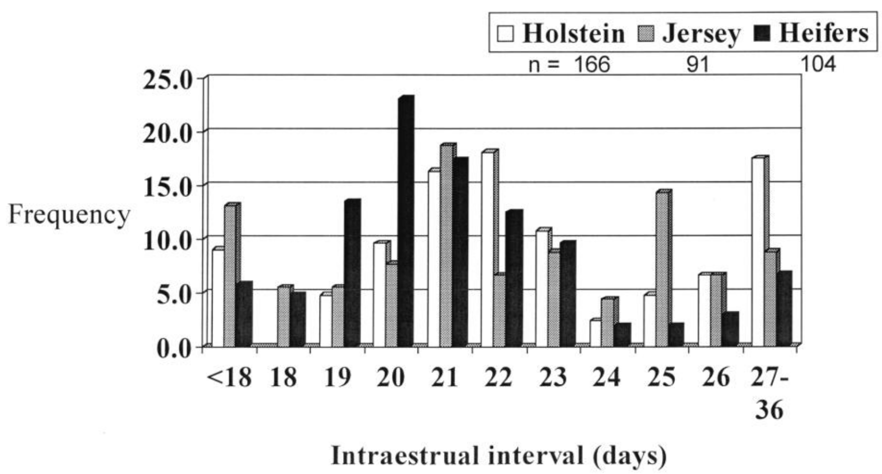

Figure 1. Variation in the duration of the estrous cycle for heifers and Jersey and Holstein cows located at the Virginia Tech Dairy Center.

Duration of Estrus

Characteristics of estrus were evaluated in a large field trial (17-herds) that utilized the HeatWatch system to detect mounting activity associated with estrus (Dransfield et al., 1998). The profile of the duration of estrus and standing mounts associated with estrus is presented in Figure 2. The duration of estrus, defined as the time interval from first to last standing event, ranged from 33 minutes to 35.8 hours, and the overall mean duration across the 17 herds was 7.1 ± 5.4 hours. Duration of estrus across herds did not differ significantly. Two herds were excluded from Figure 2 because the transmitters were routinely removed once estrus was identified to prevent the loss of the transmitter by mounting activity.

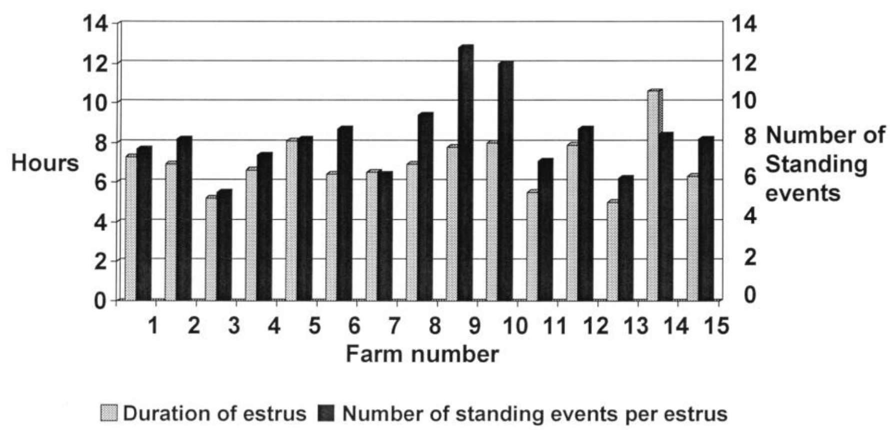

Figure 2. Duration of estrus and standing event per estrus across 15 herds monitored for mounting activity with the HeatWatch system.

