Veterinary Reproductive Programs

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Abstract

Reproduction influences farm gross income about 10%. Gross margin per cow is maximized when herd pregnancy rate (pregnancy efficiency) is above 30%. Pregnancy rate (PR) is calculated as the heat detection rate (HDR) times the conception rate (CR). Since CR is typically below 40% on most farms, HDR needs to be above 80% to achieve a PR above 30%.

Herd reproductive programs are most effective when they are used to control HDR. Furthermore, first insemination heat detection rates have a higher economic value than repeat heat detection rates. Synchronization programs using prostaglandin alone or in combination with GnRH have a high potential return for producers to improve reproductive efficiency. Synchronization programs have value on dairy farms as they control HDR, improve labor efficiency for insemination, and coordinate veterinary activities for pregnancy examination on a scheduled basis.

Definitions

Terms used in this paper include heat detection rate (HDR), conception rate (CR), voluntary waiting period (VWP), and breeding period (BP). HDR is defined as the number of cows inseminated divided by the number available to be inseminated over a 21-day period. HDR describes the probability that any open cow is inseminated over the next 21-day period. Heat detection may be further divided into that for first insemination (FSTHDR), and for repeat insemination after first service (RPTHDR).

Conception rate (CR) in this paper is defined as the number of cows confirmed pregnant at 35 days or more post-breeding, divided by total number of cows inseminated, for any given service number or period of time. Actual conception rates will be higher in a herd, but due to early embryonic mortality prior to pregnancy exam, these rates usually are not observed in dairy herds. CR represents the probability that an inseminated cow becomes pregnant.

Voluntary waiting period (VWP) is the time post-calving when insemination will commence. The breeding period (BP) is the time in days from the VWP a cow will continue to be inseminated until she is culled for failure to become pregnant. Typically the BP is 210 days for most cows and herds.

Introduction

Historically, reproductive efficiency has been measured in units of time (days open, calving interval, age at first calving) and semen (services per conception).[8] Time units include the calving interval, (CI, the time in days or months between successive calvings), days open (DOPN, the days postcalving when conception occurs) and the age at first calving (AFC, months).[8,12,16] Semen units have been indexed on a conception (SPC) basis (calculated as the number of units of semen divided by the total number of pregnant cows) or on a cow basis (number of units of semen divided by the total number of cows inseminated). SPC may be calculated for only cows confirmed pregnant or for all cows inseminated, in which case it really is an index of services per cow. Another index of herd reproductive efficiency is herd turnover or replacement, measured as the proportion of cows leaving and entering the herd each year.

CI is a historical measure, requiring two successive calvings. It does not denote current herd reproductive performance. DOPN is a more current measure of reproductive efficiency, however, it is not defined for animals which are not confirmed pregnant or have not yet been inseminated. Therefore, it does not specify the reproductive efficiency in the whole herd. Furthermore, DOPN is still a historical measure, as cows must be confirmed pregnant to define the term. At any given point in time, cows confirmed pregnant in a herd represent information that is 4 to 16 months old. Cows which have calved in the last 4 months contribute very little information to DOPN data. In addition, DOPN and CI are not normally distributed and therefore are not appropriately described by conventional statistics, such as the mean and standard deviation. SPC has similar problems, as cows not yet confirmed pregnant are difficult to handle in the calculation.

These measures are traditional, but not very dynamic as indexes of reproductive efficiency. They have a high moment of inertia and change slowly when reproductive management changes on a farm, as gestation time in a cow is 280 days. In addition CI and DOPN may be dramatically influenced by culling and herd turnover. These measures can take on many values depending on culling in the herd. In addition, cows not yet inseminated and beyond the VWP are never included in these calculations. Therefore, these measures of reproductive efficiency are not very useful. They should be junked.

