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Dry Period Management and Optimization of Post-Partum Reproductive Management in Dairy Cattle

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Contents

Dry period and early post-partum management are decisive factors for fertility in lactating dairy cows. Previous studies have shown that decreased dry matter intake (DMI) and increased non-esterified fatty acids (NEFA) negatively affect fertility and subsequent milk production. The traditional dry period decreases DMI prior to parturition, resulting in a decrease in energy intake. A negative energy balance increases NEFA concentration, and increased NEFA may impair the immune system, especially by decreasing neutrophil function prior to parturition. Earlier studies have shown that post-partum health disorders, including retained placenta and metritis, were correlated with periparturient neutrophil function. In addition, decreased DMI is also linked to a reduced body condition score (BCS) in dairy cows. These events in the periparturient period negatively affect fertility. Some manipulation, such as shortening the dry period, may be a solution to increased DMI in the periparturient period, preventing post-partum disorders and subsequent fertility issues. This article aims to explain the effects of shortening the dry period on reproduction and early post-partum treatments to improve fertility. In addition, timed artificial insemination protocols will be discussed for use during the post-partum period to improve fertility in dairy cows.

Introduction

Milk production and reproductive performance are two major determinants of dairy cow profitability. Milk production per dairy cow has dramatically increased over the last several decades, but the reproductive performance of dairy cows has declined worldwide (Lucy 2001; Royal et al. 2000; Stevenson 2001). High-producing dairy cows typically experience a variable period of negative energy balance (EB) during early lactation owing to insufficient dry matter intake (DMI) to compensate for higher milk production. Improvement in EB from its nadir (most negative level) in early lactation towards a positive state provides an important signal for the initiation of ovarian activity (Butler et al. 1981). Energy balance during the first 3–4 weeks post-partum has been correlated with the interval corresponding to the first post-partum ovulation (Beam and Butler 1998; Lucy et al. 1991). The early resumption of ovarian activity is important because fertility at first breeding may increase as the number of oestrous cycles prior to breeding increases (Thatcher and Wilcox 1973).

Worldwide, milk production has increased continuously over the last 40 years owing to genetic selection and changes in the management and nutrition in dairy operations. This article will focus on the effects of (i) shortening dry period on reproduction, (ii) early post-partum treatments to improve fertility and (iii) synchronization protocols to maximize fertility and eliminate the need for oestrous detection.

Effects of Shortening Dry Period on Reproduction

A majority of the literature indicates that a dry period (DP) between lactations is necessary to achieve maximal milk production. A dry period of 2 months is needed to achieve maximum milk yield during the following lactation (Sorensen and Enevoldsen 1991). Dry matter intake decreases dramatically in the week prior to parturition (Bertics et al. 1992), resulting in a decrease in energy intake at a critical point in time. Additionally, changing cows from one diet to another over a short period of time may not allow the rumen environment adequate time to adjust to the new diet (Dirksen et al. 1985). One potential solution is to shorten the DP and provide a high-energy (HE), low-fibre diet throughout the DP and into lactation. Shortening the DP to <60 days has been promoted during the past few years. Several experiments designed to examine the effects of reducing the DP to approximately 4 weeks have shown no difference in milk production and/or fat-corrected milk in the subsequent lactation (Annen et al. 2004; Bachman 2002; Gulay et al. 2003; Rastani et al. 2005).

Rastani et al. (2005) designed a study to detect the effect of shortening or eliminating DP on energy balance, non-esterified fatty acid (NEFA) concentrations, DMI and reproduction. These data were evaluated both pre- and post-partum period in lactating dairy cows. In this study, cows were divided into three treatment groups. The first treatment reflected traditional (T) dry cow management practices. These cows had a 56-day DP and were fed a low-energy (LE) diet from 56 to 29 days pre-partum, followed by a moderate-energy (ME) diet from 28 days pre-partum to parturition. The second treatment group had a shortened (S) DP of 28 days; these cows were fed a HE diet throughout lactation and the DP. The third treatment group had no planned (N) DP and remained on a HE diet. The most intriguing results, including energy balance, DMI, NEFA levels and reproductive data, were observed in the N dry period group. Mean pre-partum DMI was greater in the N group than in S and T cows (Fig. 1). Cows in the N group did not go through negative EB, compared with S or T cows, during the post-partum period (Fig. 2). NEFA levels were also lower in N cows compared with S and T cows. However, although the N cows displayed the most interesting and favourable data (greater DMI, higher EB and lower NEFA levels), it is

