**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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1   **Short Communication: The reproductive and economic impact among 6 reproductive**

2   **programs for lactating dairy cows including a sensitivity analysis of the cost of hormonal**

3   **treatments**

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8                                                              **Abstract**

9            Hormonal synchronization protocols can dramatically improve the reproductive

10   efficiency of dairy herds, yet some farmers continue to question the economics of these

11   programs based on the cost of hormonal treatments, and hormonal treatment costs vary

12   dramatically among countries. Our objective was to compare the economic impact of

13   reproductive management programs that incorporate varying degrees of detection of estrus and

14   timed AI. A reproductive economic analysis simulation model (the UW-Cornell

15   DairyRepro$ decision tool) was used to compare the economic impact of pairs of reproductive

16   management programs. We simulated sets of scenarios for 2 analyses. In the first analysis, we

17   calculated the economic impact of switching from a Presynch-Ovsynch program to a Double-

18   Ovsynch program that included a second $PGF_{2\alpha}$ treatment during the Breeding-Ovsynch

19   portion of the protocol (**Double-Ovsynch+PGF**). In the second analysis, we conducted a

20   breakeven analysis in which we incrementally increased the cost of hormonal treatments within

21   various reproductive management programs. Our analyses revealed that a Double-

22   Ovsynch+PGF protocol, the most intensive program evaluated, was more profitable than other

23   programs including a Presynch-Ovsynch protocol with 100% timed AI or a Presynch-Ovsynch

24  protocol that incorporated detection of estrus, despite the higher up-front cost incurred by using

25  more hormonal treatments. This advantage remained until the cost of hormones were 5 to 14

26  times more than the current US market prices and 2 to 6 times greater than the current

27  European market prices. The cost of GnRH had a greater impact on the net profit gain than the

28  cost of $PGF_{2\alpha}$.

29  Keywords: reproduction, intensive synchronization program, economic impact

30                                   **Short Communication**

31          Advances in the understanding of the reproductive physiology of dairy cows have lead

32  to the development of management strategies and technologies that improve reproductive

33  performance. Commercial dairy farms are challenged with making the most profitable

34  management decisions among many options and implementing them correctly. Methods for

35  enhancing fertility and breeding efficiency include: detection of estrus **(ED)** (Xu et al., 1998;

36  Rorie et al., 2002), synchronization of estrus (Folman et al., 1984; Momcilovic et al., 1998),

37  and synchronization of ovulation and timed artificial insemination **(TAI)** (Pursley et al., 1995;

38  Moreira et al., 2001; Souza et al., 2008). The newest TAI protocols for first AI (i.e., Double-

39  Ovsynch and G6G), not only increase the AI service rate, but also increase P/AI to TAI

40  (Carvalho et al., 2018). Strategies that maximize ED, which is widely implemented on dairies,

41  have made significant contributions to the profitability of dairy herds (Pecsok et al. 1994). A

42  major limitation of ED, however, is the presence of anovular cows. The proportion of cows that

43  have not re-initiated cyclicity by the end of the voluntary waiting period varies among herds

44  and among parities within a herd and ranges from 5% to 40% (Walsh et al., 2007; Santos et al.,

45  2009; Bamber et al., 2009). The lack of estrous behavior in anovular cows precludes AI to a

46  detected estrus, and many anovular cows are submitted to hormonal protocols for TAI.

47    Protocols for synchronization of ovulation use sequential treatments of GnRH and

48    PGF$_{2\alpha}$ to control follicular development, luteal regression, and time of ovulation.

49    Synchronization of ovulation allows for more precise timing of AI than relying on detection of

50    estrus alone for the timing of AI (Pursley et al., 1995, Souza et al. 2008; Valenza et al., 2012;

51    Fricke et al., 2014). Furthermore, optimization of the hormonal milieu during the Ovsynch

52    protocol increases P/AI for cows at first TAI (Souza et al., 2008; Carvalho et al., 2014) and for

53    cows resynchronized to receive subsequent TAI (Giordano et al., 2012; Lopes et al., 2013;

54    Carvalho et al., 2015). Many farms combine ED and TAI by observing and inseminating cows

55    detected in estrus after the second PGF$_{2\alpha}$ treatment of a Presynch-Ovsynch protocol

56    (Stangaferro et al. 2018 and 2019), whereas cows not detected in estrus complete the protocol