Duration of estrus based on video recording (Hurnik et al., 1975) varied with the number of cows in estrus simultaneously, increasing from 7.5 to 10.1 hours for 1 or 3 cows in estrus at one time, respectively. In 1927, Sir John Hammond was the first to report the duration of estrus for lactating cows and heifers at 19.3 and 16.1 hours, respectively. Hammond (1927) reported no breed differences in duration of estrus; however, a significant seasonal difference was reported. Trimberger and Davis (1943) reported that the duration of estrus in cows was not different for the four major dairy breeds (Holstein, Jersey, Guernsey and Ayrshire) with individual cows ranging from 2.5 to 28 hours with a mean of 17.8 hours. Interesting was the fact that the duration of estrus in heifers was generally shorter in length averaging 15.3 hours with Jersey heifers having a slightly longer duration than the other three breeds (17.4 versus 14.5 hours). The duration of estrus for lactating Holsteins and Jerseys located at the University Dairy Center was monitored with HeatWatch system from 1995 to 2002 (Nebel et al., 2002). Holsteins averaged 7.4 hours from first to last standing event, whereas, Jerseys had a slightly longer duration of mounting activity of 8.9 hours. Over 30% of the Holsteins exhibited standing estrus for less than 4 hours, in contrast to 35% of the Jerseys having an estrus period lasting greater than 10 hours.

Mounting Activity

The profile of the duration of estrus and standing mounts associated with estrus monitored by HeatWatch in 17 dairy herds is presented in Figure 2. The overall mean ($\pm$ SD) number of standing events per estrus was 8.5 $\pm$ 6.6 (n = 2055). Herd averages for standing events per estrus ranged from 6.2 $\pm$ 5.0 to 12.8 $\pm$ 9.9. The conception rate was lower in cows (n = 260) inseminated after only one recorded standing event than for cows (n = 2401) exhibiting 2 or more standing events (36 versus 46%). Cows that were identified in estrus and inseminated with only one standing event were removed from the data set prior to calculation of means for estrus characteristics to account for cows that were possibly not in estrus.

The two herds representing the range in standing events per estrus both used a free stall and dry lot housing system. However, the herd with the fewest standing events per estrus (herd 13) also had the fewest number of cows to interact for detection. Using continuous observation by video recording, Walton et al. (1987) reported 8.8 standing events for cows following treatment with cloprostenol to induce estrus and 5.5 standing events for spontaneously occurring estrus in lactating Holstein cows. Factors related to environment, nutrition, herdmates, and condition of feet and legs dramatically affect behavioral characteristics of estrus and may explain herd variation of estrus characteristics. Data collected from the Virginia Tech Dairy Center over the past 7 years (1995 estrus periods) revealed a similar pattern of mounting activity with a mean of 7 standing events per estrus for Holstein cows and 17 for Holstein heifers. Again, individual cows exhibited a wide variation in mounts during estrus ranging from 1 to 154 for cows and 1 to 64 for heifers. There was a significant difference in mounting activity between breeds. Jersey cows averaged 9.5 standing events while Jerseys heifers averaged 27.4 standing events per estrus. Almost 50% of the Holsteins had less than 6 standing events, but over 60% of the Jerseys had 6 or more standing events during estrus.

Intensity of Estrus

For the 17 herds that monitored estrus activity with the HeatWatch system (Dransfield et al., 1998) the distribution of estrus periods by duration and intensity with corresponding conception rates of each category is presented in Figure 3. Only 8.4% (n = 201) of the estrus periods were classified as high intensity (greater than 1.5 standing events per hour) and of long duration (greater than 7 hours in length). Practically these estrus periods would be the easiest to detect; however, they represent less than 10% of the total estrus periods identified. In contrast, approximate one-quarter of all estrus periods monitored were classified has low intensity and of short duration and may help explain why when evaluating DHI production records it is rare to have a farm identify greater than 70% of the possible heats. Conception rates did not differ across the four categories of estrus periods and was actually the highest (49.8%) for the periods that were classified as having low intensity and of short duration.

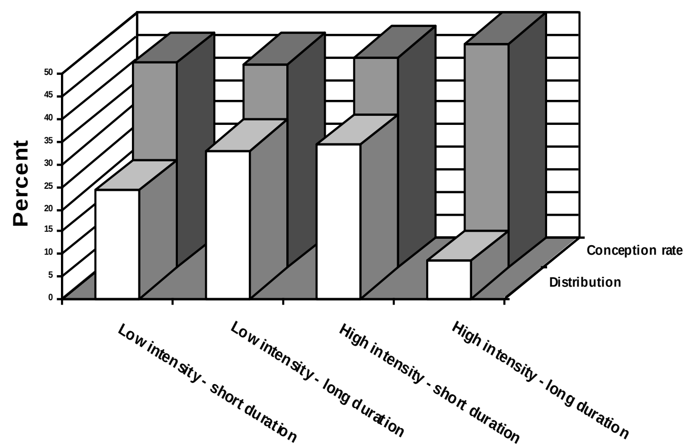

Figure 3. The distribution of estrus periods with respective conception rates categorized by intensity and duration of estrus for Holstein cows across 15 herds monitored for mounting activity with the HeatWatch system.