Table 1. Comparison of several synchronization protocols such as Ovsynch, Presynch-Ovsynch and Double-Ovsynch. Shown are synchronization protocol types, number of cows used, mean DIM to begin protocols and percentage of pregnancy per artificial insemination (AI)

Study	Synchronization protocol	Number of cows	Mean DIM	Percentage of pregnancy per AI	p value
LeBlanc and Leslie (2003)	Ovsynch	506	At 52	36.6	> 0.05
	One dose $PGF_{2\alpha}$ before 10 days Ovsynch			37.3	
Cordoba and Fricke (2001)	Ovsynch	50	At 66	44.0	> 0.05
	One dose $PGF_{2\alpha}$ before 12 days Ovsynch	52		38.5	
El-Zarkouny et al. (2004)	Ovsynch	304	At 59–79	37.5	< 0.01
	Presynch-Ovsynch (Presynch-12)	310		46.8	
Navanukrav et al. (2004)	Ovsynch	134	At 99	37.3	< 0.05
	Presynch-Ovsynch (Presynch-14)	135	At 89	49.6	
Moreira et al. (2001)(all cows)	Ovsynch	97	At 37	36.0	> 0.05
	Presynch-Ovsynch (Presynch-12)	88		36.9	
Moreira et al. (2001) (only cyclic cows)	Ovsynch	67	At 37	34.4	< 0.01
	Presynch-Ovsynch (Presynch-12)	66		46.9	
Souza et al. (2008)	Presynch-Ovsynch (Presynch-12)	180	42	41.7	0.03
	Double-Ovsynch	157		49.7	
Peters and Pursley (2002)	Ovsynch	209	At 49–55	38.3	0.87
	Presynch with $PGF_{2\alpha}$-3d-GnRH 7 days after Ovsynch	218		41.5	
Portaluppi and Stevenson (2005)	Presynch-Ovsynch (Presynch-12) (2nd GnRH 48 h + TAI 48 h)	224	At 24–44	22.8	< 0.05
	Presynch-Ovsynch (Presynch-12) (2nd GnRH 48 h + TAI 72 h)	221		23.5	
	Presynch-Ovsynch (Presynch-12) (2nd GnRH 72 h + TAI 72 h)	220		31.4	

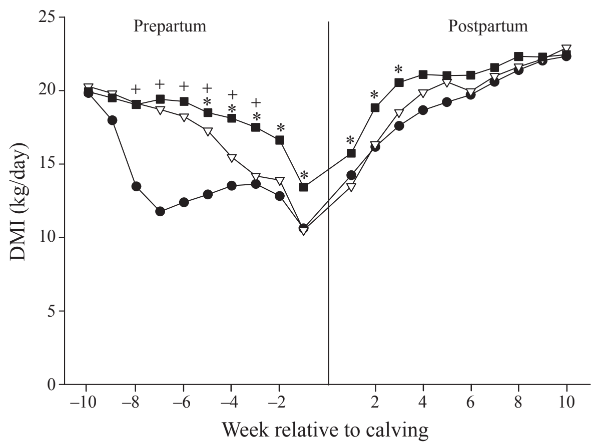

Fig. 1. Dry matter intake (kg/day) of cows with different dry period lengths. N (■): no dry period, S (△): shortened dry period, T (●): traditional dry period (from Rastani et al. 2005)