57    and receive TAI. Although incorporation of estrus into a Presynch-Ovsynch protocol increases

58    AI service rate, it also decreases P/AI by 35% compared to 100% TAI after a Presynch-

59    Ovsynch protocol (Borchardt et al., 2016). By contrast, submission of lactating Holstein cows

60    to a Double-Ovsynch+PGF protocol and TAI for first insemination increases the percentage of

61    cows inseminated within 7 d after the end of the voluntary waiting period and increases P/AI at

62    33 and 63 d after first insemination resulting in 64 and 58% more pregnant cows, respectively,

63    than submission of cows for first AI after detection of estrus at a similar day in milk range

64    (Santos et al., 2017).

65    The assessment of the overall economic value of different reproductive management

66    programs (Cabrera and Giordano, 2013; Cabrera, 2014) can be achieved by simulating

67    reproductive performance along with its costs and benefits on a farm-by-farm basis (Giordano

68    et al., 2011; 2012; Kalantari and Cabrera, 2012), and calculating the expected net return (De

69    Vries et al., 2010; Fricke et al., 2010; Cabrera, 2011). In this study, we used a simulation model

70 to compare the economic impact of current and alternative reproductive programs (the UW-

71 Cornell DairyRepro$ decision tool; Giordano et al., 2012). This study had three major

72 objectives: 1) to analyze the economic profitability of a more intensive reproductive protocol

73 involving more hormonal treatments; 2) to determine if increased hormonal treatment costs

74 would be compensated for by increased production of calves and increased P/AI; and 3) to

75 estimate how high the cost of hormones would have to be to render intensive synchronization

76 protocols that require more hormonal treatments non-profitable. To answer to these questions,

77 a 1,000-cow commercial dairy herd was simulated using the UW-Cornell

78 DairyRepro$ decision tool. For comparison consistency and to avoid analysis bias, non-studied

79 variables such as mortality rate, body weight, involuntary culling rate, lactation curves, milk

80 price, among others, were kept constant among scenarios at default levels described by

81 Giordano et al. (2012).

82      Six reproductive management programs for first TAI were simulated. The first program

83 simulated was a PreSynch-Ovsynch protocol with ED incorporated after the second $PGF_{2\alpha}$

84 treatment (**PreSynch-Ovsynch+ED**). The second program simulated was a PreSynch-Ovsynch

85 protocol for 100% TAI with ED incorporated after first TAI (**PreSynch-Ovsynch+EDpost**). In

86 these first two protocols, CR for PreSynch-Ovsynch was set at 35% (Caraviello et al., 2006),

87 Service Rate (SR) for ED was set at 60%, and CR for ED was set at 30% (Giordano et al., 2012;

88 Fricke et al., 2014). Programs 3 through 5 were Presynch-Ovsynch protocols for 100% TAI

89 which were simulated with varying CR to TAI (35%, 40%, 45%; Caraviello et al., 2006; Sousa

90 et al., 2008; Stangaferro et al., 2018). The sixth protocol simulated was a Double-

91 Ovsynch+PGF protocol (Carvalho et al., 2015; Wiltbank et al., 2015) in which CR was set at

92 50% (Souza et al., 2008; 2013; Santos et al., 2017). In all simulations, Ovsynch was used as the

93   resynch protocol, with a 30% CR to TAI (Lopes et al., 2013). These protocols were chosen to

94   reveal the difference in profitability between the most intensive program (i.e., a Double-

95   Ovsynch+PGF protocol) compared to a PreSych-Ovsynch protocol. The protocols that

96   incorporated ED were selected to understand if incorporation of AI to a detected estrus during

97   these programs would be profitable if performed with PreSych-Ovsynch, and this profitability

98   difference was calculated compared to a Double-Ovsynch+PGF protocol.

