Short communication: Economic impact among 7 reproductive programs for lactating dairy cows, including a sensitivity analysis of the cost of hormonal treatments

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ABSTRACT

Although hormonal synchronization programs can improve reproductive efficiency of dairy herds, some farmers question the economics of these programs based on the upfront cost of hormonal treatments as opposed to the economic value of the resulting reproductive performance. Our aim was to compare the economic impact of reproductive management programs that incorporate varying degrees of detection of estrus and timed artificial insemination (AI) in dairy herds with year-round calving in confinement total mixed ration systems. A reproductive economic analysis simulation model was used to compare the economic impact of pairs of reproductive management programs. We simulated sets of scenarios for 2 analyses. In the first analysis, we calculated the economic impact of switching from a Presynch-Ovsynch program to a Double-Ovsynch program that included a second PGF_{2α} treatment during the Breeding-Ovsynch portion of the program (Double-Ovsynch+PGF). In the second analysis, we conducted a break-even analysis in which the cost of hormonal treatments was incrementally increased within various reproductive management programs. Our analyses revealed that a Double-Ovsynch+PGF program, the most intensive program evaluated, was more profitable than other programs compared, including a Presynch-Ovsynch program with 100% timed AI or a Presynch-Ovsynch program that incorporated detection of estrus, despite the higher upfront cost incurred by using more hormonal treatments. This advantage remained until the cost of hormones was increased 5 to 14 times current US market prices and 2 to 6 times current European market prices. The cost of GnRH had a greater impact on net profit gain than the cost of PGF_{2α}. In conclusion, more intensive reproductive programs that use more hormonal treatments but result in substan-

tially increased reproductive performance are more profitable than less intensive programs and remain so even if hormone prices are unusually high.

Key words: reproduction, intensive synchronization program, economic impact

Short Communication

Advances in the understanding of the reproductive physiology of dairy cows have led to the development of management strategies and technologies that improve reproductive performance. Commercial dairy farms are challenged with making the most profitable management decisions among many options and implementing them correctly. Methods for enhancing fertility and breeding efficiency include detection of estrus (ED) (Xu et al., 1998; Rorie et al., 2002), synchronization of estrus (Folman et al., 1984; Momcilovic et al., 1998), and synchronization of ovulation and timed AI (TAI) (Pursley et al., 1995; Moreira et al., 2001; Souza et al., 2008). The newest TAI programs for first AI (i.e., Double-Ovsynch and G6G) not only increase the AI service rate but also increase conception rate or pregnancy per AI (P/AI) to TAI (Carvalho et al., 2018). Strategies that maximize ED, which are widely implemented at dairies, have made significant contributions to the profitability of dairy herds (Pecsok et al., 1994). A major limitation of ED, however, is the presence of anovular cows, ranging from 5 to 40% among herds, at the end of the voluntary waiting period (Walsh et al., 2007; Santos et al., 2009; Bamber et al., 2009). The lack of estrous behavior in anovular cows precludes AI to a detected estrus, and many anovular cows are submitted to hormonal programs for TAI.

Hormonal programs for synchronization of ovulation use sequential treatments of GnRH and PGF_{2α} to control follicular development, luteal regression, and time of ovulation (Carvalho et al., 2018). Synchronization of ovulation allows for more precise timing of AI than relying on ED for timing of AI (Pursley et al., 1995; Souza et al., 2008; Valenza et al., 2012; Fricke

