New Strategies For Heat Detection And Timing Of Artificial Insemination

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Observing cows for signs of heat and inseminating them at the optimum time are necessary steps for effective reproductive management of a dairy herd. Artificial insemination (A.I.) has become one of the most important agricultural technologies of this century and most dairy producers have adopted some aspect of this technology in order to maintain a competitive agricultural business. However, inefficiency reproductive performance in modern dairy herds has not only been a source of frustration to producers and their consultants but has also substantially reduced potential profits in dairy operations. Several of these costs, such as increased semen, veterinary, and drug costs, receive inevitable attention because they are entered directly in the balance sheet. However, the major opportunity costs (potential profit due to fewer days open, fewer cull cows, lower days in milk, and increased replacements from A.I. sired heifers) are often over looked because they can be difficult to accurately calculate and are not entered directly in the balance sheet.

Increases in herd size and milk yield have been implicated as contributors to the decreased reproductive efficiency experienced by many U.S. dairy farms. For example, during the past ten years the average Virginia DHI dairy herd has experienced a 33% increase in milking cows and a 20% increase in milk yield per cow without the same increase in additional labor force. During this same time period the average calving interval has increased from 13 to 14 months. This decrease in reproductive efficiency conservatively cost $7,700 per year per herd if one assumes a $2 loss per day open and the average herd is 128 cows.

The major factor limiting optimum reproductive performance on many farms is failure to detect heat in a timely and accurate manner. Using November 1996 Dairy Herd Improvement information from 9042 dairy farms that process their records at the DRPC@Raleigh the average days to first breeding was 95 days compared to the stated goal of 70 days. Thus, 25 days or approximately one estrous cycle (time interval between two consecutive heat periods) was loss presumably due to failure to detect heat. Historically the approach taken by management has been passive, by waiting for cows to cycle and be detected in heat for A.I., rather than proactive which now can be accomplished by the incorporation of a systematic breeding program that induces heat or allows for appointment breeding without the need for heat detection.

Systematic Breeding Programs

Systematic breeding programs have been developed and are being used to some degree. The two most promising systematic breeding programs, OvSynch and Target Breeding, will be discussed. The principal benefit of these programs is that they provide an organized approach for administering first service A.I. Both programs provide the flexibility to set the start of A.I. breeding, if the desire is 45 or 70 days. These systems facilitate the breeding of more cows A.I., provide an increase in the number of inseminations within a given period, and eliminates natural service from at least the start of the breeding program. Systematic breeding programs have the potential to increase the reproductive performance of the dairy herds while maintaining A.I. as the dominant breeding option. These programs do require daily heat detection to identify cows that return from the initial injection scheme. Moreover, reproductive management is based on a systematic approach to whole herd rather than on the health and status of individual cows.

Regulation of estrus in lactating dairy cows has been primarily limited to the use of prostaglandins (Ferguson and Galligan, 1993; Kristula et al., 1992; Pankowski et al., 1996; and Stevenson et al., 1989;). Two prostaglandin (PG) products are commercially available for use in lactating dairy cows, Lutalyse and Estrumate . These PG products are from a class or group of hormones which generally cause regression of the corpus luteum of the ovary and usually subsequent expression of heat and ovulation within 2 to 5 days after administration. However, heat is not precisely synchronized because it does not take into account the follicular population at the time of luteal regression, some cows require 48 hours and others 120 hours to mature a dominant follicle for ovulation. Thus, appointment breeding is not practical for two reason: 1) not all cows are in the luteal phase of the cycle and thus will not respond to PG; and 2) the variation in follicular development due to the timing of the next follicular wave does not allow for consistent timing of a follicle that will produce estrogen for behavior expression and release of a ova for fertilization. Numerous schemes have been developed to systematically schedule PG administration and periods of observation for signs of heat that can be adapted to most any farm routine.