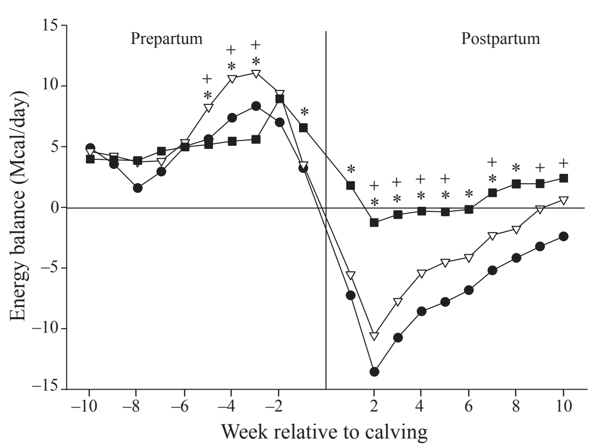

Fig. 2. Energy balance (Mcal/day) of cows with different dry period lengths. N (■): no dry period, S (△): shortened dry period, T (●): traditional dry period (from Rastani et al. 2005)

not possible to apply this strategy in commercial dairy farms owing to lower milk production in subsequent lactation.

In order to obtain reproductive data, cows' ovaries were evaluated by ultrasound, and blood samples were collected three times per week, beginning at 6 or 7 days post-partum and continuing until 7 days after the second ovulation (Gumen et al. 2005). The most dramatic effect observed was that the first post-partum ovulation occurred earlier in N cows than in S and T cows (Fig. 3). Furthermore, the average number of days from calving until the first detection of a 10-mm follicle was fewer in N (8.0 days) and S (8.9 days) than in T (10.5 days). Cows that were on the no planned dry treatment had a higher first service conception rate, fewer services per conception and fewer days open. However, these data should be evaluated carefully due to the small number of animals in each group. A recent study performed in a large commercial dairy examined the effects of shortening the dry period on reproduction in a large number of cows (Watters et al. 2009). Cows were assigned to either 55 days dry (traditional) or 34 days dry (shortened) groups. The first post-partum ovulation occurred earlier in the shortened dry group than in the traditional group (35 vs 43 days). The percentage of cows that were classified as anovulatory by 70 days post-partum was more than twofold greater for cows in the traditional group than in the shortened group (Watters et al. 2009). Thus, shortening or eliminating the dry period could be used as a management tool for achieving better reproduction in dairy cows. We present a simplified model (Fig. 4) to explain the effect of shortening or eliminating the dry period on fertility. In this model, increasing DMI before calving is the key element for better reproduction.

Health disorders can have a major impact on the profitability of a dairy herd. Infection and subsequent inflammation of the uterus compromise uterine health and contribute to decreased reproductive efficiency in

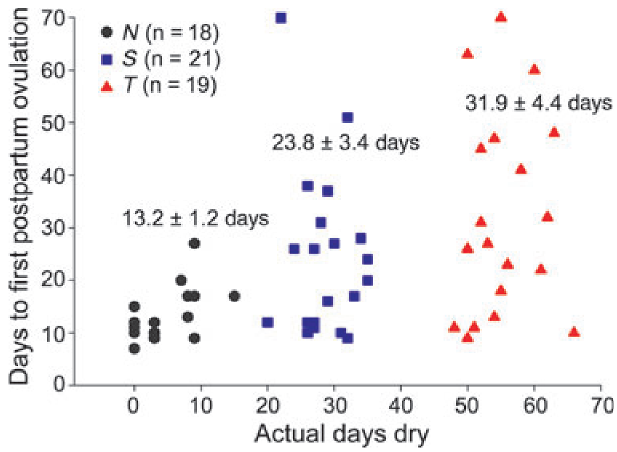

Fig. 3. Scatter plot of actual days dry and days from calving to first post-partum ovulation for cows with a traditional (56 days) dry period (T), a shortened (28 days) dry period (S) or no planned dry period (N). Average days from calving to first ovulation are also shown for each treatment (mean ± SEM) (from Gumen et al. 2005)

