ASSESSING THE PROFITABILITY OF REPRODUCTIVE MANAGEMENT PROGRAMS FOR DAIRY HERDS – NEW INSIGHTS AND TOOLS FOR PROGRAM SELECTION

J. O. Giordano
Department of Animal Science
Cornell University

INTRODUCTION

The relationship between reproductive performance of dairy herds and milk production and the consequent impact on the profitability of dairy farm systems has long been recognized (Touchberry et al., 1959; Louca and Legates, 1968; Oltenacu et al., 1980). Total milk sales, number of culled cows, and number of replacement heifers born are among the major sources of income affected by reproductive performance of lactating dairy cows (Britt, 1985; De Vries, 2004; Meadows et al., 2005). Feed cost, labor cost, and veterinary expenses are also highly influenced by the reproductive program because lactation length, dry period length, and number of services to conceive are highly correlated to the reproductive performance of cows. Therefore, at the time of selecting a long-term reproductive management strategy, all factors that contribute to the variation in reproductive and economic performance need to be considered for analysis.

It remains a major challenge for dairy producers, veterinarians, and consultants to define the reproductive management strategy that would maximize 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 whether the on-farm application of these programs and technologies will be economically beneficial. Due to the multiple factors affected by changes in reproductive management and the timing required to quantify the productive and economic impact of changes in reproductive performance it has been difficult to perform comprehensive analyses under field conditions. Consequently, another approach has been to use computer simulation models to predict the dynamics of dairy herds after changes in reproductive management and the economic implications of such changes (De Vries, 2004; Groenendaal et al., 2004; Meadows et al., 2005;Giordano et al., 2011; 2012). These simulation models can then be used as an aid in the decision-making process by incorporating them into decision support tools that allow dairy producers and consultants to evaluate different reproductive management programs under the conditions of specific farm operations. For example, in farms combining programs that use timed AI (TAI) and estrus detection (ED) to inseminate cows it is frequent to observe different levels of performance for cows detected in estrus and cows that are allowed to complete the synchronization protocol and reach TAI. In these cases, determination of the appropriate balance between cows AI in estrus and TAI for a particular farm can be assessed by using a recently developed decision support tool presented herein.

The objectives of this paper were: 1) to briefly describe a new decision support tool created based on a simulation model that simulates on a daily basis the reproductive, productive, and economic dynamics of dairy herds; and 2) to use this decision support tool to assess the economic and reproductive outcomes of multiple performance scenarios observed after implementation of a typical reproductive management approach widely used by dairy herds in the US.

DECISION SUPPORT TOOL

A schematic representation of the herd dynamics in the daily Markov-chain model used to create the decision support tool is presented in Figure 1. Cows enter the lactating herd after calving and begin to transition into lactation in daily steps until the end of the voluntary waiting period (VWP). From the end of the VWP until the DIM cutoff for insemination (determined as an input) cows have a daily probability of pregnancy. Cows conceiving after AI transition into the pregnant stream and progress throughout the entire gestation until dry-off at 220 d and calving occurs at 282 d. After calving, cows transition into their next lactation. Pregnant cows have a daily probability of pregnancy loss from 30 to 281 d in gestation. Cows suffering pregnancy loss return to the non-pregnant cow stream. Cows failing to become pregnant after successive service attempts are coded as “do-not-breed” (DNB) and remain in the herd until milk production falls below a predefined threshold (MBT) when they are culled (Repro Repl). Every day throughout lactation cows have a daily probability of culling due to non-reproductive reasons and death. All cows leaving the herd for any reason are replaced the next day with a first lactation cow.

