Pregnant vs. Open: Getting Cows Pregnant and the Money it Makes

Paul Fricke[1], Steve Stewart[2], Paul Rapnicki[2], Steve Eicker[3], and Michael Overton[4]

[1]University of Wisconsin-Madison, Department of Dairy Science, Madison, WI
[2]University of Minnesota, College of Veterinary Medicine, St. Paul, MN
[3]Valley Agricultural Software, King Ferry, NY
[4]University of California-Davis, Veterinary Medicine Teaching and Research Center, Tulare, CA

Introduction

In dairy farming like every other business, profit is the difference between expenses and revenue. The simplicity of this statement hides two problems. First, expenses occur before revenue is realized. Second, it is almost always easier to estimate expenses than it is to predict revenue. Unfortunately, it is necessary to spend money to make money. It is not a goal to maximize expenses, but neither is it a goal to minimize expenses. Reproduction on a dairy farm is a dramatic example of this concept. Reproductive expenses occur months-to-years before the revenue is realized. On many dairies, these expenses are carefully tracked and include: 1) semen and/or bulls, 2) labor and technicians for inseminations, 3) labor and drugs for treatments and synchronization, 4) labor for pregnancy examinations, and 5) facilities for sorting and handling these animals. It is not difficult to accurately estimate each of these expenses. Some dairies have even further analyzed these total expenses to estimate the cost per cwt of milk, the cost per cow per year, or even the cost per pregnancy. These efforts are misguided unless there is a simultaneous attempt to estimate the revenue that accrues from these expenses.

Estimating the Value of a Pregnancy

Estimating the future revenue from reproduction is extremely difficult. In short, we need to estimate the value of a pregnancy. A large number of known and unknown factors affect this estimate. Some factors are specific to the cow (i.e., her future production potential, age, and days-in-milk) and others factors affect all cows (i.e., milk price, feed price, and heifer and salvage costs). Even the “value of a pregnancy” can have multiple meanings. A cow that never becomes pregnant will exit the dairy at the end of her current lactation if not sooner. In simple terms, she will produce milk and consume feed until that day, then she will be sold for beef price, and a replacement will then occupy her space. That estimate might be the difference between replacement price and beef price. However, a more appropriate question is what is the value of getting a cow pregnant TODAY? This approach will help quantify the return on reproductive interventions, realizing that she might become pregnant in the future if she does not get pregnant today.

Commercial dairy managers spend much time and effort trying to achieve pregnancies and are quite reluctant to cull animals once they become pregnant (Grohn, Eicker et al., 1998; Grohn and Rajala-Schultz, 2000). For example, non-pregnant cows were 7.5 times more likely to be culled than pregnant cows (Grohn, Eicker et al., 1998). Culling for reproductive failure is one of the most frequent reasons cited by dairy farmers for involuntary culling (Esslemont and Kossaibati, 1997; Bascom and Young, 1998). Compared with other factors responsible for culling, reproduction deserves special attention because reproductive efficiency is a primary determinant of lactation length for cows that establish pregnancy and remain in the herd (Lehenbauer and Oltjen, 1998). Although there is considerable value in achieving a pregnancy, it is clear that establishing a pregnancy does not increase the value of individual cows equally. A short discussion of a method to estimate the value of a pregnancy (or the cost of an abortion) for a given cow follows.

Variables to be Considered when Estimating the Value of a Pregnancy for an Individual Cow

1) Future Expected Production

Future expected production has an impact on the value of a pregnancy. For example, compare two pregnant cows that are identical in stage of lactation, age, health, and in all other ways except their expected future production. The cow with the higher future expectation is more valuable in nearly all cases. Or compare two non-pregnant cows – again identical except for future expected production. More effort can be expended attempting to achieve pregnancy for the cow with the higher production potential, because her pregnancy will have more value under most circumstances. Granted, she will consume more feed, but the value of the marginal milk will far exceed the incremental feed costs.

2) Age of the Cow

Age of the cow has an impact on the value of the pregnancy. A young cow will be expected to survive in the herd longer, and although younger cows tend to milk less in the current lactation, they can be expected to milk more in subsequent lactations. As cows age, they appear to be more prone to certain diseases, and they are more likely to be culled than younger cows, so achieving pregnancy may not have as much long-term benefit as in younger cows.

3) Current Days in Milk

The normal decline in milk production after peak milk means that non-pregnant cows in later lactation have lesser value than identical cows in earlier lactation due to decreased income in the current lactation. Therefore, within any given cow a pregnancy that occurs later in lactation usually has lesser value than one that occurs earlier in lactation.

4) Stage of Pregnancy

The value of a pregnancy increases as gestation ensues. A cow later in gestation is closer to the beginning of a new lactation. One reminder of this would be the comparison of the fate of a cow that aborts at seven months in gestation versus one that aborts at 60 days in gestation.

5) Disease, Somatic Cell Count, etc.

While certain diseases or conditions may seal the fate of the individual cow, in many or most cases the impact of disease will be reflected in the production of the cow. Therefore, most of the difference in pregnancy value among cows due to disease is reflected in milk production.

6) Price of Milk

The price of milk affects how much incremental milk is required to offset the cash expense of replacing the cow. When milk prices are higher, it takes less milk to justify replacements.

However, using current elevated milk prices as predictors of future revenue is probably a mistake for making management decisions.

7) Value of Cull Animals and Cost of an Average Replacement

When a cow is replaced, there is a cash cost involved. This cost is the difference between the cash received for the culled cow, and the cash necessary to bring the average replacement into the milking herd. This cost should include some factor for death loss and housing and feeding springing heifers until they freshen.

