CONTROL OF ESTRUS IN COWS

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Introduction

Estrous synchronization and artificial insemination (AI) are reproductive management tools that have been available to beef producers for over 30 years. Synchronization of the estrous cycle has the potential to shorten the calving season, increase calf uniformity, and enhance the possibilities for utilizing AI. Artificial insemination allows producers the opportunity to infuse superior genetics into their operations at costs far below the cost of purchasing a herd sire of similar standards. These tools remain the most important and widely applicable reproductive biotechnologies available for beef cattle operations (Seidel, 1995). However, beef producers have been slow to utilize or adopt these technologies into their production systems.

Several factors, especially during early development of estrus synchronization programs, may have contributed to the poor adoption rates. Initial programs failed to address the primary obstacle in synchronization of estrus, which was to overcome puberty or postpartum anestrus. Additionally, these programs failed to manage follicular waves, resulting in more days during the synchronized period in which detection of estrus was necessary. This ultimately precluded fixed-time AI with acceptable pregnancy rates. More recent developments focused on both corpus luteum and follicle control in convenient and economical protocols to synchronize ovulation. These developments facilitated fixed-time AI (TAI) use, and should result in increased adoption of these important management practices (Patterson et al., 2003). Current research has focused on the development of methods that effectively synchronize estrous in postpartum beef cows and replacement beef heifers by decreasing the period of time over which estrous detection is required, thus facilitating the use of TAI (Lamb et al., 2001, 2006, Larson et al., 2006). This new generation of estrus synchronization protocols uses two strategies which are key factors for implementation by producers because they: 1) minimize the number and frequency of handling cattle through a cattle-handling facility; and 2) eliminate detection of estrus by employing TAI.

High priority needs to be placed on transferring these current reproductive management tools and technology to producers, veterinarians and industry personnel to ensure they are adopted at the producer level and to provide the necessary technical support to achieve optimum results. Because current management, breed, economic, location, and marketing options are producer specific, it is essential to ensure that transfer of this technology is not presented in blanket recommendations. Producers receiving all the necessary, applicable information packaged to include, but not limited to, protocol administration, economic implications, and genetic improvements to the cowherd are more apt to implement these tools into their management systems and achieve positive outcomes as a result. Without timely transfer of this technology within the United States, our research products and technology will be more effectively utilized in foreign countries competing with the United States to produce and market high quality, uniform beef products. The recent development of estrous synchronization protocols for TAI in beef cows has the potential to alter reproductive performance in numerous herds.

Abbreviations, Terms and Protocol Definitions

Abbreviations

Artificial insemination (**AI**); controlled internal device release (vaginal implant containing 1.38 g progesterone; **CIDR**); corpus luteum (**CL**); gonadotropin-releasing hormone (dose = 100 μg; **GnRH**); days (**d**); hours (**hr**); human chorionic gonadotropin (**hCG**); melengesterol acetate (fed at 0.5 mg/head/day; **MGA**); prostaglandin $F_{2\alpha}$ (dose = 25mg; **PG**); artificial insemination at a predetermined fixed-time (**TAI**).

Terms

Synchronization rate: Proportion of females detected in estrus to total number treated.
Conception rate: Proportion of females becoming pregnant to those exhibiting estrus and inseminated during the synchronized period.
Pregnancy rate: Proportion of females becoming pregnant to total number treated.

Protocols Requiring Detection of Estrus

2 shot PG: Two injections of PG administered 11 to 14 d apart
MGA-PG: MGA is fed for a period of 14 d with PG administered 19 d after MGA withdrawal.
Select Synch: GnRH followed in 7 d with an injection of PG.
7-day CIDR-PG: CIDR inserted for 7 d with PG administered on d 7.
Select Synch + CIDR: CIDR inserted for 7 d with GnRH administered at CIDR insertion and PG administered on d 7 at CIDR removal.
7-11 Synch: MGA is fed for 7 d with PG administered on the last d of feeding, followed by Select Synch initiated 4 d later.

Protocols for TAI

MGA Select + fixed-time AI: MGA is fed for 14 d, GnRH is administered 12 d after MGA withdrawal, and PG is administered 7 d after GnRH. Insemination is performed 72 hr after PG with GnRH administered at AI.
Ovsynch: GnRH is administered followed in 7 d with the administration of PG. A second GnRH is administered at 48 hr with a TAI 16 hr later.
CO-Synch: GnRH is administered followed in 7 d with the administration of PG. Insemination is performed 48 to 72 hr after PG with GnRH administered at AI.
7-day CO-Synch + CIDR: GnRH is administered at CIDR insertion followed 7 d later with the administration of PG at CIDR removal. Insemination is performed 66 hr after PG and CIDR removal with GnRH administered at AI.
5-day CO-Synch + CIDR: GnRH injection simultaneous to insertion of a CIDR, followed 5 d later with CIDR removal and administration of 2 injections of PG; the first at CIDR removal and the second 12 h later; a TAI is performed 72 h after first PG and CIDR removal concurrent with a second GnRH injection.

