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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Short Communication: The reproductive and economic impact among 6 reproductive programs for lactating dairy cows including a sensitivity analysis of the cost of hormonal treatments

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Abstract

Hormonal synchronization protocols can dramatically improve the reproductive efficiency of dairy herds, yet some farmers continue to question the economics of these programs based on the cost of hormonal treatments, and hormonal treatment costs vary dramatically among countries. Our objective was to compare the economic impact of reproductive management programs that incorporate varying degrees of detection of estrus and timed AI. A reproductive economic analysis simulation model (the UW-Cornell DairyRepro$ decision tool) 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 $PGF_{2\alpha}$ treatment during the Breeding-Ovsynch portion of the protocol (**Double-Ovsynch+PGF**). In the second analysis, we conducted a breakeven analysis in which we incrementally increased the cost of hormonal treatments within various reproductive management programs. Our analyses revealed that a Double-Ovsynch+PGF protocol, the most intensive program evaluated, was more profitable than other programs including a Presynch-Ovsynch protocol with 100% timed AI or a Presynch-Ovsynch protocol that incorporated detection of estrus, despite the higher up-front cost incurred by using more hormonal treatments. This advantage remained until the cost of hormones were 5 to 14 times more than the current US market prices and 2 to 6 times greater than the current European market prices. The cost of GnRH had a greater impact on the net profit gain than the cost of $PGF_{2\alpha}$.

Keywords: reproduction, intensive synchronization program, economic impact

Short Communication

Advances in the understanding of the reproductive physiology of dairy cows have lead 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 artificial insemination **(TAI)** (Pursley et al., 1995; Moreira et al., 2001; Souza et al., 2008). The newest TAI protocols for first AI (i.e., Double-Ovsynch and G6G), not only increase the AI service rate, but also increase P/AI to TAI (Carvalho et al., 2018). Strategies that maximize ED, which is widely implemented on 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. The proportion of cows that have not re-initiated cyclicity by the end of the voluntary waiting period varies among herds and among parities within a herd and ranges from 5% to 40% (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 protocols for TAI.

Protocols for synchronization of ovulation use sequential treatments of GnRH and $PGF_{2\alpha}$ to control follicular development, luteal regression, and time of ovulation. Synchronization of ovulation allows for more precise timing of AI than relying on detection of estrus alone for the timing of AI (Pursley et al., 1995, Souza et al. 2008; Valenza et al., 2012; Fricke et al., 2014). Furthermore, optimization of the hormonal milieu during the Ovsynch protocol 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 and TAI by observing and inseminating cows detected in estrus after the second $PGF_{2\alpha}$ treatment of a Presynch-Ovsynch protocol (Stangaferro et al. 2018 and 2019), whereas cows not detected in estrus complete the protocol and receive TAI. Although incorporation of estrus into a Presynch-Ovsynch protocol increases AI service rate, it also decreases P/AI by 35% compared to 100% TAI after a Presynch-Ovsynch protocol (Borchardt et al., 2016). By contrast, submission of lactating Holstein cows to a Double-Ovsynch+PGF protocol and TAI for first insemination increases the percentage of cows inseminated within 7 d after the end of the voluntary waiting period and increases P/AI at 33 and 63 d after first insemination resulting in 64 and 58% more pregnant cows, respectively, than submission of cows for first AI after detection of estrus at a similar day in milk range (Santos et al., 2017).

The assessment of the overall economic value of different reproductive management programs (Cabrera and Giordano, 2013; Cabrera, 2014) can be achieved by simulating reproductive performance along with its 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 (the UW-Cornell DairyRepro$ decision tool; Giordano et al., 2012). This study had three major objectives: 1) to analyze the economic profitability of a more intensive reproductive protocol involving more hormonal treatments; 2) to determine if increased hormonal treatment costs would be compensated for by increased production of calves and increased P/AI; and 3) to estimate how high the cost of hormones would have to be to render intensive synchronization protocols that require more hormonal treatments non-profitable. To answer to these questions, a 1,000-cow commercial dairy herd was simulated using the UW-Cornell DairyRepro$ decision tool. For comparison consistency and to avoid analysis bias, non-studied variables such as mortality rate, body weight, involuntary culling rate, lactation curves, milk price, among others, were kept constant among scenarios at default levels described by Giordano et al. (2012).