An excellent study conducted in New York with three commercial herds and 1624 cows compared two reproductive management scenarios using PG with a program based on routine rectal palpation, intrauterine therapies, and veterinary intervention (Pankowski, et al., 1996). One program was based on the following assumptions: 1) rectal palpation is not sensitive for correctly identifying functional corpus lutea, 2) controlled studies have indicated that uterine infusions may not be beneficial, and 3) heat induced by therapeutic use of PG may cleanse the uterine environment and increase fertility. The second program included the following concepts in addition to those of the first program: 1) PG at a scheduled interval may result in synchronization of estrus and improved reproductive efficiency, and 2) a higher pregnancy rate may result from PG administered at 14 day interval than at the original recommendations of 11 day intervals.

The reproductive program which included a therapeutic injection of PG at 25-32 days postpartum (no rectal palpation) and another PG injection just prior to the end of the voluntary waiting period (VWP) resulted in similar reproductive performance to the program consisting of routine rectal palpation and intrauterine therapies. Pregnancy rate, first service A.I. rate, first service conception rate, overall conception rate, percentage of cows that became pregnant, and culling rates were not different between these two programs Table 1. Although no difference in reproductive performance occurred among programs partial budgeting indicated that PG treatment costs were $4.46 and $15.61 less per cow for the 2x and 3x PG programs respectively, when compared to the cost of rectal palpation and veterinary intervention. Therefore, compared with a traditional reproductive program based on rectal palpation, use of PG without rectal palpation could result in equivalent reproductive performance at lower costs. When PG was used for postpartum reproductive therapy and synchronization of estrus, reproductive performance and net economic benefit were increased compared with the other two programs. Increased cost for PG did lower the advantage of the 2x and 3x PG programs; however, even when PG was figured at $4 per dose the advantage of the 3x program was $13.33 over the routine rectal palpation and veterinary intervention program.

Table 1: Reproductive performance and partial budget and sensitivity analysis for postpartum therapeutic PG (2 PG) and PG at scheduled 14 day intervals (3 PG) compared with routine rectal palpation and veterinary intervention (RP).

Term	RP	2 PG	3 PG
Number of cows	472	443	461
First service conception rate, (%)	43	45	47
Overall conception rate, (%)	51	53	53
Cows culled, (%)	21	21	20
Days open			
all cows	113	114	107
pregnant cows	111	111	104
Doses of PG	1289	1630	1890
Rectal palpations	944	0	0
Cost of therapy[1]	1055	435	163
Net cost per cow (compared to RP)[2]		-4.46	-15.61
PG $3 per dose		-3.88	-14.70
PG $3 per dose and rectal palpation $.90		-1.01	-11.87
PG $4 per dose		-3.12	-13.33

1: Includes all prebreeding palpations (excludes pregnancy palpations)

2: Rectal palpation $2.25 per palpation, PG $2.25 per dose, value of saved day open $2. Adapted from Pankowski et al., 1996. J. Dairy Sci. 78:1477 1488.

Target Breeding Program

An aggressive proactive program, termed Target Breeding, has been advanced by which cows are administered PG prior to the end of the VWP combined with 14 day PG administration until detection of heat and A.I. The intention of this treatment is to setup cows into a stage of the cycle which contains a mid cycle corpus luteum, where it is most responsive to the second administration of prostaglandin 14 days later. Generally with this program, cows are not inseminated if they exhibit heat following the initial PG injection.

Once a VWP has been established for a herd, cows are listed chronologically according to calving dates. Cows within 14 days of the VWP are administered the setup PG injection, for convenience injections are usually given once a week for all cows that surpassed the specified target date. Fourteen days later, cows receive the first breeding injection of PG and are observed for heat and inseminated accordingly. Cows that are not observed in heat are reinjected 14 days later, observed for heat, and inseminated. The PG administrations are continued at 14 day intervals until heat is detected. Some producers and veterinarians may prefer to examine cows that fail to exhibit heat after the third PG injection. Others may appointed breed at a specified time (usually 80 hours) after the third or fourth PG injection.