Development of estrous synchronization methods for TAI.

Initial estrous synchronization systems focused on altering the estrous cycle by regressing the CL with an injection of PG followed by detecting estrus between 18 and 80 hr after the injection. Once systems involving a single injection of PG became successful, researchers focused on multiple injections of PG to further reduce days required for heat detection and AI (Lauderdale et al., 1974; Seguin et al., 1978). The next generation of estrous synchronization systems involved the use of exogenous progestins (MGA and CIDR), which (while administered) prevented estrus from occurring. Progestins were used to delay the time of estrus following a natural or induced luteolysis and extend the length of the estrous cycle (Brown et al., 1988; Lucy et al., 2001). Not until the discovery that growth of follicles in cattle occurs in distinct wave-like patterns (Fortune et al., 1988) were scientists able to embark on the third generation of estrous synchronization systems. Controlling follicular waves with a single injection of GnRH to cows at random stages of their estrous cycles causes release of luteinizing hormone leading to synchronized ovulation and luteinization of mostly large dominate follicles (≥ 10 mm; Garverick et al., 1980; Bao and Garverick, 1998; Sartori et al., 2001). Consequently, a new follicular wave is initiated in all cows within 2 to 3 d of GnRH administration. Luteal tissue that forms after GnRH administration is capable of undergoing PG-induced luteolysis 6 or 7 d later (Twagiramungu et al., 1995). A drawback of this method, however, is that approximately 5 to 15% of cows are detected in estrus on, or before, the day of PG injection, thus reducing the proportion of females that are detected in estrus and inseminated during the synchronized period (Kojima et al., 2000; Lamb et al., 2001). Based on this foundation, much of the current work has focused on three areas: 1) development of reliable protocols that rely solely on TAI; 2) development of systems that require a maximum of three animal handlings; and 3) research to ensure that the systems are successful in both anestrus and estrous cycling females at any stage of the estrous cycle. This review is an update on these developments for synchrinzation of the estrous cycle in cows.

Use of MGA in Cow Protocols

During the past 25 years numerous researchers have generated data to devise successful estrous synchronization protocols utilizing MGA in beef cows such as MGA-PG, MGA Select and 7-11 Synch (Kojima et al., 2000; Patterson et al., 1989, 2003). Melengestrol acetate is an orally active progestin. When consumed by cows on a daily basis, MGA will suppress estrus and prevent ovulation (Imwalle et al., 2002). Melengestrol acetate may be fed with a grain or a protein carrier and either top-dressed onto other feed or batch mixed with larger quantities of feed. Melengestrol acetate is fed at a rate of 0.5 mg/animal/day in a single daily feeding. The duration of feeding may vary between protocols, but the level of feeding is consistent and critical to success. Animals that fail to consume the required amount of MGA on a daily basis may prematurely return to estrus during the feeding period. This can be expected to reduce the estrous response during the synchronized period. Therefore, adequate bunk space (60 linear cm/head) must be available so that all animals consume feed simultaneously (Patterson et al., 2003).

Animals should be observed for behavioral signs of estrus each day of the feeding period. This may be done as animals approach the feeding area and before feed distribution. This practice will ensure that all females receive adequate intake. Cows will exhibit estrus beginning 48 hours after MGA withdrawal, and this will continue for 6 to 7 days. It is generally recommended that females exhibiting estrus during this period not be inseminated or exposed for natural service because of reduced fertility females experience at the first heat after MGA withdrawal.

In spite of the success in development of the MGA protocols, the use of MGA as part of any estrus synchronization protocol in beef cows constitutes an extralabel use of medicated feed that is prohibited by the Animal Medicinal Drug Use and Clarification Act and regulation 21 CFR 530.11(b). The feeding of MGA is specifically approved for estrus suppression in heifers only. Although 35 years of feeding MGA to beef cows and beef heifers has demonstrated MGA is safe, effective and economical, the **feeding of MGA to adult cows is not an FDA approved label claim and therefore is strictly prohibited by the FDA**. It is unfortunate that the MGA label does not include all reproductively mature beef cattle, but it does not.

Overview of the CIDR Device

The CIDR is an intravaginal progesterone insert, used in conjunction with other hormones to synchronize estrous in beef and dairy cows and heifers. The CIDR was developed in New Zealand and has been used for several years to advance the first pubertal estrus in heifers and the first postpartum estrus in cows. The CIDR is a "T" shaped device with flexible wings that collapse to form a rod that can be inserted into the vagina with an applicator. On the end opposite to the wings of the insert a tail is attached to facilitate removal with ease. The backbone of the CIDR is a nylon spine covered by progesterone (1.38g) impregnated silicone skin. Upon insertion blood progesterone concentrations rise rapidly, with maximal concentrations reached within an hour after insertion. Progesterone concentrations are maintained at a relatively constant level during the seven days the insert is in the vagina. Upon removal of the insert, progesterone concentrations are quickly eliminated.

