Effect of delayed breeding during the summer on profitability of dairy cows

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ABSTRACT

The objective of this retrospective observational cohort study, combined with simulation, was to evaluate the effect of extending the voluntary waiting period (VWP) during the summer on profitability on a Florida dairy farm. Data from Holstein cows ($n = 1,416$) that calved between June and September of 2007 and 2008 were used. Cows that calved between June 1 and July 21 (regular group; REG; $n = 719$) were artificially inseminated (AI) for the first time upon estrus detection (ED) after the second PGF_{2α} of the Presynch protocol administered between 57 and 63 d in milk (DIM), or underwent timed AI using the Ovsynch protocol (TAI) if not detected in estrus. Cows that calved between July 22 and September 18 (extended group; EXT; $n = 697$) underwent AI for the first time after the first or second PGF_{2α} starting November 14 or November 21 or underwent TAI if not detected in estrus. For second and subsequent AI, all cows underwent AI upon ED or enrolled on TAI after nonpregnancy diagnosis. Following these schemes, average VWP in the REG group and EXT group were 60 and 83 d, respectively. Overall profitability for both experimental and subsequent parities were calculated by subtracting the costs existing of feeding costs (\$0.30/kg lactating cow diet; \$0.25/kg dry cow diet), breeding costs (\$2.65/dose PGF_{2α}; \$2.40/dose GnRH; \$0.25/injection administration; \$10/seminal straw; \$5/AI; \$3/pregnancy diagnosis), and other costs (\$3/d) from the daily revenues with milk sales (\$0.44/kg of milk), cow sales (\$1.76/kg of live weight), and calf sales (\$140/calf). A herd budget simulation was used to predict future cash flow after culling or end of subsequent parity until 6 yr after the start of the study to account for all cash flow consequences of extended VWP. Cows in the EXT group had greater first-service pregnancy per AI (PAI1) but still had greater days open and calving interval. Delaying breeding did not affect total cash flow because the EXT group had greater

combined profitability for the experimental parity and subsequent parity but lesser future cash flow. Delayed breeding during the summer increased PAI1 but did not improve overall reproductive efficiency and did not affect overall profitability.

Key words: delayed breeding, summer, profitability, dairy cow

INTRODUCTION

Reproductive performance and milk production are important factors that affect the profitability of a dairy farm (De Vries, 2006a; Galvão et al., 2013). Reproductive success in a dairy is typically measured by reproductive indices such as days open (DO), calving interval (CI), service rate, pregnancies per AI (PAI), and pregnancy rate. The voluntary waiting period (VWP) from calving to the start of the breeding period is an important component of reproductive management because it affects pregnancy rate, DO, and CI (Van Amburgh et al., 1997; Tenhagen et al., 2003). Determination of the optimal VWP is a great challenge for dairy producers because of the lack of reproductive, productive, and economic data associated with different VWP.

Several studies have used simulation models to evaluate the effect of extending the VWP on farm profitability, and the economic benefits vary depending on several factors such as level of milk production, pregnancy rate, and parity, among others (Sørensen and Østergaard, 2003; De Vries, 2006b; Inchaisri et al., 2011). In general, shorter VWP are optimal for average-producing cows, whereas above-average cows benefit from longer VWP. The effects of seasonality on the value of extending the VWP have not been studied through simulation models. Modeling the full seasonal effects of heat stress on cow performance may not be accurate because of a lack of suitable literature. Therefore, the use of actual cow performance data could be preferred.

Few studies have evaluated farm profitability when the VWP was extended using actual cow records. Extending the VWP by 54 to 60 d (from 71–93 DIM to 124–154 DIM) throughout the year in cows with above-average milk production resulted in increased milk yield in the subsequent parity in primiparous cows

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and increased profitability for both primiparous and multiparous cows (Arbel et al., 2001). Extending the VWP by 90 d (from 60 to 150 DIM) increased profitability by \$274/cow per year in cows receiving recombinant bovine somatotropin (Van Amburgh et al., 1997). Furthermore, extending the VWP by 20 d (from 53–59 to 73–81 DIM for low-producing cows and from 73–81 to 94–102 DIM for high-producing cows) resulted in increased PAI and similar time to pregnancy, which is expected to maintain the CI (Tenhagen et al., 2003).

Most dairy farms use a VWP of approximately 60 d (range from 30 to 90 d; DeJarnette et al., 2007). In their survey of 673 herds in the United States, season was the second most frequently cited reason for altering the VWP [postpartum health (50%), season (18%), milk yield (18%), parity (14%), and other reasons (14%)]. Among the herds that altered the VWP by season ($n = 120$), 63% (75/120) did so to avoid inseminating cows during the summer months, 22% (26/120) tried to avoid calving during the winter months, and 16% (19/120) tried to avoid calving during the summer (DeJarnette et al., 2007). In areas with summer heat stress, such as Florida, reproductive performance is often compromised and some dairy farmers stop breeding altogether during parts of the years (Du, 2013).

An economic evaluation of delayed inseminations during the summer using actual farm records is not available. Therefore, the first objective of this retrospective observational cohort study was to evaluate the effects of extending the VWP during the summer on cow performance of a dairy farm in Florida. The second objective was to evaluate the full economic effects of delayed inseminations in the experimental parity on subsequent parities using simulation. This approach combined the benefits of using actual farm records with the flexibility of using simulation to better estimate the full effects of delaying inseminations during the summer.

