Reproductive Challenges of High Producing Dairy Cows

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Introduction

Within a dairy herd, total milk production is determined by the proportion of cows producing milk at any given time and the level of milk production of the individual cows within the herd. Improving reproductive efficiency helps to maintain the maximal number of cows producing milk at optimal levels. Reproductive efficiency in dairy cattle currently is suboptimal primarily due to four factors: 1) poor detection and expression of estrus behavior, 2) a high incidence of anovular cows near the end of the voluntary waiting period, 3) poor conception rates of lactating cows, and 4) a high incidence of pregnancy loss for cows that conceive. Over the past decade, the development of hormonal protocols that synchronize follicular development, luteal regression, and ovulation thereby allowing for timed AI without the need to rely on visual estrus detection has helped to overcome factor 1 and to some extent factor 2 above, and development of systematic resynchronization systems for cows failing to conceive to an AI service is underway. Regarding factor 3, the body of scientific literature supports the notion that fertility of lactating dairy cows has decreased over the past 50 years. Factor 3 is closely related to factor 4 because fertility assessed at any point during pregnancy is a function of both conception rate and pregnancy loss. Development of strategies that reduce the rate of embryonic loss after AI will therefore result in an increase in conception rate. A final factor that negatively affects reproduction in dairy cattle is twinning, and the observation that twinning has increased in dairy cattle over time suggests a concurrent change in one or more of these causative factors during this same period. Management strategies need to be developed to avoid or mitigate the negative effects of twinning in dairy herds, especially if twinning rates continue to increase. Future development of reproductive management strategies during the next decade must be focused on both the applied and basic aspects of understanding and overcoming the limitations imposed by these factors.

Pregnancy Risk

The rate at which cows become pregnant in a dairy herd is determined by an interaction between service rate and conception rate. Although pregnancy rate is not always the mathematical product of conception rate and service rate, this equation approximates pregnancy rate in large groups of cows. Thus, maximizing both conception and service rate provides opportunities for management control of reproduction and profitability in a dairy operation. A practical method for determining pregnancy rate is to observe the number of successful outcomes (pregnancies) that occur during periods when eligible cows are at “risk” to become pregnant (21-day reproductive cycles). On many large dairies, a commercially available computer software program is used to monitor reproductive performance by calculating pregnancy, service, and conception rates on a daily, weekly, or monthly basis. Pregnancy rates for lactating dairy cows in the upper

Midwest region of the United States can vary between 5% to 30% among farms depending on the service and conception rate and average about 14% (Rapnicki et al., 2001).

Factors Affecting Service Risk

Service risk is defined as the percentage of eligible cows that are inseminated during a 21-day period. In herds using AI, the service risk directly reflects estrus detection efficiency because a cow must first be detected in estrus before she can be inseminated. Unfortunately, less than 50% of all estrus periods are accurately detected on an average dairy farm in the United States (Senger, 1994). Estrus detection rates for lactating dairy cows in the upper Midwest region of the United States can vary between 5 to 60 percent among farms with an average of 35 to 40% (Rapnicki et al., 2001).This inefficiency in estrus detection not only increases time from the end of the voluntary waiting period to first AI but also can increase the average interval between AI services to 40 to 50 days (Stevenson and Call, 1983). Many dairy managers choose to focus on improving conception risk 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 conception rate (Barr, 1975). Economic cost analysis of improving the estrus detection rate (i.e., service risk) 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). Thus, management strategies that improve the service risk in an operation result in a net profit to the dairy enterprise.

Expression and Detection of Behavioral Estrus

Dairy farmers have the most control over the AI service risk in their herds, and service risk 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.

Older literature and textbooks cite the average duration of estrus behavior in dairy cattle to be about 18 hours (Roberts, 1986). Research from Virginia Tech using radiotelemetric monitoring of estrus behavior, however, has shown that lactating dairy cows express estrus behavior poorly compared with dairy heifers. The duration of estrus behavior in lactating dairy cows is estimated to be from 7.1 ± 5.4 hours (Dransfield et al., 1998) to 9.5 ± 6.9 hours (Walker et al., 1996). Nearly one-quarter of cows in this study had estrus periods that were classified as low intensity (<1.5 standing events/h) and short duration (<7h). 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). Higher producing cows have recently been reported to exhibit a shorter duration of estrus than lower producing cows (Lopez et al., 2003). This reduction in estrus duration significantly decreases estrus detection efficiency in dairy herds.

The number of times per day cows are observed, as well as the timing and location of these observations, profoundly influences estrus detection rate. Because of the short duration of estrus behavior, detection of estrus 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 anovulation due to nutritional deficiencies or health problems. Environmental factors such as heat stress, poor footing, or other environmental stresses may also reduce estrus behavior. Ovariectomized cows treated with estradiol showed more mounting activity and standing activity on dirt surfaces compared with concrete surfaces (Britt et al., 1986). In a subsequent study, mounting activity was 15-fold greater on a dirt floor than on a concrete floor (Vailes and Britt, 1990).