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et al., 2014). Furthermore, optimization of the hormonal milieu during the Ovsynch program increases P/AI for cows at first TAI (Souza et al., 2008; Carvalho et al., 2014) and for cows resynchronized to receive subsequent TAI (Giordano et al., 2012; Lopes et al., 2013; Carvalho et al., 2015). Many farms combine ED (i.e., observation or automated activity monitoring, **AAM**) and TAI by observing and inseminating cows detected in estrus after the second PGF_{2α} treatment of a Presynch-Ovsynch program (Stangaferro et al., 2018, 2019), whereas cows not detected in estrus complete the program and receive TAI. Although inseminating cows detected in estrus during a Presynch-Ovsynch program increases AI service rate, it also decreases P/AI compared with a Presynch-Ovsynch program without ED (Fricke et al., 2014; Borchardt et al., 2016). This delicate tradeoff depends on the specific reproductive program and the herd's reproductive performance. By contrast, submission of lactating Holstein cows to a Double-Ovsynch+PGF program and TAI for first insemination increased the percentage of cows inseminated within 7 d after the end of the voluntary waiting period and increased P/AI at 33 and 63 d after first insemination, resulting in 64 and 58% more pregnant cows, respectively, compared with submission of cows for first AI after ED at a similar DIM range (Santos et al., 2017). Although primiparous and multiparous cows could have different favorable programs with customized voluntary waiting periods (Stangaferro et al., 2019), most modern dairy farm systems apply a consistent reproductive program to the entire herd for practical management reasons.

The assessment of the overall economic value of various reproductive management programs (Cabrera, 2014; Cabrera and Giordano, 2019) can be achieved by simulating reproductive performance along with the associated costs and benefits on a farm-by-farm basis (Giordano et al., 2011, 2012; Kalantari and Cabrera, 2012) and calculating the expected net return (De Vries et al., 2010; Fricke et al., 2010; Cabrera, 2011). In this study, we used a simulation model to compare the economic impact of current and alternative reproductive programs for managing reproduction on dairy farms with year-round calving that likely have confinement TMR systems (the UW-Cornell DairyRepro\$ decision tool; Giordano et al., 2012). The most novel aspect of our simulation is the sensitivity analysis of hormonal treatment costs among the various reproductive management programs. This study had 2 major objectives: (1) to analyze the profitability of an intensive reproductive program involving more injections (i.e., Double Ovsynch) compared with less intensive ones (Presynch-Ovsynch) in different geographic areas (i.e., the United States and Europe) depending on variation of hormonal

treatment costs, and (2) to estimate how high the cost of hormonal treatments would have to be to render intensive synchronization programs unprofitable.

To answer these questions, we simulated a 1,000-cow commercial dairy herd with year-round calving, using the UW-Cornell DairyRepro\$ decision tool (Giordano et al., 2012). For comparison consistency and to avoid analysis bias, variables that were not studied, such as mortality rate, body weight, involuntary culling rate, lactation curves, milk price, cost of feeding, dry period, fixed cost, female calf values, heifer replacement value, and salvage value, were kept constant among scenarios using default values described by Giordano et al. (2012). Furthermore, we did not evaluate the effect of program compliance on reproductive performance, which can be an issue on some farms (Galvão et al., 2013). Although more complex programs require more compliance, farms using those programs are likely to have a high level of compliance.

Seven reproductive management programs were simulated (Figure 1). Cows were submitted to a Presynch-Ovsynch program with 100% TAI, or with service rate by ED before or post TAI. Furthermore, an AAM system and a Double-Ovsynch with double PGF_{2α} were simulated. The voluntary waiting period was set at 50 d for programs with ED before the first TAI. The first injection of the synchronization programs occurred at 36 DIM; therefore, the TAI occurred at d 63 for the Double-Ovsynch program and at d 72 for the Presynch-Ovsynch program. In all cases, milk price was set at \$0.36/kg. The first program simulated a Presynch-Ovsynch program with ED incorporated after the second PGF_{2α} treatment (**Presynch-Ovsynch+ED**) using TAI for first service for cows not bred to ED (Figure 1A). The second program simulated a Presynch-Ovsynch program for 100% TAI, with ED incorporated after first TAI (**Presynch-Ovsynch+EDpost**; Figure 1B). In programs 1 and 2, P/AI for Presynch-Ovsynch was set at 35% (Caraviello et al., 2006), service rate for ED was set at 60%, and P/AI for ED was set at 30% (Giordano et al., 2012). Programs 3 through 5 simulated Presynch-Ovsynch programs (Figure 1C) for 100% TAI and were simulated with varying P/AI to TAI (35% [baseline], 40%, and 45%; Caraviello et al., 2006; Souza et al., 2008; Stangaferro et al., 2018). The sixth program simulated ED with AAM before and after first insemination, with service rate set at 70% and P/AI set at 35% before first AI and at 30% for subsequent AI (Figure 1D). The cost of the AAM system was included in the simulation (Fricke et al., 2014). The seventh program simulated a Double-Ovsynch+PGF program (Carvalho et al., 2015; Wiltbank et al., 2015) in which P/AI was set at 50% (Souza et al., 2008, 2013; Santos et al., 2017) (Figure 1E). In all simulations, Ovsynch was