MATERIALS AND METHODS

Animals and Housing

Lifetime parity records from cows ($n = 1,416$) that calved during the summers (from June 1 to September 30) of 2007 ($n = 391$) or 2008 ($n = 1,025$) were collected from a dairy farm located in Trenton, Florida. During 2007, the dairy milked approximately 3,000 Holstein cows; during 2008, the dairy milked approximately 4,000 Holstein cows with a rolling herd average of approximately 10,000 kg of milk. Primiparous and multiparous cows were housed separately in freestall barns equipped with sprinklers and fans. All cows received the same TMR to meet or exceed the nutrient

requirements for a lactating Holstein cow producing 45 kg of milk per day with 3.5% fat and 3.2% true protein (NRC, 2001). The diet consisted of ryegrass silage, corn silage, alfalfa hay, ground corn, citrus pulp, soybean meal, molasses, minerals, and vitamins. Cows were fed twice daily and milked thrice daily.

Reproductive Management and VWP Groups

During the summers of 2007 and 2008, cows were bred using 2 different protocols as determined by the dairy farm's management (Figure 1). Cows that calved between June 1 and July 21 underwent AI upon estrus detection (**ED**) after the second $\text{PGF}_{2\alpha}$ of the Presynch protocol (Moreira et al., 2001) between 57 and 63 DIM, or were enrolled in the Ovsynch timed AI (**TAI**) program if not detected in estrus by 12 d after the second $\text{PGF}_{2\alpha}$; these cows were assigned to the regular group (**REG**; $n = 719$). Cows that calved between July 22 and September 30 underwent AI after the first or second $\text{PGF}_{2\alpha}$ starting November 14 or November 21 or were enrolled in the TAI program if not detected in estrus by 12 d after the second $\text{PGF}_{2\alpha}$; these cows were assigned to the extended group (**EXT**; $n = 697$). The VWP was defined as the interval between calving date and the second $\text{PGF}_{2\alpha}$ if cows calved between June 1 and July 21 or the interval between calving date and the first $\text{PGF}_{2\alpha}$ if cows calved between July 22 and September 30. Following these schemes, average VWP in the REG and EXT groups were 60 d (range = 57–63 d) and 83 d (range = 64–121 d), respectively.

Each cow was only included once, but 151 cows out of the 391 that enrolled in summer 2007 calved again in summer 2008. The majority of these cows ($n = 118$; 54 REG and 64 EXT) had a VWP that would fall in the same initial VWP group assignment, but 18 REG cows had extended VWP in 2008 and 15 EXT cows had regular VWP in 2008. After first AI, cows that returned to estrus immediately underwent AI. Pregnancy diagnosis was performed by ultrasonography between 28 and 34 d after AI in cows that had not been re-inseminated. All nonpregnant cows were enrolled in the TAI program.

Data Collection and Exclusion Criteria

All the production and reproduction data were extracted from the dairy farm's management software (DHI-Plus, DHI Computing Service Inc., Provo, UT) for 2 consecutive parities starting from calving until death, sale, or the end of the second parity. The records were transferred into Excel (Microsoft, Redmond, WA) and organized using SAS 9.3 (SAS Institute Inc., Cary, NC). The variables extracted were cow number, date of birth, parity, calving date, date of first $\text{PGF}_{2\alpha}$, date

Figure 1. Diagram of reproductive management during the summers of 2007 and 2008.

of second PGF_{2α}, AI dates, pregnancy diagnosis dates, conception date, dry date, and sold or dead date or subsequent calving date, and monthly DHIA milk weights. Three hundred eighty-nine cows with incomplete lactation records (i.e., missing monthly milk weights) were excluded from the analysis.

Milk and Fat Production

Total milk production in the parity for each cow was calculated from their monthly milk weights using test-day methods reported by Wiggans (1985). The parity ended when cows were culled or were dried off. Because the farm did not test the fat content in milk, we estimated fat percentage in milk (fat %) to be able to calculate FCM as previously reported (De Vries et al., 2006; Galvão et al., 2013). Mathematically,

$$\text{Fat \%} = 12.86 \times \text{DIM}^{-1.081} \times \exp[0.0926 \times (\ln \text{DIM})^2] \times (\ln \text{DIM})^{1.107}$$

$$\text{and FCM (kg/d)} = 0.4 \times \text{MILK} + 0.15 \times \text{Fat \%} \times \text{MILK},$$

where MILK is the milk yield (kg/d). Fat-corrected milk was later used to estimate DMI because the farm did not record individual DMI.