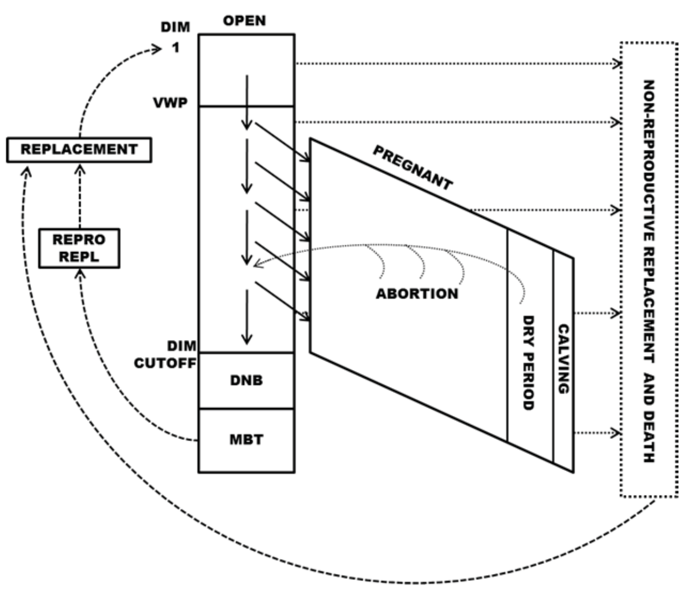

Figure 1. Schematic representation of the daily Markov-chain model used to create the decision support tool. VWP = voluntary waiting period, DNB = do-not-breed, MBT = milk below threshold, DIM cutoff = maximum number of days in milk for insemination.

The distribution of cows in the different states of lactation number, DIM, and reproductive status generated by the herd dynamics is then integrated with the different productive and economic parameters entered as input to calculate the Net Value ($/cow per yr.) for each reproductive program compared. For a detailed description of the simulation model and decision support tool see Giordano et al., 2012.

The decision support tool was developed as a standalone executable program with Visual Basic.Net 2010 and will be available soon to the general public. Using this decision support tool it is possible to compare multiple scenarios and situations including (but not limited to):

- Utilization of different synchronization of ovulation protocols for first service TAI, resynchronized services or both,
- Compare the impact of changes in estrus detection efficiency and fertility of AI services as well as any management change that could impact both of these parameters,
- Compare different costs for each of the resources and activities associated with performing reproductive management programs including the cost of labor, semen, hormones for synchronization, pregnancy diagnosis, and use of technologies for estrus detection such as activity monitors,
- Changes in milk production, economics conditions (e.g., price of milk, feeding cost), replacement costs, and replacement decisions.

CASE STUDY: ASSESSING THE IMPACT OF INSEMINATING COWS IN ESTRUS AND THEIR CONCEPTION RATE DURING A TIMED AI PROGRAM ON THE ECONOMIC AND REPRODUCTIVE PERFORMANCE OF A DAIRY HERD

The main objective of the case study was to simulate a set of plausible scenarios of reproductive management and performance observed in dairy herds. A reproductive program which consisted of 100% timed artificial insemination (TAI) was used as baseline for comparison to multiple programs combining estrus detection (ED) and TAI having a different percentage of cows AI after estrus detection (30 to 70%) with different levels of fertility (low, medium, and high). This broad range of performance was selected to have a wide representation of current dairy farm reproductive results observed in herds combining Ovsynch type synchronization programs with ED in the US. Many other strategies and management options are used in the industry; however, the type of program simulated herein is widely used. Moreover, it is not the purpose of this work to evaluate every potential reproductive management program but rather exemplify the type of analysis that can be performed with this type of decision support tool.

Program 1 (100% TAI) relied completely on TAI for all services after synchronization for first postpartum AI with the Presynch-Ovsynch protocol (Moreira et al., 2001) whereas the Ovsynch protocol (Pursley et al., 1995) was used for resynchronization of ovulation for second and subsequent services. For Program 1, the end of the VWP was set at 72 DIM coincident with the first service TAI. Thirty-two days following a previous TAI, all cows initiated the Ovsynch Resynch protocol regardless of their pregnancy status. Seven days later, non-pregnancy diagnosis was performed by rectal palpation and those cows failing to conceive continued the protocol to receive their next TAI 42 d after the previous service.

For Programs 2 to 16, the same synchronization of ovulation protocols were used except that AI after ED was added between the end of the VWP set at 50 DIM and the first TAI at 72 DIM and in between TAI services (ED was discontinued at the time of the first GnRH of the Ovsynch protocol for all AI services). The proportion of cows inseminated after ED was sequentially increased from 30 to 70% in 10% point increments (Table 1). Furthermore, three groups of programs were created for which the CR after ED was 25 (low; programs 2 to 6), 30 (medium; programs 7 to 11) and 35% (high; programs 12 to 16). Under most circumstances (not always), when ED is added before or between TAI services, a reduced CR is observed for those cows inseminated to TAI because the fertility potential of the population of cows reaching this point is different than when no estrus detection is added (Chebel et al., 2004; Keskin et al., 2011). Therefore, for each 10% point increment in ED before first service TAI from 30 to 70%, the initial CR of 40% after TAI services decreased by 2% points (Table 1). Additionally, the CR of second and subsequent TAI services also was decreased by 2% points when the proportion of cows receiving AI after ED was 60 and 70% (Table 1). The DIM cutoff for insemination was set at 300 DIM for all programs.

