

Economic impact of reproductive performance in dairy herds and approaches for program selection

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Abstract

Implementation of an effective reproductive management program is critical to success of dairy operations, as herd reproductive performance is inextricably linked to farm profitability. Therefore, understanding the multiple sources of variation in herd cash flow affected by reproductive management is fundamental to support informed decisions when defining reproductive management or level of desired herd performance. Ideally, selecting a reproductive management program or level of desired reproductive performance is based on an objective measure of expected profitability. Approaches available for determination of the economic impact of reproductive management programs include: (1) decision support tools that simulate dairy herd dynamics and economics; (2) extrapolation of expected trends in profitability gain for changes in reproductive metrics (e.g. 21 day pregnancy rate or days open); and (3) extrapolation of results from research experiments conducted through simulation or on commercial dairy farms. This review includes a summary of the main factors associated with reproductive management that contribute to variation in herd profitability and a brief description of approaches available to support selection of reproductive management programs based on their expected economics.

Keywords: Profitability, pregnancy, dairy cow, dairy heifer

Introduction

Effects of reproductive performance of dairy cattle on profitability of dairy operations have long been recognized. Total milk sales, number of cows replaced and number of replacement heifers born are among the major sources of income affected by reproductive performance of lactating dairy cows. Rearing costs and opportunity cost of delayed lactation are 2 major factors driving economics for dairy heifers. Costs of feed, labor and veterinary inputs are also influenced by reproductive programs, as lactation length, dry period length, days in rearing and number of services to conceive depend primarily on reproductive performance. Therefore, when selecting a reproductive management strategy, all factors that contribute to variations in reproductive and economic performance need to be considered.

It remains a major challenge for dairy producers, veterinarians, and consultants to define the reproductive management strategy that maximizes profitability for a farm operation. Numerous management strategies and reproductive technologies can be implemented in dairy farms to optimize reproductive efficiency; however, it is usually challenging to determine their economic benefits or drawbacks in the field. This is primarily due to the multiple factors affected by changes in reproductive management and the time required to quantify productive and economic impact of changes in reproductive performance. Consequently, practitioners must be aware of biological, management and economic factors that drive herd profitability and various approaches available to identify reproductive management strategies that optimize profitability for specific dairy herds. These include: general herd profitability trends expected in response to changes in reproductive performance; use of software decision making tools based on models that simulate herd dynamics and economics; and data from research studies conducted with simulation tools or field experiments.

Reproductive management and performance factors that affect herd profitability

Due to multiple inputs and outputs affected by reproductive management programs and the reproductive performance of dairy herds, several economic parameters are affected by changes in reproductive management and respective herd performance. Among the most relevant are effects of timing of pregnancy on milk production efficiency and replacement dynamics (cows sold and calves born) and cost of reproductive program implementation. Reproductive performance can also have direct

implications on herd health and milk production; however, these are more complex and difficult to quantify.

Milk production efficiency

Number of lactations and productive efficiency per lactation in the lifetime of cows is defined by the occurrence and timing of pregnancy; therefore, cows with frequent calvings will have more lactation peaks and a greater lifetime total yield compared to cows with less frequent calvings. In addition, feed intake and milk yield during lactation are not completely synchronized, thereby cows convert feed into milk with different efficiencies according to stage of lactation. Although feed intake has a somewhat similar pattern of change than milk yield during lactation, rate and timing of increase and decrease of feed intake and milk yield are uncoupled in early and late lactation. Whereas maximum dry matter intake usually occurs several weeks after cows reach peak milk yield, rate of intake decline after peak is more gradual than milk yield. Therefore, the ratio of milk value produced to feed costs, usually known as income over feed cost (IOFC), is high early in lactation but decreases as lactation progresses. Therefore, timing of pregnancy during each lactation cycle becomes a critical factor for cow profitability, as it determines the amount of time that cows spend in the most efficient part of their lactation curve throughout their lifetime (highest IOFC), which in turn, affects overall profitability of the dairy operation.