99   Because our objective was to compare the difference in hormonal costs among the

100   programs, all non-hormonal reproduction costs were set at $0 in the UW-Cornell

101   DairyRepro$ decision tool. The cost of each GnRH treatment was set at $2.6, and the cost of

102   each $PGF_{2\alpha}$ treatment was set to $2.3 to reflect cost of hormones in the US market (Giordano et

103   al., 2012). In addition, the cost of each GnRH treatment was set at $6.7 and the cost of each

104   $PGF_{2\alpha}$ treatment was set to $5.1 to reflect cost of hormones in the European market. Cost of

105   hormonal treatments for the European market were based on 11 values for the most common

106   commercial $PGF_{2\alpha}$ products (Cloprostenol 500 μg) and 5 values of the most common GnRH

107   (Gonadorelin 100 μg) products in the Italian market in November, 2018. Based on these costs,

108   the economic simulations were run to calculate the total net profit ($/cow per yr) and the

109   aggregated hormonal cost of each program. The UW-Cornell DairyRepro$ decision tool was

110   also used to calculate the number of hormonal treatments required per cow per yr for the

111   various protocols.

112   Using the PreSynch-Ovsynch protocol with a 35% P/AI as the baseline, the number of

113   hormonal treatments and net profit gain of the various reproductive management protocols was

114   compared (Table 1). Although PreSynch-Ovsynch protocols use fewer hormonal treatments

115   than a Double-Ovsynch+PGF protocol (1.4 to 3.0 fewer treatments per cow per yr); the

116   Double-Ovsynch+PGF protocol was more profitable. The Double-Ovsynch+PGF protocol

117   attained $40.4 greater profit per cow per yr than the PreSynch-Ovsynch + ED protocol and

118   $28.9 more than PreSynch-Ovsynch + EDpost protocol based on hormonal costs in the US

119   market. Also, the Double-Ovsynch+PGF protocol was more profitable than the 100% TAI after

120   a Presynch-Ovsynch protocol ($21.2 to $46.2 more per cow per yr, depending on CR; Table 1).

121   These results are directly related to the increased reproductive performance of a Double-

122   Ovsynch+PGF protocol (higher CR to first AI) compared to the other protocols. Furthermore,

123   inclusion of ED after the first TAI (i.e., the PreSych-Ovsynch + EDpost protocol) was a more

124   profitable strategy than using ED either before the first TAI (i.e., the PreSynch-Ovsynch + ED

125   protocol) or not incorporating ED at all based on 35% and 40% CR, respectively. This outcome

126   might result because fewer cows are submitted to a resynch protocol at a lower CR when

127   applying more intensive protocols for first TAI that have an increased conception rate. The

128   PreSynch-Ovsynch protocol with a 45% CR had the second greatest net profit among the

129   programs compared because of its higher CR counteracting the resynch cost. The gain in

130   profitability when switching to a Double-Ovsynch+PGF protocol based on US market prices

131   was greater (Table 1) because of the ratio of the costs between GnRH and $PGF_{2\alpha}$, which was

132   113% in the US market compared to131% in the European market.

133         The second comparison we made addressed the concern of whether a more intensive

134   synchronization protocol will still result in higher profitability than the less intensive

135   reproductive management protocols based on higher costs of hormones. We therefore

136   conducted sensitivity analyses by incrementally increasing the cost of hormonal treatments to

137   determine the breakeven point at which hormonal costs offset the net profit of 1) having the

138   costs of GnRH and $PGF_{2\alpha}$ at US and European market costs and raising both costs by multiples;

6

139  2) setting the cost of GnRH at European market average cost of \$6.7 and increasing the cost of

140  $PGF_{2\alpha}$; and 3) setting the cost of $PGF_{2\alpha}$ at European market average cost of \$5.1 and increasing

141  the cost of GnRH. The ability to vary hormonal treatment costs in the UW-Cornell

142  DairyRepro\$ decision tool made it possible to simulate these scenarios. For this analysis, all

143  general costs such as labor for administering hormonal treatments, labor for transrectal

144  palpation for pregnancy diagnosis and insemination, and the non-studied variables like

145  lactation curve and other herd parameters, were kept as default in the UW-Cornell

146  DairyRepro\$ decision tool (Giordano et al., 2012). Briefly, labor cost for administering

147  hormonal treatments was set at \$15/hr, and labor for transrectal palpation for pregnancy

148  diagnosis was set at \$105/hr. The cost of insemination included semen cost of \$5/AI and a

149  labor cost of insemination at \$5/AI. Groups of simulations were run to compare the most

150  intensive Double-Ovsynch+PGF protocol with each of the other defined protocols compared in

151  this simulation. In each pair-group comparison, the cost of GnRH and/or $PGF_{2\alpha}$ treatments was

152  increased until the net profit became negative, then the breakeven point was identified as the

153  intercept of the trend line with the x-axis (Figure 1). These x-axis intercepts define the

154  hormonal treatment costs at which a Double-Ovsynch+PGF protocol would have an equal net

155  profit to the protocol it was compared against.