<u>Reproductive Program Cost</u>. Input parameters to calculate the cost of performing each of the reproductive programs was assumed to be for a 1,000-cow commercial herd in New York. The cost of $PGF_{2\alpha}$ was set at $2.3/dose whereas the cost of GnRH at $2.6/dose according to the market value of two commercially available products. The cost of semen was set at $10/dose and performing an insemination was set at $6/AI. The veterinary cost of performing pregnancy diagnosis by rectal palpation was set at $105/h. First pregnancy diagnosis for pregnant cows occurred at 39 d in gestation with 2 pregnancy reconfirmations at 67 and 221 d in gestation. The cost of performing detection of estrus was calculated based on 1 laborer performing the task 4/h per day 7 d a week at $15/h.

<u>Milk Production Fitting</u>. Observed milk production records were collected from a 1000-cow herd in New York and fitted with the MilkBot model. A factor for milk production depression because of gestation was used based on De Vries (2004) that indicated that milk production would be reduced by 5, 10, and 15% in months of gestation 5, 6, and 7, respectively.

<u>Price of Milk, Feed, Calves, Replacement, and Salvage Value</u>. Input prices included: $18.5/cwt, $0.13/lb and $0.06/lb of feed (dry matter) for lactating and non-lactating cows respectively, $125/calf for females, $25/calf for males, $1,150/heifer replacement, and $0.60/lb for culled cows. All input variables represent approximate values observed in upstate New York for the fall of 2012.

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

Program Number	Program	1st AI ED before 1st TAI	1st AI CR ED before 1st TAI	1st AI CR TAI	2nd and subsequent AI ED before TAI	2nd and subsequent AI CR ED before TAI	2nd and subsequent AI CR TAI
1	TAI 1	-	-	42	-	-	30
2	TAI+ED 2	30	25	40	30	25	30
3	TAI+ED 3	40	25	38	40	25	30
4	TAI+ED 4	50	25	36	50	25	30
5	TAI+ED 5	60	25	34	60	25	28
6	TAI+ED 6	70	25	32	70	25	28
7	TAI+ED 7	30	30	40	30	30	30
8	TAI+ED 8	40	30	38	40	30	30
9	TAI+ED 9	50	30	36	50	30	30
10	TAI+ED 10	60	30	34	60	30	28
11	TAI+ED 11	70	30	32	70	30	28
12	TAI+ED 12	30	35	40	30	35	30
13	TAI+ED 13	40	35	38	40	35	30
14	TAI+ED 14	50	35	36	50	35	30
15	TAI+ED 15	60	35	34	60	35	28
16	TAI+ED 16	70	35	32	70	35	28

NET VALUE DIFFERENCES FOR THE REPRODUCTIVE MANAGEMENT PROGRAMS COMPARED IN THE CASE STUDY

The net value differences between the 16 programs combining TAI and ED (programs 2 to 16) with the 100% TAI program (TAI 1) are presented in Figure 2. All programs having 25% CR after ED breedings before 1st service TAI and between resynchronized TAI services had a lower NV than TAI 1. As the proportion of cows inseminated after ED increased from 30 to 60%, the NV differences increased from 6.8 to 19.4 $/cow per yr in favor of TAI 1. A slight decreasing trend in the NV differences was observed when the percentage of cows receiving AI after ED was 70%; however, the NV differences remained within the 19 $/cow per yr range. By contrast, for programs having 30% CR to AI services after ED (7 to 11), the NV was always superior for the combined programs with differences ranging from 0.6 to 4.0 $/cow per yr in favor of the combined programs. Similarly, when the CR to AI services between TAI was 35%, the NV differences were all positive ranging from 12.3 to 23.1 $/cow per yr in favor of the programs in which ED was added between TAI services. In most cases, the NV differences with TAI 1 increased by every 10 percentage point increment in the percentage of cows inseminated after ED to reach a maximum difference when ED was 70%.