Retention rate of the CIDR during a seven-day period exceeds 97%. In some cases, vaginal irritation occurs resulting in clear, cloudy or yellow mucus when the CIDR is removed. Cases of mucus are normal and does not have an impact on effectiveness of the CIDR. Caution should be taken when handling CIDRs. Individuals handling CIDRs should wear latex or nitrile gloves to prevent exposure to progesterone on the surface of the insert and to prevent the introduction of contaminants from the hands into the vagina of treated females. The inserts are developed for a one-time use only. Multiple use may increase the incidence of vaginal infections.

Initial CIDR/$PGF_{2\alpha}$ Protocols for Cows

During the seven days of CIDR insertion, progesterone diffusion from the CIDR does not affect spontaneous luteolysis. Assuming all cows have 21 day estrous cycles, there will be two populations of females after six days of CIDR treatment: females without corpora lutea and females with corpora lutea more than six days after ovulation. All females, therefore, have corpora lutea that are potentially responsive to an injection of $PGF_{2\alpha}$. Although most research data indicates that only about 90% of corpora lutea in cows more than six days after ovulation regress promptly to an injection $PGF_{2\alpha}$, only about 60% of the females will have corpora lutea at the time of $PGF_{2\alpha}$ treatment (assuming that spontaneous corpora lutea regression beings about 18 days after ovulation). Therefore, about 95% of the females treated with the FDA approved CIDR/$PGF_{2\alpha}$ protocol are synchronized to exhibit estrus within a few days of CIDR insert removal. However, more than 95% of the treated females will be synchronized to exhibit estrus if estrous behavior is monitored for five days after removal of the CIDR insert.

An advantage of a progestin-based estrous synchronization protocol is that administration of progestins to prepubertal heifers and postpartum anestrous cows have been demonstrated to hasten cyclicity. When suckled beef cows were assigned randomly in replicates to one of three groups (Lucy et al., 2001): 1) untreated controls, 2) a single intramuscular (IM) injection of 25 mg $PGF_{2\alpha}$ ($PGF_{2\alpha}$ alone), or 3) administration of a CIDR insert for 7 d with an IM administration of $PGF_{2\alpha}$ on day 6 of the 7 d CIDR insert administration period (CIDR + $PGF_{2\alpha}$) no differences were detected between the CIDR + $PGF_{2\alpha}$ treatment group and either the $PGF_{2\alpha}$ alone or control groups for first-service CR for either the first 3 d of AI or the entire 31 d of AI. More cows were pregnant after either 3 d or 7 d of AI in the CIDR + $PGF_{2\alpha}$ group than in either the $PGF_{2\alpha}$ alone or the control group. No differences were detected in PR to first services during the 31 d AI period between the CIDR + $PGF_{2\alpha}$ and either the $PGF_{2\alpha}$ alone or the control group. Therefore, insertion of the CIDR increased the synchronization rates within the first 3 d following $PGF_{2\alpha}$, resulting in enhanced pregnancy rates. A drawback of the current protocol is that $PGF_{2\alpha}$ was administered on d 6 after CIDR insertion (a day before CIDR removal). For beef producers this tends to be impractical, because the cows need to be handled a minimum of four times including an AI. Therefore, a more practical modification of this protocol is to inject $PGF_{2\alpha}$ the on the day of CIDR removal.

Advances in Protocols Using the CIDR for Cows

7-day CO-Synch + CIDR Protocol

Inclusion of the CIDR in the CO-Synch procedure appears to be the most researched alternative method for synchronizing beef cows. We (Lamb et al., 2001) published data in which the CIDR was included in the CO-Synch estrous synchronization procedure (Table 1). The CIDR was inserted at the time of the first injection of GnRH and removed at the time of the injection of $PGF_{2\alpha}$. Overall, there was a positive effect of including the CIDR in the CO-Synch protocol; however, this positive effect was not consistent across all locations. Second, the positive effect of including the CIDR was absent in the cows that were cycling and had high progesterone concentrations at the time of $PGF_{2\alpha}$ treatment, which may explain why there was not a positive effect at each location. Along with parity, days postpartum, calf removal, and cow body condition (Table 2) our previous report (Lamb et al., 2001) also indicated that location variables, which could include differences in pasture and diet, breed composition, body condition, postpartum interval, and geographic location, may affect the success of fixed-time AI protocols.

