Reproduction for Florida Cattle

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Introduction

The ultimate goal for cow/calf producers is to obtain one live calf from each cow, every year. Unfortunately most beef cattle operations fail to achieve an annual 100% calving rate. For a producer to ensure that each cow calves on a yearly basis, cows are required to conceive within 83 days after calving. Many beef cattle have not even resumed their estrous cycles by this point, especially cows that have given birth to their first calf! Several factors contribute to delaying the onset of estrous cycles in postpartum cows; however, nutrition and suckling are the two critical factors that tend to dictate when cows begin to cycle. Because most beef cows are suckled within the first few months after calving, nutrition becomes the major component that can be managed to enhance productivity of beef cows. Yet, we must keep in mind that the goal of sound nutritional management, in a beef production setting, is to satisfy the cow's reproductive needs.

Beef producers in Florida need cows to become pregnant, deliver healthy calves, and wean productive calves to make their operations viable. The failure of breeding females to become pregnant directly impacts the economic viability of every beef operation, yet few producers realize how reproductive management impacts their individual operations. Infertile beef cows and heifers can fall into three primary groups: 1) cows that fail to become pregnant during the breeding season (usually 60 to 120 days); 2) cows that become pregnant but fail to calve; and 3) cows that become pregnant late in the breeding season. Infertility that leads to the failure of a cow or heifer to calve during the subsequent calving season results in the single largest economic loss to beef producers, because no economic return will be realized from those cows for at least one additional year (unless producers have multiple breeding seasons or a split breeding season). Cows that fail to become pregnant during the breeding season do not give producers an opportunity to market a calf, becoming an economic liability to producers.

Cost of Infertility to Florida Cattlemen

Beef females fail to become pregnant for numerous reasons, such as anestrous / prepuberty (cows and heifers that do not start their estrous cycles during the breeding season), disease, or sub-optimal management. In addition, cows may also become pregnant but fail to calve because they lose their pregnancy at some stage of gestation due to a disease or trauma event. Either way, the economic impacts of cows failing to calve is profound. Approximately 34.5% of all US beef producers utilize pregnancy detection as a management method to determine whether cows are pregnant and use the tool to make culling decisions. Pregnancy detection usually occurs about 30 to 90 days after the end of the breeding season. In the Southeast United States (including Florida) only 19.4% of producers use this tool for making culling decisions. Pregnancy diagnosis affords producers an opportunity to cull cows that are not pregnant. However, in an effort to maintain a steady population of brood cows, removing these cows from the herd may reduce a producer's flexibility to cull other cows that may fail to produce thrifty calves, or that should otherwise be culled for more legitimate production characteristics such as poor genetics, temperament, structural concerns, and poor health. Previous reports (Bellows et al., 2002) indicate that approximately 4.5% of the cow herd is culled annually because they fail to become pregnant!

For the 65.5% (or 81.6% in the Southeast United States) of beef producers who fail to use pregnancy diagnosis in their operations, the first opportunity that they have to determine which cows are not pregnant is after the subsequent calving season. At that point, producers may decide to either retain the cows that failed to calve, or cull those cows prior to the next breeding season. Either way, there is a significant cost to the producer for maintaining those cows for a full year without producing a calf. With no calf sale, costs of supplemented feed, pasture, and other expenses directly decrease the lifetime profitability of open cows. Often overlooked or neglected facets of infertility are the cows that become pregnant but fail to calve or calve later in the calving season. When cows are diagnosed as pregnant, but fail to calve or calve late in the calving season, they have a negative impact on the return a producer may realize from the sale of calves. For instance, infertility during the early stages of the breeding season that resolves with time can manifest itself in the form of reduced calf weight. As an example, calves gain between 1.5 and 2 lbs per day while suckling their dam. A calf conceived on the first day of the calving season has the opportunity to gain 90 to 120 more lbs than a calf born 60 days into the breeding season. Reducing infertility will ensure that more females calve towards the beginning of the calving season.

Producers can calculate the impact of infertility on their own operations, by simply calculating the revenue generated by exposed cow in the herd. Using recent data (CattleFax, 2008) the following example demonstrates the cost of infertility on a typical Florida operation. Example: Calf price for 500 weight feeder calves is $1.00/lb; percentage of pregnant cows is 85%; and, weaning weights average 500 lbs. Therefore, the following calculation may be used (assuming that there is little or no difference in the maintenance costs of a pregnant or nonpregnant cow):

1) Value of weaned calf per exposed cow if 100% cows are pregnant =
   500 lbs x 100% x $1.00/lb = **$500 per cow**
2) Value of weaned calf per exposed cow when 85% cows are pregnant =
   500 lbs x 85% x $1.00/lb = **$425 per cow**
3) Loss due to failure to become pregnant during the breeding season =
   $500 - $425 = $75

Thus, this case demonstrates that infertility costs the producer $75 per exposed cow (or $5 per exposed cow for every 1% decrease in pregnancy rate). In addition, there are additional costs associated with calf mortality after calving and late calving cows that also decrease the overall revenue per exposed cow. Obviously producers cannot overcome all infertility, but understanding the costs associated with infertility may ensure that changes occur to enhance the factors responsible for improving fertility and reduce the negative influences on fertility. Management related factors are: 1) nutritional management to ensure that postpartum anestrus or prepuberty can be overcome; 2) selection of fertile animals among breeds and within breeds; 3) use of crossbreeding for hybrid vigor; 4) selection and handling of animals in ways that reduce stress; 5) use of reproductive management tools such as estrous synchronization and artificial insemination to alter the calving distribution; 6) following a stringent vaccination program to reduce the incidence of disease; 7) use of bulls that have passed a breeding soundness exam and are capable of breeding all of the cows in a pasture or herd. Environmental factors are: 1) heat stress that reduces conception and pregnancy rates; 2) overly extensive beef operations that limit the implementation of sound management procedures; and, 3) excessive rain and mud that reduce fertility.