There are more fundamental flaws with these traditional measures of reproductive efficiency. DOPN and CI are outcomes, influenced by HDR, CR, VWP, and culling.[17,25] Reproductive efficiency should be defined in terms of the inputs which determine the CI and DOPN. These parameters are the critical control points of the reproductive management program on a farm. Since calving interval, age at first calving, and herd turnover are outcomes determined by heat detection efficiency, conception rate, the breeding period, and the voluntary waiting period, it is more timely to assess reproductive efficiency by calculating these indices on a dairy farm. Since DOPN is historically used to describe reproductive efficiency, background economic information will be referenced using this term. However, other more dynamic terminology will be described further in the paper.

Economics of Reproductive Performance

Milk produced per cow per day may be increased 4 ways in a dairy herd: 1) genetic selection (basis of cow selection and AI programs); 2) improved nutrition; 3) improved control of disease and management factors which lower yield (mastitis, metritis, heat stress, etc.); and 4) increased reproductive efficiency. Reproductive efficiency influences average milk produced per day, percent days in milk, and average days in milk for a herd. Reproductive efficiency also influences calves born per year and the generation interval, which influences genetic gain.

Income on dairy herds is derived primarily from sale of milk, calves, cull cows, and dairy replacement stock. Typically, the majority (>70%) of income is realized from sale of milk. Reproductive efficiency influences the magnitude of income associated with each of these income streams.[1-5,14,17-18,22,25] Farm management determines profit by controlling the cost of feed, labor, semen, drugs, and veterinary care utilized to achieve the income. Periparturient health problems increase the fixed cost associated with each lactation. The shape of the lactation curve and fixed cost per lactation influence the optimum time between successive parturitions for a dairy herd. However, there are general rules which can be followed for any dairy herd in addressing reproductive performance. Traditionally, a yearly calving interval has been identified as the economically optimum for dairy farms.[12,16]

Economic returns associated with reproduction are opportunity dollars and are realized only when animals re-calve and proper culling decisions are made. The economic returns associated with reproductive efficiency are fluid. That is, they are associated with animal flow in a herd, which is dependent upon lactation length and time to re-calving and herd replacement. In contrast, income over feed costs is somewhat static, as a producer can assess the cost of feed against the production of milk each day and determine if the ration is cost-effective. That cannot be done with reproduction, as the cost of the reproductive program today is influencing returns in the future.

Reproductive costs associated with breeding and veterinary fees occur now, while returns occur in the future associated with the time to the next lactation. If the animal leaves the herd prior to next lactation or encounters difficulty at calving or in the post-parturient period and leaves the herd sooner than expected, returns on the reproductive investment are not realized or are reduced. Because of the time delay in realizing returns from reproduction, they are particularly sensitive to risk. Unlike feed costs which may be compared with milk production costs concurrently, reproductive costs must be compared with returns which will happen in the future, subject to the risk of future calving. Economic assessment of reproduction must account for the time dimension of returns and the risk of realizing those returns. Because returns associated with reproduction occur in the future and are somewhat intangible, producers are insensitive to losses associated with reproductive inefficiency.

Reproduction influences milk produced per day, calves born per year, and animal replacement over a lifetime.[1-5,14,17-18,22,25] Milk produced/cow/day increases by 2.93 lb/day per 1,000 lb increase in the average 305-day production (M305). For example, at a production of 18,000 lb, average milk/day will be 57.28 lb, whereas average milk/day will be 62.99 lb at a production of 20,000 lb M305. For every increase in days open, milk produced per day decreases as a function of M305 yield (-.00397 lb + -.00168*M305). At 18,000 lb M305 the reduction in yield per day open over 40 days is -.0342 lb; at 20,000 lbs M305, the reduction in yield per day open over 40 days is -.0375 lb. Losses are higher for higher production. The reduction in milk produced per day with increasing days open is the fundamental principal which determines the value of reproductive efficiency.