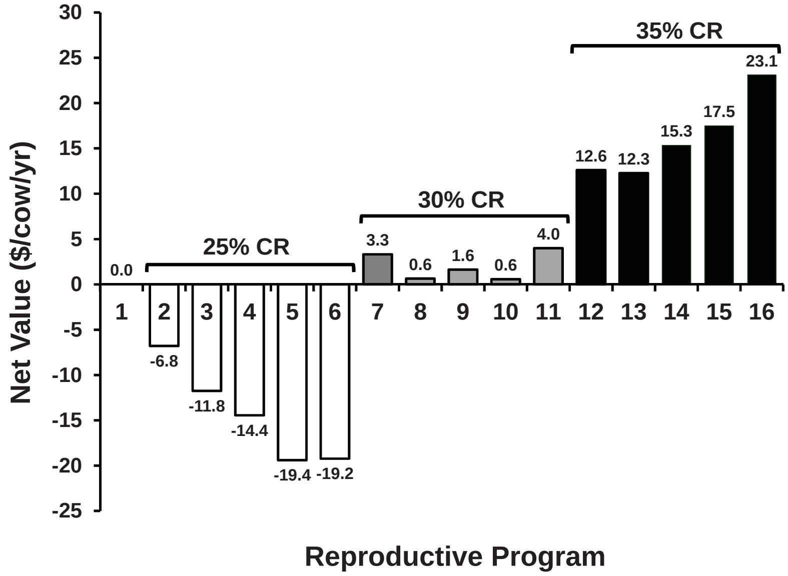

Figure 2. Difference in Net Value (NV; $/cow per yr) for 15 programs combining estrus detection and timed AI with a 100% timed AI program as defined in Table 1.

Under the conditions specified for this particular case study, these results indicated that the fertility of cows inseminated after ED and the consequent change in the population of cows reaching the TAI services are critical factors that impact the economic outcomes in herds combining TAI and ED. When compared to a program relying solely on TAI with achievable results in commercial dairy farms, those programs having 25% CR to the ED services had a lower NV at all levels of ED. This is interesting because when these lower CR values are observed on a farm, allowing more cows to receive a TAI is a more convenient strategy than inseminating them a few days earlier in estrus. Similar results were previously observed after simulation of other reproductive management programs (Giordano et al., 2011) strongly suggesting that inseminating cows detected in estrus before completion of a synchronization protocol and obtaining low CR has a negative impact on herd reproductive performance and profitability. Cows that would have a greater chance of becoming pregnant after TAI are prevented from reaching this point and are subject to a longer time interval until they are re-inseminated and have a chance to conceive. These results also seem to suggest that attempts to reduce reproductive cost by inseminating cows in estrus by preventing them from completing a synchronization protocol may not always be beneficial for the farm. Low fertility after ED inseminations actually reduces farm profitability. Despite lower reproductive program cost for programs using ED in the case study, when all factors that generate cost and revenues are considered the lower costs were insufficient to overcome the negative impact of lower reproductive performance.

The detriment of increasing the percentage of cows receiving AI after ED increased as the percentage of cows receiving AI after ED increased from 30 to 60% as demonstrated by the continued decrease in NV for the programs with 25% CR. Obviously, farms that have a lower CR than 25% would have even lower NV compared to a reproductive management program with TAI having the CR chosen for this simulation.

As the CR to ED inseminations increased from 25 to 30% a major change was observed in the NV for all programs which were superior to TAI 1 in all cases. The smaller differences observed between TAI 1 and programs TAI+ED 7 through 11 indicated that there was no major economic advantage of performing either of these programs. An interesting implication of these observations for dairy operations is that when the percentage of cows receiving AI after a detected estrus before 1st service TAI and subsequent AI services is within 30 to 70% with a CR of 30%, neither major gains nor losses should be expected if cows receive AI after a detected estrus or reach the TAI.