Perhaps with small changes to beef cattle operations Florida producers can reduce the overall losses to the Florida beef industry and the national beef industry. When extrapolated from the data reported by the National Animal Health Monitoring Service (NAHMS 1997) and inventories accessed using the National Agricultural Statistics Service (NASS) the cost of infertility to the 950 thousand cows owned by Florida beef producers exceeds $71 million. In addition, the cost of infertility to the entire United States producers with a cow population of 42.5 million cows likely reduces revenue in excess of $1.06 billion.

Effects of Postpartum Anestrus on Fertility

The factor that most limits the conception of suckled beef cows to AI and synchronization is the proportion of cows that are not cycling (Short et al., 1990). Continual presence of a suckling calf prolongs and delays the reinitiation of estrous cycles (Williams, 1990). Insufficient nutrient intake and poor body condition are also limiting factors, but temporary or permanent calf removal usually initiates estrus within a few days (Williams, 1990). Young cows generally are more prone to have prolonged anestrus because of their additional growth requirements (Short and Adams, 1988, Short et al., 1990). The first priority is maintenance of essential body functions to preserve life. Once maintenance is met, remaining nutrients accommodate growth. Finally, lactation and the initiation of estrous cycles are supported. Older cows have no growth requirement, thus nutrients are more likely to be available for milk production and initiation of estrous cycles. Because of this priority system, young, growing cows generally produce less milk and are anestrus longer after calving. When the incidence of cyclicity was determined in 3,269 cows at the beginning of the breeding season, the major limiting factors that were found to affect the rate of cyclicity at the beginning of the breeding season included the age of the cow, body condition, and days postpartum (Stevenson et al., 2003).

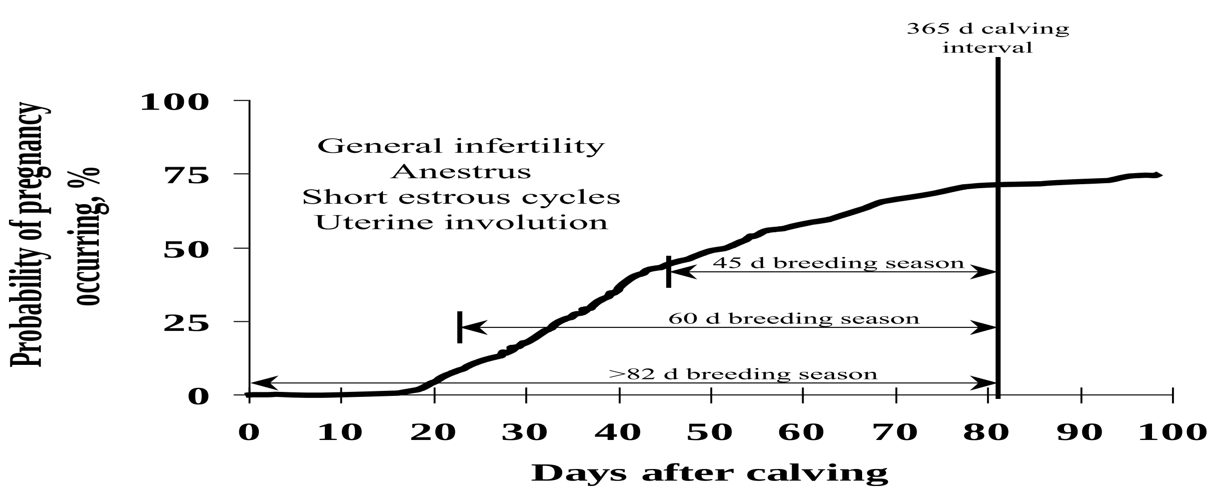
Generally, beef cows do not experience a period of negative energy balance because they fail to produce the quantity of milk that dairy cows produce; however, beef cows need to be in good enough condition to resume estrous cycles after parturition and overcome general infertility, anestrus, short estrous cycles, and uterine involution just to maintain a yearly calving interval. For producers with shorter calving intervals with cows in good condition, the probability of a pregnancy is generally very good. But in herds that utilize calving seasons of greater than 60 days, maintaining a 365 day calving interval becomes increasingly more difficult (Figure 1; Short et al., 1990)

Nutritional Management Considerations

Body condition score as an indicator of reproductive efficiency.

Body condition scoring (BCS) is a reliable method to assess the nutritional status of recipients. A visual body condition scoring system developed for beef cattle uses a scale from 1 to 9, with 1 representing emaciated and 9 obese cattle (Whitman, 1975). A linear relationship exists between body weight change and body condition score, where an approximate 88 lb weight change is associated with each unit change in BCS (using the 1 to 9 scale). Managers of breeding age females should understand when cows can be maintained on a decreasing plane of nutrition, when they should be maintained on an increasing plane of nutrition, or when they can be kept on a maintenance diet. Understanding the production cycle of the cow and how to manipulate the diet will improve the ability of the females to conceive to AI (Mapletoft et al., 1986; Beal, 1999; Lamb et al., 2001; Larson et al., 2006).