Due to the shape of the lactation curve, income over feed costs is not uniform throughout a lactation (Figure 1). Returns are highest in early lactation. Fifty percent of the income over feed costs for a lactation is realized

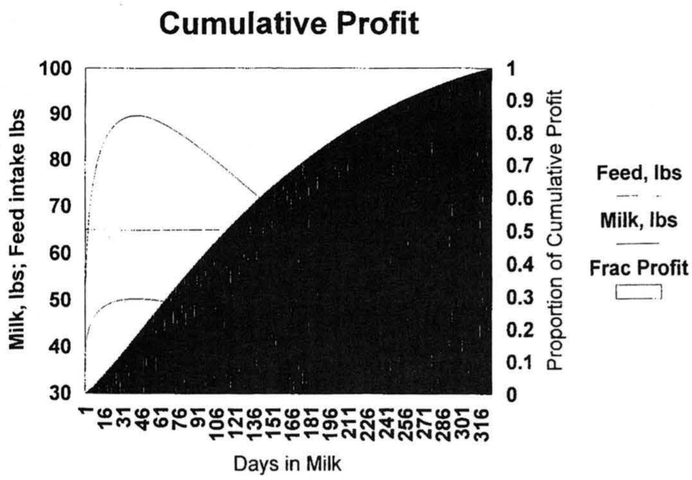

Figure 1. Cumulative income over feed costs within a lactation for an average dairy cow.

by 100 to 120 days post-calving. The remaining 50% is realized over the next 200 days of lactation. Thus, not all milk produced within a lactation has equal value. Milk produced in the first 100 days of lactation has 3 times the value of milk produced in the latter half of lactation. Producers realize more returns for investment when cows spend a higher proportion of their lifetime in early lactation than in later lactation.

The cash streams associated with reproduction occur over different time dimensions: daily, annually, and generationally (Figure 2). Initially, until the animal first calves, returns are negative as costs of raising and breeding for first calving accumulate. After calving, income from sale of milk results in positive returns. Income is not constant following calving, but follows the shape of the lactation curve. Since milk production occurs over an extended time period, milk prices also may fluctuate during the lactation cycle and influence returns. After 3 lactations, the average cow is culled. Accumulation of costs and income results in a cumulative cash flow curve (Figure 2).

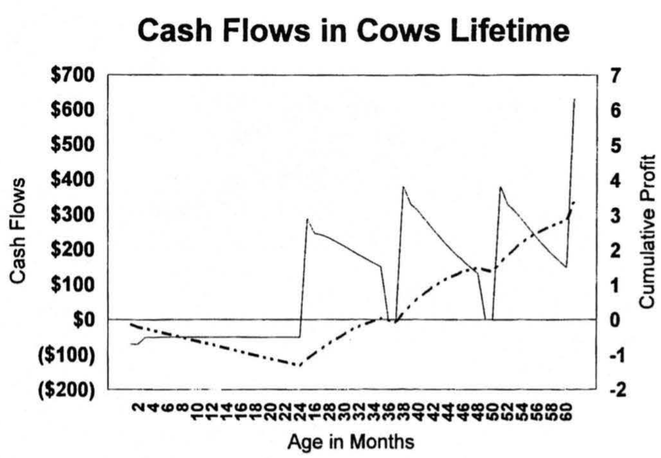

Figure 2. Cash flow and cumulative cash flow over a lifetime.

Methods are available to account for the time dimension of reproduction. These methods include discounting, annuity and risk adjustments to evaluate reproductive returns. Lifetime cash flows may then be discounted based on time of cumulation and annualized to returns per year or per month using an annuity function. Since every animal within a herd spends variable lengths of time in the herd, discounting and annuity formulas place each animal on a common dollar value scale for economic comparisons. Net present value enables one to calculate the current value of an animal at any stage of her life cycle (Figure 3).

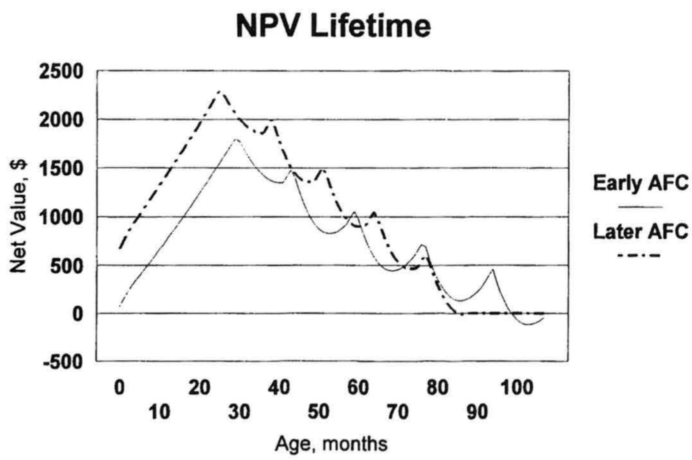

Figure 3. Net present value (NPV) against monthly age for two reproductive management programs, high reproductive efficiency, early age at first calving (Early AFC); low reproductive efficiency (Later AFC).