The Value of a Pregnancy

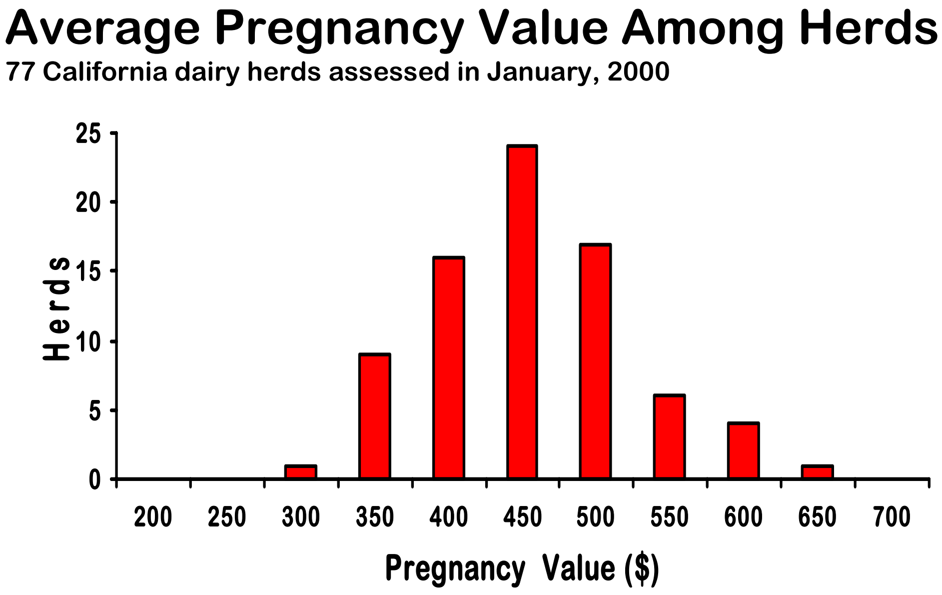

Figure 1. Distribution of average pregnancy values among 77 dairy herds in California assessed in January, 2000 and calculated using the PGVAL module of Dairy Comp 305.

Figure 1 shows the average pregnancy values among 77 dairy herds in California calculated using the PGVAL module of Dairy Comp 305 which uses the factors explained in the preceding discussion to model the value of a pregnancy. Average pregnancy value ranged from $300 to $650 among these farms with a mode of $450. Differences in reproductive efficiency among these farms accounts for much of the variation in Figure 1. Pregnancies are worth less per occurrence on farms with better reproduction because these farms have more overall pregnancies, whereas pregnancies are worth more per occurrence on farms with worse reproduction because these farms have fewer overall pregnancies. For herds under either scenario, establishing pregnancy is an extremely profitable management goal.

Pregnancy Rate

Pregnancy rate (**PR**), defined as the proportion of eligible cows that become pregnant each 21 day cycle, is the preferred parameter for evaluating reproductive performance. Pregnancy rate is a risk of success or failure per unit of time and is calculated by dividing the number of pregnancies within a 21-day cycle by the number of eligible cows present during that same 21-day period. Pregnancy rate is less biased than either days-open or calving-interval because it considers all eligible cows (not just successes) and usually contains less lag than calving interval. It is more sensitive to detecting recent changes in reproductive performance and provides useful information for most of the lactating cows. Based on database surveys, PR nationwide appears to average between 13-15%. However, there are a growing number of dairies that can maintain PR in the mid-20s with excellent reproduction.

The Economics of Improving Pregnancy Rate

There are three primary sources of economic gains that are the result of improvements in reproductive efficiency. The first (and the greatest) is the amount of marginal milk that should be realized. The second is the value of the additional calves that are born. And of course, there is a cash expense when the non-pregnant cow is replaced. The value of the additional marginal milk depends primarily on milk price and to a lesser degree, on the price of feed. Additionally, if we assume that the shape of the lactation curve is similar across different levels of production, higher producing herds have the most to gain from improvements in reproductive management due to the higher levels of milk that can be produced in early lactation compared with lower producing herds. Therefore, the economic gains from reproductive management are greatest during periods of high milk prices and are greater for herds with high levels of milk production.

To investigate the potential economic returns that may be realized by improving PR, a stochastic simulation model was built using Excel® spreadsheets and @RISK® simulation software (Overton, unpublished). Briefly, distributions describing conception risk (CR), service risk (SR), and rolling herd milk production averages, fit from data obtained from approximately 95 herds representing approximately 150,000 cows in California, are used to mimic the normal variation seen between and within dairies. Simulated pregnancy rates are obtained by multiplying randomly generated samples from the CR distribution and SR distribution. Herd specific data that may influence on-farm profitability, including dry period length, stillbirth losses, herd replacement risks, rolling herd milk production, milk price, pharmaceutical costs, labor costs, and feed costs are entered. The model's inputs, herd-specific data, and pre-set distributions are linked to breeding simulation tables for both the current and the proposed new reproductive program and are used to project cumulative pregnancy rate over 210 days of breeding. The proposed program modifies the current program's sampled SR, CR or both, by a given factor depending upon the change being evaluated. For example, one can mimic the potential beneficial effect of increasing SR by 10% in the program.

The input table, herd-specific data, and pregnancy risk projections are then linked to partial budgets (modifications of original work by Wolf) to compare predicted economic returns resulting from changes in daily milk yield as a result of changes in PR and calving interval. This partial budget uses work by Oltenacu et al. (1980) and Hady et al. (1994) to estimate daily milk change as a result of reproductive efficiency changes. Daily milk is estimated by using a modification of the Woods equation that predicts milk based on stage of the lactation curve. Stochastic modeling with @RISK® simulation software, utilizes Monte Carlo sampling of the pre-set distributions and runs 1000 iterations. The returns are expressed as dollars gained (or lost) per lactating cow per year as a result of the changes in PR. Results are displayed as either expected averages or as probability distributions, with a mean and 90% confidence interval.

