THE EFFECT OF ARTIFICIAL INSEMINATION OR NATURAL SERVICE BREEDING

SYSTEMS ON REPRODUCTIVE PERFORMANCE, CALVING CHARACTERISTICS,

WEANING CHARACTERISTICS, AND STEER BACKGROUNDING PERFORMANCE IN

A COMMERCIAL BEEF HERD

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Title

The effect of artificial insemination or natural service breeding systems on reproductive performance, calving characteristics, weaning characteristics, and steer backgrounding performance in a commercial beef herd.

By

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State

University's regulations and meets the accepted standards for the degree of

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ABSTRACT

Two experiments were conducted to evaluate the effects of beef cattle breeding systems that incorporate artificial insemination (AI) or the use of natural service mating on resultant reproductive performance, calving characteristics, weaning characteristics, and steer backgrounding performance. In Exp. 1, females were assigned to 1 of 2 treatments: 1) exposed to natural service bulls (**NS**, n = 541) or 2) bred via AI on the first day of the breeding season, followed by exposure to bulls (**TAI**, n = 535). Final pregnancy rates were similar among treatments. However, more TAI calves were born within the first 21 d of the calving season and resulted in heavier weaning weights of these calves compared with NS. In Exp. 2, steer progeny from Exp. 1 were evaluated in a 69 d backgrounding study. Calves born early in the calving season had greater feed intake and gain compared with calves born later in the calving season regardless of treatment.

ACKNOWLEDGEMENTS

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AI……………………………………………………………….Artificial Insemination

BCS………..……………………………………………………..Body Condition Score

BSE…………….………………………………………………Breeding Soundness Exam

BW………………..…………………………………………………………..Body Weight

CGREC…...…………………………………….Central Grasslands Research Extension Center

CIDR…………………………………………………………Controlled Internal Drug Release

CL……………...………………………………………………………...Corpus Luteum

cm………………..……………………………………………………...Centimeter

CPYG………………..……………………………………...Calculated Predicted Yield Grade

d…………………………..…..………………………………………………….Day

DPP……………………………………………………………….…………Days Postpartum

EPD…………………………………………………………….Expected Progeny Difference

ES……………………………………………………………….………Estrus Synchronization

g………………………..…...……………………………………………….Gram

G:F………………………………………………………………………….Gain:Feed

GnRH……………………………………………………Gonadotropin Releasing Hormone

hd……………………………………………………………………..…………Head

HG……………………………………………………………………………Heart Girth

HREC………………………………………………….Hettinger Research Extension Center

i.m.……………………………………………………………..…………intermuscular

kg…………………..……………………………………………………….Kilogram

LM………..…………………………………………………Longissimus Muscle

LMA………..……………………………………………Longissimus Muscle Area

mg………..……………………………………………………..………Milligram

MGA……………………………………………………………..Melengestrol Acetate

ml…………………..…………………………………..…………………….Milliliter

NS…………………………………………………………………Natural Service

P4………………………………..……………………………..……………….Progesterone

$PGF_{2\alpha}$…………………………………..…………………..…………Prostaglandin $F_{2\alpha}$

RIBFAT……………………………………………………..……..12th Rib Back Fat

TAI………..…………………………………………….Fixed-Time Artificial Insemination

U.S.……………..…………………………………………………United States

USDA……………..………………………………..United States Department of Agriculture

CHAPTER 1: INTRODUCTION AND LITERATURE REVIEW

Introduction

Good herd reproductive performance is essential for cow-calf producers (Osoro and Wright, 1992). Producers need cattle to become pregnant, give birth, and raise a healthy calf to weaning (Dickerson, 1970). Failure in these areas can negatively impact productivity and ultimately affect producers' profitability. Few studies are available that document changes in livestock producers' productivity and profitability with the use of estrus synchronization (**ES**) and artificial insemination (**AI**; Sprott, 1999) compared to the traditional natural service breeding system. Thus more research is needed to help producers make well informed decisions with production and financial management.

Livestock producers need to be aware of the cost and logistics associated with the usage of ES protocols (Odde, 1990). Profitability and productivity changes can impact a beef producer's decision to use ES and AI in their breeding program (Sprott, 1999). Tools available for beef producers, such as a partial budget analysis, can help determine if utilizing ES and AI in their reproductive management system could be successful (Rodgers et al., 2012). It is necessary to capture premiums from meat quality or valued genetic offspring with the use of ES and AI with producers having the knowledge of the costs of implementing ES and AI and a well-planned and executed marketing strategy (Sprott, 1999). Even with knowledge and a well-planned marketing strategy, commercial beef producers need fixed-time AI protocols to regularly achieve 50% or greater pregnancy rates for greater acceptance of AI (Sá Filho et al., 2009) regardless of breed/sire used; since income can be highly influenced by pregnancy rates using AI. Market prices can also influence success of an AI program, as AI calves at marketing may cover the cost of the synchronize program (Sprott, 1999). There are many research reports that

compare different AI protocols (Lauderdale, 2009); however, there is little research that compare

the use of AI and a clean-up bull to a strictly NS system on pregnancy rates and calf

performance. This literature review will assess different breeding systems through the calf's life

from conception to slaughter.

Literature Review

The Cow-Calf Sector

Cow-calf producers need to achieve a sustainable reproductive standard. On a basic level

this standard requires cows to become pregnant and raise a healthy calf to weaning (Dickerson,

1970). Management of variables such as pasture consistency, diet, breed composition, BCS,

postpartum interval, and geographic location (Lamb et al., 2001) are critical for successful

production in the cow-calf sector.

There are essential reproductive attributes for cattle to achieve on both the male and

female side. The bulls (males) need to generate viable sperm and successfully copulate with

females. To test the viability of the sperm, a breeding soundness exam (**BSE**) can be performed

and evaluated by a veterinarian (Society for Theriogenology, 1993). Bulls also need libido,

which is the sexual desire to copulate with females (Farin et al., 1989).

The female has to have several attributes to accomplish the necessary steps of becoming a

productive female in the herd. This starts with the heifer; to maximize lifetime productivity,

heifers should become pubertal at or before 15 months of age and be bred to calve at 24 months

of age (Patterson et al. 1992); which also minimizes cost of production. Heifers reaching

puberty earlier have greater the pregnancy rates during the breeding season (Varner et al., 1977).

In order for a heifer to reach puberty, she needs to reach a target BW (Funston et al., 2012a).

The target weight can be 60 to 65% of mature BW and as low as 50 to 57% of mature BW for a less costly development (Funston and Deutscher, 2004; Roberts et al., 2009; Funston and Larson, 2011; Mulliniks et al., 2012). Intensive production systems targeting 60 to 65% of BW for heifer development may increase pregnancy rates but may not improve overall profitability or sustainability (Funston et al., 2012a). To achieve target BW, producers can alter the rate of gain and timing of the gain in heifers, which can reduce the feed required and therefore decrease feed costs (Clanton et al., 1983; Lynch et al., 1997; Freetly et al., 2001).

For primiparous and multiparous cows, general infertility (decrease of fertility to any estrus), lack of uterine involution, anestrus, and short estrous cycles are responsible for postpartum infertility (Short et al., 1990). The major factor of postpartum infertility is anestrus, which is affected by two major components; suckling and nutrition, as well as a few minor effects: season, breed, parity, dystocia, presence of a bull and uterine palpation (Short et al., 1990). Another factor of infertility is a short estrous cycle, which is the first ovulation preceding parturition (Short et al., 1990). The short estrous cycle usually occurs with the first ovulation after parturition. This cycle may occur with a less obvious or possibly absent standing estrus and a short-lived corpus luteum that produces progesterone for a small amount of time compared to the subsequent ovulation (Perry et al., 1991).

The interval between calving and first estrous can influence profitability and production by affecting the first-service conception rates and postpartum interval to conception (Randel, 1990). To facilitate cows to overcome their postpartum anestrous, cows should be at a BCS of $\geq$ 5 at calving (Dunn and Kaltenbach, 1980; Richards et al., 1986). Body condition at calving has a greater effect on the cow's reproductive performance than at any other time (Osoro and Wright, 1992) and reduces the length of anestrus (Wright et al., 1987). Younger cattle are more prone to

prolonged postpartum interval than mature cows because of the added stress of lactation along with the need for additional nutrition for continued growth (Mulliniks et al., 2012). Several other management practices may minimize the influence of anestrus and infertility which include: restricting the breeding season to ≤ 45 d, reducing cases of dystocia and stimulating estrous activity via a sterile bull and estrus synchronization (**ES)**, and using complete, partial, or short-term weaning (Short et al., 1990).

Different Breeding Options for Cow-Calf Producers

The two breeding options reviewed in this paper are natural service (**NS**) and artificial insemination (**AI**). Natural service is a system which uses herd bulls to breed the cows. Artificial insemination is a system that uses a technician who inseminates the cows and may utilize different pharmaceutical products to synchronize estrus. Many biotechnologies in reproduction are available for beef producers such as artificial insemination, ES, embryo transfer, and in vitro fertilization that can improve production of food animals (Rodgers, 2008). When considering what breeding system to utilize, producers who wish to implement a more labor intensive breeding system, such as ES and AI, need to consider their on and off farm activities and/or employment (Sprott, 1999). There are other breeding options available to producers and include embryo transfer and in vitro fertilization (Rodgers, 2008). Producers need to evaluate their specific operation to determine which of the two breeding systems is most appropriate for their situation.

Breeding System 1: Natural Service

Natural service is the breeding system whereby bulls are placed with cows for breeding purposes. Approximately 95.7% of all beef operations solely use herd bulls to breed the females

in their herds (NAHMS, 2009). The breeding season can range from one cycle, 21 d, to 365 d, with the National Animal Health Monitoring Service (NAHMS, 2009) reporting 34.0% of beef operations, which accounts for 48.4% of the beef cow inventory, having one breeding season (the removal of the bull from the cows and/or heifers for at least a 30 d period). Therefore, 54.5% of beef operations had no set breeding season, which represents 34.1% of U.S. beef cattle (NAHMS, 2009).

Bull Characteristics

Mature bulls can achieve a greater final pregnancy rate than younger bulls; however, yearling bulls had a greater number of mounts and reduced pregnancy rates compared to older bulls (Pexton et al., 1990), which indicates that breeding is a learned behavior and requires practice (Chenoweth, 1983). Mature bulls have larger scrotal circumference than younger bulls, and younger bulls have a greater increase in primary sperm abnormalities than mature bulls (Chenoweth et al., 1983). Since mature bulls may increase pregnancy rates, average stocking rate (the ratio between numbers of females to bulls) in the U.S. for mature bulls is 25.1 females per bull; whereas, for a yearling bull the average rate is 17.4 females per bull (NAHMS, 2009). When following these stocking rates beef producers may expect calving rates to be 91.5% of all females exposed (NAHMS, 2009). Approximately 65% of cattle will become pregnant in the first 21 d of the breeding season using strict bull breeding (Lauderdale, 2009).

Breeding Soundness Exams

A Breeding soundness exam (**BSE**) is a tool that a veterinarian can perform for beef producers to test the viability of a bull's sperm for certain standards and other physical characteristics as set by the guidelines by the Society of Theriogenology (1993). The BSE

should be performed prior to the initiation of the breeding season and within enough time to retest or replace bulls that fail the exam (Dahlen, 2012). A veterinarian, or allied professional, conducts the exam by examining the bull's reproductive organs and collecting a seminal ejaculate via electo-ejaculation. The bull's sperm needs to be formed with less than 30% defects [underdeveloped, double forms, acrosome defects, etc. (Barth and Oko, 1989)], with a minimum of 30% motility of sampled sperm. The bulls also must meet a minimum recommended scrotal circumference for the bull's specific age; with 30 cm for bulls less than 15 months of age to 34 for greater than 2 year old bulls (Society of Theriogenology, 1993). Other characteristics the bull must have to pass a BSE are to be free of abnormalities of the accessory glands, prepuce, and penis, and a non-reproductive evaluation to verify the bull is free from vision, foot, or leg problems. Bulls are classified into three types: satisfactory, deferred, and unsatisfactory. A satisfactory classification is used for bulls that meet or surpass the minimum requirements of those listed above. Deferred status describes bulls that fail to meet one or more of the given criteria, but may improve in time. Unsatisfactory classification is given to bulls that have one or more attributes that will not improve over time, and therefore are recommended to be culled (Society of Theriogenology, 1993). A BSE does not evaluate the bull's libido, or "sexual desire." A bull that passes a BSE still needs libido to mount the females. Libido can be monitored by the producer by physically watching the bull mount females, particularly yearling bulls, and if they actively search and breed females (Dahlen, 2012).

Bull Management

If the breeding season is less than 365 d, bulls need different management than cows. Bulls tend to lose condition during the breeding season and may continue to lose condition after the breeding season on native pastures (Barth, 2012). Decline in body condition may reduce

scrotal circumference and therefore reduce semen quality (Barth, 2012). During the non-breeding season, the bulls should gain any condition that was lost and then maintain the optimal BCS (5 to 6, out of 9). When bulls are wintered, they need to be in facilities that allow for adequate exercise, allow subordinate bulls to evade sparring, and minimize destruction to the facility (Barth, 2012).

Effect of Bulls on Females

When both postpartum multiparous (Zalesky et al., 1984) and primiparous (Custer et al., 1990; Fernandez et al., 1993) suckled cows are exposed to bulls, cyclicity can be initiated earlier compared to non-exposed cows. Although the factors responsible for the biostimulatory effect to initiate cyclicity are not well understood (Beradinelli and Joshi, 2005), it is essential to have the females cycle during the breeding season to be bred by the bulls. Without females being receptive to the males, copulation and pregnancy will be unlikely in a natural service breeding system.

Breeding System 2: Artificial Insemination

The use of AI is minimally used in the beef industry, with 7.4% of beef operators utilizing AI (NAHMS, 2009). More beef producers use AI on their heifers (16.3%) compared to mature cattle (5.2%; NAHMS, 2009). Use of AI for heifers is more popular because heifers are usually managed more intensely and developed in dry lots and are more easily accessible to run through a chute. The use of AI throughout the U.S. is low due to several factors and include labor (39.1%), to difficult/complicated (17.2%), and cost (16.8%; NAHMS, 2009). The ES protocol will dictate the amount of labor a producer needs. The simplistic AI system uses estrus detection for 21 d to inseminate all females in the herd. Utilizing estrus detection method

requires labor to observe and inseminate the cattle at different times. When utilizing estrus detection, AI technicians use the AM/PM rule (a female observed in the morning in her first standing estrous is inseminated that evening or a female observed in first standing estrous in the evening is inseminated the following morning (Trimberger and Davis, 1943). Breeding using estrus detection can utilize ES as well.

Estrus Synchronization

Estrus synchronization manipulates the cattle's estrous cycle to bring a large proportion of the cattle into estrus at a predetermined time (Odde, 1990), thereby concentrating estrus observation and labor needed to a shorter interval. Estrus synchronization protocols with estrus detection led to the development of protocols that eliminated estrus detection and therefore enabled fixed-time AI (**TAI**) protocols (Geary et al., 2001; Lamb et al., 2001, 2006; Larson et al., 2006; Busch et al., 2007). The TAI research resulted in protocols that enable producers the ability to breed cattle at a fixed point in time, on a given day or the first day of the breeding season, with pregnancy rates similar (approximately 65%) to bull breeding for a 21 d period (Lauderdale, 2009).

Fixed-time AI can follow a certain period of estrus detection as a clean-up method in females that are not detected in estrus. Heifers without the TAI clean-up in the estrus detect protocols, pregnancy rates would be less compared to protocols that use solely TAI (Lamb et al., 2006). Fixed time AI protocols without estrus detection is ideal and appropriate for producers who do not wish to use more labor for require heat detection (Larson et al., 2006).

Producers that wish to utilize reproductive technologies of AI and ES have various choices of protocols that are recommended by the Beef Reproduction Task Force (2012) that is separated for heifers (Figure 1.1) and cows (Figure 1.2). These protocols have several options

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BEEF COW PROTOCOLS - 2013

HEAT DETECTION

Select Synch

GnRH | PG

0 ... 6 ... 7 ... 13

treatment day

Heat detect & AI

Select Synch + CIDR®

GnRH | PG

CIDR®

0 ... 7 ... 13

treatment day
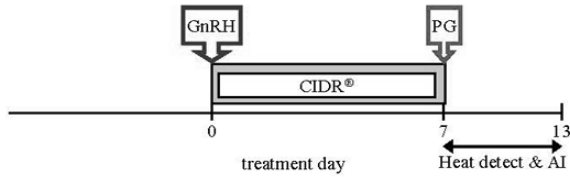
Heat detect & AI

PG 6-day CIDR®

Heat detect and AI days 0 to 3. Administer CIDR to non-responders and heat detect and AI days 9 to 12. Protocol may be used in heifers.

PG | GnRH | PG

CIDR®

0 ... 3 ... 9 ... 12

Heat detect & AI ... treatment day ... Heat detect & AI
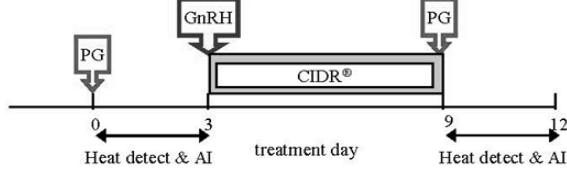
HEAT DETECT & TIME AI (TAI)

Select Synch & TAI

Heat detect and AI day 6 to 10 and TAI all non-responders 72 – 84 hr after PG with GnRH at TAI.

GnRH | PG | GnRH / AI

.. 72 - 84 hr ..

0 ... 6 ... 7 ... 10

treatment day

Heat detect & AI

Select Synch + CIDR® & TAI

Heat detect and AI day 7 to 10 and TAI all non-responders 72 - 84 hr after PG with GnRH at TAI.

GnRH | PG | GnRH / AI

CIDR®

.. 72 - 84 hr ..

0 ... 7 ... 10

treatment day
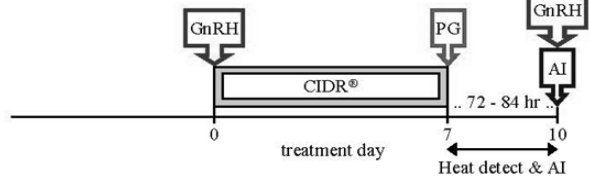
Heat detect & AI

PG 6-day CIDR® & TAI

Heat detect & AI days 0 to 3. Administer CIDR to non-responders & heat detect and AI days 9 to 12. TAI non-responders 72 - 84 hr after CIDR removal with GnRH at AI. Protocol may be used in heifers.

PG | GnRH | PG | GnRH / AI

CIDR®

.. 72 - 84 hr ..

0 ... 3 ... 9 ... 12

Heat detect & AI ... treatment day ... Heat detect & AI
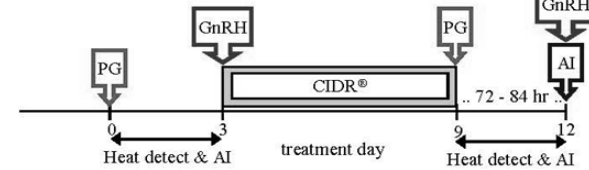
FIXED-TIME AI (TAI)*

7-day CO-Synch + CIDR®

Perform TAI at 60 to 66 hr after PG with GnRH at TAI.