Figure 1. Relationship of length of breeding season to fertility during the postpartum period (Short et al., 1990)



Body condition score at calving has been shown to be a more predictable indicator of the duration of postpartum anestrus than prepartum change in either weight or BCS (Whitman, 1975; Lalman et al., 1997). When cows were thin at calving or had a BCS of 4 or less, increased postpartum level of energy increased the percentage of females exhibiting estrus during the breeding season. Body condition score at parturition and breeding are the dominant factors influencing pregnancy success, although body weight changes during late gestation modulate this effect. However, altering poor body condition after parturition may reduce the negative impact on reproduction, but seldom overcomes or eliminates those negative effects. A recent study (Stevenson et al., 2003b), using blood samples at initiation of the breeding season to determine estrous cycling status, demonstrated that only 47.2 % of the cows were cycling at the onset of the breeding season. However, as BCS increased, the percentage of cows that were cycling also increased. It is important to note that when cows had a body condition of less than 4 at the beginning of the breeding season, only 33.9% had resumed their estrous cycles.

Prepartum nutritional effects on reproduction.

The general belief is that cows maintained on an increasing plane of nutrition prior to parturition usually have a shorter interval to their first ovulation than cows on a decreasing plane of nutrition. Energy restriction during the prepartum period results in a low BCS at calving, prolonged postpartum anestrus, and a decrease in the percentage of cows exhibiting estrus during the breeding season (Perry et al., 1991). Pregnancy rates and intervals from parturition to pregnancy also are affected by level of prepartum energy (Perry et al., 1991). Conversely, when prepartum nutrient restriction was followed by increased postpartum nutrient intake, the negative effect of prepartum nutrient restriction was partially overcome; however, the effectiveness of elevated postpartum nutrient intake depended on the severity of prepartum nutrient restriction (Perry et al., 1991; Lalman et al., 1997). The effect of BCS prior to calving also has implications for calf birth and weaning weights. When cows were fed to achieve a BCS of either 4 or 6 prior to calving, body weights were greater and calf birth and weaning weights (with similar genetics) also were greater for those cows in a BCS of 6 (Spitzer et al., 1995). Despite the greater birth weights, there was no difference in calving difficulty, demonstrating the added advantage for well conditioned cows to wean calves with greater weaning weights. In addition, there tended to be an increased number of cows calving with a medium BCS that were cycling at the beginning of breeding season and after a 60-day breeding season than cows in poor condition, resulting in a greater proportion of cycling cows at various stages of the breeding season (Spitzer et al., 1995).

Postpartum nutrition.

Numerous studies document that increasing nutritional levels following parturition increase conception and pregnancy rates in beef cows (Wiltbank et al., 1962; Whitman, 1975). Increasing the postpartum dietary energy density increased body weight and BCS and decreased the interval to first estrus (Lalman et al., 1997). However, suckled beef cows in relatively poor BCS gaining in excess of 2.2 lb/d while consuming an 85% concentrate diet did not resume cyclic ovarian activity before 70 d postpartum (Lalman et al., 1997). Therefore, although an enhanced plane of nutrition after calving may partially overcome the negative effects of poor prepartum nutrition, the added stress and negative impact of suckling and lactation also must be considered.

A major impact on postpartum fertility is the length of the breeding season. Having a restricted breeding season has many advantages, such as a more uniform and older calf crop, but most importantly a breeding season of 60 d or less increases the percentage of females cycling during the next breeding season. If the breeding season is shortened, then all cows have a higher probability for pregnancy during the next breeding season. Strategic feeding to obtain ideal BCS can be achieved by understanding the production cycle of the cow. The period of greatest nutritional need occurs shortly after calving; a cow is required to produce milk for a growing calf, regain weight lost shortly before and after parturition, and repair her reproductive tract to become pregnant within 3 month after calving. During this stage, a cow usually is consuming as much feed as she can and adjusting BCS at this time often is futile. Cows usually are grazing and tend to consume their full protein, vitamin and mineral requirements; however, the grass is often lush with a high percentage of moisture which occasionally can cause a deficiency in energy (NRC, 1996).

Considerations for the First-Calf Heifer

For cattle producers, heifers that have just given birth to their first calf (first-calf heifers) are the toughest group of females to manage. Giving birth for the first time is a shocking experience for a heifer, but stress associated with the first birth also is confounded with numerous other management related issues. After birth, the first-calf heifer is required to nurse a young calf, her reproductive tract needs to undergo repair (uterine involution) to prepare for the next pregnancy, and she is required to maintain her own condition in order to become pregnant during the subsequent breeding season. All of these factors are new to a heifer and she is required to do this at a time when she is introduced to the mature cow herd. In other words, a heifer that has just given birth needs to compete with older, more aggressive cows for feed and yet continue to grow to a mature weight and become pregnant to calve during the following calving season.

In most herds, 15 to 20% of the cow herd is replaced annually by replacement females. These replacement females represent the future genetics of the operation and could dictate the ultimate profitability of the operation. Sound selection for females that will produce offspring on a yearly basis, nurture their offspring until weaning with a minimum of disease or sickness, and wean their offspring with acceptable weaning weights is paramount to a successful operation.

Replacement, virgin beef heifers require little input from a producer. After weaning, heifers selected as replacements usually are forgotten or neglected until shortly before the breeding season. However, the management decisions on how we treat our replacement heifers, usually affects their performance for a period of time following the birth of their first calf. In fact, when one considers that a replacement heifer remains in the herd for almost three years before she makes a financial contribution to the producer, it is imperative that we pay close attention to our genetic selection and management of our future “bread winners”.

