14,000 Kg and Beyond - Current Benchmarks and Future Challenges for Dairy Cattle Reproduction

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Take Home Messages

- Reproductive efficiency in dairy cattle currently is suboptimal due to poor artificial insemination service rates and poor conception rates.
- The rate at which cows become pregnant in a dairy herd is called the pregnancy rate and is determined by an interaction between service rate and conception rate.
- Service rate (the percentage of eligible cows that are inseminated during a 21-day period) is poor due to inadequate estrus detection, poor expression of estrus behavior, and a high incidence of anovular cows during early lactation.
- Conception rate (the percentage of cows that conceive after a single AI service) is poor in lactating dairy cows due to a high incidence of embryonic loss during early gestation.
- New reproductive management protocols may help maintain service and conception rates in lactating cows, but more research is needed to fully understand factors affecting poor fertility in dairy cattle.

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 (Vandehaar, 1998). Reproductive efficiency dramatically affects both of these factors. Thus, improving reproductive efficiency helps to maintain the maximal number of cows in a herd producing milk at optimal levels. The body of scientific literature on dairy cattle reproduction supports the idea that fertility of lactating dairy cows has decreased over the past 50 years (Lucy, 2001). The rate at which cows become pregnant in a herd is termed the pregnancy rate, and pregnancy rate is determined by an interaction between the service rate and the conception rate. Reproductive efficiency in dairy cattle currently is suboptimal due to poor artificial insemination service rates and poor conception rates and pregnancy rate can be improved by increasing either the service rate or the conception rate. This paper will overview recent research that has begun to address physiologic and management factors that affect both service and conception rates in lactating dairy cows.

■ Pregnancy Rate

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 Rate

Service rate is defined as the percentage of eligible cows that are inseminated 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 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 rate 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 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). Thus, management strategies that improve the service rate 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 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.

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 estrus 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 Rate

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.

To illustrate the advantages of programming cows to receive first AI service, we will compare reproductive data from two dairy farms in Wisconsin that employ two different strategies to initiate first postpartum AI (Figure 1). For both graphs, days in milk (DIM) at first breeding is plotted on the vertical axis (y-axis) and date of freshening (or time) is plotted on the horizontal axis (x-axis). Each square represents an observation, or a cow within the herd, and a bold line has been drawn horizontally at 100 DIM. In both plots, cows receiving first AI service before 100 DIM fall below the bold line, whereas cows receiving first AI service after 100 DIM fall above the bold line. The upper plot in Figure 1 shows the pattern of cows receiving first AI service for cows in a herd managed using visual detection of estrus for first postpartum AI service, whereas the lower plot shows the pattern of cows receiving first AI service for cows managed in a herd that uses a hormonal protocol for timed artificial insemination for first postpartum AI.