Anovular Cows

Recent studies that have evaluated anovular conditions (i.e., lack of reproductive cyclicity) in dairy cattle have reported that 20% to 30% of postpartum cows are anovular between 50 to 75 DIM (Pursley et al., 2001; Cordoba and Fricke, 2001; Gumen et al., 2003). Anovulation in high-producting dairy cows is characterized by growth of follicles past deviation but not to ovulatory size and by growth of follicles to larger than ovulatory size resulting in large cysts (Wiltbank et al., 2002), whereas the condition of "static" ovaries has rarely been reported in these studies. These high rates of anovulation contribute to poor service rates despite the best estrous detection program because the cows fail to display behavioral estrus.

In one study (Pursley et al., 2001), lactating dairy cows (n=633) from six Midwest herds were assigned randomly to receive Ovsynch or Ovsynch + CIDR at a random stage of an estrous cycle. Blood was sampled to quantify P_4 10 d before first GnRH, at first GnRH, at removal of CIDR, at $PGF_{2\alpha}$, and 36 h post- $PGF_{2\alpha}$ to determine cycling status at time of first GnRH, status at time of $PGF_{2\alpha}$ (high or low P_4). Nearly 29% (182/633) of these cows were classified as anovular, and anovular cows receiving a CIDR during Ovsynch had greater conception rates at 56 d after TAI than anovular cows not receiving a CIDR (36% vs. 22%, respectively).

In another study (Gumen et al., 2003), Lactating Holstein cows (n=316) were evaluated for anovular condition and subjected to either Ovsynch or detection of estrus for first postpartum AI. Weekly ultrasound and blood samples were used to classify anovular cows and measure the diameter of the largest follicle. Anovular cows included 28% of 122 primiparous cows and 15% of 194 multiparous cows. Of 64 anovular cows, 20% had follicles ≥25 mm that might be considered cystic, whereas 58% had 15 to 24 mm follicles and 22% had 9 to 14 mm follicles. Although 20% of lactating cows were not cyclic by about 60 d postpartum, nearly all cows ovulated after the second GnRH injection of Ovsynch; however, anovular cows had lower conception than ovular cows whether inseminated after detected estrus or after Ovsynch. There also was a strong negative correlation between the incidence of anovulation and body condition score (BCS) at TAI.

In summary, treatments that increase circulating progesterone can help in the treatment of anovular cows by potentially increasing GnRH/LH pulses and allowing the final stages of follicular growth or resetting the hypothalamic responsiveness to the positive feedback effects of estradiol (Wiltbank et al., 2002). Incorporation of a CIDR device with the Ovsynch protocol may be the best strategy for dealing with lactating dairy cows that are anovular at the end of the voluntary waiting period. Also, nutritional management to improve BCS and change in BCS for postpartum cows may reduce the overall incidence of anovulation in a dairy herd.

Strategies for Improving Service Risk

It is a fundamental principle of reproductive biology that inseminating a cow is the first step toward establishing a pregnancy. Unfortunately, many cows do not receive their first postpartum AI service until after 100 days in milk. First postpartum AI service represents a unique opportunity for reproductive management of lactating dairy cows because all cows have a known pregnancy status at this time (e.g., nonpregnant), which allows for use of hormonal synchronization systems that use $PGF_{2\alpha}$ without the risk of aborting a previously established pregnancy. Furthermore, reducing the interval from calving until first AI service for all cows in the herd has a profound effect on reproductive efficiency. The interval that must elapse from calving until a cow is eligible to receive her first AI service is termed the Voluntary Waiting Period (VWP). As the name implies, the duration of this interval is voluntary (i.e., a management decision) and traditionally varies from 40 to 70 days on most dairies.

Factors Affecting Conception Risk

Dairy cow fertility commonly is measured by calculating the percentage of cows that conceive after a single AI, also known as the conception risk. Conception risk 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 conception risk in nonlactating dairy heifers has remained above 50% during this same period (Spalding et al., 1974; Foote, 1975; Pursley et al., 1997b). Thus, this disparity in conception risk cannot be attributed to differences in genetic selection or semen quality between heifers and lactating cows. Conception risk for lactating dairy cows in the upper Midwest region of the United States can vary between 15% to 60% among farms with an average of 35% to 40% (Rapnicki et al., 2001).

Table 1. Effect of inseminator on conception rates of nonlactating Holstein dairy heifers during the 42 d AI breeding period (Adapted from Rivera et al., 2003a, b).