Replacement dynamics

Dynamics of cows leaving the herd due to reproductive failure or other reasons and number of replacements born can be dramatically affected by timing of pregnancy.¹ To maintain herd size constant, cows that leave the herd due to sale or death are replaced immediately by a recently calved heifer. For cows sold, the farm incurs a cash cost of replacement. This is the difference between the market value (if the replacement is bought) or the cost of rearing until calving (if the replacement heifer is raised by the operation) and salvage value. Value of the calf born from the replacement animal contributes to offset the cash cost of culling. As failure to become pregnant during lactation and delayed pregnancy result in a greater proportion of cows culled and the cash cost of replacing cows is usually negative, reduced reproductive performance can lead to substantial economic losses for dairy herds. Of note, the economic detriment of an excessive replacement rate due to poor reproductive performance is exacerbated under market conditions characterized by elevated replacement heifer costs, unfavorable prices for cull cows and poor value of calves born.

Reproductive program cost

Regardless of the type of method to submit cows for insemination, all reproductive programs incur a cost of implementation. Calculation of this cost should include hormonal treatments (if used), AI, detection of estrus during lactation, pregnancy testing and labor associated with each activity. Although research studies have suggested that cost of reproductive programs is not the main contributor to cash flow differences between reproductive management programs, reproductive cost can generate noticeable profitability differences when input costs are substantial or many AI services per cow are required to achieve the desired level of reproductive performance.

General trends for economics of reproductive performance

Although trends and associations between metrics of reproductive performance and herd profitability hold true for certain scenarios and conditions, in general it is not possible to generalize results from deterministic or even stochastic estimations of herd performance and profitability to all herds and management conditions. Thus, focus should be on extrapolating trends and the expected magnitude of rate of gain in profitability, rather than extrapolating absolute values for differences in profitability associated with certain changes in metrics of reproductive performance.

For example, it is well accepted that increasing the 21 day pregnancy rate (21DPR) follows the law of diminishing variable returns whereby, the same level of gain in 21DPR results in greater profitability gains at low versus high levels of reproductive performance. Nevertheless, the magnitude of

the change in profitability for the same gain of 21DPR may vary dramatically from herd to herd and the value of multiple economic and performance inputs used for calculation.

Similarly, number of days from calving to conception, also known as days open (DO), has been extensively used to quantify economic impact of reproductive performance.²⁻⁴ The basis of such approach has been that maximum profitability of a dairy herd is observed when cows have a specific number of DO that results in an ideal calving interval. Cows that conceive after the ideal number of DO incur economic losses. Then, the economic value of a program or specific strategy under consideration is determined by comparing its economic outcome to that of a hypothetical scenario in which all cows have an ideal number of DO. Numerous epidemiological studies provided insights regarding implications of reproductive performance for dairy herds based on the calculation of the cost of DO. However, a major caveat of this approach is that the difference in DO generated by various reproductive programs is unknown, unless herd dynamics are compared in the field or simulated and the cost of DO usually changes dramatically based on specific herd and economic conditions.

Thus, practitioners should understand limitations of direct extrapolation of economic estimations, due to changes in reproductive management across herds and within a herd over time, given multiple interactions among inputs and outputs and their expected absolute values.

Decision making tools

The myriad of factors that affect farm costs and revenues, and the lag time between changes in reproductive performance and realization of benefits or losses, creates challenges for economic analyses of reproductive management programs under field conditions. Therefore, simulation models have been created to incorporate both performance and economic field data in combination with herd dynamics simulation to predict potential impact of various reproductive management strategies on profitability of dairy farms.³⁻⁷