The intensity of estrus (standing events per hour) across the four seasons of the year for Holstein cows and heifers located at the Virginia Tech Dairy Center is presented in Figure 4. Intensity of estrus for each season was significantly lower for cows when compared to heifers. Estrus intensity was lowest during the spring and summer for cows and intensity of estrus for heifer was lowest during the summer with no difference during the other three seasons. These findings support why it is easier to detect heifers in heat and why it is most difficult to detect lactating cows during periods of elevated environmental temperature.

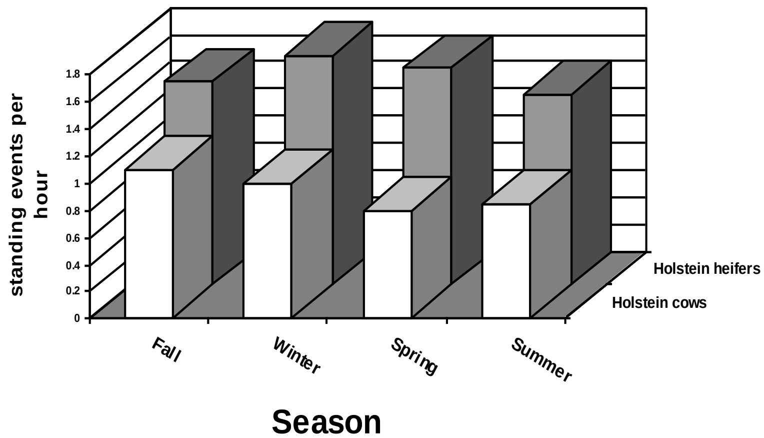

Figure 4. Intensity of estrus (number of standing events divided by duration of standing activity) for Holstein cows and heifers across seasons.

Onset of Estrus

The circadian distribution of the onset of standing activity for the 17-herd study is shown in Table 1. There were no differences in the distribution of onset of estrus among the 6-hour periods. Using time lapse video recording Hurnik et al. (1975) disclosed the highest frequency of onset of standing estrus was observed during 6:00 p.m. to mid-night. Twelve years later, when the study was repeated with more advanced video equipment, the hourly distribution of estrus onset was tested against a normal distribution and no significant pattern of onset was revealed (Amyot and Hurnik, 1987).

Table 1. The circadian distribution of first and last standing events of behavioral estrus as identified by the HeatWatch system (n= 2,055 periods of estrus).

	12:01 AM to 6:00 AM	6:01 AM to 12:00 PM	12:01 PM to 6:00 PM	6:01 PM to 12:00 AM
Onset of first standing event, (%)	24.5	28.4	19.8	27.3
Termination of last standing event, (%)	24.8	27.8	23.4	24.0

(Adapted from Dransfield et al., 1998)

Conflicting data concerning diurnal and nocturnal estrual activities are found in the literature. While the factors underlying these discrepancies are probably of a complex nature, a photoperiod effect directly or indirectly influencing estrual expression may be a predominant one. In Amyot and Hurnik's study (1987), the sensitivity of the cameras permitted a nocturnal illumination of less than 3 lux, which is 90% less than the illumination used in the earlier study (Hurnik et al., 1975). If estrual activities are light mediated, then suppression of estrus expression should be expected during the nocturnal period.

The distribution in onset of estrus is shown graphically for cows (n = 1410) located at the Virginia Tech Dairy Center (Figure 5). For cows, the periods associated with movement had an increased number of onsets of estrus with the period (11:00 p.m. to 1:00 a.m.) corresponding with the night milking having the greatest number of onsets. For heifers, the periods associated with feeding had a significantly greater number of onsets (at the University this occurred at 8:00 a.m. for the concentrate and 12:00 noon for the orts obtained from the milking herd).