GnRH | PG | GnRH / AI

CIDR®

.. 60 - 66 hr ..

0 ... 7 ... 10

treatment day
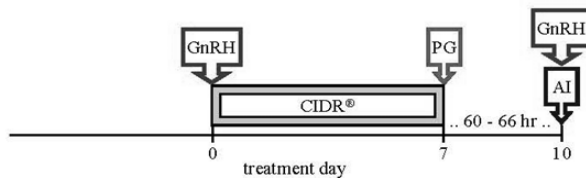
5-day CO-Synch + CIDR®

Perform TAI at 72 ± 2 hr after CIDR removal with GnRH at TAI. Two injections of PG 8 ± 2 hr apart are required for this protocol.

GnRH | PG / PG | GnRH / AI

CIDR® | 8±2 hr

.....72 ± 2 hr..

0 ... 5 ... 8

treatment day
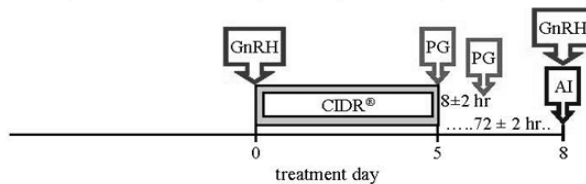
FIXED-TIME AI (TAI)*
for *Bos indicus-influenced* cows only

PG 5-day CO-Synch + CIDR®

Perform TAI at 66 ± 2 hr after CIDR removal with GnRH at TAI. Two injections of PG 8 ± 2 hr apart are required for this protocol.

PG | GnRH | PG / PG | GnRH / AI

GnRH

CIDR® | 8±2 hr

.....66 ± 2 hr..

0 ... 5 ... 8

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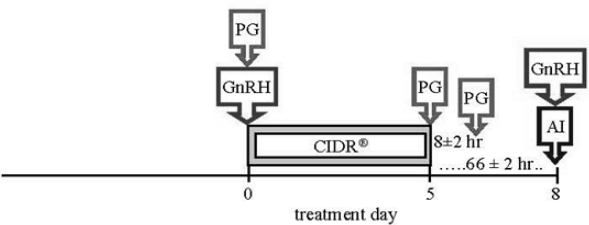
* The time listed for "Fixed-time AI" should be considered as the approximate average time of insemination. This should be based on the number of cows to inseminate, labor, and facilities.

GnRH — Cystorelin®, Factrel®, Fertagyl®, OvaCyst®

PG — estroPLAN®, Estrumate®, In-Synch®, Lutalyse®, ProstaMate®

Approved 12-06-12 | *Beef Reproduction Task Force*

Figure 1.1 Beef cow artificial insemination and estrus synchronization recommended protocols. Beef Reproduction Task Force, 2012.

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BEEF HEIFER PROTOCOLS - 2013

HEAT DETECTION

1 Shot PG

Heat detect & AI

treatment day

7-day CIDR®-PG

Heat detect & AI

treatment day

MGA®-PG

Heat detect & AI

treatment day

HEAT DETECT & TIME AI (TAI)

Select Synch + CIDR® & TAI

Heat detect and AI day 7 to 10 and TAI all non-responders
72 - 84 hr after PG with GnRH at TAI.

Heat detect & AI

MGA®-PG & TAI

Heat detect and AI day 33 to 36 and TAI all non-responders
72 - 84 hrs after PG with GnRH at TAI.

Heat detect & AI

14-day CIDR®-PG & TAI

Heat detect and AI day 30 to 33 and TAI all non-responders
72 hrs after PG with GnRH at TAI.

Heat detect & AI

FIXED-TIME AI (TAI)*

7-day CO-Synch + CIDR®

Perform TAI at 54 ± 2 hr after PG with GnRH at TAI.

treatment day

14-day CIDR®-PG

Perform TAI at 66 ± 2 hr after PG with GnRH at TAI.

treatment day

MGA®-PG

Perform TAI at 72 ± 2 hr after PG with GnRH at TAI.

treatment day

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

GnRH — Cystorelin®, Factrel®, Fertagyl®, OvaCyst®

PG — estroPLAN®, Estrumate®, In-Synch®,
Lutalyse®, ProstaMate®

Approved 12-06-12

Beef Reproduction Task Force

Figure 1.2 Beef heifer artificial insemination and estrus synchronization recommended
protocols. Beef Reproduction Task Force, 2012.

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for producers to take into consideration: the labor and costs associated with each protocol, including estrus detection, TAI, and a combination of estrus detect and TAI (Beef Reproduction Task Force, 2012). The TAI protocol appeals to producers who want to reduce the number and frequency of cattle handling and eliminates estrus detection (Lamb et al., 2010, Larson et al., 2006). Regardless of protocol used, in order to maximize pregnancy rates the chosen protocol should be followed as closely as possible (Lamb et al., 2006). Compliance is key for ES protocol success, if on any given day only 90% of injections are done properly and cattle need 3 injections ($90\% \times 90\% \times 90\% = 73\%$), one will not achieve acceptable protocol compliance (Fricke, 2011)

Artificial Insemination Development

During the 1950s, research revealed a method to use frozen semen to rapidly affect the genetic change of beef herds (Foote, 2002). Research from the 1950s through 1960s focused on daily estrus detection which was determined to be a key factor of AI success (Lauderdale, 2009). The resulting understanding accelerated research to control estrus and added more control to breeding management (Lauderdale, 2009), leading to the development of estrus synchronization as a tool that has been available for beef producers for more than 30 yr. (Lamb et al., 2010).

Products Used and Effects on Cow

To utilize ES, certain pharmaceuticals are administered to manipulate cows' estrus cycle. Currently in the U.S., ES protocols incorporate prostaglandin $F_{2\alpha}$ (**PGF$_{2\alpha}$**), gonadotropin releasing hormone (**GnRH**), and progesterone (**P4**) and have been approved by the Food and Drug Administration for use in the U.S. (Lauderdale, 2009).

Prostaglandins

Administration of $PGF_{2\alpha}$ causes regression of a mature corpus luteum present in the ovary as soon as d 5 and as late as d 15 of a typical bovine estrus cycle (Lauderdale, 1972; Louis et al., 1972; Rowson et al., 1972; Roche, 1974; Hafs and Manns, 1975). Natural occurring $PGF_{2\alpha}$ is produced in the uterus when a pregnancy is not recognized (Senger, 1997). Prostaglandin $F_{2\alpha}$ is ineffective at causing luteolysis in anestrous cattle (Lucy et al., 2001) or early in the estrus cycle (Lauderdale, 1972; Rowson et al., 1972), but it is effective from d 6 through 16 of a typical bovine estrous cycle (Lauderdale et al., 1981). An ES protocol that only utilizes $PGF_{2\alpha}$ is a series of 2 injections 10 to 12 d apart but requires labor for heat detection. After the first injection (assuming cattle are distributed uniformly within the d of the estrus cycle) approximately 70% of cyclic cattle will show estrus approximately 3 d post injection; these cattle along with the remaining 30% of the cattle will be responsive to the second injection (Odde, 1990).

Gonadotropin Releasing Hormone

Gonadotropin releasing hormone induces an ovulation in the majority of cyclic (90%) and non-cyclic (76%) cattle (Troxel et al., 1993). Gonadotropin releasing hormone is released from the hypothalamus by a negative feedback pathway when estrogen reaches a specific blood concentration for that individual female (Senger, 1997). The GnRH causes release of the lutenizing hormone to cause an ovulation (Kittock et al., 1972; Mauer and Rippel, 1972; Zolman et al., 1973). Follicle stimulating hormone is also released when a shot of GnRH is administered. The release of follicle stimulating hormone initiates a new follicular wave after aministration of GnRH regardless of luteal status and/or if ovulation was induced by the GnRH (Twagiramungu et al., 1994).

Progesterone

Progesterone is naturally produced by the corpus luteum (**CL**) from d 5 to 15 of the estrus

cycle and inhibits GnRH release, prevents reproductive behavior, and maintains pregnancy

(Senger, 1997). Exogenous P4 delayed estrus in females that did not have a natural occurring

CL (Roche et al., 1999). This exogenous P4 administered for 7 d prior to an injection of $PGF_{2\alpha}$

allowed a greater proportion of cycling females to regress their CL with the injection $PGF_{2\alpha}$

(Macmillan and Peterson, 1993). There are two progestin products available to producers,

controlled internal drug release (**CIDR**; vaginal insert containing 1.38 g of P4; EAZI-BREED

$CIDR^{®}$, Zoetis LLC, Madison, NJ) and melengestrol acetate (**MGA**; fed at 0.5 mg/ (animal/d);

Zoetis LLC, Madison, NJ; Lamb et al., 2010). The CIDR is approved for cows and heifers, but

the use of MGA is not approved for suckled cows (Lamb et al., 2010).

Attributes of Success

Fertility of cattle is affected by estrous cyclicity. The proportion of cyclic cattle is

affected by BCS, parity, and days postpartum (Larson et al., 2006). The number of females that

become pregnant by AI is affected by the number of females that are cyclic prior to the breeding

season (Sprott, 1999). When properly performed, producers may expect pregnancy rates to AI to

be greater than or equal to 50% (54% to 63% for various protocols) of females inseminated

(Lamb et al., 2010). The majority of AI and/or TAI protocols utilize a clean-up herd bull for the

duration of the breeding season after AI has taken place. If pregnancy rates to AI are > 50%, this

theoretically should result in shorter calving season length. A high proportion of cattle being

bred on a single day or during a short duration of days should concentrate the calving season;

therefore, allowing a producer to focus labor needs for a shorter time rather than a long, drawn

out process (Larson et al., 2006; Lamb et al., 2010).

Overcoming Anestrus

The first obstacle in using ES and obtaining ideal pregnancy rates in multiparous cows is overcoming postpartum anestrus (Larson, et al., 2006). Addressing postpartum anestrus is necessary in order for ovulation and ES programs to be effective (Lamb et al., 2001). Body condition score and days postpartum at the start of the breeding season can affect the ability of ES protocols to work efficiently for the beef producer (Lamb et al., 2001). In several conflicting studies, cattle that were cyclic had greater TAI pregnancy rates than non-cyclic (Larson et al., 2006), had reduced TAI pregnancy rates (Sá Filho et al., 2009), or had no differences between cyclic and non-cyclic heifers on pregnancy rates (Lamb et al., 2006). Parity can have an effect on cyclic status. Larson et al. (2006) reported 39.9% of primiparous cows were cyclic while 71.3% of multiparous cattle were cyclic at the start of the breeding protocol. Days postpartum can also alter conception rates, with cows > 50 d postpartum having greater pregnancy rates than cattle with ≤ 50 d postpartum before the beginning of the breeding season (Lamb et al., 2001; Larson, et al., 2006).

The first cycle that occurs postpartum may have a less obvious or absent estrus, a short-lived CL (≤ 12 d; Odde et al., 1980; Williams and Ray, 1980), and produce progesterone for a small amount of time compared to the following ovulation (Perry et al., 1991). If the ES products cause the females to perceive a short cycle, then the females will have an increased chance of becoming pregnant by the clean-up bull earlier in the breeding season, within the first 21 d of the breeding season compared to cattle not receiving ES products. Initiation of cyclicity of anestrus cattle may be the largest benefit to beef producers by improving fertility in response to the ES protocol (Lamb et al., 2010). The use of a CIDR in an ES protocol increased pregnancy rates in cattle with low concentrations of progesterone and in non-cyclic cattle (Lamb et al., 2001).

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Proper AI Technique

Proper AI techniques are critical in order to achieve acceptable pregnancy rates. The semen should be stored in a well-sealed semen tank that is filled with liquid nitrogen (-196° C). The recommended semen handling protocol requires the semen straw to be thawed in a 35° C water bath for at least 45 seconds and no longer than 15 minutes (Dalton, et al., 2004). The semen straws need thermal and hygienic protection while loading AI syringes, transporting, and insemination. The AI syringe is then inserted in vagina by the technician's dominant hand at an upward angle (30°) and is guided through the cervix via rectal manipulation with the AI technician's other hand (DeJarnette and Nebel, 2012). Successful passage of the AI syringe through the cervical lumen needs to be done properly (Peters et al., 1984). The semen is then deposited in the desired anatomical site, the body of the uterus (Dalton et al., 2004). The AI technician must avoid cervical insemination which accounts for 17% of attempted uterine body depositions (Peters et al., 1984) and reduces fertility by 10% (Macpherson, 1968).

Direct Comparisons of Breeding Systems

A major difference between NS and AI breeding systems is the labor associated with implementing the system. Natural service breeding systems do not require the use of a skilled AI technician or administration of ES products. Only management of bulls is recommended; a BSE of the bulls should be performed and fed to maintain bull weight and BCS during the breeding season and non-breeding season. The genetic potential that can be reached and a shift in age of calves are the two major differences between NS and AI breeding systems.

Genetic Differences

Rapid genetic improvement in beef production has been identified when progeny tested AI bulls are used (Lauderdale, 2009). Research led to the biggest advantage of using AI; the use of proven AI sires allows producers to utilize superior genetics in their herd at costs well below the expense of buying a herd bull with similar genetic qualities (Lamb et al., 2006). A beef producer could inseminate their entire herd with the same sire which would be unlikely for a herd bull to do in the same time span in a large herd when using AI. Expected progeny differences (**EPD**) are a summarization of all available information (individual's own performance record, genomic predictions, progeny records of other relatives in the pedigree, and genetic correlations of traits) that is calculated into a genetic merit and be used to make comparisons to other individuals (Thrift and Thrift, 2006). Traits such as birth weights, weaning weights, yearling weights, calving ease direct, and others need to be recorded within a certain window of time (Spangler, 2011). The EPDs in sire directories can be used to compare one bull to another in the same breed, but not predict actual performance of offspring. The EPDs of AI sire bulls have a greater accuracy than those of most herd bulls, primarily because of the number of offspring the AI sires can achieve; herd sires would likely sire less than 100 offspring in his lifetime, assuming 3 productive yr with an assumption of 30 pregnancies per yr. Sires that are used for AI could produce thousands of offspring in the same amount of time and, as long as enough semen was harvested, could produce progeny even well after the bull's death. The larger number of progeny that is produced leads to a greater EPD accuracy, which is the reliability that the genetic potential of a sire will be on the EPD traits. Higher accuracy gives producers an incentive to utilize AI by allowing producers more confidence on the performance of the producers calves. An EPD comparison showed current Angus sires (American Angus

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Association, 2013) had reduced calving ease direct, weaning weight, yearling weight, and a greater birth weight compared to active AI sires from a semen company (Select Sires, Inc., 2013).

Commercial cow-calf beef producers that implement AI likely need sires that improve their income by one or more of the following: 1) improving weaning weights, 2) increasing carcass quality, 3) having desirable maternal traits in their replacement heifers, and 4) reducing the number of dystocia cases (Sprott, 1999). Seedstock producers use AI sires that produce offspring with recognizable pedigrees (Sprott, 1999) and offspring that are desirable for commercial producers. Producers can use a sire that has a greater accuracy and utilize traits that producers see fit for their operation.

Age of Calves

Changing the average day of conception can alter the calving season because the calves that are conceived by AI are born earlier in the calving season which translates to older and heavier weights at marketing than their counterparts not conceived by AI (Sprott, 1999). Calves conceived by AI had mean birth of 4.5 d earlier than calves conceive by only herd bulls (Rodgers et al., 2012). This leads to, on average, an older and heavier calf at weaning because of the increased days of suckling and consuming the pastures compared to the later born calf sired by NS bulls. When using an ES protocol, a 50% pregnancy rate by AI is expected and calves conceived to AI would be generally closer in age than the other half of the calf crop sired by NS bulls. The greater AI sired calves may result in a tighter grouped lot weights and less varied frame scores within a lot which would result in a higher price at the stockyards (Seeger et al., 2011).

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Comparisons of the Life Cycle

Pregnancy Rates

In a NS system, conception would likely follow an even distribution with 1/21st of the herd showing estrus on a given day. The advantage of utilizing TAI instead of solely natural service is with natural service breeding and a 63 d breeding season cattle would have 3 opportunities to become pregnant (with a 21 d estrus cycle); whereas, with a TAI protocol the breeding season would be 45 d long to give cattle the same number of opportunities to conceive (Odde, 1990). Using an ES protocol increased pregnancy rates throughout the breeding season and reduced the mean interval from calving to conception when compared to a NS system (Sá Filho et al., 2009). *Bos indicus* females were exposed to an ES protocol had greater pregnancy rates at d 30 and 90 of the breeding season compared to cattle only exposed to natural service (Sá Filho et al., 2009). Cattle that fail to become pregnant by AI will come into heat from d 15 to 26 after TAI with the majority (47% of non-pregnant cattle) of females returning to heat between d 20 to 22 (Larson et al., 2009). Producers need to be aware of this influx of cattle returning to estrus; bull to non-pregnant female ratio is recommended to be 1:16 to provide adequate bull power to produce acceptable pregnancy rates whereas a greater ratio (1:50) may reduce pregnancy rates (Healy et al., 1993). Pregnancy rates for *Bos taurus* females that were exposed to either NS or TAI are not available at this time and require studying.

Calving

Distribution of Season

The use of ES can potentially shorten the calving season, increase calf uniformity, and enhance the possibilities for utilizing AI (Larson et al., 2006; Lamb et al., 2006; Lamb et al., 2010). The combined use of ES and AI may concentrate the calving season which would focus labor to fewer days (Rodgers et al., 2012), including a shorter observation period for dystocia (Sprott, 1999). Since all females in a herd have the opportunity to become pregnant on a single day, producers may be concerned that the ES cattle will all give birth on a single day, and death loss may increase if weather conditions are unfavorable (Odde, 1990). However, cattle that have conceived by ES and TAI have variation in gestation length, with about 20% of the cattle calving on the peak day of the calving season (Odde et al., 1987).

Changing the average day of conception can alter the calving season because the calves that are conceived by AI are born earlier in the calving season, which translates to older and heavier weights at marketing than their counterparts not conceived by AI (Sprott, 1999). Mean calving day was earlier for a group of cows receiving TAI compared to cows receiving NS, 26.8 and 31.3 ± 0.8 d, respectively (Rodgers et al., 2012). Cattle exposed to TAI had a greater proportion of females calving during the first and second 10 d intervals of the calving season than the control treatment cattle, while the percentage of control treatment cattle that calved was greater than the TAI cattle for the third and fourth 10 d intervals of the calving season (Rodgers et al., 2012). This resulted in a greater majority of cattle in the TAI treatment giving birth in the first 20 d of the calving season, with fewer calves born during the next 10 d intervals (Rodgers et al., 2012). This change in overall birth date, may impact performance after weaning (Funston et al., 2012b; Fike et al., 2010).

