Economics of the Voluntary Waiting Period and Value of a Pregnancy

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INTRODUCTION

We all know that it is important to get cows pregnant in a timely matter. But some cows are more important to get pregnant than others. It is helpful to first determine the optimal day of conception for each individual cow. This provides the target of the reproductive program. Profitability is maximized when every cow gets pregnant at her optimal time after calving (at a low cost). In this paper the optimal time of conception, the optimal time of first service, the insemination value, and the value of a new pregnancy are discussed. Sources are both a brief review of the literature and results obtained from new cash flow projections. The results highlight the importance of conception at the optimal time after calving; which is dependent on cow performance, management, and prices. Furthermore, they are a step towards obtaining daily economic information on individual cows that help with prioritization of breeding decisions.

BRIEF LITERATURE REVIEW

Historically, the optimal calving interval has been 12 to 13 mo (Stevenson, 2004). Because reproductive efficiency is not completely controlled, the goal was to breed cows as soon as possible after calving when the involution of the uterus and return to cyclicity were more or less completed. With the advent of rbST and higher producing, more persistent cows through improvements in genetics and management; the optimal time of conception, time of first service, and voluntary waiting period (**VWP**) are being reconsidered.

Many researchers have studied or discussed one or more aspects of fertility, milk production, and economics associated with early breeding (Weller and Folman, 1990; Van Amburgh et al., 1997; Dekkers et al., 1998; Arbel et al., 2001; Tenhagen et al., 2004; McGrath et al., 2003; Sørensen and Østergaard, 2003; Stevenson, 2004; Stevenson and Phatak, 2005; LeBlanc, 2007). In summary, fertility early in lactation has played a major role in the decision when to start breeding cows. Fertility probably peaks around 80 to 100 d after calving. There is some support that higher producing cows might benefit from a longer VWP, especially first lactation cows; but this conclusion is not shared by all authors.

Many reproductive specialists have recommended a 70-d VWP for first AI after a PreSynch + Ovsynch program (Prentice, 2006). Some of this delay is motivated by the observation that first lactation cows that conceive early may not reach their production potential in the second lactation, because they have not had adequate time to grow and restore body condition (Olson, 2004).

Recently, several studies have shed some light on the actual VWP in practice and the factors dairy producers consider when making first breeding decisions. In a study of 33 million first services from 1995 to 2005, Miller et al. (2007) found that first lactation cows had longer days to first service (**DFS**) than second lactation cows, but only by a few days. Holsteins that calved in March and April were serviced later than those that calved during other months. Cows that calved during September and October were serviced the earliest. Median DFS was between 87 and 97 d. Herds that were believed to have synchronized breeding had 17 fewer DFS than herds that bred based on traditional estrous detection. Median VWP was 56 d.

DeJarnette et al. (2007) surveyed approximately 4000 herds in a young sire progeny testing program about their VWP practices. The average VWP reported was 56 d. Among the responding herds, 64 % changed the VWP for postpartum health (50 %), season (18 %), milk yield (18 %), lactation number (14 %), and other reasons (14 %). The most cited reason for extending the VWP was a difficult birth or early postpartum metabolic diseases, but observed DFS were not significantly different from herds that did not alter the VWP for these reasons. In Holstein herds that changed their VWP based on milk yield, the high producing group was first serviced on average 14 d later than the low producing group. Many producers said that cows were assigned a VWP (in days) equal to the pounds of milk at peak production. Of the herds that changed the VWP based on lactation number, 65 % used a longer VWP for first lactation cows (74 d) compared with older cows (57 d). Actual difference in interval to first service was 9 d. But 35 % of these herds used a shorter VWP for first lactation cows (55 d) compared to older cows (70 d). Here the actual difference in time to first service was 7 d. Of the herds that considered season in their VWP, 78 % did so to avoid insemination, calving, or both during the summer. Mostly, cows that calved during July through September had longer DFS. Also, 22 % of these herd owners said that the VWP was altered to avoid calving during the winter.

Caraviello et al. (2006) reported on a survey of 153 herds in a progeny testing program. They reported an average VWP of 52 d for first lactation cows and 53 d for greater lactation cows. Of the respondents, 27 % considered milk production for the VWP and 24 % considered body condition score. In contrast, only 7 % of the respondents in the survey by DeJarnette et al. (2007) reported that the VWP was altered based on body condition score. Their survey did not contain a specific question about the effect of body condition score, however, so this factor may be underreported.

