BEEF SYSTEMS MANAGEMENT STRATEGIES: CALVING DATE SELECTION, ESTRUS SYNCHRONIZATION, AND POST-WEANING MANAGEMENT

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BEEF SYSTEMS MANAGEMENT STRATEGIES: CALVING DATE SELECTION, ESTRUS SYNCHRONIZATION, AND POST-SHEEP MANAGEMENT

By

Benjamin T. Tibbits

A THESIS

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The objective of an invited review and four experiments was to evaluate production implications and economic efficiencies of beef systems strategies involving calving date selection, utilization of reproductive technology, and post-weaning management of heifers and steers. The invited review in chapter II considers factors that influence a producer’s decision on when to calve beef females. The calving date decision impacts the entire beef production cycle and must take into account any environmental conditions, available resources, and cite specific advantages and/or disadvantages. Understanding the importance of varying physiological state and nutrient demands associated with lactation and gestation is critical to optimizing calving date. Calving systems vary across geographic regions. The associated differences in management strategies, along with economic drivers, contribute to the complexity of the calving date decision. Chapter III evaluates the effects of overwinter nutrition on subsequent May calving cow performance. Supplemented cows had increased ($P < 0.01$) BCS and BW change over winter treatment period compared to unsupplemented cows. Cows grazed either dormant upland range or meadow during the winter period. Pasture treatment had an effect on winter BW gain, pre-calving BW, lactation BW gain, pregnancy rate, as well as progeny birth and weaning BW. Pregnancy rate ($P = 0.05$) and calf birth BW ($P = 0.03$) were lower, and calf WW tended ($P = 0.06$) to be lower for cows that grazed
dormant range without supplement. Chapter IV compares a modified fixed-time AI protocol to fixed-time AI. Heifer reproductive performance at both AI conception and overall conception rate was similar ($P < 0.05$) in both treatments. Chapter V evaluates the effects of a Revalor G implant on reproduction and growth performance of 12 mo old beef heifers. Implanting heifers reduced conception rate by 18 percentage points in implanted heifers, but resulted in a 6 kg growth advantage over non-implanted heifers. Chapter VI compares four supplement sources on growth performance of steers grazing irrigated corn residue. Supplementing with dried distiller grains and SoyPass/SBM blend provided sufficient CP in the form of RDP and RUP for steers to gain at rates above 0.45 kg/d, while supplementing with corn grain and corn grain + RDP resulted in gains far below ($< 0.2$ kg/d) other treatments. Growing steers will require protein supplementation in the form of both RUP and RDP in order to optimize growth performance while grazing corn residue.

In Summary, these experiments provide evidence to support the following findings: (1) Due to differences between and among geographic regions and production systems, each beef operation must make cite specific decisions regarding an optimum calving date; (2) late-gestation supplementation is necessary in order to correct nutrient deficiencies experienced by May calving cows grazing dormant upland range; (3) similar AI conception rates may be achieved by fixed-time AI protocols vs. protocols involving estrus detection; (4) implanting heifers will increase stocker gains and decrease conception rates; and (5) growing calves grazing corn residue will require protein supplementation high in both RUP and RDP in order to optimize forage intake and BW gain.
ACKNOWLEDGEMENTS

I’m grateful to University of Nebraska-Lincoln; my experience has been truly exceptional. Foremost I would like to thank my advisor Dr. Rick Funston for giving me the opportunity to pursue a master’s degree. His work as a reproductive physiologist and beef systems specialist influenced me to pursue a degree at the University of Nebraska-Lincoln. The professional, personal, and academic support he has offered will continue to bolster my career. I would also like to thank Dr. Jim MacDonald, who has challenged me in and out of the classroom by setting high expectations. Those expectations have stretched me as a student and increased the value and quality of my work. He sets an example in his work ethic, honesty, and integrity. Additionally, I would like to thank Dr. Kate Brooks for her participation on my graduate committee and for her knowledge and experience as an agricultural economist. I’m grateful to each member of my graduate committee for helping me accomplish my goals. I would also like to thank my fellow graduate students, technicians, university employees, and beef producers who aided me on projects and in the classroom. I look forward to continuing those associations throughout our professional careers.

I would like to acknowledge the value of getting to spend two years in an agricultural hub like Nebraska. The entire beef production system is contained within the state; from cow calf operations, stocker feeders, grain production, ethanol and its by-products, crop residue grazing, feedlots, and the packing industry. That type of scale and scope are unique to a few states in the Midwest. Being able to observe how each segment of the beef industry coordinates within a relatively close geographic region has been
invaluable in preparing me to contribute more effectively to the industry as a beef production manager.

I love and appreciate my sweet wife Whitney, and our three little girls, Grace, Lucy, and Anna. They have made profound sacrifices in following me to graduate school. They have been my motivation and support through this experience and have seen me at my weakest moments. During those times, it is wonderful to turn to a supportive wife and family to draw on encouragement in preparation for an exam, a big project, or in writing this thesis. I love you and appreciate the sacrifices you each have made on my behalf.

I would also like to thank my mom and dad for their guidance, love, and encouragement. My mom is truly without guile, and is a great listener. She has encouraged me to be a leader, have a vision, and to pursue lofty goals. It has truly been an honor to have her as a mother and friend. My dad works harder than any person I know. His example has given me confidence to face difficult challenges with courage. From a young age my dad made a special effort to let me work with him. Now that I have children of my own, I understand what a sacrifice it was to accommodate me while maintaining a level of professionalism in the workplace. I’m grateful to each of those who helped me along this path and thank you all for the love, direction, inspiration, and support.

My thanks would be remiss if I did not express sincere gratitude to my loving Father in Heaven and his atoning son Jesus Christ. I’ve sent a lot of prayers the Lord's way over the last two years, and am humbled and grateful for a loving God in Heaven who cares about me and answers prayers. He knows me personally; my life, my goals, my weaknesses, my strengths, and blesses me continually.
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INTRODUCTION

Beef production systems are comprised of a wide array of environmental, physiological, economic, and management factors with a number of variables all influencing the way beef is produced, processed, and consumed. Stated generally, the “Beef System” is the process of getting from pasture to plate or from conception to harvest, and the many stages and production factors in between. When discussing beef systems it is necessary to define a specific stage, location, strategy, or factor of beef production in order to have any meaningful discussion. It could mean anything from a worldwide macroeconomic level to the industry-wide flow of cattle and segment systems, transportation, or the basic production and operational levels. Every beef operation could be broken into a number of unique smaller systems that combine to influence operational output. These most basic systems are often biological systems such as animal reproduction, gestation, lactation, growth and development, animal health, nutrition, range and soil management, vaccination protocols, reproductive management, etc., but could also pertain to economic and production systems such as animal processing, labor management, accounting, reporting, budgeting, and marketing.

Understanding these individual systems and their interactions can impact producers’ decision making processes. However, due to the variable nature of beef systems, it is challenging to make universal recommendations for beef production. At the production level, single systems aggregate upward to form a large combination of smaller systems. Every beef operation is the product of this aggregation of chosen, designed, or obligate systems that affect input and output levels and contribute to its unique identity. However, variability increases the complexity of comparison and decision making.
Producer decisions are complicated not only due to varied factors, but also due to interactions among them. Additionally, beef systems differ widely across the United States and are subject to an array of environmental and economic conditions that vary among regions. Each condition has specific advantages and disadvantages that dictate optimum production levels leading to production scenarios that play out differently each year depending on changing markets, input costs, output levels, environmental impacts, and ranch objectives. Therefore, to be more specific, this thesis will discuss biological, production, and economic beef systems associated with calving date, estrus synchronization, and post-weaning management strategies.

Although the environmental, management, and economic conditions associated with beef production can be variable and often unpredictable, generally constant principles and strategies lead to sound management practices and production efficiency. Additionally, important long-term production decisions (ie. calving date, breed selection, replacement rate, selection criteria, ranch improvements, etc.) largely dictate production levels, production and marketing flexibility, timing of important production events, sustainability, profitability, and ultimately the success or failure of each beef operation.
CHAPTER I: LITERATURE REVIEW

CHOOSING A CALVING DATE – MAY CALVING IN THE NEBRASKA SANDHILLS

Calving Date Selection

Due to differences among geographic regions, production systems, and individual operations, a universal calving date is not feasible. For example, in the Nebraska Sandhills, moving calving date to late spring increased ranch profitability by decreasing feed costs (Adams et al., 1996) when compared with early-spring calving systems. However, Reisenauer Leesburg et al. (2007) concluded in the Northern Great Plains with a restricted grazing season; limited access to low-cost, high quality forage; and with calves sold at weaning, moving from an early-spring calving season to a summer or fall calving date would not improve profitability. The optimum calving date and beef system will differ among geographic production regions and individual operations. Production levels and resulting costs are affected by calving date, and environmental conditions (ambient temperature, humidity, wind, day length) and season directly affect forage resources. Precipitation, plant species, and plant mix (cool vs. warm season species) affect the quality and quantity of forage available in grazed pastures. This seasonality in grazed forages should be considered in meeting the nutrient needs of breeding females. Environmental conditions (heat stress) also affect reproductive components of reproduction in the male and female, as well as calf performance. Therefore, cows should be calved at times of the year when weather events are least likely to interfere with reproduction or calf growth (Sprott et al., 2001).
**Matching Cow Nutrient Requirements with Peaks in Forage Quality**

Rangeland pastures reach a peak in forage quality early in the growing season. Increasing plant maturity leads to decreased forage quality late in the growing season and into the dormant season (Lamb 1996). The appropriate period to match calving with optimal range forage quality will vary by location. However, matching the calving season to follow spring green-up offers females an increasing plane of nutrition that corresponds to their increasing nutritional requirements just prior to calving and throughout the post-partum period. For lactating May calving cows in the Nebraska Sandhills nutrient requirements were met entirely through grazed forages at or near the time when CP and TDN of range forages were at seasonal highs (Adams et al., 1996). Choosing a calving date that matches high forage quality with peak lactation has the potential to reduce costs (Adams et al., 1996; Stockton et al., 2007). Additionally, cows graze dormant, low quality forage during the dry period when nutrient requirements are at seasonal lows. This pairing of high nutrient demand with high forage quality, and low nutrient demand with low forage quality can extend the grazing period and decrease the amount of harvested feed needed per year, which may lead to greater overall ranch profitability (Adams, 1996).

**Late-Spring Calving Systems**

The concept of May calving is built on 2 objectives: match cow nutrient needs with forage quality and decrease the amount of harvested feed per animal. Adams et al. (1996) found May calving cows could graze forage for a longer period of time when peaks in forage quality were matched with peaks in nutrient needs of cows. April calving beef operations reported feeding 758 kg/yr of hay per cow, compared with 1,486 kg/yr of
hay per cow for February calving operations (Clark et al., 2004; Stockton et al., 2007). Adams et al. (2001b) found in a late-spring calving season, hay could be reduced by 1,363 kg when compared with late-winter calving seasons. When both objectives are achieved, overall ranch profitability may be increased. Kruse et al. (2008) found feed cost per cow to be approximately 45% less for a late-spring (May to June) compared with either a late-winter (January to February) or early-spring (March to April) calving system in eastern Montana when averaged over 3 yr. Changing calving date influences other factors such as lactation, breeding, calf growth, marketing, etc., which all should be considered before changing the calving date.