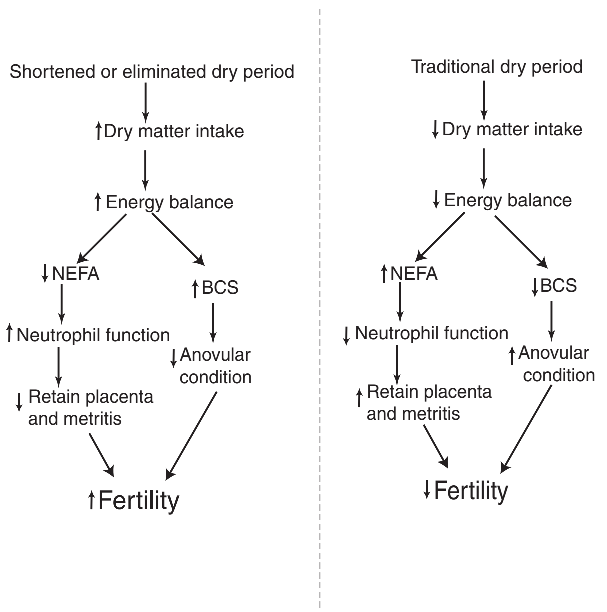

Fig. 4. Simplified model of the effect of shortening or eliminating the dry period on fertility

dairy cows (Fourichon et al. 2000). These problems can be caused by decreasing DMI and increasing NEFA prior to parturition (Fig. 4). Hammon et al. (2006) showed that cows with puerperal metritis or endometritis had significantly lower DMI beginning 1 week prior to parturition, compared with cows with normal uterine health. Decreased DMI prior to parturition is well documented and is associated with mobilization of lipids, which are released from adipose tissue as NEFA (Grummer et al. 2004). Decreased DMI and increased NEFA levels are temporally associated with the periparturient suppression of immune function and may contribute to the impairment of the immune system in dairy cows (Rukkwamsuk et al. 1999). Studies have shown a relationship between periparturient peripheral blood neutrophil (PMN) suppression during the periparturient period and retained placenta (Gunnink 1984; Kimura et al. 2002) and metritis (Cai et al. 1994) in dairy cows. In addition, PMN function of periparturient dairy cows is impaired relative to non-parturient cattle (Kehrli et al. 1989). These data suggest that some uterine health disorders are associated with the impairment of PMN function and the negative energy status that begins prior to calving and extends into early lactation. As explained above, shortening or eliminating the dry period could have a beneficial effect on DMI, immune systems and subsequent post-partum uterine health in lactating dairy cows (Fig. 4).

After parturition, nutritional requirements of high-yielding dairy cows increase abruptly with milk production and result in negative EB (Butler 2003) because DMI is inadequate to fully meet the increasing energetic requirements of milk production. The negative EB resulted in loss of BCS as the cow mobilized body fat reserves to support milk production and energy requirements. Mobilization of body fat during negative EB increased plasma concentrations of NEFA and beta-hydroxybutyrate (BHBA) both of which were associated with reduced fertility (Garnsworthy et al. 2008). Excessive negative EB reduces insulin and insulin-like growth factor-I (IGF-1) concentrations (Beam and Butler 1999; Butler 2000) and increases growth hormone leading to delays in oestrous cycles and impaired oocyte quality and corpus luteum function in high-yielding dairy cows. In addition, negative EB delays the time of first post-partum ovulation through inhibition of LH pulse frequency and low levels of blood glucose, insulin and IGF-1 that collectively restrain oestradiol production by dominant follicles (Butler 2000). Consequently, it is expected that increasing EB of dairy cows should result in greater reproductive efficiency. The feeding management practice that help maximize DMI, and thereby increase energy intake, should be emphasized throughout the transition period to overcome early-lactation negative EB. The most common strategy used to reduce the extent of negative EB and BCS loss in early lactation is to increase dietary energy concentration by increasing the starch or fat components of the diet (Garnsworthy et al. 2008). Increasing the energy density of diets via supplementation of starch or non-fibre carbohydrates will potentially increase dry matter and energy intakes and reduce body fat mobilization, liver triglyceride, plasma NEFA and BHBA concentrations. In addition, such a change in carbohydrate source in diets has implications for rumen function, milk composition, nutrient partitioning and metabolic hormones, particularly insulin (Sutton 1989; Sutton et al. 2003; Reynolds 2006). Some researchers reported that dietary manipulation of insulin status affects post-partum anoestrus (Gong et al. 2002) and oocyte quality (Fouladi-Nashta et al. 2005). Insulin was increased by diets with high starch content (Gong et al. 2002; Reynolds 2006). Garnsworthy et al. (2008) reported that plasma-insulin-to-glucagon ratio increased with increasing dietary starch and decreasing dietary fat concentration. Gong et al. (2002) observed that high-insulin diet significantly ($p < 0.05$) increased the proportion of cows ovulating within 50 days of calving. In conclusion, the feed quality and availability is the most important factor that affects energy intake in dairy cows. Therefore, a few nutritional management strategies have been proposed to increase energy intake during early post-partum period. Feeding high-quality forages (more digestible), increasing starch and non-fibre carbohydrates, increasing the concentrate-to-forage ratio or adding supplemental fat to diets are some of the most common strategies to improve energy intake in dairy cows. However, nutritional approaches to overcoming the negative EB have been unsuccessful. Therefore, further research is required to better understand the effects of nutrients on reproductive performance.