Item	Inseminator 1	Inseminator 2	Inseminator 3	Overall
Experiment 1				
Total, %	11[a]	4[a]	54[b]	31
(no./no.)	(5/47)	(2/48)	(51/94)	(58/189)
Experiment 2				
Total, %	18[a]	10[a]	66[b]	36
(no./no.)	(7/38)	(2/20)	(27/41)	(36/99)
Experiments 1 & 2				
Overall, %	14[a]	6[a]	58[b]	33
(no./no.)	(12/85)	(4/68)	(78/135)	(94/288)

[a,b]Within a row, percentages with different superscripts differ ($P < 0.01$).

Four general factors that determine conception rate 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. AI efficiency refers to factors affecting pregnancy rates due to AI technique. Mathematically, conception rate is the product these four factors, and all four of these factors need to be optimized in a dairy herd to achieve maximal conception rates. We recently conducted an experiment on a large custom heifer grower operation in Wisconsin in which AI efficiency was poor for two of the three herd inseminators in charge of AI during the study resulting in poor conception rates (Table 1). The unacceptably low conception rate in this field trial serves as a teachable moment for dairy farmers and the consultants in the dairy industry who advise them regarding the importance of managing the controllable factors responsible for fertility.

Pregnancy Loss

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 generally greater than 50% (Pursley et al., 1997b; Rivera et al., 2003a, b). 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.

Early embryonic loss in cattle is difficult to study because no sensitive test similar to that used for humans 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. 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 1).

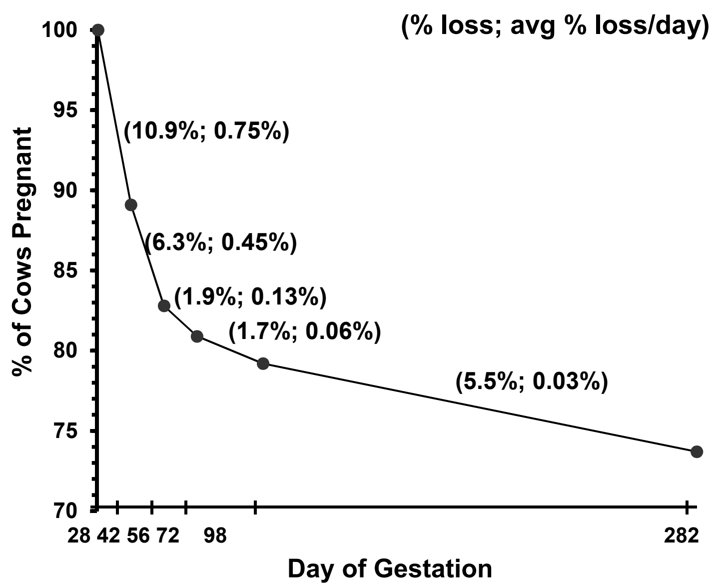

Figure 1. Pregnancy losses from 28 days post AI to calving in lactating dairy cows. Pregnancy status was determined using ultrasound at 28, 42, 56, 70, and 98 days post AI, and calving data were recorded at parturition. The conception rate at 28 days was 32%. (Adapted from Vasconcelos et al., 1997).

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 (Hansen et al., 1992). Beef cows losing weight have a higher incidence of early embryonic loss than those gaining weight suggesting 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 0.78 Mcal NEl per pound and 5%-7% total fat (DM basis).

A Novel Hypothesis

One possible physiologic mechanism for poor reproductive performance in lactating dairy cows is a reduction in circulating steroid hormone concentrations, particularly progesterone, which may be mediated by increased hepatic metabolism of steroids (Wiltbank et al., 2000). A novel hypothesis has been proposed that may account for many of the problems occurring in high producing dairy cattle (Wiltbank et al., 2000). High milk production is closely correlated with high dry matter intake (r = 0.88; Harrison et al., 1990). High dry matter intake in turn increases blood flow to the digestive tract due to requirements for digesting and absorbing the increased nutrient load. Anatomically, all blood flow from the gut must pass through the liver. It has been speculated that the digestive tract blood flow is so great during the extremely high blood flow associated with lactation that there is greatly increased liver blood flow. Increase liver blood flow would be expected to increase steroid metabolism because blood that passes through the hepatic circulation is essentially cleared of all steroids (Parr et al., 1993). Thus, high dry matter intake would result in increased metabolism of estrogens and progestins that regulate reproductive function.

Metabolism of steroids could dramatically impact various aspects of reproductive function. For example, metabolism of estradiol near the time of estrus would cause the ovulatory follicle to grow to a larger size. This is because increased estradiol secretion is required prior to induction of estrus. In addition, metabolism of progesterone could produce impaired embryonic development and potentially increased pregnancy loss. Although it is clear that lactating dairy cows have a very high steroid metabolism, the link between this high steroid metabolism and key aspects of reproductive physiology have not yet been definitively described. Research is ongoing that will ultimately support or disprove this hypothesis.

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