BW

Actual BW measurements were not available. Therefore, BW per month after calving were estimated as previously reported (De Vries et al., 2006; Galvão et al., 2013). Mathematically,

$$\text{BW (kg)} = A \times \{1 - [1 - (B/A)^{1/3}] \times \exp(-C \times \text{AGE})\}^3 - (P1/P2) \times \text{DIM} \times \exp(1 - \text{DIM}/P2) + P3^3 \times \text{DPC}^3,$$

where AGE is the cow's age in days; DPC is a parameter to adjust for stage of lactation, being 0 up to 50 d of gestation and after 50 d of gestation, being calculated by subtracting 50 from the gestation days. The parameters A, B, C, P1, P2, and P3 for first parity were 600, 42, 0.0039, 20, 65, and 0.0187, and for second and greater parities were 600, 42, 0.0060, 40, 75, and 0.0187 based on data for Holsteins (De Vries, 2006a). Body weights were used to determine salvage value of culled cows and in the calculation of DMI.

DMI

Dry matter intake for lactating cows was estimated as recommended by the NRC (2001), as previously reported (De Vries et al., 2006; Galvão et al., 2013):

$$\text{DMI (kg/d)} = 0.372 \times \text{FCM} + 0.0968 \times \text{BW}^{0.75} \times \{1 - \exp[-0.192 \times (\text{DIM}/7 + 3.67)]\}.$$

Dry cows were assumed to consume 12 kg of DM/d, as previously reported (De Vries et al., 2006; Galvão et al., 2013).

Costs and Revenues

Prices were chosen to represent the actual prices paid and received by a Florida dairy farm (Galvão et al., 2013). The price of GnRH was set at \$2.40/dose and PGF_{2α} at \$2.65/dose. Injection cost was set at \$0.25/injection, assuming an employee makes \$15.00/h and can give 60 injections per hour. Semen cost was set at \$10.00/straw. Cost of AI was set at \$5.00/AI. Pregnancy diagnosis cost was set at \$3.00/diagnosis. Calf price (average for male and female) was set at \$140/calf. Milk price was modeled at \$0.44/kg. Dry matter price for lactating cows was set at \$0.30/kg, and for dry cows at \$0.25/kg. Cull price was set at \$1.76/kg, and a replacement heifer at \$1,850/heifer. For every cow that was sold, a replacement heifer was purchased, and

replacement cost was accounted for in the future cash flow calculation. Other variable and fixed costs were set at \$2.50/cow per day.

Cash Flow Calculations

Total cash flows were calculated for 6 yr for each cow and her replacements following enrollment in the study. The total cash flow was calculated as the sum of the cash flow observed during the study time and future cash flows to complete 6 yr since the start of the study. Future cash flows were determined by simulation using a herd budget simulator. Therefore, total cash flow = study cash flow + future cash flow. Six years were needed to capture the full effects of delayed VWP in the experimental parity on subsequent parities with the cow enrolled in the study and her replacements. As for the subsequent lactation, the VWP was not extended in the simulation model.

The study cash flow captured all cash flows when the cow was present in the study, from the calving in the experimental parity until the end of the subsequent parity or culling, whichever came first. These study cash flows for both the experimental and subsequent parities were calculated by subtracting feeding, breeding, and other costs from the daily revenues calculated from milk sales, cow sales, and calf sales. These revenues and costs were directly calculated from the cow records.

Future cash flows after the cow left the study until she, or her replacements, completed 6 yr from the time she was enrolled in the study were calculated with the DairyVIP herd budget calculator (De Vries, 2004, 2006a).

Inputs for the herd budget calculator such as lactation curves and seasonality of milk yield, probability of conception, and risk of abortion were set to mimic the results for the study cows in the REG group. Nonetheless, similar inputs as in De Vries (2006a) were chosen for risk of culling to mimic a typical pattern of annual culling. Prices were the same as described for the study cows.

For cows that were culled during the study period, immediate replacement with a calving heifer was assumed. For cows that reached the end of the subsequent parity, the cash flow started with calving in the next parity. Because of the dynamic probabilistic nature of the calculator, the cash flows reached steady state after approximately 4 yr. Cash flows for fifth- and later-parity cows were assumed to be equal to cash flows for fourth-parity cows. Twelve different calving seasons were simulated. Thus, cash flows from 48 different starting calvings were simulated for 6 yr (72 mo) into the future and their monthly cash flows were stored ($48 \times 72 = 3,456$ monthly cash flows). Then, depending on

the time the cow left the study period, the cash flows for the remainder of the time until the end of yr 6 were summed.

In addition to the prices mentioned earlier for the study period, input data similar to those used in De Vries (2006a) were used if data from the study herd were not available. The default probability of conception in DairyVIP depended on days after calving and was reduced by 5, 15, 25, 35, 40, 35, 25, and 10% from April to November to simulate the effect of summer heat stress. The default daily milk production was reduced by 2.5, 7.5, 12.5, 17.5, 20.0, 17.5, 12.5, and 5.0% from April to November. Using simulation only with these inputs, the herd steady-state revenues minus variables costs were \$4.29/cow per day, which was similar to the average revenues minus variable costs in the study period.

Statistical Analysis

Continuous outcomes were analyzed using the MIXED procedure of SAS 9.3 (SAS Institute Inc.). Binary outcomes were analyzed using the GLIMMIX procedure of SAS. Time to pregnancy was analyzed using the PHREG procedure of SAS. Models included the fixed effects of VWP group, parity, interaction between group and parity, and year as random (MIXED and GLIMMIX) or strata (PHREG). Survival curves were built using MedCalc 12.4 (Ostend, Belgium). Statistical significance was declared if $P \leq 0.05$.