OvSynch Breeding Program

Researchers have shown that administration with GnRH 6 to 7 days prior to PG increased percentage of cows synchronized and reduced the time and variability to estrus in beef cows (Thatcher et al., 1993; and Twagiramungu et al., 1992). A new program has been developed that synchronizes ovulation allowing better pregnancy rates to timed A.I. than with PG (Pursley et al., 1995). An injection of gonadotropin releasing hormone (GnRH) followed seven days later with PG and followed 36 to 48 hours later with the second injection of GnRH has been shown to synchronize ovulation not estrus. An important point is that cows are not observed for signs of heat but inseminated at a specified time following the second GnRH injection.

The first injection of GnRH is given at a random stage of the estrous cycle and causes either luteinization or ovulation of the largest follicle in approximately 85% of all cows injected. The PGF2 injection regress the corpus luteum or luteinized follicle induced by GnRH. A new dominant follicle forms and is available to be ovulated by the second GnRH injection given 36 to 48 hours after the PG injection. According to preliminary results from relatively small number of breedings OvSynch program may be effective in improving the percentage of cows pregnant by 60-100 days in milk and may reduce the days to first breeding.

Cost effectiveness of the two programs (Target Breeding and OvSynch) are presented in Table 2. Two cost for PG and GnRH were used in the analysis along with two levels of heat detection (60 and 80%). High efficiencies for heat detection were used because with a synchronization program higher than average levels are easily obtained. Labor cost were difficult to estimate and will vary across operations but the point is cows will be sorted slightly less with a Target Breeding program because the initial group detected will not receive the third injection.

The cost per pregnancy was derived by dividing the total cost per cow by the estimate percent pregnant. No cost for heat detection was included in the analysis because heat detection must still proceed for all cows to catch returns are repeat services. However, the OvSynch program uses appointment breeding without heat detection which would reduce cost especially on large farms where cows could be grouped and whole corrals could be managed without the need for heat detection until after appointment breeding similar to synchronization programs used by large western U.S. beef cattle ranches. The least cost method was the Target Breeding program with $2.50 PG and 80% heat detection efficiency. The OvSynch program which used $2.50 for PG and $4.00 for GnRH was only $4.81 more expensive

Table 2: Cost analysis per pregnancy of Target Breeding and OvSynch systematic AI programs.[1]

program	PG $	GnRH $	heat det. %	% A.I.	% preg.	labor cost	cost per pregnancy
Targeted Breeding	$2.50	--	60%	73%	34%	$1.26	$20.04
	$2.50	--	80%	80%	40%	$1.19	$15.44
	$4.00	--	60%	73%	34%	$1.26	$31.80
	$4.00	--	80%	87%	40%	$1.19	$24.85
OvSynch	$2.50	$4.00	--	100%	45%	$1.50	$24.83
	$2.50	$7.00	--	100%	45%	$1.50	$38.16
	$4.00	$4.00	--	100%	45%	$1.50	$28.16
	$4.00	$7.00	--	100%	45%	$1.50	$41.50

1: Assumes 80% of cows given PG exhibit estrus, 45% pregnancy rate for both programs, labor cost at $.50 per sorting (excluding AI), three PG injections with Target breeding, OvSynch consist of two doses of GnRH and single dose of PG.

per pregnancy than the Target Breeding program that had similar cost for PG and 60% heat detection efficiency.

What Causes Cows To Show Heat?

The hormonal condition that can lead to expression of heat in the cow is a high blood level of estrogen (estradiol 17) in the presence of a low level of progesterone. The absolute amount of estrogen is probably not critical as long as it is above a threshold (approximately 10 pg/ml). The amount of progesterone is critical and it needs to be below a relatively low threshold (approximately 0.6 ng/ml). This hormonal situation normally exists when there is a mature pre ovulatory follicle secreting estrogen in the absence of a functional corpus luteum. Other conditions that can lead to expression of heat include presence of follicular cysts and presence of high levels of estrogen and low progesterone near term in pregnant cows.

Some physiological signs of heat such as edema and hyperemia of the vulva and secretion of cervical and vaginal mucus are involuntary meaning the cow herself has no control. These involuntary signs of heat are set in motion by the hormonal condition of the cow. But the more important behavioral signs such as standing, mounting, licking, butting and head resting are voluntary reflexes that are influenced greatly by existing conditions in the cow's immediate environment.