The value of a new pregnancy is closely related to optimal breeding decisions and was recently reviewed and calculated by De Vries (2006). Under assumptions for a typical Holstein herd in the US, the value of a new pregnancy was on average $278. Abortions, or the loss of pregnancy, had an average cost of $555.

ECONOMIC PRINCIPLES: CASH FLOW PROJECTIONS

The goal of optimal breeding decisions is to maximize profit per slot per year. Therefore, decisions to inseminate and replace cows should be based on expected future income or cash flows. Future cash flows for the cow currently in the slot are determined from all revenues and costs in the remainder of the lactation, as well as revenues and costs in the following lactations (if any), and revenues and costs of the future replacement heifers in the slot. Future cash flow projections also depend on future breeding and culling decisions.

More advanced computer programs that project cash flows decide whether it is optimal to cull a cow for failure to conceive at every stage of her life. Similarly, these computer programs decide whether it is optimal to breed a cow at a future breeding opportunity or not. These optimal sequential decisions (breed vs. do not breed, keep vs. cull at every stage of the cow's life) are typically made with a technique called dynamic programming. This is a search algorithm that efficiently determines optimal breeding and culling decisions now and in the future, and consequently finds the maximum present value of the future cash flows. The present value of the cash flows from the alternative, non-optimal decision is also calculated.

Once the present values of the future cash flows of both the decision to breed the cow and the decision to not breed the cow are calculated, the best decision is simply the one that leads to the highest present value. The insemination value is the extra profit expected from breeding the cow at the current breeding opportunity compared to not breeding the cow (but making optimal breeding and replacement decisions in the future). If the insemination value is less than $0, then the optimal decision is to not breed the cow at the breeding opportunity. The cow with the highest insemination value is the most important one to breed if a breeding opportunity exists.

Similarly, optimal culling decisions are based on retention values (also called retention pay-off (**RPO**), or future profitability). The retention value is the extra profit from keeping the current cow in the herd until her optimal time of replacement, considering the risk of premature culling, compared to immediate replacement with a heifer. When the retention value is greater than $0, the cow currently in the slot should be kept, at least until the next decision moment. When the retention value is less than $0, the cow should be culled. Optimal culling decisions depend on breeding decisions and optimal breeding decisions depend on culling decisions.

A third result from the dynamic programming calculations is the value of a pregnancy for individual cows. The value of a pregnancy can be thought of as the difference in the present value of future cash flows of two identical cows, with the only difference being that one is (newly) pregnant and the other one is open. It is equal to the difference in the retention values of both cows, provided both are positive (De Vries, 2006).

By keeping track of all future cash flow predictions in the dynamic programming algorithm, it is possible to determine the optimal day of conception for individual cows. This is the optimal case and the ideal situation, if we had 100 % fertility control. The optimal breeding policy with normal fertility is assumed in the case of an abortion, in future lactations, and for their replacement heifers. The optimal day of first service in this paper assumes the dairy producer can create the first breeding opportunity after calving when desired, such as with a synchronized breeding protocol.