Some simulation models used in research settings⁷ have also been used to develop decision-support tools and are readily available for use by stakeholders. For example, University of Wisconsin Cornell University (UWCU)-DairyRepro\$ tool available at: University of Wisconsin: DairyMGT.info: Tools: Reproduction or Cornell University: <http://www.ansci.cornell.edu/dm/resources.html>. The UWCU-DairyRepro calculates and compares economic value of dairy reproductive programs, including fixed time Artificial Insemination (FTAI), heat detection (HD), and combinations of FTAI and HD programs. This tool also enables inclusion of automated estrus detection systems (e.g. activity monitors) for detection of estrus in lactating dairy cows. The model behind the tool applies probabilistic reproduction survival curves with expected monetary values to determine the difference in net present value (NPV) of a current (i.e. program currently used by farm of interest) versus an alternative (i.e. program under consideration for implementation) reproductive program for a specific dairy farm. Thus, this tool facilitates economic-based decision making, as users can compare, between programs, expected direction and magnitude of economic differences.

Research on the impact of management interventions on the profitability of dairy cattle

Examples of research studies conducted with simulation or collection of data from field experiments for lactating dairy cows are provided to exemplify impacts of reproductive management on dairy herd profitability. More details about these studies are described in the literature.⁷⁻⁸

Combination of artificial insemination at detected estrus and fixed time artificial insemination or all fixed time artificial insemination

The dairy industry has widely adopted the use of hormonal protocols for synchronization of estrus and ovulation. Although some dairies rely solely on synchronization of ovulation and perform FTAI for all services, the majority implement programs combining FTAI and artificial insemination at detected estrus (AIE). In farms that use combined programs, it is frequent to observe different levels of performance for cows receive AIE and cows that receive FTAI. Thus, determination of the impact of

different proportions of cows AIE and FTAI and the respective success of each type of AI services can be useful to aid producers and consultants in their decision-making process.

In this regard, Giordano et al.⁷ simulated a set of plausible scenarios of reproductive management and performance observed in dairy herds. A reproductive program that consisted of all FTAI (AFTAI) was used as baseline for comparison to multiple combined programs with varying proportions of cows AIE (30 - 70%) and varying levels of fertility (low = 25%, medium = 30%, and high = 35%; Table 1). This broad range of performance represented a wide range of herd reproductive performance usually observed in dairy farms in the US.

The net value (NV) differences between the 16 programs combining AIE and FTAI (2 to 16) with the AFTAI are presented in Figure 1. Results indicated that fertility of cows AIE and the consequent change in the population of cows reaching FTAI are critical factors that affect profitability in herds combining FTAI and AIE. When compared to AFTAI, programs with 25% conception rate (CR) to AIE services had a lower NV at all levels of ED, suggesting that allowing more cows to receive FTAI is more economical. This is because cows that would have a greater chance of becoming pregnant after synchronization are prevented from getting a FTAI and therefore subject to a longer time interval until they are re-inseminated and have another chance to conceive. The detriment of receiving AIE was greater as the percentage of cows receiving AIE increased from 30 - 70% as demonstrated by the continued decrease in NV. However, as CR to AIE increased from 25 - 30%, a major NV positive change was observed for all programs. Thus, when 30 - 70% of cows receive AIE and CR is 30%, neither major gains nor losses should be expected if cows receive AIE or FTAI. Lastly, when compared to AFTAI programs combining AIE and FTAI with 35% CR had substantially greater NV at all levels of ED.

A practical implication of these results is that when 30 to 70% of cows receive AIE and the CR is 25%, profitability will be reduced when compared to a program like AFTAI. Thus, allowing cows to receive FTAI would be a preferred strategy. Conversely, when CR to AIE is 30 or 35% there would always be an economic advantage, albeit of different magnitude, when cows are allowed to be AIE. Although minor differences were observed when CR after ED inseminations is 30%, there is a clear benefit of inseminating cows in estrus when CR is 35%.