Figure 1: Components of the HeatWatch® electronic heat detection system.

What Affects Expression Of Heat?

Involuntary signs of heat are not influenced by a cow's immediate environment. For example, swelling and redness of the vulva and secretion of mucus are not influenced by weather; however, footing conditions do have a major influence on mounting activity and can be influenced by freezing or rainy weather.

Voluntary behavioral signs of heat are subject to many influences. The ones that are most important on most dairy farms are:

- number of sexually active animals in a group,
- freedom for sexually active animals to interact,
- freedom from interfering activities,
- ambient temperature, and
- foot conditions.

Behavioral signs of heat require that at least two animals interact. Recent studies in our laboratory indicate that secondary behavioral signs such as butting, licking, and head resting are influenced less by a cow's immediate environmental conditions than are the primary behavioral signs, mounting and standing. Most experienced observers utilize these secondary signs to pick out cows that are most likely to be in heat even when the immediate environmental conditions limit mounting and standing activity.

A cow will not be detected to stand if there is no other animal willing to mount. Mounting activity is stimulated strongly by estrogen and inhibited strongly by progesterone. Thus, mounting frequency is considerably greater for cows in proestrus or estrus than for cows that are out of heat or in mid cycle. Once there are four or more sexually active animals (proestrus or estrus) in a group, then mounting activity will normally be sufficient for efficient detection of heat. However, mounting activity is influenced considerably by the cow's immediate environment.

Cows that have foot problems, regardless of whether the problem is structural, subclinical or clinical, apparently show less mounting activity. Many of the foot problems that affect mounting activity can be alleviated by proper foot care and trimming.

There is no firm experimental evidence that high levels of milk production per se influence mounting or standing activity. There is some evidence that energy balance during the early postpartum period may influence whether a cow is detected in heat at the beginning of the first postpartum cycle. Apparently cows experiencing a severe negative energy balance can produce enough estrogen to elicit an LH surge and ovulate but not enough to cause heat. But once cycles have resumed, energy balance does not seem to affect intensity or duration of heat.

Extremes in temperature affect intensity of heat. Mounting activity is lower on "hot" or "cold" days than on days when the temperature is near the cow's thermoneutral zone. Heats may appear to be shorter when the temperatures are extreme, but it isn't clear whether this is because of less mounting activity or because of less willingness to stand.

Timing Of Insemination

Optimal timing of insemination relative to stage or onset of heat has been under investigation for nearly 70 years. As early as 1918, research recommended that ideal timing of insemination occurred 10 to 24 hours after onset of heat. Early studies, prior to the late 1950's, used fresh semen in contrast to the frozen semen of today and the housing and production levels of the herds were much different.

AM-PM Guideline

In 1943, Trimberger and Davis evaluated conception rates in dairy cattle at various periods during estrus and even today this research has been the most quoted for the timing of A.I. Cows and heifers were observed three times per day for signs of heat and once heat was identified that individual was observed every 2 hours. A few important points of the study should be noted: 1) a total of 295 cows and heifers and 489 breedings were evaluated; 2) Only 25 cows were bred before the middle of standing heat (in heat for at least 6 hours before and after insemination); 3) routine heat checks were performed 7 a.m., noon, and 6 p.m., while individuals due in heat were observed every two hours, so intense heat detection was performed. The optimal interval to A.I. under these conditions was recommended to be from 6 to 24 hours after the onset of detected mounting activity. From Trimberger's pioneering research developed the industry standard "a.m. p.m." guideline, where cows first observed in estrus in the a.m. should be inseminated the afternoon of the same day, and cows first observed in the evening should be inseminated before noon the following day.

Once-A-Day A.I.