The nutrition/reproduction interaction involves several intricate relationships. From a nutrition standpoint, energy, protein, minerals and vitamins all affect reproduction through various avenues. The hypothalamus, pituitary, and/or the ovaries can be affected by a nutritional deficiency. As beef producers, we must understand the nutrition/reproduction axis to fully appreciate how our cows respond to nutritional management and produce a live, healthy calf on a yearly basis.

Why, then, are first-calf heifers a nemesis to our beef cattle operations? Firstly, these young cows need additional nutrients, because even though they are cows, they are still growing themselves; therefore, not only do they need nutrients for their calves, but they need nutrients for further growth. Secondly, from a physiological standpoint, these cows have never experienced a birth. They generally have smaller pelvic areas than mature cows, which increases the incidence of dystocia; they have to struggle with the stress of calving for the first time; they are required to raise a calf; and, they must reinitiate estrous cycles to become pregnant during the subsequent breeding season. Even in an ideal setting, we require these young cows to perform at unrealistic levels. Nonetheless, with a little foresight we can set the stage to allow these cows to have an opportunity to become productive mature cows.

Control of the Estrous Cycle by Synchronization

Overview of Estrous Synchronization Protocols.

Gonadotropin-releasing hormone (GnRH) is widely used as an integral component of estrous and ovulation synchronization programs for both beef and dairy cattle. Combinations of GnRH, Prostaglandin ($PGF_{2\alpha}$), and two progestins (Melengesterol acetate; MGA, and a controlled internal drug releasing insert; CIDR) comprise the majority of estrous and ovulation synchronization protocols in the United States.

Briefly, GnRH ovulates a dominant follicle via LH release which results in subsequent CL formation and follicular wave emergence (via FSH; Twagiramungu, 1995). Prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) is used to lyse a CL, either spontaneously formed (Lauderdale et al., 1974) or induced via GnRH administration (Smith et al., 1987). Upon lysis of the CL estrus ensues as follicular maturity dictates, usually occurring within 4 d (Lamb et al., 2004; Larson et al., 2006). Progestins may prevent the occurrence of estrus and premature ovulation (Larson et al., 2006), and initiate cyclicity in a portion of prepubertal heifers and post-partum anestrous cows (Lucy et al., 2001). Figure 1 and Figure 2 demonstrate estrous synchronization protocols mentioned in subsequent sections for beef cows and beef heifers, respectively.

Advances in protocols for beef cows.

Preliminary studies identified significant improvements in fertility among cows that received MGA prior to the administration of $PGF_{2\alpha}$ compared with cows that received only $PGF_{2\alpha}$ (Patterson et al., 1995). When cows received a CIDR for 7 days and an injection of $PGF_{2\alpha}$ the day before CIDR removal, estrus synchrony and pregnancy rates were improved (Lucy et al., 1991). When GnRH was given 6 or 7 days prior to $PGF_{2\alpha}$, 70 to 83% of cows were in estrus within a 4 day period (Twagiramungu et al., 1995).

The use of GnRH to control follicular wave emergence and ovulation and $PGF_{2\alpha}$ to induce luteolysis led to the development of the Ovsynch protocol for dairy cows (Pursley et al., 1995). Combining the second injection of GnRH with timed artificial insemination (TAI) (CO-synch) proved to be more practical than estrus detection for beef producers because it had no negative effects on fertility (Geary et al., 2001). However, a disadvantage of this protocol is that approximately 5 to 15% of suckled beef cows exhibit estrus prior to, or immediately after the $PGF_{2\alpha}$ treatment (Lamb et al., 2001). Unless these cows are detected in estrus and inseminated, they will fail to become pregnant to TAI. Therefore, we hypothesized that the addition of a CIDR to a GnRH-based protocol would prevent the premature occurrence of estrus and result in enhanced fertility following TAI. Overall pregnancy rates were enhanced by the addition of a CIDR to a GnRH-based TAI protocol (59 vs. 48%, respectively). The CIDR delayed the onset of ovulation, resulting in more synchronous ovulation, and induced cyclicity in noncycling cows (Lamb et al., 2001). However, the efficacy of these CIDR-based TAI protocols had not been evaluated concurrently with AI protocols requiring detection of estrus in suckled beef cows. Therefore, we implemented and coordinated a multi-state, multi-location experiment to discern whether a GnRH-based + CIDR protocol for TAI could yield pregnancy rates similar to protocols requiring detection of estrus (Larson et al., 2006). Results demonstrated that the TAI protocol yielded pregnancy rates that were similar to the estrus detection protocol, even though 35% of the cows were in postpartum anestrous at the time of treatment. Utilizing a similar protocol on recipients using FTET would be practical and effective in yielding high pregnancy rates in recipients (Beal, 1999). For best results producers should consider utilizing protocols recommended by the Beef Reproduction Task Force. These protocols can be found in AI manuals and through the Beef Reproduction Task Force Group (http://westcentral.unl.edu/beefrepro/)

Advances in protocols for beef heifers.

Early studies in beef heifers demonstrated that feeding MGA for 14 days followed by $PGF_{2\alpha}$ 17 days later was an effective method of estrous cycle control in heifers (Brown et al., 1988; Patterson et al., 1989). However, when heifers were treated with $PGF_{2\alpha}$ 19 days after the 14 day MGA feeding period, there was no difference in fertility but estrus was more synchronous (Lamb et al., 2000). Following the success of this protocol, researchers began to include GnRH in estrus synchronization protocols for TAI. However, addition of GnRH to the the above protocol failed to increase pregnancy rates following TAI in heifers (Wood-Follis et al., 2004). Estrus synchronization using GnRH followed by $PGF_{2\alpha}$ successfully synchronized heifers, but the above MGA- $PGF_{2\alpha}$ protocol led to greater synchrony of estrus and, therefore, tended to be more effective (Lamb etal., 004).

