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## Effects of Maternal Nutrition and Post-Weaning Management in a Late Spring Calving System and Synchronization of Estrus using Fixed Time AI Protocols

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EFFECTS OF MATERNAL NUTRITION AND POST-WEANING MANAGEMENT  
IN A LATE SPRING CALVING SYSTEM AND SYNCHRONIZATION OF ESTRUS  
USING FIXED TIME AI PROTOCOLS

By

John Dirk Harms

A THESIS

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In Partial Fulfillment of Requirements  
For the Degree of Master of Science

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Under the Supervision of Professors Richard N. Funston and Brett R. White

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EFFECTS OF MATERNAL NUTRITION AND POST-WEANING MANAGEMENT  
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University of Nebraska, 2013

Advisors: Richard N. Funston and Brett R. White

Three experiments were conducted to determine the impact of development systems, maternal protein supplementation, and estrus synchronization systems on beef cattle. Experiment 1 evaluated the effects of winter supplementation on cow performance and the effects of post-weaning management on progeny. Late spring calving cows grazed dormant range or meadow over winter and received either supplementation or no supplementation. Steer and heifer progeny were weaned and placed on dormant meadow or fed hay ad libitum. One half of the steers were placed in the feedlot at the end of treatment and the other half grazed range over summer. Cow winter treatment did not affect cow performance. Steers and heifers fed hay had increased ADG during winter treatment compared to calves on meadow. Feedlot system did not have a significant effect on carcass data.

In experiment 2, cows were synchronized for fixed-time AI (TAI) utilizing the CO-Synch and the CO-Synch + CIDR protocols. Cows synchronized with the CO-Synch + CIDR protocol had increased AI pregnancy rates compared to CO-Synch synchronized cows. In experiment 3, heifers were synchronized for TAI using the MGA + PGF<sub>2α</sub> protocol or CO-Synch + CIDR protocol. Half of the CO-Synch + CIDR heifers received PGF<sub>2α</sub> at the time of CIDR insertion. Heifers were time stamped at the time of final

PGF<sub>2α</sub> administration and at the TAI. Pregnancy rates were not affected due to PGF<sub>2α</sub> administration at the time of CIDR insertion or time interval between final PGF<sub>2α</sub> administration and TAI.

In summary, these experiments provide evidence to support the following findings: (1) there are minimal effects of winter supplementation on late spring calving cows and progeny performance; (2) post-weaning treatment had minimal effects on heifer and steer productivity; (3) cows utilizing CO-Synch + CIDR AI protocol have higher pregnancy rates; (4) fluctuations in time interval from time of PG administration to breeding had no effects on pregnancy rates.

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## **CHAPTER 1: Review of the literature**

### ***Introduction***

The two factors that are crucial for beef cow productivity are reproduction and feed efficiency. Reproductive efficiency has long been recognized as the most important aspect in commercial beef production. A beef cow herd that produces more pregnant cows will result in more pounds of beef to be marketed. It is crucial to manage the nutritional status of the females in the herd, since cows in poor body condition entering the calving season results in an increase in postpartum interval. For a cow to continue to produce one calf each year it needs to conceive within 80 days after calving.

In the Nebraska Sandhills, cows typically calve in the spring. During the winter, additional supplementation is often fed due to the high nutrient requirements of the cow and low forage quality. Feed is the single largest cost in a cow-calf operation. To reduce these costs, shifting the calving date may offer an opportunity for the cow to better match the available resources, reducing the amount of harvested forages and feeds needed. Utilizing crop residues and alternative feed resources may be another viable option to reduce feed input costs. Supplementation of beef herds during winter has shown to have benefits beyond reproduction (Stalker et al., 2006). In the development of progeny, different post-weaning management strategies allow producers an opportunity to utilize different resources available. It also adds marketing flexibility by allowing producers to sell their calves' at the most opportune times. Different rates of gain can also affect the developing progeny. For instance, different rates of gain in heifers can affect the physiological changes necessary for puberty (Frisch, 1984).

To increase reproductive efficiency, producers can utilize numerous reproductive technologies such as: estrus synchronization, breeding soundness exams, and artificial insemination. Benefits of estrus synchronization include the use of superior genetics, shortened breeding and calving season, and a more uniform calving crop. The implementation of fixed-time AI protocols eliminates the need for estrus detection without significant losses in fertility.

### *Production Systems Research*

Beef cattle production in the United States has been a forage-based industry. Significant quantities of forages are fundamental in every production system. Unlike non-ruminants, beef cattle are able to convert range and pasture to high quality protein. Highly erodible, hilly, or mountainous areas and crop residues may have no sustainable economic use other than for grazing ruminant livestock. Also, nutrients in by-products can be utilized and do not become a waste disposal problem. The rumen serves as a vat containing the microbial enzyme cellulase, the only enzyme to digest the most abundant plant product, cellulose (Oltjen and Beckett, 1996). Ruminant livestock production takes advantage of approximately 25% of potential arable land to minimize water and soil erosion (Oltjen and Beckett, 1996). Most careful analyses conclude that if food requirements of the expanding world population are to be met, all available food production resources must be used effectively and efficiently. Ruminants are integral in those systems and as sources of human food (Oltjen and Beckett, 1996).

Research in beef cattle production has typically been characterized into 3 major components: cow-calf, stocker, and feedlot operations. Typically, the calf is not evaluated from conception to slaughter in research projects. However, early stimuli on a growing

calf may have effects later in life. The difficulties to continue research throughout the entire calf's lifetime are the cost, labor, time, and large amount of data that are generated from these projects. Research in beef production systems is highly complex because of the large number of factors that affect the system and the high degree of interaction between these factors (Massey, 1993). The concept of a beef system in beef production incorporates awareness that there is more to consider in a beef cattle enterprise than simply one level of production. These considerations could include: natural resources, input costs, markets, type of cattle, and management practices (Massey, 1993). How producers manage these different components in one part of the beef production system, could have significant effects later in the system. For instance, changes in weaning date may increase cow reproductive performance (Arthington et al., 2005) and lead to improved feedlot performance and carcass quality of the calf (Myers et al., 1999). Changes in breeding, calving, and weaning dates can have effects on the amount and quality of available forage, change grazing season constraints, and alter market strategies (Reisenauer Leesburg et al., 2007). Therefore, it is critical for producers to understand making decisions in one aspect of the industry, such as time of calving, can then have effects throughout the entire beef production system.

#### *Time of Calving*

The decision when to begin the calving season is crucial for the efficiency, profitability, and sustainability of a cow-calf producer. The “best” time of year for calving is dependent upon a number of variables. Calf production and the associated costs can be affected by calving season because environmental conditions, stage of production, and season of the year which interact to affect the nutritional status and

reproductive performance of the cow (Sprott et al., 2001). Environmental factors such as precipitation, temperature, and humidity should be taken into consideration by producers to decide which time cows should calve. The seasonality of the quality and quantity of forage produced on rangeland also needs to be considered. Precipitation, plant species, and the proportion of cool and warm season grasses affect the overall quality and quantity of the forage at any point in time. The seasonal changes in the nutrient density of rangelands are primarily associated with plant maturity (Adams et al., 1996). Nutrient requirements for mature females are greatest at peak lactation and are the least during the middle third of gestation (NRC, 2000). Selecting a calving season that best matches the cows' needs with the time when the forage is near the highest percent of protein would be optimal, and could reduce the amount of supplemented feed needed.

In the Nebraska Sandhills, cows commonly calve in the late winter and early spring. The amount of harvested and purchased feed required to sustain a cow herd in the Nebraska Sandhills is directly related to the calving date (Adams et al., 1996). Producers who started calving in the first half of April reported feeding 758 kg/yr of hay per cow compared to 1486 kg/yr of hay for those who began calving in the end of February (Clark et al., 2004; Stockton et al., 2007). May et al. (1999) compared the costs of feeding accompanied with 5 alternative calving months and the associated costs with each month and found June had the lowest cost with an estimated annual feed cost of \$173/cow. Calving in the May and June, resulted in an estimated annual feed cost savings of \$39 and \$43/cow, respectively, compared with February calving. Cows calving in the late winter months maintained condition scores at a higher average throughout the year. Late spring and summer calving cows gained less condition during the summer months and

dropped below a BCS of 5 overwinter (May et al., 1999). This may be offset by winter supplementation, but Stalker et al (2006) showed feeding supplement overwinter did not increase pregnancy rates in spring calving cows.

Market timing is another factor to consider when selecting a calving season. Cattle markets tend to have seasonal variation throughout the year and vary with respect to calf size and class (Griffin et al., 2012a). Seasonal prices are lowest when calves and culls are normally sold from herds that calve in early spring. Shifting the calving date may provide opportunities to market animals at different times; this could be economically advantageous (Stockton et al., 2007). Stockton et al. (2007) reported greater net returns associated with June calving compared to March calving due to reduced costs. Griffin et al (2012b) reported no reduction in costs but an increase in revenue as calves sold at weaning from June calving cows brought \$70.90/hd more compared to calves calved in March. The increase in market prices, production costs, operating expenses, and opportunity costs interact to determine profitability. Time of calving shifts may lead to differences in seasonal market prices, but also changes the time of breeding, which may impact fertility.

Seasonal effects on fertility have been reported (Christensen, 1980) and were directly related to changes in ambient temperature and day length (Sprott et al., 2001). Late spring and summer calving seasons move the breeding season later when increased temperatures and decreasing quality of forage could become a concern. Roman-Ponce et al., (1978) showed that during heat stress in dairy cows, uterine blood flow is decreased due to blood being shunted from the inner organs to outer extremities to help dissipate heat. Temporary heat stress near the time of estrus and ovulation can reduce oocyte

quality by altering meiotic processes, thus directly affecting conceptus quality and survival (Putney et al., 1989; Sprott et al., 2001). Putney et al. (1988) superovulated dairy heifers that were maintained normally or under hyperthermic conditions. Hyperthermic conditions began 30 h after the onset of estrus and lasted for seven days. Only 20.7% of embryos collected from stressed heifers were normal compared to the 51.5% from thermoneutral heifers. Amundson et al. (2006) analyzed ten years of calving records to quantify the effects of environmental conditions during the breeding season on pregnancy rates and found increased temperature-humidity is negatively associated with pregnancy rate. Heat stress can increase the incidence of anovulatory estrus, reduce progesterone (P4) content in the corpus luteum, increase glucocorticoid levels, and decrease luteinizing hormone concentrations (Sprott et al., 2001).

Heat stress in bulls reduces sperm quality and numbers. Heat stress for as little as 12 h has been shown to impair spermatogenesis and is attributed to an increase in temperature of testicular tissues (Skinner and Louw, 1966; Sprott et al., 2001). The degree of reproductive impairment in bulls and cows due to environmental stress is related to the timing and the duration of stress, suggesting an interaction of season and location.

The decision of when to calve is highly dependent on a number of site-specific conditions. Shifting the calving date to best match available forage has shown the potential to reduce input cost. However, supplemental feeding may still be needed to overcome times of nutrient deficiencies. Selecting a calving season is a crucial decision to best manage the resources available, and may be a method to reduce inputs and maximize profitability.

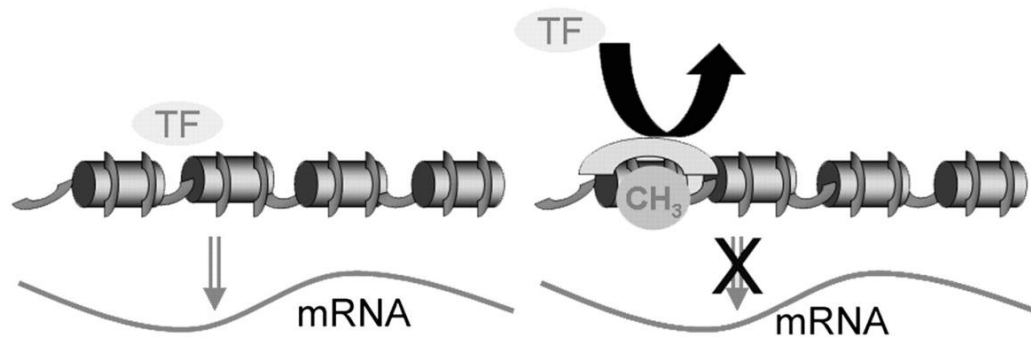
### *Epigenetic Modification and Maternal Nutrition*

The primary DNA sequence of any genome defines the potential for gene expression. Superimposed on the primary genetic sequence is an information rich epigenetic layer that has a major influence on what genes are expressed (Mathers and McKay et al., 2009). Epigenetics is defined as genomic markings or chemical modifications which are heritable from one cell generation to the next, but do not involve changes in the primary DNA sequence (Bernstein et al., 2007). Differences in the epigenome may explain how organisms with similar DNA sequences, express differences in their phenotype. Current research shows these epigenetic differences during fetal development may continue to affect the offspring later in life. The main mechanisms causing epigenetic changes to the genome are DNA methylation and histone modification.

Deoxyribonucleic acid methylation occurs at cytosine bases followed by a guanosine (CpG sites; Holliday and Griggs, 1993). In mammals, most CpG sites in DNA are methylated, but there are specific CpG-rich areas of DNA (CpG islands) where most CpG sites are not methylated (Figure 1; Zeisel, 2009; Jeltsch, 2002). These islands span the 5' end of the regulatory region of genes. Methylation in these CpG islands usually suppresses gene expression. The pattern of CpG islands varies in tissues and likely account for why genes are expressed differently among tissues (Suzuki and Bird, 2008). The family of enzymes known as DNA methyltransferases (DNMTs) catalyzes cytosine methylation. These DNMTs can work on unmodified DNA, establishing DNA methylation patterns and maintaining these patterns when DNA is duplicated (Zeisel, 2009). Deoxyribonucleic acid is tightly wound into histones and prevents access to



transcription factors. When these sites are modified by methylation or acetylation, these proteins can create gaps through which transcription factors can pass (Zeisel, 2009). Histone tails allow for posttranslational modification of specific amino acid residues (Kouzarides, 2007). Histone acetylation or methylation can alter the positioning of histone-DNA interactions and the affinity of the histone binding to the DNA, therefore effecting gene expression (Wu et al., 2004).