It is apparent that the most valuable animal in the herd is one which is to calve for the first time.[1-5] NPV increases from birth to first calving, and then declines through first lactation. NPV increases slightly prior to second calving and then declines through second lactation (Figure 3). NPV is maximal at first calving and declines throughout life, with small increases just prior to each calving. The decline in value is due to less future milk production with each successive calving and higher risk of herd removal.[1-5,14] When NPV is below that of a replacement calf, the animal should be removed from the herd.[1-5,14] This is, on average, the third lactation (Figure 3). The average cow is profitable for 3 lactations. Higher-producing cows would have longer herd lifetimes. In general, herd profit is increased in association with management activites which shift the NPV to the left and/or upwards. Decreasing age at first calving and shorter CI shift the NPV curves to the left and upwards. Management activities which reduce feed cost, increase production (bST, 3x milking), control mastitis, and reduce health costs shift the NPV upward.

As seen in Figures 2 and 3, cows with shorter days to first calving and shorter intervals between successive parturitions accumulate more profit sooner and have a higher NPV than cows with longer days to first calving and longer days between successive calvings. Economic forces predispose to a short calving interval. However, there are physiological constraints which limit how short the CI may be. These include uterine involution and repair, resumption of ovarian activity post-calving and a fixed gestation period of 280 days. Therefore, calving intervals less than 10.2 months are rare. Very short CI are often the result of abortions or premature calvings and often are associated with 2000 lb less milk production.

On the other hand, there are economic forces which predispose to a longer CI. These include costs associated with calving, particularly if a herd has a high incidence of parturient diseases, and a higher persistency of milk production. Higher costs associated with each new lacation would mediate against a short calving interval. In addition, it has been suggested that use of bST would allow for a delay in insemination. However, even with a fixed lactation cost of $300 for health problems and bST use, longer CI are not more profitable. Losses are merely reduced. Overwhelmingly, the majority of ecomomic forces push to a shorter CI, not longer. Therefore, most economic models would suggest an optimum CI of 365 to 395 days for dairy herds.

Pregnancy Rate As A Monitor of Reproductive Efficiency and Profit

Reproductive performance is influenced by four factors: heat detection rate, conception rate, the voluntary waiting period and the breeding period.[13,14,17-18,22,25] The VWP should be of sufficient time post-calving that uterine involution is complete and at least two estrous cycles have occurred prior to insemination (Wilcox). The voluntary waiting period (VWP) is typically between 40 to 60 days in most dairy herds. Conception rate may be lower if insemination occurs prior to complete uterine involution and to the third estrus post-calving.

The length of the breeding period is dynamic and should be established for each individual cow based on milk production and age.[1-5,13,14] Higher-producing cows can have longer breeding periods than lower-producing cows. Older cows will have shorter breeding periods than younger cows due to the probability of less future cumulative milk production. Generally, managers try to establish a breeding period which will result in at least 85% of cows pregnant within as short a time period as possible. Typically, the average breeding period for the average cow extends for at least 10 estrous cycles, or 210 days from the VWP.

Heat detection and conception rate determine the efficiency at which cows become pregnant from the VWP and ultimately the length of breeding period necessary to achieve 85% of cows pregnant. The higher the HDR and CR, the shorter the breeding period needed to attain 85% of cows pregnant. A statistic which captures the efficiency of rate of pregnancy from the VWP is the pregnancy rate (PR), which is calculated as the heat detection rate times the conception rate. Esselmont referred to this value as the fertility factor in a herd. The PR represents the proportion of open cows which become pregnant every 21 days within the breeding period. Theoretically, this could be as high as 63.75% (if the HDR was 85% and the CR was 75%; .6375=.85 x .75). In most dairy herds the pregnancy rate is 15% to 25%. Pregnancy rate determines days open and culls for reproductive failure.