Differences in range quality associated with different calving periods can also affect calf performance. Late-winter calving systems allow a calf’s rumen to develop in a timeframe that allows them to utilize forage when quality is high. In contrast, calves born to a late-spring calving system may not reach full rumen function until forage quality has begun to decrease. Consequently, calves born to late-spring calving systems will commonly be lighter at weaning than early season calves of the same age (Adams et al., 1996; Grings et al., 2005). Adams et al. (2001a) reported March-calving cows had heavier calves at a constant weaning age compared with progeny from June-calving cows. Calves were 23-32 kg lighter at a constant weaning age in the June system. This agrees with Sprott et al. (2001) who reported similar results for calving systems in Montana and Nebraska, which showed calves born in June were lighter at a constant age than calves born earlier in the year. Yearling retention is a common management strategy for those producers who calve later in the year, which tends to minimize the effects of depressed weaning weights in later-born calves (May et al., 1999).
Cattle markets typically have seasonal variation within a given year, creating opportunities to match a production system with seasonally higher market prices (Griffin et al., 2012). Many factors influence feeder calf prices, but supply and demand account for much of the variation between seasonal calf prices. Most spring-calving production systems have historically marketed cattle in November, resulting in a high calf supply. An increased supply results in a lower price when compared with calf prices in winter or spring. The market trend for low calf prices in the fall provides impetus for producers to consider alternative calving dates. By altering the calving date, production and marketing also shift to a different time of year, which may be economically advantageous (Stockton et al., 2007). Calves sold at an alternative time to November generally receive a higher price due to decreased supply at weaning and marketing. Late-spring calving systems allow producers an opportunity to shift the marketing window.

**Body Condition**

Reproduction, the most important factor affecting ranch profitability, is significantly influenced by nutrition management. Management strategies that optimize reproductive performance, reduce production cost, and/or increase production output lead to greater production efficiency. However, reproduction is of low biological priority in breeding females (Dunn and Moss, 1992), meaning a cow will partition nutrients to her own maintenance before partitioning nutrients to reproductive function and the estrous cycle. Osora and Wright (1992) found body condition at calving, was the most significant animal factor affecting reproductive performance. Additionally, cows calving in higher body condition ($\geq$ BCS 5) experienced shorter calving intervals. Therefore, when nutrient quality or quantity is limited and breeding females experience significant
declines in body condition, reproductive performance may be compromised. This makes nutritional management and understanding how stage of production affects nutrient requirements critical to ensuring reproductive success. Lactation imposes nutrient maintenance requirements 20 to 30% higher than requirements for a non-lactating cow (NRC, 2000). It is difficult to economically add BW to lactating cows. Body condition score at parturition has the greatest impact on the length of the post-partum interval (Richards et al., 1986). When cows are thin at calving, long periods of post-partum anestrus occur (as reviewed by Seidel, 2011).

A study performed by Ciccioli et al. (2003) in Oklahoma was designed to determine the effects of BCS at calving and post-partum nutrition on endocrine and ovarian functions, and reproductive performance. Primiparous Angus × Hereford females in thin (BCS 4.4 ± 0.1) or moderate condition (BCS 5.1 ±0.1) were fed to gain either 0.45 kg/d or 0.90 kg/d for the first 71 ± 3 d postpartum. Cows calving with BCS 4 or 5 had similar endocrine function and reproductive performance at first estrus. However, cows on a higher plane of nutrition gained BW, increased BCS, and had greater concentrations of IGF-I, leptin, insulin, glucose, and thyroxine in plasma, as well as a shorter interval to first post-partum estrus and ovulation, and a larger dominant follicle at first estrus than cows on the lower plane of nutrition. First estrus pregnancy rate was greater for cows on a higher plane of nutrition (76 %) than for those on a lower plane of post-partum nutrition (58%). Ciccioli et al. (2003) concluded increased intake after calving stimulated secretions of anabolic hormones, promoted fat deposition, shortened the post-partum interval to estrus, and increased pregnancy rate at first estrus. This study suggests post-partum nutrition is more critical to the resumption of estrus than BCS pre-calving.
Managing cattle to a pre-calving BCS of 5 would require more feed resources than maintaining cattle to a pre-calving BCS of 4. If an increasing plane of nutrition prior to breeding is provided, beef producers may seek production efficiencies by managing cattle to lower pre-calving BCS, then ensuring an increased plane of nutrition until breeding. However, managing cows to lower pre-calving BCS may increase reproductive risk. In dairy cows, researchers found that nutritional management during the post-partum period had a critical role to play in reproductive efficiency. Decreasing body condition was an important risk factor associated with prolonged anovulatory anoestrus (Roche et al., 2000). Researchers in Minnesota found that thin cows had a 6-10% higher energy requirement through the winter in a cold environment than cows in moderate to high body condition (Thompson et al., 1983).

**Mature Size and Milk Production Potential Influence Nutrient Requirements**

Having cows with a biological type well matched for her production environment is critical to longevity, BCS maintenance, reproductive performance, and sustainability (Crossbreeding Beef Cattle for Western Range Environments, 1999). Increasing visceral mass associated with larger cows will increase nutrient requirements and the amount and quality of forage resources (NRC, 2000). In areas where forage resources are limited in either quantity or quality, mature BW should be limited. Geographic regions that have high rainfall and high quality forage can support larger cows.

Lactation imposes the greatest nutrient demand on cattle. Cows with high potential for milk production may require supplementation when their nutrient requirements are not well matched with forage quality or availability. Additionally, lactating cows in their first or second parturition must meet requirements for growth and
lactation. During lactation, it becomes challenging for young breeding females to maintain body condition reserves to re-breed and stay in the cowherd. (Whittier 1995). Lactating cows in a nutrient deficit will partition fat reserves to milk production to maintain milk production levels which results in decreased body condition.

**Late-Gestation Nutrition**

Energy requirements increase 1.3 to 1.5 times maintenance in late gestation (Quigley III and Drewry. 1998). Therefore, cattle diets should contain sufficient energy to support fetal growth plus maintenance. Additionally, mineral requirements increase during pregnancy. In dairy cattle, Ca accretion rate in the conceptus increased from 2.3 g/d at 190 d of gestation to 10.3 g/d at 280 d of gestation. Corresponding P accretion were 1.9 and 5.4 g/d. Rates of accumulation for Mg, K, and Na in the conceptus at 280 d was 0.2, 1.0, and 1.4 g/d respectively, and Fe, Zn, Cu, and Mn accumulated in the conceptus at rates of 18.0, 11.7, 1.6, and 0.3 mg/d (House and Bell, 1993), which suggests the importance of minerals to the developing fetus.

Supplemental protein during mid-to-late gestation appears to be critical to fetal development, as the majority of fetal growth occurs during this period. Supplementing beef cows during late gestation can affect the lifelong productivity of the calf. Larsen et al. (2009) concluded conceptus growth is sensitive to direct and indirect effects of maternal dietary intake. They observed dam nutrition had an effect on calf post-weaning growth, carcass composition, and calf health in the feedlot. Additionally, a lack of nutrients early to mid-gestation reduces the formation of secondary muscle fibers in ruminants. Nutrient deficiency during mid to late gestation decreases the number of
intramuscular adipocytes and muscle fiber sizes, thus affecting marbling (quality grade) of meats (Du et al., 2011).

Heifers born to dams that received protein supplementation during mid to late gestation had higher pregnancy rates than contemporaries. Additionally, a greater number of heifers calved during the first 21 d of calving from supplemented cows. When cows were supplemented with protein, their heifer progeny had greater WW, pre-breeding BW, weight at first pregnancy diagnosis, and BW prior to second breeding season (Martin et al., 2007), suggesting fetal development of heifer progeny was influenced by dam nutrition.

In summary, calving date selection is an economically relevant decision impacting many factors of production as well as the timing of important production events such as calf weaning and marketing. Optimizing calving date is critical to ranch sustainability and profitability. Selecting cows well adapted to their production environment is and pairing peaks in forage quality with peaks in nutrient requirements is a prudent approach available to many beef producers. Understanding changes in physiological state of beef females throughout a production cycle is critical to meeting their nutritional requirements. Maintaining adequate body condition ensures reproductive performance and progeny performance.
ESTROUS SYNCHRONIZATION AND ARTIFICIAL INSEMINATION IN BEEF
HEIFERS AND POSTPARTUM BEEF COWS

The Estrous Cycle

The estrous cycle, occurring over an 18 to 24 d period (most commonly 21 d), is controlled by hormones secreted by glands or organs in minute quantities. These hormones are transported in the bloodstream and elicit specific responses from target tissues. The estrous cycle can be described as a cascade of events controlled by various blood hormone concentrations. The hypothalamus is a small region in the brain that plays a critical role in initiating and controlling the estrous cycle; it secretes gonadotropin releasing hormone (GnRH), which via the bloodstream, targets the pituitary gland. In response to the hormonal stimuli sent from the hypothalamus, the pituitary gland releases gonadotropins into the bloodstream, specifically follicle-stimulating hormone (FSH) and luteinizing hormone (LH). Acting together, FSH and LH elicit a response from target tissues in the ovary by stimulating the maturing ovarian follicle to produce estrogen. Follicle stimulating hormone stimulates the growth of follicles, which contain the ovum or egg, and follicle maturation occurs under the influence of FSH. As a follicle grows, the side opposite the egg bulges from the surface of the ovary and becomes thin. At this point the follicle is mature and termed the Graafian follicle. The thin portion then ruptures (ovulation) and releases its contents including the egg into the infundibulum to await fertilization. Luteinizing hormone acts on the ovarian tissues at the site of ovulation; the cells that developed within the follicle differentiate, creating a structure called the corpus luteum (CL). The CL is stimulated by FSH and LH to produce estrogen and progesterone. Estrogen acts on the nervous system to cause the cow to express heat and standing estrus.
Additionally, estrogen prepares the uterus for sperm transport, capacitation of sperm, and ova transport (Hixon, 1993; Deutscher 1980). At approximately day 16 to 18, if no growing embryo is detected by the uterus, it begins to secrete prostaglandin, which causes luteolysis. With the CL no longer producing progesterone, the pituitary gland begins to increase secretions of gonadotropins. Increased blood concentration of LH stimulates the dominant follicle to produce estrogen and causes the animal to come back into estrus. The estrous cycle is summarized in Table 1.

**Table 1.** Ovarian changes during a typical 21-day estrous cycle in which pregnancy does not occur. (adapted from Deutscher, 1980).