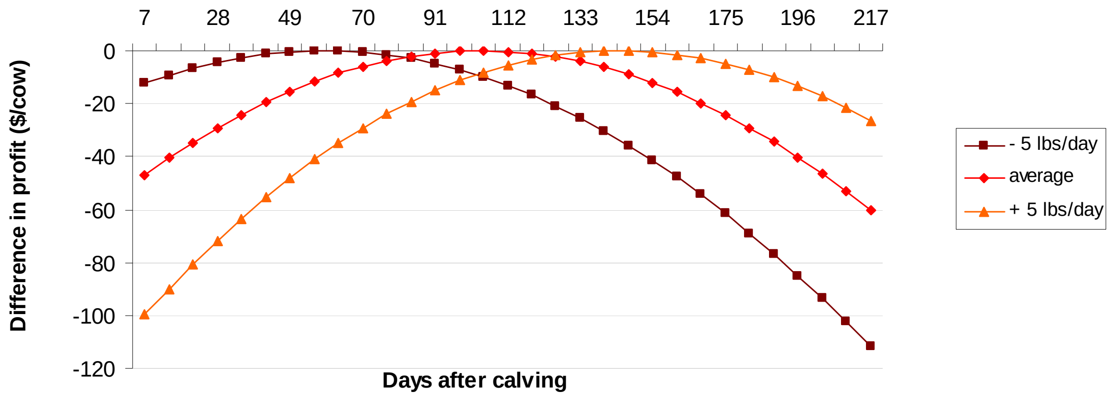

Figure 1. Economic loss ($/cow) caused by conception earlier or later after calving compared to the optimal day of conception for first lactation cows. Results for three lactation curves are shown: average curve, + 5 lb/d and – 5 lb/d compared to the average.

DEFAULT ASSUMPTIONS

The computer program described in De Vries (2006) was extended to make breeding and culling decisions weekly instead of monthly. A maximum of 104 wk in the current lactation are considered. Open cows may be inseminated up to 64 wk in the current lactation. The gestation period is 40 wk. The performance of cows in the eighth lactation is the same as for cows in later lactations. Replacement heifers are purchased when needed. Replacement heifers were expected to perform like average cows. The program determines optimal breeding and culling decisions now and in the future, as well as the optimal days of conception and first service, insemination values, and values of pregnancy.

The computer program uses many inputs to best mimic actual prices and the performance of cows. Accurate estimation of future cash flows involves predictions of (at least) milk yield, days dry, risk of pregnancy and abortion, risk of death and other risks that cause premature culling, feed intakes, bodyweights, labor needs, veterinary costs, as well as prices. Some key inputs were: 60 % service rate, maximum 35 % conception risk, $20 breeding cost, $2000 heifer price, $0.42 cull price per lb of body weight, $0.18/lb milk price, $0.11/lb lactating cow feed cost. No attempt was made to represent an *average* herd.

Lactation curves were based on data from a herd in Florida. First lactation cows peaked at d 123 with 70.28 lb of milk. Total milk yield in 305 d was 20,067 lb. Second and third lactation cows had very similar lactation curves with a peak of 87 lb at d 74. Total milk yield in 305 d was approximately 22,800 lb. Later lactation curves were taken to be the same as third lactation curves. Thus, first lactation curves peaked later, at a lower yield, and were more persistent.

Conception risk increased from 13 % at d 14 to 35 % at d 84 and then slowly decreased again to 26 % at d 365 after calving, partly based on results from De Vries and Risco (2005). Older cows had slightly lower conception risks. Cows were assumed to have a breeding opportunity every 3 wk.

Seasonality in milk production and conception risk was included when mentioned in the results. Daily milk yield for all cows was smoothly decreased to 90 % in July and August. Conception risk was smoothly decreased to 80 % in July and August (i.e., 80 %*35 % = 29.8 % at d 84) . Both milk production and conception risk were assumed to be 100 % of the default from December through March.

The effect of lactation length on cow performance in future lactations was not included in the analyses. Cows that conceive late in lactation might have greater body condition scores at calving and consequently may be more at risk for health problems and reduced milk production in the next lactation. Also the effects of calving problems or metabolic diseases were not directly included, other than in the risk of premature culling.