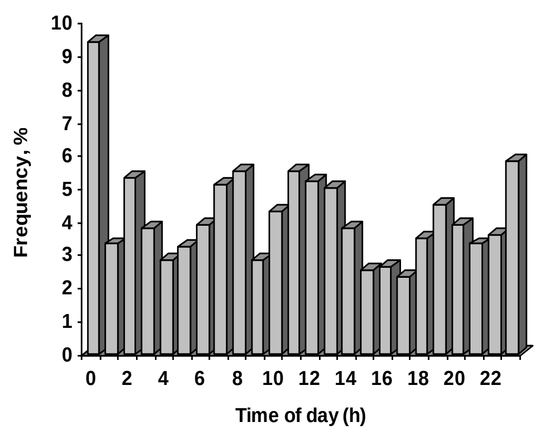

Figure 5. The distribution in onset of standing estrus for cows (n = 1410) located at the Virginia Tech Dairy Center.

Using the HeatWatch system to monitor mounting activity in New Zealand pasture-fed cows, the onset of estrus and distribution of total mounting activity occurred equally throughout the day when grouped into 6-hour periods (Xu et al., 1998). However, individual hourly variation did occur with the greatest number of first mounts or estrus onsets between 12:00 noon and 3:00 p.m. and between 9:00 and 11:00 p.m. Total mounting activity did not parallel the hourly distribution of estrus onsets and was more evenly distributed across the day despite a trend toward more mounting activity in the afternoon.

When the precise onset of estrus has been determined for a significant number of estrus periods, all studies have revealed that the onset of estrus “standing activity” was evenly distributed throughout the day.

▪ Timing of Insemination

The ultimate goal of the heat detection program should be to predict the time of ovulation, thus allowing for insemination that will maximize the opportunity for conception. Ovulation occurs 24 to 32 hours after the onset of estrus (average of 27.6 hours; Walker et al., 1996) and is triggered by the same hormonal mechanism that causes the cow to display estrus. The rise in estradiol-17β concentrations that occurs almost simultaneously with the onset of estrus activity (Stevenson et al., 1998) is responsible for the initiation of behavioral estrus. Estradiol-17β is also indirectly responsible for the release of luteinizing hormone; thus, estradiol-17β is ultimately responsible for ovulation. The rise in estradiol-17β that initiates this cascade of events is probably independent of most environmental influences; thus, the onset of estrus is equally distributed during the day and should dictate, within management constraints, the timing of insemination.

Once the ovum has ovulated, its estimated viable life is less than 12 hours, unless it becomes fertilized (Brackett et al., 1980). If frozen-thawed semen from most bulls is handled properly, it is estimated to have a viable life span of less than 36 hours. Sperm are not capable of fertilizing the ovum immediately upon thawing and insemination because they must traverse the uterus, enter the oviducts, and complete a process of maturation known as capacitation. The transport of viable sperm to the site of fertilization requires a minimum of 6 hours to obtain a population capable of fertilization and sperm numbers progressively increase over 8 to 18 hours before they start to decline (Hawk, 1983; Wilmut and Hunter, 1984) during which the process of capacitation is completed (Hawk, 1987). The subsequent 12 to 16 hours represent the period of maximal fertile life of sperm, followed by rapidly declining motility and fertility. Biological events that affect the successful timing of insemination are shown graphically in Figure 6.

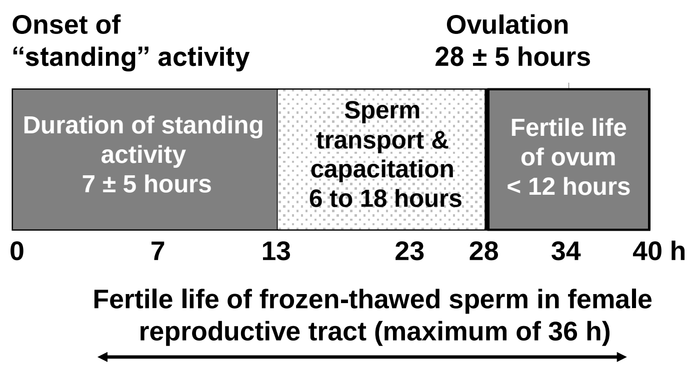

Figure 6. Biological events that affect the fertilization of artificial inseminated dairy cows.