Six reproductive management programs for first TAI were simulated. The first program simulated was a PreSynch-Ovsynch protocol with ED incorporated after the second $PGF_{2\alpha}$ treatment (**PreSynch-Ovsynch+ED**). The second program simulated was a PreSynch-Ovsynch protocol for 100% TAI with ED incorporated after first TAI (**PreSynch-Ovsynch+EDpost**). In these first two protocols, CR for PreSynch-Ovsynch was set at 35% (Caraviello et al., 2006), Service Rate (SR) for ED was set at 60%, and CR for ED was set at 30% (Giordano et al., 2012; Fricke et al., 2014). Programs 3 through 5 were Presynch-Ovsynch protocols for 100% TAI which were simulated with varying CR to TAI (35%, 40%, 45%; Caraviello et al., 2006; Sousa et al., 2008; Stangaferro et al., 2018). The sixth protocol simulated was a Double-Ovsynch+PGF protocol (Carvalho et al., 2015; Wiltbank et al., 2015) in which CR was set at 50% (Souza et al., 2008; 2013; Santos et al., 2017). In all simulations, Ovsynch was used as the resynch protocol, with a 30% CR to TAI (Lopes et al., 2013). These protocols were chosen to reveal the difference in profitability between the most intensive program (i.e., a Double-Ovsynch+PGF protocol) compared to a PreSych-Ovsynch protocol. The protocols that incorporated ED were selected to understand if incorporation of AI to a detected estrus during these programs would be profitable if performed with PreSych-Ovsynch, and this profitability difference was calculated compared to a Double-Ovsynch+PGF protocol.

Because our objective was to compare the difference in hormonal costs among the programs, all non-hormonal reproduction costs were set at $0 in the UW-Cornell DairyRepro$ decision tool. The cost of each GnRH treatment was set at $2.6, and the cost of each $PGF_{2\alpha}$ treatment was set to $2.3 to reflect cost of hormones in the US market (Giordano et al., 2012). In addition, the cost of each GnRH treatment was set at $6.7 and the cost of each $PGF_{2\alpha}$ treatment was set to $5.1 to reflect cost of hormones in the European market. Cost of hormonal treatments for the European market were based on 11 values for the most common commercial $PGF_{2\alpha}$ products (Cloprostenol 500 μg) and 5 values of the most common GnRH (Gonadorelin 100 μg) products in the Italian market in November, 2018. Based on these costs, the economic simulations were run to calculate the total net profit ($/cow per yr) and the aggregated hormonal cost of each program. The UW-Cornell DairyRepro$ decision tool was also used to calculate the number of hormonal treatments required per cow per yr for the various protocols.

Using the PreSynch-Ovsynch protocol with a 35% P/AI as the baseline, the number of hormonal treatments and net profit gain of the various reproductive management protocols was compared (Table 1). Although PreSynch-Ovsynch protocols use fewer hormonal treatments than a Double-Ovsynch+PGF protocol (1.4 to 3.0 fewer treatments per cow per yr); the

Double-Ovsynch+PGF protocol was more profitable. The Double-Ovsynch+PGF protocol attained $40.4 greater profit per cow per yr than the PreSynch-Ovsynch + ED protocol and $28.9 more than PreSynch-Ovsynch + EDpost protocol based on hormonal costs in the US market. Also, the Double-Ovsynch+PGF protocol was more profitable than the 100% TAI after a Presynch-Ovsynch protocol ($21.2 to $46.2 more per cow per yr, depending on CR; Table 1). These results are directly related to the increased reproductive performance of a Double-Ovsynch+PGF protocol (higher CR to first AI) compared to the other protocols. Furthermore, inclusion of ED after the first TAI (i.e., the PreSych-Ovsynch + EDpost protocol) was a more profitable strategy than using ED either before the first TAI (i.e., the PreSynch-Ovsynch + ED protocol) or not incorporating ED at all based on 35% and 40% CR, respectively. This outcome might result because fewer cows are submitted to a resynch protocol at a lower CR when applying more intensive protocols for first TAI that have an increased conception rate. The PreSynch-Ovsynch protocol with a 45% CR had the second greatest net profit among the programs compared because of its higher CR counteracting the resynch cost. The gain in profitability when switching to a Double-Ovsynch+PGF protocol based on US market prices was greater (Table 1) because of the ratio of the costs between GnRH and $PGF_{2\alpha}$, which was 113% in the US market compared to131% in the European market.