156      Based on our analysis hormonal treatment costs would need to be 5 to 14 times greater

157  in the US market and 2 to 6 times greater in the European market for any of the Presynch-

158  Ovsynch protocols to be more profitable than the Double-Ovsynch+PGF protocol. The greater

159  P/AI at first insemination after a Double-Ovsynch+PGF protocol compensates for the

160  additional hormonal treatment costs so that the cost of hormonal treatments would need to

161  increase substantially before it becomes less profitable than any of the other programs. When

162 the CR of Presynch-Ovsynch protocols increased, the breakeven point was reached earlier

163 because the advantage of the increased CR of Double-Ovsynch+PGFis was decreased.

164  To investigate the cost of one of the hormonal treatments to reach the breakeven point,

165 we ran hypothetical scenarios in which the cost of one hormone was constant but the cost for

166 the other hormone was incrementally increased. In this simulation, the cost of $PGF_{2\alpha}$ was set at

167 \$5.1/dose, and the cost of GnRH was set at \$6.7/dose (i.e., the average European market price).

168 Breakeven hormonal costs from this analysis are reported in Table 2.

169  Overall, the breakeven cost was more sensitive to the cost of GnRH than to the cost of

170 the $PGF_{2\alpha}$ (Table 2). When the cost of GnRH was fixed, the cost of $PGF_{2\alpha}$ could increase

171 considerably before the breakeven point was reached or no breakeven point could be reached

172 by the model. A complete Presynch-Ovsynch protocol uses 2 GnRH and 3 $PGF_{2\alpha}$ treatments,

173 whereas the Double-Ovsynch+PGF protocol uses 4 GnRH and 3 $PGF_{2\alpha}$ treatments with a

174 higher proportion of GnRH treatments (57% vs. 40%) and a lower proportion of $PGF_{2\alpha}$

175 treatments (43% vs. 60%). If ED was not incorporated into the reproductive program and the

176 cost of GnRH was fixed, profit increased even when the cost of $PGF_{2\alpha}$ increased. Thus, the

177 breakeven points are not reached by the model when increasing the cost of $PGF_{2\alpha}$. For example,

178 when compared with PreSyncOv 40 with the cost of $PGF_{2\alpha}$ fixed at \$5.1/dose, the cost of a

179 GnRH treatment was \$22.4/dose at the break-even point (Table 2). By contrast, in the first

180 study, one breakeven point was reached when the price was \$20.7/dose for $PGF_{2\alpha}$ and

181 \$23.4/dose for GnRH (Figure 1(a), 9 times the US market prices), indicating that a greater

182 $PGF_{2\alpha}$ cost determines an even higher cost of GnRH to reach the breakeven point. This can be

183 explained by the higher CR of the Double-Ovsynch+PGF protocol that leads to fewer cows

184 submitted to a resynch protocol. Consequently, fewer GnRH treatments per pregnancy are used

185    on average (Table 1). For protocols that incorporate ED, fewer cows are submitted to hormonal

186    treatments which decreases total hormone costs of the protocol; thus, a breakeven point was

187    reached even when the GnRH cost was fixed, but when the cost of $PGF_{2\alpha}$ was unusually high

188    (Table 2).

189        In conclusion, our economic evaluation found that more intensive reproductive

190    programs that use more hormonal treatments but result in substantially increased reproductive

191    performance are more profitable than less intensive programs and remain superior even if

192    hormonal prices are unusually high. Results from these analyses could be reproduced or

193    adjusted by applying the UW-Cornell DairyRepro$ decision support tool that is openly

194    available at UW-Madison and Cornell University websites.

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196    **References**

197    Bamber R. L., G. E. Shook, M. C. Wiltbank, J. E. P. Santos, and P. M. Fricke. 2009. Genetic

198        parameters for anovulation and pregnancy loss in dairy cattle. J. Dairy Sci. 92:5739-

199        5753.

200    Borchardt, S., P. Haimerl, and W. Heiwieser. 2016. Effect of insemination after estrous detection

201        on pregnancy per artificial insemination and pregnancy loss in a Presynch-Ovsynch

202        protocol: A meta-analysis. J. Dairy Sci. 99:2248-2256.