RESULTS

Technical Results

The effect of delaying breeding on production and reproductive outcomes in the current parity is shown in Table 1 and Figures 2, 3 and 4. We observed an effect of VWP group on PAI to first AI, DO, and CI, in which cows in the EXT group had greater PAI (37.7 vs. 32.1; $P = 0.02$), longer DO (156 vs. 139 d; $P < 0.001$), and longer CI (428 vs. 408 d; $P < 0.001$). We also found an interaction between VWP group and parity on milk yield per lactation, milk yield per day, DIM, days in lactation (DIM and days dry), VWP, proportion that conceived, proportion that calved again, proportion sold, and proportion culled (Table 1). Milk yield per lactation, DIM, days in lactation, and proportion that calved again were greater for EXT primiparous than for REG primiparous, whereas we found no difference between VWP groups in multiparous cows. The proportion that conceived was greater for EXT primiparous than for REG primiparous but was lesser for EXT multiparous than for REG multiparous. Proportion sold and

proportion culled were lesser for EXT primiparous than for REG primiparous, whereas we found no difference between VWP groups in multiparous cows. Although we detected an interaction between group and parity on milk yield per day, we found no significant differences between EXT and REG, depending on parity. As expected, the VWP was shorter for REG than for EXT, although the differences were greater in primiparous. The lactation curves for primiparous and multiparous cows are shown in Figure 2. Although VWP had no effect on milk yield, REG primiparous cows produced more milk on milk tests 2 and 3 ($P < 0.001$), and REG multiparous cows produced more milk on milk test 11, whereas EXT multiparous cows produced more milk on milk test 13 ($P < 0.02$). Average time to culling was shorter for the REG group compared with the EXT group (199 vs. 234 d; $P = 0.04$); however, this difference was because the average time to culling was shorter for REG compared with EXT in primiparous cows (167 vs. 290 d; $P < 0.001$), whereas we found no difference in multiparous cow (224 vs. 214 d; $P = 0.59$). To better visualize the differences in the patterns of culling between REG and EXT groups in primiparous and multiparous cows, Kaplan-Meier survival curves are shown for cows that were culled (Figure 3). In primiparous cows, the REG group had decreased median days

to culling compared with the EXT group (62 vs. 285 d; $P = 0.01$), whereas we found no difference in multiparous cows (219 vs. 203 d; $P = 0.53$). Because most of the difference in culling was because of an increased proportion of REG primiparous cows sold (Table 1), we compared the reasons for selling primiparous cows. It was observed that most of the REG primiparous cows were sold for reason “dairy” (70%; farmer-entered primary culling reason, where the cow is sold to another dairy to continue milk production), whereas most of the EXT primiparous cows (50%) were sold because of reproductive failure (sold for beef). Only 8% of EXT primiparous cows were sold for dairy and 20% of REG primiparous were sold because of reproductive failure. Primiparous cows sold for dairy were sold on average at 57 DIM (range = 43 to 94 DIM), whereas those sold because of reproductive failure were sold on average at 400 DIM (range = 46 to 792 DIM).

Cox proportional hazard survival analysis showed that cows in the EXT group had decreased hazard of first AI (hazard ratio = 0.35; 95% CI = 0.31–0.40; $P < 0.001$); however, this difference was due to the difference in VWP, because when the data were left-censored to the end of the VWP, the hazard of first AI was numerically greater for the EXT group (hazard ratio = 1.1; 95% CI = 0.98–1.24; $P = 0.11$). The Kaplan-Meier

Table 1. Effect of delaying breeding on production and reproductive outcomes in the experimental parity

Variable ¹	Primiparous		Multiparous		P-value		
	EXT ²	REG ²	EXT	REG	Group	Parity	Interaction
Number of cows	293	313	404	406	—	—	—
Milk, kg/parity	9,943 ^a	8,349 ^b	10,342 ^A	10,299 ^A	<0.001	<0.001	<0.001
Milk, kg/d	28 ^a	26 ^a	31 ^A	32 ^A	0.80	<0.001	0.002
DIM	356 ^a	296 ^b	320 ^A	317 ^A	<0.001	0.21	<0.001
Days dry	62	59	61	60	0.09	0.73	0.37
DIM + days dry	409 ^a	338 ^b	361 ^A	358 ^A	<0.001	0.06	<0.001
VWP, d	86 ^a	60 ^b	80 ^A	60 ^B	<0.001	<0.001	<0.001
PAI first AI, %	39	36	37	29	0.02	0.10	0.34
Days open	158	134	157	144	<0.001	0.36	0.23
Conceived, %	94 ^a	78 ^b	80 ^A	86 ^B	0.001	0.01	<0.001
Calved again, %	84 ^a	69 ^b	67 ^A	68 ^A	<0.001	<0.001	<0.001
Calving interval, d	427	404	430	413	<0.001	0.15	0.47
Sold, %	13 ^a	29 ^b	25 ^A	22 ^A	0.002	0.07	<0.001
Died, %	3	3	8	10	0.89	<0.001	0.61
Culled, %	16 ^a	31 ^{b,3}	33 ^A	32 ^A	<0.001	<0.001	<0.001

^{a,b,A,B}Different superscripts within the same row and within the same parity differ ($P < 0.05$).