**Figure 1.** Epigenetic marks alter gene expression. Normally, transcription factors bind to promoter regions of DNA and induce gene expression producing mRNA. However, when specific CpG islands in the promoter are methylated, capping proteins that prevent access of the transcription factor to DNA are attracted, and gene expression is suppressed (adapted from Zeisel, 2009).

The DNA and histone methyltransferases all use S-adenosylmethionine (SAM) as the methyl donor. S-adenosylmethionine is formed from methyl groups derived from choline, methionine, or methyl-tetrahydropolate (Zeisel, 2009). Therefore, diet can directly influence epigenetic marking. Choline, methionine, and folate metabolism are metabolically related at the point of which homocysteine is converted to methionine. Therefore, the effects of these nutrients on epigenetic marking are interrelated, as changing the metabolism of one of these methyl donors results in compensatory changes in other methyl donors due to intermingling metabolic pathways.

Maternal diets high or deficient in choline, methionine, or methyl folate during pregnancy results in epigenetic changes in gene expression in the fetus that can have permanent effects on the offspring (Zeisel, 2009). Niculescu et al., (2006) reported that decreased choline availability to a mother during development of the fetal brain was associated with changes in DNA methylation that are specific to some CpG islands within genes that regulate cell cycling, thus effecting brain development. Maternal nutritional status is a crucial factor in the growth, development and function of the offspring. Prenatal growth trajectory is sensitive to direct and indirect effects of maternal dietary intake from the earliest stages of embryonic development (Robinson et al., 1995). Producers must manage the nutrient requirements of the animal knowing the offspring could be affected.

Cow/calf producers generally supplement protein to meet the energy requirements of gestating cows grazing dormant forages over winter. This supplementation of protein has been shown to have an influence on postnatal growth and health of the animal. In a review by Funston and Summers (2013), the effects of protein supplementation and nutrient restriction in early to mid-gestating cows include: changes in placental development, increased uterine blood flow, modified follicular development, and altered muscle development.

Funston et al. (2010) demonstrated heifers from dams receiving protein supplementation during late gestation tended to be younger at puberty compared to heifers from dams not receiving supplement. In addition, Martin et al. (2007) found a higher pregnancy rate for heifers from protein supplemented compared to unsupplemented (93 vs. 80%) dams. There was also an increased percentage of heifers

calving in the initial 21 d of the calving season from heifers from supplemented dams compared to heifers from unsupplemented dams (77 vs. 49%). Stalker et al. (2006) reported an increase in weaning BW and ADG from birth to weaning in calves born from cows that were protein supplemented. There was also an increase in percentage of live calves at weaning from supplemented dams. Larson et al. (2009) demonstrated steers from cows supplemented protein in late gestation had higher marbling scores. A greater proportion of steers born to supplemented cows graded USDA Choice compared to steers from dams not supplemented protein. Martin et al. (2007) demonstrated that RFI and DMI intake can also be affected by late gestation protein supplementation, depending on subsequent postpartum dam treatment. Heifers born to protein supplemented dams had increased DMI and RFI if cows were fed hay in early lactation. Therefore, protein supplementation of the cow during gestation can affect the offspring throughout its lifetime.

### *Protein Supplementation*

Low-quality and dormant forages are important sources of nutrients used to maintain and develop beef cattle. To best optimize the utilization of these forages, it is generally accepted to increase intake and digestion via supplemental nutrients. Rumen degradable protein (RDP) is considered to be the “first limiting” nutrient in low quality forages. Providing adequate amounts of RDP to ruminants fed low-quality forages, commonly promotes an increase in forage intake and flow of nutrients to the small intestine (Hannah et al., 1991; Köster et al., 1996). This is due to the RDP facilitating microbial fermentation and the production of microbial protein. However, microbial crude protein production is often inadequate to meet the metabolizable protein (MP)

requirement of young growing cows, resulting in a need for supplemental rumen undegradable protein (RUP; Klopfenstein, 1996). Rumen undegradable protein has been used as a means to complement the supply of microbial protein to the duodenum in cows during gestation and lactation (Strauch et al., 2001). Thus, protein supplementation is a crucial component of the beef production system.

Supplementation is commonly recommended during periods of low-quality forage. Bellows and Short (1978) reported that improving the nutrient status of cows and heifers before calving can decrease the postpartum interval which may improve reproductive performance. Researchers have reported indications of improved conception rates with the feeding of elevated RUP, especially in cows with marginally low states of nutrition (Dhuyvetter et al., 1993). However, increases in reproductive success are not apparent in all circumstances and may only relate to cows with higher nutrient requirements associated with growth and/or lactation (DelCurto et al., 2000). In spring calving cows, Stalker et al. (2006) showed cows supplemented with 0.45 kg·animal·d of a 42% CP supplement maintained BW during prepartum treatment (December 1 to February 28) and sustained a higher BCS (4.85) entering the breeding season compared to cows not supplemented. Cows that were not supplemented lost 29 kg BW over the treatment period and entered the breeding season in a lower BCS (4.6). However, this did not result in an increase in pregnancy rates as supplemented cows did not differ compared to unsupplemented cows (93.2 vs. 90.3%). Additional benefits of supplementation were discovered, as feeding supplemental protein resulted in an increase net return of \$25.38/calf due to increased calf weaning BW and percentage of live calves weaned. Larson et al. (2009) showed similar results as cows that received supplementation were

heavier and had increased BCS at precalving and prebreeding times. Similar to Stalker et al. (2006), supplementation did not affect pregnancy rates.

The strategy or goal of supplementation should be to use the most efficient delivery system to minimize costs and variation in animal intake within a group of cattle. By providing a supplement delivery system that optimizes uniformity of consumption and minimizes economic inputs, producers can effectively improve their beef cattle production systems (DeIurto et al., 2000). Factors such as: forage quality and quantity, age, and nutritional status (body condition), need to be evaluated to determine the necessity of protein supplementation.

#### *Post-Weaning Steer Development*

Weaned steers are often placed into a backgrounding or stocker program to achieve adequate frame size before entering the feedlot. Steers fed to higher rates of BW gain during backgrounding are fatter when entering the feedlot and are generally assumed to be less efficient. Steers may experience compensatory growth following a period of reduced nutrition. Compensatory growth is defined as rapid growth occurring after a period of feed restriction. During compensatory growth, an accelerated protein turnover is observed and characterized by increased synthesis related to the degradation of protein in the viscera and then the muscles. This results in improved protein accretion and decreased nitrogen excretion. Since less energy is required for muscle deposition than fat, growth rate is improved (Hornick et al., 2000). This improved growth is most likely the results of endocrine alterations.

Lewis et al. (1990) assigned steers to three different winter treatments designed to produce three different rates of gain over winter (106 d) These steers were then placed

on pasture for grazing (116 d) and then sent to a feedlot (112 d). Average winter gains of .28, .38, and .50 kg·d were established for each winter treatment. A linear decrease in pasture gain was observed as winter gain increased. During the feedlot phase, no differences in daily gain, feed intake, or feed conversion were observed due to winter treatment. This may be due to compensatory growth in the pasture phase before the feedlot.

Hersom et al. (2004) fed steers overwinter on three different levels of gain: high-gain on wheat grass (HGW), low-gain on wheat grass (LGW), and native range (NR). After winter treatment, steers entered the feedlot and were fed a high-concentrate diet to a common backfat endpoint. Dry matter intake (% of mean BW) for NR (2.40 kg) and LGW (2.50 kg) was greater than for HGW steers (2.21 kg). There were no significant differences in live BW ADG, gain efficiency, and carcass characteristics. Research has shown that when cattle are adjusted to equal fat thickness at slaughter, different rates of gain over winter will not influence carcass quality (Klopfenstein et al., 2000).

#### *Calf-fed vs. Yearling-fed Systems*

Two major types of post-weaning beef cattle production systems include intensive and extensive systems. In an intensive or calf-fed system, cattle are weaned and fed a high concentrate diet until slaughter. In extensive or yearling-systems, cattle are grown in a backgrounding program after weaning and fed crop residues or harvested/grazed forages prior to feedlot entry. Intensive calf-feeding production systems result in improved feed efficiency, but calves are usually lighter, and days on feed are increased compared to yearling-development (Griffin et al., 2007).

The genetics of the calf can have a significant effect on what system may be the most profitable. If larger framed calves are placed in intensive production systems, there is potential for cattle to produce overweight discounts (Griffin et al., 2007). Camfield et al. (1999) demonstrated that large framed, later maturing steers developed in the calf-fed system had a 288.6 kg HCW which was 54.7 kg heavier than small framed, earlier maturing steers. Breed may also have a significant influence. Gregory et al. (1994) found smaller, British breeds had lower live weights and lower HCW compared to Continental breeds.

To control for different breeds and body types, Harris et al. (1997) used cloned Brahman steers to evaluate the effects of calf- and yearling-feeding systems on production performance and carcass characteristics. In the first experiment, steers were assigned to a calf-fed system and started in the feedlot or placed in a yearling system and allowed to graze pasture for 123 d before entering the feedlot. Both groups were fed to an endpoint of 16 m. In the second experiment steers were placed in similar treatments and fed to a constant live weight end point (approximately 530 kg). When calves were fed to an age endpoint there was no difference in ADG between calf-fed and yearling fed steers. Calf-fed steers did produce heavier carcasses and higher yield grades and increased quality grades. This is likely due to the increased amount of time on feed for the calf-fed steers. When they were fed to a BW endpoint, yearling-fed steers gained more rapidly compared to calf-fed steers (1.68 vs. 1.31 kg·d). This may be due to compensatory gain and suggests age of the animal may also have an effect on ADG. Yearling-steers fed to a BW endpoint had a decreased quality grades compared to the calf-fed steers. This demonstrates the importance of properly selecting the type of steer to best fit each

system. However, feeding cattle to age or BW endpoint may not be the best management method.

When comparing cattle of different types or treatments, it is important to compare cattle at equal fat points (Tedeschi et al., 2004). Griffin et al. (2007) compared calf- and yearling-fed steers by analyzing performance and carcass characteristics along with economic factors. In the study, heavier weaned steers entered the calf-fed system and lighter weaned steers grazed cornstalks for approximately 140 d before entering the feedlot. Upon entering the feedlot, yearling-fed steers were heavier than the calf-feds due to increased growth during grazing. This led to a 38 kg increase in final BW for yearling-fed steers. Yearling-fed steers consumed more DM per day compared to calf-feds, however, calf-feds consumed 381 kg more total DM during the finishing period. This was due to the additional 78 d longer on feed compared to the yearling-system. Yearling steers had 0.33 kg greater ADG during feeding, however, calf-fed steers had an 18.7% greater G:F than yearling-fed steers. Hot carcass weights were 24 kg heavier for yearling-fed steers compared to calf-fed but there was no difference in percentage choice or yield grade.

Yearling-fed steers have an advantage in the feedlot as they have higher ADG and less total feed consumed. However, yearling-fed steers require more days of ownership to reach harvest and the risk of carcasses being too heavy. Calf-fed steers grow more efficiently but require more feed in the feedlot as they are on feed longer (Griffin et al., 2007). The animal's genetics, breed, all need to be considered in deciding which type of finishing system to utilize.



### *Post-Weaning Heifer Development*

The success of a replacement heifer development program is dependent upon heifer fertility. Post-weaning nutrition affects the timing of puberty in beef heifers. Heifers that conceive early in their first breeding season have a greater lifetime production than heifers that calve later in the season (Lesmeister et al., 1973). Patterson et al. (1992a) used records for age at puberty and length of postpartum interval from heifers calving at 2 yr of age and found a significant negative relationship between age at puberty and length postpartum interval.

Weaning heifer BW and post-weaning growth rate influences age at puberty. Current management recommendations for heifers to calve as 2-yr-olds include exposing them to breeding before the mature cow herd. This practice may result in a small percentage of heifers being bred on their pubertal estrus. Fertility of heifers bred on pubertal estrus is 21% lower than for those bred on their third estrus (Byerley et al., 1987). This means heifers need to reach puberty 1 to 3 mo before the age at which they are to be bred. Earlier age at puberty in relation to breeding is to ensure a high percentage of heifers are cycling and the effects of lowered potential pregnancy rates from the pubertal estrus are minimized (Patterson et al., 1992b). Patterson et al. (1992b) indicated that puberty can be expected to occur at a genetically predetermined size among individual animals and only when animals reach these determined weights, with body type in consideration, can acceptable pregnancy rates be obtained. Guidelines were established that replacement heifers should reach 60 to 65% of their expected mature BW by breeding.

Short and Bellows (1971) reported heifers gaining 0.45 kg·d reached puberty at 411 d compared to heifers which gained 0.68 kg·d who reached puberty at 380 d. Varner et al. (1977) separated heavy and light heifers and determined that age of puberty decreased by 16 d and pregnancy rates increased by 11% for the heavy group. Funston and Deutscher (2004) developed spring-born heifers on either high- or low-gain treatment. Heifers in the low-gain treatment reached 53% mature BW at prebreeding compared to high-gain which reached 58% mature BW. However, the pregnancy rates did not differ (92 vs. 88%). Funston and Larson (2011) developed heifers in a traditional dry lot development system (DL) and extensive grazing system (EXT) utilizing crop residue and winter range. Heifers developed on the EXT system weighed 52 kg less than DL heifers and remained lighter entering the breeding season (336 vs. 387 kg). Only 46% of EXT heifers reached puberty before breeding, compared with 88% for DL; however final pregnancy rates were similar.