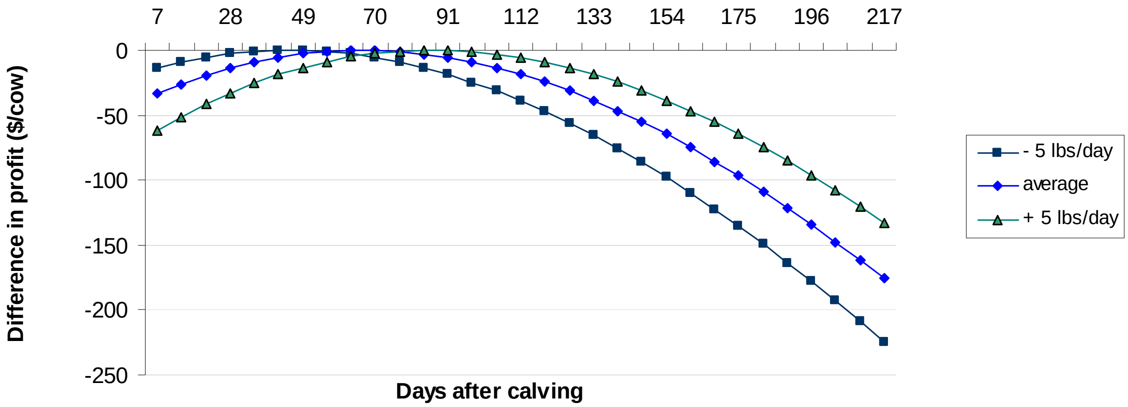

Figure 2. Economic loss ($/cow) caused by conception earlier or later after calving compared to the optimal day of conception for second lactation cows. Results for three lactation curves are shown: average curve, + 5 lb/d and – 5 lb/d compared to the average.

RESULTS

Optimal Days to Conception

Figures 1 and 2 show the economic loss caused by conception earlier or later after calving compared to the optimal day of conception. These results do not consider the actual risk of conception, which is very low early after calving. The optimal day of conception is reached when the economic loss is $0 (top of the curve). Optimal day of conception for average first lactation cows was 105 d and for second lactation cows it was 63 d (Table 1). For lower producing cows, fewer days to conception were optimal. Similarly, for higher producing cows greater days to conception were optimal. First lactation cows had fewer days to conception than later lactation cows.

The economic loss from a non-optimal day of conception (conception was either too early or too late) was much smaller in first lactation cows than in second lactation cows. This is primarily caused by the much flatter lactation curve of first lactation cows. This trend is in agreement with Holmann et al. (1984) who found that profitability was not affected very much when calving interval was either somewhat shorter or longer than 13 mo (115 d to conception).

The slopes of the curves in Figures 1 and 2 can be used to estimate the cost per extra day open. As is expected, cost per extra day open is negative (a financial gain) before the optimal days of conception and positive (a financial loss) after the optimal day of conception. At d 150 after calving, cost per extra day open was $1.00 for first lactation cows and $1.80 for second lactation cows. Meadows et al. (2005) found similar costs per extra day open.

Different assumptions about conception risk, prices, milk production, or seasonality obviously affect the results (Table 1). Optimal days to conception vary more in first lactation cows than in second lactation cows. But the economic loss from non-optimal days to conception is less in first lactation cows. Increases in heifer prices, herd average milk production, and milk production in first lactation cows resulted in greater optimal days to conception. Typically, greater optimal days to conception were observed when it was more important to keep current cows in the herd. Seasonality in milk production and conception risk had a large effect on optimal days to conception. Conception in the late summer was avoided, either by a short interval from calving to conception or a long interval from calving to conception. Thus, January calvings have shorter days to conception and July calvings have longer days to conception. Given the reduced performance in the summer, cows should calve in the winter if there are no constraints. DeLorenzo et al. (1992) found similar results. These results also confirm breeding practices of many dairy producers in areas with summer heat stress. If seasonality in milk production was not included, then optimal days to conception for the low, average, and high producing cows calving in January were 49, 91, and 140 d, respectively compared to 7, 28, and 91 d if seasonality in milk production was included. Again, actually establishing pregnancy so early after calving

Table 1. Effects of various assumptions on the optimal days to conception for first and second lactation cows by level of milk yield[1].

Assumptions[2]	Optimal Days to Conception, d					
	Lactation 1			Lactation 2		
	- 5 lb	Average	+ 5 lb	- 5 lb	Average	+ 5 lb
Default	56	105	147	42	63	84
+ 5 % Conception risk	56	98	140	42	63	84
$15/cwt Milk price	56	98	133	42	63	84
$2400 Heifer price	70	112	147	49	70	91
Increased lact. 1 milk	154	189	224	35	56	77
Increased herd milk	70	112	154	49	70	91
Less persistency	21	56	91	21	42	56
Seasonality:						
January calving	7	28	91	14	28	42
April calving	7	196	210	7	56	112
July calving	126	140	154	105	112	126
October calving	63	84	98	63	70	77

[1] Average curve, + 5 lb/d and – 5 lb/d compared to the average.
[2] Default: $2000 heifer price, $18/cwt milk price, no seasonality in milk production and conception risk.
+ 5 % Conception risk: + 5 percentage units greater conception risk compared to the average.
Increased lact. 1 milk: more persistent, greater milk yield in the first lactation but not later lactations.
Increased herd milk: + 5 lb/d compared to the average lactation curve.
Less persistency: decreased persistency in all lactations.

may be biologically improbable. Clearly, the effect of seasonality in milk production on optimal days to conception can be large.