¹Milk, kg/parity = total milk produced during the experimental parity; Milk, kg/d = average milk production per day during the experimental parity; DIM = number of days in milk during the experimental parity; Days dry = number of days dry for cows that got pregnant during the experimental parity; VWP = voluntary waiting period; PAI first AI, % = percentage of cows pregnant per AI; Days open = number of days from calving until conception for cows that conceived during the experimental parity; Conceived, % = percentage of cows that conceived during the experimental parity; Calved again, % = percentage of cows that conceived during the experimental parity and calved again; Calving interval, d = interval in days between the calving that initiated the experimental parity and a subsequent calving for cows that calved again; Sold, % = percentage of cows sold during the experimental parity; Died, % = percentage of cows that died during the experimental parity; Culled, % = percentage sold plus died.

²Cows in the REG group ($n = 719$) had a voluntary waiting period (VWP) between 57 and 63 d; cows in the EXT group ($n = 697$) had a VWP between 64 and 121 d (average = 83 d).

³Percentage sold plus percentage died does not add up to percentage culled because of rounding off (90 cows were sold and 8 cows died).

Figure 2. Monthly milk yield (kg) for primiparous (A) or multiparous (B) cows. Cows in the REG group had voluntary waiting period (VWP) between 57 and 63 d; cows in the EXT group had a VWP between 64 and 121 d (average 83 d). Asterisks indicate statistical difference ($P < 0.02$).

survival curve for time to first AI in Figure 4A shows the true difference in median days to first AI for the REG versus EXT groups (75 vs. 94 d), and Figure 4B show the median days to first AI when the data were left-censored to the end of the VWP (17 vs. 5 d).

Cox proportional hazard survival analysis also showed that cows in the EXT group had decreased hazard of pregnancy (hazard ratio = 0.84; 95% CI = 0.75–0.94; $P = 0.002$), but again this difference was due to the difference in VWP, because when the data were left-censored to the end of the VWP, the hazard of pregnancy was actually numerically greater for the EXT group (hazard ratio = 1.1; 95% CI = 0.99–1.25; $P = 0.08$). The Kaplan-Meier survival curve for time to pregnancy in Figure 5A shows the true difference in median days to pregnancy for the REG versus EXT

Figure 3. Kaplan-Meier survival curves for time to culling (sold or died) for primiparous (A) or multiparous (B) cows. Cows in the REG group had voluntary waiting periods (VWP) between 57 and 63 d; cows in the EXT group had a VWP between 64 and 121 d (average 83 d). In primiparous cows, the REG group had decreased median days to culling compared with the EXT group (62 vs. 285 d; $P = 0.01$). Nonetheless, in multiparous cows, median days to culling did not differ between REG and EXT groups (219 vs. 203 d; $P = 0.53$).

groups (113 vs. 139 d), and Figure 5B show the median days to pregnancy when the data were left-censored to the end of the VWP (54 vs. 53 d).

The effect of delaying breeding on production and reproductive outcomes in the subsequent parity is shown in Table 2. The only effect of VWP group was on VWP, with cows in the EXT group having greater VWP in the subsequent parity (63 vs. 61 d; $P = 0.005$). We also observed an interaction between VWP group and parity on milk yield per parity, milk yield per day, and CI. Calving interval was shorter for EXT primiparous than for REG primiparous cows, whereas we found no difference between VWP groups in multiparous cows.

Figure 4. Kaplan-Meier survival curve for time to first AI from calving (A) or from the end of the voluntary waiting period (VWP; B). Cows in the REG group ($n = 719$) had a VWP between 57 and 63 d; cows in the EXT group ($n = 697$) had a VWP between 64 and 121 d (average 83 d). The REG group had decreased median days open compared with the EXT group (75 vs. 94 d; $P < 0.001$). Nonetheless, from the end of the VWP, the REG group had a numerical increase in median days open (17 vs. 5 d; $P = 0.11$).

Figure 5. Kaplan-Meier survival curve for time to pregnancy from calving (A) or from the end of the voluntary waiting period (VWP; B). Cows in the REG group ($n = 719$) had a VWP between 57 and 63 d; cows in the EXT group ($n = 697$) had a VWP between 64 and 121 d (average 83 d). The REG group had decreased median days open compared with the EXT group (113 vs. 139 d; $P < 0.001$). Nonetheless, from the end of the VWP, median days open did not differ between REG and EXT groups (54 vs. 53 d; $P = 0.08$).

Although we detected an interaction between group and parity on milk yield per parity and milk yield per day, we found no significant differences between EXT and REG groups, depending on parity.

Economic Results

The effect of delaying breeding on profitability in the experimental parity is shown in Table 3. With the exception of breeding cost, VWP group affected all other incomes and costs. We detected an interaction between VWP group and parity for all revenues and costs.

