Management Strategies for Improving Reproductive Efficiency in Lactating Dairy Cows

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▪ Take Home Messages

- Dairy producers should strive to improve pregnancy rate by improving the AI service rate in their herd.
- Estrus detection is poor on most dairy farms not only because of inadequate estrus detection protocols, but because expression of estrus behavior is poor in lactating dairy cows.
- Estrus detection aids are useful tools for improving estrus detection efficiency and AI service rates.
- Because lactating dairy cows exhibit a high rate of early embryonic loss, cows diagnosed pregnant early during gestation should be scheduled for a second pregnancy diagnosis at around 56 days post AI.

▪ Introduction

Reproductive inefficiency in lactating dairy cows not only is a source of frustration to dairy producers and their consultants but also substantially reduces dairy farm profitability. Artificial insemination (AI) is one of the most important agricultural technologies developed this century, and most dairy producers use AI to some degree in their herds to remain competitive in the current economic climate of the dairy industry. However, reproductive inefficiency in lactating dairy cows substantially reduces the impact and efficiency of AI in dairy operations. It is important that dairy producers understand the factors that affect the rate at which cows become pregnant in their herd as well as the management factors they can control to improve this rate.

▪ Improving Pregnancy Rate

Timely rebreeding of postpartum lactating cows is essential for reducing average days open and the corresponding calving interval. A successful breeding program enhances profitability by maximizing the time cows spend in the most productive portion of lactation. The rate at which cows become pregnant in a dairy herd, commonly called the pregnancy rate, is defined as the number of eligible cows (i.e., non-pregnant cows past the producer's voluntary waiting period) in a herd that conceive every 21 days. Two major factors determining pregnancy rate are: 1) conception rate or pregnancy rate per artificial insemination, and 2) estrus detection rate or service rate.

Pregnancy Rate / Artificial Insemination (PR/AI)

Dairy cow fertility commonly is measured by calculating the percentage of cows that conceive after a single AI service, also known as the pregnancy rate per artificial insemination (PR/AI). Pregnancy rate per AI in lactating dairy cows has decreased from 66% in 1951 (Spalding et al., 1974), to about 50% in 1975 (Spalding et al., 1974; Macmillan and Watson, 1975), to about 40% in 1997 (Butler et al., 1995; Pursley et al., 1997a), whereas PR/AI in heifers has remained at 70% during this same period (Spalding et al., 1974; Foote, 1975; Pursley et al., 1997b). Thus, this disparity in PR/AI cannot be attributed to differences in genetic selection or semen quality between heifers and lactating cows, but is likely due to physiological changes or stresses associated with increased milk production per cow that have occurred during this time.

Four general factors that determine PR/AI in a dairy herd include: 1) cow fertility; 2) bull fertility; 3) accuracy of heats; and 4) AI efficiency. Cow fertility refers to any cow-related factors that influence establishment of pregnancy and include factors such as inadequate nutrition and environmental stresses. Bull fertility refers to the quality of semen used for AI. Accuracy of heats refers to the timing of AI relative to estrus rather than to service rate or accuracy of heat detection (discussed in the next section). AI efficiency refers to factors affecting pregnancy rates due to AI technique.

Table 1 illustrates the four factors that affect fertility and how they might interact to determine PR/AI. Of these four factors, accuracy of heats and AI efficiency can be maximized through careful reproductive management practices. Furthermore, although fertility varies among bulls, the fertility of semen acquired through major AI organizations is controlled and should not limit PR/AI. Changes in bull fertility can dramatically influence pregnancy rate per AI by reducing the ability of sperm to bind to the oocyte, by changing the fertilization rate, or by altering later embryonic development (Eid et al., 1994; Nadir et al., 1993). Additionally, AI at the wrong time of the estrous cycle (inaccurate estrus detection), improper semen handling, or improper insemination techniques can also substantially reduce pregnancy rate per AI (Grossman et al., 1995).