203    Cabrera, V. E., 2011. The economic value of changes in 21-day pregnancy rate and what controls

204        this value. 21st American Dairy Science Association Discover Conference: Improving

205        Reproductive Efficiency of Lactating Dairy Cows. Itasca, IL. 10 May 2011.

206    Cabrera, V. E. 2014. Economics of fertility in high-yielding dairy cows on confined TMR

207        systems. Animal 8:211-221.

208    Cabrera, V. E., and J. O. Giordano. 2013. Evaluating the economic value of changing the

209        reproductive management program for a specific dairy farm. DAIReXNET eXtension.

210        23 Oct. 2013.

211    Caraviello, D. Z., K. A. Weigel, P. M. Fricke, M. C. Wiltbank, M. J. Florent, N. B. Cook, K. V.

212        Nordlund, N. R. Zwald, and C. L. Rawson. 2006. Survey of management practices on

213        reproductive performance of dairy cattle on large US commercial farms. J. Dairy Sci.

214        89:4723–4735.

215    Carvalho, P. D., J. N. Guenther, M. J. Fuenzalida, M. C., Amundson, M. C. Wiltbank, P. M.

216        Fricke. 2014. Presynchronization using a modified Ovsynch protocol or a single

217        gonadotropin-releasing hormone injection 7 d before an Ovsynch-56 protocol for

218        submission of lactating dairy cows to first timed artificial insemination. J. Dairy Sci.

219        97(10):6305-15.

220  Carvalho P. D., M. J. Fuenzalida, A. Ricci, A. H. Souza, R. V. Barletta, M. C., Wiltbank, P. M.

221        Fricke. 2015. Modifications to Ovsynch improve fertility during resynchronization:

222        Evaluation of presynchronization with gonadotropin-releasing hormone 6 d before

223        initiation of Ovsynch and addition of a second prostaglandin $F_{2\alpha}$ treatment. J Dairy Sci.

224        98(12):8741-52.

225  Carvalho, P. D., V. G. Santos, J. O. Giordano, M. C. Wiltbank, and P. M. Fricke. 2018.

226        Development of fertility programs to achieve high 21-day pregnancy rates in high-

227        producing dairy cows. Theriogenology 114:165-172.

228  De Vries, A., J. Van Leeuwen, and W. W. Thatcher, 2010. Economics of improved reproductive

229        performance in dairy cattle. University of Florida IFAS Extension.

230  Folman, Y., M. Kaim, Z. Herz, and M. Rosenberg. 1984. Reproductive management of dairy

231        cattle based on synchronization of estrous cycles. J. Dairy Sci. 67:153–160.

232  Fricke, P.M., S. Stewart, P. Rapnicki, S. Eicker, and M. Overton. 2010. Pregnant vs. open:

233        Getting cows pregnant and the money it makes. eXtension, DAIReXNET Reproduction

234        Resources.

235  Fricke P.M., J.O. Giordano, A. Valenza, G. Lopes Jr., M.C. Amundson, P.D. 2014. Reproductive

236        performance of lactating dairy cows managed for first service using timed artificial

237        insemination with or without detection of estrus using an activity-monitoring system J.

238        Dairy Sci., 97:2771-2781.

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

242 Giordano, J. O., A. Kalantari, P. M. Fricke, M. C. Wiltbank, and V. E. Cabrera. 2012. A daily
243        herd Markov-chain model to study the reproductive and economic impact of
244        reproductive programs combining timed artificial insemination and estrus detection. J.
245        Dairy Sci 95:5442-5460.

246 Kalantari, A. S., and V. E. Cabrera. 2012. The effect of reproductive performance on the dairy
247        cattle herd value assessed by integrating a daily dynamic programming with a daily
248        Markov chain model. J. Dairy Sci. 95:6160-6170.

249 Lopes, G. Jr., J. O. Giordano, A. Valenza, M. M. Herlihy, J. N. Guenther, M. C. Wiltbank, P. M.
250        Fricke. 2013. Effect of timing of initiation of resynchronization and presynchronization
251        with gonadotropin-releasing hormone on fertility of resynchronized inseminations in
252        lactating dairy cows J. Dairy Sci., 96:3788-3798.