Calf revenues (\$118 vs. \$96), milk revenues (\$4,375 vs. \$3,674), and other costs (\$1,226 vs. \$1,013) were greater ($P < 0.05$) for EXT than REG in primiparous cows, whereas we found no difference in multiparous cows. On the other hand, sold revenue was less for EXT than REG in primiparous cows (\$132 vs. \$277; $P < 0.001$), whereas we found no difference in multiparous cows. Breeding cost was less for EXT than REG in multiparous cows (\$42 vs. \$50; $P = 0.002$) but we found no difference in primiparous cows. Although most costs and revenues were affected by VWP group, the profitability in the experimental parity was similar between

Table 2. Effect of delaying breeding on production and reproductive outcomes in the subsequent parity

Variable ¹	Primiparous ² (now second parity)		Multiparous ² (now ≥third parity)		P-value		
	EXT ³	REG ³	EXT	REG	Group	Parity	Interaction
Number of cows	247	215	269	275	—	—	—
Milk, kg/parity	9,858 ^a	10,446 ^a	9,925 ^A	9,236 ^A	0.85	0.04	0.02
Milk, kg/d	30 ^a	32 ^a	32 ^A	30 ^A	0.54	0.74	0.01
DIM	309	321	284	274	0.91	<0.001	0.13
Days dry	60	59	60	60	0.46	0.30	0.90
DIM + days dry	355	368	317	308	0.79	<0.001	0.16
VWP, d	63	61	63	61	0.005	0.58	0.59
PAI first AI, %	38	33	37	40	0.66	0.45	0.20
Days open	132	136	149	143	0.79	0.02	0.37
Conceived, %	93	94	83	78	0.97	<0.001	0.18
Calved again, %	76	80	56	57	0.26	<0.001	0.51
Calving interval, d	390 ^a	402 ^b	401 ^A	397 ^A	0.28	0.49	0.05
Sold, %	19	15	36	33	0.13	<0.001	0.58
Died, %	4	5	8	10	0.75	<0.009	0.74
Culled, %	23	20	44	43	0.26	<0.001	0.52

^{a,b,A,B}Different superscripts within the same row and within the same parity differ ($P < 0.05$).

¹Milk, kg/parity = total milk produced during the subsequent parity; Milk, kg/d = average milk production per day during the subsequent parity; DIM = number of days in milk during the subsequent parity; Days dry = number of days dry for cows that got pregnant during the subsequent parity; VWP = voluntary waiting period; PAI first AI, % = percentage of cows pregnant per AI; Days open = number of days from calving until conception for cows that conceived during the subsequent parity; Conceived, % = percentage of cows that conceived during the subsequent parity; Calved again, % = percentage of cows that conceived during the subsequent parity and calved again; Calving interval, d = interval in days between the calving that initiated the subsequent parity and a subsequent calving for cows that calved again; Sold, % = percentage of cows sold during the subsequent parity; Died, % = percentage of cows that died during the subsequent parity; Culled, % = percentage sold plus died.

²Cows that started the study as primiparous cows would be second parity in the subsequent parity, and cows that started the study as multiparous cows would be ≥third parity in the subsequent parity.

³Cows in the REG group ($n = 719$) had a voluntary waiting period (VWP) between 57 and 63 d; cows in the EXT group ($n = 697$) had a VWP between 64 and 121 d (average = 83 d).

the EXT and REG groups. The profitability in the experimental parity was only affected by parity, with multiparous being more profitable than primiparous (\$1,835 vs. \$1,354; $P < 0.001$).

The effect of delaying breeding on profitability in the subsequent parity is shown in Table 4. We found no effect of VWP group on any of the costs, revenues, or profitability in the subsequent parity. We detected only an interaction between VWP group and parity on milk revenues; however, we found no difference between EXT

and REG, depending on parity. Again, we found an effect of parity on profitability in the subsequent parity, but now with cows that were previously primiparous (now second parity) being more profitable than cows that were previously multiparous (now ≥third parity; \$1,891 vs. \$1,712; $P < 0.001$).

The effect of delaying breeding on study cash flow (current plus subsequent parity), future cash flow from the time the cow left the herd or the end of the subsequent parity until 6 yr after enrollment and total cash

Table 3. Effect of delaying breeding on profitability in the experimental parity

Variable ¹	Primiparous		Multiparous		P-value		
	EXT ²	REG ²	EXT	REG	Group	Parity	Interaction
Calf revenues	118 ^a	96 ^b	93 ^A	95 ^A	0.003	<0.001	<0.001
Milk revenues	4,375 ^a	3,674 ^b	4,551 ^A	4,532 ^A	<0.001	<0.001	<0.001
Sold revenues	132 ^a	277 ^b	262 ^A	233 ^A	0.01	0.06	<0.001
Feed costs	2,040 ^a	1,634 ^b	1,957 ^A	1,923 ^A	<0.001	0.02	<0.001
Breeding costs	45 ^a	41 ^a	42 ^A	50 ^B	0.50	0.09	<0.001
Other costs	1,226 ^a	1,013 ^b	1,083 ^A	1,074 ^A	<0.001	0.60	<0.001
Profit	1,326	1,382	1,838	1,833	0.56	<0.001	0.49

^{a,b,A,B}Different superscripts within the same row and within the same parity differ ($P < 0.05$).

¹All values in \$/parity.

²Cows in the REG group ($n = 719$) had a voluntary waiting period (VWP) between 57 and 63 d; cows in the EXT group ($n = 697$) had a VWP between 64 and 121 d (average = 83 d).