Advancements in genetics over the last 20 y may explain the similar pregnancy rates. Since 1985, there has been a substantial increase in bull scrotal circumference (Funston et al., 2012). This would result in a decrease in age of puberty for heifers, reducing the problem of heifers not reaching puberty before the time of breeding (Gasser et al., 2006). Several studies have shown no associations between nutritionally related changes in age at puberty and final pregnancy rates (Ferrell, 1982; Buskirk et al., 1995; Freetly and Cundiff, 1997; Lynch et al., 1997). A genetic basis for these results may exist as Freetly and Cundiff (1997) reported pregnancy rates, not age or BW at puberty, were greater in heifers AI sired in bulls born after 1988 compared to bulls born between 1982 and 1984.

Control of the reproductive processes resides in the brain centers of the hypothalamus. The hypothalamic-ovarian axis is responsible for the function and control of the female reproductive tract. This axis is driven by pulses of gonadotropin-releasing hormone (GnRH) secreted into the portal system of the median eminence from neurons in parts of the hypothalamus. Gonadotropin-releasing hormone is the primary stimulator of luteinizing hormone (LH) secretion from the anterior pituitary. This regulates ovarian development and maturation; and is the causative agent of ovulation (Whittier et al., 2008).

During prepubertal development, GnRH secretion is depressed through a lack of positive feedback due to low concentrations of estradiol ( $E_2$ ) secreted from the developing antral follicles of the ovaries. This causes infrequent pulses of GnRH secretion which results in infrequent pulses and decreased secretion of LH. Puberty in heifers is preceded by an increase in frequency of episodic release of LH, possibly due to an increase in positive feedback of  $E_2$  on LH (Moran et al., 1989). The pulsatile nature of LH secretion is recognized by the dominant follicle to determine whether or not they enter final stages of development. If LH pulses are infrequent, then the maturation of follicles will not occur, therefore, ovulation is suppressed (Whittier et al., 2008). During maturation, theca cells secrete androstendione which is aromatized to  $E_2$  by granulosa cells. This increase in estrogen will eventually activate the GnRH surge and subsequent LH surge resulting in ovulation. Changes in the hypothalamus, particularly sensitivity to negative feedback effects of  $E_2$  and alterations to the frequency of GnRH release, are prerequisites for normal timing of puberty in the beef heifer (Armstrong et al., 1992).

It is during this post-weaning development that the “sensitivity” to  $E_2$  feedback begins to decrease. This allows the frequency of GnRH pulses to increase which in turn increases LH pulses (Whittier et al., 2008). As the heifer grows, these factors induce or interact with various metabolic signals. Dietary energy restriction can decrease the frequency of LH pulses and delay the onset of puberty in beef heifers. An acute increase in energy intake after a long period of nutrient restriction resulted in increased frequency of LH pulses within 14 d of increased feed intake (Kurz et al., 1990). This indicates nutrition during the post-weaning period can impact reproductive efficiency.

### *Puberty*

The onset of puberty coincides with the first opportunity for a heifer to conceive and should be defined as the first ovulatory estrus followed by a luteal phase of normal duration. In the prepubertal heifer, reduced sensitivity of GnRH to the negative inhibition of  $E_2$  causes an increase in GnRH pulses followed by an increase in LH pulse frequency (Whittier et al., 2008). This increase in LH pulse frequency is responsible for final development and maturation of the dominant antral follicle. During the final maturation of dominant follicles,  $E_2$  is secreted in increasing quantities which triggers behavioral estrus and preovulatory release of LH. The gonadostat hypothesis suggests an initial inhibitory effect of  $E_2$  on gonadotropin secretion followed by a gradual decrease in the negative effects of  $E_2$ . The decreased sensitivity to  $E_2$  allows for the eventual LH surge and ovulation (Atkins et al., 2013; Day and Anderson, 1998).

The amount of GnRH present in the hypothalamus does not change during maturation (Kinder et al., 1995). Changes in estrogen receptor (ER) and kisspeptin may help explain the final maturation of the hypothalamus before puberty (Atkins et al.,

2013). Neurons with ER are found in several regions of the hypothalamus. Day and Anderson (1998) reported a decrease in ER positive neurons in the anterior hypothalamus and medial basal hypothalamus leading up to puberty, and this decline was associated with an increase in LH pulse frequency. This reduction in ER may explain the reduced sensitivity to  $E_2$  and thus increase GnRH and LH secretion (Atkins et al., 2013). In mice, kisspeptin has been shown to be a potent stimulator of GnRH secretion and may be acting directly on GnRH neurons (Clarkson and Herbison, 2006). Hypothalamic expression of kisspeptin and the kisspeptin receptor increases near the expected time of puberty (Castellano et al., 2005). In ewes, it has been shown that increased LH pulsatility during sexual maturation is associated with a reduction in the suppressive effects of  $E_2$  on kisspeptin expression (Redmond et al., 2011).

Onset of puberty may also be linked to attainment of a critical BW and a minimum percentage of body fat. Metabolic signals are important for the initiation of puberty (Frisch, 1984). Leptin may act as a metabolic gate for puberty as circulating leptin concentration increases during pubertal development until a threshold is reached. Thus, leptin is a permissive signal for puberty and not a triggering signal for the initiation of puberty (Barb and Kraeling, 2004).

The age of puberty could also be accelerated using a number of management strategies. Exogenous progestins have been shown to hasten the age of puberty. Progesterone has been shown to increase the number of  $E_2$  receptors in the mediobasal hypothalamus (Blache et al., 1994). The hypothalamus is a major site of action of  $E_2$  in inducing the preovulatory GnRH surge. Increasing the number of  $E_2$ -responsive cells may augment the ability of the positive feedback system to respond to the  $E_2$  signal (Caraty

and Skinner, 1999). Lucy et al. (2001) used an intravaginal progesterone-releasing insert (controlled internal drug-releasing device, CIDR) to induce puberty in beef heifers.

Heifers treated with the CIDR had an increase in noncycling heifers displaying estrus, and an increase in pregnancy rates. Social interactions between bulls and prepubertal heifers also results in a decreased age of puberty. Roberson et al. (1991) exposed prepubertal heifers to bulls for 70 d and found an increase in the proportion of heifers attaining puberty compared to heifers not exposed to bulls. Genetic progress, including the increase in bull scrotal circumference may also lead to decrease in age of puberty.

### *Estrous Cycle*

After the onset of puberty, the female enters a period of reproductive cyclicity that continues throughout her reproductive life. The estrous cycle consists of a series of predictable events beginning with estrus, and ending at the subsequent estrus. The onset of this cycle generally begins with the onset of puberty. The normal duration of the estrous cycle for heifers is 18-24 d, with 21 d being the most common, and estrus lasting 12-18 h (Forde et al., 2011, Senger, 2003). The cycle consists of two distinct phases, the follicular and luteal phase. The follicular phase is the period following regression of the CL to ovulation, which usually ranges from 4 – 6 d. During the follicular phase, final maturation and ovulation of the dominant follicle occurs allowing for potential fertilization. The luteal phase, is the period following ovulation when the corpus luteum (CL) is formed, ranging from 14 -18 d (Forde et al., 2011). During the luteal phase follicles continue to grow and regress but do not produce high concentrations of E<sub>2</sub> (Senger, 2003).

The estrous cycle can be divided into 2 phases, follicular and luteal, which can be broken further into two components. The follicular phase can be divided into the proestrus phase, characterized by luteolysis, formation of ovulatory follicles, and  $E_2$  secretion; and the estrus phase, characterized by maximal  $E_2$  secretion and sexual receptivity (Senger, 2003). The luteal phase is divided into metestrus, the period between ovulation and the formation of a functional CL, and diestrus, characterized by a functional CL and high levels of progesterone ( $P_4$ ). These phases are regulated by the hormones of the hypothalamus (GnRH), anterior pituitary (follicle-stimulating hormone; FSH, and LH), the ovaries ( $P_4$ ,  $E_2$ , and inhibin), and the uterus (prostaglandin  $F_{2\alpha}$ ;  $PGF_{2\alpha}$ ). These hormones function utilizing a system of positive and negative feedback to control the estrous cycle (Forde et al., 2011) and concentrations vary throughout the estrous cycle (Figure 2).

#### *Endocrine Regulation of Estrous Cycle*

Follicular emergence occurs in 2 or 3 waves during the luteal phase of the estrous cycle in cattle (Matton et al., 1981) and is prompted by the release of FSH from the anterior pituitary (Adams et al., 1992; Ginther et al., 1996). A number of these follicles are then recruited for growth and maturation. The rise in FSH then declines once a follicle has reached 4-5 mm (Ginther, 2000). This follicle will attain dominance and as this follicle increases in size  $E_2$  and inhibin concentrations increase in the follicular fluid (Hillier, 1994) allowing negative feedback to reduce FSH to basal concentrations (Sunderland et al., 1994; Ginther, 2000). After the emergence of this dominant follicle, the other follicles will regress and undergo atresia. Granulosa cells within the follicle will then produce LH receptors and will no longer be dependent on FSH (Beg et al., 2001).

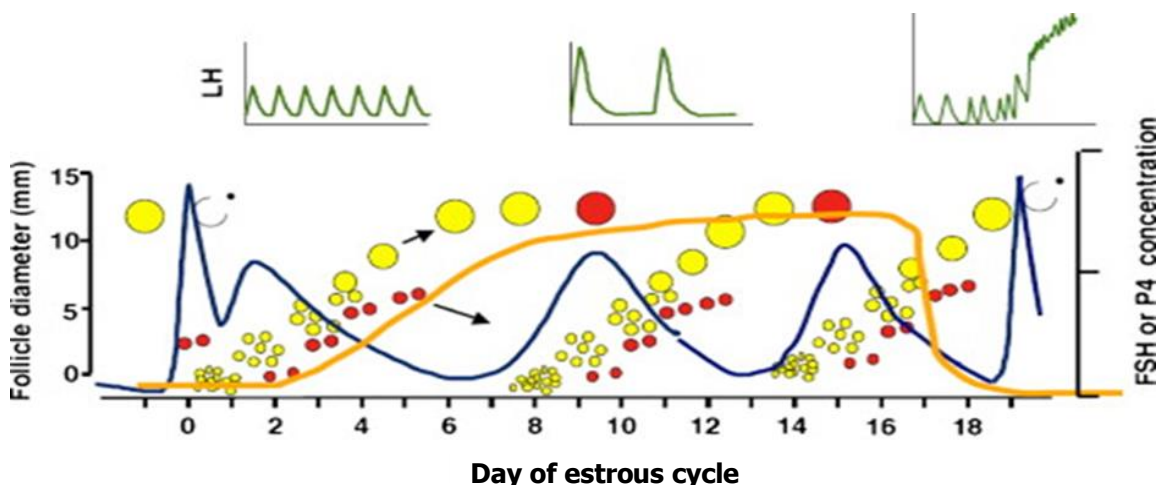
At this time, P4 concentrations are low due to the absence of a functional CL. The dominant follicle is secreting increasing quantities of E<sub>2</sub> which stimulates a GnRH surge from the hypothalamus. This results in a wave of LH being released from the anterior pituitary to stimulate the final growth, maturation, and ovulation of the dominant follicle (Forde et al., 2011). The increase in E<sub>2</sub> secretion is also responsible for estrus behavior necessary for successful mating.

The main luteotrophic hormone in cattle, LH (Hansel, 1966), is responsible for stimulating luteinization of the theca and granulosa cells of the pre-ovulatory follicle into luteal cells (Alia and Hansel, 1984; Forde et al., 2011). The function of the CL is to produce sufficient concentrations of P4 to maintain pregnancy (if a conceptus is present) and to decrease gonadotropin secretion to prevent behavioral estrus from reoccurring (Forde et al., 2011). During this time in the luteal phase, FSH is still being secreted and follicular waves are still present. Production of P4 by the CL will prevent the surge of GnRH and LH to induce ovulation, therefore the dominant follicle in the first or second wave (in a three wave cycle) would undergo atresia (Figure 2; Senger, 2003). If an oocyte is fertilized, the CL will remain and continue producing P4 throughout the pregnancy. If there is no fertilization, luteolysis will occur (Kojima, 2003).

Luteolysis is the disintegration or regression of the CL. Hormones that control this process are oxytocin and P4 from the CL, and PGF<sub>2α</sub> produced from the uterus (Senger, 2003). As the luteal phase progresses, the CL is producing lower concentrations of P4 allowing an increase in E<sub>2</sub> secretion from a follicle and an increase in oxytocin receptors in the uterus. As these receptors bind oxytocin, this stimulates the uterine secretion of PGF<sub>2α</sub>. Prostaglandin F<sub>2α</sub> is transported to the uterus via a vascular



countercurrent exchange mechanism, allowing  $\text{PGF}_{2\alpha}$  to reach the ovary and begin luteolysis (Senger, 2003).



**Figure 2.** Schematic depiction of the pattern of secretion of FSH, LH, and P4; and the pattern of growth of ovarian follicles during the estrous cycle in cattle. Each wave of follicular growth is preceded by a transient rise in FSH concentrations. Healthy growing follicles are shaded in white, atretic follicles are shaded. A surge in LH and FSH concentrations occurs at the onset of estrus and induces ovulation. The pattern of secretion of LH pulses during an 8-h window early in the luteal phase (greater frequency, lesser amplitude), the mid-luteal phase (lesser frequency, lesser amplitude) and the follicular phase (high frequency, building to the surge) is indicated in the inserts in the top panel (adapted from Forde et al., 2011).

### *Estrus Synchronization*

Synchronization of estrus implies the manipulation of the estrous cycle to bring a large percentage of females into estrus at a predetermined time. Ideally, an estrus synchronization system should elicit a fertile estrus in the majority of females within a set time-frame (Odde, 1990). Benefits of synchronization include increases in the proportion of females conceiving early in the breeding season, and decreasing the length of the calving season, which allows for a more uniform calf crop (Dziuk and Bellows, 1983). Females that conceived to a synchronized estrus calved earlier in the calving season and weaned calves that were 9.5 kg heavier than calves from unsynchronized cows (Schafer

et al., 1990) and have greater productivity throughout their lifetime (Lesmeister et al., 1973).