Two large field trials have evaluated the use of once a day versus a.m. p.m. A.I. In a trial conducted in New York state using professional A.I. technicians and fresh semen (not frozen), 44,707 cows were bred either before noon the same morning of observation, between noon and 6 p.m., or after 6 p.m. the same day (Foote, 1979). There was no difference in 150 to 180 day non return rates (a measure of pregnancy rates) for cows bred the same morning or during the p.m. following a morning detection. Non return rates for cows inseminated before noon on the day of detected heat (67.1%) were similar to those for cows inseminated between noon and 6 p.m. (69.9%) and after 6 p.m. the same day (68.9%), whereas non return rates the following afternoon were

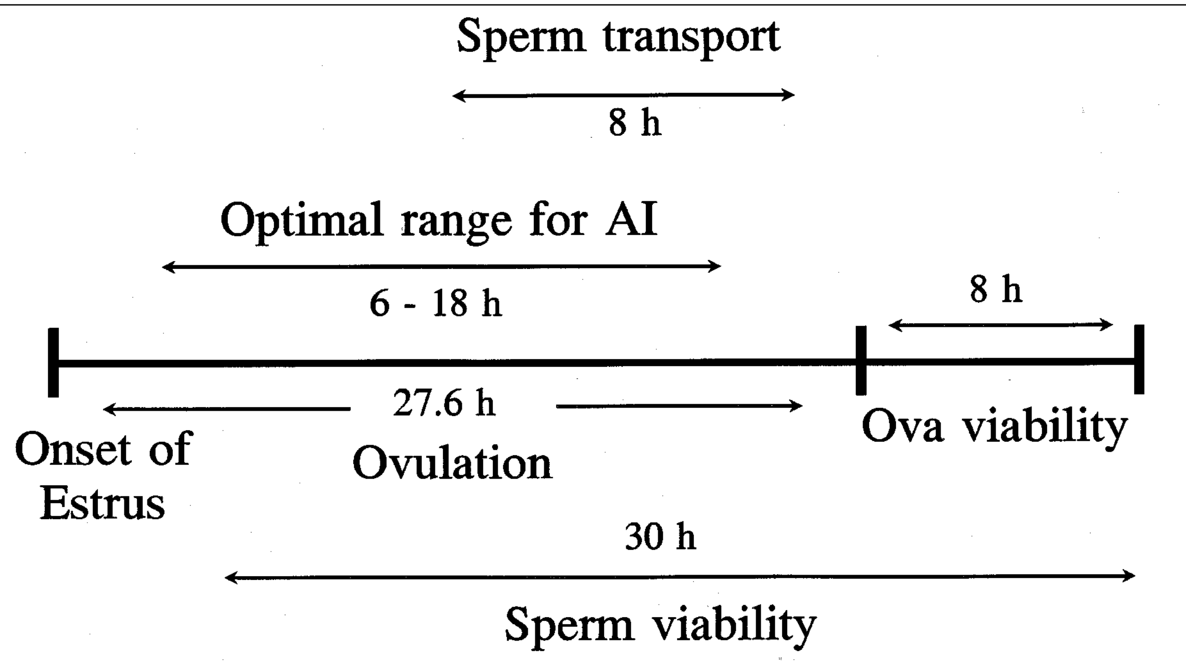

Figure 2. Model for Optimal time of AI in cattle.

less (62.7%). The second study was conducted in Pennsylvania again using professional A.I. technicians, but with frozen semen (Nebel et al., 1994). A total of 7,240 first service inseminations were evaluated. Half the herds bred cows using the a.m. p.m. guideline and the other half of the herds bred only once a day during a predetermined 3 hour period, after three months the herds switched so each herd used both method and at anyone time half the herds were using each method. Non return rates (90 day) for the once a day was 58.4 versus 57.8% for cows bred following the a.m. p.m. guideline. A slight advantage was revealed for herds that used once a day during the mid morning.

Timing When Onset Of Heat Is Known

The HeatWatch estrus detection system is the first system that monitors cows 24 hours daily for mounting activity (Figure 1). The technology behind the HeatWatch system is known as Radio Frequency Data Communication. A miniaturized radio transmitter, powered by a replaceable 3 volt lithium battery, is placed inside a disposable 10 inch by 8 inch mesh nylon fabric patch which is glued to the tailhead of the cow. Activation of the pressure sensor, which is approximately inch tall, 2 inches wide and 3 inches long, sends a radio transmission (range .25 mile) to a receiver that is placed in a central location on the farm. Transmitted data includes date, time and duration of each mount a cow receives. The receiver is hard wired to a buffer which stores standing events information associated with estrus until downloaded to the HeatWatch software. The HeatWatch sorts information by cow and generates management list such as "standing heat", "suspect heat", "inactive cows", etc.