Birth Characteristics

The advantage of using proven bulls, producers can utilize sires with reliable EPD's for decreased or increased birth weight compared to the unproven herd bulls. By choosing a sire with decreased birth weight and increased calving ease EPDs, cases of dystocia should also be reduced (Sprott, 1999). On the other hand, increased birth weights have been shown to result in greater preweaning growth (Smith et al., 1976). When heifer calves were born earlier in the calving season, birth weighed was less than heifer calves born 16 d later, steers also born earlier in the calving season had lighter birth weight than later born steers (Funston, et al., 2012b). This may be due to the fact that cows that are managed together when calving may be on a higher plane of nutrition; therefore cows that calved later were consuming high quality feed for a longer time, and therefore had increased birth weights for calves born later in the calving season (Funston et al., 2012b).

Weaning

Calves resulting from AI breeding system will likely be older than NS calves and have a greater genetic potential for increased weaning weights. Average birth date has been shown to be 4.5 d earlier for TAI calves compared to NS calves (Rodgers et al., 2012). A more exaggerated example of change in birth date, if calves that were conceived by AI had a 26 d earlier days to conception would result in 26 d earlier birth date, which would yield an extra 20.8-24.2 kg of weight at weaning compared to calves not conceived with synchrony (Sprott, 1999). Growth from birth to weaning has been shown to be a linear curve with calf age (Minyard and Dinkel, 1965) but from d 153 of calf age growth increases at a decreasing rate (Johnson and Dinkel, 1951). Calves that are born earlier in the normal calving season were heavier at weaning because of two factors: age and rate of pre-weaning gain (Lesmeister et al.,

1973). Older calves may be able to better utilize grass on pasture and consume larger quantities

of milk from the dam than younger calves (Lesmeister et al., 1973). Weaning weight has been

reported (Funston et al., 2012b) to be the 13 kg heavier for calves born in the first 21 d compared

to 21 to 42 d of the calving season. Rodgers et al. (2012) used AI sires and NS bulls with similar

EPDs, and anticipated no weaning weight improvement. Weaning weights per cow calving and

per cow exposed was greater for the TAI treatment cattle compared to the control treatment

cattle (Rodgers et al., 2012). If AI sires had genetic advantage over herd sires, a premium could

be developed from these AI sired calves and give producers an extra economically desirable

breeding system compared to natural service (Johnson and Jones, 2008). From EPD differences,

one would anticipate AI sired offspring to outperform offspring sired by natural service bulls,

however more studies need to evaluate this statement.

Post-weaning

   Steers

   Steers that are older and heavier at weaning may have decreased days on feed in the

backgrounding and finishing phases because older calves have been shown to have a greater

ADG then younger calves (Smith et al., 2003). However, younger calves at weaning are more

feed efficient than the older calves (Myers et al., 1999; Schoonmaker et a., 2001). Hot carcass

weight increased as calf age increased and the proportion of earlier born steers had a USDA

quality grade of modest or greater was increased compared to younger steers (Funston et al.,

2012b). Younger calves at harvest had lower yield grade and a reduction in marbling creating

less valuable carcasses (Funston et al., 2012b). The advantage of using proven sires in

conjunction with producing older calves with AI and ES has the potential to gain a premium on

the rail.

Heifers

Heifers that were born later in the calving season had greater pre-weaning and post-weaning ADG, however, had reduced fertility (Funston et al., 2012b). Replacement heifers that were born earlier in the calving season had decreased first calf birth weight and earlier calving date (Funston et al., 2012b). These heifers that were born during the first 21 d of the calving season had greater weaning, prebreeding, and precalving BW, percent cyclic before breeding; and greater pregnancy rate compared with heifers that were born in the last 21 d of the calving season (Funston et al., 2012b). The cattle that calved late their first productive yr tended to calve late or be open the next yr (Burris and Priode, 1958; Kill et al., 2012). This will lead to a domino like effect, where late calvers will further extend the calving season and may need to be culled from the herd in order to have a concentrated calving season.

Economic Comparisons of the Systems

Breeding Returns

Utilizing an AI breeding system may allow producers to reduce the number of bulls needed for the herd by half. The reduction could pay for the necessary equipment and labor needed to perform the AI protocol. A beef producer needs to achieve pregnancy rates greater than 50% to AI and which may allow the producer to reduce the number of bulls to breed the remaining open cattle. However, beef producers should consider the risk associated with reducing bull numbers. If poor AI pregnancy rates occurs, then bull power in the herd may be insufficient to produce adequate pregnancy rates.

In a partial budget analysis, reduced costs could be credited to the reduction of the number of herd sires from a bull:cow ratio of 1:17 for control to a 1:30 for TAI (Rodgers et al.,

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2012). Semen and bull purchase price can result in varying economic output when comparing AI and NS; high semen price could result in a reduced economic return for AI whereas, a high bull purchase price could equate to a higher economic return for the use of AI (Johnson and Jones, 2008). At lower cow to bull ratios, systems that incorporated AI were more cost effective than natural service; at a 20 cow:bull ratio, AI resulted in pregnancies for $1.19/45.4 kg/offspring less than natural service (Johnson and Jones, 2008). Cost per pregnancy for AI is generally more expensive than natural service pregnancies, which ranged from $46 to $95 due to different ES products used (Johnson and Jones, 2008). The value of ES and AI greatly varies depending on management and environmental conditions (Odde, 1990).

Calf Performance Returns

With the use of proven sires and an average older calf, producers may achieve greater premiums due to the uniformity and greater weights achieved by the calves. The majority of profits seen were due to the weaning weights of exposed cows to the ES and TAI treatment (Rodgers et al., 2012). Cattle exposed to the TAI treatment had a greater percentage that weaned a calf than cattle exposed to the NS treatment, 84% and 78%, respectively (Rodgers et al., 2012). The advantage of incorporating ES and TAI on weaning weights was associated with a reduction in culling rates of cattle before the calving season began, or decreased the culling rates of cows and calves early in the calving season, since there was no difference in weaning weights per cow weaning a calf (Rodgers et al., 2012).

Conclusions

The benefits of using artificial insemination protocols over natural service systems has been heavily touted and theorized, however, more research that uses natural service as a control

to artificial insemination systems describing the true effects needs to be conducted. The use of artificial insemination did shift the calving distribution to be earlier in the calving season compared to natural service. The shift in distribution may yield the short term advantage by both increasing the postpartum to breeding interval and creating a slightly higher proportion of older calves in the artificial insemination system compared to the natural service system. A greater postpartum interval may increase the proportion of cycling females and therefore increase pregnancy rates. Previous research has also shown that older steers may perform better than the younger counterparts from weaning to harvest, however research needs to be done to properly evaluate the effects of a natural service breeding system to an artificial insemination system in a commercial beef herd.

Literature Cited

American Angus Association. 2013. www.angus.org. accessed June 20, 2013.

Barth, A. D. and R. J. Oko. 1989. Abnormal morphology of bovine spermatozoa. Iowa State University Press, Ames, IA.

Barth, A. D. 2012. Managing bull development to optimize fertility. Proceedings, Applied Reproductive Strategies in Beef Cattle, Sioux Falls, SD. pp. 121-126.

Beef Reproductive Task Force. 2012. Applied reproductive strategies in beef cattle, Sioux Falls, SD.

Berardinelli, J. G. and P. S. Joshi. 2005. Introduction of bulls at different days postpartum on resumption of ovarian cycling activity in primiparous beef cows. J. Anim. Sci. 83:2106-2110.

Burris, M. J. and B. M. Priode. 1958. Effect of calving date on subsequent calving performance. J. Anim. Sci. 17:527–533.

Busch, D. C., D. J. Wilson, D. J. Schafer, N. R. Leitman, J. K. Haden, M. R. Ellersieck, M. F. Smith, and D. J. Patterson. 2007. Comparison of progestin-based estrus synchronization protocols before fixed-time artificial insemination on pregnancy rate in beef heifers. J. Anim. Sci. 85:1933-1939.

Chenoweth, P. J. 1983. Sexual behavior of the bull: A review. J. Dairy Sci. 66:173-179.

Clanton, D. C., L. E. Jones, and M. E. England. 1983. Effect of rate and time of gain after weaning on the development of replacement beef heifers. J. Anim. Sci. 56:280–285.

Custer, E. E., J. G. Berardinelli, R. E. Short, M. Wehrman, and R. Adair. 1990. Postpartum interval to estrus and patterns of LH and progesterone in first-calf suckled beef cows exposed to mature bulls. J. Anim. Sci. 68:1370–1377.

Dahlen, C. R. 2012. Control of estrus with natural service. Proceedings, Applied reproductive strategies in beef cattle, Sioux Falls, SD. pg 129-137.

Dalton, J. C., A. Ahmadzadeh, B. Shafii, W. J. Price, and J. M. DeJarnette. 2004. Effect of simultaneous thawing of multiple 0.5-mL straws of semen and sequence of insemination on conception rate in dairy cattle. J. Dairy Sci. 87:972-975.

DeJarnette, M. and R. Nebel. 2012. A.I. technique in cattle. Select Sires 2012 beef sire directory. Pp. 60-61.

Dickerson, G. 1970. Efficiency of animal production – Molding the biological components. J. Anim. Sci. 30:849-859.

Dunn, T. G. and C. C. Kaltenbach. 1980. Nutrition and the postpartum interval of the ewe, sow and cow. J. Anim. Sci. 51(Suppl. 2):29-31.

Farin, P. W., P. J. Chenoweth, D. F. Tomky, L. Ball, and J. E. Pexton. 1989. Efficiency of single-sire mating programs with beef bulls mated to estrus synchronized females. Theriogenology 32:705-716.

Fernandez, D., J. G. Berardinelli, R. E. Short, and R. Adair. 1993. The time required for the presence of bulls to alter the interval from parturition to resumption of ovarian activity and reproductive performance in first-calf suckled beef cows. Theriogenology 39:411–419.

Fike, G. D., M. E. King, L. R. Corah, and W. D. Busby. 2010. Effect of time of birth within the spring calving season on performance and carcass traits of beef calves fed in the Iowa Tri-County Steer Carcass Futurity. J. Anim. Sci. 88:E-Supp. 2. 823.

Foote, R. H. 2002. The history of artificial insemination: Selected notes and notables. J. Anim. Sci. 80:1-10.

Freetly, H. C., C. L. Ferrell, and T. G. Jenkins. 2001. Production performance of beef cows raised on three different nutritionally controlled heifer development programs. J. Anim. Sci. 79:819–826.

Fricke, P. M. 2011. Seven musts for getting cows bred. Hoards Dairyman. March 2011.

Funston, R. N. and G. H. Deutscher. 2004. Comparison of target breeding weight and breeding date for replacement beef heifers and effects on subsequent reproduction and calf performance. J. Anim. Sci. 82:3094-3099.

Funston, R. N. and D. M. Larson. 2011. Heifer development systems: Dry-lot feeding compared with grazing dormant winter forage. J. Anim. Sci. 89:1595-1602.

Funston, R. N., J. L. Martin, D. M. Larson, and A. J. Roberts. 2012a. Physiology and

    endocrinology symposium: Nutritional aspects of developing replacement heifers. J.

    Anim. Sci. 90:1166-1171.

Funston, R. N., J. A. Musgrave, T. L. Meyer, and D. M. Larson. 2012b. Effect of calving

    distribution of beef cattle progeny performance. J. Anim. Sci. 90:5118-5121.

Geary, T. W., R. R. Salverson, and J. C. Whittier. 2001. Synchronization of ovulation using

    GnRH or hCG with the CO-Synch protocol in suckled beef cows. J. Anim. Sci. 79:2536-

    2541.

Hafs, H. D. and J. G. Manns. 1975. Onset of oestrus and fertility of dairy heifers and suckled

    beef cows treated with prostaglandin $F_{2\alpha}$. Anim. Prod. 21:13.

Healy, V. M., G. W. Boyd, P. H. Guitierrez, R. G. Mortimer, and J. R. Piotrowski. 1993.

    Investigating optimal bull:heifer ratios required for estrus-synchronized heifers. J. Anim.

    Sci. 71:291-297.

Johnson, L. E. and C. A. Dinkel. 1951. Correction factors for adjusting weaning weights of range

    calves to the constant age of 190 days. J. Anim. Sci. 10:371.

Johnson, S. K. and R. D. Jones. 2008. A Stochastic model to compare breeding system costs for

    synchronization of estrus and artificial insemination to natural service. Prof. Anim. Sci.

    24:588-595.

Kill, L. K., E. M. Mousel, R. A. Cushman, and G. A. Perry. 2012. Effect of heifer calving date

    on longevity and lifetime productivity. J. Anim. Sci. 95(Suppl. 1):131.

Kittock, R. J., J. H. Brittand, and E. M. Convey. 1972. Effect of GnRH on LH and progesterone

    in cystic cows. J. Anim. Sci. 35:1120 (Abstr.).

Lamb, G. C., C. R. Dahlen, J. E. Larson, G. Marquezini, and J. S. Stevenson. 2010. Control of
the estrous cycle to improve fertility for fixed-time artificial insemination in beef cattle:
A review. J. Anim. Sci. 88(E. Suppl.) E181-E192.

Lamb, G. C., J. E. Larson, T. W. Geary, J. S. Stevenson, S. K. Johnson, M. L. Day, R. P.
Ansotegui, D. J. Kesler, J. M. DeJarnette, and D. G. Landblom. 2006. Synchronization of
estrus and artificial insemination in replacement beef heifers using gonadotropin-
releasing hormone, prostaglandin $F_{2\alpha}$, and progesterone. J. Anim. Sci. 84:3000-3009.

Lamb, G. C., J. S. Stevenson, D. J. Kesler, H. A. Garverick, D. R. Brown, and B. E. Salfen.
2001. Inclusion of an intravaginal progesterone insert plus GnRH and prostaglandin $F_{2\alpha}$
for ovulation control in postpartum suckled beef cows. J. Anim. Sci. 79:2253-2259.

Larson, J. E., K. N. Thielen, B. J. Funnel, J. S. Stevenson, D. J. Kesler, and G. C. Lamb. 2009.
Influence of a controlled internal drug release after fixed-time artificial insemination on
pregnancy rates and returns to estrus of nonpregnant cows. J. Anim. Sci. 87:914-921.

Larson, J. E., G. C. Lamb, J. S. Stevenson, S. K. Johnson, M. L. Day, T. W. Geary, D. J. Kesler,
J. M. DeJarnette, F. N. Schrick, A. DiCostanzo, and J. D. Arseneau. 2006.
Synchronization of estrus in suckled beef cows for detected estrus and artificial
insemination and timed artificial insemination using gonadotropin-releasing hormone,
prostaglandin $F_{2\alpha}$, and progesterone. J. Anim. Sci. 84:332-342.

Lauderdale, J. W. 1972. Effects of $PGF_{2\alpha}$ on pregnancy and estrous cycle of cattle. J. Anim. Sci.
35:246 (Abstr.).

Lauderdale, J. W., J. F. McAllister, D. D. Kratzer, and E. L. Moody. 1981. Use of prostaglandin
$F_{2\alpha}$ in cattle breeding. Acta Vet. Scand. (Suppl.) 77:181-191.

Lauderdale, J. W. 2009. ASAS Centennial Paper: Contributions in the Journal of Animal Science to the development of protocols for breeding management of cattle through synchronization of estrus and ovulation. J. Anim. Sci. 87:801-812.

Lesmeister, J. L., P. J. Burfening, and R. L. Blackwell. 1973. Date of first calving in beef cows and subsequent calf production. J. Anim. Sci. 36:1-6.

Louis, T. M., H. D. Hafs, and D. A. Morrow. 1972. Estrus and ovulation after uterine prostaglandin $F_{2\alpha}$ in cows. J. Ani. Sci. 35:247 (Abstr.).

Lucy, M. C., H. J. Billings, W. R. Butler, L. R. Ehnis, M. J. Filds, D. J. Kesler, J. E. Kinder, R. C. Mattos, R. E. Short, W. W. Thatcher, R. P. Wettemann, J. V. Yelich, and H. D. Hafs. 2001. Efficacy of an intravaginal progesterone insert and an injection of $PGF_{2\alpha}$ for synchronizing estrus and shortening the interval to pregnancy in postpartum beef cows, peripubertal beef heifers, and dairy heifers. J. Anim. Sci. 79:982-995.

Lynch, J. M., G. C. Lamb, B. L. Miller, R. T. Brandt Jr., R. C. Cochran, and J. E. Minton. 1997. Influence of timing of gain on growth and reproductive performance of beef replacement heifers. J. Anim. Sci. 75:1715–1722.

Macpherson, J. W. 1968. Semen placement effects on fertility in bovines. J. Dairy Sci. 51:807-808.

Macmillan, K. L. and A. J. Peterson. 1993. A new intravaginal progesterone releasing device for cattle (CIDR-B) for oestrous synchronization, increasing pregnancy rates and the treatment of postpartum anestrus. Anim. Reprod. Sci. 33:1-25.

Mauer, R. R., and R. H. Rippel. 1972. Response of cattle to synthetic gonadotropin releasing hormone. J. Anim. Sci. 35:249 (Abstr.).

Minyared, J. A. and C. A. Dinkel. 1965. Weaning weight of beef calves as affected by age and

    sex of calf and age of dam. J. Anim. Sci. 24:1067-1071.

Mulliniks, J. T., D. E. Hawkins, K. K. Kane, S. H. Cox, L. A. Torell, E. J. Scholljegerdes, and

    M. K. Petersen. 2012. Metabolizable protein supply while grazing dormant winter forage

    during heifer development alters pregnancy and subsequent in-herd retention rate. J.

    Anim. Sci. 91:1409-1416.

Myers, S. E., D. B. Faulkner, F. A. Ireland, L. L. Berger, and D. F. Parrert. 1999. Production

    systems comparing early weaning to normal weaning with or without creep feeding for

    beef steers. J. Anim. Sci. 77:300.

NAHMS. National Animal health Monitoring System. 2009. Part II. Reference of beef cow-calf

    management practices in the United States, 2007-08. Fort Collins, CO. Pp. 1-48.

Odde, K. G., H. S. Ward, G. H. Kiracofe, R. M. McKee, and R. J. Kittok. 1980. Short estrous

    cycles and associated serum progesterone levels in beef cows. Theriogenology. 14:105-

    112.

Odde., K. G., D., G. LeFever, H. S. Mauck, and R. E. Taylor. 1987. Calving distribution of

    estrous synchronized beef cows. Colorado State Univ. Beef Program Rep. p 89. Fort

    Collins.

Odde, K. G. 1990. A review of synchronization of estrus in postpartum cattle. J. Anim. Sci.

    68:817-830.

Osoro, K. and I. A. Wright. 1992. The effect of body condition, live weight, breed, age, calf

    performace, and calving date on reproductive performance of spring-calving beef cows. J.

    Anim. Sci. 70:1661-1666.

Patterson, D. J., R. C. Perry, G. H. Kiracofe, R. A. Bellows, R. B. Staigmiller, and L. R. Corah. 1992. Management considerations in heifer development and puberty. J. Anim. Sci. 70:4018-4035

Perry, R. C., L. R. Corah, G. H. Kiracofe, J. S. Stevenson, and W. E. Beal. 1991. Endocrine changes and ultrasonography of ovaries in suckled beef cows during resumption of postpartum estrous cycles. J. Anim. Sci. 69:2548-2555.