The development of methods to control the estrous cycle occurred in distinct phases (Patterson et al., 2003). The discovery that P4 inhibited ovulation (Ulberg et al., 1951) and preovulatory follicular maturation (Nellor and Cole, 1956; Hansel et al., 1961; Lamond, 1964) was the basis for synchronization. Efforts to prolong the luteal phase of the estrous cycle, or establish an artificial luteal phase was accomplished by administering exogenous P4. Later, progesterone agents were combined with estrogens or gonadotropins in estrus synchronization systems (Patterson et al., 2003).

One of the most widely used progestins available today is melengestrol acetate (MGA). Melengestrol acetate is utilized in feedlot operations and heifer development systems to suppress or synchronize estrus; it is not approved for use in suckled beef cows. Zimbelman and Smith (1966) reported an effective dose of 0.5 mg/hd fed 14 to 18 d to suppress estrus and also resulted in an increase in BW gain (Bloss et al., 1966). Zimbelman et al. (1970) reviewed the effectiveness of MGA fed 10 to 18 d as an estrus synchronization agent and discovered the percentage of first-service conception rates was 14% lower for MGA-treated animals compared with the controls. Inskeep (2004) demonstrated MGA over an 18 d period caused frequent small FSH and LH pulses in the cow due to reduced GnRH synthesis in the hypothalamus. Inskeep (2004) confirmed that supplementation of MGA and other low progesterone supplements results in the formation of large persistent follicles due to the low pulses of FSH and LH that occur during supplementation. This persistent follicle will continue to produce estradiol (Fortune and Rivera, 1999) delaying the FSH surge for the next follicular wave. The

increase in estrogen decreases pregnancy rates due to a more mature oocyte being ovulated (Diskin et al., 2006; Inskeep, 2004). This reduction in conception rate was temporary and was confined to breeding at estrus occurring within about 10 d after MGA withdrawal (Odde, 1990). The advantages of utilizing MGA for estrus synchronization are the ease of administration to the animals and the low cost.

Controlled internal drug release devices were developed in New Zealand and approved for estrus synchronization cattle in the United States in 2002. The CIDR is a t-shaped vaginal insert containing 1.38 g progesterone in silicon molded over a nylon spine (Mapletoft et al., 2003). Insertion of a CIDR in ovariectomized cows increased plasma progesterone concentrations near luteal levels (5 to 7 ng/mL) by 24 h, decreasing to 2 to 3 ng/ml after 2 to 3 d of CIDR insertion. Plasma concentration declined to baseline by 12 h after CIDR removal (Martinez et al., 2002). This rapid rise and fall in serum progesterone concentrations may more effectively manage LH secretion and follicle development to prevent the ovulation of aged follicles seen in cows treated with MGA (Kinder et al., 1996).

Prostaglandin  $F_{2\alpha}$  and its analogues were initially reported to be luteolytic in bovine in the early 70's (Lauderdale, 1972). Because of the luteolytic nature of these compounds they can be successfully used to synchronize estrus in cattle. Prostaglandin  $F_{2\alpha}$  is ineffective in causing luteolysis in the early stage of the estrous cycle (Lauderdale, 1972) as  $PGF_{2\alpha}$  needs a responsive CL to elicit an effect. Injections of  $PGF_{2\alpha}$  into prepuberal or anestrous cows would also be ineffective due to the absence of luteal tissue. If cattle are distributed equally across the estrous cycle, approximately 70% of the cycling cattle should exhibit estrus after the first injection (Odde, 1990). Methods of

synchronizing estrus with  $\text{PGF}_{2\alpha}$  include the one and two injection protocols. In the one injection method, estrus detection and breeding would be required 5 d before the  $\text{PGF}_{2\alpha}$  injection. This ensures females which would be unresponsive to the  $\text{PGF}_{2\alpha}$  would be bred (Lauderdale et al., 1980). In the two injection method, 70% of females should exhibit estrus in the next 2 – 5 d. Females not detected in estrus should receive a second injection 11 to 14 d after the first injection (Lauderdale, 1979).

A synchronization system that initially utilizes MGA or a CIDR and then administration of  $\text{PGF}_{2\alpha}$  during the late luteal phase should improve estrus synchrony and increase pregnancy rates. Brown et al. (1988) synchronized heifers with two treatments. In the first treatment, heifers were fed 0.5 mg/hd/d of MGA for 14 to 16 d and 16 or 17 d after final MGA feeding, heifers were injected with 25 mg of  $\text{PGF}_{2\alpha}$  (MGA- $\text{PGF}_{2\alpha}$ ). In the second treatment, heifers were given a 9-d norgestomet implant plus an injection containing 3 mg norgestomet and 5 mg estradiol at implant insertion (Syncro-Mate B, SMB). Heifers synchronized with MGA-  $\text{PGF}_{2\alpha}$  had increased synchronized pregnancy rate (57.3 vs. 36.6%) compared to the SMB treatment. Lucy et al. (2001) demonstrated cows and heifers treated with a CIDR for 7 d and treated with  $\text{PGF}_{2\alpha}$  on d 6 had increased estrus activity within the first 3 d of the experiment and increased subsequent pregnancy rates compared to  $\text{PGF}_{2\alpha}$  and control cows. The discovery that ovarian follicles grow in distinct wave-like patterns, with generally one follicle becoming dominant (Fortune et al., 1988) allowed development of a new generation of synchronization protocols to develop. The addition of GnRH to protocol has proven to be successful in improving estrus synchronization (Patterson et al., 2003).

Beef producers have been slow to adopt these technologies into their production system (NAHMS, 1997). Recent research on synchronization protocols has attempted to minimize the number of times cattle are handled, and eliminate estrus detection by employing fixed-time AI (TAI). Larson et al. (2006) demonstrated CO-Synch + CIDR TAI protocols yielded similar pregnancy rates to the Co-Synch + CIDR estrus synchronization method (54 vs. 53%). The MGA-PGF2 $\alpha$ -GnRH TAI synchronization protocol, with MGA fed for 14 d, administration of PGF2 $\alpha$  19 d later, and GnRH administration with TAI 72 h later has achieved acceptable pregnancy rates (Deutscher, 2000). Producers utilizing these systems need to consider costs, labor, facilities, and duration of the protocol in their selection.

### **SUMMARY/OBJECTIVES**

In the Nebraska Sandhills, cows commonly calve in the late winter and early spring. By better matching the cow's nutrient requirements to available forage, we may reduce the need for winter supplementation. Nutrient restriction during pregnancy may affect subsequent postnatal growth and development of the fetus. Early-gestation restriction has been shown to affect placental development. Late-gestation restriction affects final development of organs and nutrient uptake of the fetus for tissues required for growth and reproduction. Cows supplemented with protein during winter have shown increased calf weaning BW, increased fertility, and increased carcass characteristics in their progeny. Cows that calve in the late spring in the Sandhills may not require supplementation due to the increasing quality of forage available during the spring.

Post-weaning management of heifers, requiring them to reach 60% mature BW by breeding, may not be validated. Research has supported an inverse correlation between

post-weaning growth rate and age of puberty. Heifers with less than the 60% mature BW recommendations have been shown to achieve acceptable pregnancy rates. The reason for this earlier puberty may be due to genetic advancement over time. Reducing feed inputs in the heifer development without affecting productivity would be advantageous to ranch profitability. Post-weaning management of steers has shown utilizing different rates of gain in the finishing system can affect their efficiency, and carcass characteristics.

Estrus synchronization is a valuable tool allowing producers to shorten the breeding and calving seasons, and produce a more uniform calf crop. Utilizing a TAI system using progestins, GnRH, and PGF<sub>2α</sub>, producers can utilize superior genetics and reduce the need for heat detection during the breeding season. Many TAI protocols have become available that produce acceptable results and research is continually being conducted to increase fertility amongst these protocols.

Based on the preceding literature, the research objectives for the experiments in the following chapters are outlined below.

### **Objectives**

- ❖ Evaluate winter grazing and supplementation response on cow reproduction and progeny performance.
- ❖ Determine the effects of different post-weaning rates of gain on steers and heifers and the subsequent results on performance and productivity.
- ❖ Compare the pregnancy rates of late-spring calving cows subjected to two different fixed-time AI protocols
- ❖ Identify the time interval from PGF<sub>2α</sub> administration to AI in two fixed-time AI protocols and the effect on heifer pregnancy rates

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## Chapter 2:

### Effects of Winter Supplementation on Cow Performance and Post-Weaning Management on Steer and Heifer Progeny in a Late Spring Calving System

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**ABSTRACT:** A trial was conducted to evaluate effects of winter supplementation on cow performance and effects of post-weaning management on steer and heifer progeny. Pregnant, May-calving, crossbred cows ( $n = 176$ ;  $BW = 477 \pm 69$  kg) grazed dormant upland range or meadow from December 1 to February 28 and received 0 or 0.45 kg/d (DM) of 32% CP supplement in a  $2 \times 2$  factorial arrangement. Calves were weaned January 1, blocked by BW and subsequently placed on 1 of 2 spring treatments: 1) graze dormant meadow with 0.45 kg/d supplement, or 2) offered meadow hay (ad libitum) plus 1.81 kg/d supplement. One half of steer calves from each spring system were then placed in a feedlot (calf-fed system) on May 15. The remaining steers and heifers grazed upland range until approximately August 30, when the steers were placed in a feedlot (yearling-fed system). Heifers were maintained in a single group. The first 2 yr of data are presented. Supplemented cows had increased ( $P < 0.01$ ) BCS and BW change over winter trt compared to unsupplemented cows. Subsequent pregnancy rates were not influenced ( $P = 0.60$ ) by winter treatment. Steers fed hay following weaning had increased ( $P = 0.03$ ) ADG during the spring compared with steers grazing meadow. In the yearling-fed system, hay-fed steers remained heavier ( $P = 0.05$ ) through second implant, although final BW was similar ( $P = 0.28$ ). Post-weaning management did not

influence steer carcass data. Heifers managed on hay post weaning had greater ( $P = 0.03$ ) ADG through spring treatment compared with meadow heifers; however, percent pubertal and pregnancy rates were similar ( $P = 0.49$ ). Post-weaning management affected calf BW from weaning through the treatment period; however, preliminary data indicate minimal effects of spring treatments on subsequent heifer pregnancy rate or steer feedlot and carcass characteristics.

**Key words:** beef cattle, supplementation, yearling systems

## INTRODUCTION

The greatest variable cost associated with cow-calf production is feed (May et al., 1999). The amount of harvested and purchased feed required to sustain a cow herd in the Nebraska Sandhills can be reduced by calving late in the spring, better matching the cow's nutrient requirement with grazed forage (Adams et al., 1996; Clark et al., 2004). Altering the calving date shifts production and market windows to a different time, which may be economically advantageous (Stockton et al., 2007). Shifting the calving date may also provide flexibility to sell calves at different ages and BW (Griffin et al., 2012). The nutritional requirements of a spring calving, beef cow grazing dormant Sandhills range during late gestation typically exceed the nutrient content of the grazed forage (NRC, 2000). Protein is commonly supplemented to maintain cow BCS during winter grazing. Supplementing protein also increases weaning BW and the proportion of live calves at weaning (Stalker et al., 2006). Supplementing beef cows during late gestation has been shown to affect the lifelong productivity of the calf by altering postweaning growth, carcass composition, calf health in the feedlot (Larson et al., 2009), and heifer fertility (Martin et al., 2007). Different post-weaning management of heifers can also

significantly affect progeny development as various rates of gain post-weaning have been shown to affect age at puberty and fertility in heifers (Patterson et al., 1992). Griffin et al. (2007) placed steers in two separate finishing systems and demonstrated differences in feed efficiency and final carcass characteristics. The objectives of the current study are to evaluate the effects of winter supplementation while grazing dormant Sandhills winter range or meadow on cow performance and effects of post-weaning management on steer and heifer progeny.

## MATERIALS AND METHODS

All procedures and facilities utilized are in accordance with the approval of the University of Nebraska-Lincoln Institutional Animal Care and Use Committee.

### *Cow-calf management*

An ongoing trial is being conducted utilizing composite Red Angus × Simmental cows and their progeny at the Gudmundsen Sandhills Laboratory (**GSL**), Whitman, and West Central Research and Extension Center (**WCREC**), North Platte. Cows grazed either dormant upland winter range or meadow from December 1 to March 29 and received 0 or 0.45 kg DM animal<sup>-1</sup>·d<sup>-1</sup> of a 32% CP supplement (Table 1). Supplement was delivered 3 times/wk on a pasture (35.6 ha) basis. Cows were managed as a common group the remainder of the year. Cows were estrus synchronized with a single injection of PGF<sub>2α</sub> (Lutalyse, Pfizer Animal Health, New York, NY ) 5 d after being placed with bulls (1:20 bull to cow ratio) beginning approximately August 1 and continuing for 45 d. Pregnancy was determined via rectal palpation or ultrasonography at weaning in early January. Cows were removed from the study for reproductive failure, calf death, or injury. After weaning, calves were placed on 1 of 2 spring treatments: graze dormant

meadow with 0.45 kg DM animal<sup>-1</sup>·d<sup>-1</sup> supplement (**MDW**), or offered meadow hay (ad libitum) and 1.81 kg DM animal<sup>-1</sup>·d<sup>-1</sup> supplement (**HAY**).

#### *Heifer management*

After January weaning, heifers were blocked by BW and assigned to either MDW or HAY treatment until May 15. Spring treatments were replicated twice. Following spring treatment, heifers were managed as a single group. Heifers were moved to upland range pastures for the breeding season. Two blood samples were collected 10 d apart prior to the breeding season. Heifers were considered estrous cycling if serum progesterone concentrations were > 1 ng/mL. Heifers were estrus synchronized with a single injection of PGF<sub>2α</sub> (Lutalyse, Pfizer Animal Health, New York, NY) 5 d after being placed with bulls (1:20 bull to heifer ratio) on approximately July 25 for 45 d. Pregnancy was determined via transrectal ultrasonography in late October. Data reported was collected in 2011 (n = 65) and 2012 (n = 65).