<table>
<thead>
<tr>
<th>Day(s)</th>
<th>Stages of the estrous cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 1</td>
<td>The cow is in estrus (standing heat) on <em>Day 0</em> for an average of 18 h (range 12 to 24 h). Approximately 12 h after the end of estrus, the mature Graafian follicle ruptures (ovulation) in response to a surge of LH released by the pituitary gland.</td>
</tr>
<tr>
<td>1 to 2</td>
<td>The cells that formerly lined the follicle change and become the lutein cells of the corpus luteum. This change in cell form is caused by hormonal action, primarily LH.</td>
</tr>
<tr>
<td>2 to 5</td>
<td>The CL grows rapidly in both size and function. Numerous follicles may be seen on the ovary at this stage, but by <em>Day 5</em> they have begun to regress.</td>
</tr>
<tr>
<td>5 to 16</td>
<td>The CL continues to develop and reaches its maximum growth and function about <em>Day 10</em>. It secretes the hormone progesterone, which inhibits LH release by the pituitary gland. During this period, the ovaries are relatively inactive except for the functional CL. No follicles reach maturity and/or ovulate because of the existence of the high levels of progesterone.</td>
</tr>
<tr>
<td>16 to 18</td>
<td>The CL regresses rapidly due to some luteolytic activity of the uterus. Evidence is increasing that this may be a prostaglandin.</td>
</tr>
<tr>
<td>18 to 20</td>
<td>The CL is almost nonfunctional and progesterone release is suppressed, removing the blocking action of progesterone on LH and FSH. Of the several follicles that commence growth, one becomes more prominent by a surge in progesterone. Of the several follicles that commence growth, one becomes more prominent by a surge in rapid growth and activity. As the Graafian follicle grows, it secretes increasing amounts of estrogen. The remainder of the follicles regress.</td>
</tr>
<tr>
<td>21 or 0</td>
<td>With an increase in estrogen release by the Graafian follicle and a corresponding decrease in progesterone by the regressing CL, estrus or heat will occur. The high estrogen level in the blood triggers a release of LH near the end of heat. Following this surge in blood levels of LH, the mature follicle ruptures to release the egg and the cellular tissue left becomes luteinized in response to the stimulation of a hormonal complex to form a new CL.</td>
</tr>
</tbody>
</table>
Reproductive Technology

Reproductive technology, namely estrus synchronization and AI, is based on understanding the timing of critical hormonal events in the estrous cycle and finding methods to intervene or influence the estrous cycle at its critical stages. Hixon (1993) said, “The objective of any successful synchronization program is to manipulate the estrous cycle of normally cycling females so that a large percentage will exhibit estrus with normal fertility at a pre-determined time.”

Prior to the advent of reproductive technology during the 1940s and 1950s, reproductive management, in both the beef and dairy cattle segments, generally consisted of purchasing a bull every 2 years from a neighbor thought to have a herd with above average genetics. That system is still relatively close to methods used by beef producers for the majority of beef cattle herds today (Seidel, 2011). One difference would be that most seedstock producers today truly raise cattle of above average genetics. However, adoption and implementation of reproductive technology has been slow and seen only in a small portion of beef operations. Artificial insemination has been commercially available to beef producers since the 1940s and is used extensively in the dairy industry. In contrast, limited implementation has been observed in the beef industry, with the majority observed in the purebred segment, although recent semen sales indicate increasing implementation in the beef industry (Lamb et al., 2010) likely occurring in both heifer development and commercial applications.

Estrus synchronization and AI have inherent advantages in beef production systems over natural service; however, disadvantages to such systems have limited the use of reproductive technology on many beef operations. Estrus synchronization and AI
protocols offer a number of production advantages. 1) They provide an opportunity for genetic improvement, which could affect fed cattle performance as well as improve genetics in retained replacement females. It is cheaper to access an outstanding herd sire via purchasing semen (i.e. $25/straw) as opposed to purchasing a herd bull of similar genetic merit (i.e. > $5000). 2) Estrus synchronization and AI can increase synchrony early in the breeding period, resulting in greater weaning weights due to older, heavier calves. This is especially advantageous to producers who market calves at a determined endpoint such as weaning. Synchronizing estrus can increase the proportion of females that become pregnant early in the breeding season, resulting in shorter calving seasons and more uniform calf crops (Dzuik and Bellows, 1983). 3) Herd productivity may increase as a result of genetically superior retained females. 4) A tighter calving season, resulting from estrus synchronization, allows for a longer post-partum interval and for proper uterine involution to occur prior to re-breeding. For most herds, non-pregnant and late pregnant cows are the most costly problem in the operation (Seidel, 2011). 5) Fewer bulls are needed when AI is utilized and may reduce production costs. 6) Initiation of estrous cycles in non-cycling cows is likely the primary manner in which beef producers may improve fertility in response to estrus synchronization and TAI protocols (Lamb et al., 2010). These reproductive management tools remain the most important and widely applicable reproductive biotechnologies available for beef cattle operations (Seidel, 1995).

However, despite these advantages of reproductive technologies, adoption rates in the beef industry have been limited. The USDA National Animal Health Monitoring System conducted a survey (2007 to 08) in 24 major U.S. beef producing states to
determine commonly used cow-calf health and management practices. They found only 12.4% of beef heifers are exposed to AI, and with mature cows, that number fell to 4.1% (USDA, 2009). Although these numbers have likely increased somewhat in recent years, perceived risks associated with estrus synchronization and AI protocols have limited their implementation. Incorporating reproductive technology requires increased management and knowledge to coordinate and facilitate labor, resources, synchronization drug administration, AI technique, and facilities. Increased investment in breeding tools, semen, facilities, and synchronization drugs is required. Additionally, reproductive risk is introduced if mistakes are made, or problems arise (i.e. semen storage failure, improper drug administration, improper AI technique, etc.).

Because the industry has sold commodity beef based on average values for so long, it is difficult for many beef producers to market calves so they are paid for the true value of the genetics produced (in AI systems). These genetic differences are more often observed at harvest in carcass quality characteristics such as yield grade or marbling score, than at weaning, although there is a trend toward rewarding known genetics earlier in the production system (Dunn, 2000, as reviewed by Johnson and Jones, 2005).

Recent economic and production drivers have increased demand for bred replacement females. Capitalizing on this demand, some producers have shifted heifer marketing from fed heifers to programs that develop bred replacement females. Implementation of reproductive strategies has been greater in heifer development strategies. Producers may choose to utilize AI to capitalize on the general preference of some buyers to purchase AI-bred vs bull-bred replacement females. This perceived demand may allow beef producers to utilize reproductive technology to achieve a
marketing advantage of AI vs bull-bred heifers. According to the Missouri Show-Me-Select Replacement heifer program, over an 11-yr period, AI-bred heifers had a $54 average higher value over natural-service bred heifers (University of Missouri, 2011).

Bull purchase price has increased significantly in recent years as well as costs associated with feeding and maintaining bulls. Consequently, AI systems have become even more competitive when compared with bull-bred systems. In historical evaluation of AI vs. natural service when only the cost per pregnancy was taken into account, few AI systems competed well with natural service; however, recent increases in bull costs and feed costs, as well as advancements in reproductive technology have made AI systems far more competitive than in previous reviews, which compared only the cost of pregnancy and did not include potential value introduced by AI systems (Loseke, 1989; Miller et al., 2004; Johnson and Jones, 2005).

In a stochastic model comparing AI vs natural service, Johnson and Jones (2008) evaluated various production scenarios, which included varying herd size (30, 100, and 300 hd), synchronization method (Select Synch, Select Synch + CIDR, and MGA-PG), and cow to bull ratio (20, 30, and 40) to determine which conditions an AI system has a cost advantage over natural service. Industry averages were used for AI conception rates (50%), bull purchase price ($2,422), and other management and herd costs associated with each breeding systems. An assessment of the economic feasibility of estrus synchronization and AI should include potential returns influenced by AI systems and account for the random nature of various inputs, as well as economic risk in the decision making process. Therefore, incorporating an AI value that would recognize the value of added synchrony and superior genetics in AI studs leads to a higher endpoint value.
When an AI advantage was recognized by the model, AI was established as lower cost than natural service in 70% of simulations. As herd size increased, and cow to bull ratio decreased, AI was more likely to have lower costs than natural service. Simulations of a herd size of 300, a cow to bull ratio of 20:1, and a synchronization protocol using a progesterone insert had lower cost than natural service 83% of the time. On the other end of the spectrum, a herd size of 30, cow to bull ratio of 30:1, using any of the 3 synchronization protocols resulted in lower costs for AI in less than or equal to 2% of simulations. They also determined the 3 most important factors influencing the AI vs. natural service cost comparison were bull purchase price, semen cost, and genetic value of AI systems. They concluded, when relatively minimal value increases for the age and genetics of AI-sired calves were incorporated into the simulation for typical cow to bull ratios, AI became economically beneficial and produced lower cost than natural service breeding systems (Johnson and Jones, 2008). In recent years bull purchase prices have become much higher (> $5000) than those used in this stochastic model. Considering bull purchase price as the primary factor affecting breeding strategy cost in this stochastic model, AI systems are much more likely to be comparable, if not superior, to natural service breeding systems purely from a cost standpoint. Additionally, advancements in reproductive technologies in fixed-time AI (FTAI) and heat detection AI techniques have made the estimate in this model for AI conception rate (50%), even more conservative. Additionally, a producer can influence the costs associated with utilizing reproductive technology through labor and facilities management.

*Fixed-time Artificial Insemination*
Recent research in estrus synchronization and AI has been focused on developing effective and practical strategies for FTAI. Improved reproductive response to AI and protocols that facilitate easier implementation will lead to further implementation of reproductive technology in the production setting. The understanding of the importance of follicular growth for synchronizing ovulation with subsequent high fertility has increased the number of options available to producers for FTAI and synchronization of estrus (Johnson and Jones, 2008). Fixed-time AI synchronization protocols introduce 2 efficiencies that are key factors for implementation by producers because they 1) minimize the number and frequency of handling cattle and 2) eliminate detection of estrus. These factors have increased adoption of FTAI protocols, which is supported by the observation that more semen has been purchased and frozen from beef sires in recent years than in any previous period in the past 30 years (Lamb et al., 2010).

Lamb et al. (2006) evaluated whether similar reproductive performance could be achieved by a FTAI protocol compared with a protocol involving heat detection, heat detection plus TAI, and a protocol involving an injection of GnRH at the time of controlled internal drug release (CIDR) insertion to enhance fertility in beef heifers. This study observed similar conception rates among all treatment groups, but reported a tendency for higher conception rates in the treatment combining heat detection and FTAI. However, they concluded the protocol involving a GnRH injection at CIDR insertion yielded the most consistent pregnancy rates among locations and yielded pregnancy rates similar to protocols involving heat detection and clean-up AI, justifying FTAI protocols as a viable method for synchronization, thus eliminating the necessity for heat detection.
In the Nebraska Sandhills, Neilson et al. (2015) evaluated a 19-h delayed AI following a GnRH injection in hybrid estrus detection and timed AI protocol. In that study they utilized the melengestrol acetate (MGA) – prostaglandin F2α (PG) estrus synchronization protocol and applied estrus detection aids to all heifers. Heifers detected in estrus within the first 72 h after PG injection were bred via AI. Seventy-two h following the PG injection, heifers not detected in estrus were administered GnRH, and randomly assigned to 1 of 2 treatment groups: 1) immediately AI or 2) AI 19 ± 1 h following GnRH injection. Heifers receiving AI from estrus detection had a higher ($P < 0.01$) pregnancy rate than either time AI treatment (70 vs. 56, 47 ± 6%), but pregnancy rate was similar among both timed AI treatments (56 vs. 47 ± 6%). They concluded there was no benefit to delayed AI of non-estrus beef heifers compared with traditional TAI at the time of GnRH injection.