Peters, J. L., P. L. Senger, J. L. Rosenberger, and M. L. O'Connor. 1984. Radiographic evaluation of bovine artificial inseminating technique among professional and herdsman-inseminators using .5 and .25 mL French straws. J. Anim. Sci. 59:1671-1683.

Pexton, J. E., P. W. Farin, G. P. Rupp, and P. J. Chenoweth. 1990. Factors affecting mating activity and pregnancy rates with beef bulls mated to estrus synchronized females. Theriogenology. 34(6):1059-1070.

Randel, R. D. 1990. Nutrition and postpartum rebreeding in cattle. J.Anim. Sci. 68:853–862.

Richards, M. W., J. C. Spitzer, and M. B. Warner. 1986. Effect of varying levels of postpartum nutrition and body condition at calving on subsequent reproductive performance in beef cattle. J. Anim. Sci. 62:300.

Roberts, A. J., T. W. Geary, E. E. Grings, R. C. Waterman, and M. D. MacNeil. 2009. Reproductive performance of heifers offered ad libitum or restricted access to feed for a one hundred forty-day period after weaning. J. Anim. Sci. 87:3043-3052.

Rodgers, J. C. 2008. An economic evaluation of estrous synchronization and timed artificial insemination in beef cows (Master's thesis). University of Minnesota, St. Paul, MN.

Rodgers, J. C., S. L. Bird, J. E. Larson, N. DiLorenzo, C. R. Dahlen, A. DiCostanzo, and G. C. Lamb. 2012. An economic evaluation of estrous synchronization and timed artificial insemination in suckled beef cows. J. Anim. Sci. 90:4055-4062.

Roche, J. F. 1974. Synchronization of oestrus and fertility following artificial insemination in heifers given prostaglandin $F_{2\alpha}$. J. Reprod. Fertil. 37:135.

Roche, J. F., E. J. Austin, M. Ryan, M. O'Rourke, M. Mihm, and M. G. Diskin. 1999. Regulation of follicular waves to maximize fertility in cattle. J. Reprod. Fertil. Suppl. 54:61-71.

Rowson, L. E. A., R. Tervit, and A. Brand. 1972. The use of prostaglandin for synchronization of oestrus in cattle. J. Reprod. Fertil. 29:145.

Sá Filho, O. G., E. R. Vilela, T. W. Geary, and J. L. M. Vasconcelos. 2009. Strategies to improve fertility in postpartum multiparous *Bos indicus* cows submitted to a fixed-time insemination protocol with gonadotropin-releasing hormone and prostaglandin $F_{2\alpha}$. J. Anim. Sci. 87:2806-2814.

Schoonmaker, J. P., F. L. Fluharty, S. C. Loerch, T. B. Turner, S. J. Moeller, and D. M. Wuff. 2001. Effect of weaning status and implant regimen on growth, performance, and carcass characteristics in steers. J. Anim. Sci. 79:1074-1084.

Seeger, J. T., M. E. King, D. M. Grotelueschen, G. M. Rogers, and G. S. Stokka. 2011. Effect of management, marketing, and certified health programs on the sale price of beef calves sold through a livestock video auction service from 1995 through 2009. J. Am. Vet. Med. Ass. 239:451-466.

Select Sires, Inc. www.selectsiresbeef.com. Accessed June 20, 2013.

Senger, P. L. 1997. Pathways to Pregnancy and Parturition. 2nd Revised Edition. Current Conceptions, Inc. Pullman, WA.

Short, R. E., R. A. Bellows, R. B. Staigmiller, J. G. Berardinelli, and E. E., Custer. 1990.

    Physiological mechanisms controlling anestrus and infertility in postpartum beef cattle. J.

    Anim. Sci. 68:799-816.

Smith, G. M., D. B. Laster, and K. E. Gregory. 1976. Characterization of biological types of

    cattle I. dystocia and preweaning growth. J. Anim. Sci. 43:27-36.

Smith , D.L., D. L. Wiggers , L. L. Wilson , J. W. Comerford, H. W. Harpster, and E. H. Cash.

    2003. Postweaning Behavior and Growth Performance of Early and Conventionally

    Weaned Beef Calves. Prof. Anim. Sci. 19:23-29.

Spangler, M. L. 2011. revised. EPD Basics and definitions. NebGuide G1967.

Sprott, L. R. 1999. Management and financial considerations affecting the decision to

    synchronize estrus in beef females. J. Anim. Sci. 77:1-10.

Society for Theriogenology. 1993. Guidelines for the bull breeding soundness evaluation. In:

    Guidelines for uniform beef improvement programs, 9th edition, 2010.

Thrift, F. A. and T. A. Thrift. 2006. Review: Expected versus realized progeny differences for

    various beef cattle traits. Prof. Anim. Sci. 22:413-423.

Trimberger, G. W. and H. P. Davis. 1943. Conception rate in dairy cattle from artificial

    insemination at various stages of oestrus. Nebr. Agric. Exp. Stn., Res. Bull. 129, 1-4.

Troxel, T. R., L. C. Cruz, R. S. Ott, and D. J. Kesler. 1993. Norgestomet and gonadotropin-

    releasing hormone enhance corpus luteum function and fertility of postpartum suckled

    beef cows. J. Anim. Sci. 71:2579-2585.

Twagiramungu, H., L. A. Guilbault, J. G. Proulx, and J. J. Dufour. 1994. Influence of corpus

    luteum and induced ovulation on ovarian follicular dynamics in postpartum cyclic cows

    treated with buserelin and cloprostenol. J. Anim. Sci. 72:1796-1805.

Varner, L. W., R. A. Bellows, and D. S. Christensen. 1977. A management system for wintering replacement heifers. J. Anim. Sci. 44:165-171.

Williams, G. L. and D. E. Ray. 1980. Hormonal and reproductive profiles of early postpartum beef heifers after prolactin suppression or steroid-induced luteal function. J. Anim. Sci. 50:906-918.

Wright, I. A., S. M. Rhind, A. J. F. Russel, T. K. Whyte, A. J. Mcbean, and S. R. McMillen. 1987. Effects of body condition, food intake and temporary calf separation on the duration of the post-partum anoestrus period and associated LH, FSH, and prolactin concentrations in beef cows. Anim. Prod. 45:395-402.

Zalesky, D. D., M. L. Day, M. Garcia-Winder, K. Imakawa, R. J. Kittok, M. J. D'Occhio, and J. E. Kinder. 1984. Influence of exposure to bulls on resumption of estrous cycles following parturition in beef cows. J. Anim. Sci. 59:1135–1139.

Zolman, J., E. M. Convey, J. H. Britt, and H. D. Hafs. 1973. Release of bovine luteinizing hormone by purified porcine and synthetic gonadotropin-releasing hormone. Proc. Soc. Biol. Med. 142:189-193.

CHAPTER 2: EFFECTS OF ARTIFICIAL INSEMINATION AND NATURAL SERVICE BREEDING SYSTEMS ON REPRODUCTIVE PERFORMANCE AND CALF PERFORMANCE TO WEANING[1]

Abstract

One thousand seventy-six Angus crossbred females were used to evaluate the effects of 2 different breeding systems on reproductive performance and subsequent calf performance. In each of 2 years cattle were stratified by age and BCS, then assigned randomly to 1 of 2 breeding systems: 1) females exposed to natural service bulls for the duration of the breeding season (**NS**; n = 541), or 2) females exposed to estrous synchronization and a fixed-time AI (7-d Co-Synch + CIDR) on d 0, followed by exposure to natural service bulls for the duration of the breeding season (**TAI**, n = 535). Bulls were introduced to all cattle on d 1 and both treatments were managed as a cohort in the same pastures. Blood samples were collected on d -20 and -10 to determine cyclic status. On d 49 and again at least 40 d after bull removal from pastures, transrectal ultrasonography was used to determine presence and age of fetus. Calving date, dam identification, calving ease, calf vigor, and birth weight was recorded within 24 h of birth during the calving season. At weaning, BW, hip height, heart girth, body length, and carcass ultrasound measurements were recorded. A price simulation of calves was performed by buyers from local livestock markets with replicated pens of calves. The proportion of females pregnant in the first 10 d of the breeding season was affected by treatment $\times$ cyclic status ($P = 0.030$), with cyclic TAI (59.4%) and non-cyclic TAI (53.9%) greater than cyclic NS (36.0%), while non-cyclic NS intermediate (44.4%). A greater proportion ($P < 0.05$) of TAI cattle (81.7%) were detected

pregnant on d 49 compared with NS cattle (77.5%), but no differences were present ($P > 0.05$)

for final pregnancy check. Cattle in the TAI treatment became pregnant 5.48 d earlier ($P < 0.05$)

than cattle in the NS treatment. During the calving season, a greater proportion ($P < 0.05$) of TAI

cattle gave birth in the first 21 d (54.2%) than NS cattle (39.6%); whereas a greater proportion (P

< 0.05) of NS cattle (34.4%) gave birth 22 to 42 d of the calving season than TAI cattle (18.8%).

There was a treatment × calf age ($P = 0.06$) for weaning weight, heart girth, LMA, 12th rib back

fat, and calculated preliminary yield grade; with TAI calves born in the first 21 d of the calving

season having the largest measurements than all other treatment × calf age group. Steers in the

TAI treatment had an increased ($P < 0.05$) price per steer ($836.31/hd) than NS steers

($814.72/hd), however, heifers did not receive a price premium ($P > 0.05$) among treatments.

Keywords: artificial insemination, beef calves, estrous synchronization, natural service

Introduction

Good herd reproductive performance is essential for a cow-calf producer in today's U.S.

beef industry (Osoro and Wright, 1992). Producers need cattle to become pregnant, give birth,

and raise a healthy calf to weaning (Dickerson, 1970). The use of AI as a reproductive tool may

result in greater pregnancy rates than those obtained from natural service (Dziuk and Bellows,

1983). The use of AI is limited, however, 7.4% beef operations have incorporated this

technology (NAHMS, 2009). Labor, costs, difficult or complicated AI protocols are reasons

producers do not use AI, however, several benefits may be present (NAHMS, 2009).

Many concepts exist that tout the benefits of implementing AI breeding system (Sprott,

1999; Larson et al., 2006; Johnson and Jones 2008); however, producers may consider

implementation of AI with more scientific data that compares AI and natural service to better

estimate whether to utilize AI on their operation and create greater profits. There are few studies available that compare natural service breeding system with systems that incorporate modern AI protocols (Sá Filho et al., 2009; Rodgers et al., 2012).

Cattle exposed to estrous synchronization (**ES**) and AI had greater pregnancy rates throughout the breeding season compared to a natural service system; however, this study used *Bos indicus* cattle which behave very differently than *Bos taurus* and ended upon pregnancy determination (Sá Filho et al., 2009). An ES and AI system shifted the calving distribution with the mean calving date to be earlier and calves had greater weaning weights per exposed cow were increased compared with a natural service system (Rodger et al., 2012); however, this study did not report at pregnancy rates for the 2 treatments.

Therefore, the objectives of this study were to evaluate the impact of incorporating an AI breeding protocol at the initiation of the breeding season on pregnancy rates, average day of conception, birthing difficulties, calving season length, and calf performance.

Materials and Methods

All procedures were approved by the Institutional Animal Care and Use Committee of North Dakota State University.

Animals and Treatments

One thousand seventy-six females were used to evaluate the effects of breeding systems on pregnancy rates, average day of conception, birthing difficulties, calving season length, and calf performance in a two year study. A combination of 187 crossbred Angus heifers (yr 1, n = 86; yr 2, n = 101; Central Grasslands Research Extension Center; **CGREC**) and 889 crossbred

Angus cows (yr 1, n = 79 and 399, Hettinger Research Extension Center; **HREC** and CGREC, respectively; yr 2, n = 412, CGREC) were used (Table 2.1).

Table 2.1 Breeding female average traits

	Year 1	Year 2
No. of breeding females	564	513
BCS[1]	5.18 ± 0.64	5.11 ± 2.40
DPP[2], d	65.61 ± 14.48	78.15 ± 16.08
Parity[3]	2.86 ± 2.28	3.12 ± 2.67

[1] Body condition score, scale of 1 to 9 (adapted from Whitman, 1975).
[2] Days postpartum at time of breeding.
[3] Range 0 to 10.

In yr 1, all cows were stratified by age, BCS, and days postpartum; and all replacement heifers were stratified by date of birth and BCS, and then assigned to 1 of 2 treatments (Figure 2.1) in a completely randomized design. The 2 treatments included: 1) exposed to natural service bulls for the duration of the breeding season (**NS**, n = 541), or 2) exposed to fixed-time artificial insemination followed by exposure to natural service bulls (clean-up bulls) for the duration of the breeding season (**TAI**, n = 535). In yr 2, cows remained on the same treatment as the previous breeding season and incoming replacement heifers were once again stratified by date of birth and BCS, and then randomly assigned to either the NS or TAI treatment.

Cattle were subdivided within locations (CGREC and HREC) to ensure appropriate pasture stocking rates and allowed for proper timing of the AI protocol. In yr 1 at CGREC, heifers were in four different pastures of 15, 15, 15, and 41 hd/pasture while mature cattle grouped in two locations that contained primiparous and second year calvers (CGREC 1) and multiparous females (CGREC 2). All cattle within the HREC were randomly divided in 2 pastures of 40 and 38 hd (HREC 1 and HREC 2, respectively). In yr 2, CGREC contained heifers in four different pastures of 18, 18, 20, and 45 hd/pasture. Mature cows were grouped by

primiparous, second year calvers, and eight year old females at the CGREC 1 location; with all

other multiparous cows pastured in the CGREC 2 location.
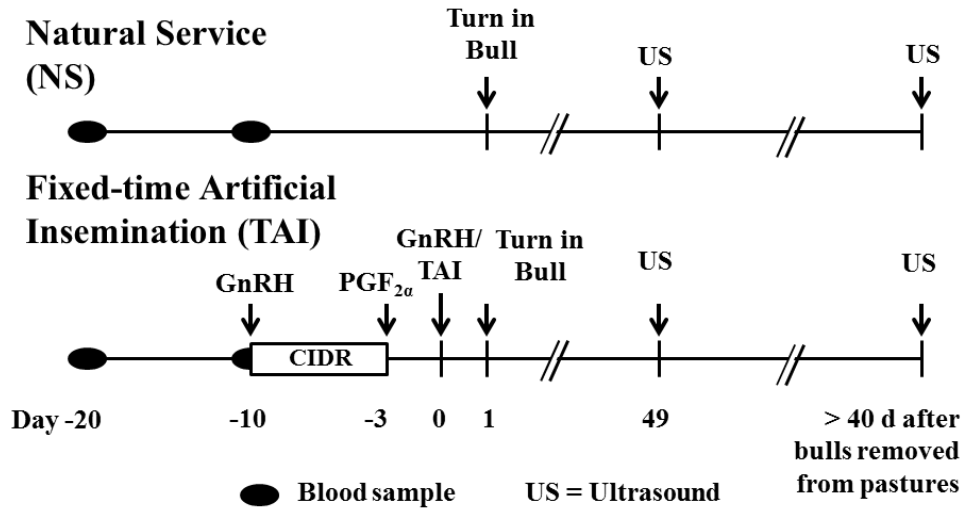
Figure 2.1 Treatment schematic for the breeding females assigned to the fixed-time AI (TAI) or natural service (NS). Blood samples (●) were collected on all females on d -20 and -10. All TAI treated cows received a controlled internal drug release (CIDR; 1.38 g of progesterone, Eazi-Breed CIDR, Zoetis LLC, Madison, NJ;) insert and injected with GnRH (100 μg, i.m. Factrel, Zoetis LLC, Madison, NJ) on d -10. On d -3, the CIDR was removed and an injection of $PGF_{2\alpha}$ (25 mg, i.m. Lutalyse, Zoetis LLC, Madison, NJ) was given. On d 0, TAI cattle received a second injection of GnRH and were fixed-time artificial inseminated. On d 1, bulls were exposed to all females in both treatments. US = ultrasound.

Females in the TAI treatment were synchronized with the 7-d Co-Synch + CIDR (Larson

et al., 2006) protocol. Gonadotropin-releasing hormone (**GnRH**; as 100 μg as 2 mL of Factrel

i.m.; Zoetis LLC, Madison, NJ) was administered and a controlled internal drug releasing device

(**CIDR**; 1.38 g of progesterone, Eazi-Breed CIDR, Zoetis LLC, Madison, NJ) was inserted,

followed in 7 d by removal of CIDR inserts and injection of prostaglandin $F_{2\alpha}$ (**$PGF_{2\alpha}$**; 25 mg,

Lutalyse i.m., Zoetis LLC, Madison, NJ). Cows were bred 60 to 66 h after injection of GnRH

and heifers bred 54 h after injection of GnRH.

Bulls were introduced to all cattle on d 1 and both treatments were managed as a cohort in the same pastures. All bulls passed a breeding soundness exam (Society for Theriogenology, 1993) and stocked at a rate of 27.0 cows/bull and 17.1 heifers/bull at the CGREC locations and 16.2 cows/bull at the HREC locations. The breeding season length for CGREC and HREC was 49 and 63 d, respectively.

Pregnancy Determination

Transrectal ultrasonography was used to determine presence and age of a viable fetus (Aloka 500 with a 5 MHz linear probe, Corometrics Medical Systems, Inc., Wallingford, CT) on d 49 and again at least 40 d after the bulls were removed from breeding pastures. At both scans the fetus was visualized and evaluated for the presence of a heartbeat. Crown-rump measurements were determined at each respective ultrasound session and used to calculate fetal age (Hughes and Davies, 1989). Cattle pregnant within the first 10 d of the breeding season were defined as cattle with a pregnancy estimated to be from 39 to 49 days old. Cattle pregnant within the first 21 d of the breeding season were defined as cattle with a pregnancy estimated to be from 29 to 49 days old. At the final pregnancy check, cattle were re-evaluated for pregnancy to determine season ending pregnancy rates and if any pregnancies were lost between d 49 and final check. Pregnancy loss was defined as cattle pregnant at first ultrasound then not pregnant or re-established a pregnancy by final pregnancy determination.

Pasture Characteristics

Pastures at the CGREC consisted primarily of Kentucky bluegrass (*Poa pratensis* L.; Neville and Patton, unpublished data) with blue grama (*Bouteloua gracilis* [H. B. K.] Lag. Ex Griffiths), needle and thread [*Hesperostipa comate* (Trin. + Rupr.) Barkworth], sun sedge (*Carex*

inops spp. *heliophila* L.H Bailey) and western snowberry (*Symphoricarpos occidentalis* Hook.)

being secondary forage species (Hirschfeld et al., 1996). At HREC, pastures consisted of

intermediate wheatgrass (*Thinopyrum* intermedium [Host] Barkworth and D. R. Dewey), alfalfa

(*Medicago sativa* L.), crested wheatgrass (*Agropyron cristatum* [L.] Gaertn), smooth brome

(*Bromus inermis* Leyss), and sweetclover [*Melilotus officinalis* (L.) Lam].

Blood Sample and Analysis

Blood samples for all females were taken on d -20 and -10 via coccygeal or jugular

veinipuncture into 10 mL Vacutainer tubes containing sodium heparin (BD, Franklin Lakes, NJ).