Figure 1. Schematic diagram of treatments used in this study. (A) Presynch-Ovsynch+ED; (B) Presynch-Ovsynch+EDpost; (C) Presynch-Ovsynch; (D) Presynch-Ovsynch+ED+EDpost (with AAM system); and (E) Double-Ovsynch+PGF. ED = estrus detection; TAI = timed AI; EDpost = estrus detection performed after first AI; AAM = automated activity monitoring; Preg. = pregnancy.

used as the resynch program, with a 30% P/AI to TAI (Lopes et al., 2013). These programs were chosen to reveal the difference in profitability between the most intensive program (i.e., a Double-Ovsynch+PGF program) compared with the most widely used Presynch-Ovsynch program. The programs that incorporated ED were selected to understand if incorporation of AI to a detected estrus during these programs would be profitable if performed with Presynch-Ovsynch, and this profitability difference was calculated compared with a Double-Ovsynch+PGF program.

Because our first objective was to compare the difference in hormonal treatment costs among the programs, all nonhormonal reproduction costs (e.g., semen, labor for heat detection, pregnancy check) were set at \$0 in the UW-Cornell DairyRepro\$ decision tool. Involuntary culling and other economic calculations are internally performed by the model and therefore affected by the reproductive performance of each program. The cost of each GnRH treatment was set at \$2.6 and that of each PGF_{2α} treatment was set to \$2.3 to reflect cost of hormones in the US market (Giordano et al., 2012). To reflect costs in the European market, the cost of

each GnRH treatment was set at \$6.7 and that of each PGF_{2α} treatment was set at \$5.1. The cost of hormonal treatments for the European market was based on average values for the most common commercial PGF_{2α} products (cloprostenol 500 µg) and of the most common GnRH (gonadorelin 100 µg) products among the biggest milk producers countries in Europe (Italy, the United Kingdom, and Germany). Based on these costs, the economic simulations were run to calculate the total net profit (\$/cow per year) and the aggregated hormone cost of each program. The UW-Cornell DairyRepro\$ decision tool was also used to calculate the number of hormonal treatments required per cow per year for the various programs.

The number of hormonal treatments and net profit gain of the various reproductive management programs were compared using the Presynch-Ovsynch program, with a 35% P/AI as the baseline (Table 1). An economic tradeoff occurred when ED was included in a Presynch-Ovsynch program, which decreased P/AI and increased the service rate (Fricke et al., 2014). This tradeoff was part of our study, and from our results, including ED either before or after TAI would have