Development of a TAI protocol in beefs heifers has not been as straightforward as in cows, especially considering that at the time of estrus synchronization, a majority (greater than 85%) of heifers have attained puberty (Lamb et al., 2006). The primary reason for failure of TAI in heifers appears to be the inability to synchronize follicular waves with GnRH. After an injection of GnRH at random stages of the estrous cycle, 75 to 90% of postpartum beef cows ovulated (Thompson et al., 1999; El-Zarkouny et al., 2000), whereas only 48 to 60% of beef and dairy heifers ovulated in response to the same treatment (Macmillan and Thatcher, 1991; Pursley et al., 1995; Moreira et al., 2000). We have found no difference in synchrony of estrus or pregnancy rate in CIDR-treated heifers whether or not GnRH is administered at CIDR insertion, suggesting that response to GnRH in heifers at CIDR insertion may be of limited value (Lamb et al., 2004).

In a large, multi-location (12 locations) study using GnRH, PGF$_{2\alpha}$, and CIDR; GnRH did not enhance pregnancy rates following estrus detection but the addition of a CIDR to a GnRH-based TAI protocol yielded similar pregnancy rates to those utilizing estrus detection (Lamb et al., 2006). Nevertheless, a bewildering fact remains that the average pregnancy rate for these protocols ranged from 53 and 58 %, whereas pregnancy rates in MGA (with PGF$_{2\alpha}$ administered 19 days after MGA removal) or a long-term CIDR (with PGF$_{2\alpha}$ administered 16 days after MGA removal) protocols followed by PGF$_{2\alpha}$ have been reported to range from 60 and 75 % (Lamb et al., 2000, 2004; Dahlen et al., 2003; Patterson et al., 2003; Kojima et al., 2004; Wood-Follis et al., 2004). Further research is required to understand methods of estrous cycle control in heifers to develop estrus synchronization protocols for TAI.

Conclusion

For a reproductive management system in Florida to be effective, numerous factors need to be put in place to ensure success. Nutrition, estrous cycle control, and female management are all responsible for the success or failure in a given program. Producers, veterinarians, extension personnel, and all members of the reproductive management team need to be aware of the short- and long-term factors that contribute to females conceiving to either AI or a bull, maintaining the embryo/fetus to term, delivering the calf without assistance, raising and weaning a healthy calf.

References

Beal WB. Streamlining embryo transfer. 18th Annual Convention AETA, Colorado Springs, CO, USA; 78-85, 1999.

Bellows DS, Ott, SL and Bellows RA. 2002. Cost of reproductive disease and conditions in cattle. Prof Anim Sci. 18:26-32.

Brown LN, Odde KG, LeFever DG, King ME, Neubauer CJ. Comparison of MGA-PGF2□ to Syncro-Mate B for estrous synchronization in beef heifers. Theriogenology 30:1-12, 1988.

CattleFax. Unprecedented times. 2008. CattleFax update Issue 25:June 20, 2008:p3.

Dahlen CR, Lamb GC, Zehnder CM, Miller LR, DiCostanzo A. Fixed-time insemination in peripuberal, light-weight replacement beef heifers synchronized with PGF2□ and GnRH. Theriogenology 59:1827-1837, 2003.

El-Zarkouny SZ, Cartmill JA, Hensley BA, Stevenson JS. Pregnancy in dairy cows after synchronized ovulation regimens with or without presynchronization and progesterone. J. Dairy Sci. 87:1024-1037, 2000

Geary TW, Whittier JC, Hallford DM, MacNeil MD. Calf removal improves conception rates to the Ovsynch and CO-Synch protocols. J Anim Sci 79:1-4, 2001.

Lalman DL, Keisler DH, Williams JE, Scholljegerdes EJ, Mallet DM. Influence of postpartum weight and body condition change on duration of anestrus by undernourished suckled beef heifers. J Anim Sci 75:2003-2008, 1997

Lamb GC, Cartmill JA, Stevenson JS. Effectiveness of Select Synch (gonadotropin-releasing hormone and prostaglandin F2[alpha]) for synchronizing estrus in replacement beef heifers. Prof Anim Sci 20:27-33, 2004.

Lamb GC, Larson JE, Geary TW, Stevenson JS, Johnson SK, Day ML, Ansotegui RP, Kesler DJ, DeJarnette JM, Landblom D. Synchronization of estrus and artificial insemination in replacement beef heifers using GnRH, $PGF_{2\alpha}$ and progesterone. J Anim Sci 84:3000-3009, 2006.

Lamb GC, Nix DW, Stevenson JS, Corah LR. Prolonging the MGA-prostaglandin $F_{2\alpha}$ interval from 17 to 19 days in an estrus synchronization system for heifers. Theriogenology 53:691-698, 2000.

Lamb GC, Stevenson JS, Kesler DJ, Garverick HA, Brown DR, Salfen BE. Inclusion of an intravaginal progesterone insert plus GnRH and prostaglandin $F_{2\alpha}$ for ovulation control in postpartum suckled beef cows. J Anim Sci 79:2253-2259, 2001.

Larson JE, Lamb GC, Stevenson JS, Johnson SK, Day ML, Geary TW, Kesler DJ, DeJarnette JM, Schrick FN, DiCostanzo A, Arseneau JD. Synchronization of estrus in suckled beef cows for detected estrus and artificial insemination and timed artificial insemination using gonadotropin-releasing hormone, prostaglandin F2alpha, and progesterone. J Anim Sci 84:332-342, 2006.