Samples were immediately placed on ice for 2 hours then centrifuged in a refrigerated unit (5° C)

at $1,200 \times$ g for 20 min with plasma collected and stored at -20°C in a commercial freezer. The

concentrations of plasma progesterone (**P₄**) were analyzed in duplicate by RIA using

progesterone kits (Coat-A-Count; Diagnostic Products Corp. Los Angeles, CA). The assay kit

was validated for bovine serum (Kirby et al., 1997) using an assay volume of 100 µL. Assay

tubes for the standard curve contained 0.1, 0.25, 0.5, 1, 2, 5, 10, and 20 ng/tube of known

progesterone concentrations. Assay sensitivity for a 100 µL sample was 0.1 ng/mL. In yr 1 the

intra and inter-assay CV were 5.5% and 6.3%; respectively, while in yr 2 the intra and inter-

assay CV were 9.7% and 5.9%; respectively. Females were considered to be cyclic at the

initiation of treatments if at least 1 of 2 blood samples had concentrations of $P_4 \geq 1$ ng/mL (Perry

et al., 1991).

Wintering

All cattle at the CGREC location were managed as one herd after weaning and remained

on pasture until December 1. All heifers were placed into a dry lot and fed a once daily ration

consisting of approximately 2 kg of corn/hd/d and a mixture of corn silage and grass hay. Primiparous cows were placed into a small winter pasture and multiparous cows placed in a large winter pasture and fed once daily of grass and alfalfa/grass hay starting December 1 and January 1 for primiparous and multiparous group; respectively. The HREC cows were kept in their respective pastures until December, then comingled in a field of unharvested corn. Cows were then moved to a drylot and fed harvested forage until calving.

Calves

Only calves born from treatments administered in yr 1 were used for data analysis at the time of writing. Within 24 h of birth, calving date, dam ID, calving ease, calf vigor, and birth weights (collected with an electronic portable scale) were recorded. Calving ease was subjectively determined using a 1 to 5 scale with 1 = no assistance, 2 = assisted, easy, 3 = assisted difficult, 4 = assisted, very difficult, and 5 = caesarean (adapted by Colburn et al., 1997). Calf vigor was subjectively determined using a 1 to 5 scale with 1 = normal calf, 2 = weak calf that nursed without assistance, 3 = weak calf that was assisted to nurse (lived), 4 = weak calf that was assisted to nurse (died), 5 = stillborn (adapted from Riley et al., 2004). The calving season (d 0) was defined as the day that the third calf was born at each location, thus removing the early calvers (outliers) as classifying the start of the breeding season. For subsequent analysis, calves were divided into 3 calving categories: born within first 21 d (≤ 21; n = 246), from d 22 to 42 (22-42; n = 131), and born after d 42 (> 42; n = 49). All bull calves were banded within 24 hrs of birth. All calves were managed with their respective dam through weaning. Any calf that needed to be fostered (n = 2) prior weaning was placed with a cow whose offspring died and calf performance was excluded from analysis.

All calves were branded and vaccinated for respiratory, clostridial, *Hemophilus somnus*, and Mannheimia diseases; and all cows vaccinated for *Bacillus anthracis*, bovine rhinotracheitis, respiratory, leptospirosis, *Campylobacter fetus* diseases and treated with a parasiticide and placed in pastures in late May/early June in their respective CGREC 1, CGREC 2, and heifer groups. At this time the remaining cattle to calve were grouped together and re-evaluated for pregnancy, then transported with their calf to their appropriate pasture.

Body weaning weights (**WW**), physical characteristics, and carcass traits were determined at weaning. Weaning weight per female exposed was calculated by females that did not wean a calf, WW was 0. Weaning weight per female calving was calculated by those females that calved but did not wean a calf, WW was 0. Physical characteristics evaluated included measurements of hip height (**HH**), heart girth (**HG**; Wanderstock and Salisbury, 1946), and body length (**BL**; Kidwell, 1955). Carcass traits were determined via real time ultrasonography (Aloka 500 with a 3 MHz linear probe, Corometrics Medical Systems, Inc., Wallingford, CT) and software (CUP Lab™ UICS chute side software, Walter and Associates, LLC, Ames, IA) . Measurements included area of the LM between the 12th and 13th rib (**LMA**), rib fat measured two-thirds of the way down the LM (**RIBFAT**), and intramuscular fat measured over the 12th and 13th rib (**IMF**). Calculated preliminary yield grade (**CPYG**) was calculated with a 12th rib fat of 0.0 cm being CPYG of 2.0 and every 0.254 cm increase in RIBFAT increases CPYG by 0.25 (American Meat Science Association, 2001).

Price Simulation

    Heifers

       The GGREC heifers born from yr 1 were assigned to 8 replicate pens based on treatment

and date of birth of the calving season at weaning and a sales price simulation performed. In

order to have even numbers per pen, age was defined for heifers born in the TAI treatment as

Early = d 0 to10 (n = 2) and Late = d 11 to 59 (n = 2) of the calving season. Age was defined for

heifers born in the NS treatment as Early = d 0 to 23 (n = 2) and Late = d 17 to 56 (n = 2) of the

calving season. Buyers from a local livestock market (Napoleon Livestock Auction, Napoleon,

ND) viewed pens independently and assign values to pens of heifers as replacements based on

market dynamics at the time of simulation.

    Steers

       Steers from both CGREC and HREC born from yr 1were assigned to 24 replicate pens

based on treatment and date of birth of the calving season to perform a sales price simulation. In

order to have even numbers per pen, age was defined for steers as Early = d 0 to 26 (n = 16) and

Late = d 26 to 62 (n = 8) of the calving season. Buyers from a local livestock market

(Stockmen's Livestock Exchange, Dickinson, ND) viewed pens independently and assign values

to pens steers based on market dynamics at the time of simulation.

Statistical Analysis

       All categorical data were analyzed using the GLIMMIX procedures of SAS (SAS Ins.

Inc., Cary, NC) and continuous data were analyzed by GLM procedure with animal as

experimental unit. The statistical model for the proportion of females pregnant within the first

10 d of breeding season, proportion of females pregnant within the first 21 d, proportion of females with detectable pregnancy on d 49, final pregnancy, pregnancy loss, and days to conception first included the effects of parity (0, 1, or ≥ 2), treatment (TAI or NS), year (1 or 2) and the respective interactions and then included the effects of parity (0, 1, or ≥ 2), treatment (TAI or NS), cyclic status (cyclic or non-cyclic), year (1 or 2) and respective interactions.

The statistical model for date of birth of the calving season, birth weight, calving ease, calf vigor, weaning weight, hip height, heart girth, body length, intramuscular fat, calculated preliminary yield grade, 12th rib LM area, 12th rib fat, exposed weaning weight and weaning weight for cows calving included the effects of treatment (TAI or NS), cyclic status (cyclic or non-cyclic), calf sex (male or female) and respective interactions.

Another statistical model for date of birth of the calving season, birth weight, calving ease, calf vigor, weaning weight, hip height, heart girth, body length, intramuscular fat, calculated preliminary yield grade, 12th rib LM area, 12th rib fat, and exposed weaning weight included the effects of treatment (TAI or NS), 21 d age increments of the calving season (≤ 21, 22-42, or > 42), calf sex (male or female), and the respective interactions. Any calf that needed to be fostered on to another dam were excluded from the weaning measurement analysis.

The statistical model of 21 d calving season increments included the effect of treatment, group, and treatment $\times$ group interaction.

Price simulation experimental unit was pen, and the model included treatment, age, and treatment $\times$ age interaction. Significance was determined with an alpha of $P < 0.05$.

Reproductive Performance

The proportion of females that were cyclic at the initiation of the treatments was 42.0% in yr 1 and 81.3% in yr 2. The proportion of cows cyclic at breeding in yr 2 tended ($P = 0.08$) to be greater in the TAI treatment (81.9%) compared with the NS treatment (74.6%). The proportion of females pregnant to the fixed-time AI was not different ($P > 0.05$) for yr 1 (55%, 153 of 277) or yr 2 (58%, 144 of 249).

There was a treatment × cycling status interaction (Figure 2.2; $P = 0.030$) for the proportion of females pregnant in the first 10 d of the breeding season. The proportion of cyclic females in the TAI treatment that became pregnant during the first 10 d of the breeding season was greater ($P < 0.05$) than all cattle in the NS treatment; whereas, the proportion of non-cyclic TAI females pregnant was not different ($P > 0.05$) to non-cyclic NS females but greater ($P < 0.05$) then cyclic NS females.

The proportion of females that became pregnant in the first 21 d of the breeding season was not different ($P > 0.05$) among TAI (57%, 315 of 526) and NS (65%, 345 of 529) treatments. The proportion of females that became pregnant in the first 21 d of the breeding season was different ($P < 0.05$) between years, with yr 2 (66%, 335 of 507) having a greater proportion than yr 1 (59%, 325 of 548).

A greater proportion ($P < 0.05$) of TAI females (81.7%, 425 of 520) were detected pregnant on d 49 of the breeding season compared with females in the NS females (77.5%, 407 of 525) across both years.

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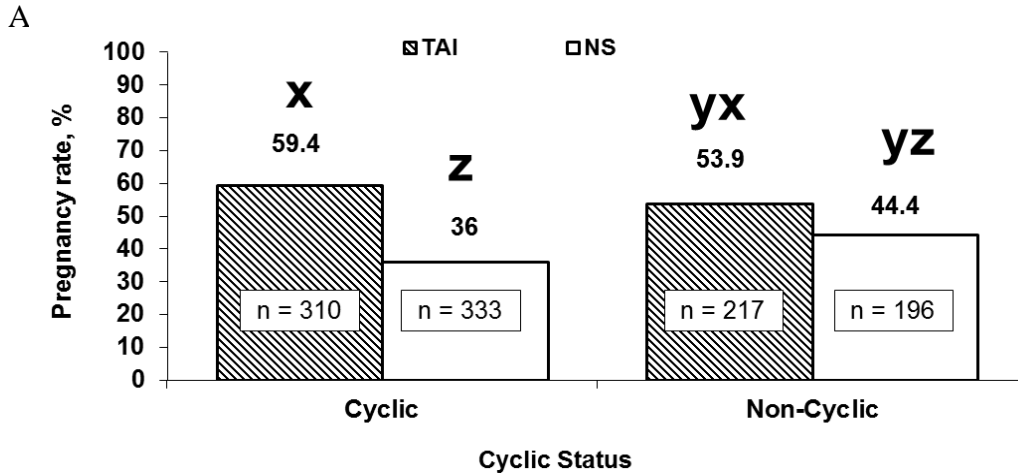
Figure 2.2 Effect of cyclic status and treatment on the proportion of females that became pregnant during the first 10 d of the breeding season. Treatment[1] × Cyclic Status ($P = 0.030$).
[x,y,z] Means lacking common letter differ $P < 0.05$.
[1] Treatments were dam's given either exposed to fixed-time AI (**TAI**) 7 d CO-Synch + CIDR with clean-up bull or natural service (**NS**) bulls for the duration of the breeding season.

In the model that did not include cyclic status, the proportion of females pregnant at the final pregnancy check in the TAI (90%, 475 of 525) treatment was not different ($P > 0.05$) compared to female in the NS (90%, 478 of 530) treatment. A year effect was present for final pregnancy check, with yr 2 (92.4%, 473 of 512) being greater ($P < 0.05$) than yr 1 (88.4%, 490 of 554). There was a treatment × cyclicity status × year interaction ($P = 0.010$; Figure 2.3) present for the final pregnancy check with the proportion of cyclic yr 1 TAI females being greater ($P < 0.05$) than non-cyclic yr 1 TAI females and non-cyclic yr 2 NS females. In yr 1, the non-cyclic TAI females had reduced pregnancy rates compared to the yr 2 non-cyclic TAI females, cyclic TAI, and cyclic NS females.

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A cyclic status × treatment interaction ($P = 0.029$) was present (Figure 2.4), with cyclic TAI cattle having a reduced ($P < 0.05$) average day to conception compared with both cyclic and non-cyclic NS females. Cyclic NS females became pregnant later in the breeding season compared to the non-cyclic NS females. Non-cyclic TAI females had a reduced days to conception compared to cyclic NS females; however, they were intermediate to cyclic TAI and non-cyclic NS females. Pregnancy loss was not influenced by treatment, cycling status, year, or the respective interactions ($P > 0.05$).
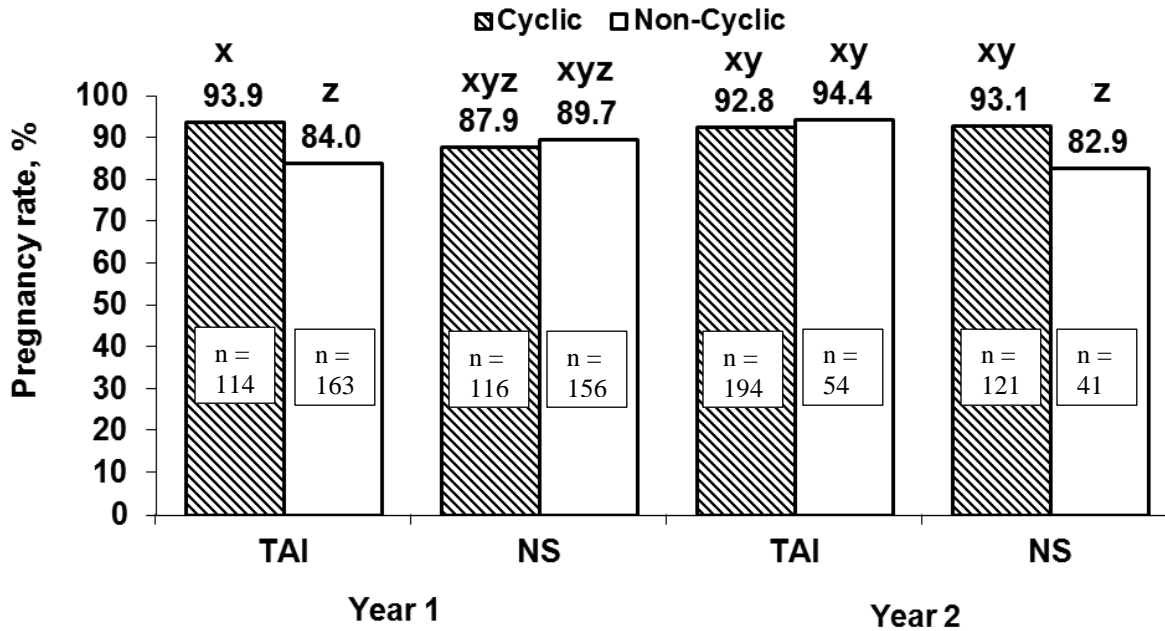
Figure 2.3 Effect of treatment, cyclic status, and year on the proportion of females pregnant at final pregnancy check. Treatment[1] × Cyclic Status × Year ($P = 0.010$).
[x,y,z] Means lacking common letter differ ($P < 0.05$).
[1] Treatments were dam's given either exposed to fixed-time AI (**TAI**) 7 d CO-Synch + CIDR with clean-up bull or natural service (**NS**) bulls for the duration of the breeding season.
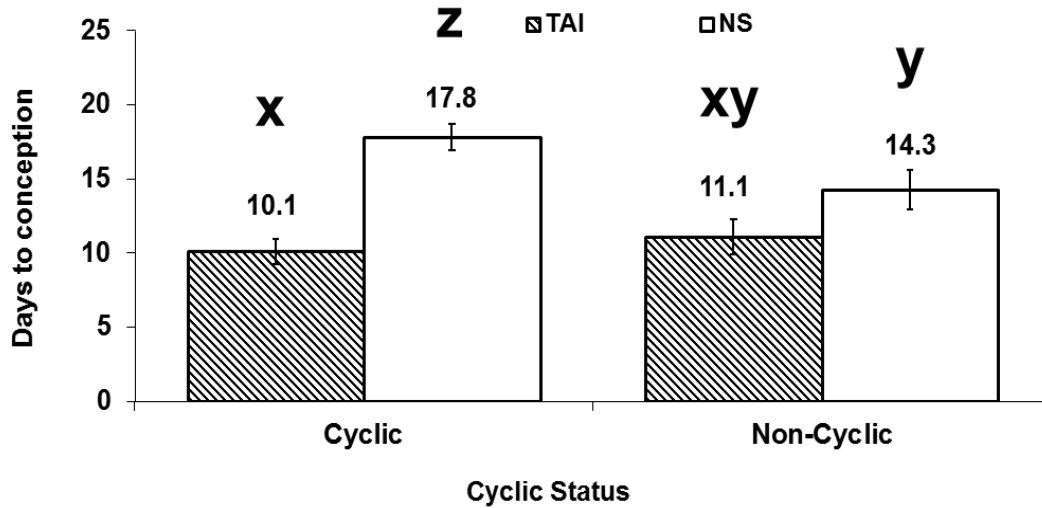
Figure 2.4 Effect of treatment[1] and cyclic status on average days to conception.
Treatment × Cyclic Status ($P = 0.029$).
[x,y,z] Means lacking common letter differ ($P < 0.05$).
[1] Treatments were dam's given either exposed to fixed-time AI (**TAI**) 7 d CO-Synch + CIDR with clean-up bull, or natural service (**NS**) bulls for the duration of the breeding season.

Calving and Calf Characteristics

During the calving season, a greater proportion ($P < 0.05$) of TAI cattle gave birth in the first 21 d of the calving season compared to the NS treatment (Figure 2.5). From d 22 to 42; however, more females in the NS treatment ($P < 0.05$) gave birth compared to cattle in the TAI treatment. No differences ($P > 0.05$) were present among treatment in the proportion of females that calved after d 43 or failed to have a calf (**NC**, either was called open at final pregnancy check or pregnant but did not calf).

Then average date of parturition for TAI cattle was 6.95 d earlier ($P < 0.05$) than the NS cattle (Table 2.2). In addition, the average birth weight of calves was reduced ($P < 0.05$) in the TAI treatment compared to calves in the NS treatment. Calving ease and calf vigor; however, were not affected by treatment ($P > 0.05$).