The key to proper timing of insemination and maximizing fertilization rates is to inseminate cows at a time to allow ovulation to occur when adequate numbers of viable sperm are present in the lower regions of the oviducts. Studies using pedometry (Maatje et al., 1997) and the HeatWatch system (Dransfield et al., 1998) have independently obtained an optimal time of insemination either 6 to 17 hours after an increase in locomotive activity or 4 to 14 hours following the first standing event associated with the onset of estrus. Based on the innovative research of Trimberger and Davis (1943) using three daily visual inspections for estrus, cows should be inseminated about 12 hours after being observed in standing estrus. Usually the actual onset of standing activity is unknown; thereby, for the average Holstein cow detected in heat using three daily visual observation periods she would be 3.5 hours from the initiation of standing behavior, so deposition of semen 12 hours later would be 16 hours after the onset of standing estrus and 12 hours prior to ovulation. With once-daily observation for estrus timing of insemination is less precise and insemination should be performed soon after detection because ovum viability not sperm viability is the limiting biological factor that determines a successful outcome (Figure 6).

Components for a Successful Heat Detection Program:

- **Establish standard operating procedures**: Be sure your employees know when and where to watch for heats, what signs to look for, as well as who should be notified of cows in heat.
- **Use records**: Record every heat period and use breeding wheels, calendars, and heat expectancy charts to ensure special attention is paid to cows anticipated to be in heat.
- **Allow for group interaction**: Group open cows together whenever possible, as cows tend to congregate when approaching heat.
- **Minimize sore feet**: Mounting activity is more frequent in cows with healthy feet. Provide a “concrete free” area for cows to spend at least a few hours a day.
- **More is better:** Observe cows three times a day, four times is better especially if performed every six to eight hours. Remember, the average heat only lasts 7 hours for Holstein cows.
- **Watch efficiently**. Cows are less likely to show heats during feeding or milking times. Avoid heat detection at these times, and make sure cows are not disrupted by the presence of an observer.
- **Location, Location, Location**: Make observations in areas where cows have good footing and few obstacles to hinder interaction.
- **Use aids wisely**: Heat detection aids, such as Kamar, Beacon, or Estrus Alert heatmount devices or paint/chalk should be used to supplement, not replace visual detection. Be sure to manage the information these devices provide, and the heat detection system should be used for all eligible cows.
- **Use hormone treatments**: If hormonal treatments will be used, ensure the program is implemented correctly. It is especially important to observe cows three weeks after breeding to catch those that did not conceive.
- **Don’t take shortcuts:** Write down heats and observe cows closely to ensure the cow is in heat.

Conclusion

The limiting factor toward obtaining efficient reproductive performance in the majority of herds is the failure to detect estrus in a timely and accurate manner. Expression of estrus in cycling cows requires good nutrition, excellent cow comfort, the best hoof health possible, consistency of procedures used to detect estrus by all involved, and attention to details. The onset of standing activity has been shown to be equally distributed during the day, and approximately 25% of all estrus periods were classified as having low intensity (less than 1.5 standing events per hour) and of short duration (less than 7 hours). These two characteristics strongly contribute to the low efficiency of heat detection.

Guidelines for the timing of insemination set forth by Trimberger (1948) suggest the optimal interval for pregnancy results is for insemination to occur approximately 12 hours after initial observation of standing behavior. Results from systems that more accurately determine the precise onset of standing activity would suggest insemination should be performed earlier following the detection of estrus. Using the a.m.-p.m. guideline would lower the probability of resulting pregnancy, as many cows observed most likely have been in estrus for several hours prior to the detection of estrus. Results from our work with the HeatWatch system would suggest that, if the onset of estrus is unknown, insemination should be performed no later than 8 hours after the initial observation of standing activity to obtain the greatest odds of conception.

To enhance the efficiency of estrus detection an aggressive program that incorporates frequent visual observation, records monitoring, judicial use of aids, and liberal use of hormones to induce luteal regression with everyone on the management team focused and committed to improving pregnancy rates can improve reproductive performance. A goal should be to have 100% of the cows inseminated by 24 days after the start of the breeding period or by 85 days in milk if a 60 day voluntary period is used. Timed insemination with either Pre-Synch, Ovsynch or a CIDR's protocol can give a good starting point to the breeding program and set the stage for re-synchronization or intensive heat detection following first service.