Pregnancy rate may be calculated from survival curves (Figure 4).[6-7,11] Survival curves plot the occurrence of failure of pregnancy against time (days to last breeding). In other words, the proportion of open cows is plotted against days to last breeding. When last insemination results in pregnancy, the failure time curve declines from a high of 100% (no cows pregnant) to a low of 0% (all cows pregnant). The failure time curve begins to decline from 100% at the VWP in the herd. The cows remaining nonpregnant over time are potential culls for reproductive failure. PR is the hazard of pregnancy every 21 days. The median days open in a herd is the point in time when 50% of the cows have failed.

As a measure of reproductive efficiency, pregnancy rate has advantages over classical measures such as days open and calving interval (Figure 4).[11] Survival functions can handle censored observations, such as

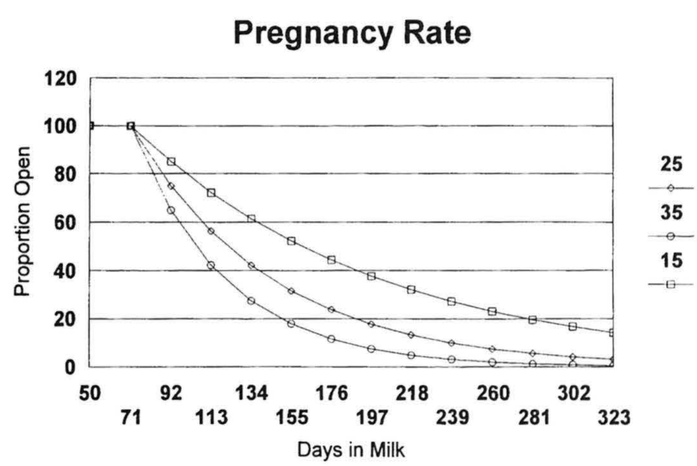

Figure 4. Survival functions of reproductive efficiency with three pregnancy rates (PR): 15%, 25% and 35%.

cows which have been removed from the herd and cows which are not yet confirmed pregnant, minimizing bias in assessing reproductive efficiency. In addition, failure time curves may be analyzed statistically for changes in herd performance. Moreover, assessing HDR and CR in a herd allows one to calculate the PR which dictates what the future survival function in a herd will be. Goals for HDR and CR may be established, which will determine the PR and days open and culls for reproductive failure in a herd. Thus, PR is a very prospective index of reproductive efficiency.

What should PR be a herd? The value which maximizes economic returns. Plotted in Figure 5 is the gross margin per cow plotted against PR ranging from 0 to 1.00. This data was generated using Dairy Oracle, a program designed to evaluate economic returns from reproductive management.[13] Gross margin asymptotes with little increase at a PR of 35%. To maximize economic returns associated with reproductive efficiency, the pregnancy rate should be 35% or greater. There is little gain in income above 35%. As pregnancy rate increases from 15% to 20%, gross income per cow increases by $150 to $200 (Figure 5). An increase in pregnancy rate from 20% to 25% is associated with an increase in gross income of $100 to $150 per cow per year. An increase in pregnancy rate from 25% to 35% is associated with an increase in gross income of $50 to $100 per cow per year. As pregnancy rate increases above 35%, marginal returns are smaller. Economic optimums are obtained when pregnancy rates equal 35%.