Table 2.2 Effects of treatment and calf sex on birth weight, calving ease, and calf vigor

Item	Treatment[1]		Calf Sex	
	TAI	NS	Female	Male
No. of calves	234	227	232	229
Average date of birth of calving season, d	17.6 ± 1.07^{x}	24.6 ± 1.11^{y}	20.0 ± 1.10	22.2 ± 1.07
Birth weight, kg	37.1 ± 0.38^{x}	38.4 ± 0.40^{y}	36.2 ± 0.39^{x}	39.3 ± 0.40^{y}
Calving ease[2]	1.1 ± 0.02	1.1 ± 0.02	1.0 ± 0.02^{x}	1.1 ± 0.02^{y}
Calf vigor[3]	1.2 ± 0.05	1.1 ± 0.05	1.2 ± 0.05	1.2 ± 0.05

[1] Treatments were dam's given either exposed to fixed-time AI (**TAI**) 7 d CO-Synch + CIDR with clean-up bull, or natural service (**NS**) bulls for the duration of the breeding season.
[2] Scale of 1 to 5; 1 = no assistance, easy birth; 5 = cesarean delivery (adapted from Colburn et al., 1997).
[3] Scale of 1 to 5; 1 = extremely alert and lively; 5 = dead (adapted from Riley et al., 2004).
[x,y] Means within row and factor lacking common superscript differ ($P < 0.05$).
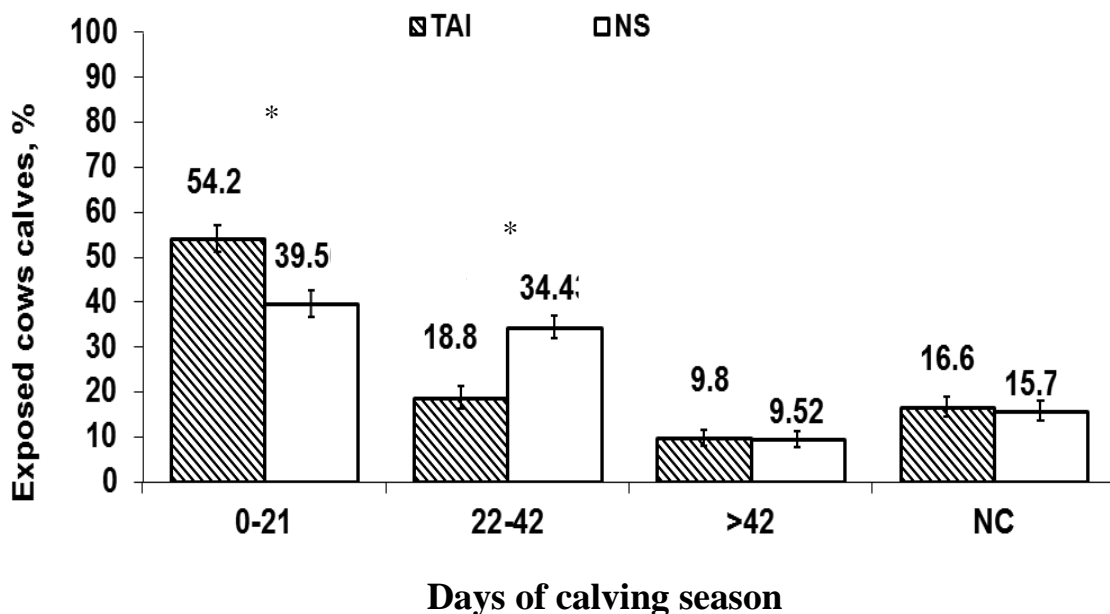
Figure 2.5 Effect of treatment[1] on calving distribution of yr 1.
[*]Means within factor lacking common superscript differ ($P < 0.05$).
NC, either was called open at final pregnancy check or pregnant but did not calf.
[1] Treatments were dam's given either exposed to fixed-time AI (**TAI**) 7 d CO-Synch + CIDR with clean-up bull or natural service (**NS**) bulls for the duration of the breeding season.

There was no effect ($P > 0.05$) of calf sex (Table 2.2) on average date of birth of the

calving season. There was an effect of calf sex effect ($P < 0.05$) on birth weight, with male

calves heavier ($P < 0.05$) than female calves. Male calves also had a greater ($P < 0.05$) calving ease score compared to female calves. Calf vigor was not different ($P > 0.05$) between calf sexes.

Calf Weaning

Weaning weight, preweaning gain, HH, and BL (Table 2.3) were not affected by treatment ($P > 0.05$). However, HG was greater ($P < 0.05$) for TAI calves compared to NS calves. Parity had an effect on preweaning ADG, with calves born from multiparous cows having the greater ($P < 0.05$) ADG (1.12 ± 0.01 kg/d) compared with calves from offspring from primiparous cows (1.08 ± 0.2 kg/d), which were greater ($P < 0.05$) than calves born from nulliparous cows (1.03 ± 0.02 kg/d). Calves from dams that were cyclic at the beginning of the breeding season (in yr 1) that gave birth had a greater ($P < 0.01$) preweaning ADG (1.13 ± 0.01 kg/d) compared to non-cyclic dam's offspring (1.05 ± 0.01 kg/d). There was no effect of treatment on reproductive efficiencies (Table 2.4) for any of the variables.

Male calves were 7.7 kg heavier ($P < 0.05$) at weaning (Table 2.3) compared with female counterparts. In addition, preweaning ADG, HH, and HG were greater ($P < 0.05$) for male calves compared to female calves. Body length was not different ($P > 0.05$) between calf sexes.

Table 2.3 Effects of treatment and calf sex on weaning weight **(WW)**, preweaning ADG, hip height **(HH)**, heart girth **(HG)**, and body length **(BL)**

	Treatment[1]		Calf Sex	
Item	TAI	NS	Female	Male
No. of calves	217	215	215	217
WW, kg	207.3 ± 2.17	202.7 ± 2.25	200.9 ± 2.24^y	208.6 ± 2.17^x
Preweaning ADG, kg/d	1.1 ± 0.01	1.1 ± 0.01	1.1 ± 0.01^y	1.1 ± 0.01^x
HH, cm	105.5 ± 0.37	105.1 ± 0.38	103.8 ± 0.38^x	106.8 ± 0.37^y
HG[2], cm	139.4 ± 0.48^x	137.9 ± 0.50^y	137.9 ± 0.49^x	139.5 ± 0.48^y
BL[3], cm	65.6 ± 0.30	65.2 ± 0.31	65.4 ± 0.31	65.3 ± 0.30

[1] Treatments were dam's given either exposed to fixed-time AI (**TAI**) 7 d CO-Synch + CIDR with clean-up bull or natural service (**NS**) bulls for the duration of the breeding season.
[2] Heart girth measurements (adapted from Wanderstock and Salisburty, 1946).
[3] Body length measurements (adapted from Kidwell, 1955).
[x,y] Means within factor lacking common superscript differ ($P < 0.05$).

Table 2.4 Effects of treatment[1] on reproductive efficiencies

	Treatment[1]		
Item	TAI (#)	NS (#)	*P*-value
No. of females	282	282	
	…………………% (no.)………………..		
Cows that calved, %	83.3 (235)	83.7(236)	0.895
Calves born alive, %	80.9 (228)	81.9 (231)	0.731
Calf death loss to weaning, %	3.5 (10)	3.8 (11)	0.831
Cows weaning a calf, %	78.4 (221)	78.7 (222)	0.901
	………. Mean ± SE……….		
Weaning weight of cows weaned a calf, kg	207.6 ± 2.0	203.2 ± 2.0	0.120
Weaning weight of cows calving, kg	192.6 ± 3.9	189.5 ± 3.9	0.571
Weaning weight of females exposed, kg	159.2 ± 5.3	160.5 ± 5.3	0.809

[1] Treatments were dam's given either exposed to fixed-time AI (**TAI**) 7 d CO-Synch + CIDR with clean-up bull, or natural service (**NS**) bulls for the duration of the breeding season.

Calves that were born to the cattle in the TAI treatment were not different ($P > 0.05$) for

IMF and LMA (Table 2.5) compared to NS calves. Calves in the TAI treatment had an increase

($P < 0.05$) in RIBFAT of 0.058 cm over NS calves. The increase in RIBFAT for TAI calves

resulted in an increase of CPYG of 0.06 over NS calves. Male calves had greater (P < 0.05)

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IMF, CPYG, and RIBFAT compared to female calves (Table 2.5); however, there was no

difference ($P > 0.05$) in LMA between sexes.

Table 2.5 Effects of treatment and calf sex on ultrasound carcass characteristics that include intramuscular fat **(IMF)**, 12th rib LM area **(LMA)**, rib fat between the 12th and 13th ribs **(RIBFAT)**, and calculated preliminary yield grade **(CPYG)**

Item	Treatment[1]		Calf Sex	
	TAI	NS	Female	Male
No. of calves	217	215	215	217
IMF	3.48 ± 0.05	3.51 ± 0.05	3.39 ± 0.05^x	3.61 ± 0.05^y
LMA, cm^2	38.72 ± 0.45	38.56 ± 0.45	38.51 ± 0.45	38.76 ± 0.45
RIBFAT, cm	0.54 ± 0.01^x	0.48 ± 0.01^y	0.54 ± 0.01^x	0.48 ± 0.01^y
CPYG	2.53 ± 0.01^x	2.47 ± 0.01^y	2.53 ± 0.01^x	2.47 ± 0.01^y

[1] Treatments were dam's given either exposed to fixed-time AI (**TAI**) 7 d CO-Synch + CIDR with clean-up bull or natural service (**NS**) bulls for the duration of the breeding season.
[x,y] Means within factor lacking common superscript differ ($P < 0.05$).

When calf age (< 21, 22-42, and >42) was included in the analysis, a treatment × calf age

interaction ($P = 0.006$) was present for WW and HG (Table 2.6). Calves in the TAI treatment

and born in the first 21 d of the calving season had the heaviest weights and largest HG ($P <$

0.05) followed by calves from the NS treatment born in the first 21 d. Calves born from d 22 to

42 had heavier WW and larger HG ($P < 0.05$) than calves born > 42d of the calving season, but

no differences ($P > 0.05$) among treatments. There was no difference ($P > 0.05$) in preweaning

gain among calf ages.

There was a treatment × calf age interaction ($P = 0.006$) for LMA, RIBFAT, and CPYG

(Table 2.6). Calves in the TAI treatment and born in the first 21 d of the calving season had the

largest LMA ($P < 0.05$) followed by calves from the NS treatment born in the first 21 and 22 to

42 d. Calves in the TAI treatment born from d 22 to 42 had larger LMA ($P < 0.05$) than calves

in the NS born > 42 d of the calving season, with calves in the TAI treatment born > 42 d of the

calving season having the smallest LMA. Calves in the TAI treatment born in the first 21 d of

the calving season had greater ($P < 0.05$) RIBFAT than all other contemporary groups, with

calves in the NS treatment born in the first 21 d having greater ($P < 0.05$) RIBFAT compared to calves in the NS treatment born > 42 d of the calving season. Likewise, since RIBFAT is used to calculate CPYG, CPYG was greatest ($P < 0.05$) for calves in the TAI treatment calves born in the first 21 d than all other contemporary groups, with calves in the NS treatment born in the first 21 d of the calving season greater ($P < 0.05$) than calves in the NS born > 42 d. Hip height and BL were affected ($P < 0.01$) by calf age; HH and BL increased as the calves were born earlier in the calving season. Intramuscular fat was greater ($P < 0.05$) for calves born earlier compared to the late born calves, whereas the middle born calves were intermediate.

Price Simulation

Heifers or steers born in the TAI treatment did not receive a greater ($P > 0.05$) price per 45.45 kg (Table 2.7) compared to heifers or steers born in the NS treatment; however, steers from the TAI received an additional $21.59 over steers from the NS treatment. Calf age did effect ($P < 0.05$) predicted price, with heifers and steers that were born late in the calving season receiving greater dollars per 45.45 kg compared to early born calves. Although, price per heifer tended ($P = 0.076$) to be greater for early born heifers compared to late born heifers, price per steer was greater ($P < 0.05$) for early born compared to late born steers.

Table 2.6 Effects of treatment x calf age on weaning weight **(WW)**, hip height **(HH)**, heart girth **(HG)**, body length **(BL)**, intramuscular fat **(IMF)**, 12th rib LM area **(LMA)**, rib fat between the 12th and 13th ribs **(RIBFAT)**, and calculated predicted yield grade **(CPYG)**

| | Treatment[1] | | | | | | | | |
| | TAI, calving period[2] | | | NS, calving period[2] | | | *P* - value | | |
Item	≤ 21	22 – 42	> 42	≤ 21	22 – 42	> 42	Trt	Age	Trt x Age
No. of calves	140	45	26	106	86	23			
WW, kg	220.4 ± 2.26^w	192.7 ± 3.84^y	165.1 ± 4.91^z	211.6 ± 2.62^x	197.9 ± 2.77^y	176.7 ± 5.32^z	0.36	< 0.001	< 0.01
HH[3], cm	106.6 ± 0.42^x	105.0 ± 0.69^y	101.1 ± 0.92^z	106.7 ± 0.49^x	104.6 ± 0.51^y	101.0 ± 0.99^z	0.75	< 0.01	0.83
HG[4], cm	142.3 ± 0.51^w	136.2 ± 0.83^y	130.7 ± 1.12^z	140.0 ± 0.59^x	137.7 ± 0.62^y	131.1 ± 1.20^z	0.83	< 0.01	< 0.01
BL, cm	66.3 ± 0.35^x	65.1 ± 0.57^y	62.2 ± 0.76^z	66.0 ± 0.40^x	64.9 ± 0.42^y	61.9 ± 0.82^z	0.55	< 0.01	0.99
IMF	3.65 ± 0.05^x	3.50 ± 0.09^{xy}	3.30 ± 0.12^y	3.56 ± 0.06^x	3.57 ± 0.07^{xy}	3.41 ± 0.13^y	0.66	0.03	0.38
LMA, cm^2	41.07 ± 0.52^w	36.04 ± 0.84^y	31.55 ± 1.10^z	39.60 ± 0.58^x	38.51 ± 0.58^x	34.83 ± 1.16^y	0.03	< 0.001	0.001
RIBFAT	0.58 ± 0.01^w	0.46 ± 0.02^{xyz}	0.44 ± 0.03^{xyz}	0.50 ± 0.02^x	0.47 ± 0.02^{xyz}	0.42 ± 0.03^z	0.10	< 0.01	< 0.01
CPYG	2.58 ± 0.01^w	2.45 ± 0.02^{xyz}	2.43 ± 0.03^{xyz}	2.49 ± 0.02^x	2.47 ± 0.02^{xyz}	2.42 ± 0.03^z	0.10	< 0.01	< 0.01

[1] Treatments were dam's given either exposed to fixed-time AI (**TAI**) 7 d CO-Synch + CIDR with clean-up bull or natural service (**NS**) bulls for the duration of the breeding season.

[2] Calving period was calves born within first 21 d (≤ 21), from d 22 to 42 (22-42), and born after d 42 (> 42).

[3] Heart girth measurements (adapted from Wanderstock and Salisbury, 1946).

[4] Body length measurements (adapted from Kidwell, 1955).

w,x,y,z Means within factor lacking common superscript differ (*P* < 0.05).

Table 2.7 Effects of treatment and calf age on price simulation

Item	Treatment[1]		Calf Age[2]	
	TAI	NS	Early	Late
Heifers				
Price, $/45.45 kg	149.75 ± 1.00	151.33 ± 1.00	148.50 ± 1.00[y]	152.58 ± 1.00[x]
Price, $/heifer	711.57 ± 15.02	692.90 ± 15.02	727.48 ± 15.02	676.99 ± 15.02
Steers				
Price, $/45.45 kg	165.34 ± 1.13	165.94 ± 1.13	160.03 ± 0.92[y]	171.25 ± 1.30[x]
Price, $/steer	836.31 ± 5.98[x]	814.72 ± 5.98[y]	850.84 ± 4.88[x]	800.20 ± 6.91[y]

[1] Treatments were dam's given either exposed to fixed-time AI (**TAI**) 7 d CO-Synch + CIDR with clean-up bull, or natural service (**NS**) bulls for the duration of the breeding season.
[2] Calf age for heifers born from TAI treatment to be Early = d 0 to 10 and Late = d 11 to 59 of the calving season, and heifers born from NS treatment to be Early = d 0 to 23 and Late d 17 to 56 of the calving season. Calf age for steers born to be Early = d 0 to 26 and Late = d 26 to 62 of the calving season.
[x,y] Means within row and factor lacking common superscript differ ($P < 0.05$).

Discussion

Reproductive Performance

Final pregnancy rates comparing only treatment effects demonstrated no difference between treatments. This was unexpected, since several reports cite the potential of AI greater pregnancy rates than those obtained from natural service (Dziuk and Bellows, 1983; Johnson and Jones, 2008; Larson et al., 2006; Lamb et al., 2010). *Bos indicus* showed a distinct advantage of using an ES and AI protocol over a NS system (Sá Filho et al., 2009), actual comparisons in *Bos tarus* cattle are lacking. Reports of breeding system differences in *Bos tarus* may give producers data and decision making knowledge to implement a new breeding system in their herd.

The conception rate for cyclic TAI treated females was not different than non-cyclic TAI, however, cyclicity status has been shown to affect pregnancy rates to AI (Sprott, 1999; Larson et al., 2006). The cyclic and non-cyclic TAI cattle had greater 10 d pregnancy rates compared to cyclic NS cattle, whereas non-cyclic NS rates were not different for non-cyclic TAI. Estrus

synchronization and AI protocol has been reported to produce greater pregnancy rates at d 30, 60, and 90 than a NS breeding system (Sá Filho et al., 2009).

Differences in pregnancy rates at d 10 were not present at d 21 or 49. The pregnancy rates in the first 21 d of the breeding season were not different among treatments, only different from yr 1 and 2. This could be the result of a greater cyclicity status of the cattle in yr 2. This may have led to an overall greater pregnancy rates, regardless of treatment, in first 21 d of the breeding season. Another factor may be an increase in estral activity for non-cyclic NS because the increased estral activity from the cattle exposed to an ES protocol may have altered NS cattle to begin their estrous cycle earlier (Rodger et al., 2012). The female pheromones or cervical mucus from cyclic cattle may increase the proportion of anestrous cows causing them to begin cycling earlier compared to anestrous cattle not exposed to cyclic cattle (Wright et al., 1994).

For final pregnancy rates, there was a treatment × cyclic status × year effect. In yr 2 a decrease in pregnancy rates was observed in non-cyclic NS cattle compared to the cyclic and non-cyclic TAI and cyclic NS cattle. In yr 1 cyclic TAI was greater compared to non-cyclic TAI, and the cyclic and non-cyclic NS cattle were intermediate. Non-cyclic cattle have been reported to have reduced pregnancy rates compared to cyclic cattle regardless of treatment exposed to (Sá Filho et al., 2009). No difference in final pregnancy rates between cyclic and non-cyclic cattle occurred when they were given a 7 d CO-Synch + CIDR (Busch et al., 2008), which is contrary in yr 1 but similar to yr 2. The decrease in yr 1 of non-cyclic TAI may be the result of a slight numerically reduced AI pregnancy rate of 4% and, therefore cattle were unable to return to similar pregnancy rates to the cyclic TAI treatment.

The advantage of TAI through the breeding season was that TAI cattle became pregnant earlier in the breeding season compared to NS cattle. The reason for the earlier attainment of

pregnancy is that over half of the TAI cattle became pregnant on the first day of the breeding season. Since cyclic TAI cattle had a greater pregnancy rate to AI than non-cyclic TAI cattle (Stevenson et al., 2003), non-cyclic TAI cattle had a slight increase in days to conception compared to cyclic TAI.