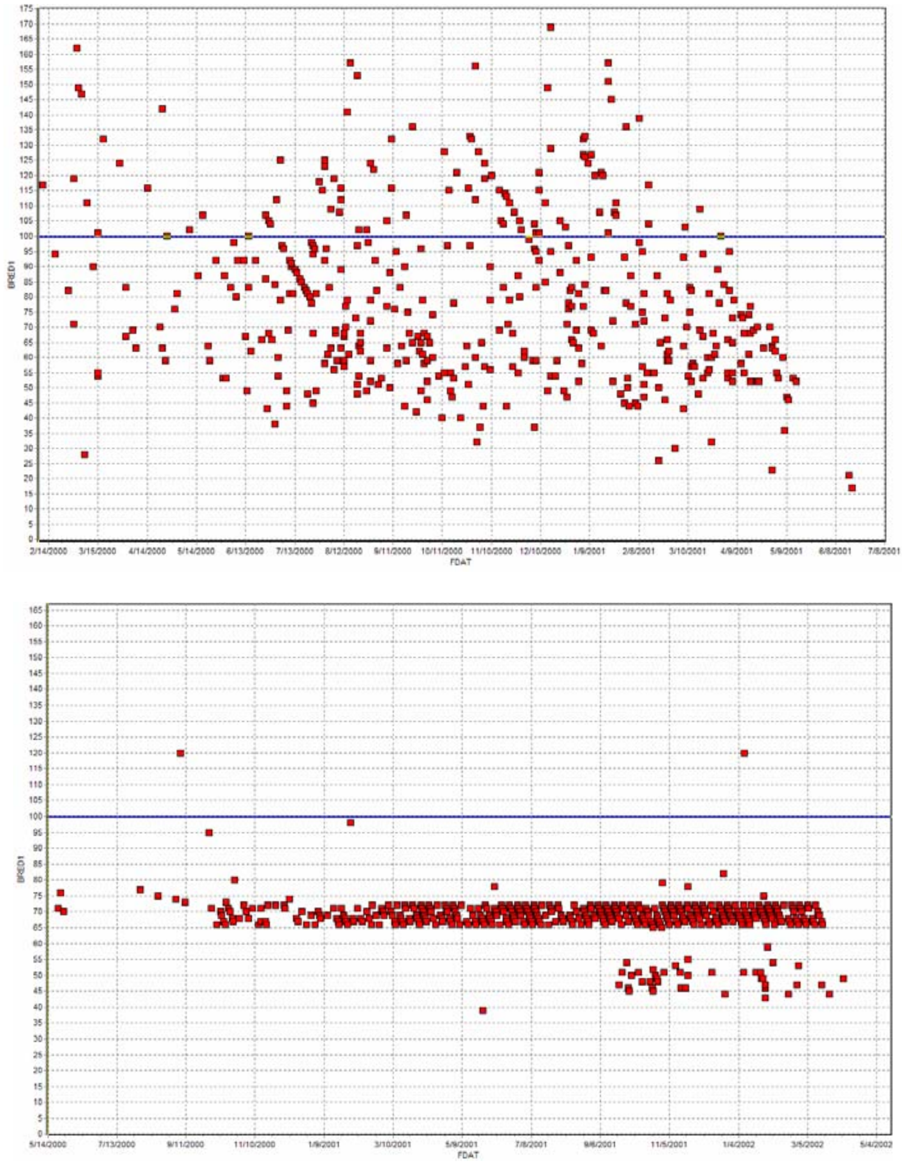

Figure 1. Days in milk at first breeding (y-axis) by date of freshening (x-axis) for cows managed using visual detection of estrus for first postpartum AI service (upper panel) and cows managed using Presynch and timed artificial insemination for first postpartum AI service (lower panel).

Nearly one-third of the cows in the herd shown in the upper panel of Figure 1 exceed 100 DIM before first AI. It should be obvious that none of these cows has a chance of becoming pregnant before 100 DIM because they have not yet been inseminated. If the upper graph reflects the reproductive performance to first AI on your farm, you should consider using a controlled breeding program to initiate first postpartum AI. Use of a controlled breeding program such as Ovsynch or Presynch/Ovsynch for initiating first AI exposes all cows in the herd to the risk of becoming pregnant at or very near the end of the VWP. In the lower panel of Figure 1, nearly all cows receive their first postpartum AI service between 65 and 73 DIM. In this scenario, the end of the VWP is roughly equal to the average day at first service for the entire herd. Of course, not all cows will conceive to first service; conception rates in lactating dairy cows are poor, and hormonal breeding programs increase pregnancy rate by increasing service rate, not conception rate. Figure 1 illustrates two extremes with regard to initiating first postpartum AI service. Many farms have adopted blended approaches in which cows receive AI to a standing estrus for a period of time after the VWP. Any cows not receiving AI by a predetermined DIM are enrolled into a controlled breeding protocol to receive a fixed-time AI service.

▪ Factors Affecting Conception Rate

Dairy cow fertility commonly is measured by calculating the percentage of cows that conceive after a single AI, also known as the conception rate. Conception rate 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 rate 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 rate cannot be attributed to differences in genetic selection or semen quality between heifers and lactating cows. Conception rates 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).

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.

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			Overall
	1	2	3	
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 ($P < 0.01$).

Early Embryonic 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 2).

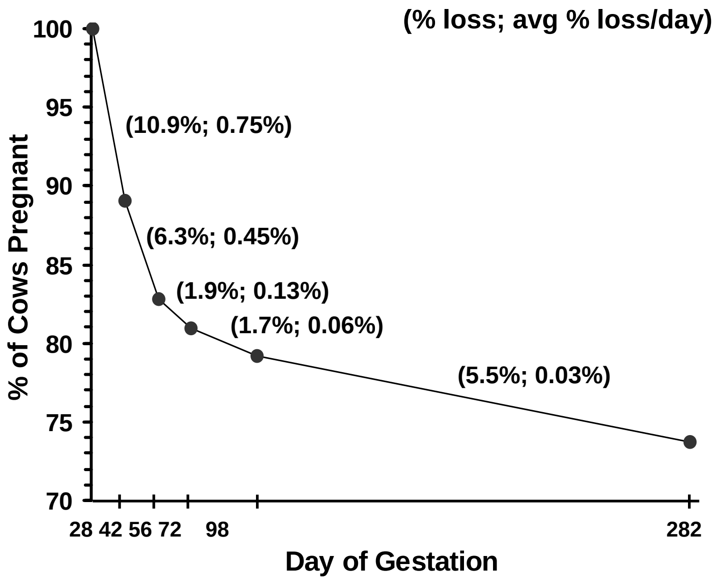

Figure 2. Pregnancy losses from 28 days post AI to calving in lactating dairy cows. Pregnancy status was determined using ultrasound at 28, 42, 56, 70, and 98 days post AI, and calving data were recorded at parturition. The conception rate at 28 days was 32%. (Adapted from Vasconcelos et al., 1997).