Factors Which Most Influence Reproduction in a Herd

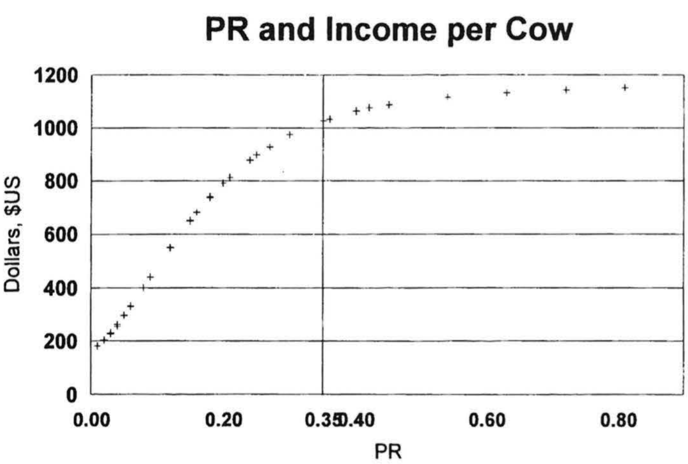

Figure 5. Gross margin per cow per year as a function of pregnancy rate.

Control of reproductive efficiency in dairy herds entails understanding the factors which most influence performance. Table 1 presents the results of 3000 simulations with all combinations of HDR and CR varying from .1 to 1.0 and VWP varying from 40 to 80 days. Heat detection was further partitioned into detection of estrus for first insemination and detection of estrus for repeat insemination. The table presents regression coefficients for each variable on the dependent variables for calving interval (CI) and culls for reproductive failure described as a percent of the herd. Below each variable is the partial r-square for that particular variable in describing the dependent variable with other variables in the model.

Heat detection for first insemination (FSTHDR) accounts for 42% of the variation in CI. Others have observed the importance that HDR, especially for first insemination, has on reproductive efficiency.[9,10,20-21] Next most influential factors on variation in CI are VWP (25%) and CR (24%). If CI is to be controlled in a herd one must first control FSTHDR. Reducing cows culled for reproductive failure is most influenced by CR, second by heat detection for repeat insemination (RPTHDR), and third by FSTHDR. VWP has no effect on culling for reproductive failure as breeding period is fixed from the VWP and not by days in milk.

Table 1. Influence of management factors on measures of reproductive efficiency.

Item	Intercept	FSTHDR	RPTHDR	CR	VWP
CI, m	13.17	- 2.41	- .41	- 1.84	.033
partial r^2		.42	.01	.24	.25
Culls, %	76.82	-22.33	-18.61	-60.82	
partial r^2		.078	.080	.58	

The data in Table 1 demonstrate that CI is most influenced by FSTHDR. This confirms data from Heeersche,[9] Jansen et al.,[10] Pecsok et al.,[20-21] and Rounsaville,[25] who found that days open and/or calving interval were most associated with heat detection efficiency on farms. The above data further identify that FSTHDR has greater value than RPTHDR in controlling herd reproductive performance. The implication of this data is that herd reproductive programs should be structured to control FSTHDR to have the largest effect on CI. VWP and CR are of secondary importance. Culling for reproductive failure is most influenced by CR. When cows are inseminated they are less likely to be culled if they become pregnant sooner, which is more probable with higher CR.

Reproductive Management Programs

Reproductive management programs should be structured to first control FSTHDR. Too often, veterinary reproductive programs have been structured based on postpartum cow examination with the intent to control CR. These programs have been ineffective at maintaining reproductive efficiency in dairy herds. Over the last 30 years reproductive performance has declined, despite a great deal of information describing the economic benefit of reproductive management. Part of the reason for the decline has been the lack of appropriate application of technologies to control reproduction in dairy herds. In addition, producers have invested dollars in activities associated with reproductive programs that have little potential return, thus inhibiting investment in activities with higher return potential.

With the advent of tools to control FSTHDR, herds with HDR below 70% should be enrolled in some form of synchronization program, such as OVSYNCH, Targeted Breeding, or a combination thereof.[6-7,15,23] These programs are described elsewhere and will not be detailed here.[6-7,15,23] The reader is referred to other references.

For these programs to be successful, however, very specific criteria must be followed. First, records have to be sufficient on the farm to ensure cows can be assigned to appropriate injection schedules at appropiate days postpartum. For a herd to benefit from a synchronization program, over 85% of cows need to be enrolled in the program. So, first records are required.