Optimal Days to First Service

Figures 3 and 4 illustrate the economic loss from starting the first service earlier or later than the optimal day of first service. These results assume that the time of first breeding opportunity can be determined by the dairy producer, such as with a synchronized breeding protocol. In general, the optimal day of first service is earlier than the optimal day of conception, although the reverse can be true when fertility is very low. The difference is greater when the optimum days to conception are later. First lactation cows again have flatter curves, similar to the economic loss curves for days to conception. The flatter the curve, the less important the optimal DFS was. The optimal DFS was 63 d for the average first lactation cow and 42 d for the average second lactation cow. Low producing cows should start their breeding period sooner and first breeding for higher producing cows could be delayed, typically by 1 or 2 wk.

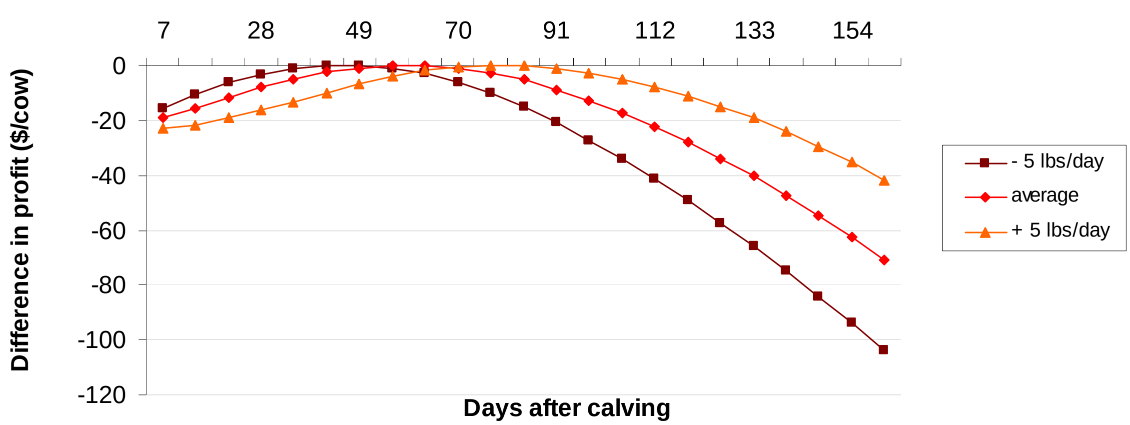

Figure 3. Economic loss ($/cow) caused by first service at various days after calving compared to the optimal day of first service for first lactation cows. Results for three lactation curves are shown: average curve, + 5 lb/d and – 5 lb/d compared to the average.

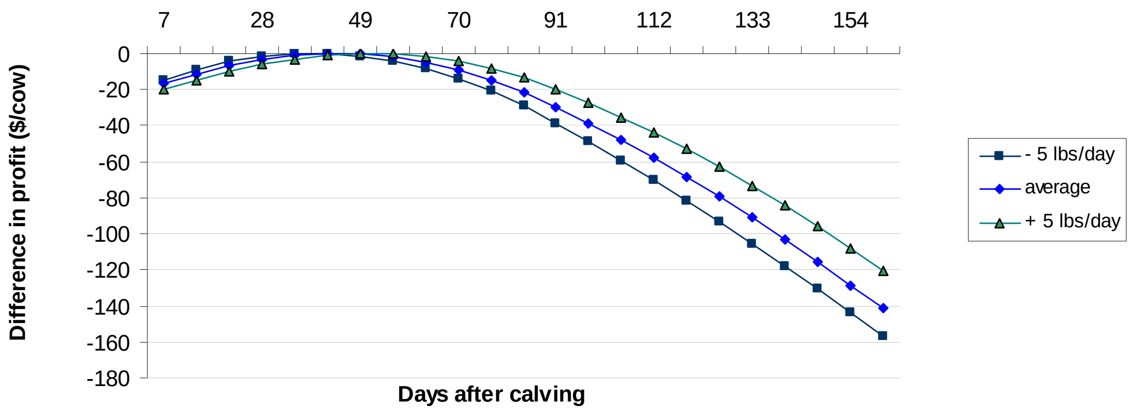

Figure 4. Economic loss ($/cow) caused by first service at various days after calving compared to the optimal day of first service for second lactation cows. Results for three lactation curves are shown: average curve, + 5 lb/d and – 5 lb/d compared to the average.