Lauderdale J W, Seguin BE, Stellflug JN, Chenault JR, Thatcher WW, Vincent CK, Loyancano AF. Fertility of cattle following $PGF_{2\alpha}$ injection. J Anim Sci 38:964-967, 1974.

Lucy MC, Billings HJ, Butler WR, Ehnis LR, Fields MJ, Kesler DJ, Kinder JE, Mattos RC, Short RE, Thatcher WW, Wettemann RP, Yelich JV, Hafs HD. Efficacy of an intravaginal progesterone insert and an injection of PGF2alpha for synchronizing estrus and shortening the interval to pregnancy in postpartum beef cows, peripubertal beef heifers, and dairy heifers. J Anim Sci 70:1904-1910, 2001.

Kojima FN, Bader JF, Stegner JE, Schafer DJ, Clement JC, Eakins RL, Smith MF, Patterson DJ. Substituting EAZI-BREED CIDEER inserts (CIDR) for Melengestrol acetate (MGA) in the MGA Select protocol in beef heifers. J Anim Sci 87(Suppl.1):255, 2004.

Mapletoft RJ, Lindsell CE, Pawlyshyn V. Effects of clenbuterol, body condition and non-surgical embryo transfer equipment on pregnancy rates in bovine recipients. Theriogenology 25:172 (abstract), 1986.

Macmillan KL, Thatcher WW. Effects of an agonist of gonadotropin-releasing hormone on ovarian follicles in cattle. Biol Reprod 45:883-889, 1991.

Moreira F, de la Sota RL, Diaz T, Thatcher WW. Effects of day of the estrous cycle at the initiation of a timed artificial insemination protocol on reproductive responses in dairy heifers. J Anim Sci 78:1568-1576, 2000.

NAHMS 1997. Part 1: National Animal Health Montiroing Service, USDA, APHIS. Beef Cow-Calf Management Practices. USDA-APHIS Center for Epidemiology and Animal Health, Fort Collins, CO. Pp. 1-55.

NASS. National Agricultural Statistics Services. http://www.nass.usda.gov/. Accessed 06/28/08.

NRC. Nutrient Requirements of Beef Cattle (7th Ed.). National Academy Press, Washington, DC. 85-96, 1996.

Patterson DJ, Hall JB, Bradley NW, Schillo KK, Woods BL, Kearnan JM. Improved synchrony, conception rate, and fecundity in postpartum suckled beef cows fed melengestrol acetate prior to prostaglandin $F_{2\alpha}$. J Anim Sci 73:954-959, 1995.

Patterson DJ, Kiracofe GH, Stevenson JS, Corah LR. Control of the bovine estrous cycle with melengestrol acetate (MGA): A review. J Anim Sci 67:1895, 1989.

Patterson DJ, Kojima FN, Smith MF. A review of methods to synchronize estrus in replacement beef heifers and postpartum cows. J Anim Sci 81(ESuppl.2):E166-177. Online. Available: http://www.asas.org/symposia/03esupp2/jas2402.pdf, 2003.

Perry RC, Corah LR, Cochran RC, Beal WE, Stevenson JS, Minton JE, Simms DD, Brethour JR. Influence of dietary energy on follicular development, serum gonadotropins, and first postpartum

ovulation in suckled beef cows. J Anim Sci 69:3762-3773, 1991.
Pursley JR, Mee MO, Wiltbank MC. Synchronization of ovulation in dairy cows using $PGF_{2\alpha}$ and GnRH. Theriogenology 44:915-923, 1995.
Short RE, Adams DC. Nutritional and hormonal interrelationships in beef cattle reproduction. Can J Anim Sci 68:29-39, 1988.
Short RE, Bellows RA, Staigmiller RB, Berardinelli JG, Custer EE. Physiological mechanisms controlling anestrus and infertility in postpartum beef cattle. J Anim Sci 68:799-816, 1990.
Smith VG, Chenault JR, McAllister JF, Lauderdale JW. Response of postpartum beef cows to exogenous progestogens and gonadotropin releasing hormone. J Anim Sci 64:540-551, 1987.
Spitzer JC, Morrison DG, Wetteman RP, Faulkner LC. Reproductive responses and calf birth and weaning weights as affected by body condition at parturition and postpartum weight gain in primiparous beef cows. J Anim Sci 73:1251-1257, 1995.
Stevenson JS, Johnson SK, Milliken GA. Symposium Paper: Incidence of postpartum anestrus in suckled beef cattle: Treatments to induce estrus, ovulation, and conception. Prof Anim Sci 19:124-134, 2003.
Thompson KE, Stevenson JS, Lamb GC, Grieger DM, Loest CA. Follicular, hormonal, and pregnancy responses of early postpartum suckled beef cows to GnRH, norgestomet, and prostaglandin$F_{2\alpha}$. J Anim Sci 77:1823-1832, 1999.
Twagiramungu HL, Guilbault A, Dufour JJ. Synchronization of ovarian follicular waves with a gonadotropin-releasing hormone agonist to increase the precision of estrus in cattle: A review. J Anim Sci 73:3141-3151, 1995.
Williams GL. Suckling as a regulator of postpartum rebreeding in cattle: A review. J Anim Sci 68:831-852, 1990.
Whitman RW. Weight change, body condition and beef-cow reproduction. Ph.D. Dissertation. Colorado State Univ., Fort Collins, 1975.
Wiltbank JN, Rowden WW, Ingalls JE, Gregory KE, Koch RM. Effect of energy level on reproductive phenomena of mature Hereford cows. J Anim Sci 21:219-225, 1962.
Wood-Follis SL, Kojima FN, Lucy MC, Smith MF, Patterson DJ. Estrus synchronization in beef heifers with progestin-based protocols. I. Differences in response based on pubertal status at the initiation of treatment. Theriogenology 62:1518-1528, 2004.