#### *Steer management*

After January weaning, steers were blocked by BW and assigned to either MDW or HAY treatment. Spring treatments were replicated twice. On May 15, one-half of the steers from each spring treatment were placed in a feedlot at WCREC (calf-fed system). The remaining steers were implanted with Revalor G (40 mg trenbolone acetate and 8 mg estradiol, Merck Animal Health, Summit, NJ) and subsequently grazed upland summer range until approximately August 30, and then placed in the feedlot (yearling-fed system). Upon feedlot entry, steers were limit fed 5 d at 2.0% BW, weighed 2 consecutive d, and adapted (21 d) to a common finishing diet of 48% dry rolled corn, 40% corn gluten feed, 7% prairie hay, and 5% supplement. In the calf-fed system,

Synovex Choice (100 mg trenbolone acetate and 14 mg estradiol benzoate, Ft. Dodge Animal Health, Overland Park, KS) was administered at feedlot entry and Synovex Plus (200 mg trenbolone acetate and 28 mg estradiol benzoate, Ft. Dodge Animal Health, Overland Park, KS) approximately 100 d later. In the yearling-fed system, Ralgro (36 mg zeranol, Merck Animal Health, Summit, NJ) was administered at feedlot entry, followed by Synovex Plus approximately 60 d later. Steers were slaughtered when estimated visually to have 1.3 cm fat thickness over the 12<sup>th</sup> rib. Steers were slaughtered at a commercial abattoir, and carcass data were collected after a 24 h chill. Final BW was calculated from HCW using a standard dressing percentage (63%). Data reported were collected in 2011 (n = 68) and 2012 (n = 54).

#### *Statistical analysis*

Cow and progeny winter, spring, and steer feedlot treatments were applied on a pasture or group basis. Pasture (n = 4/yr) served as experimental unit for cow performance and reproductive data. Spring treatment (n = 4/yr) served as experimental unit for heifers. Spring treatment × feedlot treatment served as the experimental unit for the steers. Data were analyzed with the GLIMMIX procedure of SAS (SAS Inst., Inc., Cary, NC). Model fixed effects for cow data included winter treatment and age. Spring treatment, feedlot system, and appropriate interactions ( $P < 0.05$ ) were included in the progeny model. Year was considered a random effect for cow and calf variables.

## **RESULTS AND DISCUSSION**

Cows that grazed meadow or received supplement had greater ( $P < 0.01$ ) BW gain over the treatment period compared to cows grazing range or without supplement (Table 2). Pasture and supplement also had a significant affect ( $P < 0.01$ ) on change in

BCS over winter treatment. Pasture treatment also had a significant affect ( $P < 0.01$ ) on pre-calving BCS. Winter treatments did not affect cow BW at precalving, prebreeding, or weaning ( $P > 0.10$ ). Calf birth BW, calving difficulty, calf vigor, were also not affected ( $P > 0.15$ ) by winter treatment. There was a tendency for an increase ( $P = 0.07$ ) in pregnancy rates for cows that grazed the meadow compared to cows grazing range pasture. A difference of 21 % ( $\pm 17$  %) in pregnancy rates was observed between the youngest (3-yr-old) cows and older cows despite a lack of significance (67 vs. 88%,  $P = 0.24$ ). This may be a result of limited data at this point. Moving to a late-spring calving season moves the breeding season to late summer, coinciding with declining forage nutrient quality, which may have a greater impact on pregnancy rates in young growing cows (Renss and Scarmuzzi, 2003).

The effects of spring management system on heifer progeny are presented in Table 3. Heifers on HAY treatment had greater ( $P = 0.03$ ) spring ADG than MDW heifers and tended ( $P = 0.10$ ) to have increased BW in May and July. Percent pubertal at the beginning of the breeding season and pregnancy rates were similar ( $P > 0.39$ ) between treatments. Patterson et al. (1992) reported improved nutrition during the post-weaning to prebreeding phase allowed for successful breeding of yearling beef heifers, whereas decreased nutritional levels during post-weaning to prebreeding delayed first estrus and pregnancy rates. Currently, heifers on HAY treatment have a numerically higher proportion of heifers pubertal prior to breeding (77.7 vs. 69.4%) and higher pregnancy rate (67.5 vs. 60.5%) compared with MDW heifers despite a lack of significance ( $P = 0.39$ ). Again, this may be related to limited data. Pregnancy rates were numerically (approximately 20%) lower than pregnancy rates in March-born heifers on

the same ranch (Larson et al., 2011), which may be a function of declining nutrient quality during the later breeding season. Younger cows and heifers may require supplemental nutrition during the breeding season to achieve similar pregnancy rates as beef females in an earlier spring calving herd. Funston et al. (2010) reported a tendency for heifers born to protein supplemented dams to be younger at puberty and have increased pregnancy rates. This tendency was not found in this data as heifers born to protein supplemented cows did not differ ( $P = 0.47$ ) from heifers born from non-supplemented dams for pubertal rates (73.1 vs. 67.9%) or pregnancy rates (78.5 vs. 75.0%) were similar thus far.

Steers on HAY treatment had greater ( $P = 0.03$ ) ADG compared with steers on MDW during the treatment period. In the calf-fed system, steers on HAY treatment tended to have greater ( $P = 0.06$ ) feedlot entry BW than steers on MDW treatment and tended ( $P = 0.06$ ) to have greater BW at second implant in August. Spring treatment did not influence ( $P > 0.10$ ) final BW or carcass characteristics in the calf-fed system (Table 4). In the yearling-fed system, steers on HAY treatment had greater ( $P = 0.05$ ) BW entering the feedlot in September until time of second implant ( $P = 0.02$ ) in November. Spring treatment had no effect ( $P > 0.10$ ) on final BW or carcass characteristics in the yearling-fed system. At present, with 2 yr of data, steers from the calf-fed and yearling-fed systems have similar ( $P \geq 0.34$ ) feedlot ADG and carcass characteristics. Previous research by Stalker et al. (2006) demonstrated steers born from protein supplemented cows had increased weaning BW. Larson et al (2009) also saw an increase in weaning BW, and increases in HCW and marbling score in spring calving cows.

Currently, neither winter management system for cows, or spring treatment for progeny has had significant effects on pregnancy rates or progeny performance.

Additional data and subsequent economic analysis are required to make specific recommendations relating to management strategies for a late spring calving herd in the Nebraska Sandhills.

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**Table 1.** Composition and nutrient analysis of supplement

Item	DM, %
Ingredient	
Dried distillers grains with solubles	62.0
Wheat middlings	11.0
Cottonseed meal	9.0
Dried corn gluten feed	5.0
Molasses	5.0
Calcium carbonate	3.0
Trace minerals and vitamins <sup>1</sup>	3.0
Urea	2.0
Nutrient	
CP	31.6
Undegradable intake protein, % CP	47.6
TDN	89.4

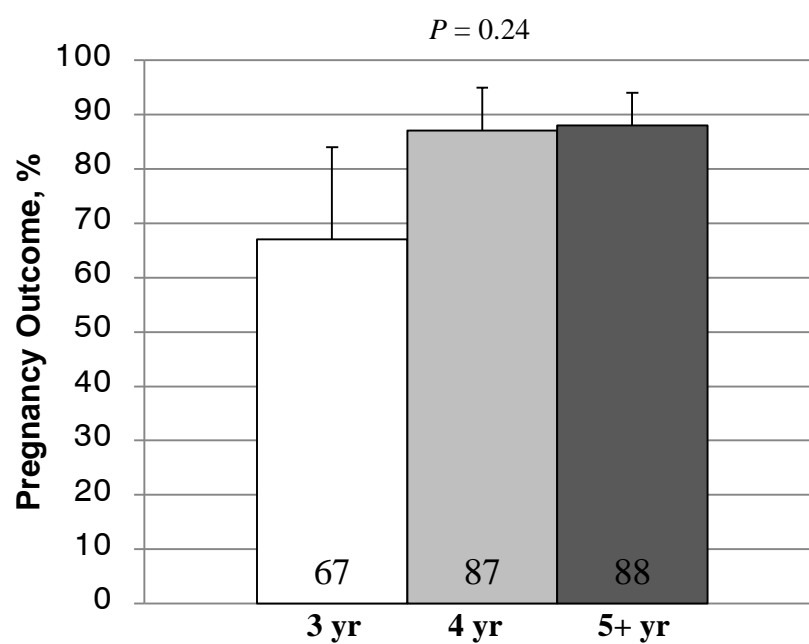
<sup>1</sup>Formulated to include 80 mg·0.45 kg monensin.

**Table 2.** Effects of winter grazing treatment<sup>1</sup> on cow BCS, BW, pregnancy rate, and calf BW

Item	Meadow		Range		SE	P-Value		
	NS	SUP	NS	SUP		Pasture	Supp.	Pasture x Supp.
Cow BCS								
January	4.4	4.4	4.5	4.4	0.2	0.64	0.39	0.65
Winter change	-0.2	0.0	0.0	0.2	0.1	<0.01	<0.01	0.18
Pre-calving	4.5	4.6	4.8	4.8	0.2	<0.01	0.20	0.58
Pre-breeding	5.3	5.4	5.4	5.4	0.1	0.31	0.61	0.46
Cow BW								
January BW, kg	448	453	450	447	9	0.87	0.93	0.68
Winter BW gain, kg	48	54	34	51	4	<0.01	<0.01	0.06
Pre-calving BW, kg	478	485	466	480	23	0.32	0.24	0.65
Pre-breeding BW, kg	489	481	500	499	0.1	0.50	0.60	0.57
Pregnancy rate, %	84.4	87.1	70.7	82.9	0.1	0.07	0.12	0.32
Calf BW								
Birth BW, kg	36	36	34	35	0.1	0.07	0.74	0.31
Pre-breeding BW, kg	101	97	97	102	2.5	0.74	0.96	0.07
Weaning BW, kg	198	197	192	199	3.6	0.66	0.44	0.24

<sup>1</sup>Winter grazing treatments: Meadow = dams grazed dormant meadow, Range = dams grazed dormant range, NS = animals received no supplementation, SUP = animals received 0.45 kg DM·animal<sup>-1</sup>·d<sup>-1</sup> 32% CP supplement.

**Figure 1.** The effects of cow age<sup>1</sup> on cow pregnancy rates in a late spring calving system.



<sup>1</sup>Age determined by animal date of birth. Any animals 5 years of age or greater were included in 5+ yr.

**Table 3.** Effects of spring grazing treatment on heifer performance<sup>1</sup>

	HAY	MDW	SE	<i>P</i> -Value
Winter ADG <sup>2</sup> , kg	0.69	0.38	0.02	0.03
May BW, kg	279	238	3	0.07
June BW, kg	311	279	4	0.12
July BW, kg	326	295	4	0.10
May to July ADG <sup>3</sup> , kg	0.80	0.94	0.03	0.18
October BW, kg	370	342	4	0.12
July to October ADG <sup>4</sup> , kg	0.42	0.46	0.04	0.34
October BCS	5.7	5.5	0.05	0.22
Pubertal <sup>5</sup> , %	77.7	69.4	7.7	0.47
Pregnancy rate, %	67.5	60.5	3.6	0.39

<sup>1</sup>Winter grazing treatments: HAY = heifers offered meadow hay (ad libitum) plus 1.81 kg DM·animal<sup>-1</sup>·d<sup>-1</sup> 32% CP supplement; MDW = heifers grazed winter meadow with 0.45 kg DM·animal<sup>-1</sup>·d<sup>-1</sup> 32% CP supplement.

<sup>2</sup>Calculated from January weaning date to end of winter treatment on May 15 (126 d).

<sup>3</sup>Calculated from removal of winter treatment on May 15 to July 14 (60 d).

<sup>4</sup>Calculated from July 14 to Oct 26 (104 d).

<sup>5</sup>Considered pubertal if serum progesterone concentrations were > 1 ng/mL.

**Table 4.** Effects of spring treatment and feedlot system on steer performance<sup>1</sup>

	HAY		MDW		SE	P-Value		
	Calf-fed	Yearling-fed	Calf-fed	Yearling-fed		Winter	System	Winter x System
Winter ADG <sup>2</sup> , kg	0.68	0.71	0.36	0.36	0.02	0.03	0.64	0.63
May BW, kg	289	295	252	248	5	0.07	0.86	0.48
Feedlot entry, kg	289	367	252	337	6.8	0.06	0.09	0.62
Feedlot ADG <sup>3</sup> , kg	1.77	1.90	1.90	1.88	0.01	0.47	0.39	0.31
Final BW, kg	667	684	656	649	13	0.28	0.77	0.42
HCW, kg	420	431	413	409	7	0.28	0.77	0.42
Marbling score <sup>4</sup> , kg	520	555	521	544	8.4	0.71	0.43	0.70
12 <sup>th</sup> rib fat, cm	1.43	1.50	1.43	1.47	0.09	0.90	0.65	0.88
LM area, cm <sup>2</sup>	95	96	93	92	3	0.41	0.94	0.76
Yield grade	3.17	3.36	3.25	3.35	0.12	0.83	0.43	0.78
USDA Choice, %	93.4	96.3	90.1	100.0	0.06	0.95	0.34	0.52
Upper 2/3 Choice, %	0.03	0.03	0.03	0.06	0.38	0.75	0.74	0.75
1,000 lb carcass, %	10.8	28.1	18.1	4.3	0.09	0.42	0.83	0.84

<sup>1</sup>Winter grazing treatments: HAY = heifers offered meadow hay (ad libitum) plus 1.81 kg DM·animal<sup>-1</sup>·d<sup>-1</sup> 32% CP supplement; MDW = heifers grazed winter meadow with 0.45 kg DM·animal<sup>-1</sup>·d<sup>-1</sup> 32% CP supplement. Feedlot System: Calf-fed = steers entering feedlot on May 15; Yearling-fed = steers entering feedlot on August 30.