When compared to the 100% TAI program and all other combinations of TAI and ED, programs having 35% CR had substantially greater NV at all levels of ED. These programs outperformed TAI 1 by 12.3 to 23.1 $/cow per yr and some of the lowest performing programs by ~30 to 40 $/cow per yr. In all cases when compared to TAI 1, these programs had a smaller percentage of pregnant cows up to approximately 150 DIM because the higher CR to first service in TAI 1 generated a substantial difference after each of the TAI services, particularly during the early part of the breeding period (data shown in Figure 3 for TAI+ED 14 only). However, as DIM progressed the greater CR to the ED inseminations in the combined programs outweighed this early difference and they were capable of outperforming TAI 1. Indeed, in all cases combined programs had a greater percentage of pregnant cows by the DIM cutoff for AI.

Based on the results for the other subsets of programs with lower CR to AI after ED (TAI+ED 2 to 11), it was not surprising to observe a better performance for the programs with 35% CR because for 2nd and subsequent AI services the CR was always greater than that of TAI breedings. Cows inseminated after a detected estrus had a shorter interbreeding interval and greater chances of conceiving than cows reaching the TAI; hence, the NV of all these programs was greater than TAI 1 at all levels of ED.

A major practical implication of these results is that interesting trends in the economic and reproductive performance of programs (Presynch-Ovsynch and Ovsynch alone or in combination with ED) typically used in commercial US dairy herds were observed. According to these results, when 30 to 70% of cows receive AI to a detected estrus and the CR of these inseminations is 25% the economic outcome will be negative when compared to the 100% TAI program with 42% CR after 1st service and 30% CR after 2nd and subsequent services. Another factor to consider is the impact of the change in the population of cows reaching the TAI as the percentage of cows that receive AI after estrus in the combined programs increased. The consequent decrease in CR for cows reaching the TAI services was another reason for the overall lower economic performance of these programs. These observations suggest that allowing cows to complete the synchronization protocol and receive a TAI would be a preferred strategy. Conversely, whenever the CR to ED inseminations was 30 or 35% there would always be an economic advantage, even though a different magnitude of NV change is anticipated according to the percentage of cows receiving AI after ED and the resulting CR. While very minor differences were observed when CR after ED inseminations was 30%, there is a clear benefit of inseminating cows in estrus when CR is 35%.

REPRODUCTIVE DYNAMICS

Survival curves for pregnancy for a subset of programs are presented in Figure 3 to illustrate the impact of adding ED with different fertility outcomes to a 100% TAI program. The programs represented in Figure 3 are those with 50% of cows inseminated after ED (TAI+ED 4, 9, and 14) within each of the 3 CR groups (25, 30, and 35%) and also the survival curve for the 100% TAI program (TAI 1). These programs were selected to represent and compare scenarios frequently observed in commercial dairy operations in the US. Under the simulated conditions of this case study; all combined programs had a greater proportion of pregnant cows after the end of the VWP at 50 DIM until 72 DIM when cows receive first service in TAI 1. Thereafter, TAI 1 outperformed TAI+ED 4 throughout the entire breeding period until the DIM cutoff for AI which was set at 300 DIM. Conversely, TAI 1 and TAI+ED 9 had similar percentages of pregnant cows except for some specific time points in which TAI+ED 9 had more pregnant cows (because cows in TAI 1 had not yet received their subsequent TAI). At the end of the period TAI 1 had a slightly greater percentage of pregnant cows. Finally, when comparing the performance of TAI 1 and TAI+ED 14, the program using ED had a greater percentage of pregnant cows throughout the entire AI period except after each of the TAI services until 151 DIM.

RELATIVE CONTRIBUTION OF STUDIED ECONOMIC FACTORS TO THE NET VALUE DIFFERENCES AMONG REPRODUCTIVE MANAGEMENT PROGRAMS

When assessing the relative contribution to the differences among the 16 programs, IOFC accounted for the greatest average difference between programs (7.1 $/cow per yr; range = $0.0 to $19.2) (Figure 4). On the other hand, the average difference between programs due to culling cost and reproductive program cost was very similar in magnitude and variation with 4.4 (range = 0.0 to 12.5) and 3.6 (range = 0.0 to 12.8) $/cow per yr for culling and reproductive program costs, respectively (Figure 4). Furthermore, calf value had the lowest contribution to the difference with 2.1 $/cow per yr and ranging between 0.0 and 6.0 $/cow per yr (Figure 4). Because IOFC accounted for the greatest mean difference and variation between programs, it is clear that the greatest effect of changes in reproductive performance was improving milk production efficiency. In general, culling cost and reproductive program cost had a significantly smaller contribution to the differences among programs. However, in some cases they contributed to major differences between programs suggesting that profitability can be greatly affected by the impact of culling cost and reproductive program cost. Finally, calf value was the factor with the least influence on the differences among programs. This could be explained, at least in part, by the low value of new born calves and replacement heifers as well as the high value of culled cows used as input in the case study (representative of the current market conditions).