Figures 2 and 3 are graphs from a set of simulations performed using the model. In these graphs, PR is manipulated by increasing SR and CR in a consistent manner to simulate increased PR's, starting with a baseline of only 8% and increasing to a theoretical 30%. The initial rolling herd average is set at approximately 18,000 lbs. Other assumptions used in the model include replacement cost of $2,200, breeding cost of $15/service including semen, heat detection and inseminator fees, feed cost of $158/ton of dry matter, newborn heifer calves at $450 and bull calves at $85, and an interest rate of 6%.

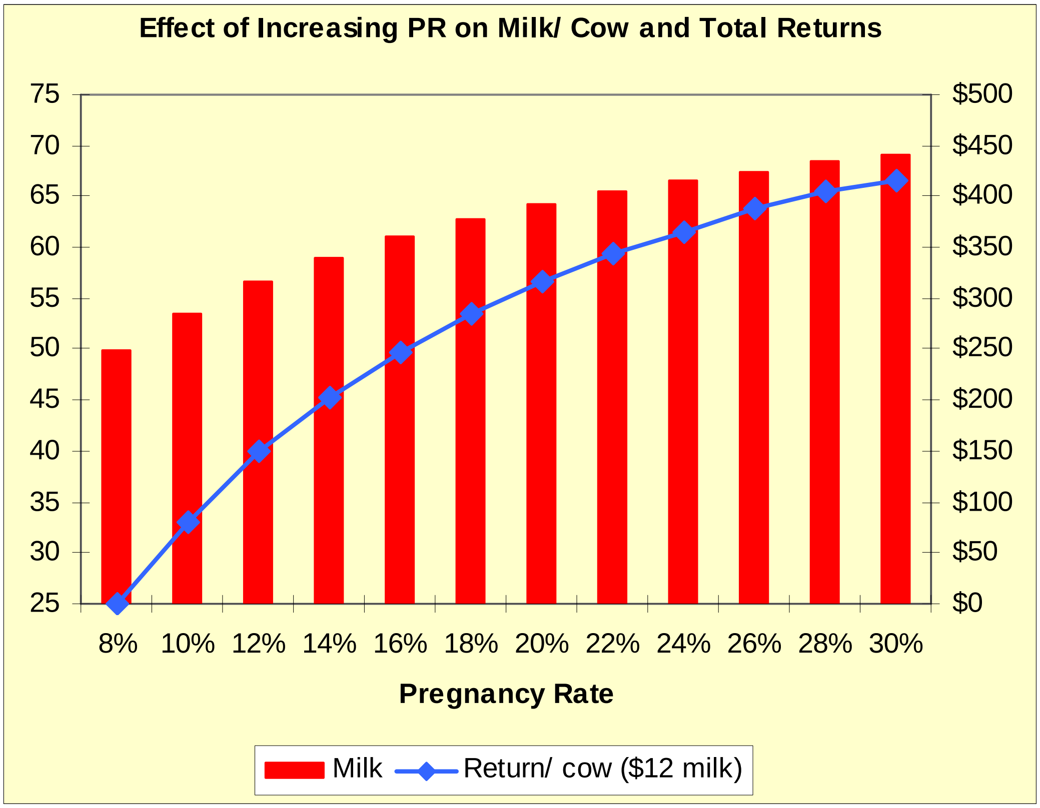

Figure 2. Predicted effect of increasing pregnancy rate on milk/ cow/ day and net marginal returns.

Predicted daily milk/cow in lactation as a result of changes in calving interval as well as predicted changes in economic returns as compared to the baseline values at 8% PR are shown in Figure 1. Daily milk production and total economic return increases with each unit of PR increase, but the magnitude of the change decreases as you approach a PR of 30%. For example, in a herd with a rolling herd average of ~18,000 lbs, under the assumptions given in the model, increasing PR from 10% to 12% is worth approximately $70/cow for the 2-unit change in PR when milk is worth $0.12/ lb. By comparison, improving from 26% to 28% PR is only worth about $17/cow for the same 2-unit change. Eventually, there is a point of diminishing returns above which there is no additional benefit to be gained by further increasing PR.