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. Increased 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.

■ Future Directions and Management Interventions

Submission of lactating cows for first AI using synchronization of ovulation and TAI has been widely adopted by the dairy industry in the United States. Although reliance on synchronization of ovulation and TAI for improving service rate to first AI reduces the impact of poor estrus detection efficiency, the high submission rate to first TAI often is followed by a time lag that can exceed 60 d before cows failing to conceive are re-inseminated (Fricke et al., 2003). Because AI conception rates of high producing lactating dairy cows are reported to be 40 % or less (Pursley et al., 1997a,b; Fricke et al., 1998; Jobst et al., 2000), 60 % or more of the cows that receive TAI will fail to conceive and, therefore, require a resynchronization strategy for aggressively initiating subsequent AI services. Hormonal resynchronization systems that program nonpregnant cows to receive subsequent TAI services need to be developed and assessed so that these strategies can be implemented to aggressively manage reproduction in lactating dairy cows on commercial dairies (Fricke, 2002; Fricke et al., 2003).

Recently, new results were reported from a key field trial that is one of the first to report the efficacy of initiating a systematic Resynch system at various intervals after first TAI under field conditions (Fricke et al., 2003). Our objective was to compare conception rate to first TAI service after a Presynch/Ovsynch protocol with conception rates after resynchronization of ovulation using Ovsynch at three intervals post TAI (Resynch). Lactating dairy cows (n =711) on a commercial dairy farm in North-central Wisconsin were enrolled into this study on a weekly basis beginning on May 10, 2001 and ending on May 30, 2002. All cows received a Presynch/Ovsynch protocol to receive first postpartum TAI as follows: 25 mg $PGF_{2\alpha}$ (d 18 ± 3; d 32 ± 3; d 46 ± 3); 50 µg GnRH (d 60 ± 3); 25 mg $PGF_{2\alpha}$ (d 67 ± 3) and 50 µg GnRH (d 69 ± 3) postpartum. All cows received TAI immediately after the second GnRH injection of the Presynch/Ovsynch protocol (d 0) as per a Cosynch TAI schedule. At first TAI, cows were randomly assigned to each of three treatment groups for resynchronization of ovulation (Resynch) using Ovsynch [50 µg GnRH (d -9); 25 mg $PGF_{2\alpha}$ (d -2) and 50 µg GnRH + TAI (d -0)] to induce a second TAI for cows failing to conceive to first TAI service. All cows (n=235) in the first group (Day 19) received a GnRH injection on d 19 post TAI and continued the Ovsynch protocol if diagnosed nonpregnant using transrectal ultrasound on d 26 post TAI. Cows (n=240) in the second (Day 26) and cows (n=236) in the third (Day 33) groups initiated the Ovsynch protocol if diagnosed nonpregnant using transrectal ultrasound on d 26 post-TAI or d 33 post-TAI, respectively. Results from this study are shown in Table 2.

Table 2. Conception rate to first timed artificial insemination (Presynch), second timed artificial insemination (Resynch), and pregnancy loss for cows conceiving to Presynch (Adapted from Fricke et al., 2003).

Treatment	Conception rate (%)		Pregnancy loss[1] (%)
	Presynch TAI	**Resynch TAI**	
Day 19	46.0[a]	23.3[a]	27.8[a]
Day 26	42.1[a]	33.9[b]	27.7[a]
Day 33	32.6[b]	37.8[b]	11.7[b]
Overall	40.2	32.0	23.4

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

[1]Cows conceiving to Presynch TAI that subsequently were diagnosed nonpregnant at pregnancy recheck.

Differences in conception rate to first TAI and pregnancy loss can be accounted for because the pregnancy check was conducted 26 d post TAI for the Day 19 and Day 26 groups, whereas the pregnancy check for the Day 33 group was conducted on 33 d post TAI. Most important, the Day 19 group had a lower conception rate to Resynch than did the Day 26 and Day 33 treatment groups. Based on these data, the Day 19 scheme should not be used to resynchronize cows for second service, whereas the Day 26 and 33 groups resulted in similar conception rates to Resynch. Studies are ongoing to further improve protocols for reproductive management of dairy cattle for first and subsequent AI services.

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