Economics of manipulating the duration of the voluntary waiting period

Insemination and conception risks after the end of the voluntary waiting period (VWP) are the 2 major determinants of time to pregnancy during lactation. Nonetheless, duration of the VWP can also influence timing of pregnancy, because it determines when cows become eligible for insemination. Through its impact on timing of pregnancy, VWP duration has a direct effect on profitability of dairy cows. Traditionally, dairy farms in the US began inseminating cows at ~ 40 - 50 DIM because suboptimal estrus detection and fertility to AI required that cows received multiple services to conceive. In recent years, however, better reproductive management programs that ensure inseminating cows by a set DIM, led to increases in reproductive and productive performance of well-managed dairy herds. Improved detection of estrus and fertility reduces the number of inseminations needed to conceive and variation in the interval for cows to become pregnant. Thus, there is an opportunity to better control timing of pregnancy during lactation and thereby maximize profitability. In this regard, manipulating VWP duration may be a simple and inexpensive change, with potential to impact profitability of dairy herds.

In a recent experiment, we evaluated reproductive performance, herd exit dynamics and economics of dairy cows managed with variable duration of the VWP. We hypothesized that extending VWP duration from 60 - 88 DIM impacts reproductive performance and profitability of lactating Holstein cows. Cows from 3 commercial farms in NY State received FTAI after synchronization with the Double-Ovsynch protocol at 60 ± 3 or 88 ± 3 DIM. Reproductive performance and cash flow for up to 18 months after calving in the experimental lactation were compared. Results of this experiment are presented in detail in the literature.^{1,8}

For primiparous cows, cash flow per slot per 18 months or per day was similar for the VWP60 and VWP88 treatment, despite a \$68 numerical difference in favor of the VWP88 group (Table 2). Interestingly, most of the difference between treatments was due to greater replacement cost for the

Table 1. Expected reproductive performance of programs used for simulation in the case study.

Program Number	Program	First AI			Second and subsequent AI		
		AIE ^a before 1 st FTAI ^b	CR AIE ^c before 1 st FTAI	CR FTAI	AIE before FTAI	CR AIE before FTAI	CR FTAI
1	AFTAI ^d	-	-	42	-	-	30
2	FTAI+AIE 2 ^e	30	25	40	30	25	30
3	FTAI+AIE 3	40	25	38	40	25	30
4	FTAI+AIE 4	50	25	36	50	25	30
5	FTAI+AIE 5	60	25	34	60	25	28
6	FTAI+AIE 6	70	25	32	70	25	28
7	FTAI+AIE 7	80	25	30	80	25	28
8	FTAI+AIE 8	30	30	40	30	30	30
9	FTAI+AIE 9	40	30	38	40	30	30
10	FTAI+AIE 10	50	30	36	50	30	30
11	FTAI+AIE 11	60	30	34	60	30	28
12	FTAI+AIE 12	70	30	32	70	30	28
13	FTAI+AIE 13	80	30	30	80	30	28
14	FTAI+AIE 14	30	35	40	30	35	30
15	FTAI+AIE 15	40	35	38	40	35	30
16	FTAI+AIE 16	50	35	36	50	35	30
17	FTAI+AIE 17	60	35	34	60	35	28
18	FTAI+AIE 18	70	35	32	70	35	28
19	FTAI+AIE 19	80	35	30	80	35	28

^aPercentage of cows AI after estrus detection (AIE) before first time AI.

^bFTAI = Fixed time artificial insemination.

^cConception rate (CR) of cows AI after detection of estrus.

^dProgram all fixed time artificial insemination (AFTAI) relied on 100% FTAI for all services after synchronization of ovulation for first postpartum AI with the Presynch-Ovsynch protocol whereas the Ovsynch protocol was used for second and subsequent AI services. The voluntary waiting period was 72 d and the interval between 2 successive inseminations was 42 days.

^ePrograms combining FTAI with estrus detection (FTAI + AIE 2 to 19), used the same synchronization of ovulation protocols than FTAI except that AI after AIE was added between the end of the VWP set at 50 DIM and the first FTAI at 72 DIM and in between FTAI services (AIE was discontinued at the time of the first GnRH of the Ovsynch protocol for all AI services)

VWP60 treatment, because the small differences observed for the rest of the parameters offset each other. The difference in replacement cost was primarily due to greater cost in the subsequent lactation because a slightly greater percentage of second-lactation cows left the herd before the end of the 18 month period.