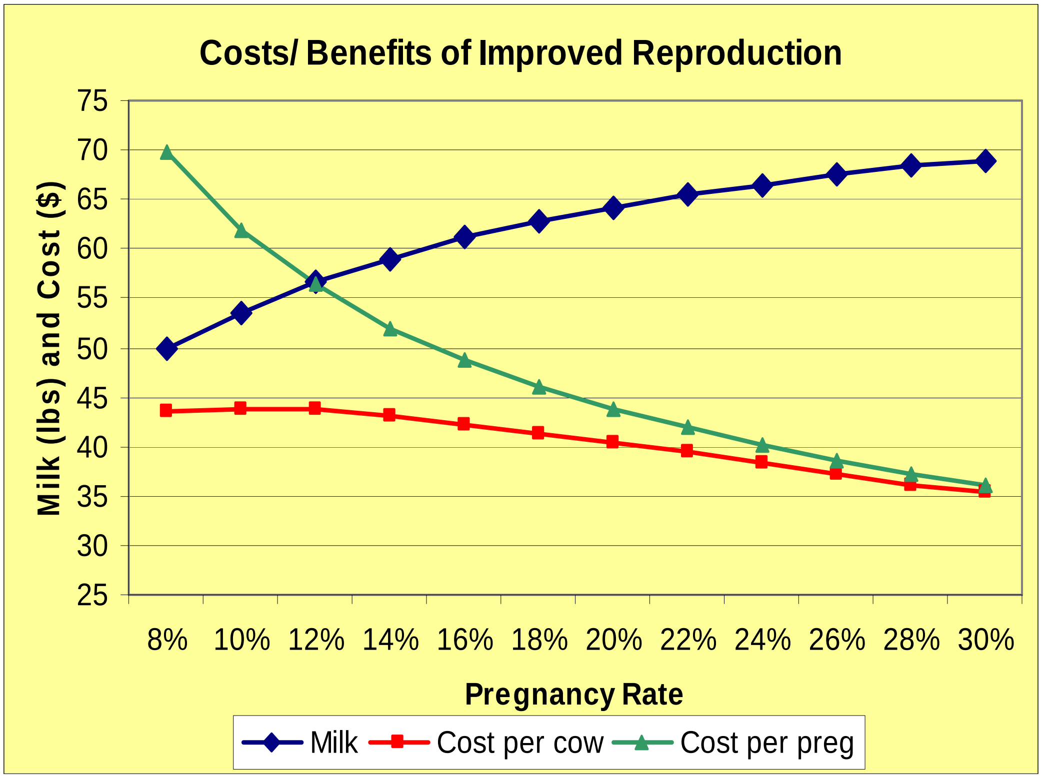

Figure 3. Effect of changes in reproductive efficiency on breeding management costs.

Figure 3 illustrates the effects of changes in reproductive efficiency on breeding management costs. In this graph, milk/cow is shown along with predicted reproductive management costs/cow and repro costs/pregnancy, based on a breeding cost of $15.00 as mentioned previously. The predicted costs/cow in the herd are relatively stable across time, but costs/pregnancy decrease drastically as the reproductive efficiency increases. On the far left, there is a wide spread between these costs, but as the dairy approaches 30% PR, the costs merge toward each other, again suggesting an eventual point of diminished marginal returns. This graph assumes that the increased PR is achieved with no incremental expenses (as reflected by the decrease in cost per cow as pregnancy rate is increased in Figure 3), which is rather unlikely.

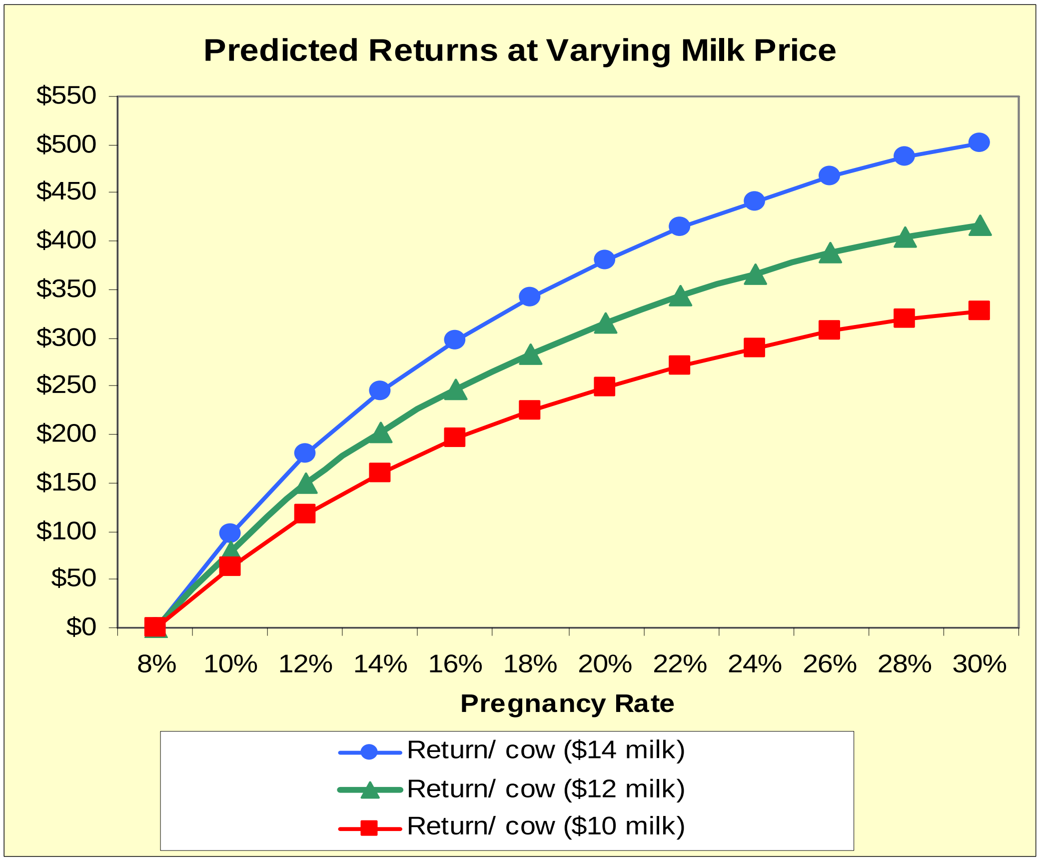

Figure 4. Effect of milk price on predicted economic returns from changes in reproductive efficiency.

Figure 4 illustrates the dramatic effect that milk price has on predicted economic returns from changes in reproductive efficiency. In this set of scenarios, changes in predicted marginal returns associated with changes in PR are modeled as in Figure 2, except we now have a comparison among 3 different milk prices. As shown in Figure 4, when milk is valued at $14/cwt, a change in PR from 16 to 18% is worth approximately $44. However, when milk is down to $10/cwt, this same change is worth only about $29.