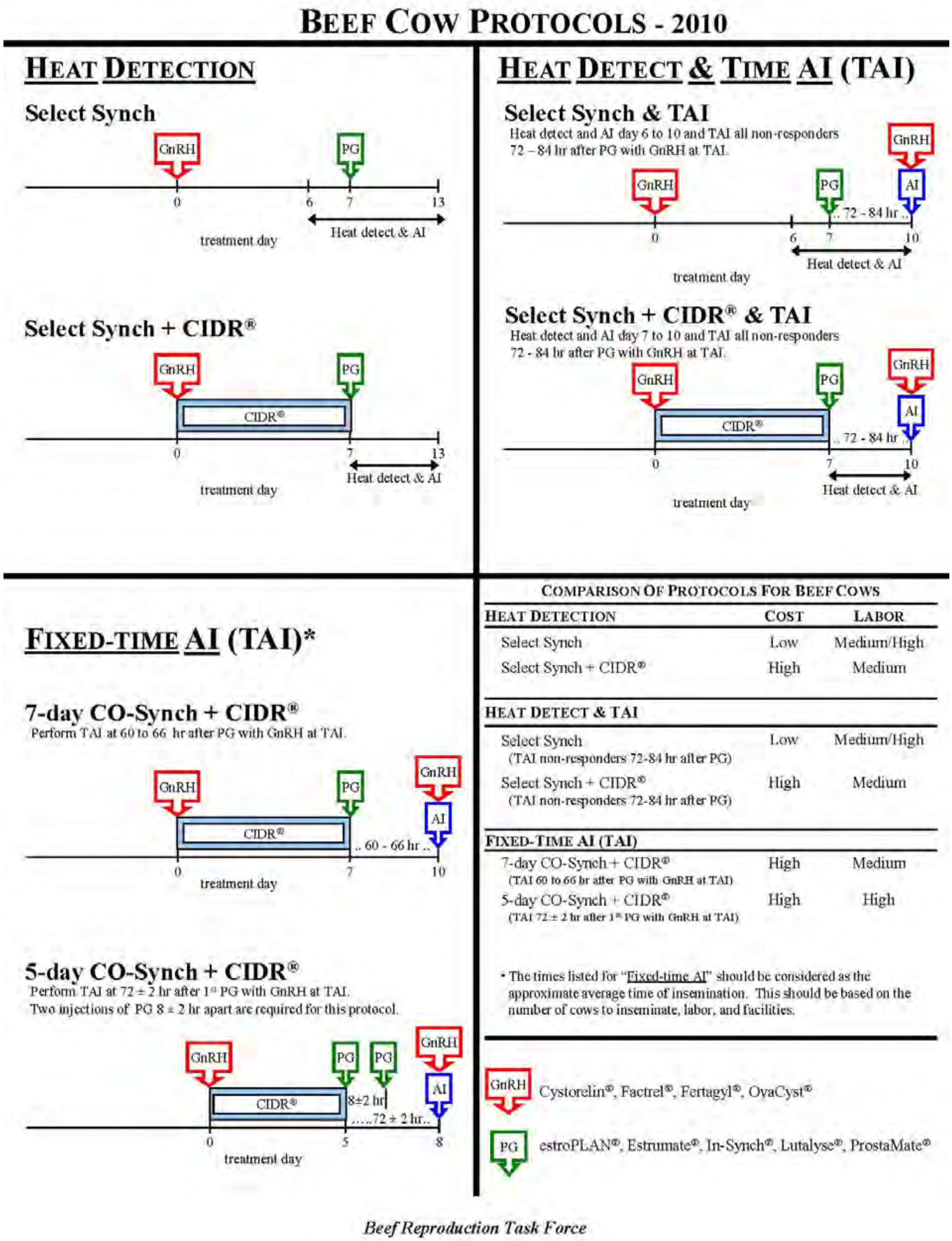
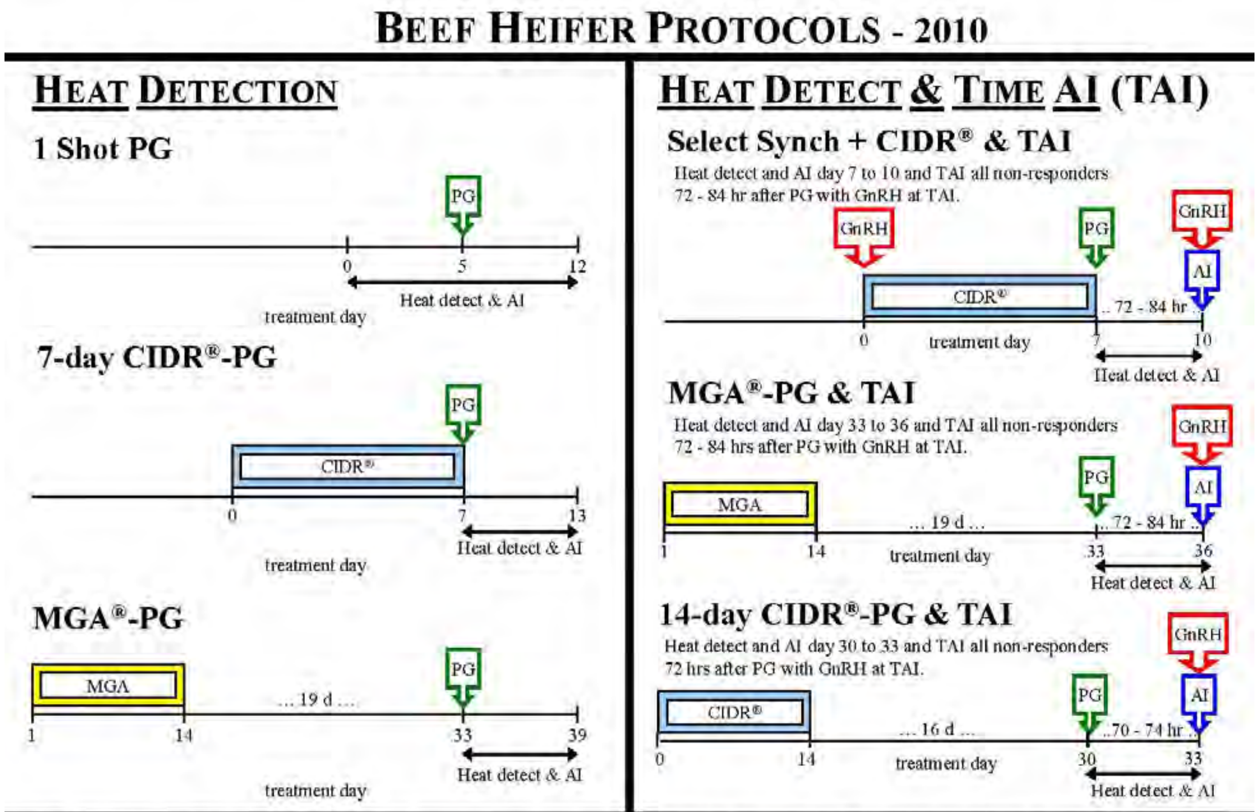
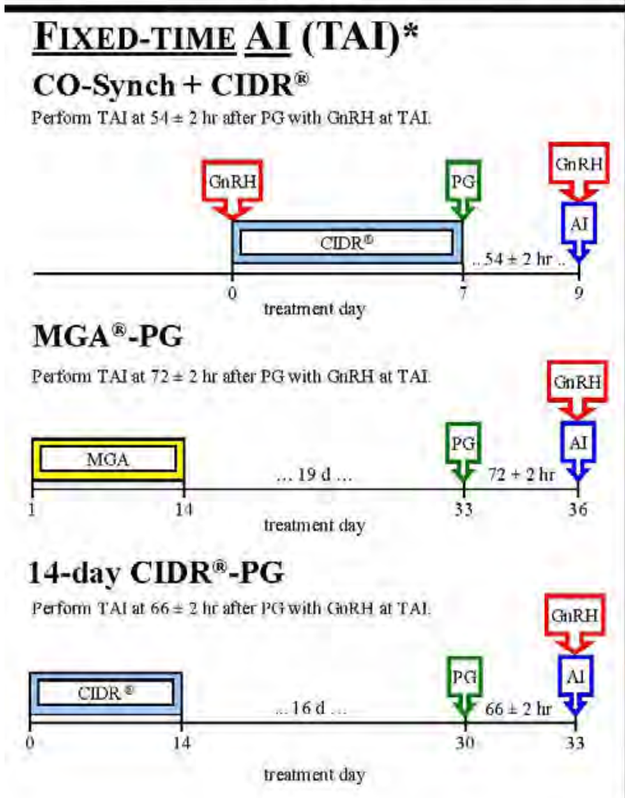