Second, programs need to drive FSTHDR above 80% to affect herd performance. If FSTHDR are not above 80%, expect little improvement from existing management. This means for most farms, insemination on appointment must be done in a percentage of cows, depending on the program. OVSYNCH programs ovulation so 100% of cows are inseminated by appointment. Targeted Breeding may require 20% to 25% of cows be inseminated on appointment, usually using two breedings, 24 hours apart. Appointment insemination with Targeted Breeding requires that cows are cycling.

Third, programs must operate on a scheduled basis, either weekly or biweekly within a herd. Injections need to be consistent on a day of the week to schedule other activites with synchronization programs.

Fourth, programs need to be integrated with an early pregnancy check to control RPTHDR. With rectal palpation this can be reliably done between 32 to 38 days post-insemination. This may be done with ultrasound at 25 to 28 days post-insemination, and with milk progesterone testing at 21 days postinsemination. This examination is concerned with reliably predicting open cows and reassigning them to the breeding pool at the next scheduled synchronization group. The most important cow is the open cow at pregnancy exam. This cow should be placed back into a synchronization program to control days between inseminations. Less than 15% of cows should have 48 days or longer between inseminations.

Fifth, monitoring cow assignment and CR for cohorts of cows as they move through the program. Synchronization programs break the herd reproductive program into cohorts of cows.[23] Blocks of cows are managed.

Each month it is possible to evaluate:

- the scheduling of cows for first insemination (cows due to be inseminated this month)
- proportion of cows first inseminated within 21 days from the VWP (FSTHDR, goal >80%; cows inseminated within the last month)
- CR in cows at first insemination (cows inseminated last month)
- cows for repeat insemination (cows open at this pregnancy check for reassignment to the synchronization pool and the proportion of cows reinseminated that had been open at last month's pregnancy check).

Each month the success of the breeding program is apparent. The PR can be calculated as the proportion first inseminated within 21 days of the VWP times the CR in this group. The PR will be apparent within 30 to 35 days of insemination for each cohort of cows.

By monitoring cohorts of cows, it becomes apparent where the problems in the herd may be.[11,23] Low CR can be associated very closely with a group of cows, either due to body condition loss, calving problems, or seasonal effects. Low insemination rates (<80%) indicate immediately that reproductive effiency will be low in that cohort of cows. PR in each cohort will dictate what the CI in the herd will be.

References

1. Dijkhuizen, A.A., Stelwagen, J. and Renkema, J.A. Economic Aspects of Reproductive Failure in Dairy Cattle. I. Financial Loss at Farm Level, Preventive Vet. Med. 3:251-263, 1984.
2. Dijkhuizen, A.A., Renkema, J.A. and Stelwagen, J. Economic Aspects of Reproductive Failure in Dairy Cattle.II.The Decision to Replace Animals, Preventive Vet. Med. 3:265-276, 1984.
3. Dijkhuizen, A.A., Stelwagen, J., and Renkema, J.A. A stochastic model for the simulation of management decisions in dairy herds, with special reference to production, reproduction, culling, and income. Prev. Vet. Med., 4:273-289, 1986.
4. Dijkhuizen, A.A., and Stelwagen J. An economic comparison of four insemination and culling policies in dairy herds by method of stochastic simulation. Livestock Prod. Sci., 18.239-252, 1988.
5. Esslemont, RJ., and Eilis, P.R. Components of herd calving interval. Vet. Rec., 95.319-320, 1974.
6. Ferguson, JD and DT Galligan. Prostaglandin Synchronization Programs in Dairy Herds - Part 1. The Compen. Cont. Ed. North Am. Edition. Dairy Production Management. 15(4) : pp646-654, 1993.
7. Ferguson, JD and DT Galligan. Prostaglandin Synchronization Programs in Dairy Herds - Part II. The Compen. Cont. Ed. North Am. Edition. Dairy Production Management. 15(8): pp. 1127-1130, 1993.
8. Fetrow, J., D. McClary, R. Harman, K. Butcher, L. Weaver, E. Studer, J. Ehrlich, W. Etherington, W. Guterbock, D. Klingborg, J. Reneau, and N. Williamson. Calculating selected reproductive indices: Recommendations of the American Association of Bovine Practitioners. J. Dairy Sci. 73:78-90, 1990.
9. Heersche, G., Jr. and Nebel, R.L. Measuring Efficiency and Accuracy of Detection of Estrus, J. Dairy Sci. 77:2754-2761, 1994.
10. Jansen J., Dijkhuizen A A., and Sol, J. Parameters to monitor dairy herd fertility and their relation to financial loss from reproductive failure. Prev. Vet. Med., 4:409-418, 1987.
11. Lee, L, JD Ferguson, and D Galligan. Disease and reproduction in Holstein cattle assessed by survival analysis. J. Dairy Sci. 72:1020-1026, 1989.
12. Louca, A., and Legates J.E. Production losses in dairy cattle due to days open. J. Dairy Sci., 5i:573, 1968.
13. Marsh, W.E., and Morris, R.S. ORACLE: Predicting performance