Cyclicity

In yr 2, the percentage of cyclic cattle was larger compared to yr 1 for all cattle, which may be due to treatment interactions. Cattle that received treatments in both years had a tendency to increase cyclic status of cattle in the TAI treatment. Therefore, use of ES products in one year may influence cycling status the next year. In addition, since mean calving date for TAI cattle was influenced by treatments, the use of ES and AI did increase days postpartum (**DPP**) in yr 2 for TAI cattle by 6.95 d compared to NS cattle. Days postpartum can change the cyclic status; cattle with every 10 d increase in DPP had a cyclicity increased by 5.5% (Larson et al., 2006). At the initiation of treatments in yr 2, 76.6% of multiparous cattle were cyclic, similar to Stevenson et al. (1997) and Larson et al. (2006) who reported multiparous cows were 71.3% and 72.6% cyclic, respectively. However, in yr 1 cycling status was low for multiparous cattle at 43.4% and extremely low for the primiparous cattle at 21.4%. Regardless of year, the ranges of cyclicity in the herd were still in the range reported 5 herds across 4 yrs varying from 23 to 98% for primiparous cows and 42 to 100% for mature cows (Stevenson et al., 2003).

Calving and Calf Crop Characteristics

During the calving season, a greater proportion of calves in the TAI treatment were born in the first 21 d compared to the NS calves, which is likely due to the large proportion of TAI females that became pregnant on the first day of the breeding season. During the next 21 d

interval of the calving season, NS cattle had a greater proportion giving birth than the TAI. In the last 21 d interval, there was no difference in the proportion of cattle giving birth for either treatment. The distribution of calves in the NS treatment was similar to other reports (Rodgers et al., 2012; Whittier et al., 1991). There have been many reports that theorize that ES and AI shorten the calving season, thereby reducing the labor required for calving (Sprott, 1999; Larson et al., 2006; Lamb et al., 2006; Lamb et al., 2010). The use of ES and AI did not shorten the calving season, but merely shifted the distribution to have a greater proportion of TAI cattle that gave birth earlier in the calving season compared to NS cattle (Rodgers et al., 2012). Thus, the length of the calving season is not a factor of breeding system. The length of the calving season is dictated by the length of bull exposure.

At calving, male calves had greater birth weights (Bellows et al., 1971; Smith et al., 1976; Anderson et al., 1978; Riley et al., 2007) and calving difficulties, which may be due to the larger body size of the males (Crowley, 1965; Bellows et al., 1971; Laster et al., 1973) compared to female calves. Birth weight was also reduced with TAI calves being 1.32 kg lighter than NS calves. Lighter birth weight can be accounted for by the selection criteria for the bulls used in this study, which was low birth weights and moderate growth. Sire average EPDs for birth weight used in AI was decreased compared to the average NS sire. Since herd bulls were the same for both treatments, this change in mean birth weight is due to the AI bulls used, which was expected from the selection criteria for AI sires. Calf vigor was not influenced by treatment, which was expected by design because of equal distribution parity of cattle since older cows were in the herd because they were good mothers.

Weaning

Steers from this study that were born from TAI treatment received a greater estimated price per steer over steers born from NS treatment. In a sale price simulation, the economical factor for producers to use ES and AI may be to get more calves born earlier in the breeding season (Fike et al., 2010; Funston et al., 2012). Also, producers using AI methods may be able to market heifers at a premium if sold as bred heifers. Heavier heifers gained $1.28/kg greater than lighter heifers, so AI heifers gained a premium of $18.70/hd. However, pens of heifers expected to calve outside a 30 d window were discounted $24.30/hd in a study that looked at replacement heifers in the Show-Me-Select heifer program (Parcell et al., 2006). The heifers in our study were not pregnant and therefore may be the cause of no difference in estimated price.

Early TAI calves had greater WW compared to early born NS calves; this may be the result of using superior genetics in AI sires (Lamb et al., 2010) in combination with age of calf (Johnson and Dinkel, 1951; Sprott, 1999). The older calves may have had a faster rate of preweaning gain, allowing them to better utilize grass on pasture and consume larger quantities of milk from the dam than younger calves (Lesmeister et al., 1973). However, our results did not indicate an age effect on preweaning gain. Regardless of treatment, calves that are early born in the calving season had the heaviest WW (Fike et al., 2010). The WW per exposed cow was not altered by treatment; between our 2 treatments there were similar proportions of cattle that did not calf during the calving season. Producers who wish to see dramatic changes in WW for calves after 1 yr of implementation of an AI breeding system may not see the results based on our finding if strictly evaluating as a treatment difference. Exposed WW and WW per cow calving was not effected by treatment. The implementation of an ES and AI breeding system did

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not improve the survival rate of calves to weaning. The majority of survival of calves is more based on management of the cattle rather than the breeding system implemented.

Male calves were heavier at weaning than female calves, which is similar to Riley et al. (2007). Steer calves have been shown to grow at an 8% faster rate than heifer calves (Marlowe and Gaines, 1958). When age of calf is put into the model, the early born TAI calves had the greatest WW compared to all other ages and treatment combinations.

Heart girth followed a similar trend to WW, with early born TAI having the greatest HG of all other calves. The combination of the largest number of calves in the early born TAI with the largest HG, and the oldest calves having the largest HH and BL may lead to a more uniform calf crop at weaning, which may compensate for the 44.7% of the remaining calves in the middle and late born TAI. Hip height and BL increased as calves became older. Hip height increased with age, which was due to the fact the calves were simply getting bigger to reach their mature body weight and size.

Intramuscular fat was influenced by age of calf with older calves having the greatest and the youngest having the least, with middle born being intermediate. It has been reported that marbling increases at a linear rate ($P < 0.05$) with calf age (Bruns et al., 2004). Calves older at weaning have greater marbling score and acceptance in brand specific programs (Fike et al., 2010). The CPYG and RIBFAT was the greatest for early born TAI calves, with the only other significance between early born NS and late born NS calves. The increase in RIBFAT may result in fewer days on feed at the feedlot resulting in reduced cost to the producers. The increased carcass characteristics may provide a premium for the early born TAI calves and, thereby provide producers an economically desirable breeding system compared to natural

service, which is incentive to produce AI calves when a genetic premium can be attained (Johnson and Jones, 2008).

Implications

Although no treatment effect existed on the proportion of cattle pregnant at final check or average weaning weight, a price premium may be realized for producers if artificial insemination is used in their commercial beef herd. These price premiums may be due to several factors including earlier average birth date, greater proportion of half siblings, physically larger weaned calves, enhanced carcass characteristics, or a combination of all of these. In fact, the greatest price premium may be due to the calves being born earlier in the calving season. Estrus synchronization and artificial insemination did change the distribution of calves born in the calving season, allowing producers to concentrate more labor when the influx of calves are born. Thus, in the later portions of the calving season, labor can be assessed and managed to be more effective in other areas such as planting, fencing, etc. Additional resources need to compare the traditional natural service system to modern reproductive technologies to gain greater insight for commercial cattlemen in their decision to utilize these methods in their operation.

Literature Cited

American Meat Science Association. 2001. Beef Grading and Evaluation pg. 18 from Meat Evaluation Handbook. AMSA Savoy, IL.

Anderson, D. C., C. C. O'Mary, E. L. Martin. 1978. Birth, preweaning and postweaning traits of Angus, Holstein, Simmental, and Chianina sired calves. J. Anim. Sci. 46:362-369.

Busch, D. C., D. J. Schafer, D. J. Wilson, D. A. Mallory, N. R. Leitman, J. K. Haden, M. R. Ellersieck, M. F. Smith, and D. J. Patterson. 2008. Timing of artificial insemination in

postpartum beef cows following administration of the CO-Synch + controlled internal drug-release protocol. J. Anim. Sci. 86:1519-1525.

Bellows, R. A., R. E. Short, D. C. Anderson, B. W. Knapp, and O. F. Pahnish. 1971. Cause and effect relationships associated with calving difficulty and calf birth weight. J. Anim. Sci. 33:407-415.

Bruns, K. W., R. H. Pritchard, and D. L. Boggs. 2004. The relationships among body weight, body composition, and intramuscular fat content in steers. J. Anim. Sci. 82:1315-1322.

Colburn, D. J., G. H. Deutscher, M. K. Nielsen, and D. C. Adams. 1997. Effects of sire, dam traits, calf traits, and environment on dystocia and subsequent reproduction of two-year-old heifers. J. Anim. Sci. 75:1452-1460.

Crowley, J. P. 1965. The effect of Charolais bulls on calving performance. Irish J. Agr. Res. 4:205.

Dickerson, G. 1970. Efficiency of animal production – Molding the biological components. J. Anim. Sci. 30:849-859.

Dziuk, P. J. and R. A. Bellows. 1983. Management of reproduction of beef cattle, sheep, and pigs. J. Anim. Sci. 57:355-379.

Fike, G. D., M. E. King, L. R. Corah, and W. D. Busby. 2010. Effect of time of birth within the spring calving season on performance and carcass traits of beef calves fed in the Iowa Tri-County Steer Carcass Futurity. J. Anim. Sci. 88:E-Supp. 2. 823.

Funston, R. N., J. A. Musgrave, T. L. Meyer, and D. M. Larson. 2012. Effect of calving distribution of beef cattle progeny performance. J. Anim. Sci. 90:5118-5121.

Hirschfeld, D. J., D. R. Kirby, J. S. Caton, S. S. Silox, and K. C. Olson. 1996. Influence of grazing management on intake and composition of cattle diet. J. Range Mange. 49:257-263.

Hughes, E. A. and D. A. Davies. 1989. Practical uses of ultrasound in early pregnancy in cattle. Vet. Rec. 124:456-458.

Johnson, L. E. and C. A. Dinkel. 1951. Correction factors for adjusting weaning weights of range calves to the constant age of 190 days. J. Anim. Sci. 10:371.

Johnson, S. K. and R. D. Jones. 2008. A stochastic model to compare breeding system costs for synchronization of estrus and artificial insemination to natural service. Prof. Anim. Sci. 24:588-595.

Kidwell, J. F. 1955. A study of the relation between body conformation and carcass quality in fat calves. J. Anim. Sci. 14:233-242.

Kirby, C. J., M. F. Smith, D. H. Keisler, and M. C. Lucy. 1997. Follicular function in lactating dairy cows treated with sustained release bovine somatotropin. J. Dairy Sci. 80:273-285.

Lamb, G. C., J. E. Larson, T. W. Geary, J. S. Stevenson, S. K. Johnson, M. L. Day, R. P. Ansotegui, D. J. Kesler, J. M. DeJarnette, and D. G. Landblom. 2006. Synchronization of estrus and artificial insemination in replacement beef heifers using gonadotropin-releasing hormone, prostaglandin $F_{2\alpha}$, and progesterone. J. Anim. Sci. 84:3000-3009.

Lamb, G. C., C. R. Dahlen, J. E. Larson, G. Marquezini, and J. S. Stevenson. 2010. Control of the estrous cycle to improve fertility for fixed-time artificial insemination in beef cattle: A review. J. Anim. Sci. 88(E. Suppl.) E181-E192.

Larson, J. E., G. C. Lamb, J. S. Stevenson, S. K. Johnson, M. L. Day, T. W. Geary, D. J. Kesler, J. M. DeJarnette, F. N. Schrick, A. DiCostanzo, and J. D. Arseneau. 2006.

Synchronization of estrus in suckled beef cows for detected estrus and artificial

insemination and timed artificial insemination using gonadotropin-releasing hormone,

prostaglandin $F_{2\alpha}$, and progesterone. J. Anim. Sci. 84:332-342.

Laster, D. B., H. A. Glimp, L. V. Cundiff, and K. E. Gregory. 1973. Factors affecting dystocia

and the effects of dystocia on subsequent reproduction in beef cattle. J. Anim. Sci.

36:695-705.

Lesmeister, J. L., P. J. Burfening, and R. L. Blackwell. 1973. Date of first calving in beef cows

and subsequent calf production. J. Anim. Sci. 36:1-6.

Marlowe, T. J. and J. A. Gaines. 1958. The influence of age, sex, and season of birth of calf, and

age of dam on preweaning growth rate and type score of beef calves. J. Anim. Sci.

17:706-713.

NAHMS. National Animal health Monitoring System. 2009. Part II. Reference of beef cow-calf

management practices in the United States, 2007-08. Fort Collins, CO. Pp. 1-48.

Osoro, K. and I. A. Wright. 1992. The effect of body condition, live weight, breed, age, calf

performace, and calving date on reproductive performance of spring-calving beef cows. J.

Anim. Sci. 70:1661-1666.

Parcell, J. L., K. C. Dhuyvetter, D. J. Patterson, and R. Randle. 2006. The value of heifer and

calf characteristics in bred heifer price. Prof. Anim. Sci. 22:217-224.

Perry, R. C., L. R. Corah, G. H. Kiracofe, J. S. Stevenson, and W. E. Beal. 1991. Endocrine

changes and ultrasonography of ovaries in suckled beef cows during resumption of

postpartum estrous cycles. J. Anim. Sci. 69:2548-2555.

Riley, D. G., C. C. Chase, Jr., T. A. Olson, S. W. Coleman, and A. C. Hammond. 2004. Genetic
and nongenetic influences on vigor at birth and preweaning mortality of purebred and
high percentage Brahman calves. J. Anim. Sci. 82:1581-1588.

Riley, D. G., C. C. Chase, Jr., S. W. Coleman, and T. A. Olson. 2007. Evaluation of birth and
weaning traits of Romosinuano calves as purebreds and crosses with Brahman and
Angus. J. Anim. Sci. 85:289-298.

Rodgers, J. C., S. L. Bird, J. E. Larson, N. DiLorenzo, C. R. Dahlen, A. DiCostanzo and G. C.
Lamb. 2012. An Economic Evaluation of Estrous Synchronization and Timed Artificial
Insemination in Suckled Beef Cows. J. Anim. Sci. 90:4055-4062.

Sá Filho, O. G., E. R. Vilela, T. W. Geary, and J. L. M. Vasconcelos. 2009. Strategies to improve
fertility in postpartum multiparous *Bos indicus* cows submitted to a fixed-time
insemination protocol with gonadotropin-releasing hormone and prostaglandin $F_{2\alpha}$. J.
Anim. Sci. 87:2806-2814.

Smith, G. M., D. B. Laster, and K. E. Gregory. 1976. Characterization of biological types of
cattle I. dystocia and preweaning growth. J. Anim. Sci. 43:27-36.

Society for Theriogenology. 1993. Guidelines for the bull breeding soundness evaluation. In:
Guidelines for uniform beef improvement programs, 9th edition, 2010.

Sprott, L. R. 1999. Management and financial considerations affecting the decision to
synchronize estrus in beef females. J. Anim. Sci. 77:1-10.

Stevenson, J. S., D. P. Hoffman, D. A. Nichols, R. M. McKee and C. L. Krehbiel. 1997. Fertility
in estrus-cycling and noncycling virgin heifers and suckled beef cows after induced
ovulation. J. Anim. Sci. 75:1343-1350.

Stevenson, J. S., G. C. Lamb, S. K. Johnson, M. A. Medina-Britos, D. M. Grieger, K. R. Harmoney, J. A. Cartmill, S. Z. El-Zarkouny, C. R. Dahlen, and T. J. Marple. 2003. Supplemental norgestomet, progesterone, or melengestrol acetate increases pregnancy rates in suckled beef cows after timed inseminations. J. Anim. Sci. 81:571-586.

Wanderstock, J. J. and G. W. Salisbury. 1946. The relation of certain objective measurements to weights of beef cattle. J. Anim. Sci. 5:264-271.

Whitman, R. H. 1975. Weight changes, body condition and beef cow reproduction. PhD Diss. Colorado State University, Fort Collins.

Whittier, J. C., R. W. Caldwell, R. V. Anthony, M. F. Smith, and R. E. Morrow. 1991. Effect of a prostaglandin F2 alpha injection 96 hours after introduction of intact bulls on estrus and calving distribution of beef cows. J. Anim. Sci. 69:4670-4677.

Wright, I. A., S. M. Rhind, A. J. Smithand, and T. K. Whyte. 1994. Female-female influences on the duration of the post-partum anoestrous period in beef cows. Anim. Prod. 59:49-53.

CHAPTER 3: EFFECTS OF ARTIFICIAL INSEMINATION AND NATURAL SERVICE BREEDING SYSTEMS ON STEER PROGENY BACKGROUNDING PERFORMANCE[2]

Abstract

The objective of this project was to determine the effect of backgrounding performance on steers originating from 2 different breeding. One hundred eighty-four steers were born from dams exposed to 1 of 2 treatments: natural service (**NS**, cows were only exposed to herd bulls for the duration of the breeding season) and fixed-timed artificial insemination (**TAI**, cows exposed to estrous synchronization and fixed-time AI followed by natural-service bulls). Within dam's treatment steers were divided into 2 blocks: calves born from d 0 to 26 of the calving season (**Early**, n = 119) and calves born after d 26 of the calving season (**Late**, n = 65) and were placed in 1 of 24 pens for a 69 d backgrounding period. Diets consisted of 61.7% ground grass hay, 25.8% barley, and 12.54% liquid supplement, on a DM basis and were delivered once daily. At the beginning and end of the study, steer weights were determined on 2 consecutive days and physical characteristics were collected that included hip height (**HH**), heart girth (**HG**), and body length (**BL**). There was a treatment × block interaction ($P = 0.001$) for initial BW, with Early TAI were had the heaviest ($P < 0.05$) weights (249.2 kg) compared to Early NS (233.2 kg) which were heavier ($P < 0.05$) than Late TAI and NS (212.2 and 210.5 kg, respectively). Steers in the NS treatment had greater ($P < 0.05$) ADG than TAI steers, 1.31 and 1.18 kg/d, respectively. Steers in the TAI treatment (0.16 G:F) had lower ($P < 0.05$) G:F than NS steers (0.18 G:F). Early born steers had greater ($P < 0.05$) final BW, DMI, and ADG (330 kg, 7.45 kg/d, and 1.30 kg, d, respectively) compared to Late born steers (294 kg, 6.80 kg/d, and 1.19 kg/d,

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respectively). There was a treatment × block interaction ($P = 0.002$) for initial HG, Early TAI steers had larger ($P > 0.05$) HG (143 cm) compared to Early NS (140 cm) and both Early TAI and Early NS were larger ($P < 0.05$) than Late TAI and NS (137 and 137 cm, respectively). In summary, the greatest advantage of the 2 breeding system on backgrounding performance was increasing calf age. Early born steers had greater final BW, DMI, and ADG than Late born calves.

Keywords: artificial insemination, backgrounding, natural service, steers

Introduction

Relatively abundant forage supplies and the allure of selling calves at greater weights in early winter have attracted many producers in the upper Great Plains to backgrounding their calves after weaning. A recent survey revealed that in 2009 to 2011 approximately 42.9% of the North Dakota calf crop was retained by owner through a backgrounding phase (Dahlen et al., 2013).

One potential method of maximizing calf performance during the backgrounding phase is by making genetic improvements to the calf crop (Johnson and Jones, 2008). Artificial insemination can rapidly improve the genetic base of a herd compared with most natural service bulls by utilizing superior AI genetics at costs well below buying a herd bull with similar qualities (Lamb et al., 2006). The percent of producers that use AI is 7.6% (NAHMS, 2009) of all beef operation and the increase of implementation may be a way to increase profits for producers. Sires with superior growth and feed efficiency genetics may produce offspring with improved performance in the post-weaning phase (Johnson and Jones, 2008; Welch et al., 2012). Producers selecting for optimal growth traits with high accuracy EPDs can optimize

backgrounding performance after weaning. Weaning weight per exposed cow to AI has been reported to be increased over a natural service breeding system (Rodgers et al., 2012).