Table 4. Effect of delaying breeding on profitability in the subsequent parity

Variable ¹	Primiparous ² (now second parity)		Multiparous ² (now $\geq$ third parity)		<i>P</i> -value		
	EXT ³	REG ³	EXT	REG	Group	Parity	Interaction
Calf revenues	107	113	78	80	0.30	<0.001	0.65
Milk revenues	4,338 ^a	4,596 ^a	4,367 ^A	4,064 ^A	0.85	0.03	0.02
Sold revenues	203	156	377	343	0.16	<0.001	0.82
Feeding costs	1,829	1,953	1,730	1,695	0.35	<0.001	0.09
Breed costs	44	46	44	40	0.58	0.22	0.10
Other costs	1,064	1,104	951	924	0.79	<0.001	0.16
Profit	1,829	1,953	1,730	1,695	0.36	<0.001	0.10

^{a,b,A,B}Different superscripts within the same row and within the same parity differ ($P < 0.05$).

¹All values in \$/parity.

²Cows that started the study as primiparous cows would be second parity in the subsequent parity, and cows that started the study as multiparous cows would be $\geq$ third parity in the subsequent parity.

³Cows in the REG group ($n = 719$) had a voluntary waiting period (VWP) between 57 and 63 d; cows in the EXT group ($n = 697$) had a VWP between 64 and 121 d (average = 83 d).

flow from study enrollment until 6 yr after enrollment are shown in Table 5. Study cash flow was greater for EXT than REG (\$2,996 vs. \$2,840; $P = 0.05$). We detected an interaction between VWP group and parity on future cash flow, which showed that future cash flow was lesser for EXT than REG in primiparous cows (\$5,237 vs. \$5,575; $P = 0.001$), whereas we found no difference in multiparous cows (\$5,387 vs. \$5,419; $P = 0.55$). Although VWP group had no effect on total cash flow, we did detect an interaction between VWP group and parity, which showed that total cash flow was lesser for EXT than REG in primiparous cows (\$8,013 vs. \$8,198; $P = 0.05$), whereas we found no difference in multiparous cows (\$8,624 vs. \$8,510; $P = 0.16$).

Although the VWP was only minimally affected in 2008 by having cows from 2007 that calved again in the summer of 2008 and had an extended VWP, we conducted an additional economic analysis excluding the year 2007. Similar to the initial analysis, VWP did not affect the profitability in the experimental parity ($P = 0.43$) or the subsequent parity ($P = 0.13$);

however, the significant difference in the study cash flow was lost although it was still numerically greater for the EXT group (\$2,867 vs. \$2,709; $P = 0.09$). We detected the same interaction between VWP and parity on future cash flow where future cash flow was lower for EXT than REG in primiparous cows ($P < 0.001$). We found no overall effect of VWP group on total cash flow and the same interaction between VWP and parity on total cash flow ($P = 0.03$) was observed. However, the significant difference was lost although it was still numerically greater for the REG group (\$8,164 vs. \$7,970; $P < 0.08$). These losses of significance are probably due to a loss of power because of the smaller sample size.

DISCUSSION

This study evaluated the effects of extended VWP during the summer on technical and economic results using cow records obtained from a dairy farm in Florida subject to summer heat stress. The dairy farm extended the VWP during 2007 and 2008 because PAI was

Table 5. Effect of delaying breeding on cash flows in the experimental parity and subsequent parity (study cash flow), future cash flow, and total cash flow

Variable	Primiparous		Multiparous		<i>P</i> -value		
	EXT ¹	REG ¹	EXT	REG	Group	Parity	Interaction
Study cash flow ²	2,766	2,605	3,226	3,074	0.05	<0.001	0.96
Future cash flow ³	5,237 ^a	5,575 ^b	5,387 ^A	5,419 ^A	<0.001	0.95	<0.001
Total cash flow ⁴	8,013 ^a	8,198 ^b	8,624 ^A	8,510 ^A	0.57	<0.001	0.02

^{a,b,A,B}Different superscripts within the same row and within the same parity differ ($P < 0.05$).

¹Cows in the REG group ($n = 719$) had a voluntary waiting period (VWP) between 57 and 63 d; cows in the EXT group ($n = 697$) had a VWP between 64 and 121 d (average = 83 d).

²Sum of cash flows from the experimental and subsequent parities.

³Cash flow from the time the cow left the herd or the end of the subsequent parity until 6 yr after enrollment.

⁴Total cash flow from study enrollment until 6 yr of enrollment.

thought to be low during the summer. Although studies using simulation models to evaluate the economic effect of extending the VWP have produced mixed results (Sørensen and Østergaard, 2003; De Vries, 2006b; Inchausti et al., 2011), both on-farm studies found in the literature evaluating the economic effect of extending the VWP resulted in greater profitability for the EXT group (Van Amburgh et al., 1997; Arbel et al., 2001). Furthermore, extending the VWP was found not to affect time to pregnancy (Tenhagen et al., 2003). These studies did not consider seasonality due to summer heat stress on cow performance, however.