▪ References

Allrich, R.D. (1994) Endocrine and neural control of estrus in dairy cows. J. Dairy Sci. 7:2738-2744.

Amyot, E. and Hurnik, J. F. (1987) Diurnal patterns of estrous behavior of dairy cows housed in a free stall. Can. J. Anim. Sci., 67:605-614.

Brackett, B.G., Oh, Y.K., Evan, J.F., and Donawick, W.J. (1980) Fertilization and early development of cow ova. Biol. Reprod. 23:189-205.

Britt, J.H., Scott, R.G., Armstrong, and Whitacre, M.D. (1986) Determinants of estrous behavior in lactating Holstein cows. J. Dairy Sci. 69:2195-2202.

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

Hammond, J. (1927) In: The physiology of reproduction in the cow. University Press. Cambridge, England. pp 9-49.

Hawk, H.W. (1983) Sperm survival and transport in the female reproductive tract. J. Dairy Sci. 66:2645-2660.

Hawk, H.W. (1987) Transport and fate of spermatozoa after insemination of cattle. J. Dairy Sci. 70:1487-1503.

Hurnik, J.F., King, G.J. and Robertson, H.A. (1975) Estrous and related behavior in postpartum Holstein cows. Appl. Anim. Ethol., 2:55-68.

Leonard, F.C., O'Connell, J.O., and O'Farrell, K. (1994) Effects of different housing conditions on behavior and foot lesions in Friesian heifers. Vet. Rec. 134:490-494.

Maatje, K., Loeffler, S.H., Engel, B. (1997) Predicting optimal time of insemination in cows that show visual signs of estrus by estimating onset of estrus with pedometers. J. Dairy Sci. 80:1098-1105.

Nebel, R.L., Bame, J.H. and Pearson, R.E. (2002) Factors affecting the intensity, duration and onset of estrus in Holstein and Jersey cattle. J. Dairy Sci. 85(Suppl. 1):266.

Nebel, R.L., M.G. Dransfield, S.M. Jobst, and J.H. Bame. (2000) Automated electronic systems for the detection of oestrus and timing of AI in cattle. Anim. Reprod. Sci. 60-61:713-723.

Stevenson, J.S. (2001) A review of oestrous behaviour and detection in dairy cows. Vol. 1, pages 43-62 in Fertility in the High Producing Dairy Cow, Occasional pub. no. 26, Brit. Soc. Anim. Sci.

Stevenson, J.S., Lamb, G.C., Kobayashi, Y. and Hoffman, D.P. (1998) Luteolysis during two stages of the estrous cycle: subsequent endocrine profiles associated with radiotelemetrically detected estrus in heifers. J. Dairy Sci., 81:2897-2903.

Trimberger, G.W. (1948) Breeding efficiency in dairy cattle from artificial insemination at various intervals before and after ovulation. Nebraska Agric. Exp. Stn. Res. Bull. 153:1-26.

Trimberger, G.W. and Davis, H.P. (1943) Conception rate in dairy cattle from artificial insemination at various stages of estrus. Nebraska Agric. Exp. Stn. Res. Bull. 129:1-14.

Walker, W.L., Nebel, R.L., and McGilliard, M.L. (1996) Time of ovulation relative to mounting activity in dairy cattle. J. Dairy Sci. 79:1555-1561.

Walton, J.S., Veenhuizen, L.P., and King, G.J . (1987) Relationships between time of day, estrous behavior, and the preovulatory luteinizing hormone surge in Holstein cows after treatment with cloprostenol. J. Dairy Sci. 70:1652-1663.

Wilmut, I., and Hunter, R.H.F. (1984) Sperm transport into the oviducts of heifers mated early in estrus. Reprod. Nutr. Dev. 24:461-468.

Xu, Z.Z., McKnight, D.J., Vishwanath, R., Pitt, C.J. and Burton, L.J. (1998) Estrus detection using radiotelemetry or visual observation and tail painting for dairy cows on pasture. J. Dairy Sci., 81:2890-2896.