The second comparison we made addressed the concern of whether a more intensive synchronization protocol will still result in higher profitability than the less intensive reproductive management protocols based on higher costs of hormones. We therefore conducted sensitivity analyses by incrementally increasing the cost of hormonal treatments to determine the breakeven point at which hormonal costs offset the net profit of 1) having the costs of GnRH and $PGF_{2\alpha}$ at US and European market costs and raising both costs by multiples;

2) setting the cost of GnRH at European market average cost of $6.7 and increasing the cost of $PGF_{2\alpha}$; and 3) setting the cost of $PGF_{2\alpha}$ 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 possible to simulate these scenarios. For this analysis, all general costs such as labor for administering hormonal treatments, labor for transrectal palpation for pregnancy diagnosis and insemination, and the non-studied variables like lactation curve and other herd parameters, were kept as default in the UW-Cornell DairyRepro$ decision tool (Giordano et al., 2012). Briefly, labor cost for administering hormonal treatments was set at $15/hr, and labor for transrectal palpation for pregnancy diagnosis was set at $105/hr. The cost of insemination included semen cost of $5/AI and a labor cost of insemination at $5/AI. Groups of simulations were run to compare the most intensive Double-Ovsynch+PGF protocol with each of the other defined protocols compared in this simulation. In each pair-group comparison, the cost of GnRH and/or $PGF_{2\alpha}$ treatments was increased until the net profit became negative, then the breakeven point was identified as the intercept of the trend line with the x-axis (Figure 1). These x-axis intercepts define the hormonal treatment costs at which a Double-Ovsynch+PGF protocol would have an equal net profit to the protocol 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 protocols to be more profitable than the Double-Ovsynch+PGF protocol. The greater P/AI at first insemination after a Double-Ovsynch+PGF protocol compensates for the additional hormonal treatment costs so that the cost of hormonal treatments would need to increase substantially before it becomes less profitable than any of the other programs. When the CR of Presynch-Ovsynch protocols increased, the breakeven point was reached earlier because the advantage of the increased CR of Double-Ovsynch+PGFis was decreased.

To investigate the cost of one of the hormonal treatments to reach the breakeven 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 $PGF_{2\alpha}$ was set at \$5.1/dose, and the cost of GnRH was set at \$6.7/dose (i.e., the average European market price). Breakeven hormonal costs from this analysis are reported in Table 2.

Overall, the breakeven cost was more sensitive to the cost of GnRH than to the cost of the $PGF_{2\alpha}$ (Table 2). When the cost of GnRH was fixed, the cost of $PGF_{2\alpha}$ could increase considerably before the breakeven point was reached or no breakeven point could be reached by the model. A complete Presynch-Ovsynch protocol uses 2 GnRH and 3 $PGF_{2\alpha}$ treatments, whereas the Double-Ovsynch+PGF protocol uses 4 GnRH and 3 $PGF_{2\alpha}$ treatments with a higher proportion of GnRH treatments (57% vs. 40%) and a lower proportion of $PGF_{2\alpha}$ 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 $PGF_{2\alpha}$ increased. Thus, the breakeven points are not reached by the model when increasing the cost of $PGF_{2\alpha}$. For example, when compared with PreSyncOv 40 with the cost of $PGF_{2\alpha}$ 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 study, one breakeven point was reached when the price was \$20.7/dose for $PGF_{2\alpha}$ and \$23.4/dose for GnRH (Figure 1(a), 9 times the US market prices), indicating that a greater $PGF_{2\alpha}$ cost determines an even higher cost of GnRH to reach the breakeven point. This can be explained by the higher CR of the Double-Ovsynch+PGF protocol that leads to fewer cows submitted to a resynch protocol. Consequently, fewer GnRH treatments per pregnancy are used on average (Table 1). For protocols that incorporate ED, fewer cows are submitted to hormonal treatments which decreases total hormone costs of the protocol; thus, a breakeven point was reached even when the GnRH cost was fixed, but when the cost of $PGF_{2\alpha}$ was unusually high (Table 2).