253 Momcilovic, D., L. F. Archbald, A. Walters, T. Tran, D. Kelbert, C. Risco, and W. W. Thatcher.
254        1998. Reproductive performance of lactating dairy cows treated with gonadotropin-
255        releasing hormone (GnRH) and/or prostaglandin F2a ($PGF_{2\alpha}$) for synchronization of
256        estrus and ovulation. Theriogenology 50:1131–1139.

257 Moreira, F., C. Orlandi, C. A. Risco, R. Mattos, F. Lopes, and W. W. Thatcher. 2001. Effects of
258        presynchronization and bovine somatotropin on pregnancy rates to a timed artificial
259        insemination protocol in lactating dairy cows. J. Dairy Sci. 84:1646–1659.

260 Pecsok, S. R., McGillard, M. L. and Nebel, R. L. 1994. P/AIs 1. Derivation and estimates for
261        effects of estrus detection on cow profitability. J. Dairy Sci. 77:3008-3015.

262 Pursley, J. R., M. O. Mee, and M. C. Wiltbank. 1995. Synchronization of ovulation in dairy cows

263         using $PGF_{2\alpha}$ and GnRH. Theriogenology. 44:915–923.

264 Rorie, R. W., T. R. Bilby, and T. D. Lester. 2002. Application of electronic estrus detection

265         technologies to reproductive management of cattle. Theriogenology 57:137–148.

266 Santos, V. G., P. D. Carvalho, C. Maia, B. Carneiro, A. Valenza, Fricke P.M. 2017. Fertility of

267         lactating Holstein cows submitted to a Double-Ovsynch protocol and timed artificial

268         insemination versus artificial insemination after synchronization of estrus at a similar

269         day in milk range. J. Dairy Sci. 100:8507–8517.

270 Santos, J. E. P., H. M. Rutigliano, M. F. Sa Filho. 2009. Risk factors for resumption of

271         postpartum estrous cycles and embryonic survival in lactating dairy cows. Anim.

272         Reprod. Sci. 110:207-221.

273 Souza, A. H., H. Ayres, R. M. Ferreira, and M. C. Wiltbank. 2008. A new presynchronization

274         system (Double-Ovsynch) increases fertility at first postpartum timed AI in lactating

275         dairy cows. Theriogenology 70:208–215.

276 Souza, A. H., P. D. Carvalho, R. D. Shaver, M. C. Wiltbank, and V. Cabrera. 2013.

277         Epidemiology of synchronization programs for breeding management in US dairy

278         herds. J. Dairy Sci. 96(Suppl. 1):288.

279 Stangaferro, M. L., R. Wijma, M. Masello, and J. O. Giordano. 2018. Reproductive performance

280         and herd exit dynamics of lactating dairy cows managed for first service with the

281         Presynch-Ovsynch or Double- Ovsynch protocol and different duration of the voluntary

282         waiting period. J. Dairy Sci. 101:1673–1686.

283    Stangaferro, M. L., R. Wijma, and J. O. Giordano. 2019. Profitability of dairy cows submitted to

284          the first service with the Presynch-Ovsynch or Double-Ovsynch protocol and different

285          duration of the voluntary waiting period. J. Dairy Sci. 102(5):4546–4562

286    Valenza, A., J. Giordano, G. Lopes Jr., L. Vincenti, M. C. Amundson, and P. Fricke. 2012.

287          Assessment of an accelerometer system for detection of estrus and treatment with

288          gonadotropin-releasing hormone at the time of insemination in lactating dairy cows. J.

289          Dairy Sci. 95:7115–7127.

290    Walsh, R. B., D. F. Kelton, T. F. Duffield, K. E. Leslie, J. S. Walton, and S. J. LeBlanc. 2007.

291          Prevalence and risk factors for postpartum anovulatory condition in dairy cows. J. Dairy

292          Sci. 90:315-324.

293    Wiltbank M. C., G. M. Baez, F. Cochrane, R. V. Barletta, C. R. Trayford, R. T. Joseph. 2015.

294          Effect of a second treatment with prostaglandin $F_{2\alpha}$ during the Ovsynch protocol on

295          luteolysis and pregnancy in dairy cows. J Dairy Sci. 98(12):8644-54.

296    Xu, Z. Z., D. J. McKnight, R. Vishwanath, C. J. Pitt, and L. J. Burton. 1998. Estrus detection

297          using radiotelemetry or visual observation and tail painting for dairy cows on pasture. J.