Table 1. Interaction among four factors affecting pregnancy rate per AI (PR/AI) in lactating dairy cows.

Hypothetical Case	Female Fertility	Bull Fertility	Accuracy of Heats	AI Efficiency	PR/AI
Heifers	85%	95%	95%	95%	73%
Lactating Cows	50%	95%	90%	95%	41%
Lactating Cows + AI problems	50%	95%	90%	50%	21%

The first line of Table 1 shows a situation in which all factors are optimized when inseminating heifers. As mentioned previously, heifer fertility is high and has remained unchanged over the past 40 years. The second line shows a situation when all factors are optimized when inseminating lactating cows. Thus, differences in fertility between heifers and lactating cows may account for the observed differences in PR/AI. Unfortunately, factors that limit cow fertility are poorly understood, and cow fertility is less than 50% even on well managed farms with excellent nutritional and reproductive management. Thus, management strategies should be developed to maximize PR/AI while realizing that high-producing herds under excellent management will likely not exceed a PR/AI of 50%.

Service Rate

Service rate is defined as the percentage of eligible cows bred during a 21-day period. In herds using AI, the service rate directly reflects estrus detection efficiency because a cow must first be detected in estrus before she can be bred. Unfortunately, less than 50% of all estrus periods are accurately detected on an average dairy farm in the United States (Senger, 1994). This inefficiency in estrus detection not only increases time to first AI but can increase the average interval between services to 40 to 50 days (Stevenson and Call, 1983). Many dairy managers choose to focus on improving PR/AI in their herds; however, over three times as much of the variation in average days open among farms is due to differences in service rate as is due to differences in PR/AI (Barr, 1975). Economic cost analysis of improving the estrus detection rate (i.e., service rate) by 20 to 30%, and assuming a 50% AI conception rate, resulted in an estimated annual benefit of $83 per cow (Pecsok et al., 1994). Similarly, increasing the estrus detection rate from 35 to 55% reduced average days open from 136 to 119 days, resulting in a net return per cow of $60 per year (Oltenacu et al., 1981). Thus, management strategies that improve the service rate in an operation result in a net profit to the producer.

Figure 1 graphically illustrates the potential effect of management strategies that improve either PR/AI (left panel) or service rate (right panel) in a theoretical herd with normal fertility and having no sterile or severely infertile cows. The top line in both graphs represents the pregnancy rate for a herd with a PR/AI of 40% and a service rate of 40%. In this scenario, the herd has a median days open of 150 days, and by 250 DIM nearly 20% of cows in the herd are not pregnant. The left panel of Figure 1 illustrates the effect of improving PR/AI from 40% to 50% while maintaining a 40% service rate. In this scenario, median days open is reduced to 135 days, however, nearly 12% of cows in the herd are not pregnant by 250 DIM. In contrast, the right panel of Figure 1 illustrates the effect of improving service rate from 40% to 90% while maintaining a PR/AI of 40%. In this scenario, median days open is reduced to about 100 days, and by 200 DIM nearly all cows in the herd are pregnant. Thus, although managers should strive to maximize PR/AI, increasing service rate has a greater impact on improving reproductive performance of a herd.