Table 2 shows the effects of some variations in assumptions on the optimal DFS. There is less effect of variations in the assumptions on the optimal DFS than on days to conception. The trends in optimal DFS follow those for optimal days to conception. Relative differences in milk production between cows in the same herd had more effect on the optimal DFS than the absolute level of milk production in the herd. These results are in agreement with the observation that the average VWP in practice is approximately 56 d (Miller et al., 2007; DeJarnette et al., 2007) and further that first breeding for higher producing cows, especially in the first lactation, could be delayed a few weeks (Weller and Folman, 1990; DeJarnette et al., 2007). Also, the results confirm the observation that cows calving in the winter had fewer DFS than those that calved in the summer. In herds that depend on estrous detection for the first breeding, the VWP is shorter than the time of first breeding.

Table 2. Effects of various assumptions on the optimal days to first service for first and second lactation cows by level of milk yield[1].

Assumptions[2]	--------------------Optimal Days to First Service, d--------------------					
	Lactation 1			Lactation 2		
	- 5 lb	Average	+ 5 lb	- 5 lb	Average	+ 5 lb
Default	49	63	77	42	42	49
+ 5 % Conception risk	42	63	84	35	42	49
$15/cwt Milk price	49	56	77	42	42	49
$2400 Heifer price	49	63	77	42	42	49
Increased lact. 1 milk	91	126	154	42	42	49
Increased herd milk	49	63	84	42	49	56
Less persistency	35	42	56	35	35	42
Seasonality:						
January calving	35	42	56	28	35	35
April calving	42	63	112	35	42	49
July calving	70	84	98	56	63	70
October calving	42	56	63	42	42	49

[1] Average curve, + 5 lb/d and – 5 lb/ d compared to the average.
[2] Default: $2000 heifer price, $18/cwt milk price, no seasonality in milk production and conception risk.
+ 5 % Conception risk: + 5 percentage units greater conception risk compared to the average.
Increased lact. 1 milk: more persistent, greater milk yield in the first lactation but not later lactations.
Increased herd milk: + 5 lb/d compared to the average lactation curve.
Less persistency: decreased persistency in all lactations.

Table 3. Insemination value ($) for first and second lactation cows by day after calving and level of milk yield.[1]

Day after calving	Insemination value, $ — Lactation 1			Lactation 2		
	- 5 lb	Average	+ 5 lb	- 5 lb	Average	+ 5 lb
Day 42	14	4	-7	27	20	13
Day 154	64	55	46	78	82	81
Day 266	88	91	92	43	78	97

[1] Average curve, + 5 lb/d and – 5 lb/d compared to the average.

Insemination Value

Ideally, every cow gets pregnant at her individual optimal day after calving. In practice, with less than 100 % fertility control, this is not achievable. Therefore, dairy producers start breeding cows before their optimal day of conception. The insemination value for an individual is an estimate of the value of breeding the cow at the breeding opportunity (ovulation) compared to not breeding her at that opportunity. Typically over the course of the lactation, the insemination value rises to a maximum and then declines again (Table 3). The insemination value for first lactation cows reaches a peak much later in lactation. This is a result of a more persistent lactation curve. Insemination values typically are lower in older cows.

The insemination values in Table 3 assume that the next breeding opportunity is in 3 wk, and that the risk that breeding opportunity is serviced is 60 % (which is equivalent to 35 d between breedings). The optimal DFS presented earlier assumed that the dairy producer controls the week of the first breeding opportunity. As a result, the insemination value early in lactation can be positive and suggests that the cow should be bred (because the next breeding opportunity is on average 3 wk/60 % = 5 wk later); whereas the optimal time of first service could be just 1 or 2 wk later. Thus herds that do not control the first breeding opportunity should breed cows earlier than those that control the timing of the first breeding opportunity.