Echternkamp and Thallman, (2011) found cows expressing estrus leading up to timed-AI (TAI) had greater pregnancy rates than cows not expressing estrus. This is also supported by Perry et al. (2005) who suggests females expressing estrus prior to a TAI have higher pregnancy rates than non-estrus animals. However, this contrasts the results found by Lamb et al. (2006), concluding similar first service conception rates may be achieved by FTAI protocols in beef heifers when compared with AI protocols involving heat detection and clean-up AI.

As discussed by Nielson et al. (2015), a study performed by Mallory et al. (2010) compared MGA and CIDR synchronization protocols, finding no difference in AI pregnancy rate; however, a variance of interval to estrus after PG injection tended to be greater in heifers synchronized with a CIDR, which suggests the MGA- PG protocol may
have an advantage over CIDR protocol in producing a tighter synchrony among heifers, lending itself more effectively to FTAI protocols.
POST-WEANING MANAGEMENT STRATEGIES

Heifer Development

Leading research authorities in beef production suggest the heifer development period is vitally important to sustainable, profitable, and efficient beef production systems. Deutscher and Funston (2004) stated, “Proper development of replacement heifers is critical and needs to be accomplished at low costs without sacrificing performance. Heifers should be managed to reach puberty early, conceive early in the first breeding season, calve unassisted, and breed back early for their second calf.” It is well established proper management of heifers preceding their first breeding season is critical to their reproductive success (reviewed by Lamb et al., 2006). Management of replacement beef heifers should focus on factors that enhance physiological processes that promote puberty. Age at puberty is important as a production trait when heifers are bred to calve as 2-yr-olds and in systems that impose restricted breeding periods. Calving by 24 mo of age is necessary to obtain maximum lifetime productivity (reviewed by Patterson et al., 1992). Heifers that calve early during their first calving season have a higher lifetime calf production than those that calve later in the season (Lesmeister et al., 1973). One of the major determinants of a heifers’ ability to conceive during her first breeding season is the age at which she attains puberty, especially in relation to the onset of the breeding season (Short et al., 1990).

Heifers commonly selected for breeding are used to replace females culled from the herd, expand the herd, or sold as pregnant heifers. Historically, heifers were first bred as 2-yr-olds, but as beef production systems have become more intensive over the last few decades, more and more producers have bred their heifers as yearlings to first calve
as 2-yr-olds. However, producers in regions that have predominately slow-maturing breeds, less intensive management systems or limited quality and (or) quantity of forages still commonly breed heifers as 2-yr-olds. The southeastern and southwestern regions of the United States commonly breed at 2 yr of age due to limited forage availability on desert ranges, poor forage quality in subtropical areas and higher proportions of slower-maturing crossbred or purebred *Bos indicus* cattle (Short et al., 1990).

Chronological age of beef heifers, although important, is not the only factor influencing sexual maturity and onset of the estrous cycle in beef females. Maturity studies in beef heifers suggest diet and energy status affect physiological changes in beef heifers (Frisch, 1984). Achieving adequate reproductive rates in beef heifers will depend on the proportion of heifers attaining puberty prior to the breeding season. Even if heifers reach their first estrous cycle at breeding, fertility of the first estrus is less than subsequent estrous cycles. Byerley et al. (1987) reported heifers should experience 2 or 3 estrous cycles prior to the breeding season. In this study, heifers were either bred on the first estrus (E1) or on the third estrus (E3), pregnancy rates were 57 and 78% for heifers in E1 and E3, respectively, suggesting the fertility of pubertal estrus in beef heifers is lower than third estrus. Further, higher fertility of third estrus may be related to maturational changes associated with cycling activity and or age. In 3 studies, Vraspir et al. (2014) evaluated whether pubertal status and number of estrous cycles prior to breeding influences conception rate in beef heifers. Heifers that were pubertal prior to breeding were born approximately 4 d earlier than non-pubertal heifers, suggesting age is an important factor affecting pubertal status. Additionally, in contrast with the finding in Byerley et al. (1987), Vraspir et al. (2014) observed improved pregnancy rate in heifers
that had experienced at least one estrous cycle prior to breeding, however, multiple estrous cycles prior to breeding did not improve subsequent pregnancy rate.

It is well established post-weaning growth rate can influence age of puberty (Arije and Wiltbank; Short and Bellows, 1971; Wiltbank et al., 1985). Additionally, it is important heifers become pregnant early in the breeding season, because early-bred heifers have greater lifetime productivity potential than later-bred females (Cushman et al., 2013). Therefore, traditional development methods utilized accelerated growth rates in order to attain a recommended threshold body size of 60 to 65% mature BW prior to the breeding season (Patterson et al., 1992). These high-input development systems may maximize pregnancy rate, but may not optimize profit or sustainability (reviewed by Funston et al., 2007). Energy requirements associated with this type of targeted gain are expensive and contribute significantly to development system costs. Therefore, more recent studies have challenged traditional thinking by developing strategies that would reduce the input costs of heifer development systems by decreasing either the amount or quality of feed inputs.

Funston and Deutscher (2004) developed heifers to reach a pre-breeding target BW of 53 or 58% of mature BW. They reported similar pregnancy rates from the initial through fourth breeding season for both treatment groups. Spring-born heifers that reached 53 or 58% of mature BW at breeding had similar reproduction and first calf production traits, and feed costs were $22/heifer less for heifers developed to 53% of mature BW. This report concluded opportunities may exist to lower traditional target breeding weights, which would decrease development costs for replacement females because developing heifers on a slower rate of gain decreases feed costs.
A study performed at Fort Keogh evaluated lifetime productivity of heifers developed with either unlimited or restricted access to feed during the post-weaning development period to determine the viability of reducing pre-breeding target weights. Pregnancy rate was similar for heifers developed on the 2 protocols. During the 140 d post-weaning development period, the restricted diet reduced harvested feed inputs per pregnant female by 22% (Robert et al., 2007). Both studies performed in Nebraska and Montana show heifers can be developed to a lower pre-breeding BW and experience reproductive performance similar to those heifers developed to greater pre-breeding BW. Additionally, these studies suggest an opportunity for beef producers to improve efficiency and decrease production costs by decreasing amount or quality of feed inputs used in heifer development systems (Funston and Deutscher, 2004; Roberts et al., 2007).

Martin et al. (2008) developed heifers to a pre-breeding BW of either 50% mature BW before a 60-d breeding season or 55% of mature BW before a 45-d breeding season. Pre-breeding and pregnancy diagnosis BW were greater for those heifers developed to 55% mature BW, but overall pregnancy rate did not differ. Heifers developed to 50% mature BW had later calving dates and lighter calf weaning weights (194 ± 4 vs. 199 ± 4 kg) compared with heifers developed to 55% mature BW. Interestingly, attainment of puberty prior to the breeding season was similar between treatment groups. This contrasts earlier research, which would suggest heifers developed to 50% mature BW should have reached puberty later than heifers developed at accelerated rates (Arije and Wiltbank, 1971; Short and Bellows, 1971; Wiltbank et al., 1985). Additionally, early reports would suggest heifers fed a lower plane of nutrition during the development period should experience a greater incidence and severity of dystocia (Bellows and Short, 1978;
Patterson et al., 1991). However, Martin et al., (2008) reported no differences in calf birth BW or the proportion of heifers requiring assistance between treatments. They concluded the development costs for a heifer developed to 50% mature BW prior to the breeding season resulted in $17 cost reduction as opposed to heifers developed to 55% mature BW. Although further research is needed, there is data to support the viability of low-input heifer development systems that target a lower rate of gain during the development period and lower target pre-breeding BW than traditional recommendations.

In a review, Funston et al. (2007) suggest substantial changes in cattle genetics and the economic environment have occurred in past 20 yr indicating traditional approaches should be re-evaluated. One major factor contributing to the success of low-input heifer development systems may relate to genetic changes in age of puberty and that is the association between scrotal circumference in bulls and age of puberty in their female offspring. Since the mid-1980s, scrotal circumference has been used as an indicator trait for puberty. Additionally, the industry shifted from calving heifers at 3 yr of age to 2 yr of age, which increased selection pressure for age of puberty; however, due to the long generation interval in cattle, genetic progress has likely been slow.

Clanton et al. (1983) evaluated the timing and rate of post-weaning growth and development in systems that capitalize on compensatory gain to achieve targeted pre-breeding BW and concluded adequate growth and development of replacement heifers is necessary, but much latitude exists in the rate and time of growth between weaning and breeding. Early reports demonstrate taking advantage of compensatory gain did not have detrimental effects on reproductive performance (Clanton et al. 1983; Lynch et al., 1997). Delaying gain until 47 or 56 d prior to breeding season was not detrimental to
reproductive performance, but successfully reduced the quantity of harvested feed needed (Lynch et al., 1997). Delaying gain until the latter part of the postweaning period reduced energy intake of beef heifers, but did not affect calving rate, age at calving, postpartum interval, and second year pregnancy rate (Freetly et al., 2001).

Heifers that grazed pasture regrowth for the initial 56-d post weaning, then entered the drylot experienced similar reproductive performance to heifers developed entirely in a drylot setting. Heifers that grazed pasture had lower BW after the initial 56-d period; however, similar pre-breeding BW was observed between the grazed and drylot heifers (Grings et al., 1998). Additionally, Marston et al. (1995) observed heifers developed in a drylot reached puberty 29 d before contemporaries that grazed pasture and were fed protein supplement, despite similar pre-breeding BW. However, no difference was observed in conception rate or age at first calving.

Postweaning management strategies focused on heifer development greatly impact production efficiency, input costs, longevity of individual beef females, and overall ranch profitability. Therefore, researchers and beef producers have pursued effective reproduction, nutrition, and beef systems strategies to optimize the development of young breeding females and increase production efficiency. Additionally, advancements in the field of heifer development have led to progress in post-development strategies and entire herd production management, and breakthroughs in heifer development lead to improved overall ranch productivity, herd management, sustainability, and profitability.

*Growth Implants in Heifer Development Systems*
Traditional high-input heifer development systems strive to maximize reproductive rates in replacement females. This type of heifer development strategy is regularly observed in systems that market a calf crop at weaning and forego the stocker enterprise; retaining a limited number of potential replacement females over the winter development period. In contrast, some beef producers have chosen to retain all heifers after weaning to run either as a stocker animal or potential replacement females. When excess heifers are retained after weaning, lower pregnancy rates can potentially be accepted and non-pregnant heifers transferred to the stocker enterprise.

It’s well established administering growth implants in stocker systems result in increased gains and improved efficiency, and is a common practice across the beef industry. Several growth implants approved by the FDA can be administered to stocker steers and heifers. Zeranol (ZER; 36 mg of zeranol), was approved in the late 1960s for both heifers and steers (Mallinckrodt Veterinary, 1984). A sustained-release drug delivery system (E-17β; 24 mg estradiol-17β) was introduced to the market in 1982 and is composed of a silicon rubber core with microcrystals impregnated in the outer silicone matrix (Elanco Animal Health, 1982). Finally, trenbolone acetate plus estradiol (TBA + E2; 40 mg TBA plus 8 mg E2) was approved in the mid-1990s for weaned steers and heifers.