a positive net profit gain over the baseline. Although Presynch-Ovsynch programs use fewer hormonal treatments than a Double-Ovsynch+PGF program (1.4 to 3.0 fewer treatments per cow per year), the Double-Ovsynch+PGF program was more profitable. The Double-Ovsynch+PGF program attained \$42.2 greater profit per cow per year than the Presynch-Ovsynch+ED program and \$27.7 more than Presynch-Ovsynch+EDpost program based on hormone costs in the US market. Also, the Double-Ovsynch+PGF program was more profitable than the 100% TAI after a Presynch-Ovsynch program (\$20.9 to \$44.3 more per cow per year, depending on P/AI; Table 1). These results are directly related to the increased reproductive performance of a Double-Ovsynch+PGF program (higher P/AI to first AI) compared with the other programs. Furthermore, inclusion of ED after the first TAI (i.e., the Presynch-Ovsynch+EDpost program) was a more profitable strategy than using ED either before the first TAI (i.e., the Presynch-Ovsynch+ED program) or not incorporating ED at all based on 35% and 40% P/AI, respectively. The program with AAM could increase the ED rate, which leads to lower use of hormones use when combined with TAI programs, thus offsetting the cost of the system, especially when the hormone price is high. This outcome might be due to fewer cows being submitted to a resynch program at a lower P/AI when more intensive programs for first TAI that have an increased P/AI are used. The Presynch-Ovsynch program with a 45% P/AI had the second greatest net profit among the programs compared because of its higher P/AI counteracting the resynch cost for the US market. The gain in profitability when switching to a Double-Ovsynch+PGF program based on US market prices was greater (Table 1) because of the ratio of the costs between GnRH and PGF_{2α}, which was 113% in the US market compared with 131% in the European market.

The second comparison (second objective) addressed whether a more intensive synchronization program still results in higher profitability than the less intensive reproductive management programs when the costs of hormonal treatments are higher. We therefore conducted sensitivity analyses by incrementally increasing the cost of hormonal treatments to determine the break-even point at which hormone costs offset the net profit by (1) setting the costs of GnRH and PGF_{2α} at US and European market costs and raising both costs by multiples; (2) setting the cost of GnRH at the European market average cost of \$6.7 and increasing the cost of PGF_{2α}; and (3) setting the cost of PGF_{2α} at European market average cost of \$5.1 and increasing the cost of GnRH. The ability to vary hormonal treatment costs in the UW-Cornell DairyRepro\$ decision tool made it

Table 1. Comparison of the number of hormonal injections and net profit between different reproductive synchronization programs

Reproductive program ¹	First AI		First TAI		Later AI ²			Average no. of injections per cow per year ³		Net profit gain over the baseline (\$/cow per year) ⁴	
	Service rate (%)	P/AI (%)	P/AI (%)	P/AI (%)	Service rate (%)	P/AI (%)	Total	GnRH	PGF _{2α}	PGF _{2α} at \$2.3 and GnRH at \$2.6 ⁵	PGF _{2α} at \$5.1 and GnRH at \$6.7 ⁵
Presynch-Ovsynch (baseline)	0	0	35	0	0	0	7.8	3.12	4.68	—	—
Presynch-Ovsynch	0	0	40	0	0	0	7.6	3.04	4.56	11.9	12.8
Presynch-Ovsynch	0	0	45	0	0	0	7.4	2.96	4.44	24.2	25.1
Presynch-Ovsynch+ED	60	30	35	0	0	0	6.2	2.48	3.72	2.1	7.9
Presynch-Ovsynch+EDpost	0	0	35	60	30	30	6.3	2.52	3.78	19.1	22
Presynch-Ovsynch+ED+EDpost (with AAM system)	70	35	35	70	30	30	4.1	1.74	2.36	20.7	34.4
Double-Ovsynch+PGF	0	0	50	0	0	0	9.2	5.24	3.96	44.3	38.4

¹Presynch-Ovsynch = Presynch-Ovsynch program with 35%, 40%, and 45% pregnancy per AI (P/AI); ED = estrus detection performed before first AI service with 60% service rate (SR) and 30% P/AI; EDpost = estrus detection performed after first AI program with 60% SR and 30% P/AI; ED with AAM = 70% SR and 35% P/AI before AI and SR 70% and P/AI 30% after AI; Double-Ovsynch+PGF = Double-Ovsynch with a repeated injection at second prostaglandin with 50% P/AI. AAM = automated activity monitoring.