In a later study involving 14 locations in 7 states we (Larson et al., 2006) evaluated both fixed-time AI protocols and detection of estrus protocols with a clean-up AI. These protocols were compared to GnRH/ $PGF_{2\alpha}$ protocols. Although the location accounted for the greatest variation in overall pregnancy rates the Select Synch + CIDR & TAI protocol

(Figure 1) was the protocol that most consistently yielded the greatest pregnancy rates within each location. However, the CO-Synch protocol was an effective Fixed-time AI protocol that yielded pregnancy rates of 54%.

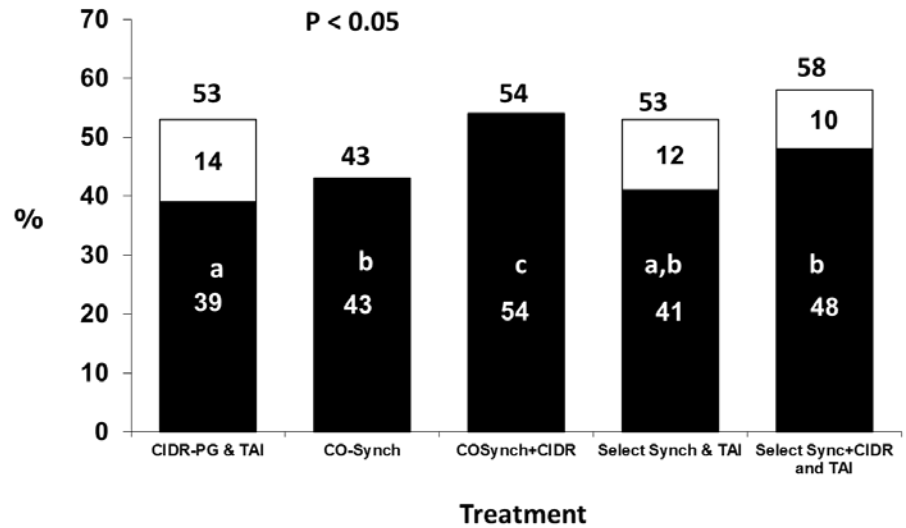


Figure 1. Pregnancy rates of cows treated with two TAI treatments (CO-Synch; CO-Synch + CIDR) and three heat detect and TAI treatments (CIDR-PG & TAI; Select Synch & TAI; Select Synch + CIDR & TAI). Percentages in whit represent the percentage of cows pregnant that failed to express estrus and were inseminated to the TAI .

Calving data during the subsequent calving season was also assessed. Of the 1,752 calvings, 994 calves (56.7%) were the result of AI after estrus synchronization. Average duration of gestation among all AI sired calves was 281.9 ± 5.2 d (× ± SD), and the range was 258 to 296 d. Duration of gestation was similar among treatments, but a location effect was detected, which may have included breed, sire and management differences. Period of gestation was greater for male (282.9 ± 0.2 d) than female calves (280.9 ± 0.2 d), and single calves were carried 3.0 d longer than multiple calves. For those cows from which calving data was recorded, the average interval from the $PGF_{2\alpha}$ injection (Day 0 of the study) to calving among all cows was 297.3 ± 17.7 d (× ± SD) with a range of 258 to 373 d. Although average calving interval was similar among treatments, a location effect was detected.

Table 1. Pregnancy rates in suckled beef cows after treatment with CO-Synch or CO-Synch + CIDR (Lamb et al., 2001)

	Treatment[a]		
Item	CO-Synch	CO-Synch+CIDR	Overall
	---------------- no. (%) ------------------		
Body condition[b]			
≤ 4.5	12/40 (30)	11/36 (31)	23/76[x] (30)
4.5 to 5.5	30/74 (41)	40/80 (50)	70/154[y] (45)
≥ 5.5	19/32 (59)	11/13 (85)	31/45[z] (69)
Days postpartum			
≤ 50	23/60 (38)	27/58 (47)	50/118[x] (42)
51-60	25/62 (47)	36/54 (67)	61/116[y] (53)
61-70	28/49 (62)	25/44 (57)	53/93[y] (57)
71-80	18/41 (44)	30/45 (67)	48/86[y] (56)
> 80	44/75 (59)	42/72 (58)	86/147[y] (59)
Parity[c]			
Multiparous	61/138 (44)	79/132 (60)	140/270 (52)
Primiparous	25/50 (50)	20/45 (44)	45/95 (47)

[a] See recommended protocol sheets for treatment descriptions.
[b] Body condition scores from IL and MN only.
[c] Parity data from KS and MN only.
[xyz]Percentages within an item and column differ ($P < .05$).

At calving, gender was recorded in 1,490 calves, with 770 (52.2%) male calves compared with 704 females. In addition, 15 sets of twins and a single set of triplets were recorded. Gender ratio of calves that conceived to AI at estrus synchronization favored bulls (i.e., 52.7% of 841 calves born were male). Similarly, of the 635 calves that conceived to clean-up bulls, 51.7% were male. No difference was detected in gender ratio for AI compared with natural-sired calves. Multiple birth rate for AI-sired calves [1.1% (9 of 850)] was similar to that of calves sired by clean-up bulls [0.9% (6 of 641)].