The use of growth implants and other performance-enhancing technologies have recently come under scrutiny in public view, which may have an impact on the beef industry. Capper and Hayes (2012) created a model to quantify the environmental and economic impact of eliminating growth-enhancing technologies from the U.S. beef production system. They estimated significant increases would be seen in feedstuff and
land requirements, increased carbon emissions, manure output, and increased water required to maintain production. Withdrawing growth-enhancing technology would reduce both the economic and environmental sustainability of the industry.

Delaying the deposition of fat or the administration of estrogenic compounds may increase mature protein mass (Owens et al., 1993). Implants are used to increase muscling in cattle without adding excess backfat (Nielson et al., 2015). Hundreds of studies show consistently increased growth performance in animals administered a growth implant at varying times in the production cycle when compared with the performance of their contemporaries. However, the nutritional status of the animal largely controls the metabolic responses and interactions of endogenous and exogenous (implant) hormones that mediate growth and performance. (Lemieux et al. 1983; Preston, 1987; Reinhardt et al., 1992; Wester et al., 1994; Kuhl et al. 1997). Diets should contain energy amounts that exceed 1.5 times the amount required for maintenance in order to elicit a measurable response (Preston, 1987). This equates to a recommended gain of 0.3 to 0.5 kg/d to obtain a reasonable response to growth implants. (Elanco Animal Health, 1982; Fort Dodge Animal Health, 1983; Mallinckrodt Veterinary, 1984; Laudert et al., 1984; Lusby and Gill, 1985; Sewell, 1990; Gill and Bevers, 1994; Brandt et al., 1995). These studies provide evidence that growth response to implants will increase when the nutritional status of stocker animals improves.

Originally, growth implants were utilized primarily in the finishing stage of production, but over the past several decades, the use of growth implants have been implemented in earlier stages development. Implanting grazing stocker animals is one of the most profitable management tools available to operators (Kuhl, 1997). Anabolic
implants typically increase cattle weight gains by 8 to 18% or 7 to 18 kg during the grazing season. As discussed by Kuhl (1997), in heifers from 3 studies (n = 494) over an average of 116-d grazing period, TBA + E2 increased stocker gains by 12 kg (15.3%) vs controls and was 4.6% greater than responses to Ralgro (Hoechst Roussel Vet, 1991).

Growth implants have not been used as widely in heifer calves because of concern about the detrimental effects on subsequent reproductive performance of heifers kept as herd replacements (Selk, 1997). Consequently, less research has been performed on heifers than steers. Results from implant studies on reproductive performance are inconsistent. Some of this variation is likely due to small numbers of heifers in some treatment groups in addition to the many factors that influence reproductive success. Multiple studies have shown decreased reproductive performance of beef heifers implanted once with ZER at weaning (Nelson et al., 1972; Pruitt et al., 1980; Pritchard et al., 1989). However, weaning is not the recommended time for administering growth implants.

If a beef producer is not concerned with maximizing conception rate in potential replacement females, one could implant heifers and accept a decreased conception rate and increased stocker gains. In a 2-yr Montana study, weaned heifers were separated into 2 weight classes and divided between implant and non-implanted control. Heifers were developed in a drylot until 1 mo prior to breeding season. Weaned heifers were implanted with ZER at 8 and 11 mo of age. Rates of gain in the drylot were greater for implanted vs. control heifers in both Trial 1 (0.53 vs. 0.48 kg/d) and Trial 2 (0.70 vs. 0.63 kg/d). Pregnancy rate was 16 percentage points lower in implanted heifers vs. control (62 vs.
78%) in Trial 1, but did not differ (88 vs. 87%; implant vs. control, respectively) in Trial 2 (Staigmiller et al., 1983).

In a similar study, implants were administered to crossbred beef heifers at 1, 6, or 9 mo, or at multiple intervals. Heifers receiving a combination of 2 implants had greater ADG from weaning to breeding than control or heifers implanted 3 times. Conception rates in a 62-d breeding season were comparable for implanted vs. non-implanted control heifers (93 vs. 96%), with the exception of heifers receiving implants at both 1 and 6 mo of age (56%). Calf birth weight, dystocia score, cow re-breeding rate, and calf weaning weight were not affected by implant treatment (Deutscher et al., 1984). Moran et al. (1990) observed decreased pregnancy rates when heifers were repeatedly implanted with TBA (200 mg of TBA) or ZER, and TBA + E2. Devine et al. (2015) implanted heifers at 255 ± 12 d with TBA, TBA + E2, and ZER. AI and overall pregnancy rate tended to be 18 and 21% respectively, less than nonimplanted heifers. The effects of implants on pregnancy rates seem to be dose and age dependent.

**Growth, Forage Quality, and Supplementation**

Nutrition provides the building blocks and catalysts for all metabolic processes in the body. Justus von Liebig formulated his law of the minimum, which states that growth is limited by the availability of whatever nutrient is most scarce. The value derived from genetic engineering, genetic selection, and metabolic manipulation will be limited if the animals nutrition is limited. (Cline et al., 1986). When animals are supplied adequate nutrients, they can express their genetic potential, and optimize growth. Additionally, environmental impacts and animal health are vital factors that contribute to performance. Growth can be defined as an increase in tissue mass. Due to compensatory gain, a period
of restricted growth and fat deposition associated to back-grounding and stocker systems can result in greater endpoint slaughter weight.

Grazing ruminants often require energy supplementation at critical phases of development, due to either low forage availability (quantity), or nutrient content (quality) of the forage relative to nutrient requirements (Horn and McCollum, 1987). Forage quality decreases with increasing plant maturity (Lamb et al, 1996). The concentration of fiber in grazed forages increases with plant maturity, as well as a decrease in the concentration of cell solubles (Merchen, 1988). In the Nebraska Sandhills, steers had greater OM intake, OM digestibility and particulate passage rates were faster for immature hay fractions, than mature fractions, which demonstrates the interaction between stage of maturity and rumen microbe function. With forage senescence, forage quality declined, which reduced forage intake and digestibility. Differences observed in OM intake and OM digestibility between immature and mature hay fractions was attributed to slower rate of passage (Lamb et al., 1996). In a subsequent Nebraska study, diet samples were collected and analyzed for CP, RDP, RUP, digestibility, and fiber components to estimate seasonal changes in forage quality of native Sandhills range and subirrigated meadow. They found diet samples highest in CP, RDP, RUP, and digestibility during periods of active growth (Lardy, 1997).

Dry matter intake for ruminants grazing poor quality forage diets is greatly influenced by RDP, which is required for proper rumen function. Forage proteins are quickly degraded in the rumen (Klopfenstein et al., 2001). Passage rate and the extent of digestion in the rumen depend on adequate protein and energy availability to the rumen microbe population (Merten and Ely, 1982). Mature or dormant forages often lack
sufficient amounts of RDP for microbes to optimize rumen function (NRC, 2000). The first limiting nutrient for summer-calving cows grazing native forage during breeding and late lactation was RDP (Lardy, 1997). Therefore, growing animals grazing mature or dormant forages or crop residues often require supplemental RDP in order to meet nutrient requirements and optimize performance and efficiency on grazed forages (NRC, 2000). Protein supplementation on cattle grazing low quality forage has been shown to consistently improve forage DMI and growth (McCollum and Galyean, 1985; Peterson et al., 1985; Bert et al., 1994; Lamb et al., 1997; Schauer et al., 2005). Supplemental RDP was shown to enhance rumen fermentation, directly impacting the rate of passage and increasing forage intake (Köster et al., 1996). A Nebraska study with steers grazing native Sandhills rangeland demonstrated organic matter intake increased linearly ($P < 0.10$) with increasing levels of RDP (Lamb et al., 1996).

In addition to meeting the RDP requirement in cattle, it is important to consider the growth response cattle may experience when supplements also contain sufficient RUP as well. When forage is in active growth, cattle respond to RUP supplementation because forage protein is highly degraded in the rumen, which may limit growth through a MP deficiency (MacDonald et al., 2006). Growth performance is improved via supplementation in growing animals grazing low quality forage, although protein supplementation has been shown to improve performance of growing animals grazing high quality forage as well. When DDG was supplemented to animals consuming both low and high quality forage, ADG was improved (Morris et al., 2005). Therefore, supplementation is necessary at critical stages of development and performance will improve if supplement source contains protein in the form of RDP and RUP.
Some forage diets may lack sufficient energy to meet nutrient requirements. Supplemental energy sources vary widely and include grains, digestible fiber sources, and high quality harvested forages (Caton and Dhuyvettor, 1997). When supplemental energy is provided, a substitution of concentrate for forage is commonly observed, which, depending on management objectives, may or may not be desired. For instance, when a producer’s objective is to stretch the forage resource, a relatively high substitution rate is advantageous. However this does not regularly maximize growth performance when energy supplements (concentrates) are provided in low amounts. To maximize growth, a greater amount of concentrate must be fed. Supplementation strategies vary based on performance objectives; however, it is well established energy and protein supplementation may be required to optimize growing animal performance. Additionally, supplementing with energy sources (starch) may reduce performance in animals grazing forage (fiber) due to the negative associative effect of starch on fiber digestion (Ahern et al., 2011).

**Corn Residue Grazing**

Corn residue is an abundant feed resource available to some beef producers. For most beef operations, harvested feed used primarily during the overwinter period is the greatest expense. Grazing corn residue has the potential to extend the grazing period and decrease the amount of harvested feed needed per animal, allowing producers to decrease annual feed cost and labor associated with feed delivery. Residue grazing occurs outside the traditional growing season, making it a viable and economical choice for beef producers to decrease production costs when proximity allows.
When cattle graze corn residue, they select the highest quality parts first, then move on to less palatable parts of lesser quality. Residual grain is the highest quality component of crop residue, followed by the husk, leaf, stem, and cob. The leaf and husk component make up about 39% of available crop residue, and is favored by grazing animals. The stem and cob are rarely consumed (Wilson et al., 2004). Relative amounts and values of corn residue plant parts are presented in Table 1. Forage quality is highest when cattle are first introduced to a field and due to the selectivity of grazing, trampling, and environmental losses, forage quality declines as the season progresses.

Table 2. Relative amounts and values of corn residue plant parts (adapted from Wilson et al., 2004)

<table>
<thead>
<tr>
<th>Plant Parts</th>
<th>Husk</th>
<th>Leaf</th>
<th>Stem</th>
<th>Cobb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent of residue DM</td>
<td>12</td>
<td>27</td>
<td>49</td>
<td>12</td>
</tr>
<tr>
<td>CP, % DM</td>
<td>3.6</td>
<td>7.8</td>
<td>4.5</td>
<td>2.2</td>
</tr>
<tr>
<td>In Vitro DM disappearance, %</td>
<td>67</td>
<td>47</td>
<td>45</td>
<td>35</td>
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<td>Palatability</td>
<td>High</td>
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It has been established corn residue contains adequate CP and energy to support mature, non-lactating, beef females and is widely utilized during the overwinter period by beef producers located a feasible distance from corn residue (Wilson et al., 2004; Warner, 2012; NRC, 2000). However, those nutrients may not meet the requirements for growing animals. Corn residue lacks sufficient CP to support and optimize gain in growing animals. Numerous studies have been conducted that characterize performance of growing animals grazing corn residue with varying levels and source of supplement. Wilson et al. (2004) concluded growing calves may require at least 0.16 kg/d of RUP and 0.4 kg/d of total protein supplementation to optimize gain. Therefore, recommendations are to supplement growing animals grazing corn residue with protein supplements high in both RUP and RDP to optimize gain and performance (Gutierrez-Ornelas et al., 1991).
Assuring microbial need for NH₃ and N intermediates are met and any additional protein needs made up by RUP (Fernandez-Rivera et al., 1989).