298          Dairy Sci. 81:2890–2896.

299

300 **Table 1.** Comparison in the number of hormonal treatments and net profit between different

| Reproductive Program[3] | P/AI (%) | Approximated number of treatments[1] (#/cow per yr) | | | Net Profit gain over the baseline[2] ($/cow per yr) | |
| | | 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 |

301 reproductive synchronization programs.

302 [1]Approximated number of treatments for hormones. GnRH proportion in protocols: Presynch-

303 Ovsynch protocols: 40%; Double-Ovsynch+PGFprotocol: 57%.

304 [2]Net profit gain over the baseline is the value of the net profit difference when alternating the

305 baseline protocol to the listed one.

306 [3]**PreSynch-Ovsynch** (Presynch-Ovsynch protocol with 35%, 40%, 45% CR)**, ED** (Estrus

307 detection performed before first AI service with 60% SR and 30% CR), **EDpost** (Estrus

308 detection performed after first AI protocol with 60% SR and 30% CR), **Double-Ovsynch**

309 **PG2x** (Double Ovsynch with a repeated injection at second prostaglandin with 50% CR).

310 [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

311 and GnRH at $6.7/dose representing the European market.

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313

314 **Table 2**. The cost ($/dose) of GnRH or $PGF_{2\alpha}$ at breakeven profit points (bold numbers), when

315 the other hormonal cost was set constant at European market price, comparing Presynch-

316 Ovsynch programs against the most intensive synchronization program, the Double-

317 Ovsynch+PGF.

| | Cost ($/dose) at the breakeven point compared with Double-Ovsynch+PGF[1] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Presynch-Ovsynch (35% CR) + ED | | |
| Hormones | Presynch-Ovsynch[2] | | | | | | | |
| | 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** |

318 [1]Double-Ovsynch PG2x (Double-Ovsynch+PGF with 50% CR).

319 [2]PreSynch-Ovsynch (Presynch-Ovsynch protocol with 35%, 40%, 45% CR).

320 [3]ED (Estrus detection performed before first AI service with 60% SR and 30% CR).
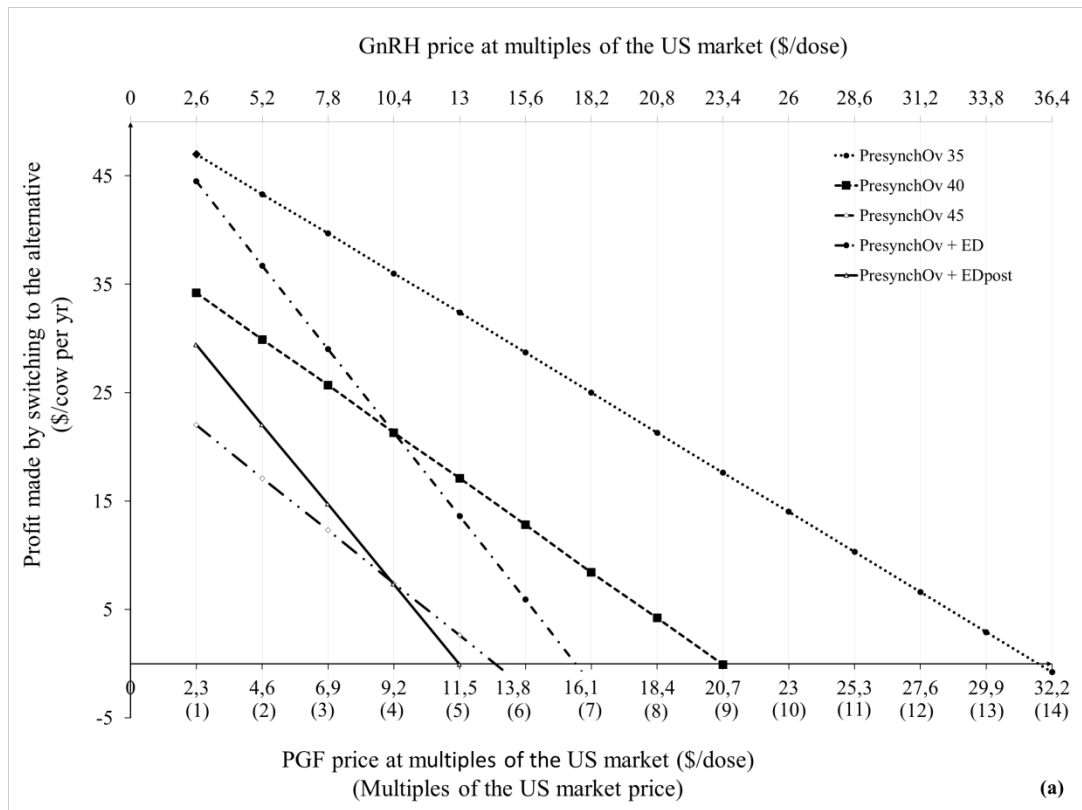
321 [4]EDpost (Estrus detection performed after first AI protocol with 60% SR and 30% CR).