The level of milk production has a significant effect on the insemination value. The lower producing cow (-5 lb/d) had greater insemination values earlier in lactation, but these values were lower later in lactation. Low producing cows have less time to get pregnant in their lactation before they should be culled. Therefore it is important to get them pregnant early in lactation. Late in lactation it becomes more important to get the higher producing cow pregnant (if she is still open). Higher producing cows should get more time to get pregnant. This is also observed in practice where average days to conception for higher producing cows are typically greater than for lower producing cows (Stevenson, 2004). More high producing cows are allowed to conceive late in lactation and thus contribute to a longer average days to conception.

In general, increased reproductive efficiency resulted in a lower insemination value early in lactation, but a greater insemination value later in lactation. Further, increased persistency lowered the insemination value early in lactation. These results are in agreement with earlier findings (Dekkers et al., 1998).

Value of a New Pregnancy

The economic value of a new pregnancy is highly correlated with the insemination value. Table 4 shows values by lactation number, milk yield, and selected days after calving. The values are slightly different from those reported in De Vries (2006), mostly because of a slightly different set of assumptions. Just like the insemination value, the value of a new pregnancy increases during the course of the lactation until late in lactation when it starts to decrease again. The value of a new pregnancy is greater for low producing cows early in lactation, but their peak value is lower and earlier than higher producing cows. However, the increase in value of pregnancy continues longer in lactation than the insemination value. Early and late in lactation, the value of a new pregnancy may be positive; whereas the insemination value is negative. The value of a new pregnancy is therefore less desirable for breeding decisions than the insemination value. The economic consequences of using the value of a new pregnancy for breeding decisions are small, however.

Table 4. Value of a new pregnancy ($) for first and second lactation cows by day after calving and level of milk yield[1].

Day after calving	Value of a New Pregnancy, $					
	Lactation 1			Lactation 2		
	- 5 lb	Average	+ 5 lb	- 5 lb	Average	+ 5 lb
Day 42	124	83	42	169	144	114
Day 154	238	212	184	284	292	286
Day 266	342	349	350	220	321	376

[1] Average curve, + 5 lb/d and – 5 lb/d compared to the average.

CONCLUSIONS

Optimal days to conception in first and second lactation cows were 105 and 63 d, respectively. Similarly, optimal DFS were 63 and 42 d, respectively. It follows that cows that get pregnant at first service typically get pregnant too early compared to the optimal day of conception.

Higher producing cows, compared to their herd mates, had greater optimal days to conception and first service. Herd mate deviation appeared to have greater effects on the optimal days than absolute level of milk production. Economic losses from non-optimal days to conception or first service were smaller for first lactation cows than for older cows.

Low producing cows had greater insemination values in early lactation than higher producing cows. Because herd mate deviation in milk production is important, accurate methods are needed to predict milk production for individual cows early in lactation. It is then possible to develop tools to calculate accurate insemination values to support breeding decisions on farms.

Insemination value is typically lower early in lactation than in mid-lactation (although it reduces again late in lactation). However, improvement in reproductive efficiency early in lactation is still economically the most valuable, because it affects many more open cows.

Insemination value and pregnancy value are correlated but insemination value is a better criterion to base breeding decisions on. The definition of insemination value is important, however. The economic consequences of using the value of a new pregnancy, instead of the insemination value, for breeding decisions are small.

Moderate seasonality in milk production and conception risk can have significant effects on the optimal day to conception and first service. Seasonality in milk production plays an important role in optimal breeding decisions and should not be ignored.

The economic value of improvements in fertility in the summer is dependent on the seasonality in milk production. If milk production is significantly reduced in the summer, ideally calving in the late spring or early summer should be avoided for most cows. It may be more valuable to improve fertility control in the winter so cows can calve in the fall. This would affect the calving pattern. There may be many practical constraints on dairy farms that make seasonality in the calving pattern less desirable; for example limited space in the transition facilities, labor availability, and parlor capacity. Furthermore, the results presented assume a replacement heifer can immediately be purchased and enter the lactating herd. Closed herds will have to balance the season in which most calves are born with the need for replacement heifers during the year. This may also have consequences for the optimal age of first calving. Thus the optimal days to conception and first service will depend on whether the herd is closed or not. These constraints were not considered in the results presented in this paper.

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