Thus, when attempting to extrapolate results of our experiment to other farms, it is important to recognize the dominance of replacement cost over total profitability, as a different replacement cost dynamics (i.e. different culling pressure and different cash cost of culling) may be observed across herds and changing market conditions. Indeed, when the potential effect of changes in economic conditions was simulated, replacement costs accounted for up to ~ 80% of total variation in cash flow.

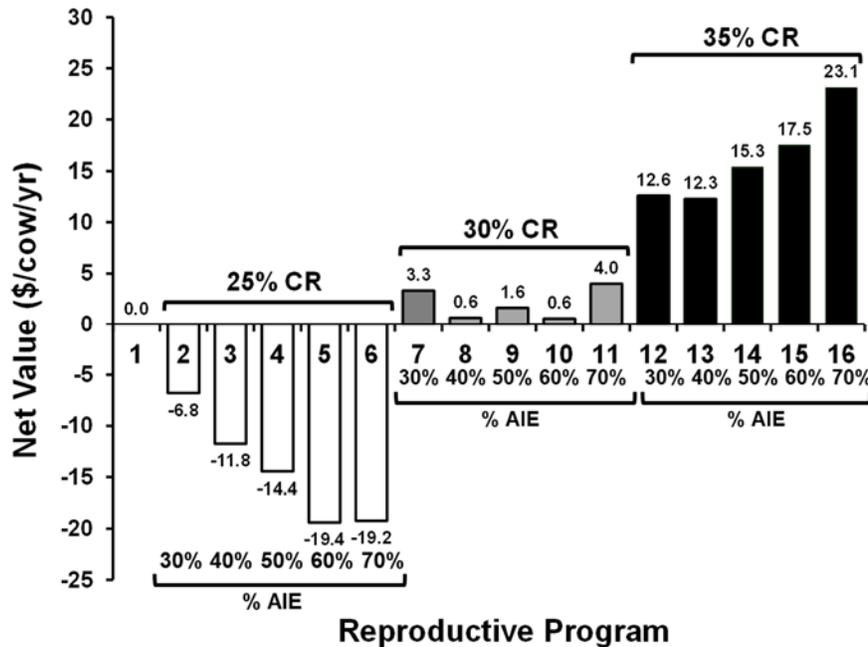


Figure 1. Difference in Net Value (NV; \$/cow per year) for 15 programs combining estrus detection and timed AI with an all fixed time artificial insemination program (AFTAI).

Interestingly, for multiparous cows, results were opposite to those of primiparous cows. Although a statistically significant difference between treatments was not observed, cows in the VWP60 were more profitable by \$85 per slot per 18 months than cows in the VWP88 treatment (Table 2). In this case, however, replacement cost was greater for the VWP88 reflecting increased culling pressure in non-pregnant cows in the VWP88 treatment in later lactation. Such contrast in results for overall cash flow likely reflected differences in milk production persistency (i.e. lactation curves are less persistent for multiparous than primiparous) and the interaction between parity and risk of leaving the herd as lactation progressed. Although to a lesser extent than for primiparous cows, replacement cost explained a substantial proportion of numerical economic differences for results with fixed economics values or when we simulated varying economic conditions.

In summary, economic outcomes for our experiment suggest that extending the VWP from 60 to 88 DIM when using AFTAI to submit cows for first service may result in greater (numerical) profitability for primiparous cows, primarily through a reduction in replacement costs. Conversely, the same extension of the VWP duration for multiparous cows may lead to economic losses (numerical), primarily due to greater replacement cost and reduced IOFC that cannot be offset by reduced reproductive program costs.

Results from our experiment should be interpreted with caution because in spite of the large number of cows included, we did not detect statistically significant differences for overall cash flow, all cows received rbST and the particular replacement dynamics of the herds involved in our research may have been affected by individual farm management decisions and economic conditions during the trial.

Table 2. Effect of extending duration of the voluntary waiting period from 60 to 88 DIM on revenues and expenses during 18 months after calving in the experimental lactation.