5-day CO-Synch + CIDR Protocol

More recently, research has been conducted to determine whether reducing the interval from GnRH to $PGF_{2\alpha}$ from 7 to 5d in a Select-Synch + CIDR or CO-Synch + CIDR estrous synchronization program would result in equal or greater pregnancy rates (Bridges et al., 2008). In Experiment 1, cows were treated with either a 7 or 5d Select-Synch + CIDR program. A second $PGF_{2\alpha}$ treatment was given to all cows in all experiments at 12h after the initial $PGF_{2\alpha}$ (to ensure that luteolysis occurred with the 5d program). Estrous response, interval to estrus, conception rate, and first service AI pregnancy rates were similar between treatments.

In a second experiment cows were treated with either a 7 or 5d CO-Synch + CIDR program, with TAI concomitant with GnRH at 60 h after $PGF_{2\alpha}$. In this study the authors indicated that TAI pregnancy rates were similar between treatments. Further experiments utilized cows that were treated with either a 7 or 5d CO-Synch + CIDR program with timed-AI concurrent with GnRH at either 60 h (7d) or 72 h (5d) after CIDR withdrawal. Pregnancy rates to TAI were 9.1 to 13.3% ($P<0.05$) greater for the 5 than 7d program. The authors concluded that pregnancy rates were improved with a 5d CO-Synch + CIDR program with timed-AI at 72 h after CIDR withdrawal, compared to a 7d CO-Synch + CIDR program with timed-AI at 60 h after CIDR withdrawal. Therefore, 5d CO-Synch + CIDR protocol may be a suitable alternative for TAI for producers willing to handle cows a second time on the day the CIDRs are removed.

In another study when cows in 7 d CO-Synch + CIDR protocol were inseminated at 66 h after a single injection of PG compared to cows receiving the 5 d CO-Synch + CIDR protocol no improvements were noted (Wilson et al., 2009). We observed that when the interval between GnRH and PG was 7 d a proportion of cows ovulated follicles of smaller than normal diameter, which resulted in decreased fertility (Lamb et al., 2001). These females may have had lower preovulatory concentrations of estradiol (Perry et al., 2005). Perhaps the smaller follicles at the time of synchronized ovulation resulted from spontaneous atresia of follicles and initiation of a new follicular wave closer to the PG injection in cows that did not respond to the initial GnRH. Therefore, a reduction in the interval from 7 to 5 d would be expected to reduce the likelihood that this pattern of follicular growth would occur and result in greater estradiol concentrations during proestrus (Bridges et al., 2009). However, an increase in the interval from PG to TAI from 60 to 66 h in the 7 d CO-Synch + CIDR protocol may also enhance estradiol concentrations and improve fertility (Busch et al., 2008).

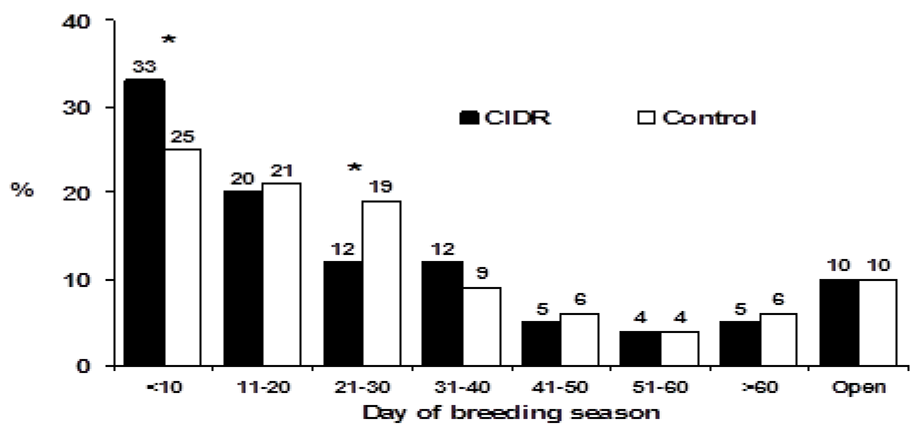
Although improvement in FTAI pregnancy rates with the 5-d CO-Synch + CIDR approach was beneficial, the current recommendation of 2 doses of $PGF_{2\alpha}$ given 8 h apart increases animal handlings and may limit the adoption of this protocol. Therefore, we (Bridges et al., 2012) determined if 2 doses of $PGF_{2\alpha}$ administered concurrently at CIDR removal was an efficacious method for delivery of $PGF_{2\alpha}$ in the 5-d CO-Synch + CIDR protocol. Postpartum beef cows (n = 2,465) from 13 herds in 8 states were enrolled in the 5-d CO-Synch + CIDR protocol and assigned to receive either 2 doses of $PGF_{2\alpha}$ (25 mg/dose) 8 h apart with the initial injection given at CIDR removal (8h- $PGF_{2\alpha}$): 2 doses (25 mg/dose) of $PGF_{2\alpha}$ delivered in 2 injection sites, both administered at CIDR removal (Co- $PGF_{2\alpha}$): or a single 25-mg dose of $PGF_{2\alpha}$ at CIDR removal (1x- $PGF_{2\alpha}$). Fixed timed-AI pregnancy rates were greater for the 8h- $PGF_{2\alpha}$ (55%) than the 1x- $PGF_{2\alpha}$ (48%) treatment, with the Co- $PGF_{2\alpha}$ (51%) treatment intermediate and not different from the other treatments. Therefore, the Beef Reproduction Task Force continues to recommend that 2 doses of $PGF_{2\alpha}$ be administered 8 h apart, with the first dose occurring at CIDR removal.