**Supplement Source**

*Dry-rolled corn.* Corn is one of the most commonly used grains in ruminant diets. It provides relatively high levels of starch and is widely incorporated into finishing diets, although it may be used as a supplement in earlier stages of production as well.

According to the NRC (2000), corn contains 90% TDN and 9.8% CP. The starch component of corn comprises approximately 70% on a DM basis. The protein in corn is about 55 to 60% RUP while the remaining fraction is RDP. Like all cereal grains, corn is low in calcium and relatively high in phosphorous.

When corn is used as a supplement in forage-based diets, it may negatively affect forage utilization. This is most commonly observed in cattle consuming low quality forage. Therefore, corn should be used at relatively low levels in forage-based diets.

When whole corn is fed, the animal must process the grain via mastication to make the nutrient contents available in the rumen. Cracking or rolling corn prior to feeding increases digestibility 5 to 10% (as reviewed by Lardy, 2013).

*Urea – non-protein nitrogen.* Urea is a non-protein nitrogen compound that can be used to provide supplemental RDP in beef cattle diets and in cattle grazing applications. Supplemental urea usually contains 42 or 45% N. on average, amino acids contain 16% N; therefore, urea has a protein equivalent of either 262 or 281% based on its N concentration. When urea is consumed by a ruminant animal, it is rapidly degraded in the rumen into CO₂ and ammonia. Rumen microbes can utilize ammonia as a nitrogen source, resulting in increased microbial crude protein as rumen microorganisms move
through the digestive tract and cell proteins are made available to the host animal. Additionally, ammonia from degraded urea can be absorbed through the rumen wall into the bloodstream and then carried to the liver. In the liver, ammonia is converted to urea and excreted in the urine or recycled back to the rumen through saliva or blood (Sewell, 1993). In prepartum cows grazing low quality forage, Köster et al. (2002) found urea could replace between 20 and 40% of the RDP in a high-protein supplement without altering supplement palatability or cow and calf performance when DIP was offered in adequate amounts.

*Dried distillers grains (DDG).* The development and expansion of the ethanol industry has led to an increase in corn production in the Midwest. Dried distillers grains is high in protein (30% CP), energy (104% TDN), and is a good source of RUP. Dried distillers grains contain approximately 50% more CP in the form of RUP and has a greater energy value than corn in forage based diets (Benton et al., 2006; Loy et al., 2003). Additionally, DDG contain P concentrations that meet requirements of growing animals on forage-based diets, reducing or eliminating the need for supplemental P (NRC, 2000).

The starch component of DDG is largely removed during the milling process, which makes supplementing with DDG effective in high-fiber diets, avoiding any detrimental effects of starch on fiber digestion. Supplementation with DDG has been shown to consistently improve BW gain and is an effective strategy to meet protein requirements in growing animals consuming forage. When steers grazed smooth bromegrass pastures, supplementing DDG increased ADG by 0.27 kg/d over unsupplemented cattle. They found each 0.45 kg of DDG supplement would replace
approximately 0.45 kg of forage intake (Watson, 2011). MacDonald et al. (2006) reported a replacement rate of 0.17 kg forage replaced per 0.45 kg DDG supplemented. Morris et al. (2005 and 2006) also reported in growing heifers and steers an observed increased forage replacement rate and ADG with increasing levels of DDG. When yearling steers continuously grazed native Sandhills pasture and were supplemented with varying levels of DDG, forage intake decreased linearly with increasing levels of DDG supplementation, and ADG increased linearly with increasing levels of DDG supplementation (Morris et al., 2006). This data supported the concept that the grazing period could be extended when DDG supplementation is offered.

Heifers grazing smooth bromegrass in Eastern Nebraska were used to determine the relative contribution of RUP and fat in DDG to animal performance. Average daily gain was improved by 0.6 kg/d for every 0.10% BW increase in DDG supplementation. Cattle supplemented with corn bran + corn gluten meal gained 38% as much as cattle supplemented with DDG, while cattle supplemented with corn bran + corn oil, showed no improvement over control. Researchers concluded neither fat nor RUP account for all the observed improvement in ADG from supplementing DDG (MacDonald et al., 2006). In a study to determine the effects of DDG on reproductive performance of replacement heifers, Martin et al. (2007) found when heifers fed prairie hay supplemented with either DDG or an isocaloric control (dried corn gluten feed, whole corn germ, urea), age at puberty, BW and BCS at pregnancy diagnosis were not affected. However AI conception rate was greater in heifers supplemented with DDG.

Additionally, DDG is an effective supplement to combine with corn residue grazing to optimize gain and improve intake. Jones et al. (2015) observed steers grazing
irrigated corn residue and supplemented DDG at 0.3, 0.5, 0.7, 0.9, and 1.1% BW. Average daily gain increased linearly with increasing level of DDG supplementation. In a similar study, steers were offered higher amounts of DDG than in the Jones et al. (2015) study and the response was quadratic as supplement amount increased (Gustad et al., 2006), suggesting an optimal rate of DDG supplementation in calves grazing corn residue. A Nebraska study observed an optimal rate of 1.1% BW of DDG to increase performance and minimize feed refusals in steers grazing corn residue (Jones et al., 2014).

*SoyPass.* Soybean meal a commonly used livestock supplement in the United States (Mass et al. 1999). However, most of the protein available to ruminants in soybean meal is in the form of RDP, which does not optimize MP availability for cattle. Through a process known as the Maillard reaction, soybean meal can be nonenzymatically browned and heated, which enhances its nutritive value for ruminants. In 3 trials Cleale et al. (1987) demonstrated non-enzymatic browning reduced ruminal degradation of soybean meal, increased the flow of soybean meal N to the intestine, and improved efficiency of soybean meal protein utilization by ruminants. The browning process complexes the protein and reducing sugars by chemical condensation, which is desired; but if taken to a further degree, the process can cause the polymerization of the condensation process, which is not desired. If polymerization occurs, the product is unaffected by acid in the abomasum and becomes unavailable through the entire gastrointestinal tract. However, when proper condensation occurs, the product is a protein sugar complex that is not degraded by rumen microbes, but is broken down by acid in the
abomasum and becomes available in the small intestine. The result is a greater concentration of RUP and MP supplied to the animal (Mass et al., 1999).

SoyPass (Borregaard Lignotech, Rothchild, WI) is produced by adding sulfate liquor to soybean meal and treating the mixture with heat. Sulfate liquor contains xylose, a reducing sugar, which facilitates the condensation product and increases the RUP concentration. The result is a supplement containing similar CP concentration to soybean meal, but RUP (bypass protein) concentration is greater in SoyPass (70%) than in soybean meal (30%), therefore gain and protein efficiency are improved with increasing availability of MP (Mass et al. 1999; MacDonald et al., 2003). This is supported by Lardy (1997), who concluded supplementation of RUP increased weight gains of weaned and nursing calves without affecting forage intake (Lardy, 1997). Additionally, SoyPass has found application in the dairy industry. Researchers demonstrated SoyPass will support the same level of production at half the amount of supplemental soybean meal (Nakamura et al., 1992).

For the ruminant animal, SoyPass is an excellent source of RUP that may be incorporated into supplementation strategies to optimize protein absorption in the small intestine. This is of particular interest when an animal has a relatively high protein requirement as in periods of growth or lactation.
SUMMARY/OBJECTIVES

In conclusion, the preceding literature has established, due to differences among geographic regions and production systems, a universal calving date is not feasible. Calving date selection is influenced by environmental, economical, physiological, and production factors, affecting every phase of cow-calf production, which affects nutrient requirements. Each beef operation must make site-specific decisions regarding optimum calving date. Managing body condition and appropriately allocating feed resources according to nutrient needs of breeding females largely dictates production performance, sustainability, and ranch profitability. When peaks in nutrient requirements during early gestation are well matched with seasonal peaks in forage quality, the amount of harvested feed needed per animal can be reduced, which may increase overall ranch profitability. Managing breeding females well adapted to their production environment is critical to longevity, productivity, and profitability. Milk production potential, breed, and mature body size will influence nutrient needs of breeding females and should be considered when choosing herd sires and replacements for a given production environment. When forage quantity or quality is limited, milk production and mature size should be limited.

Reproductive technologies allow beef producers to synchronize estrus, increase calving interval, and introduce genetics of high quality herd sires. Additionally, in heifer development systems, AI allows producers to select for low birth weight and calving ease in herd sires to decrease dystocia. Improvements in FTAI protocols will increase implementation in the production setting.

Administering growth implants is an effective strategy to increase gains in stocker animals. Numerous studies show the positive growth response when growth implants are
utilized. However, implanting heifer calves has been shown to compromise reproductive performance.

Corn residue is an abundant feed source available to some beef producers. Corn residue contains energy and protein concentrations sufficient to support mature non-lactating cows, but lacks sufficient nutrients to support growing animals. Therefore, protein supplementation is required to optimize intake and BW gain in calves grazing corn residue. Protein sources containing both RUP and RDP are effective supplements in achieving acceptable over-winter gains.

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

**Objectives**

- Evaluate factors that influence a producer’s decision on when to calve beef females.
- Evaluate the effects of winter grazing and supplementation on cow performance.
- Compare fixed-time AI to a modified estrus detection protocol to evaluate the necessity of estrus detection.
- Evaluate the effects of implanting heifers with Revalor G at 12 mo of age on growth and reproductive performance.
- Evaluate the effects of different supplement sources on growth performance of steers grazing irrigated corn residue, and to evaluate the viability of supplementing corn grain.
LITERATURE CITED


CHAPTER II:

INVITED SYMPOSIUM PAPER: Choosing a calving date

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ABSTRACT

Calving date affects cost and timing of production events. Due to the polyestrous nature of beef females, producers can choose a calving date that fits their production system and geographic region. Any time an entire production system is considered, decision making becomes complex. Any calving system, regardless of date, should address the relationship between nutritional requirements of beef females and the quality and quantity of available feed. Nutritional status of beef females is influenced by stage of production, and the environment, including; length of growing season, forage species, day length, topography, forage quality and availability, ambient temperature, annual rainfall, and weather extremes. These differences cause grazing and feeding strategies to vary across regions. Ideally, high nutrient demand at parturition and peak lactation overlaps with optimal weather conditions and seasonal peaks in forage quality, and lowest nutrient demand overlaps with lowest quality forage, to minimize supplemental feed cost. Calving systems that do not match nutritional demand with forage quality must address potential nutrient deficits faced by breeding females, likely occurring in late gestation and early lactation. Alternative calving systems with higher feed costs need to
justify alternative dates through increased revenue generated from higher market value, increased calf performance, or improved reproductive performance. Heat stress, resulting from high temperature and humidity, can reduce calf performance and negatively impact reproductive performance in both the male and female. Hot and humid regions may favor a breeding season during seasonally lower temperatures to minimize poor reproductive performance. Additionally, regions prone to freezing temperatures, heavy snowstorms, or other severe weather events, must consider such risks when choosing a calving date. Many differences exist across regions in regard to environment, production systems, and marketing strategies that contribute to the complexity of choosing a calving date; therefore, beef producers must make site-based decisions according to conditions present on their operation.