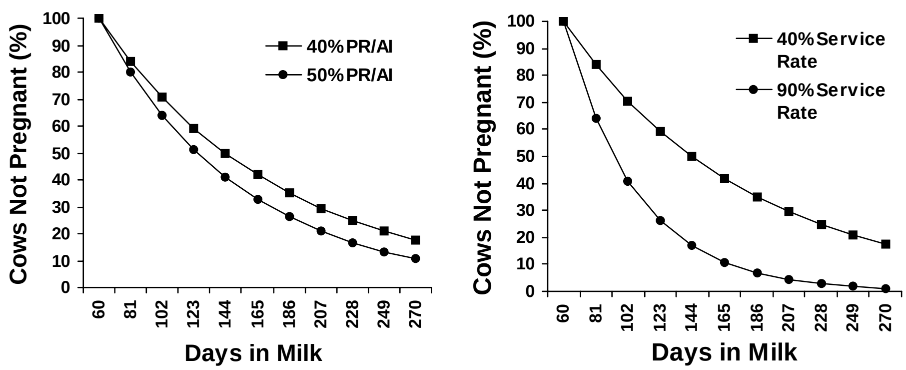

Figure 1. Graphical illustration of the potential effect of management strategies that improve PR/AI (left panel) or service rate (right panel) in a theoretical herd with normal fertility and having no sterile or severely infertile cows. The top line in both graphs represents the pregnancy rate for a herd with a PR/AI of 40% and a service rate of 40%. The left panel illustrates the effect of improving PR/AI from 40% to 50% while maintaining a 40% service rate. The right panel illustrates the effect of improving service rate from 40% to 90% while maintaining a PR/AI of 40%.

Expression of Behavioral Estrus in Dairy Cattle

Dairy producers have the most control over the service rate in their herds, and service rate can be improved by increasing estrus detection efficiency. It is essential that farm personnel accurately assess signs of estrus behavior. Standing to be mounted by a herdmate is the primary sign of estrus and is the best indicator of the fertile period. Unfortunately, recent research has shown that expression of estrus behavior is poor in lactating dairy cows making it difficult to accurately detect estrus by visual observation alone in a dairy operation.

Estrus Duration

Older literature and textbooks cite the duration of estrus behavior in dairy cattle to be about 18 hours (Roberts, 1986). Recent research using radiotelemetric monitoring of estrus behavior, however, has shown that lactating dairy cows express estrus behavior poorly compared with dairy heifers (Table 2). Other published reports have estimated the duration of estrus behavior in lactating dairy cows to be from 7.1 ± 5.4 hours (Dransfield et al., 1998) to 9.5 ± 6.9 hours (Walker et al., 1996). Although the reason for the reduction in the duration of estrus behavior is not known, milk production is negatively correlated with duration of estrus behavior (Harrison et al., 1990). This reduction in estrus duration significantly impairs estrus detection efficiency in dairy herds.

Table 2. Number of standing events and duration of estrus (mean ± SD) in Holstein dairy cattle.

Item	Heifers	Lactating Cows
No. of Animals	114	307
No. of Standing Events	16.8 ± 12.8	7.2 ± 7.2
Estrus duration (h)	11.3 ± 6.9	7.3 ± 7.2

(Adapted from Nebel et al., 1997)

In addition, the number of times per day cows are observed, as well as the timing and location of these observations, profoundly influences estrus detection rate. Based on the data in Table 2, estrus detection should be conducted at three to four evenly-spaced 20-minute intervals per day to achieve adequate results. Certain physiologic factors reduce estrus behavior including: illness, feet and leg problems, and acyclicity due to nutritional deficiencies or health problems. Environmental factors such as heat stress, poor footing, or other environmental stresses may also reduce estrus behavior.

▪ Estrus Detection Aids

Many estrus detection aids have been developed to improve estrus detection and AI service rate in dairy cows. These aids are effective if used to enhance an estrus detection program, but should never fully replace visual detection of estrus.

Tail Paint

Use of tail paint or chalk can increase estrus detection efficiency (Senger, 1994). Tail paint was originally developed as an estrus detection aid for use in dairy herds managed using grazing based systems (Macmillan and Curnow, 1977), and has been shown to be an effective estrus detection aid and for practical breeding management in New Zealand (Ducker et al., 1983; Kerr and McCaughey, 1984) Detail Oestrus Activity Tail Paint (FIL Industries Ltd, Mount Maunganui, New Zealand) is water-soluble and latex based, and is applied in a strip 5 cm wide by 20 cm long over the coccygeal vertebrae of the tail head. Once dried, the paint hardens and, according to the manufacturer, remains intact for up to six weeks unless removed by mounting activity of a herdmate during standing estrus.