²The P/AI for later timed AI (TAI) was set to 30% for all programs.

³Average number of injections for hormones. GnRH proportion was 40% in Presynch-Ovsynch programs and 57% in the Double-Ovsynch+PGF program.

⁴Net profit gain over the baseline program (Presynch-Ovsynch 35%) is the value of the net profit difference when the baseline program (the Presynch-Ovsynch program with 35% P/AI for first TAI) is compared with the listed ones.

⁵PGF_{2α} at \$2.3/dose and GnRH at \$2.6/dose representing the US market and PGF_{2α} at \$5.1/dose and GnRH at \$6.7/dose representing the European market.

Figure 2. Sensitivity analysis conducted by identifying the break-even points when the net profit gain from switching the Presynch-Ovsynch programs to Double-Ovsynch+PGF program became negative with multiples of GnRH and PGF market prices: GnRH price at multiples of the (a) US market (\$/dose) and (b) European market (\$/dose). PreSynchOv 35 = Presynch-Ovsynch program with 35% pregnancy per AI (P/AI); PreSynchOv 40 = Presynch-Ovsynch program with 40% P/AI; PreSynchOv 45 = Presynch-Ovsynch program with 45% P/AI; PreSynchOv + ED = Presynch-Ovsynch program with 35% P/AI + estrus detection before first AI service with 60% service rate and 30% P/AI; PreSynchOv + EDpost = Presynch-Ovsynch program with 35% P/AI + estrus detection after first AI service with 60% service rate and 30% P/AI; PreSynchOv with AAM = estrus detection with AAM system before first AI service with 70% service rate and 35% P/AI, estrus detection with AAM system after first AI service with 70% service rate and 30% P/AI; Double-Ovsynch+PGF = Double-Ovsynch with a repeated injection at second prostaglandin with 50% P/AI. AAM = automated activity monitoring.

possible to simulate these scenarios. For this analysis, the labor cost for administering hormonal treatments was set at \$15/h, labor for transrectal palpation for pregnancy diagnosis was set at \$105/h, and the cost of insemination included semen cost of \$5/AI and a labor cost of insemination at \$5/AI. All other nonstudied variables, such as lactation curve and other herd parameters, were kept at default values in the UW-Cornell DairyRepro\$ decision tool (Giordano et al., 2012). Briefly, groups of simulations were run to compare the most intensive Double-Ovsynch+PGF program with each of the other defined programs compared in this simulation. In each pair-group comparison, the cost of GnRH, PGF_{2α}, or both treatments was increased simultaneously by multiples until the net profit gain became negative, and the break-even point was then identified as the intercept of the trend line with the x-axis (Figure 2). These x-axis intercepts define the hormonal treatment costs at which a Double-Ovsynch+PGF program would have a net profit equal to that of the program it was compared against.

Based on our analysis, hormonal treatment costs would need to be 5 to 14 times greater in the US market and 2 to 6 times greater in the European market for any of the Presynch-Ovsynch programs to exceed the profitability of the Double-Ovsynch+PGF program. The greater P/AI when a Double-Ovsynch+PGF program for first insemination is used compensates for the additional hormonal treatment costs such that the cost of hormonal treatments would need to increase substantially before the program becomes less profitable than any of the others. When the P/AI of Presynch-Ovsynch programs increased, the break-even point was reached earlier because the advantage of the increased P/AI of Double-Ovsynch+PGF was decreased.

To investigate the cost of one of the hormonal treatments to reach the break-even point, we ran hypothetical scenarios in which the cost of one hormone was constant but the cost for the other hormone was incrementally increased. In this simulation, the cost of PGF_{2α} was set at \$5.1/dose, and the cost of GnRH was set at \$6.7/dose (i.e., the average European market price). Break-even hormone costs from this analysis are reported in Table 2.