	Primiparous				Multiparous			
	VWP60 ^a (n = 480)	VWP88 ^b (n = 471)	Difference ^c	p value ^d	VWP60 (n = 785)	VWP88 (n = 789)	Difference	p value
	\$ / slot ⁴				\$ / slot			
Milk IOFC	3,806	3,803	-3	0.95	4,363	4,324	-39	0.38
Calf value	100.5	102.9	2.4	0.59	80.78	77.98	-2.80	0.43
Replacement cost	327.3	259.0	-68.3	0.07	624.9	673.6	48.7	0.16
Reproductive cost	97.58	91.28	-6.30	< 0.01	104.14	93.63	-10.5	< 0.01
bST cost	215.9	221.6	5.7	< 0.01	219.4	224.9	5.5	< 0.01
Operating expenses	1,512	1,512	-	-	1,512	1,512	-	-
Cash flow per 18 mo	1,756	1,824	68	0.32	2,006	1,921	-85	0.19
Cash flow per day	3.25	3.37	0.12	0.32	3.71	3.56	-0.15	0.19

^aVWP60 = first service timed AI at 60 ± 3 DIM after the Double-Ovsynch protocol.

^bVWP88 = first service timed AI at 88 ± 3 DIM after the Double-Ovsynch protocol.

^cDiff = difference between VWP88 and VWP60 (Diff = VWP88-VWP60).

^dSlot is the unit of space occupied by each cow enrolled in the experiment for an 18 month period after calving in the experimental lactation.

Conclusion

The relationship between herd reproductive performance and profitability is complex due to multiple factors, inputs and outputs affected by reproductive performance. Availability of reproductive decision support tools provides practitioners with new opportunities to help their clientele. Decision support tools can be used to simulate impacts of reproductive performance and herd dynamics on profitability of a specific dairy herd. Thus, practitioners can help dairy farm managers make informed decisions regarding choice of reproductive management programs or strategies to achieve a desired level of performance. Otherwise, extrapolation of expected economic responses to changes in reproductive performance or results from research studies can be used to guide on-farm decisions.

Conflict of interest

There are no conflicts of interest to declare.

References

1. Stangaferro ML, Wijma R, Masello M, et al: Extending the duration of the voluntary waiting period from 60 to 88 days in cows that received timed artificial insemination after the Double-Ovsynch protocol affected the reproductive performance, herd exit dynamics, and lactation performance of dairy cows. *J Dairy Sci* 2017;101:717-735.
2. Louca A and Legates JE: Production losses in dairy cattle due to days open. *J Dairy Sci* 1968;51:573-583.
3. Groenendaal H, Galligan DT, Mulder HA: An economic spreadsheet model to determine optimal breeding and replacement decisions for dairy cattle. *J Dairy Sci* 2004;87:2146-2157.
4. Meadows C, Rajala-Schultz PJ, Frazer GS: A spreadsheet-based model demonstrating the nonuniform economic effects of varying reproductive performance in Ohio dairy herds. *J Dairy Sci* 2005;88:1244-1254.
5. De Vries, A: Economics of delayed replacement when cow performance is seasonal. *J Dairy Sci* 2004;87:2947-2958.
6. Giordano JO, Fricke PM, Wiltbank MC, et al: An Economic Decision-Making Support System for Selection of Reproductive Management Programs on Dairy Farms. *J Dairy Sci* 2011;94:6216-6232.
7. Giordano JO, Kalantari AS, Fricke PM, et al: A Daily Herd Markov-Chain Model to Study the Reproductive and Economic Impact of Reproductive Programs Combining Timed Artificial Insemination and Estrus Detection. *J Dairy Sci* 2012;95:5442-5460.
8. Stangaferro ML, Wijma R, Masello M, et al: Economic performance of lactating dairy cows submitted for first service timed artificial insemination after a voluntary waiting period of 60 or 88 days. *J Dairy Sci* 2018;101:7500-7516.