In conclusion, our economic evaluation found that more intensive reproductive programs that use more hormonal treatments but result in substantially increased reproductive performance are more profitable than less intensive programs and remain superior even if hormonal prices are unusually high. Results from these analyses could be reproduced or adjusted by applying the UW-Cornell DairyRepro$ decision support tool that is openly available at UW-Madison and Cornell University websites.

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

		Approximated number of treatments[1] (#/cow per yr)			Net Profit gain over the baseline[2] ($/cow per yr)	
Reproductive Program[3]	P/AI (%)	Total	GnRH	$PGF_{2\alpha}$	$PGF_{2\alpha}$ at $2.3 and GnRH at $2.6[4]	$PGF_{2\alpha}$ at $5.1 and GnRH at $6.7[4]
PreSynch-Ovsynch (baseline)	35	7.8	3.12	4.68	-	-
PreSynch-Ovsynch	40	7.6	3.04	4.56	12.7	13.7
PreSynch-Ovsynch	45	7.4	2.96	4.44	25	26.7
PreSynch-Ovsynch + ED	35 + 30	6.2	2.48	3.72	5.8	8.2
PreSynch-Ovsynch + EDpost	35 + 30	6.3	2.52	3.78	17.3	22.8
Double-Ovsynch+PGF	50	9.2	5.24	3.96	46.2	32.1

[1]Approximated number of treatments for hormones. GnRH proportion in protocols: Presynch-Ovsynch protocols: 40%; Double-Ovsynch+PGFprotocol: 57%.

[2]Net profit gain over the baseline is the value of the net profit difference when alternating the baseline protocol to the listed one.

[3]**PreSynch-Ovsynch** (Presynch-Ovsynch protocol with 35%, 40%, 45% CR)**, ED** (Estrus detection performed before first AI service with 60% SR and 30% CR), **EDpost** (Estrus detection performed after first AI protocol with 60% SR and 30% CR), **Double-Ovsynch PG2x** (Double Ovsynch with a repeated injection at second prostaglandin with 50% CR).

[4]$PGF_{2\alpha}$ at $2.3/dose and GnRH at $2.6/dose representing the US market and $PGF_{2\alpha}$ at $5.1/dose and GnRH at $6.7/dose representing the European market.

Table 2. The cost ($/dose) of GnRH or $PGF_{2\alpha}$ at breakeven profit points (bold numbers), when the other hormonal cost was set constant at European market price, comparing Presynch-Ovsynch programs against the most intensive synchronization program, the Double-Ovsynch+PGF.

Cost ($/dose) at the breakeven point compared with Double-Ovsynch+PGF[1]										
Hormones	Presynch-Ovsynch[2]						Presynch-Ovsynch (35% CR) + ED			
	35% CR		40% CR		45% CR		ED[3]		EDpost[4]	
GnRH	**32.8**	6.7	**22.4**	6.7	**14.2**	6.7	**19.0**	6.7	**13.7**	6.7
$PGF_{2\alpha}$	5.1	--[5]	5.1	--[5]	5.1	--[5]	5.1	**97.0**	5.1	**63.0**

[1]Double-Ovsynch PG2x (Double-Ovsynch+PGF with 50% CR).

[2]PreSynch-Ovsynch (Presynch-Ovsynch protocol with 35%, 40%, 45% CR).

[3]ED (Estrus detection performed before first AI service with 60% SR and 30% CR).

[4]EDpost (Estrus detection performed after first AI protocol with 60% SR and 30% CR).