In summary, sensitivity analyses of model results reveals that heat detection intensity has the largest potential impact on reproductive performance and economic returns in traditional AI breeding programs. Efforts at improving reproductive success should first focus on maximizing the herd's basic heat detection efficiency, since this area has such a large impact on reproductive success and is more easily improved compared to conception risk. For economic returns, the price of milk has the greatest effect by far, followed by the herd’s rolling herd average, heat detection intensity, conception risk, and price of feed. Of these parameters, we have the greatest opportunity to impact heat detection (service rate) compared with any of the other factors. Consequently, our emphasis in reproductive management should continue to be placed on improving service rates. Although almost any herd can potentially benefit from synchronization programs, as previously mentioned, high producing herds with heat detection issues are expected to realize the greatest potential return from adoption of improved reproductive management programs including synchronization and timed insemination.

Improving Pregnancy Rate

Since PR is a function of both service risk and conception risk, attempts to improve reproductive performance must consider both factors. Estrus detection efficiency refers to the risk for finding cows in estrus. In reproductive management, the better term to consider is submission risk (SR) since only the cows that are found in estrus and inseminated affect our goal of more pregnancies. As previously mentioned, any attempt to improve PR must consider both SR and CR. SR can be easily manipulated with the implementation of estrus or ovulation synchronization protocols, but CR is, in most circumstances, much more difficult to positively impact.

Implementation of a systematic synchronization protocol on a dairy can be achieved by answering two simple questions: 1) how will cows be submitted for first service, and 2) how will cows that fail to conceive to first service be re-enrolled for second and subsequent services. Three examples showing data from farms in Wisconsin are presented to visually represent three representative ways that farms are approaching these management scenarios.

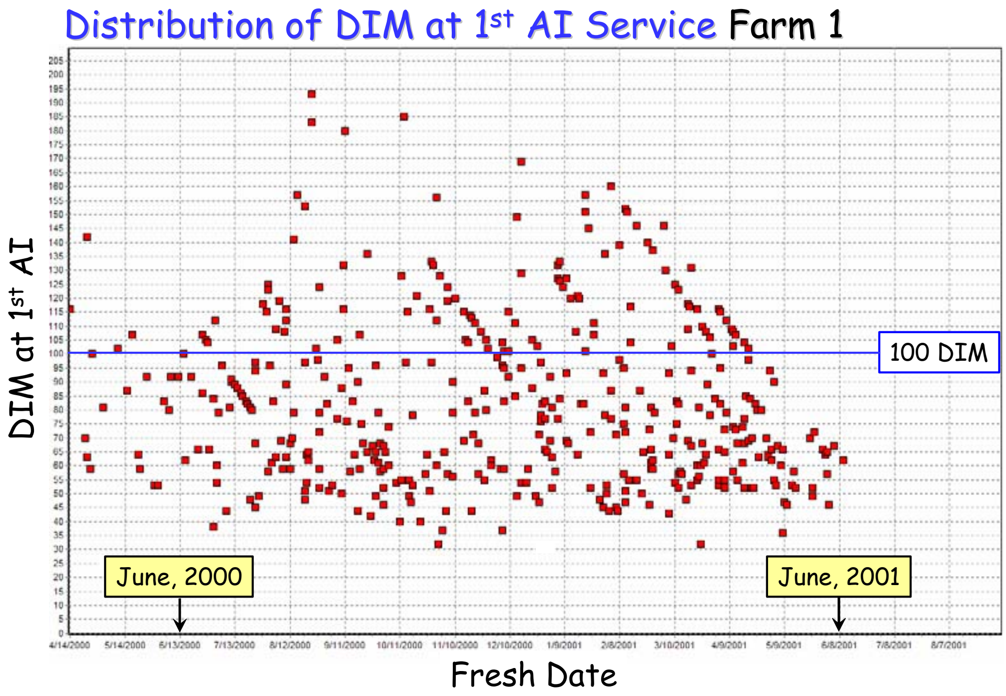

Figure 5. Days in milk at first breeding (y-axis) by date of freshening (x-axis) for cows managed using primarily visual detection of estrus for first postpartum AI service. In this herd, nearly one-third of the cows are serviced for the first time after 100 DIM.

Figure 5 illustrates the inefficiency of estrus detection for submitting cows to first AI service for a 500-cow herd managed using primarily visual detection of estrus for first postpartum AI service. Only ~10% of cows in this herd receive first insemination after a timed AI. Days in milk (DIM) at first breeding is plotted on the vertical axis (y-axis) and date of freshening (i.e., 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. 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. Nearly one-third of the cows in the herd shown in Figure 5 exceed 100 DIM before first AI service. 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. Although most dairy producers identify a set duration for the VWP, breeding decisions for individual cows often occur before the VWP elapses. The VWP for the farm illustrated in Figure 5 is 50 DIM; however, many cows are submitted for AI before this time. The decision to AI a cow for the first time postpartum is determined based on when (or if) a cow is detected in estrus rather than on a predetermined management decision. In such instances, the cow is managing the decision to breed rather than the dairy manager. The decision to inseminate a cow before the VWP elapses is motivated by one factor, and that factor is fear. Most producers fear the decision to not breed a cow detected in estrus because she may not be detected in estrus again until much later in lactation. Unfortunately, this risk is often realized on dairies that rely on visual estrus detection for AI because of poor estrus detection by dairy personnel and poor estrus expression by lactating dairy cows. Recent reports have estimated that 20-30% of lactating cows were not cycling by 60 DIM (Pursley et al., 2001; Gumen et al., 2003). If Figure 5 reflects the reproductive performance to first AI on your farm, you should consider using a controlled breeding program to initiate first postpartum AI service.