<sup>2</sup>Calculated from January weaning to end of winter treatment on May 15 (126 d).

<sup>3</sup>Calculated feedlot ADG 210 d for calf-fed system and 167 d for yearling-fed system.

<sup>4</sup>Small<sup>00</sup> = 400.

### Chapter 3:

## Effect of Two Estrus Synchronization Protocols on Reproductive Performance of May Calving Cows

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**ABSTRACT:** A 2 yr study was conducted utilizing Red Angus × Simmental cows (yr 1 n = 145, yr 2 n = 162). Cows were randomly assigned to 1 of 2 treatments: 1) cows received GnRH (100 µg, i.m.) on d 0, PGF<sub>2α</sub> (25 mg, i.m.) on d 7, and GnRH (100 µg, i.m.) with fixed-time AI (**TAI**) 48 h after PGF<sub>2α</sub> (**CO-Synch**); or 2) cows received GnRH (100 µg, i.m.) and controlled internal device release (**CIDR**) insertion on d 0, PGF<sub>2α</sub> (25 mg, i.m.) and CIDR removal on d 7, and GnRH (100 µg, i.m.) with TAI 60 h after PGF<sub>2α</sub> (**CO-Synch** + **CIDR**). Five d after TAI, bulls were placed with cows for 45 d. Cows synchronized with the CO-Synch + CIDR protocol had increased ( $P < 0.01$ ) AI and overall pregnancy rates compared to cows synchronized utilizing the CO-Synch protocol. Due to increased AI pregnancy rates, CO-Synch + CIDR cows calved 5 d ( $\pm 1$  d) earlier ( $P < 0.01$ ), resulting in a greater ( $P < 0.01$ ) proportion of cows calving within the first 21 d of the calving season compared to CO-Synch cows. However, calf weaning BW was similar among treatments ( $P = 0.76$ ). In conclusion, pregnancy rates were greater for CO-Synch + CIDR compared to the CO-Synch synchronization protocol, resulting in more calves born earlier in the calving season.

**Key Words:** artificial insemination, beef cow, controlled internal drug-release device, estrus synchronization

## INTRODUCTION

In the North Central Great Plains, the breeding season for spring calving systems coincides with high forage nutrient values (Adams et al., 1996), however, harvested forage is often needed to support increased cow nutrient demands during late gestation and early lactation. Moving the calving season to early summer could reduce harvested forage inputs (Clark et al., 2004) and would shift the breeding season to late summer, coinciding with reduced forage nutrient quality and increased environmental temperatures, possibly impacting reproductive performance (Rensis and Scarmuzzi, 2003). Estrus synchronization may allow more cows to become pregnant earlier in the breeding season as forage quality declines; which in turn, can shorten the calving season, increase calf uniformity, and decrease AI labor (Larson et al., 2006; Lamb et al., 2010). Protocols using prostaglandin  $F_{2\alpha}$  (**PGF<sub>2 $\alpha$</sub>** ), gonadotropin releasing hormone (**GnRH**), and/or a progestin have been developed to induce cyclicity and successfully synchronize estrus in beef cows (Thompson et al., 1999). The **CO-Synch** protocol in which PGF<sub>2 $\alpha$</sub>  is administered 7 d after GnRH followed by a second injection of GnRH and fixed time AI (**TAI**) 48 h after PGF<sub>2 $\alpha$</sub>  administration was compared with and without controlled internal device release (**CIDR**), however TAI occurred at 60 h and reported pregnancy rates were 43 and 54% respectively (Larson et al., 2006). Utilizing the CO-Synch protocol, 5 to 20% of cows will exhibit estrus before and immediately after PGF<sub>2 $\alpha$</sub>  administration, resulting in a recommendation for TAI 48 h after PGF<sub>2 $\alpha$</sub>  administration (Kojima et al., 2000; Lamb et al., 2001; Larson et al., 2006). Adding a controlled internal drug release (**CIDR**) device improved AI pregnancy rates in cows TAI 56 + h after PGF<sub>2 $\alpha$</sub>  administration (Dobbins et al., 2009). A direct comparison of these 2 protocols has not



been made. Therefore, the objective of this study was to compare the effects of utilizing the CO-Synch or CO-Synch + CIDR TAI protocol on reproductive performance of May calving cows.

## MATERIALS AND METHODS

The University of Nebraska-Lincoln Institutional Animal Care and Use Committee approved the procedures and facilities used in this experiment.

### *Cow Management and Estrus Synchronization*

Red Angus  $\times$  Simmental Cows (yr 1 n = 145, yr 2 n = 162) were utilized in a 2 yr study at the Gudmundsen Sandhills Laboratory (**GSL**), Whitman, NE. Cows were randomly assigned to 1 of 2 estrus synchronization protocols (Figure 1). Cows assigned to CO-Synch received 100  $\mu$ g i.m. of GnRH (Cystorelin, Merial, Duluth, GA) on d 0, 25 mg i.m. of PGF<sub>2 $\alpha$</sub>  (dinoprost tromethamine; Lutalyse, Zoetis, Florham Park, NJ) on d 7, and GnRH with TAI 48 h after PGF<sub>2 $\alpha$</sub>  administration. Cows assigned to CO-Synch + CIDR received GnRH with an intravaginal progesterone releasing insert (CIDR, Zoetis, Florham Park, NJ) for 7 d. At d 7 the CIDR was removed, PGF<sub>2 $\alpha$</sub>  was administered, and GnRH with TAI 60 h after PGF<sub>2 $\alpha$</sub>  administration. Five d after TAI, cows were placed with bulls for 45 d. Final pregnancy rate was determined using transrectal ultrasonography (Aloka SSD 500 with 7.5-MHz linear probe, Aloka Co. Ltd., Wallingford, CT) 45 d after bull removal. Artificial insemination conception rates were determined based on calving date with d from TAI to calving calculated at 281 ( $\pm$  4 d) based on average gestation lengths reported in previous literature for AI sires (Larson et al., 2006). Days to calving were calculated as d from TAI to calving for all cows that

calved. Cow BW and BCS were measured at breeding, pregnancy determination, and calving.

### *Statistical Analysis*

The study was replicated over 2 yr with cows being randomly assigned to 1 of 2 estrus synchronization protocols each yr, thus animal was the experimental unit. Data were analyzed utilizing the MIXED and GLIMMIX procedures of SAS (SAS Inst. Inc., Cary, NC). The statistical model included synchronization protocol as the fixed effect with yr and cow age as random effects. Calf sire and cow postpartum interval (calculated as calving date to TAI) were included in original model, but were not significant sources of variation and removed. A  $P$ -value  $\leq 0.05$  was considered significant.

## **RESULTS AND DISCUSSION**

Artificial insemination and final pregnancy rates were greater ( $P < 0.01$ ) for CO-Synch + CIDR synchronized cows compared to CO-Synch synchronized cows (Table 1). Previous research indicates progesterone from the CIDR increases pregnancy rates resulting in an earlier calving date (Lamb et al., 2001) and the CO-Synch + CIDR protocol may also have been more effective in initiating ovulation in anestrus cows leading to higher pregnancy rates. One factor impacting the efficacy of estrus synchronization protocols is the proportion of anestrus cattle in the herd at the initiation of the protocol (Short et al., 1990). However, progestins have been shown to initiate ovulation and estrus in a proportion of anestrus cows (Fike et al., 1997; Lucy et al., 2001). Progestogen activity on the ovary increases LH secretion causing an increase in follicular development leading to ovulation (Lucy et al., 2001). Although the CO-Synch protocol is less expensive (Geary et al., 2001), a disadvantage of this protocol is cycling

cows with low concentrations of progesterone at the time of PGF<sub>2α</sub> could be in proestrus or in estrus shortly before or immediately after PGF<sub>2α</sub> injection (Kojima et al., 2000; Lamb et al., 2001; Larson et al., 2006). PGF<sub>2α</sub> will not regress developing corpora lutea (CL) that are not present on the ovary during the first 5 d of the estrous cycle. Regression of the CL is required for the development of a preovulatory follicle, estrus behavior, and ovulation (Lucy et al., 2001). Unless these cows are detected in estrus and inseminated, they will fail to become pregnant at the time of AI. The addition of progesterone in the CO-Synch + CIDR protocol prevents the premature occurrence of estrus prior to or following PGF<sub>2α</sub> (Larson et al., 2006).

There was a 56 d difference ( $P < 0.05$ ) in postpartum interval between yr 1 and yr 2 as cows were converted from March to May calving the first yr of the study, however AI and final pregnancy rates were similar ( $P \geq 0.09$ ) between yr. There was no yr  $\times$  treatment interaction for AI pregnancy rate; however, final pregnancy rate was similar in yr 1, but greater for CO-Synch + CIDR in yr 2 ( $P < 0.01$ ). Cow age, BW, and BCS were similar ( $P \geq 0.13$ ) between synchronization treatments. There was a decrease in cow BCS from the prebreeding to pregnancy diagnosis. This decrease is likely due to the decreasing quality of forage during the breeding season. This decline in forage quality during the breeding season and early gestation could cause reductions in placental vascularity and function (Funston et al., 2010). Protein supplementation has been shown to increase uterine blood flow possibly increasing progeny performance due to increased nutrient transfer to the fetus (Funston and Summers, 2013). Calving date and d to calving were greater ( $P < 0.05$ ; Table 2) for the CO-Synch compared to the CO-Synch + CIDR protocols. A greater ( $P < 0.01$ ) percentage of CO-Synch + CIDR cows calved within the

first 21 d of the calving season. Heifers that calve earlier in the calving season tend to remain in the calving group throughout their life and wean a heavier calf through future production. Through six parturitions heifers that calved in the earliest calving group had an increase in weaning weight that amounted to the production of an extra calf in their lifetime (Cushman et al., 2013). There was a significant increase ( $P = 0.02$ ) in percent calf crop weaned per cow exposed in the CO-Synch + CIDR dams. There was a tendency ( $P = 0.09$ ) for the birth BW of calves from CO-Synch dams to be heavier than calves from CO-Synch + CIDR dams. Previous research indicates calves born in the first 21 d of the calving period are lighter at birth compared to calves born later in the calving season (Funston et al., 2012). Although calf prebreeding BW or weaning BW were not different ( $P \geq 0.14$ ), research has shown that calves born earlier in the calving season will have greater weaning BW compared to calves born later in the calving season (Funston et al., 2012). There was an increase ( $P = 0.04$ ) in weaning weight per cow exposed in the CO-Synch + CIDR dams. This is due to the higher percentage of cows that were pregnant in the CO-Synch + CIDR protocol compared to the CO-Synch protocol.

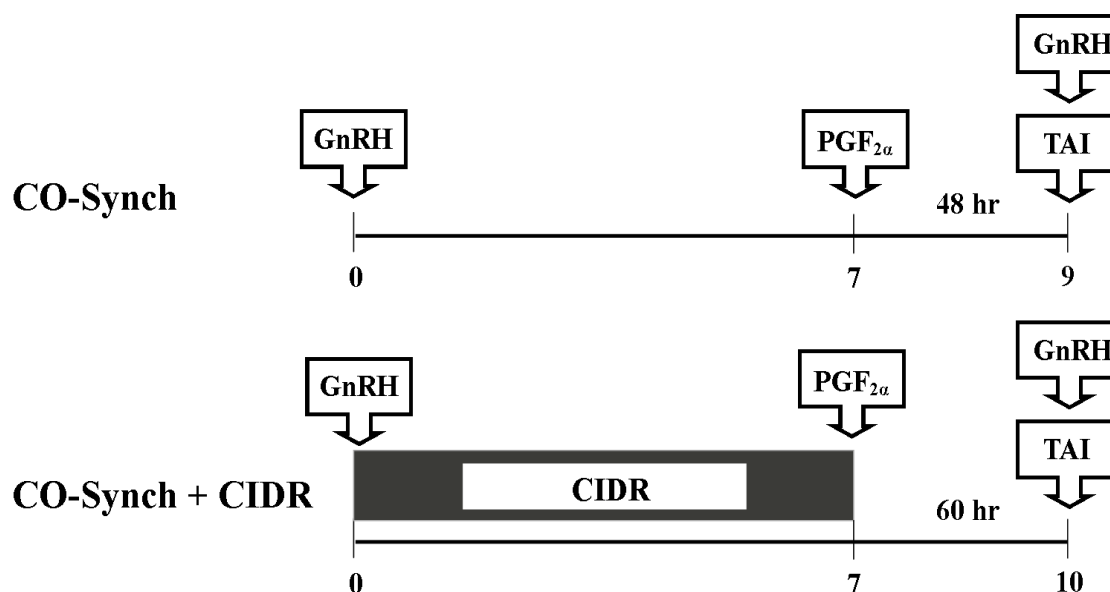
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**Figure 1.** Treatment schedules for cows assigned to CO-Synch and CO-Synch + CIDR protocols. Cows assigned to CO-Synch were administered GnRH (100 µg, i.m., Cystorelin) on d 0, PGF<sub>2α</sub> (25.m.g., i.m., Lutalyse) on d 7 and GnRH and fixed-time AI (TAI) 48 h after PGF<sub>2α</sub> administration. CO-Synch + CIDR cows received GnRH and CIDR insertion on d 0, on d 7 CIDR was removed and PGF<sub>2α</sub> was administered, and GnRH and TAI 60 h after PGF<sub>2α</sub> administration.