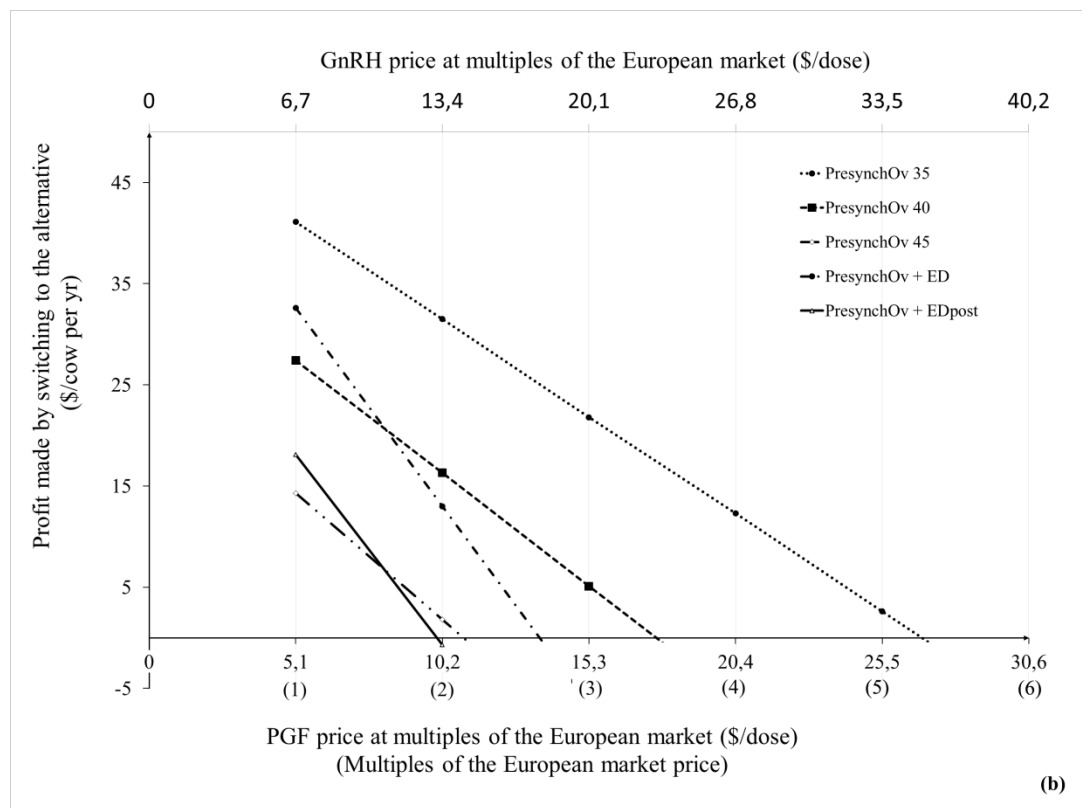322 [5]The breakeven point could not be reached.

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324

325     **Figure 1**. Sensitive analysis by identifying the breakeven points when the net profit gain by

326     switching the Presynch-Ovsynch protocols to Double-Ovsynch+PGF protocol become negative

327     with multiples of GnRH and $PGF_{2\alpha}$ for US market price (a) and European market price (b).

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

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

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

331     PreSynchOv + ED (Presync-Ovsynch protocol with 35% CR + estrus detection before first AI

332     service with 60% SR and 30% CR)

333     PreSynchOv + EDpost (Presync-Ovsynch protocol with 35% CR + estrus detection after first AI

334     service with 60% SR and 30% CR)

335     Double-Ovsynch PG2x (Double Ovsynch with a repeated injection at second prostaglandin with

336     50% CR)

337

(a)

338



(b)

339