Overall, the break-even cost was more sensitive to the cost of GnRH than to the cost of the PGF_{2α} (Table 2). When the cost of GnRH was fixed, the cost of PGF_{2α} could increase considerably before the break-even point was reached or no break-even point could be reached by the model. A complete Presynch-Ovsynch program uses 2 GnRH and 3 PGF_{2α} treatments, whereas the Double-Ovsynch+PGF program uses 4 GnRH and 3 PGF_{2α} treatments with a higher proportion of GnRH treatments (40 vs. 57%) and a lower proportion of PGF_{2α}

Table 2. The price (\$/dose) of GnRH or PGF_{2α} at break-even profit points, when the other price was set constant at the European market price in comparisons of Presynch-Ovsynch programs against the most intensive synchronization program, Double-Ovsynch+PGF

Hormone	Price (\$/dose) at break-even point compared with Double-Ovsynch+PGF ¹					
	Presynch-Ovsynch ²		Presynch-Ovsynch (35% P/AI)+ED		Presynch-Ovsynch (35% P/AI)+EDpost ⁵ (with AAM system) ³	
	35% P/AI	40% P/AI	45% P/AI	ED ⁴	EDpost ⁵	
GnRH	32.8 ⁶	22.4 ⁶	14.2 ⁶	19.0 ⁶	13.7 ⁶	9.0 ⁶
PGF _{2α}	5.1	5.1	5.1	5.1	5.1	5.1
	6.7	6.7	6.7	6.7	6.7	6.7
	— ⁷	— ⁷	— ⁷	— ⁷	— ⁷	— ⁷

¹Double-Ovsynch+PGF = Double-Ovsynch with a repeated injection at second prostaglandin with 50% pregnancy per AI (P/AI).

²Presynch-Ovsynch = Presynch-Ovsynch program with 35%, 40%, and 45% P/AI.

³ED+EDpost (with AAM system) = estrus detection with AAM system before first AI service with 70% service rate and 35% P/AI, estrus detection with AAM system after first AI service with 70% service rate and 30% P/AI. AAM = automated activity monitoring.

⁴ED = estrus detection performed before first AI service with 60% service rate and 30% P/AI.

⁵EDpost = estrus detection performed after first AI program with 60% service rate and 30% P/AI.

⁶Break-even profit point.

⁷The break-even point could not be reached.

treatments (43 vs. 60%). If ED was not incorporated into the reproductive program and the cost of GnRH was fixed, profit increased even when the cost of PGF_{2α} increased. Thus, the break-even points are not reached by the model when the cost of PGF_{2α} is increased. For example, compared with Presynch-Ovsynch 40% P/AI with the cost of PGF_{2α} fixed at \$5.1/dose, the cost of a GnRH treatment was \$22.4/dose at the break-even point (Table 2). By contrast, in the first analysis, one break-even point was reached when the price was \$20.7/dose for PGF_{2α} and \$23.4/dose for GnRH (Figure 2a, 9 times the US market prices), indicating that a greater PGF_{2α} cost determines an even higher cost of GnRH to reach the break-even point. This outcome can be explained by the higher P/AI of the Double-Ovsynch+PGF program that leads to fewer cows being submitted to a resynch program. Consequently, fewer GnRH treatments per pregnancy are used on average (Table 1). For programs that incorporate ED, fewer cows are submitted to hormonal treatments, which decreases total hormone costs of the program; thus, a break-even point was reached even when the GnRH cost was fixed, but only when the cost of PGF_{2α} was unusually high (Table 2).

In conclusion, more intensive reproductive programs that use more hormonal treatments but result in substantially increased reproductive performance are more profitable than less intensive programs. They remain more profitable even if hormone prices are unusually high, with the exception of efficient AAM systems when hormone costs are high. Results from these analyses could be reproduced or adjusted by applying the UW-Cornell DairyRepro\$ decision support tool, which is openly available at University of Wisconsin-Madison and Cornell University websites.

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