Figure 2. Estrous synchronization protocols for use in beef cows. From the Beef Reproductive Task Force; available at http://westcentral.unl.edu/beefrepro/resources.html

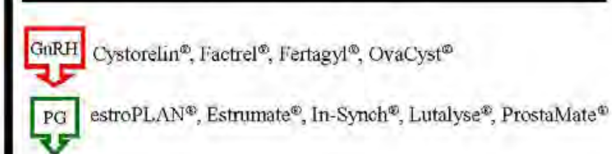




COMPARISON OF PROTOCOLS FOR BEEF HEIFERS

HEAT DETECTION	COST	LABOR
1 Shot PG	Low	High
7-day CIDR®-PG	Medium	Medium
MGA®-PG	Low	Low/Medium
HEAT DETECT & TAI		
Select Synch + CIDR® (TAI non-responders 72-84 hr after PG)	High	Medium
MGA®-PG (TAI non-responders 72-84 hr after PG)	Medium	Medium
14-day CIDR®-PG (TAI non-responders 70-74 hr after PG)	Medium	Medium
FIXED-TIME AI (TAI)		
CO-Synch + CIDR® (TAI 54 ± 2 hr after PG with GnRH at TAI)	High	Medium
MGA®-PG (TAI 72 ± 2 hr after PG with GnRH at TAI)	Medium	Medium
14-day CIDR®-PG (TAI 66 ± 2 hr after PG with GnRH at TAI)	Medium	Medium

* The times listed for "Fixed-time AI" should be considered as the approximate average time of insemination. This should be based on the number of heifers to inseminate, labor, and facilities.



Beef Reproduction Task Force

Figure 3. Estrous synchronization protocols for use in beef heifers. From the Beef Reproductive Task Force; available at http://westcentral.unl.edu/beefrepro/resources.html