Daily monitoring of tail paint retention or removal alerts the herd manager of the occurrence of or lack thereof of mounting activity associated with estrus. In this way, the tail paint serves as an aid for estrus detection in the absence of visual detection of mounting activity. Detail Oestrus Activity Tail Paint is available in four colors: red, green, blue, and yellow. These four colors have been incorporated into the Detail Management System (FIL Industries Ltd.) for use in managing reproduction in grazing based dairy systems. Briefly, all cows receive red paint at calving. Removal of red paint before the breeding period is used as an indication that the cow has resumed cyclicity, whereas retention of tail paint during this period is an indication of anestrus. At the onset of the breeding period, all cows receive green tail paint. Removal of green paint is an indication that a cow is in estrus and should receive an AI service. At the first AI service of the breeding period, blue paint is applied. Cows that fail to conceive to first AI are identified by removal of blue paint. All cows requiring a second or greater AI service receive yellow paint.

Pressure-activated Heat Mount Detectors

Use of pressure-activated heat mount detectors can increase estrus detection efficiency (Senger, 1994). These devices are affixed to the tail head of individual cows, and are activated by direct pressure from a herdmate during mounting events. Commercially available devices include Kamar heat detection patches and Bovine Beacon. Although false positives can occur, these devices are generally useful as estrus detection aids. Although primary and secondary indicators of behavioral estrus are the best methods for determining timing of AI, breeding to an activated Kamar device can yield acceptable results (Nebel et al., 1994).

Androgenized Marker Animals

Androgenized marker animals also have been shown to improve both estrus detection efficiency as well as the accuracy of estrus (Sawyer et al., 1986). This is especially true for smaller herds in which the sexually active group may include only one or two animals per day. In many cases, androgenized marker animals are fitted with marking devices or used in conjunction with tail chalk or paint. The use of Synovex-H (Syntex Laboratories, Inc., Palo Alto, CA) is a convenient method for androgenizing marker animals. Yearling freemartin heifers weighing 800 to 1,000 pounds are commonly used as marker animals, however, lactating cows should never be treated with Synovex-H because milk from treated animals can not be sold for human consumption. Older, dry cows also have been used and are good marker animals because their pecking order within the herd is already established. Over-conditioned animals, animals with poor feet or legs, and those animals at the bottom of the herd pecking order should be avoided. Treated animals are usually effective for about six months after implantation. Although animals can be retreated after their effectiveness begins to wane, most producers choose to treat a new animal. About 80% of treated freemartin heifers respond to treatment, and those animals that do not respond should be eliminated.

HeatWatch

Surface applied or implantable pressure sensors also have shown promise for providing accurate daily estrus detection (Senger, 1994). For example, the HeatWatch® system (DDx Technology) provides continuous information on mounting activity. When HeatWatch® was compared with visual estrus detection (Walker et al., 1995), efficiency of estrus detection was greater with HeatWatch® (91% vs. 51%) with similar accuracy (96% vs. 94%). Because these types of mounting detectors require physical interaction among cows, the best results are achieved when cows are housed in groups, such as, in free stalls, pastures, or lots, compared with cows housed in stanchions or tie-stalls or in poor environmental conditions.

Pedometry

Farris (1954) first showed that estrus behavior in dairy cattle is accompanied by an increase in physical activity. Kiddy (1977) was the first to use leg mounted pedometers to determine if physical activity related to estrus varied enough compared with nonestrual activity to be useful for estrus detection in dairy cattle and concluded that pedometry may be a useful method for estrus detection in dairy operations. Pedometer and computer technology improvements coupled with increases in computer software analysis programs have resulted in greatly improved pedometry systems (Koelsch et al., 1994; Senger, 1994). Comparison among various statistical comparison procedures that use pedometery data in lactating dairy cows indicate that 70% of estrual periods and 99% of nonestrual periods can be accurately predicted using currently available pedometry systems (Koelsch et al., 1994).