[5]The breakeven point could not be reached.

Figure 1. Sensitive analysis by identifying the breakeven points when the net profit gain by switching the Presynch-Ovsynch protocols to Double-Ovsynch+PGF protocol become negative with multiples of GnRH and $PGF_{2\alpha}$ for US market price (a) and European market price (b).

PreSynchOv 35 (Presync-Ovsynch protocol with 35% CR)

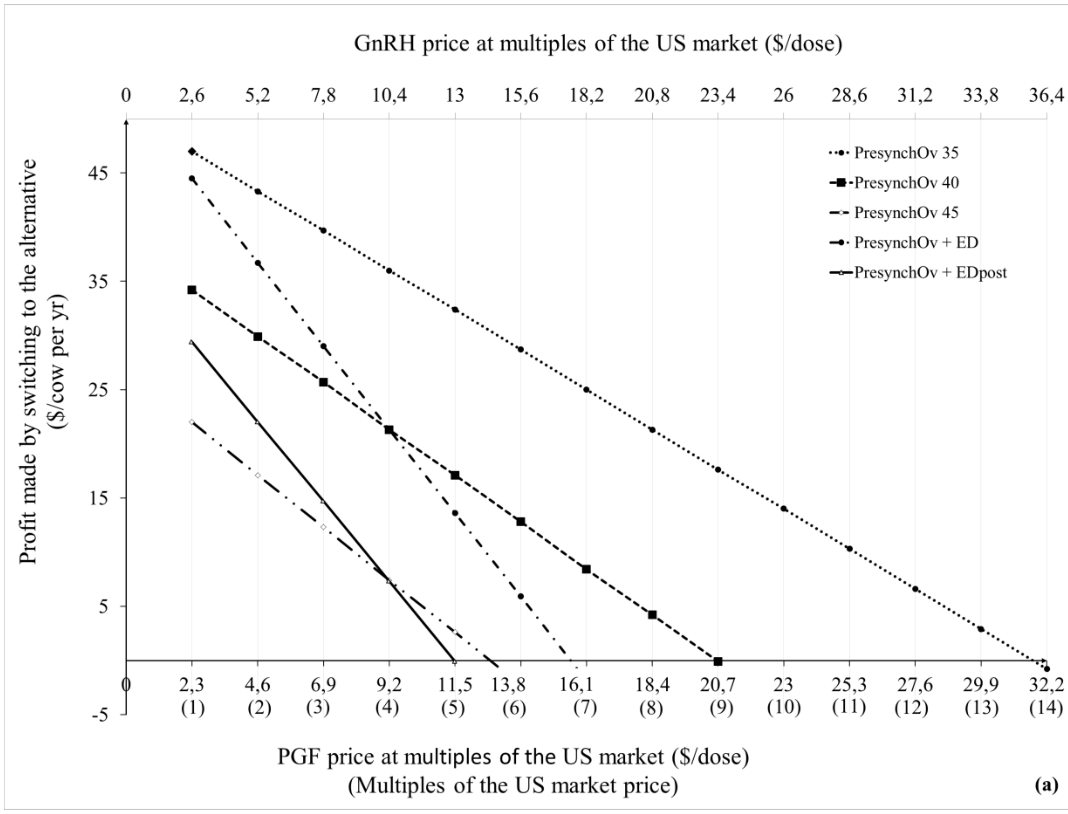
PreSynchOv 40 (Presync-Ovsynch protocol with 40% CR)