**Table 1.** Effect of CO-Synch vs. CO-Synch + CIDR estrus synchronization protocol on cow reproductive performance.

Item	CO-synch <sup>1</sup>	CO-synch + CIDR <sup>2</sup>	SEM	<i>P</i> -value
Cow age, yr	4.5	4.5	0.3	0.86
PPI <sup>3</sup> , d	109	110	28	0.61
Prebreeding BW, kg	528	523	25	0.30
Prebreeding BCS	5.5	5.6	0.2	0.25
Pregnancy diagnosis BW, kg	456	455	32	0.77
Pregnancy diagnosis BCS	4.6	4.7	0.2	0.19
Precalving BW, kg	496	488	20	0.11
Precalving BCS	4.8	4.7	0.2	0.57
AI pregnancy rate, %	32	54	4	<0.01
Final pregnancy rate, %	86	95	5	<0.01

<sup>1</sup> CO-Synch = 100 µg of GnRH (i.m., d 0), 25 mg of PGF<sub>2α</sub> (i.m., d 7) 100 µg of GnRH and TAI 48 h after PGF<sub>2α</sub>.

<sup>2</sup> CO-Synch + CIDR = 100 µg of GnRH and CIDR insertion (i.m., d 0), 25 mg of PGF<sub>2α</sub> and CIDR removal (i.m., d 7), 100 µg of GnRH and TAI 60 h after PGF<sub>2α</sub>.

<sup>3</sup> Postpartum interval.



**Table 2.** Effect of CO-Synch vs. CO-Synch + CIDR estrus synchronization protocol on calving performance.

Item	CO-synch <sup>1</sup>	CO-synch + CIDR <sup>2</sup>	SEM	P-value
Calving date, Julian d	145	140	1	<0.01
Days to calving <sup>3</sup> , d	293	288	1	<0.01
Calved first 21d, %	76	90	3	<0.01
Calf birth BW, kg	36	35	1	0.09
Prebreeding calf BW, kg	98	101	2	0.14
Weaning calf BW, kg	196	195	6	0.76
Calf crop weaned per cow exposed, %	76	86	1	0.02
Weaning BW per cow exposed, kg	149	168	22	0.04

<sup>1</sup> CO-Synch = 100 µg of GnRH (i.m., d 0), 25 mg of PGF<sub>2α</sub> (i.m., d 7) 100 µg of GnRH and TAI 48 h after PGF<sub>2α</sub>.

<sup>2</sup> CO-Synch + CIDR = 100 µg of GnRH and CIDR insertion (i.m., d 0), 25 mg of PGF<sub>2α</sub> and CIDR removal (i.m., d 7), 100 µg of GnRH and TAI 60 h after PGF<sub>2α</sub>.

<sup>3</sup> Days to calving from TAI for all cows that calved.

## Chapter 4:

### **Influence of induced early luteal regression and the effects of interval from PGF to AI on pregnancy rates in fixed-time AI synchronization systems**

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**ABSTRACT:** The objective of three experiments was to determine whether luteal regression at the onset of a fixed-time AI (**TAI**) protocol would improve pregnancy rates and if the time interval between PGF<sub>2α</sub> administration and TAI would affect pregnancy rates. Two experiments were conducted using yearling crossbred heifers: 1) heifers (n = 232) were blocked by BW into two groups and administered GnRH (100 µg, i.m.; **CO-Synch + CIDR**), or GnRH and PGF<sub>2α</sub> (25 mg, i.m.; **CO-Synch + CIDR, PGF<sub>2α</sub>**) with a controlled internal device release (**CIDR**) on d 0, CIDR removal and PGF<sub>2α</sub> on d 7, and TAI + GnRH 56 h later; 2) heifers (n = 1446) were randomly divided into five groups and received melengesterol acetate (**MGA**; 0.5 mg·animal<sup>-1</sup>·d<sup>-1</sup>) for 14 d, with PGF<sub>2α</sub> administered 19 d after last d of feeding MGA, and TAI approximately 72 h later with GnRH (**MGA-PGF & TAI**). Injection of PGF<sub>2α</sub> at the onset of the TAI protocol did not significantly increase pregnancy rates ( $P = 0.42$ ). Time interval between PGF<sub>2α</sub> administration and TAI did not have a significant ( $P \geq 0.05$ ) on pregnancy rates. In conclusion, PGF<sub>2α</sub> administration at the onset of the CO-Synch + CIDR protocol to induce luteal regression did not affect pregnancy rates and variations in the time between PGF<sub>2α</sub> administration and TAI did not decrease pregnancy rates.

**Key Words:** artificial insemination, beef heifers, estrus synchronization

## INTRODUCTION

Estrus synchronization and AI allow producers to shorten the breeding and calving seasons, produce a more uniform calf crop, and increase the genetic merit of their herd by being able to select for more desirable traits. Beef producers have been slow to adopt these technologies into their production system (NAHMS, 1997). To enhance the use of these technologies, protocols need to minimize the number and frequency of animal handlings and eliminate the need for estrus detection. Development of synchronization protocols that result in a highly synchronized and fertile estrus and ovulation can utilize fixed-time AI (**TAI**) and may increase the adoption of AI in beef herds (Busch et al., 2008; Patterson et al., 2003). The discovery that ovarian follicles in cattle grow in distinct wave-like patterns, with one follicle becoming dominant (Fortune et al., 1988) led to the development of numerous TAI synchronization protocols. The utilization of progestins, such as controlled internal drug release (**CIDR**) and melengestrol acetate (**MGA**), is beneficial to stimulate noncycling cows and heifers, and prevent premature estrus. The inclusion of a CIDR in the CO-Synch protocol increased pregnancy rates in cows TAI 48 hr after prostaglandin  $F_{2\alpha}$  (**PGF<sub>2\alpha</sub>**) administration (Lamb et al., 2001). Variations in pregnancy rate have been found when TAI occurs at different time intervals after  $PGF_{2\alpha}$  administration. Pregnancy rates in beef cows utilizing the CO-Synch + CIDR protocol were higher with TAI 56 h (Dobbins et al., 2009) and 66 h (Busch et al., 2008) after  $PGF_{2\alpha}$  administration compared to early and later TAI. Inducing luteal regression 3 d before a CIDR protocol resulted in increased pregnancy rates (Perry et al., 2012). In a 14 d MGA-  $PGF_{2\alpha}$  protocol, TAI 72 h after  $PGF_{2\alpha}$  administration

resulted in similar synchronized pregnancy rates in heifers compared to heifers AI on estrus detection (King et al., 1994). Fixed-time AI at 60 h after PGF<sub>2α</sub> resulted in decreased pregnancy rates compared to estrus detection and AI in MGA protocols (Johnson and Day, 2004). The variation in time from PGF<sub>2α</sub> to TAI could be effected by animal handling. The objectives of these studies were to determine the effects of PGF<sub>2α</sub> administration at the onset of the CO-Synch + CIDR protocol, and if TAI pregnancy rates in CIDR and MGA-based synchronization protocols are affected by early or late TAI due to animal handling following administration of PGF<sub>2α</sub>.

## MATERIALS AND METHODS

All procedures and facilities utilized are in accordance with the approval of the University of Nebraska-Lincoln Institutional Animal Care and Use Committee.

### *Heifer Management and Estrus Synchronization*

Yearling crossbred heifers (n = 232) were blocked by BW into two groups and randomly assigned to 1 of 2 TAI protocols (Figure 1). Heifers assigned to the CO-Synch + CIDR received 100 µg i.m. of GnRH (Cystorelin, Merial, Duluth, GA) and insertion of a CIDR (1.38 g of progesterone; Zoetis, Florham Park, NJ) on d 0. Half of the heifers randomly received 25mg i.m. of PGF<sub>2α</sub> (dinoprost tromethamine; Lutalyse, Zoetis, Florham Park, NJ) also on d 0. CIDRs were removed on d 7 and heifers received PGF<sub>2α</sub>, AI was performed approximately 56 h after CIDR removal. All heifers received GnRH at time on insemination and AI was performed by 4 experienced technicians. The time of PGF<sub>2α</sub> administration on d 7 and AI were recorded for each heifer. Body weight was recorded at the time of CIDR insertion and again at pregnancy determination. At a different location, a separate herd of yearling crossbred heifers (n = 1446) were randomly

divided into five handling groups and received a MGA-PGF<sub>2α</sub> based TAI protocol (Figure 1). All heifers were fed 0.5 mg of MGA·animal<sup>-1</sup>·d<sup>-1</sup> (MGA 200 Premix; Zoetis, Florham Park, NJ) for 14 d (d 0 to 14 of the experiment) and administered PGF<sub>2α</sub> 19 d after the last d of feeding MGA. Seventy-two hours after PGF<sub>2α</sub> administration, heifers were administered GnRH and received TAI. Time of PGF<sub>2α</sub> administration and AI were recorded. Heifers exhibiting signs of estrus after the treatment were marked non-pregnant and received AI 12 h later. Heifers were AI by 7 experienced technicians. Pregnancy rates were determined utilizing transrectal ultrasonography (Aloka SSD 500 with 7.5-MHz linear probe, Aloka Co. Ltd., Wallingford, CT) 45 d after AI.

### *Statistical Analysis*

Data were analyzed utilizing the GLIMMIX procedure of SAS (SAS Inst. Inc., Cary, NC). The synchronization protocol was included as the fixed effect with group, AI technician, and source of heifers included as random effects. Logistic regression analysis was used to examine effects of time and ADG on pregnancy rates. A *P* value ≤ 0.05 was considered significant.

## **RESULTS AND DISCUSSION**

Administration of exogenous GnRH has been used to cause ovulation of dominant follicles and to synchronize follicular waves in heifers and cows (Bo et al., 1995). Concentrations of steroids at GnRH administration are known to influence the magnitude and duration of the GnRH-induced LH surge (Price and Webb, 1988). Elevated concentrations of progesterone at the time of GnRH administration decreases the GnRH-induced LH surge (Colazo et al., 2008), and smaller ovulatory follicles have a reduced response to the LH surge (Perry and Perry, 2009). Priming of the pituitary gland to

release LH is believed to be controlled by estradiol (Reeves et al., 1971; Kesner et al., 1981; Padmanabhan et al., 1982). However, progesterone is also capable of suppressing GnRH receptors in the hypothalamus (Nett et al., 2002).

Injection of PGF<sub>2α</sub> causes regression of the corpus luteum (CL) in cycling animals and the majority should express estrus within 5 d (Lauderdale, 2009). Perry et al. (2012) induced luteal regression 3 d before the injection of GnRH and increased the percentage of cows that ovulated compared to cows administered GnRH at random times throughout their estrous cycles. Cows that received PGF<sub>2α</sub> before GnRH had significantly higher pregnancy rates compared to cows that did not (64 vs. 55%). To minimize handling of heifers, PGF<sub>2α</sub> was administered with GnRH at the onset of the protocol in this study. Carvalho et al. (2008) treated heifers with PGF<sub>2α</sub> at the onset of a CIDR estrus synchronization protocol and saw reduced serum progesterone concentrations, resulting in increased diameter of the dominant follicle and increased ovulation rates. In this study, there was no difference ( $P = 0.42$ ) in pregnancy rates when administering PGF<sub>2α</sub> at the onset of the CO-Synch + CIDR protocols (Figure 2).

Timing of insemination has been shown to effect pregnancy rates in CIDR based protocols. Peeler et al. (2004) had higher pregnancy rates 56 h after CIDR removal and PGF<sub>2α</sub> administration. In young cows, Dobbins et al. (2009) reported higher pregnancy rates at AI 56 h after CIDR removal and PGF<sub>2α</sub> administration. In the current study, time interval from PGF<sub>2α</sub> administration to TAI had no effect ( $P=0.60$ ) on pregnancy rates (48 vs. 43%; Figure 3). Time interval in the current study ranged from 52 to 60 h which may not be enough variation to result in pregnancy differences. Average daily gain from TAI

to pregnancy determination did not affect ( $P = 0.79$ ) pregnancy rates (Figure 5). There were no significant differences due to technician or group ( $P \geq 0.05$ ).

The peak estrus response in a MGA- PGF<sub>2α</sub> base protocol is 60 h after PGF administration. Previous research has observed TAI 48 to 72 h after PGF<sub>2α</sub> administration and has indicated that conception rates increase as interval to AI approached 60 to 72 h (Johnson and Day, 2004). Patterson et al. (1999) reported pregnancy rates of TAI 72 h after PGF<sub>2α</sub> (53%) did not differ from double insemination at 65 and 85 h (49%). In the current study, the effect of time from PGF<sub>2α</sub> to AI did not significantly ( $P = 0.47$ ) affect pregnancy rate (Figure 4). Variations in time interval from PGF<sub>2α</sub> to AI was 69 to 75, which appears to be within an acceptable range. Artificial insemination technician, group, or source of cattle did not have a significant effect ( $P \geq 0.05$ ) on pregnancy rates. In conclusion, administration of PGF<sub>2α</sub> at the onset of the CO-Synch + CIDR protocol did not improve pregnancy rates and the variations in time interval from PGF<sub>2α</sub> administration to TAI due to animal handling did not have a significant effect on pregnancy rates.