▪ Early Embryonic Loss in Lactating Cows

Pregnancy loss contributes to reproductive inefficiency in lactating dairy cows because fertility assessed at any point during pregnancy is a function of both conception rate and pregnancy loss. Conception rates at 28 to 32 days post-AI in lactating dairy cows range from 40 to 47% (Pursley et al, 1997b; Fricke et al., 1998), whereas conception rates in dairy heifers are nearly 75% (Pursley et al., 1997b). Similarly, pregnancy loss in lactating dairy cows is greater than that in dairy heifers (20% vs. 5%; Smith and Stevenson, 1995). Although the specific factors responsible for early embryonic loss in dairy cows are not known, they may be similar to those factors responsible for reduced conception rates.

Timing of Early Embryonic Loss

Early embryonic loss in cattle is difficult to study because no sensitive test similar to that used for women and mares exists. The fertilization rate after AI in beef cows is 90%, whereas embryonic survival rate is 93% by Day 8 and only 56% by Day 12 post AI (Diskin and Sreenan, 1980). In dairy cattle, only 48% of embryos were classified as normal on Day 7 after AI (Weibold, 1988). Thus, substantial pregnancy loss probably occurs within two weeks post AI.

Rectal palpation from 40 to 60 days post AI is the most common method of pregnancy diagnosis in dairy cattle. Several studies have used pregnancy diagnosis based on rectal examination to establish a conception rate from which pregnancy loss can be determined as gestation ensues. Using this technique, pregnancy loss is about 10%, with greater losses in lactating cows compared with heifers (Thurmond et al., 1990; Markusfel-Nir, 1997). Furthermore, the risk of pregnancy loss was more than four times greater during the first compared with the second and third trimesters of gestation (Markusfel-Nir, 1997).

Recently, transrectal ultrasonography was used to determine the timing of pregnancy loss from 28 days post AI to calving in lactating dairy cows (Vasconcelos et al., 1997). Pregnancy diagnosis was conducted at 28, 42, 56, 70, and 98 days post AI for 1,600 dairy cows in three herds with a rolling herd average >23,000 pounds. The conception rate of cows at 28 days post AI was 32%, and overall pregnancy loss from day 28 to calving was nearly 25%, with most losses occurring during the first 60 days of gestation (Figure 2).

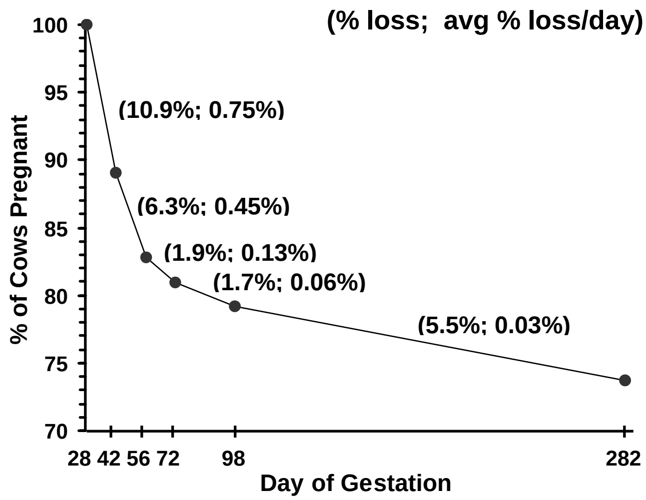

Figure 2. Pregnancy losses from 28 days post AI to calving in lactating dairy cows. Pregnancy status was determined using ultrasound at 28, 42, 56, 70, and 98 days post AI, and calving data were recorded at parturition. The conception rate at 28 days was 32%. (Adapted from Vasconcelos et al., 1997).

Factors Affecting Early Embryonic Loss

Because fertility assessed at any point during pregnancy is a function of both conception rate and pregnancy loss, factors associated with pregnancy loss may be similar to those responsible for low fertility. Nutrition can have a major impact on dairy cow fertility. A recent review (Ferguson, 1996) indicated that nutritional causes of low fertility are more like first due to energy management, second to excessive protein feeding, and third to trace element and vitamin deficiencies. In addition, greater body condition score losses from calving to breeding result in reduced fertility (Ferguson, 1996).