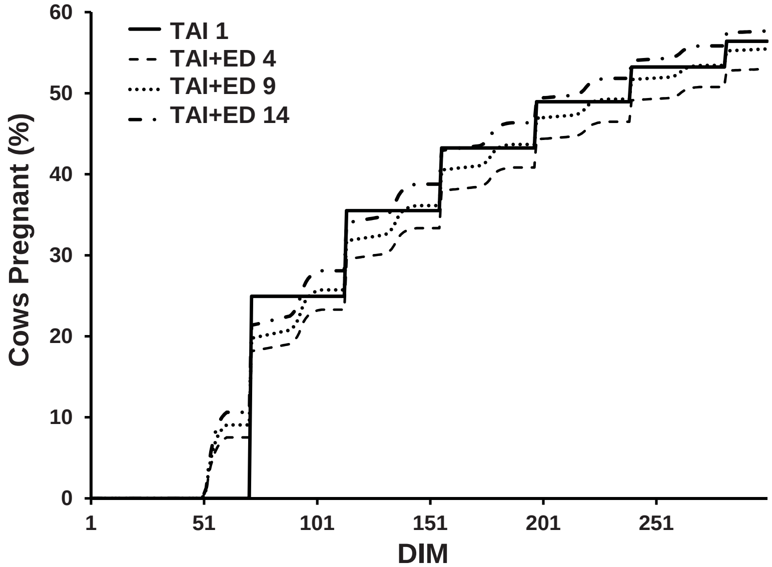

Figure 3. Accumulated percentage of pregnant cows until the DIM cutoff (300 d) for insemination for five representative programs. Program TAI 1 used as baseline for comparison with the combined programs. Combined TAI+ED programs 4, 9, and 14 were included to represent each one of the three groups with 25, 30, and 35% CR. The values represented take into account the effect of culling on the proportion of pregnant cows.

CONCLUDING REMARKS

The availability of new reproductive decision support tools provides dairy producers and consultants with new opportunities to make informed decisions at the time of selecting a management strategy for a particular dairy farm. This type of decision support tool should be an attractive resource to dairy farm consultants and managers involved in the decision-making process because using productive, economic, and reproductive data readily available from dairy farm software systems and market reports, it is possible to simulate the impact of reproductive performance and herd dynamics on the profitability of a specific dairy herd. Moreover, simulation models present a unique opportunity because they allow assessing the long term impact of reproductive performance while considering all the input cost associated with performing a reproductive program. This is of particular importance at the time of adopting a particular reproductive management program because of the lag time between the moment to invest resources to implement the program, the timing to achieve better reproductive performance, and the even longer time frame until economic benefits are realized.

As an example the results of the present case study demonstrated that the fertility of cows inseminated after a detected estrus and the consequent change in the population of cows reaching the TAI services in programs combining estrous detection and timed AI are critical factors that could impact the economic and reproductive outcomes in a dairy herd.