Hormonal Treatments to Improve Fertility During the Early Post-Partum Period

GnRH and prostaglandins have been used to manage the post-partum period, i.e. to induce the reproductive cycle, and improve uterine health in lactating dairy cows. Early resumption of cyclic ovarian activity is important for greater reproductive efficiency. An increased number of oestrous cycles before onset of breeding are related to a decrease in services per conception (Thatcher and Wilcox 1973). In several studies, GnRH treatments have been studied to induce cyclicity at 14 days post-partum. Britt et al. (1974) reported a 100% ovulation rate after GnRH implantation at day 14 post-partum. However, Gumen and Seguin (2003) indicated that while 95% of cows responded with a release of LH, only 45% of cows responded with an ovulation and the subsequent formation of the corpus luteum at 22 days post-partum. In addition, some studies have found an improved conception rate following GnRH treatment in the early post-partum period, but several other studies have shown no effect of this GnRH administration (Britt et al. 1974), and a few have even found a negative effect (Etherington et al. 1985).

$PGF_{2\alpha}$ and its analogues have been used to manipulate the bovine oestrous cycle and can be valuable aids in dairy herd reproductive health management programmes. Some studies have shown that $PGF_{2\alpha}$ has positive effects on subsequent reproductive performance when it is given in the post-partum period, even without a luteolytic action (McClary et al. 1989; Young et al. 1984). McClary et al. (1989) found that mean days open (98.6 days) and mean services per pregnancy (1.64) were lower in cows that received $PGF_{2\alpha}$ treatment at 14–16 days post-partum compared with control cows (118.8 days and 2.33, respectively). However, some studies found no beneficial effects of $PGF_{2\alpha}$ treatment in the early post-partum period. The effects of $PGF_{2\alpha}$ on fertility in dairy cows can be seen later in the post-partum period and during the synchronization protocol, as we will discuss in the section below. The use of GnRH and $PGF_{2\alpha}$ in the early post-partum period and the effect of these treatments on post-partum events are unclear and require further study.

Synchronization Protocols to Improve Fertility

In this section, we will discuss methods to improve fertility in the post-partum period with a timed artificial insemination protocol in lactating dairy cows. Reproductive efficiency is a major component of economic success in dairy herds. Some key indicators of reproductive efficiency include days open, calving interval, days post-partum at first artificial insemination (AI), oestrous detection rate and conception rate (Santos 2008). Increased milk production, insufficient nutrition and post-partum disorders (e.g. retained placenta, mastitis and metritis) have negative effects on reproductive efficiency; these effects impair fertility by delaying the first post-partum AI and extending days open and calving interval in lactating dairy cows (Wiltbank et al. 2008). Therefore, veterinarians and dairy producers employ many methodologies to improve reproductive efficiency, including the use of hormones to regulate and control the oestrous cycle.

It is well known that reproductive management in many dairies is based on oestrous detection and subsequent insemination of cows detected to be in oestrus. High milk production causes numerous changes in reproductive physiology. For instance, the duration of oestrus is < 8 h, and silent heat or anovulatory conditions are often observed in high-producing lactating dairy cows (Wiltbank et al. 2006, 2008). Because of this, timed artificial insemination (TAI) programmes have become important tools for the reproductive management at many commercial dairy farms (Pursley et al. 1997b; Rabiee et al. 2005; Souza et al. 2008). Many TAI programmes are based on the original Ovsynch protocol that can be used to synchronize the time of ovulation at first and subsequent AIs in lactating dairy cows (Pursley et al. 1997b). The Ovsynch synchronization protocol was developed to synchronize ovulation in cows using GnRH and $PGF_{2\alpha}$ (Pursley et al. 1997b). This protocol synchronizes ovulation within an 8-h period from 24 to 32 h after the second GnRH administration. This precise synchrony allows for successful AI without the detection of oestrus.