The effects of extending the VWP on production and reproductive outcomes in the experimental parity that were not conditional on parity were greater PAI to first AI, increased DO, and increased CI for the EXT group compared with REG group. Increased PAI to first AI when the VWP is extended was observed in one study (Tenhagen et al., 2003) but not in another (Van Amburgh et al., 1997). An increase in PAI to first AI in cows with extended VWP can be explained by the fact that cows are allowed to have more estrous cycles, which has been associated with increased PAI to first AI because of progesterone priming and improved uterine cleansing during estrus (Thatcher and Wilcox, 1973; Darwash et al., 1997). Nonetheless, the increase in PAI to first AI was not sufficient to eliminate the difference in time to pregnancy as observed previously (Tenhagen et al., 2003). In the study by Tenhagen et al. (2003), PAI to first AI was increased by 13.2 to 20.1 percentage points, whereas in the current study, PAI to first AI was only increased by 5.6 percentage points. This was surprising given the fact that the average delay in the current study (23 d) was similar to the delay in the study by Tenhagen et al. (2003; 21 d), and all cows in the EXT group underwent AI for the first time in a cool month (November), whereas the REG group underwent AI for the first time in warm months (August and September). Therefore, as a consequence of having greater DO, the EXT group had greater CI compared with the REG group.

The effects of VWP on production and reproductive outcomes in the experimental parity that were conditional on parity were mainly because of differences in primiparous cows. In primiparous cows, milk per parity was probably greater for the EXT group because of an increase in DIM, which was partly the result of extending the VWP and partly the result of earlier culling in REG primiparous cows. This observed earlier culling in REG primiparous cows was primarily because of more cows being sold for dairy reasons, which occurred very early in lactation. This effect was not expected and was probably a management decision unrelated to the VWP group assignment. Because EXT primiparous

cows remained in the herd longer, more of them became pregnant and calved again.

As expected, the subsequent parity was minimally affected by the VWP group. Slightly greater VWP in the subsequent parity for the EXT group was probably a result of having 64 EXT cows that were enrolled in 2007 that calved again between July 22 and September 30 in 2008; therefore, having extended VWP. There were also 15 REG cows enrolled in 2007 that calved again between July 22 and September 30 in 2008; therefore, having extended VWP, which probably contributed to the small increase in the average VWP from 60 to 61 d from 2007 to 2008. Although CI was shorter in the EXT group compared with the REG group in primiparous cows, the difference was probably a result of reproductive management decisions (i.e., decision to stop AI) unrelated to VWP group assignment and not an improvement in fertility, as DO, PAI, and proportion that calved again were not affected.

Although most revenues and costs were affected by VWP group in the experimental parity, profitability was not affected. The economic results for the experimental parity match the technical results very closely, with most of the differences being observed in primiparous cows. Therefore, the lack of effect occurred mainly because, in primiparous cows, the increase in revenues with calf and milk sales was offset by a decrease in cow sales and an increase in feed and other costs. Because VWP group had no effect on the subsequent parity, profitability was also not affected. Nonetheless, although VWP group had no effect on profitability of the experimental parity and the subsequent parity, study cash flow was increased for the EXT group, because of numerical increases in profitability in the experimental parity and the subsequent parity for the EXT group and, more importantly, because of greater and earlier culling in REG compared with EXT primiparous cows in the experimental parity. Therefore, these cows did not contribute much with income in the experimental or subsequent parities. As a consequence of this greater and earlier culling in REG primiparous cows, proportionally more REG primiparous cows contributed for longer to the future cash flow, resulting in greater future cash flow for REG primiparous cows and greater total cash flow for REG primiparous cows. The difference in culling rates between REG and EXT primiparous cows was not expected and was probably unrelated to VWP group assignment.

The findings in our study probably differ from those of other on-farm trials because in the trial by Arbel et al. (2001), only cows with above-average production had extended VWP and in the trial by Van Amburgh et al. (1997), cows were treated with recombinant bST. In both scenarios, cows are expected to have a better ratio

of milk income over feed cost, especially toward the end of the lactation, which is expected to improve overall profitability. In the trial by Arbel et al. (2001), milk per parity in the control group was approximately 2,000 kg higher than the control group in our study. Therefore, because of greater production potential, they were able to increase the revenues with milk sales without incurring excessive costs for feed. The same is true with the use of recombinant bST, where milk yield is sustained toward the end of the lactation (Van Amburgh et al., 1997). Using an optimization model, De Vries (2006a) also observed that VWP could be extended beyond 60 DIM for cows with production above the average. It was concluded that the optimal VWP increased from 35 to 140 d with increasing milk production (De Vries, 2006b).

Cows that started the study as multiparous were more profitable especially because of the greater ratio of milk income over feed cost during the experimental parity. Because of differences in physiological state; namely, that primiparous cows are still growing, primiparous cows have lower overall milk yield and lower feed conversion efficiency (Beever and Doyle, 2007), which explains the lower profitability in this group.

CONCLUSIONS

Delaying breeding during the summer in heat-stressed cows improved PAI to first AI but also extended DO and CI. Delaying breeding did not affect total cash flow over a period of 6 yr because the EXT group had greater combined profitability for the experimental parity and subsequent parity but lesser future cash flow. The decision to delay breeding during the summer in herds similar to the one used for this study may be based on other management considerations because it did not affect overall profitability.

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