Calf age at weaning can also result in greater herd performance by either shift calving or weaning date (Lusby et al., 1981). The use of ES and AI have been shown to shift the calving date compared to natural service to have cows give birth earlier in the calving season (Rodgers et al., 2012). The objective of this study was to determine the effect of incorporating AI or natural service breeding systems or the effect of calf age at the start of backgrounding on steer performance.

Materials and Methods

All procedures were approved by the Institutional Animal Care and Use Committee of North Dakota State University.

Animals and Treatments

One hundred and eighty-four Angus crossbred steer calves were used to evaluate the effects of dam breeding system on backgrounding performance. Calves originating from the Central Grasslands Research Extension Center (CGREC; n = 159; Streeter, ND) were shipped (378 km) and joined steers originated from Hettinger Research Extension Center (HREC; n = 25; Hettinger, ND) at the Southwest Feeders feedlot in Hettinger, ND for a 69 d backgrounding trial.

Five hundred sixty four crossbred Angus females were used to develop experimental pens. All cows were stratified by age, BCS, and days postpartum; all heifers stratified by date of birth and BCS, then assigned to one of 2 treatments in a completely randomized design: 1) natural service (**NS**, n = 282), exposed to natural service bulls for the duration of the breeding season, or 2) artificial insemination (**TAI**, n = 282), exposed to ES [7-d Co-Synch + CIDR

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(Larson et al., 2006)] and a fixed-time AI (d 0) followed by exposure to natural service bulls. All calves were managed with their respective dam on pastures. Results of pregnancy rates, average day of conception, birthing difficulties, calving season length, and calf performance at weaning were published previously (Steichen et al., 2013).

Pastures at the CGREC consisted primarily of Kentucky bluegrass (*Poa pratensis* L.; Neville and Patton, unpublished data) with blue grama (*Bouteloua gracilis* [H. B. K.] Lag. Ex Griffiths), needle and thread (*Hesperostipa comata* [Trin. & Rupr.] Backword), sun sedge (*Carex inops* L. H. Bailey spp. *heliophila* [Mack.] Crins), and western snowberry (*Symphoricarpos occidentalis* Hook.) being secondary forage species (Hirschfeld et al., 1996). Pastures at HREC consisted of intermediate wheatgrass (*Thinopyrum* intermedium [Host] Barkworth and D. R. Dewey), alfalfa (*Medicago sativa* L.), crested wheatgrass (*Agropyron cristatum* [L.] Gaertn), smooth brome (*Bromus inermis* Leyss), and sweetclover [*Melilotus officinalis* (L.) Lam.].

Within dam's treatment steers were divided into 2 blocks: calves born from d 0 to 26 of the calving season (Early n = 119) and calves born after d 26 of the calving season (Late, n = 65). Steers were randomly assigned to 1 of 24 pens (6-9 hd/pen; Early, n = 16; Late, n = 8). All steers were fed a common total mixed ration once daily at 0800 h with a reel auger mixer (Lucknow 285 with 8 cubic meter capacity; Lucknow Products, Helm Welding Limited, Lucknow, Ontario). The diet consisted of 61.7% ground grass hay, 25.8% barley, and 12.5% liquid supplement (Quality Liquid Feeds, Dodgeville, WI) on a DM basis (Table 3.1). The diet was balanced to achieve a target ADG of 1 kg/d. The diet had added water (0.91 kg of per head/d) to minimize dust from hay and all steers had access to fresh water in their pens. Feed ingredients were collected individually prior to the start of the experiment and were analyzed for DM, ash, CP, ADF, Ca, P, and K using AOAC (2000) procedures at a commercial laboratory

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that is certified by the National Forage Testing Association (Midwest Laboratories, Omaha, NE).

Steers were fed ad libitum with a minimum target refusal of 5%. Bunk calls were done prior to

each feeding using a 4 – point bunk scoring system (0, no feed remaining in bunk to 4, feed is

virtually untouched; Pritchard, 1993). Feed refusals were collected and weighed weekly from

each pen's bunk and samples were analyzed for dry matter.

Table 3.1 Experimental backgrounding diet

Item	Grass Hay	Barley	Liquid Supplement[1]	Added Water[2]	Total Diet
Inclusion in diet, % DM	61.7	25.8	12.5	0	100
DM, %	89.7	88.1	64.1	0	86.1
CP, %	8.7	13.6	31.4	0	12.8
NEg, mcal/kg	0.8	0.8	1.2	0	1.0
CF[3], %	1.5	1.5	0.3	0	1.4
ADF, %	43.0	6.3	---------------	0	28.2
P, %	0.1	0.4	0.8	-------------	0.3
Ca, %	0.5	0.1	2.7	-------------	0.7

[1] Quality Liquid Feeds (Dodgeville, WI): 72 % TDN, 31.4 % CP, 0.3 % CF, 2.7 % Ca, 0.8 % P, 2.6 % NaCl, 3.7 % K, 40,522 IU/kg vitamin A, 3,898 IU/kg vitamin D, 70 IU/kg vitamin E, and 232 mg/kg Rumensin.
[2] Water was added to the diet to contain 0.91 kg/head/d.
[3] Crude Fiber.

Prior to the start of the study, all steers were implanted with Ralgro (36 mg of zeranol;

Merck Animal Health, Summit, NJ) and vaccinated for bovine pneumonic pasteurellosis and

treated with a parasiticide. At the initiation and end of the study, BW and physical

characteristics were determined. Steer weights were determined on two consecutive days at the

beginning and end of the project prior to each mornings ration delivery. Physical characteristics

included measurements of hip height (**HH**), heart girth (**HG**; Wanderstock and Salisbury, 1946),

and body length (**BL**; Kidwell, 1955) to the nearest 0.5 cm. Physical measurements were taken

to determine growth of the animal. Changes in physical measurements were determined by

subtracting the final from the initial measurements.

Statistical Analysis

All measurements were averaged within pens, which served as the experimental unit. Initial BW, final BW, ADG, DMI, G:F, initial HH, initial HG, initial BL, final HH, final HG, final BL, change in HH, change in HG, and change in BL were analyzed by the general linear model of SAS (SAS Ins. Inc., Cary, N.C.). The model included treatment, block, and their interaction. Differences were considered significant at an alpha of $P < 0.05$.

Results

A treatment × block interaction ($P = 0.001$) for initial BW (Table 3.2) was present. Early TAI steers were heaviest ($P < 0.05$; 249.2 kg), Early NS (233.2 kg) were intermediate, and Late TAI and Late NS were the lightest ($P < 0.05$; 212.2 and 210.5 kg, respectively). Final body weight was approaching significance for a treatment × block interaction ($P = 0.052$). Early TAI (333.9 kg) were heaviest ($P < 0.09$), Early NS (327.4) were intermediate, and Late TAI and Late NS (290.5 and 297.2 kg, respectively) were the lightest ($P < 0.05$).

A main effect of treatment ($P < 0.05$) existed for ADG and G:F; whereas there was a block effect ($P < 0.01$) for DMI, and ADG (Table 3.2). Natural service steers had greater ($P < 0.05$) ADG than TAI steers at 1.31 and 1.18 kg/hd/d; respectively. Steers in the TAI treatment (0.16 G:F) had a reduced ($P < 0.05$) G:F ratio compared to the NS steers (0.18 G:F). Early born steers had a greater ($P < 0.05$) final BW (330 kg) than Late born steers (294 kg). Early born steers (7.45 kg/hd/d) had a greater ($P < 0.05$) DMI than Late born steers (6.80 kg/hd/d). Average daily gain followed the same trend, with Early born steers (1.30 kg/hd/d) gaining more ($P > 0.05$) compared to Late born steers (1.19 kg/hd/d).

Table 3.2 Effects of treatment × block on steer backgrounding performance

Item	TAI Early	TAI Late	NS Early	NS Late	SE	Trt	Block	Interaction
Initial BW, kg	249.2[x]	212.2[y]	233.2[z]	210.5[y]	2.06	< 0.001	< 0.001	< 0.001
Final BW, kg	333.9	290.5	327.4	297.2	3.69	0.975	< 0.001	0.052
DMI, kg/hd/d	7.56	6.78	7.34	6.82	0.17	0.541	< 0.001	0.389
ADG, kg/hd/d	1.23	1.13	1.36	1.25	0.04	0.001	0.007	0.828
G:F	0.16	0.17	0.19	0.18	0.01	< 0.001	0.655	0.377

(columns grouped: Treatment¹ — TAI (Early, Late), NS (Early, Late); SE; P – value (Trt, Block, Interaction))

[1] Treatments were dam's given either exposed to fixed-time AI (**TAI**) 7 d CO-Synch + CIDR with clean-up bull, or natural service (**NS**) bulls for the duration of the breeding season.
[x,y,z] Means within row lacking common superscript differ ($P < 0.01$).

There was a treatment × block interaction ($P = 0.002$) for initial HG (Table 3.3), with Early steers in the TAI treatment having larger ($P > 0.05$) HG (143.4 cm) compared to Early NS (140.3 cm), and both Early TAI and Early NS larger than Late TAI and Late NS (136.5 and 136.6 cm, respectively).

Table 3.3 Effects of treatment × block on backgrounding steer body measurements

	TAI Early	TAI Late	NS Early	NS Late	SE	Treatment	Block	Interaction
Initial HH, cm	108.4	106.3	108.2	106.4	0.77	0.959	0.010	0.840
Initial HG[a], cm	143.4[x]	136.5[z]	140.3[y]	136.6[z]	0.54	0.003	< 0.001	0.003
Initial BL[b], cm	66.6	63.9	65.2	63.0	0.53	0.019	< 0.001	0.610
Final HH, cm	114.9	113.1	115.7	113.3	0.50	0.441	0.003	0.600
Final HG[a], cm	163.8	156.2	162.2	157.1	0.85	0.886	< 0.001	0.290
Final BL[b], cm	70.9	68.2	71.4	69.6	0.90	0.238	0.001	0.585
Δ HH, cm	6.5	6.8	7.5	6.8	0.88	0.506	0.775	0.550
Δ HG[a], cm	19.4	19.6	21.9	20.5	0.89	0.043	0.442	0.302
Δ BL[b], cm	4.3	4.3	6.3	6.6	1.06	0.030	0.887	0.836

(columns grouped: TAI (Early, Late), NS (Early, Late); SE; P – value (Treatment, Block, Interaction))

[xy] Means within row lacking common superscript differ ($P < 0.01$).
[a] Heart girth measurements (Wanderstock and Salisbury, 1946).
[b] Body length measurements (Kidwell, 1955).
Δ = Final physical measurement subtract initial physical measurement.

A main effect of treatment ($P < 0.05$) was present for initial BL, change in HG, and change in BL; whereas, there was a block effect ($P < 0.01$) for initial HH, initial BL, final HH,

final HG, and final BL (Table 3.3). Steers originating from the TAI treatment had greater ($P <$ 0.05) initial BL (65.3 cm) compared to NS derived steers (64.1cm). Steers originating from the NS treatment had greater ($P < 0.05$) change in HG (21.2 cm) and change in BL (6.4 cm) compared to TAI originating steers (19.5 and 4.3 cm, change in HG and change in BL, respectively). Regardless of treatment, Early born steers had greater ($P < 0.05$) initial HH (108 cm), initial BL (65.9 cm), final HH (115 cm), final BL (71.2 cm) compared to Late born steers, 106, 63.5, 113, and 68.9 cm, respectively. There were no effects ($P > 0.50$) among treatment, block, or any interactions on change of HH.

Discussion

Early TAI steers tended to have greater final BW at the end of the backgrounding study compared to all other steer groups, which may lead to more income if sold on a live basis to the feedlot. Early TAI steers were able to keep their advantage of the extra weight from the preweaning phase through the backgrounding phase. The Early steers had an increased initial BW at the start of the experiment and at the end; therefore, Early steers were able to consume more than Late born steers. Late weaned calves, or simply older calves, had a heavier initial body weight at the growing phase (Grings et al., 2011) and may lead to a greater carcass weight at harvest (Fike et al., 2010). However, younger calves at weaning are more feed efficient than the older calves (Myers et al., 1999; Schoonmaker et a., 2001).

Natural service treatment steers gained an additional 0.13 kg/hd/day more than the TAI treatment steers, which was unexpected. The advantage of the NS steers had may be caused by an average younger age than TAI steers. Early steers gained an additional 0.10 kg/d than Late born calves, similarly reported by Smith et al.(2003) who showed early born, or later weaned,

calves had a greater ADG than late born calves, although Funston et al. (2012) reported no difference in ADG for different calving periods.

The Early born calves at the end of backgrounding phase had larger HH, HG, and BL compared to the Late born calves. In a review by Thrift and Thrift (2006), early weaned calves and younger calves had a postweaning growth rate equal to or less than late weaned and older calves; however, early weaned calves did have reduced DMI and an increase in F:G, or a decreased feed efficiency. This is similar to other reports (Fike et al., 2010) and our study in which Late steers had reduced DMI and were more feed efficient. Although Late steers were lighter compared to Early steers, the greater feed efficiency and reduced DMI may negate some costs associated with feed costs at backgrounding and finishing.

The Early born steers were able to maintain the advantage of beginning with a greater initial HH, HG, and BL compared to Late born calves by maintaining larger HH, HG, and BL at the end of the backgrounding period. These physical attributes may lead to a perceived uniformity when these measurements are larger or conclude that Early steers may be in a shorter calving period. An elongated calving season my reduce calf crop uniformity (Parcell et al., 2006).

Although our study did not evaluate steers after the backgrounding phase, it has been reported that early born calves have been found to have an increase in marbling score (Fike et al., 2010) and yield due to the older age at harvest (Funston et al., 2012). These early born calves may be more desirable and profitable on a BW basis but also may gain premiums at harvest compared to Late born calves. These premiums may be from a greater marbling score and therefore qualifying for breed specific programs. However, our study did not evaluate carcass characteristics at the ending of the backgrounding period.

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Implications

The utilization of a breeding system that incorporates fixed-time artificial insemination yielded an advantage of having greater pre-backgrounding and post-backgrounding body weight. The other advantage was altering the calving season to increase the amount of calves born earlier in the calving season. Calves born earlier had greater initial and final body weights during the backgrounding phase. The Early born calves also were physically larger than the Late born calves and were able to maintain the increase size through the backgrounding phase. The advantages of utilizing artificial insemination may lead to producers receiving a premium either by producing heavier steers and a greater market price from more uniform steers.

Literature Cited

AOAC International. 2000. Official methods of analysis of AOAC Interantional. W. Horwithz. Gaithersburg, Md.

Dahlen, C. R. 2013. North Dakota beef industry survey: today, tomorrow, and in the future. Nothern States Beef Conference. Watertown, SD.

Fike, G. D., M. E. King, L. R. Corah, and W. D. Busby. 2010. Effect of time of birth within the spring calving season on performance and carcass traits of beef calves fed in the Iowa Tri-County Steer Carcass Futurity. J. Anim. Sci. 88:E-Supp. 2. 823.

Funston, R. N., J. A. Musgrave, T. L. Meyer, and D. M. Larson. 2012. Effect of calving distribution of beef cattle progeny performance. J. Anim. Sci. 90:5118-5121.

Grings, E.E, W. A. Phillips, R. E. Short, H. Mayeux, and R. K. Heitschmidt. 2006. *P*ost-weaning performance of steers from varying calving and weaning strategies in Montana. Prof. Anim. Sci. 22:386-391.

Hirschfeld, D. J., D. R. Kirby, J. S. Caton, S. S. Silox, and K. C. Olson. 1996. Influence of
grazing management on intake and composition of cattle diet. J. Range Mange. 49:257-
263.

Johnson, S.K. and R.D. Jones. 2008. A stochastic model to compare breeding system costs for
synchronization of estrus and artificial insemination to natural service. Prof. Anim. Sci.
24:588-595.

Kidwell, J. F. 1955. A study of the relation between body conformation and carcass quality in fat
calves. J. Anim. Sci. 14:233-242.

Lamb, G. C., J. E. Larson, T. W. Geary, J. S. Stevenson, S. K. Johnson, M. L. Day, R. P.
Ansotegui, D. J. Kesler, J. M. DeJarnette, and D. G. Landblom. 2006. Synchronization of
estrus and artificial insemination in replacement beef heifers using gonadotropin-
releasing hormone, prostaglandin $F_{2\alpha}$, and progesterone. J. Anim. Sci. 84:3000-3009.

Lusby, K.S., R. P. Wettemann and E. J. Turman. 1981. Effects of Early Weaning Calves from
First-Calf Heifers on Calf and Heifer Performance. J. Anim. Sci. 53:1193-1197.

Myers, S. E., D. B. Faulkner, F. A. Ireland, L. L. Berger, and D. F. Parrert. 1999. Production
systems comparing early weaning to normal weaning with or without creep feeding for
beef steers. J. Anim. Sci. 77:300.

NAHMS. National Animal health Monitoring System. 2009. Part II. Reference of beef cow-calf
management practices in the United States, 2007-08. Fort Collins, CO. Pp. 1-48.

Parcell, J. L., K. C. Dhuyvetter, D. J. Patterson, and R. Randle. 2006. The value of heifer and
calf characteristics in bred heifer price. Prof. Anim. Sci. 22:217-224.

Pritchard, R. H. 1993. Bunk management. Delivering the difference. Land O'Lakes Conference.

Rodgers, J. C., S. L. Bird, J. E. Larson, N. DiLorenzo, C. R. Dahlen, A. DiCostanzo and G.C.
Lamb. 2012. An Economic Evaluation of Estrous Synchronization and Timed Artificial
Insemination in Suckled Beef Cows. J. Anim. Sci. 90:4055-4062.

Schoonmaker, J. P., F. L. Fluharty, S. C. Loerch, T. B. Turner, S. J. Moeller, and D. M. Wuff.
2001. Effect of weaning status and implant regimen on growth, performance, and carcass
characteristics in steers. J. Anim. Sci. 79:1074-1084.

Smith , D.L., D. L. Wiggers , L. L. Wilson , J. W. Comerford, H. W. Harpster, and E. H. Cash.
2003. Postweaning Behavior and Growth Performance of Early and Conventionally
Weaned Beef Calves. Prof. Anim. Sci. 19:23-29.

Thrift, F. A. and T. A. Thrift. 2006. Review: Expected versus realized progeny differences for
various beef cattle traits. Prof. Anim. Sci. 22:413-423.

Wanderstock, J. J. and G. W. Salisbury. 1946. The relation of certain objective measurements to
weights of beef cattle. J. Anim. Sci. 5:264-271.

Welch, C. M., J. K. Ahola, J. B. Hall, G. K. Murdoch, D. H. Crews, Jr., L. C. Davis, M. E.
Doumit, W. J. Price, L. D. Keenan, and R. A. Hill. 2012. Relationships among
performance, residual feed intake, and product quality of progeny from Red Angus sires
divergent from maintenance energy EPD. J. Anim. Sci. 90:5107-5117.