Implementation of Ovsynch using the "Back-Door" Approach

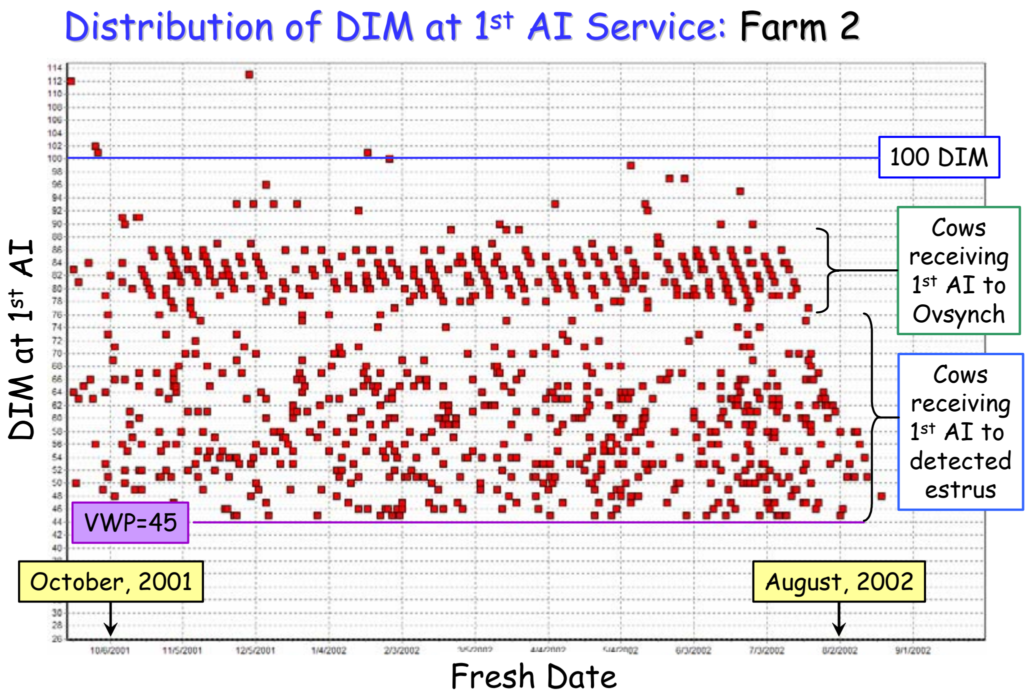

Figure 6. Days in milk at first breeding (y-axis) by date of freshening (x-axis) for cows managed using a combination of visual detection of estrus and Ovsynch and timed AI for first postpartum

AI service. In this herd, cows failing to be detected in estrus during the first 25 days after the voluntary waiting period initiate Ovsynch beginning around 70 days in milk.

Figure 6 illustrates a 1,600-cow herd managed using a combination of visual detection of estrus and Ovsynch and TAI for first postpartum AI service. Similar to Figure 5, DIM at first breeding is plotted on the vertical axis (y-axis) and date of freshening (i.e., time) is plotted on the horizontal axis (x-axis). In this herd, cows failing to be detected in estrus during the first 25 days after the voluntary waiting period (d 45 to 70) initiate the first GnRH injection of Ovsynch beginning around 70 days in milk and receive a TAI 10 d later around 80 DIM. This system is sometimes referred to as the "back-door" Ovsynch approach because Ovsynch is used as a "clean-up" system for cows failing to be detected in estrus. It is not uncommon for Ovsynch to result in a lower conception risk than AI to a detected estrus when analyzing and comparing conception risks in a herd using the back-door Ovsynch approach. This is likely because cows fail to be detected for reasons due to sickness or injury, or because these cows are anovular. Thus, the expectation should be for a lower conception risk to Ovsynch because a subset of cows with poor fertility is exposed to Ovsynch, whereas normally cycling cows are inseminated to a detected estrus.

Programming Cows for First Postpartum AI using Presynch/Ovsynch

The first results with Ovsynch (Pursley et al., 1995) indicated that all non-pregnant cows could be enrolled into the protocol regardless of their stage during the estrous cycle. Subsequent results from Vasconcelos et al. (1999) using lactating dairy cows, and those of Moreira et al. (2000) using dairy heifers showed that initiation of Ovsynch between days 5 to 12 of the estrous cycle may result in improved conception risk over the original Ovsynch protocol. Hormonal pesynchronization of cows to group randomly cycling cows to initiate Ovsynch between days 5 to 12 of the estrous cycle can be accomplished using two injections of $PGF_{2\alpha}$ administered 14 days apart before initiation of the first GnRH injection of Ovsynch. A presynchronization strategy in which two injections of $PGF_{2\alpha}$ administered 14 d apart preceded initiation of Ovsynch by 12 to 14 d has shown to improve conception risk in lactating dairy cows compared to Ovsynch (Moreira et al., 2001; Navanukraw et al., 2004). For cycling cows, conception risk increased from 29% for Ovsynch to 43% for Presynch cows; however, no statistical treatment difference was detected when all cows (cycling and anovular) were included in the analysis). Thus, use of Presynch for programming lactating dairy cows to receive their first postpartum TAI can improve first service conception risk in a dairy herd.

Implementation of a Presynch/Ovsynch Protocol

Use of a controlled breeding program such as Presynch/Ovsynch for initiating first AI service exposes all cows in the herd to the risk of becoming pregnant at or very near the end of the VWP. Figure 7, illustrates a 1,100-cow herd managed using the Presynch/Ovsynch schedule shown in Table 1. Similar to Figures 5 and 6, DIM at first breeding is plotted on the vertical axis (y-axis) and date of freshening (i.e., time) is plotted on the horizontal axis (x-axis). In this herd, 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 risk by increasing service risk, not fertility.