Utilization of the CIDR for bull breeding

To many producers artificial insemination is too technical or time consuming, yet many producers feel that with the development of fixed-time AI (TAI) protocols AI might be a technology that can be utilized to generate a greater proportion of genetically superior beef cattle. The primary reason US beef producers cite for the lack of widespread AI use to breed heifers and cows is limited time and labor (NAHMS, 1998). However, the step from using natural service without estrous synchronization to using TAI is a large jump that few producers are willing to take. Therefore, there is reason to believe that estrous synchronization for bull breeding herds is a suitable step towards altering the calving season, decreasing the breeding season length, and initiating noncycling cows to start cycling. Estrous synchronization in bull breeding herds has the potential to impact a greater number of producers, because greater than 90% of producers do not utilize AI in their current management systems. In fact, only 8.1% of beef cattle operations in the U.S. use AI management procedures regularly on replacement beef heifers or postpartum beef cows to improve reproductive management of their herds and ultimately improve profitability (NAHMS, 1997).

When estrous was synchronized for bull breeding with a single injection of PG administered at initiation of the breeding season the percentage of females detected in estrus and pregnancy rates were greater than than saline treated controls (Whittier et al., 1991). In addition, when heifers were estrous synchronized with melengestrol acetate and PGF2a and exposed to bulls, the desirable bull:heifer ratio was 1:25 or less (Healy et al., 1993). Under this premise, we (Dahlen et al., 2006) designed a study to determine whether insertion of a CIDR for 7 d prior to the breeding season and removing the CIDR on the day bulls were introduced to the cowherd would alter the overall pregnancy rates, average days to conception, and the subsequent calving distribution.

Overall pregnancy rates ranged from 59.3 to 98.9% among the 13 locations. Pregnancy rates within the first 30 days of the breeding season were similar between CIDR (64.4%) and Control (64.7%), and overall pregnancy rates were similar between CIDR (89.7%) and Control (89.6%). The average day of conception after initiation of the breeding season was shorter ($P < 0.05$) for CIDR (20.1 ± 0.8 d) compared to Control cows (23.2 ± 0.8 d). Of cows conceiving during the breeding season, more ($P < 0.05$) CIDR cows (43%) conceived during the first ten days of the breeding season than Control cows (35%; Figure 2). Therefore, insertion of a CIDR prior to the breeding season failed to increase overall pregnancy rates, but did influence the average day of conception in earlier calving cows.



* Treatments differ within period ($P < 0.05$)

Figure 2. Proportion of cows conceiving at various intervals of the breeding season for cows in Control or CIDR treatments.

Hormonal interventions after TAI

Progesterone is important for embryonic survival, growth, and pregnancy recognition. Increased concentrations of progesterone have been associated with increased conceptus growth rates. Aims of post-TAI interventions are to increase concentrations of progesterone either through inducing accessory luteal tissue, enhancing function of the original CL, and(or) supplementing with additional progesterone. Interferon-tau (INF_τ) is the factor responsible for maternal recognition of pregnancy in cattle and is secreted by the trophoblast of the growing conceptus. Cows having reduced concentrations of progesterone during the early luteal phase had little embryo elongation and embryos produced little or no INF_τ than cows with greater concentrations of progesterone (Mann et al., 1999).

Resynchronization with a CIDR increased synchronized return rates of nonpregnant females (Stevenson et al., 2003), thereby increasing the number of animals that conceive to AI while maintaining efficient use of labor. We demonstrated that supplementation of progesterone via a CIDR insert to postpartum suckled beef cows anytime from d 5 to 21 after TAI failed to enhance fertility (Larson et al., 2009; Table 2). In addition, although resynchronization of estrus in nonpregnant cows treated with a CIDR enhanced synchrony of estrus and increased the proportion of cows detected in estrus, it also had a negative impact on subsequent conception rates. Therefore, supplementation of progesterone had positive effects on fertility in dairy cows, but seems to have little beneficial effect on enhancing pregnancy rates in beef cattle.