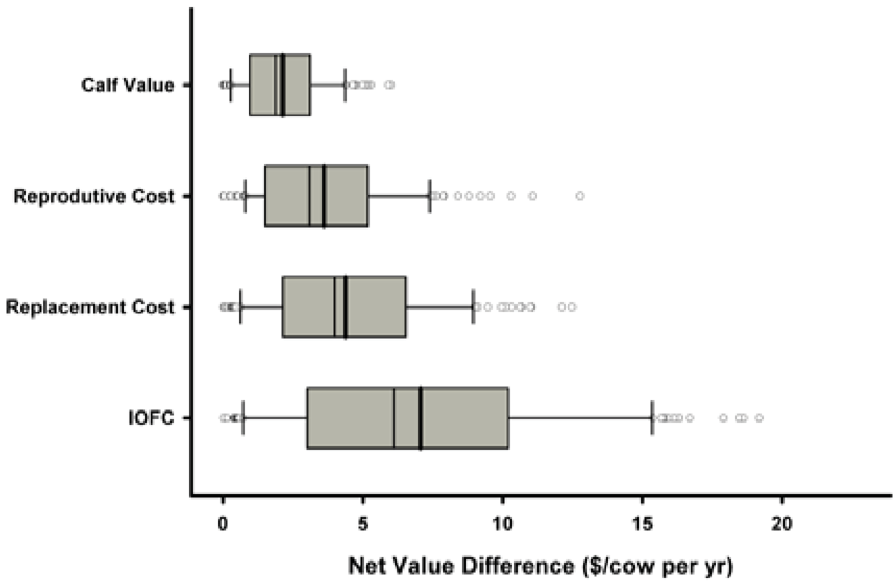

Figure 4. Box-plot representing the individual contribution of income over feed cost (IOFC), culling cost, reproductive programs cost, and calf value to the total Net Value (NV; $/cow per yr) differences between the 16 programs compared in the case study. Solid bold line inside box represents the mean difference.

ACKNOWLEDGEMENTS

This paper is in part the result of a collaborative effort with the Dairy Management (Dr. Victor E. Cabrera and Afshin S. Kalantari) and Reproductive Physiology (Dr. Paul Fricke and Dr. Milo Wiltbank) laboratories in the Department of Dairy Science at the University of Wisconsin-Madison. Appreciation is also extended to Betsey Howland and Jason Karszes for providing data and their time for discussion of this work.

REFERENCES

Britt, J. H. 1985. Enhanced reproduction and its economic implications. J. Dairy Sci. 68(6):1585-1592.

Chebel, R. C., J. E. Santos, J. P. Reynolds, R. L. Cerri, S. O. Juchem, and M. Overton. 2004. Factors affecting conception rate after artificial insemination and pregnancy loss in lactating dairy cows. Anim. Reprod. Sci. 84(3-4):239-255.

De Vries, A. 2004. Economics of delayed replacement when cow performance is seasonal. J. Dairy Sci. 87(9):2947-2958.

Giordano, J. O., P. M. Fricke, M. C. Wiltbank, and V. E. Cabrera. 2011. An economic decision-making support system for selection of reproductive management programs on dairy farms. J. Dairy Sci. 94(12):6216-6232.

Giordano J.O., Kalantari A.S., Fricke P.M., Wiltbank M.C., and Cabrera V.E. 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 Sep;95(9):5442-60.

Groenendaal, H., D. T. Galligan, and H. A. Mulder. 2004. An economic spreadsheet model to determine optimal breeding and replacement decisions for dairy cattle. J. Dairy Sci. 87(7):2146-2157.

Keskin, A., G. Yilmazbas-Mecitoglu, E. Karakaya, A. Alkan, H. Okut, A. Gumen,and M.C. Wiltbank. 2011. Effect of presynchronization strategy prior to ovsynch on fertility at first service in lactating dairy cows. J. Dairy Sci. 94, E-Suppl. 1:191.

Kuhn, M. T., J. L. Hutchison, and G. R. Wiggans. 2006. Characterization of Holstein heifer fertility in the United States. J. Dairy Sci. 89(12):4907-4920.

Louca, A. and J. E. Legates. 1968. Production Losses in Dairy Cattle Due to Days Open. J. Dairy Sci. 51(4):573-583.

Meadows, C., P. J. Rajala-Schultz, and G. S. Frazer. 2005. A spreadsheet-based model demonstrating the nonuniform economic effects of varying reproductive performance in Ohio dairy herds. J. Dairy Sci. 88(3):1244-1254.

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(7):1646-1659.

Pursley, J. R., M. O. Mee, and M. C. Wiltbank. 1995. Synchronization of ovulation in dairy cows using PGF2α and GnRH. Theriogenology 44(7):915-923.

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(8):1317-1327.

Touchberry, R. W., K. Rottensten, and H. Andersen. 1959. Associations Between Service Interval, Interval from First Service to Conception, Number of Services per Conception, and Level of Butterfat Production. J. Dairy Sci. 42(7):1157-1170.