Numerous research reports have compared the Ovsynch, modified Ovsynch and other reproductive management strategies. For instance, in early studies, pregnancy rates were found to be similar or greater in cows inseminated with TAI (Ovsynch) than in cows inseminated after detected oestrus (Pursley et al. 1997a,b). Pursley et al. (1997a) indicated that the conception rate in lactating dairy cows ($n = 310$) averaged 38% following the Ovsynch protocol or AI based on oestrous detection with three injections 14 days apart. Similarly, Gumen et al. (2003) showed that the conception rate after AI was 32% in cows receiving the Ovsynch protocol and 35% in cows inseminated after oestrous detection. Furthermore, the Ovsynch protocol reduced the median days post-partum to the first AI (54 vs 83: $p < 0.001$) and days open (99 vs 118: $p < 0.001$) in lactating dairy cows compared with the oestrous detection-based synchronization programme (Pursley et al. 1997b). In 2005, a meta-analysis of 71 trials in 53 research publications with sufficient experimental details for inclusion found that no differences were detected between Ovsynch and various other reproductive management strategies (Rabiee et al. 2005). However, the variation in conception rates between herds and between trials was substantial (Rabiee et al. 2005).

The other significant advantage of Ovsynch is that it can be applied at a random stage of the oestrous cycle (Pursley et al. 1997a), although the stage of the oestrous cycle at the initiation of Ovsynch affects fertility in response to the protocol (Bello et al. 2006; Vasconcelos et al. 1999). Cows that begin Ovsynch in the late luteal phase (Days 13–17 of oestrus) and do not ovulate in response to the first GnRH treatment may have premature regression of the CL and undergo oestrus and potentially ovulation prior to the second GnRH treatment of Ovsynch (Vasconcelos et al. 1999). Alternatively, cows that are too early in the oestrous cycle at the initiation of Ovsynch (before Day 5) have a lower ovulatory response to the first GnRH treatment and lower fertility in response to the protocol (Bello et al. 2006; Vasconcelos et al. 1999). Therefore, to obtain the best fertility results, Ovsynch should be initiated at a more optimal stage of the oestrous cycle (Days 5–12). One way to target the initiation of this protocol to the most favourable stage of the oestrous cycle is pre-synchronization with $PGF_{2\alpha}$ before the first GnRH treatment of the Ovsynch protocol. Pre-synchronization using two doses of $PGF_{2\alpha}$ administered 14 days apart with Ovsynch initiated at 11–14 days after the second $PGF_{2\alpha}$ (Presynch) has generally resulted in synchronize 90–95% cyclic cows (Moreira et al. 2001). One study showed that more than 70% of cows began the Ovsynch protocol during early-to mid-oestrus when Presynch was applied before Ovsynch, compared with 53% of cows treated with Ovsynch at a random stage of the oestrous cycle (El-Zarkouny et al. 2004).

In previous studies, pre-synchronization protocols have generally resulted in better fertility (Table 1) at first AI in lactating dairy cows (El-Zarkouny et al. 2004; Moreira et al. 2001; Navanukraw et al. 2004). Moreira et al. (2001) found an improvement in fertility when using Presynch prior to Ovsynch if only cycling cows were included in the analysis (46.9% vs 34.4%) but not if all cows were included in the analysis. Similarly, El-Zarkouny et al. (2004) reported an increase in fertility at first AI in cows treated with Presynch prior to Ovsynch (48.8%) compared with cows that did not receive Presynch (37.5%). Galvao et al. (2007) found that an 11-day interval from the second $PGF_{2\alpha}$ until the initiation of Ovsynch (Presynch-11) was preferable to a 14-day interval (Presynch-14). This improvement was probably due to the improvement in the percentage of cows that ovulate prior to the first GnRH treatment following Presynch-11 compared with Presynch-14 (Galvao et al. 2007). However, previous studies showed that Presynch with one dose $PGF_{2\alpha}$ before 10- to 12-days Ovsynch did not improve fertility (Cordoba and Fricke 2001; LeBlanc and Leslie 2003). LeBlanc and Leslie (2003) found that conception rate did not differ between Ovsynch (36.6%) and Presynch with $PGF_{2\alpha}$ before 12-days Ovsynch (37.3%) in lactating dairy cows.