Table 2. Fertility rates and estrous response to cows resyncronized with a CIDR after an initial fixed-time AI (Larson et al., 2009).

	Treatments			
Item	Control	CIDR5-14	CIDR14-21	CIDR5-21
1st service pregnancy rates, no./no. (%)[a]	131/237 (55)	125/234 (53)	112/232 (48)	124/234 (53)
2nd service pregnancy rates, no./no. (%)[b]	158/237 (67)	158/234 (68)	154/231 (67)	161/233 (69)
Non-pregnant cows exhibiting estrus, no./no. (%)[c]	44/106 (42)[w]	39/109 (36)[w]	77/120 (64)[x]	76/110 (69)[x]
Conception rates, no./no. (%)[d]	29/44 (66)[yz]	28/39 (72)[y]	41/77 (53)[z]	41/76 (54)[z]
Pregnancy loss[e]:	9/130 (7)	6/126 (5)	6/111 (5)	6/124 (5)

[a] Cows were assigned to treatments according to Figure 1.
[b] Timed AI = fixed-time AI; pregnancy rates were determined on d 30.
[c] Percentage of nonpregnant females returning to estrus d 21 to 26 after TAI.
[d] Percentage of cows pregnant after AI for cows returning to estrus.
[e] Pregnancy loss of TAI pregnancies between d 30 and 60.
[wx] Means within a row differ ($P < 0.05$).
[yz] Means within a row differ ($P < 0.10$).

The ability of hCG to induce accessory CL and increase concentrations of progesterone when administered as a post-AI intervention has been demonstrated. Increased concentrations of progesterone after hCG also were observed in anestrous beef cows, and beef heifers (Dahlen et al., 2011ab; Marquezini et al., 2011). In beef cows, concentrations of progesterone after TAI were increased in pregnant cows after treatment with hCG and treatment with hCG tended to increase pregnancy rates (Dahlen et al., 2010). Pregnant cows had greater concentrations of progesterone on d 7 after TAI than cows that were not pregnant (Dahlen et al., 2011a). Further, treatment with hCG increased volume of luteal tissue on d 14 and concentrations of progesterone on d 14 and 33 after TAI and treatment with hCG tended to increase pregnancy rates at 5 of 6 locations from 1.1 to 27 percentage points (average = 10.2) compared with saline treatment (Dahlen et al., 2010). Taken together, because of its ability to induce multiple CL and consistently increase concentrations of progesterone, hCG may increase pregnancy rates when administered to beef females 7 d after insemination. Because hCG-treated heifers having an accessory CL had greater pregnancy rates than those without an accessory CL, success of a protocol may depend on efficacy of hCG inducing an accessory CL rather than its effect on the original CL

Economics of Estrus Synchronization

Recently we performed an experiment us partial budget analysis was to determine the economic outcome of estrus synchronization and TAI in commercial cow/calf production (Rodgers et al., 2012). Suckled beef cows (n = 1,197) from 8 locations were assigned randomly within each location to 1 of 2 treatment groups: 1) cows were inseminated artificially after synchronization of ovulation using the 7-day CO-Synch + CIDR protocol (TAI; n = 582); and 2) cows were exposed to natural service (NS) without estrous synchronization (Control; n = 615). Within each herd, cows from both treatments were maintained together in similar pastures and were exposed to bulls 12 h after the last cow in the TAI treatment was inseminated. Overall, the percentage of cows exposed to treatments that subsequently weaned a calf was greater for TAI (84%) than Control (78%) cows. In addition, survival analysis demonstrated that cumulative calving distribution differed between the TAI and Control treatments (Figure 3). Weaning weights per cow exposed to treatments were greater for cows in the TAI treatment (425 lb) than those cows in the Control treatment (387 lb). Overall, increased returns plus decreased costs ($82.32), minus decreased returns plus increased costs ($33.18) resulted in a $49.14 advantage per exposed cow in the TAI treatment compared to the Control treatment (Table 3). Location greatly influenced weaned calf weights, which may have been a result of differing management, nutrition, genetic selection, production goals, and environment. We concluded that estrus synchronization and TAI had a positive economic impact on subsequent weaning weights of exposed cows.