Specific physiologic mechanisms responsible for pregnancy loss in lactating dairy cows are unknown, but may include lactational stress associated with increased milk production (Oltenacu et al., 1980; Nebel and McGilliard, 1993), negative energy balance (Butler and Smith, 1989), toxic effects of urea and nitrogen (Butler et al., 1995) or reduced ability to respond to increased environmental temperature (Stevenson et al., 1984; Hansen et al., 1992). Beef cows losing weight have a higher incidence of early embryonic loss than those gaining weight (Dunn and Moss, 1992). This suggests that negative energy balance may be involved when a high incidence of early embryonic loss is observed in dairy cows. Recommendations for minimizing the severity of negative energy balance in high-producing dairy cows include maximizing dry matter intake in early lactation and feeding diets containing .78 Mcal NEl per pound and 5%-7% total fat (DM basis).

High circulating urea and ammonia from the feeding of diets high in degraded intake protein (DIP) may adversely affect early embryonic development (Butler, 1998). Further, the feeding of excess DIP may exacerbate negative energy balance and related reproductive problems. Elrod and Butler (1993) reported increased early embryonic loss for heifers fed an energy-restricted diet containing high levels of DIP. Ferguson (1996) indicated that cows fed high amounts of DIP showed more irregular intervals between first and second service. Dietary DIP should be restricted to 10%-12% (NRC, 1989; DM basis). Also, nitrate concentrations in water and forages should be evaluated when herds are experiencing a high incidence of abortions or early embryonic loss (Davison et al., 1965).

Management of Early Embryonic Loss

At present, there is no practical way to reduce early embryonic loss in lactating dairy cows. However, recognizing the occurrence and magnitude of early embryonic loss may actually present management opportunities by taking advantage of new reproductive technologies that increase AI service rate in a dairy herd. One such technology is the use of transrectal ultrasonography for early pregnancy diagnosis. If used routinely, transrectal ultrasonography has the potential to improve reproductive efficiency within a herd by reducing the period from AI to pregnancy diagnosis to 26 to 28 days with a high degree of diagnostic accuracy (Pierson and Ginther, 1984). Furthermore, use of ultrasound could minimize embryonic loss that may occur after manipulation of the reproductive tract and conceptus during pregnancy diagnosis using rectal palpation (Paisley et al., 1978; Vaillancourt et al., 1979).

There are two main caveats to using ultrasound for routine early pregnancy diagnosis in a dairy herd. First, when using ultrasound for early pregnancy diagnosis, emphasis must be placed on identification of nonpregnant rather than pregnant cows. Of cows diagnosed pregnant at 28 days post AI, 14 to 16% experience early embryonic loss by 56 days post AI (Vasconcelos et al., 1997; Fricke et al., 1998). Therefore, cows diagnosed pregnant at 28 days post AI using ultrasound should be scheduled for reexamination around 56 days post AI, when the rate of embryonic loss per day begins to decline (Vasconcelos et al., 1997; Figure 2). Second, a management strategy must be developed to return the non-pregnant cows to service as quickly as possible after pregnancy diagnosis. Such strategies include administration of $PGF_{2\alpha}$ to cows with a responsive CL, use of estrus detection aids, synchronization of ovulation and timed AI or a combination of both methods.

▪ Conclusions

Estrus detection in lactating dairy cows is poor not only because of inadequate estrus detection protocols, but because high-producing lactating cows express estrus poorly. Dairy producers can most effectively improve pregnancy rate by improving AI service rate in their herds, and this can be accomplished by using one or more commercially available estrus detection aids. Finally, because lactating dairy cows exhibit a high rate of early embryonic loss, cows diagnosed pregnant early during gestation should be scheduled for a second pregnancy diagnosis at around 56 days post AI.

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