In the aforementioned studies, all cows were bred using timed AI after Presynch. However, at many dairies, cows are bred after the expression of oestrus with the Presynch treatments. Approximately 45–55% of cows show oestrus after the second $PGF_{2\alpha}$ injection of the Presynch protocol, and many dairies prefer the bred the cows in that time. Therefore, Ovsynch is initiated only in those cows that were not detected to be in oestrus during Presynch (Santos 2008). However, the conception rate in cows inseminated at oestrus following pre-synchronization is lower than that in cows inseminated after the completion of the entire programme (Chebel et al. 2006; Santos 2008). Stevenson and Phatak (2005) reported no difference in fertility for cows bred to oestrus during the Presynch treatments (31.3%) compared with the cows bred using TAI after the subsequent Ovsynch protocol (25.5%). A recent study (Chebel et al. 2010) reported that 48.7% of cows were bred to detected oestrus during the Presynch protocol. Although not a primary comparison in the study, similar fertility was observed in cows bred to oestrus during Presynch (36.6%) compared with cows bred using TAI following Ovsynch (33.3%) or following an Ovsynch protocol that included a controlled internal drug release (CIDR) device (38.1%). However, the insemination of cows at oestrus during pre-synchronization could be used to reduce the interval to first AI and costs associated with hormones and labour (Santos 2008).

However, studies in dairy cows that have evaluated cyclicity by serum progesterone concentrations in blood samples taken 10–12 days apart have reported anovulation frequencies ranging from 10% to 54% by 49 to 71 DIM (Gumen et al. 2003; : Moreira et al. 2001; : Wiltbank et al. 2008). Normally, non-cyclic or anovulatory cows do not respond to $PGF_{2\alpha}$ injection of pre-synchronization, and Ovsynch will be initiated in non-cyclic cows, which is not effective (Moreira et al. 2001). Non-cyclic cows have been found to be well synchronized by the Ovsynch, but pregnancy rates were low in non-cyclic cows (9%) compared with cyclic (33%) cows (Gumen et al. 2003). Lower pregnancy rates in non-cyclic cows after Ovsynch have been attributed to an increased frequency of short cycles in non-cyclic cows (Gumen et al. 2003). Some researchers have used a CIDR during the Presynch to increase the proportion of cyclic cows before Ovsynch (Bicalho et al. 2007). The CIDR was inserted 7 days after the first $PGF_{2\alpha}$ of Presynch and removed at the time of the second $PDF_{2\alpha}$. The percentage of cows with low progesterone at the beginning of the Ovsynch protocol decreased from 30.6% in the control group to 17.4% in the CIDR-treated group (Bicalho et al. 2007). In a recent study, Souza et al. (2008) developed a new pre-synchronization protocol (Double-Ovsynch); these researchers compared Double-Ovsynch with Presynch-Ovsynch in their study. They reported that the percentage of cows with low progesterone at the initiation of Ovsynch was lower in the Double-Ovsynch group (9.4%) than in the Presynch-Ovsynch group (33.3%). The positive effects of Double-Ovsynch are also seen in the pregnancy rate, which was greater in the Double-Ovsynch group (49.7%) than in the Presynch-Ovsynch group (41.7%).

In conclusion, Ovsynch, Presynch-Ovsynch and Double-Ovsynch can be used post-partum at first AI and subsequent AIs in lactating dairy cows. Using Presynch-Ovsynch or Double-Ovsynch may increase fertility at post-partum first AI by decreasing the proportion of non-cyclic dairy cows (Double-Ovsynch) and increasing uterine health (Presynch-Ovsynch) before the initiation of Ovsynch.

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Author Contributions

All authors contributed equally to the intellectual content of this paper.

Conflict of Interest

None.

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