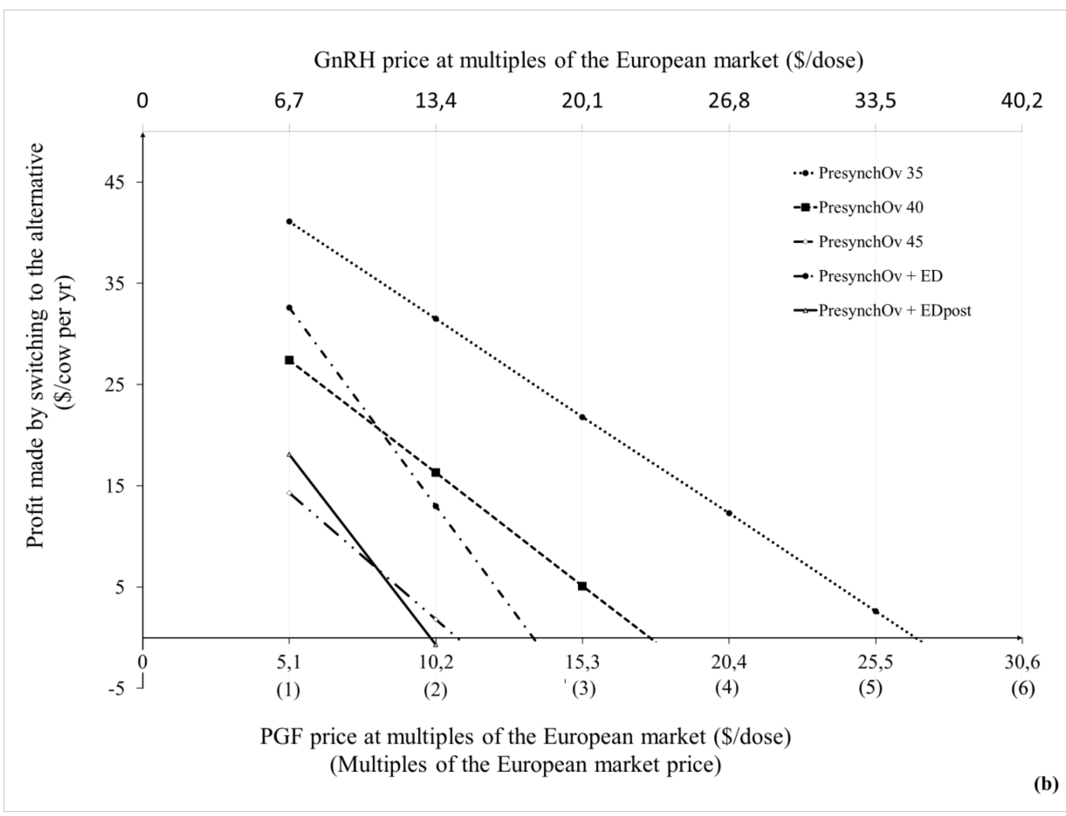
PreSynchOv 45 (Presync-Ovsynch protocol with 45% CR)

PreSynchOv + ED (Presync-Ovsynch protocol with 35% CR + estrus detection before first AI service with 60% SR and 30% CR)

PreSynchOv + EDpost (Presync-Ovsynch protocol with 35% CR + estrus detection after first AI service with 60% SR and 30% CR)

Double-Ovsynch PG2x (Double Ovsynch with a repeated injection at second prostaglandin with 50% CR)


GnRH price at multiples of the US market ($/dose)
0 2,6 5,2 7,8 10,4 13 15,6 18,2 20,8 23,4 26 28,6 31,2 33,8 36,4
Profit made by switching to the alternative ($/cow per yr)
45 35 25 15 5 -5
PresynchOv 35
PresynchOv 40
PresynchOv 45
PresynchOv + ED
PresynchOv + EDpost
0 2,3 4,6 6,9 9,2 11,5 13,8 16,1 18,4 20,7 23 25,3 27,6 29,9 32,2
(1) (2) (3) (4) (5) (6) (7) (8) (9) (10) (11) (12) (13) (14)
PGF price at multiples of the US market ($/dose)
(Multiples of the US market price)
(a)


GnRH price at multiples of the European market ($/dose)
0 6,7 13,4 20,1 26,8 33,5 40,2
Profit made by switching to the alternative ($/cow per yr)
45 35 25 15 5 -5
PresynchOv 35
PresynchOv 40
PresynchOv 45
PresynchOv + ED
PresynchOv + EDpost
0 5,1 10,2 15,3 20,4 25,5 30,6
(1) (2) (3) (4) (5) (6)
PGF price at multiples of the European market ($/dose)
(Multiples of the European market price)
(b)