**Keywords:** calving date, calving season, reproduction
INTRODUCTION

One of the most important decisions a cow-calf producer must make is choosing a calving date. This decision must take into account the entire beef production system, environmental conditions, available resources, and production, and lifestyle goals. Calving season influences when other production events occur, such as peak-lactation, re-breeding, weaning, and marketing, all of which affect an operations profitability and efficiency. Selecting a calving date results in long-term implications that do not allow for adjustments associated with yearly variations in weather, annual rainfall, and forage availability. Environmental conditions such as ambient temperature, annual rainfall, humidity, wind, elevation, and growing season are unpredictable, vary by location, and contribute to the complexity of choosing a calving date.

Calving date influences animal health, nutrition, range and resource management, labor management, lifestyle and workplace preferences, risk tolerance, marketing objectives, production costs, availability of supplemental feed, time bound grazing permits, market trends, and land use. Due to many differences within and among regions and production systems, a universal calving date that will meet the goals and objectives of every producer is not possible. Thus, advantages and disadvantages of different calving periods will be based on environmental, biological, and economic conditions. Additionally, each beef production system, regardless of region, may have site-specific advantages favoring a particular calving period.

Traditionally, calving has occurred early in the year, to ensure an older, heavier calf at fall weaning. Increased input costs in the commercial and feedlot setting, variable market prices, and environmental, and economic factors, have producers considering the
calving season and its impact on their beef production system. Many producers have adjusted calving dates to manage the physiological state of breeding females, range and forage resources, production costs, marketing strategies, and labor. In many environments, matching forage quality with cow requirements is a prudent approach to minimize production costs and increase profitability, but is not exclusively the most profitable option for every region or operation.

REVIEW AND DISCUSSION

Environmental Considerations

Matching cow nutrient requirements and peak forage quality

Nutritional requirements of beef females vary with physiological state (NRC, 2000), which is determined by calving and weaning dates (Grings et al., 2006). Periods of growth, gestation, and milk production each influence nutrient requirements for the growing and adult female. The relatively high nutritional requirements of cows in late gestation and early lactation can affect subsequent reproductive performance in limited nutritional environments (Houghton et al., 1990).

Beef females experience the greatest level of nutritional stress during lactation. Choosing a calving date that matches high forage quality with peak lactation has the potential to reduce costs (Adams et al., 1996; Stockton et al., 2007). The appropriate period to match calving with optimal range forage quality will vary by location based on environmental factors influencing forage quality. Managing the calving season to follow spring green-up provides opportunity for females to experience an increasing plane of nutrition that corresponds to the increases in nutritional requirements that occur from prior to calving throughout the post-partum period. In the Nebraska Sandhills, Adams et
al. (1996) analyzed early summer calving (May), matching peak nutrient requirements of cattle with abundant availability of low-cost high quality nutrients through grazed forage. Breeding females experienced an excess in available nutrients just prior to calving season, parturition, and the onset of lactation. During this time of high nutritional demand, requirements were met entirely through grazed forages at or near the time when CP and TDN of range forages were at seasonal highs. Consequently, cows grazed dormant pasture longer as decreases in nutrient requirements decreased concomitant with decreasing forage quality.

Post-weaning, and pre- and postpartum management can influence the response to improving range quality occurring during the spring green up due to the positive relationship between body condition and maintenance energy requirement. Cows managed at greater BCS will have greater maintenance energy requirements than cows at lower BCS (NRC, 2000). Small improvements in range quality associated with onset of green up may be sufficient to meet or exceed maintenance energy requirements of lower BCS animals, but insufficient for animals with greater body mass and maintenance energy requirements. A 3-yr study in the Nebraska Sandhills evaluated reproductive performance of cows grazing dormant range that were either supplemented or not supplemented during the prepartum period (December 1 to February 28) with 0.45 kg of supplement/cow per d (42% CP). During the calving season (March 1 to April 20), cows were managed in a common group and offered grass hay in a drylot setting at an average of 14 kg/cow per d (DM basis). During the post-partum period between calving and breeding (May 1 to May 31), half of the cows were assigned to graze sub-irrigated meadow while the other half were offered grass hay in a drylot. During the breeding
season (beginning June 1), treatment groups were combined and managed as one group grazing upland range in common pastures. Cows fed supplemental protein during the prepartum period maintained BW while unsupplemented cows experienced a 29 kg loss in BW. Cows supplemented during the prepartum period maintained a BCS of 5.1 from pre-calving through pre-breeding, whereas cows that had not received supplement exhibited an improvement in BCS from 4.7 to 4.9 from pre-calving through pre-breeding. Postpartum interval, percentage of cows conceiving within the first 21 d of breeding season, final pregnancy rate, and calf birth weight were not affected by pre-partum treatment. Cows maintained on dormant native range without supplement had a lower pre-calving BCS (4.7 vs. 5.1) and a slightly lower pre-breeding BCS (4.9 vs. 5.1) than supplemented cows, but experienced the same reproductive performance as supplemented cows, as well as experiencing a greater BCS improvement from pre-calving through pre-breeding. This study suggests a BCS as low as 4.7 is adequate for reproductive success. However, feeding supplement pre-partum increased the percentage of live calves at weaning (98.5 vs. 93.6%), and resulted in greater weaning weights (218 vs. 211 kg). Pre-partum treatment did not affect feedlot DMI, ADG, or carcass weight of offspring (Stalker et al., 2006).

Management of cows during calving and day of calving within the calving season can also impact efforts to match animal requirements to range quality. In production systems where cows are maintained on full feed in confined calving lots or pastures, nutritional quality provided through feeding may exceed that available in pasture forages. If cows are removed from confinement after calving and placed on pastures where they rely on grazed forage, a delay in timing or rate of quality improvement associated with
variation in time of green up may result in greater synchrony of nutrient demands with nutritional availability for late calving cows than earlier calving cows. Late calving cows will have a nutritional advantage because ME requirements for late gestation are less than ME requirements for early lactation and calving later allows for more days for developing higher quality range forage. This management scenario may put early calving cows at a nutritional disadvantage to later calving cows. This situation may benefit by shifting the calving season a few weeks later in the year.

Differences in range quality associated with different calving periods can also have large effects on calf performance. Late winter calving systems allow rumen development to take place in the calf within a timeframe that allows them to utilize forage when quality is high. In contrast, calves born to a late spring calving system may not reach full rumen function until forage quality has begun to decrease. Consequently, calves born to late spring calving systems will commonly be lighter at the time of weaning than early season calves of the same age (Adams et al. 1996; Grings et al., 2005). This slower rate of gain is also a function of decreased milk yield in the cow, in response to lower forage quality during lactation. Data from Grings and Phillips (2006; Table 1) demonstrate calves born in late spring gained at similar rates to other calving seasons until after 140 days of age at which time ADG decreased compared to calves born earlier. The lower ADG was associated with decreases in forage quality and colder temperatures (October – December) may have also contributed to increased calf maintenance requirements during this period.

Systems designed to rely heavily on grazed forage with minimal purchased feed inputs may result in fewer animals maintained in the herd compared with systems where
cows are provided supplemental feed as a large portion of their requirements. Kruse et al. (2008) reported for an eastern Montana operation, herd size should be 11% smaller for a late spring than early spring system using the same forage base and weaning calves at similar age but with greater amounts of harvested feed input provided to the early spring system. In a simulation of calving seasons in the Northern Great Plains conducted by Reisenauer Leesburg et al. (2007), herd size was 2% greater in the summer calving vs spring calving herd because summer calving cows were fed greater amounts of harvested feed in winter to maintain body condition, rather than allowing body condition to drop slightly during winter. A key consideration from these studies is that optimal herd size will be influenced by the level of supplemental feeding incorporated into the management strategy, further complicating economical comparison of different calving date scenarios.

**Heifer Development**

Calving period also influences management strategies for post-weaning development of replacement heifers. Key development periods in the replacement female are affected by calving season, and influence the nutritional status of growing females and costs associated with development. Heifer development costs are significant, the majority being feed cost, leading producers to seek cost-effective strategies to manage replacement females. Additionally, calving date influences when cull animals are marketed, and will be affected by seasonal changes in market price. The beef producer must consider how a calving season interacts with the heifer development strategy from a nutritional, physiological, and economic standpoint.

An ongoing University of Nebraska study is comparing 2 calving periods (March vs. May), and 2 heifer development systems (hay vs. meadow) and their subsequent
effects on growth and reproductive performance. Heifers from both calving periods (March and May) are either provided hay ad libitum with 1.81 kg/d supplement (29% CP) or allowed to graze stockpiled forage (meadow) with 0.45 kg/d supplement during the winter development period from mid-January to mid-April. Prior to and following treatment, heifers are managed as a single herd until the respective breeding seasons. Heifers that graze stockpiled forage for both March and May calving periods have a lower ADG than those fed hay during the winter development period. But due to compensatory gain, BW has not been different in June, July, or at pregnancy diagnosis. There has also been no difference observed in pubertal status or conception rate among groups (hay vs. meadow) within calving period. However, there has been a difference ($P < 0.01$) in pregnancy rates between heifers in March and May calving systems, with 87 and 63% pregnancy rates, respectively. These decreased pregnancy rates in the May calving heifers are attributed to decreasing forage quality and availability on Sandhills range during the breeding season (July and August) for a May-calving herd. Table 2 (Nielson, 2015) illustrates the decrease in range quality from June to September. Currently, breeding season supplementation strategies for the May-calving herd are being investigated to determine effect on pregnancy rates. The later breeding season would also be coupled with greater ambient temperature and some speculate could also be a contributing factor to lower pregnancy rates, however, Griffin et al. (2012a) found no difference in pregnancy rates in three different calving periods with mature cows on the same ranch. Unless younger and older beef females are differentially affected by ambient temperature to suppress pregnancy rates, it seems more likely this is a function of declining nutritional quality whereby the younger females cannot physically eat enough.
of this lower quality forage to meet requirements. This work suggests low input heifer
development systems can reduce input costs for both March and May calving systems
however, pregnancy rates are lower in the later calving system, which is important to
recognize when determining replacement rates (Table 3; Nielson, 2015).

*Lactation and Calf Weaning*

Lactation affects both feed intake and nutrient requirements and may also
influence reproduction via a short-term effect where neuronal stimuli from suckling may
lengthen post-partum interval and delay or reduce pregnancy early in the breeding period,
and through a long-term inhibitory effect due to negative nutritional status when feed
resources are insufficient to meet nutrient demands. Operations with available high
quality feed resources and minimal environmental stress can sustain larger cow size, and
greater levels of milk production for increased economic returns. But under conditions of
low feed availability, and greater environmental stress, cow size and milk production
should be limited (Table 4; BIF, 2010). This consequence is often most noticeable in
young females that conceived as yearlings, but did not regain sufficient body condition
after first calving to become pregnant the following year (Whittier, 1995). Meeting the
nutrient demands of lactation is critical for the subsequent reproductive success of beef
females. Producers should consider cow size and milk production potential when
selecting bulls and replacements to fit their environment. Figure 1 illustrates how
reproductive risk, management intensity, and cost increase due to large mature cow size,
increased milk production potential, and challenging range environments as a result of
low annual rainfall. The amount of range forage availability is predominantly influenced
by annual rainfall. In areas of low precipitation, where limited range forage availability
exists, and winter feed may be limited and costly, mature cow size and milk production potential should be limited to match breeding females biological type with their production environment. (Figure 1; BIF, 2010).