in dairy and swine herds. Proceedings of the 4th International Symposium on Veterinary Epidemiology and Economics, Singapore, November, 1986, pp. 259-261.
14. Marsh, W.E., Dijkhuizen, A.A., and Morris, R..S. An economic comparison of four culling decision rules for reproductive failure in United States dairy herds using Dairy ORACLE. J. Dairy Sci. 70:1274-1280, 1987.
15. Nebel, R.L., and S. M. Jobst. Evaluation of Systematic Breeding Programs for Lactating Dairy Cows. A reveiw. J. Dairy Sci. 81:1169-1174. 1998.
16. Olds, D., Cooper, T. and Thrift, F.A. Effects of days open on economic aspects of current lactation. J. Dairy Sci., 62.1167-1170,1979
17. Oltenacu, P.A., Milligan, R.A. Rounsaville, T.R., et al. Modeling reproduction in a herd of dairy cattle. Agric. Sys., 5:193-206, 1980.
18. Oltenacu P.A., Rounsaville, T.R., Milligan, R.A., and Foote, R.H. Systems analysis for designing reproductive management programs to increase production and profit in dairy herds. J. Dairy Sci., 64:2096-2104,1981.
19. Oltenacu, P.A., Ferguson, J.D. and Lednor, A.J. Economic evaluation of pregnancy diagnosis in dairy cattle:A Decision Analysis Approach. J. Dairy Sci. 73:2826-2831, 1990a.
20. Pecsok, S.R., McGilliard, M.L. and Nebel, R.L. Conception Rates.1. Derivation and Estimates for Effects of Estrus Detection on Cow Profitability, J. Dairy Sci. 77:3008-3015. 1994a.
21. Pecsok, S.R., McGilliard, M.L. and Nebel, R.L. Conception Rates. 2. Economic Value of Unit Differences in Percentages of Sire Conception Rates, J. Dairy Sci. 77:3016-3021, 1994b.
22. Plaizier, J.C.B., G.J. King, J.C.M. Dekkers, and K. Lissemore. Estimation of economic values of indices for reproductive performance in dairy herds using computer simulation. J. Dairy Sci. 80:2775-2783, 1997.
23. Pursley, J.R., M. W. Kosorok, and M.C. Wiltbank. Reproductive management of lactating dairy cows using synchronization of ovulation. J. Dairy Sci. 80:301-306, 1997.
24. Pursley, J.R., R.W. Silcox, and M.C. Wiltbank. Effect of time of artificial insemination on pregnancy rates, calving rates, pregnancy loss and gender ratio after synchronization of ovulation in lactating dairy cows. J. Dairy Sci. 81:2139-2144, 1998.
25. Rounsaville, T.R., Oltenacu, P.A., Milligan, R.A., et al. Effects of heat detection, conception rate, and culling policy on reproductive performance in dairy herds. J. Dairy Sci., 62:1435-1442, 1979.
26. Thatcher, W.W. and C.J. Wilcox. Postpartum estrus as an indicator of reproductive status in the dairy cow. J. Dairy Sci. 56:608-610. 1973.