Recent studies using the HeatWatch system have demonstrated promise for this technology to resolve inefficiency stated earlier with the detection of estrus on dairy farms (Stevenson et al., 1996; and Walker et al., 1996). The mean estrus period, determined from mounting activity recorded by HeatWatch , consisted of 10 mounts over 9.5 hours (Walker et al., 1996). Mean ovulation time relative to first mount associated with estrus was 27.6 ± 5.4 hours and was not different for estrus periods induced by PG or spontaneously. If we assume that normal sperm have a viable life of 30 hours and sperm transport to the site of fertilization takes a minimum of 8 hours, and ova have a fertile life of 8 hours then the optimum time of insemination should be 6 to 18 hours after first mount or onset of standing heat (Figure 2).

The optimal time for A.I. was investigated in a recent field study using 17 herds that utilized HeatWatch electronic heat detection system (Grove et al., 1996). Inseminations (2661) were performed daily during a three hour period for all cows identified in heat the previous 24 hours. This allowed for inseminations to occur at all intervals from onset of heat (the first mount detected by HeatWatch) to breeding. The highest probability of pregnancy occurred when inseminations were between 5 to 16 hours after first mount. Other factors that were identified as having a significant effect on subsequent percent pregnant were days in milk at breeding, total number of mounts during heat, season, and differences due to other herd effects.

What does this mean for a farm that has not purchased this new heat detection system?

1) At least four visual observation periods are necessary – the average heat period is only 8 hours (time from first to last stand).

2) Other activities (scraping lots, filling freestalls, etc) must not be performed during the time allotted for visually observing cows – the average cow is mounted 10 times during the heat period.

3) All of the heat periods will never be detected without visually observing cows 24 hours a day, because many cows show very little activity – less than 3 mounts for only a few seconds.

When visual observations for heat are frequent (every 4 to 6 hours) it is recommended that cows be inseminated approximately 12 hours following detection, thus the "a.m. p.m. guideline". However, a common management practice is that only one or two daily visual observation periods are utilized; therefore, results following the a.m. p.m. guideline or using once a day A.I. usually result in similar pregnancy rates because the accurate timing of heat onset is not known. With HeatWatch the electronic heat detection system the first mount of "standing" heat can be identified, thus allowing accurate timing of A.I. was 5-16 hours after the first mount or onset of heat.

Conclusions

Historically the approach taken by management has been passive, by waiting for cows to cycle and be detected in heat for A.I., rather than proactive which now can be accomplished by the incorporation of a systematic breeding program that induces heat or allows for appointment breeding without the need for heat detection. Research has shown that PG programs are cost effective and may improve herd reproductive performance compared with more traditional programs that treat individual cows. The cost effectiveness of the OvSynch program needs to be evaluated.

The AM PM guideline established in the 1940s has served as the standard for timing of A.I. A recent study using frequent ultrasonography to determine time of ovulation and the electronic heat detection system HeatWatch to determine onset of mounting activity verified Trimberger's findings that ovulation occurs approximately 28 hours after the onset of mounting activity. This study led to the reevaluation of the optimal time to insemination in lactating cows with the HeatWatch system which provides around the clock, 24-hour monitoring of standing activity. This field trial which was conducted in 17 herds using 2,661 insemination revealed that the highest pregnancy rates occurred between 5-16 hours after onset of heat (first mount). Therefore, the frequency of visual observation for signs of heat is not sufficient to optimize timing of A.I. in most herds. Timing of insemination should be based on the frequency of observation for standing heat. In herds where observations occur less than four times daily, A.I. should be performed within 4-6 hours after first observation. In herds where observation for heat are more frequent (more than three times per day) insemination should occur approximately 6-12 hours after first observing standing heat.

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