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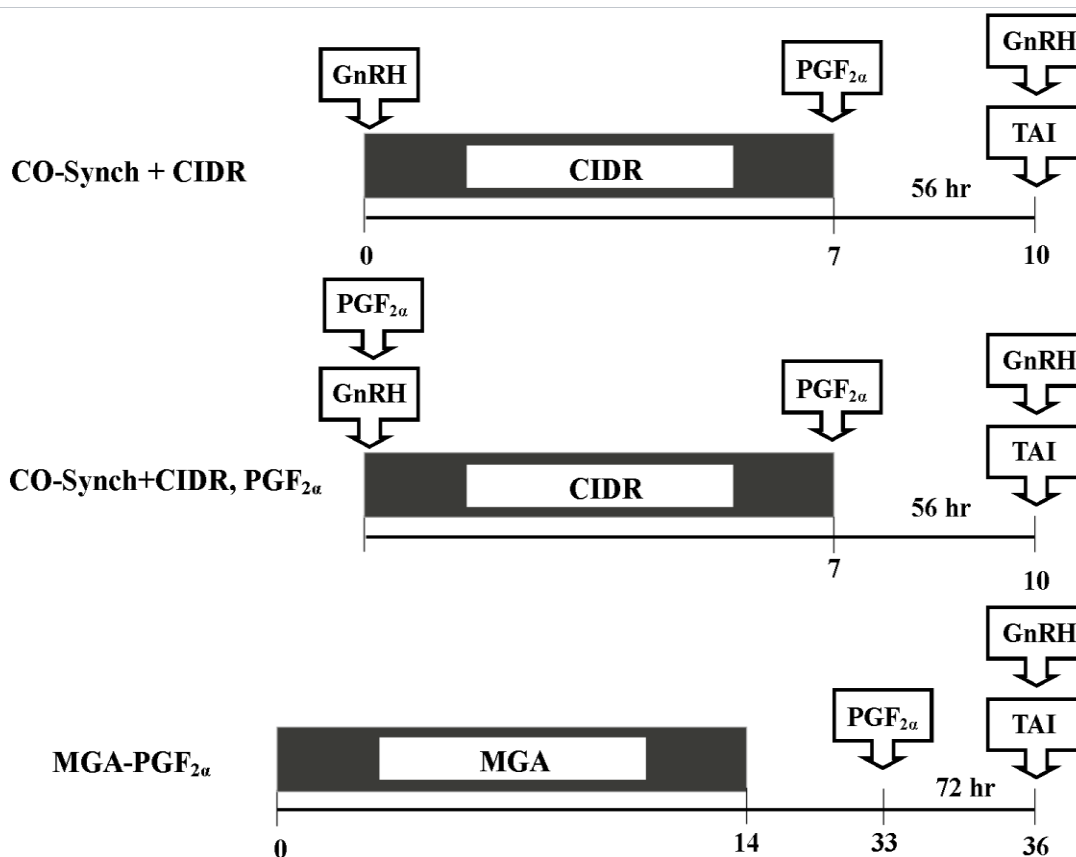
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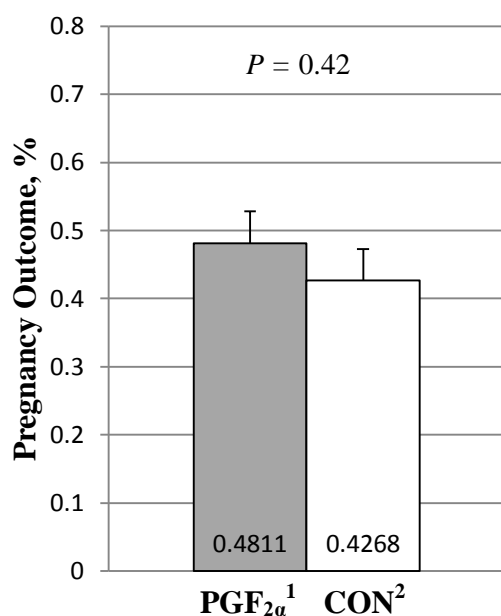


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**Figure 1.** Treatment schedules for heifers assigned to: CO-Synch + CIDR; CO-Synch + CIDR,  $\text{PGF}_{2\alpha}$ ; and MGA -  $\text{PGF}_{2\alpha}$  protocols. CO-Synch + CIDR cows received GnRH (100  $\mu\text{g}$ , i.m., Cystorelin) and CIDR insertion on d 0, on d 7 CIDR was removed and  $\text{PGF}_{2\alpha}$  (25.m.g., i.m., Lutalyse) was administered, and GnRH and fixed-time AI (TAI) 56 h after  $\text{PGF}_{2\alpha}$  administration. CO-Synch + CIDR,  $\text{PGF}_{2\alpha}$  received GnRH,  $\text{PGF}_{2\alpha}$ , and CIDR insertion on d 0, on d 7 CIDR removed and  $\text{PGF}_{2\alpha}$  was administered with GnRH and TAI 56 h later. MGA -  $\text{PGF}_{2\alpha}$  heifers were fed MGA (0.5 mg·d, MGA 200 premix) for 14 d. On d 33 heifers were administered  $\text{PGF}_{2\alpha}$  and GnRH and TAI was done 72 h later.



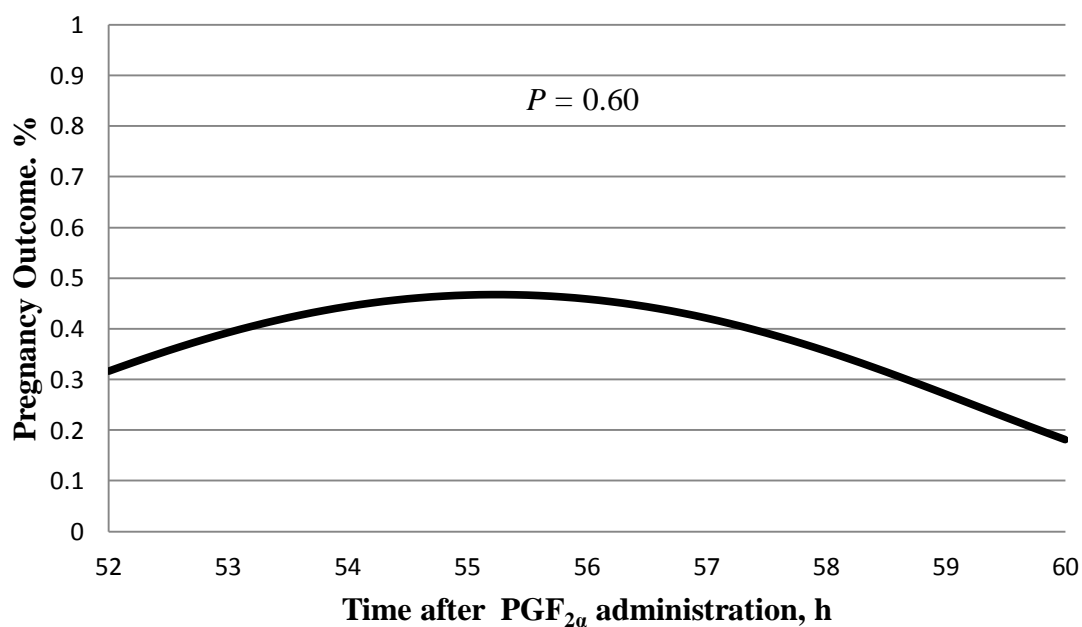
**Figure 2.** Pregnancy rates for CO-Synch + CIDR (**CON**) and CO-Synch + CIDR, PGF<sub>2α</sub> (PGF<sub>2α</sub>) estrus synchronization protocols.



<sup>1</sup>CO-Synch + CIDR = 100 µg of GnRH and CIDR insertion (i.m. d 0), 25 mg of PGF<sub>2α</sub> and CIDR removal (i.m. d 7), 100 µg of GnRH and TAI 56 h after PGF<sub>2α</sub>.

<sup>2</sup>CO-Synch + CIDR, PGF<sub>2α</sub> = 100 µg of GnRH, 25 mg of PGF<sub>2α</sub>, and CIDR insertion (i.m. d 0), 25 mg PGF<sub>2α</sub> and CIDR removal (i.m. d 7), 100 µg of GnRH and TAI 56 h after PGF<sub>2α</sub>.

**Figure 3.** Logistic regression<sup>1</sup> on the effects time interval between PGF<sub>2α</sub> administration on d 7 and TAI for the CO-Synch + CIDR<sup>2</sup> and the CO-Synch + CIDR, PGF<sub>2α</sub><sup>3</sup> estrus synchronization protocols.

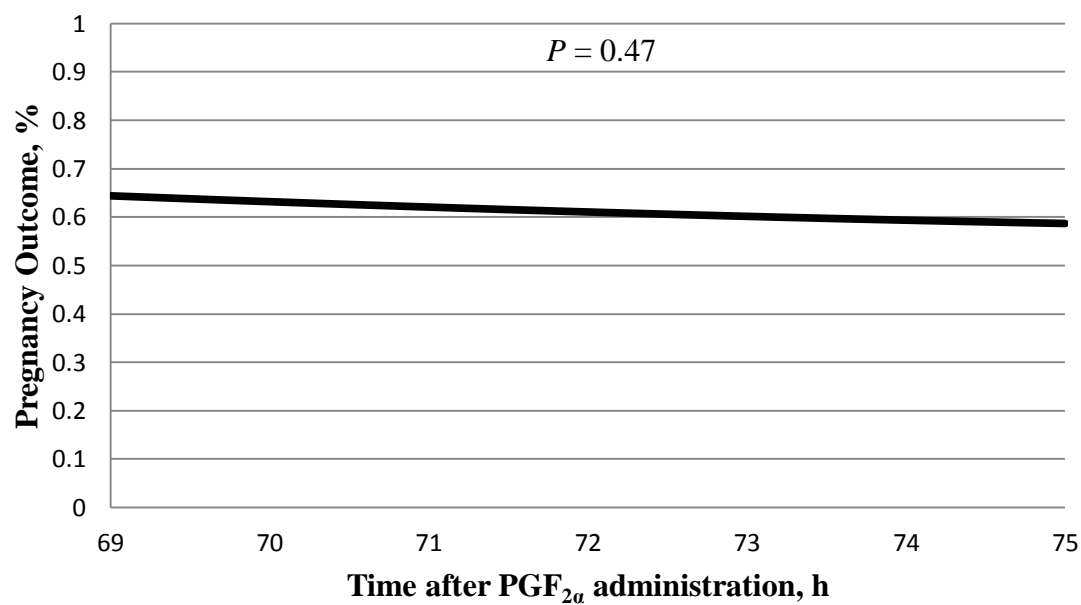


<sup>1</sup>Logistic regression analyzed utilizing the GLIMMIX procedure of SAS

<sup>2</sup>CO-Synch + CIDR = 100 µg of GnRH and CIDR insertion (i.m. d 0), 25 mg of PGF<sub>2α</sub> and CIDR removal (i.m. d 7), 100 µg of GnRH and TAI 56 h after PGF<sub>2α</sub>.

<sup>3</sup>CO-Synch + CIDR, PGF<sub>2α</sub> = 100 µg of GnRH, 25 mg of PGF<sub>2α</sub>, and CIDR insertion (i.m. d 0), 25 mg PGF<sub>2α</sub> and CIDR removal (i.m. d 7), 100 µg of GnRH and TAI 56 h after PGF<sub>2α</sub>.

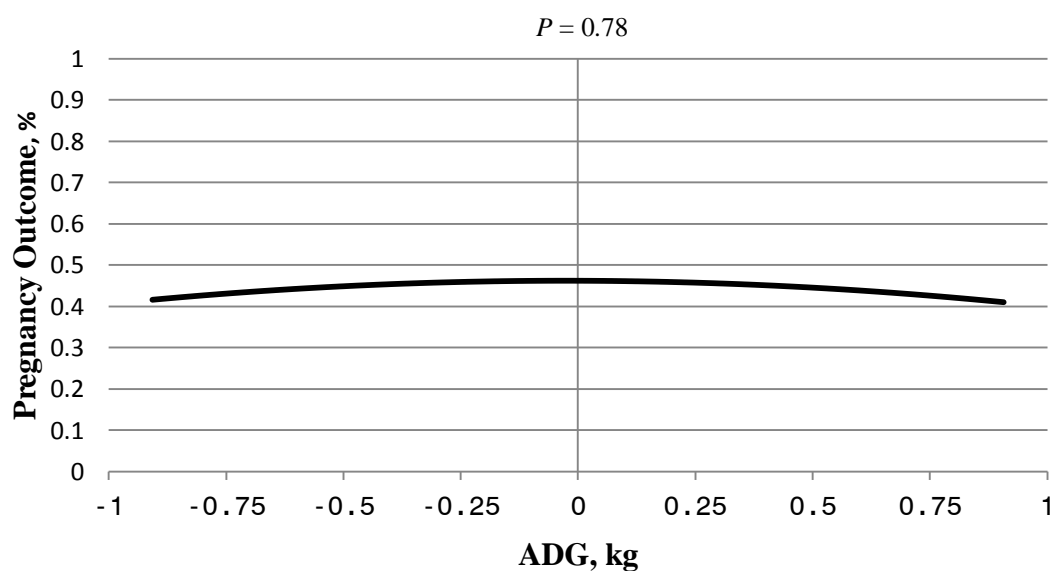
**Figure 4.** Logistic regression<sup>1</sup> on the effects time interval between PGF<sub>2α</sub> administration on d 31 and TAI for the MGA- PGF<sub>2α</sub><sup>2</sup> estrus synchronization protocol on pregnancy rates.



<sup>1</sup>Logistic regression analyzed utilizing the GLIMMIX procedure of SAS

<sup>2</sup> MGA- PGF<sub>2α</sub> = 0.5 mg of MGA administered on d 0, 25 mg of PGF<sub>2α</sub> (i.m. d 33), 100 µg of GnRH and TAI 72 h after PGF<sub>2α</sub>

**Figure 5.** Logistic regression<sup>1</sup> on the affects of BW gain from the time of CIDR insertion to pregnancy diagnosis on pregnancy rates for the CO-Synch + CIDR<sup>2</sup> and the CO-Synch + CIDR, PGF<sub>2α</sub><sup>3</sup> estrus synchronization protocols.



<sup>1</sup>Logistic regression analyzed utilizing the GLIMMIX procedure of SAS

<sup>2</sup>CO-Synch + CIDR = 100 µg of GnRH and CIDR insertion (i.m. d 0), 25 mg of PGF<sub>2α</sub> and CIDR removal (i.m. d 7), 100 µg of GnRH and TAI 56 h after PGF<sub>2α</sub>.

<sup>3</sup>CO-Synch + CIDR, PGF<sub>2α</sub> = 100 µg of GnRH, 25 mg of PGF<sub>2α</sub>, and CIDR insertion (i.m. d 0), 25 mg PGF<sub>2α</sub> and CIDR removal (i.m. d 7), 100 µg of GnRH and TAI 56 h after PGF<sub>2α</sub>