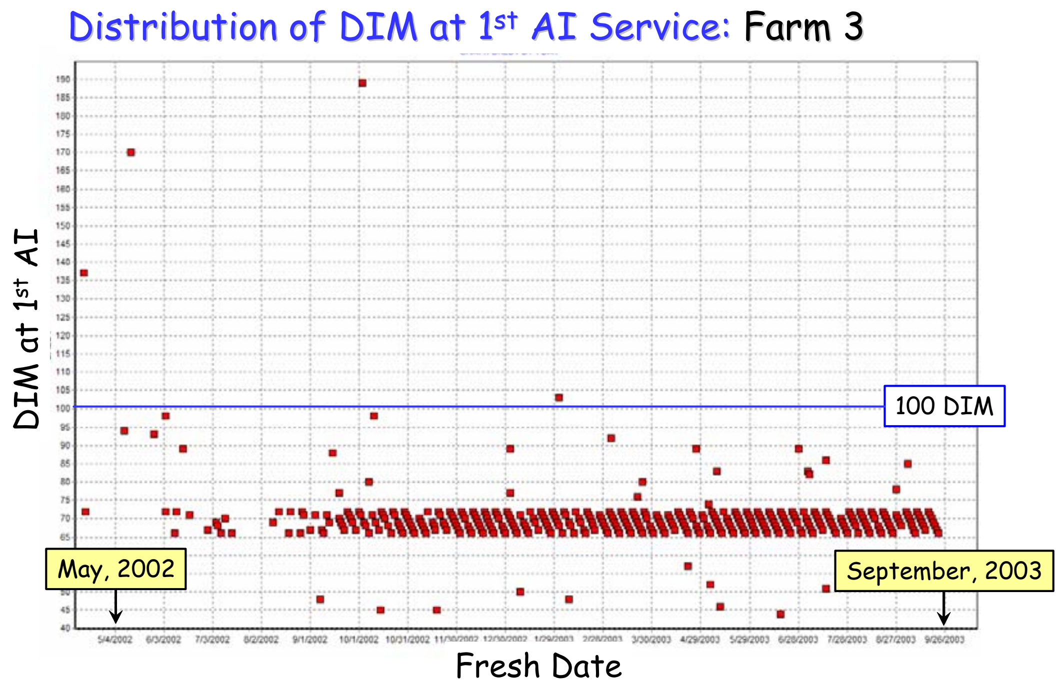

Figure 7. Days in milk at first breeding (y-axis) by date of freshening (x-axis) for cows managed using Presynch/Ovsynch and timed AI for first postpartum AI service. In this herd, 98% of cows receive a timed AI for first service and less than 5% of cows receive AI after a detected estrus.

Programming First and Second AI Service: Presynch and Resynch

Aggressive reproductive management comprises three strategies that can be implemented early during the breeding period of lactating dairy cows: 1) submit all cows for first postpartum AI service at the end of the voluntary waiting period, 2) identify non-pregnant cows post-AI, and 3) return cows failing to conceive to first AI service to second AI service. Timely rebreeding of lactating dairy cows that fail to conceive to first AI service is essential for improving reproductive efficiency and profitability in a dairy herd. Because AI conception rates of high producing lactating dairy cows are reported to be 40% or less (Pursley et al., 1997; Fricke et al., 1998), 60% or more of lactating cows will fail to conceive to a given AI service. Now that it is relatively easy to program cows for first postpartum AI service, many producers are asking how best to identify non-pregnant cows and program them for second and subsequent AI services.

We conducted a field trial to test such a system on a dairy (Fricke et al., 2003). Our objective was to compare conception risk to first TAI service after a modified Presynch protocol with conception risks 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 modified Presynch protocol to receive first postpartum TAI as follows: 25 mg $PGF_{2\alpha}$ (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 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 non-pregnant 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 non-pregnant using transrectal ultrasound on d 26 post-TAI or d 33 post-TAI, respectively.

Results from this study argue against the D19 group as a viable resynchronization strategy based on a poor PR/AI after the Resynch TAI. A veterinarian who can accurately determine pregnancy status via rectal palpation 33 d post TAI could incorporate the D33 Resynch strategy without reliance on transrectal ultrasound for early pregnancy diagnosis. Assuming that administration of GnRH to pregnant cows 33 d after TAI does not induce iatrogenic embryonic loss, all cows could be administered GnRH at 33 d after TAI. Cows would then receive $PGF_{2\alpha}$ at a nonpregnancy diagnosis via rectal palpation conducted one week later. One possible hormone injection and timed AI schedule based on this research is shown in Table 1.

Table 1. One possible hormone injection and timed artificial insemination schedule for the Presynch/Ovsynch protocol for first TAI and Resynchronization for second TAI based on the results of Fricke et al., 2003.

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
		PGF				
		PGF				
		GnRH				
		PGF		GnRH+TAI		
		GnRH				
		PG+PGF		GnRH+TAI		

PGF = prostaglandin $F_{2\alpha}$, **GnRH** = gonadotropin-releasing hormone, **TAI** = timed artificial insemination, **PG** = pregnancy diagnosis

It is possible that the optimal resynchronization strategy for this herd may not perform optimally in other herds. A difference in populations with varying proportions of cows exhibiting two or three follicular waves per cycle has been suggested to impact conception risk to Ovsynch (Cordoba and Fricke, 2002). Further research is needed to develop successful resynchronization strategies for managing reproduction in lactating dairy cows.

Protocol Compliance is Key

The physiology that underlies the hormonal protocols that allow for timed AI such as Ovsynch and Presynch has been researched extensively and continues to be a topic of active investigation among dairy scientists studying reproductive biology. Physiologic scenarios leading to reduced performance of these protocols or the mechanisms by which these protocols may improve reproduction have been reported and reviewed (Cordoba and Fricke, 2002; Navanukraw et al., 2004). Both scientific research and anecdotal evidence supports the idea that Ovsynch and Presynch work well for high producing dairy cows in North America managed under confinement systems. Many factors affect reproductive performance, and many consultants have observed a wide range of performance among farms that have adopted the exact same protocol. Reduced performance of these protocols is rarely due to physiologic responses of individual cows to the hormonal protocol, but almost always can be attributed to compliance issues at the farm level.