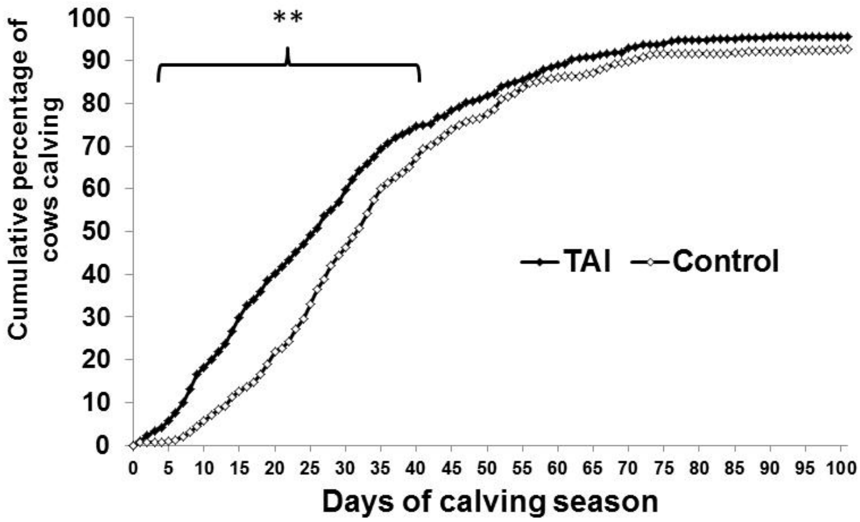


Figure 3. Survival analysis of the percentage of cows calving by day during the calving season. ** Cumulative calving percentage differs ($P < 0.05$) between TAI and Control treatments.

In the process of developing the model in the study above, utilizing a partial budget analysis, we developed a model that may be useful to beef producers to incorporate their own costs and determine the value of estrous synchronization in their own operations. This model has been converted into a smartphone application for Android and iPhone/iPad users and is called the **'AI Cowculator'** (Figure 4). The AI Cowculator may be downloaded free of charge and is a decision aid tool to assist producers to determine whether they should consider TAI rather than purchasing herd sires for their cow herds. We encourage producers and members of the allied industry to download the AI Cowculator and utilize this tool to assist in making bull buying and breeding season decisions.

Figure 4. The front page of the AI Cowculator App

Table 3. Partial budget analysis for cows exposed to estrous synchronization followed by natural service compared to cows exposed only to natural service (expressed in US dollars; Rodgers et al., 2012)[1]

Item	Increased returns[2]	Decreased costs[3]	Decreased returns[4]	Increased costs[5,6]	Gain or loss	Net additional costs[7]	Additional weight, kg[8]	Breakeven price[9]
Herd sensitivity analysis:								
1	45.71	42.81	0	33.18	55.34	-9.63		
2	31.19	21.41	0	33.18	19.42	11.77	4.43	67.26
3	56.74	48.93	0	33.18	72.49	-15.75		
4	123.15	48.93	0	33.18	138.90	-15.75		
5	-10.49	37.46	0	33.18	-6.21	-4.28		
6	44.64	24.79	0	33.18	36.25	8.39	3.15	47.94
7	30.65	32.74	0	33.18	30.21	0.44	0.17	2.51
8	55.12	24.79	0	33.18	46.73	8.39	3.15	47.94
Overall[10]	47.09	35.23	0	33.18	49.14	-2.05		

[1]All returns and costs based on a weaning weight of exposed cows.
[2]Additional weight attributed to estrous synchronization (ES) and fixed-time artificial insemination (TAI) per weaning weight of exposed cows × selling price ($121.00/45.5 kg).
[3]Annual NS bull costs: annual operating costs: grazing and supplemental feed ($365.00), veterinary medicine ($40.00), annual ownership costs: depreciation ($557.00), interest cost ($151.00), death loss ($33.00): purchase price ($3270.00).
[4]Decreased returns attributed to fewer NS bulls to be culled are included as a negative value in the decreased costs calculation.
[5]Labor hours (0.41 h) per ES/TAI cow at $10.00 per hour.
[6] Supplies: Prostaglandin = $2.07/dose, CIDR = $8.76, GnRH = $2.00/dose × 2 doses, Miscellaneous. $0.25, Semen $14.00/unit.
[7]Net additional costs as increased costs minus decreased costs.
[8]Additional weight per exposed cow to cover net additional costs at $121 per 45.5 kg (only in situations where additional costs were noted).
[9]Overall breakeven prices ($ per 45.5 kg) to cover additional costs with additional 17.5 kg pounds weaned per cow exposed to treatment.
[10]Calculated using a bull to cow ratio of 1:17.

Summary

To achieve optimal pregnancy rates with estrous synchronization, cows should be in good body condition (BCS ≥5) and treatments should be initiated only when cows are at least 50 days postpartum. Treatment of suckled cows with a CIDR and GnRH will yield industry accepted pregnancy rates. Results of the most recent CIDR based studies indicate that for a TAI protocol the 5 or 7 day CO-Synch + CIDR protocols yield the most impressive pregnancy rates for a TAI protocol, whereas the Select Synch + CIDR & TAI treatment yields the best overall pregnancy rates. In addition, cows can be resynchronized successfully with a CIDR, but caution should be taken to ensure that the CIDR is removed before day 20 after TAI to ensure conception rates are acceptable.

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