To achieve success with these hormonal protocols, each farm has to develop a system to administer the correct injections to the correct cows on the correct days, then subsequently AI the correct cows. A standard Presynch/Ovsynch protocol for submitting cows for first AI service requires that each individual cow receive 5 consecutive injections at the appropriate injection intervals. Failure to administer any one of these 5 injections dramatically or completely reduces the conception risk to first timed AI and will ultimately result in a delay in establishing pregnancy. For a farm that achieves an injection protocol accuracy of 95% on any given injection day (e.g., 95% of the cows that should get an injection actually get the correct one), on average nearly one in four cows will not successfully complete the 5 injections of the Presynch/Ovsynch protocol (e.g., 0.95 x 0.95 x 0.95 x 0.95 x 0.95 = 0.77). Thus, nothing less than 100% protocol compliance should be considered acceptable. Thus, farms that cannot achieve near 100% protocol compliance should consider focusing on other methods to improve SR including heat detection and heat detection aids.

References

Bascom, S. S. and A. J. Young. 1998. Summary of the reasons why farmers cull cows. J. Dairy Sci. 81:2299-2305.

Cordoba, M. C. and P. M. Fricke. 2002. Initiation of the breeding season in a grazing-based dairy using synchronization of ovulation. J. Dairy Sci. 85:1752-1763.

Esslemont, R. J. and M. A. Kossaibati. 1997. Culling in 50 dairy herds in England. Vet. Rec. 140:36-39.

Fricke, P. M., J. N. Guenther, and M. C. Wiltbank. 1998. Efficacy of decreasing the dose of GnRH used in a protocol for synchronization of ovulation and timed AI in lactating dairy cows. Theriogenology 50:1275-1284.

Fricke, P. M., D. Z. Caraviello, K. A. Weigel, and M. L. Welle. 2003. Fertility of dairy cows after resynchronization of ovulation at three intervals after first timed insemination. J. Dairy Sci. 86:3941-3950.

Grohn, Y. T., S. W. Eicker, B. Ducrocq, and J. A. Hertl. 1998. Effect of diseases on the culling of Holstein dairy cows in New York State. J. Dairy Sci. 81:966-978.

Grohn, Y. T. and P. J. Rajala-Schultz. 2000. Epidemiology of reproductive performance in dairy cows. Anim. Reprod. Sci. 60-61:605-614.

Gümen, A., J. N. Guenther, and M. C. Wiltbank. 2003. Follicular size and response to Ovsynch versus detection of estrus in anovular and ovular lactating dairy cows. J. Dairy Sci. 86:3184-3194.

Hady, P. J., J. W. Lloyd, T. B. Kaneene, and A. L. Skidmore. 1994. Partial Budget Model for Reproductive Programs of Dairy Farm Businesses. J. Dairy Sci. 77:482-491.

Lehenbauer, T. W. and J. W. Oltjen. 1998. Dairy cow culling strategies: making economical culling decisions. J. Dairy Sci. 81:264-271.

Moreira, F., R. L. de la Sota, T. Diaz, and W. W. Thatcher. 2000. Effect of day of the estrous cycle at the initiation of a timed artificial insemination protocol on reproductive responses in dairy heifers. J. Anim. Sci. 78:1568-1576.

Moreira, F., C. Orlandi, C. A. Risco, R. Mattos, F. Lopes, and W. W. Thatcher. 2001. Effects of presynchronization and bovine somatotropin on pregnancy rates to a timed artificial insemination protocol in lactating dairy cows. J. Dairy Sci. 84:1646-1659.

Navanukraw, C., L. P. Reynolds, J. D. Kirsch, A. T. Grazul-Bilska, D. A. Redmer, and P. M. Fricke. 2004. A modified presynchronization protocol improves fertility to timed artificial insemination in lactating dairy cows. J. Dairy Sci. 87:1551-1557.

Oltenacu, P. A., T. R. Rounsaville, R. A. Milligan, and R. L. Hintz. 1980. Relationship Between Days Open and Cumulative Milk Yield at Various Intervals from Parturition for High and Low Producing Cows. J. Dairy Sci. 63:1317-1327.

Pursley, J. R., M. O. Mee, and M. C. Wiltbank. 1995. Synchronization of ovulation in dairy cows using $PGF_{2\alpha}$ and GnRH. Theriogenology 44:915-923.

Pursley, J. R., M. R. Kosorok, and M. C. Wiltbank. 1997. Reproductive management of lactating dairy cows using synchronization of ovulation. J. Dairy Sci. 80:301-306.

Pursley, J. R., P. M. Fricke, H. A. Garverick, D. J. Kesler, J. S. Ottobre, J. S. Stevenson, and M. C. Wiltbank. 2001. NC-113 Regional Research Project. Improved fertility in anovulatory lactating dairy cows treated with exogenous progesterone during Ovsynch. J. Dairy Sci. (Midwest Branch ADSA Meetings, Des Moines, IA, Abstract 251 p. 63).

Vasconcelos, J. L. M., R. W. Silcox, G. J. Rosa, J. R. Pursley, and M. C. Wiltbank. 1999. Synchronization rate, size of the ovulatory follicle, and pregnancy rate after synchronization of ovulation beginning on different days of the estrous cycle in lactating dairy cows. Theriogenology 52:1067-1078.

Wolf, C.A. 1999. Analyzing reproductive management strategies on dairy farms, Staff Paper 99-23, Department of Ag Econ, Michigan State University.