Grings et al. (2008) demonstrated the timing of peak milk production can be influenced by quality and quantity of available grazed forage. Peak milk production in cows calving in late winter (Feb 1) occurred later (88 d post calving) than cows calving in early spring (April 1; 61 d post calving) and late spring (June 1; 51 d post calving). Cows calving in late winter were provided greater quantities of supplemental feed than cows calving in early spring which were provided access to only native range during lactation. Total estimated milk yield for late spring calving cows varied in response to yearly variation in forage quality, but milk yield in earlier calving seasons were not affected by variations in forage quality between years, likely due to the provision of supplemental feed. These results provide an example of how environmental conditions and quality and quantity of forage affect timing of peak and total milk production.

When calves are weaned and lactation ends, the nutrient requirements of dams decrease substantially. Weaning dates may be used as a strategy to manage nutrient requirements, and influence body condition. Weaning dates may be varied to shorten or prolong the lactation period based on current market prices, market outlook, environmental conditions, and available resources.

**Weather and the Environment**

In regions where drought occurs regularly, range condition is contingent upon amount of springtime rainfall (Kruse et al., 2007; Smart et al., 2007). April and May precipitation patterns and rainfall amounts in the Great Plains can be used as an indicator
of subsequent range condition. Production decisions such as stocking capacity and
grazing strategy are influenced by the expected range condition. In a drought situation,
producers managing late spring (April to June) calving seasons have less time and
flexibility in regard to managing drought. Because calving commences during May and
June when many drought management decisions are made, having very young calves and
late term cows at this time may limit a producer’s drought flexibility. Thus, calving
season can influence drought management strategies such as modified stocking rate,
early-weaning, and culling.

Important production events such as calving, nurturing young calves, and
breeding can be significantly influenced by extreme weather. In regions where winter
blizzards, freezing rain, or flooding occur regularly, producers may choose calving
seasons to avoid such risks in order to protect against potential losses. In the Northern
Great Plains, Kruse et al. (2008) reported a 4% increase in calf morbidity and 2%
increase in calf mortality for a late winter (January) compared with early (March) or late
spring (May) calving seasons, demonstrating the risk associated with calving in the
coldest part of the year.

Heat Stress

Heat stress results from a combination of high temperature and humidity
causing an extreme heat index. These conditions can negatively impact both male and
female reproductive performance. Much research has been conducted in the dairy and
beef industries to determine the effects of heat stress on reproductive performance.
Responses in beef cattle may differ slightly due to environmental, dietary, and genetic
differences in the dairy industry, but similar physiologic responses and negative impacts
on reproduction are experienced by beef females. Endocrine changes observed during times of heat stress reduce the degree of dominance of the selected follicle. Reduced follicular activity alters the ovulatory mechanism resulting in reduced oocyte quality at the onset of estrus (Dunlap and Vincent, 1971). The uterine environment is compromised during heat stress as blood flow to the uterus is reduced and uterine temperatures increase. These changes inhibit embryonic development and increase embryonic loss (Gwazdauskas et al., 1975; Roman-Ponce et al., 1978). Increased incidence of anovulatory estrus and shortened estrus was observed in heat stressed females (Younas et al., 1993), as well as longer post-partum interval and an increased number of services required for conception (Ray et al., 1992). The reproductive performance of herd bulls may also be compromised by extreme heat as spermatogenesis is sensitive to heat and exposure to a hot, humid environment may compromise the development of spermatozoa (Skinner and Louw, 1966).

Producers should make efforts to avoid the negative impacts that heat stress can have on reproductive performance, and ultimately, ranch profitability. Wright et al. (2014) evaluated the effect of ambient temperature on gestation length of Angus cows calving in either August or October while grazing native prairie in Oklahoma. August-calving cows tended to have a shorter gestation length compared with October-calving females. This difference was proposed to be in response to greater cortisol concentrations in August-calving cows during the last 4 d of gestation.

*Bos indicus* influenced genetics has introduced a more heat tolerant animal suited to perform in the hot, humid environment of the southeastern United States. Additionally, some beef producers in the Southeast choose a calving and breeding season when
ambient temperatures are lower and extreme weather is less likely to disrupt breeding or create environmental stress during calving. Precipitation patterns may also need to be considered in the selection of optimal calving season. High annual rainfall and poorly drained pastures can cause standing water, which may result in decreased performance of the growing animal as well as contribute to an increased parasite load.

Federal Grazing Allotments

Many cattle producers in western states utilize federal grazing allotments. Some of these are shared allotments where multiple producers may graze together for 4 to 6 months out of the year. Producers may choose to breed cows earlier in the year before cows are moved to the shared grazing allotments, resulting in an early calving season and older and more developed calves at the time of spring turn-out. Additionally, cattle are regularly trailed to allotment locations and it may be challenging for very young calves to travel long distances. An older calf is preferred in these conditions because many of these allotments are located in remote mountainous terrain where predation is a concern. Due to environmental factors and herd management, calving date selection may be limited in these production systems.

Economic Considerations

Marketing

Cattle markets typically have seasonal variation within a given year, creating opportunities to match a production system with seasonally higher market prices (Griffin et al., 2012b). Many factors influence feeder calf prices, but supply and demand account for much of the variation between seasonal calf prices. Most spring calving production systems have historically marketed cattle in November, resulting in a high calf supply.
An increased supply at this time results in a lower price when compared with calf prices in winter or spring. The market trend for low calf prices in the fall provides impetus for producers to consider alternative calving dates. By altering the calving date, production and marketing timing also shift to a different time of the year, which may be economically advantageous (Stockton et al., 2007). Calves sold at an alternative time to November generally receive a higher price due to decreased supply at weaning and marketing. A higher price received must offset the potential added cost of harvested feeds needed to support an alternative calving system.

Management strategies should be aimed at maintaining production levels while finding ways to minimize production costs and or maximize production revenue. Value of any productivity increase must exceed any cost increase incurred by achieving greater productivity (Sprott et al., 2001).

Reports from Adams et al. (2001b) in the central Great Plains, and Grings et al. (2005) in the Northern Great Plains, demonstrated late spring (May to June) calving reduces feed inputs, and minimizes production costs compared with winter or early spring calving. In Nebraska, late spring (May to June) calving was most profitable; whereas Reisenauer Leesburg et al., (2007) projected, March calving to be most profitable. Optimal calving date will vary across and among different regions and production systems, therefore, it’s important for beef producers to consider their operation and how it may be influenced by environment, region, and marketing conditions, before making a calving date decision.

A study evaluated late winter (February), early spring (April), and late spring (June) calving periods on Northern Great Plains rangeland to determine how calving
system and weaning age may influence cow and calf performance (Grings and Phillips, 2006; Table 1). Weaning dates were 190 and 240 days for the February and April-calving groups, and 140 and 190 days for the June-calving group. From birth to weaning, rate of gain was greater for earlier compared to later weaned calves for all calving systems. June-born calves weaned at 190 days tended to weigh less than calves of the same age from the February or April-calving groups. This difference is likely due to decreasing forage quality later in the lactation period and greater amount of environmental stress (cold temperatures) later in the year. Gross margin per cow was similar for systems with calves born in June and weaned at 190 d-of-age and those born in late winter and weaned at the same age, but were greater than an early spring calving season with calves weaned at 190 d of age. Differences were related primarily to decreased feed costs for the June calving herd. Pregnancy rate (86% for a 32-d breeding season) was not different among calving treatments. (Grings et al. 2005).

In an effort to reduce the need for harvested feed, Adams and coworkers (2001a) targeted a late spring (May to June) calving period compared with March calving. This adjustment extended the grazing period by allowing cattle to graze dormant winter forage longer with decreased amounts of supplemental hay. Calving in late spring reduced harvested forage by 1.5 tons/yr compared with March calving. Calf weaning BW at a similar age were 32 kg less for June-born calves compared with March-born calves, but the savings in hay cost for the late spring calving system more than compensated for the decrease in weaned BW. Clark et al. (1997) analyzed March vs. June calving in the Nebraska Sandhills. When comparing production costs for calves born in each calving system, March born steers averaged $31.76/cwt, while June born steers averaged
$24.11/cwt. The largest factor contributing to the difference in cost between calving systems was harvested feed. Feed cost for a March-calving cow was $125.65 vs. $4.40 for a June calving cow. Purchased feed (supplement), salt, and mineral was $15.78/cow for the March calving system, and $21.23/cow for the June calving system. Kruse et al. (2008) also found feed cost per cow to be approximately 45% less for a late spring (May to June) compared with either a late winter (January to February) or early spring (March to April) calving system in eastern Montana when averaged over 3 yr, but yr-to-yr variability was large due to winter weather conditions.

Adams et al. (2001a) also observed June-born calves weaned in December weighed less than March-born calves weaned at the same age, but received a higher price/cwt because of marketing at a time of decreased supply. June-born calves from either a range or meadow grazing treatment sold in January after weaning returned $65 to $75 more per calf than March-born calves sold in October after weaning. This difference in return was due mainly to lower production cost for a June-born calf and greater price received for June-born calves. These calves were marketed in January and received $10/cwt more than March-born calves (Adams et al., 2001b). Contrasting results come from a report using 2 bio-economic computer models to compare calving dates of March 15, May 15, and August 15 and various weaning strategies (Reisenauer Leesburg et al., 2007). Researchers concluded spring calving is expected to be more profitable than summer or early fall calving scenarios in the northern Great Plains. Both studies show how calving date is confounded by region and decisions should be based on site-specific conditions (Table 4; BIF, 2010).
A 4-yr study conducted in the Nebraska Sandhills compared net returns for 5 cow-calf production systems: 1) March calving cows wintered on native range, 2) March calving cows wintered on corn residue, 3) June calving cows wintered on native range, 4) June calving cows wintered on corn residue, and 5) August calving cows wintered on corn residue. Multiple post-weaning strategies were compared in the study. March-born steers entered feedlot at weaning (November, calf-fed). Steers and heifers born in June and August were divided into 2 post-weaning management strategies: half entered the feedlot after weaning (May, calf-fed) and the other half grazed sub-irrigated meadow and entered the feedlot as yearlings (September/October). Net returns were greatest for June calving cows and least for March calving cows (Griffin et al., 2012a). Net returns were further increased by retaining ownership of calf-fed steers through slaughter compared with selling at weaning (Griffin et al., 2012b). These data demonstrated potential impacts of calving period and timing of marketing on production system profitability.

**Labor Management**

Labor costs contribute significantly to the beef production system and may influence the decision on when to calve. Finding and retaining skilled labor and managing labor efficiently can be challenging for many beef producers. Some producers may choose to avoid labor intensive calving systems to keep from hiring additional personnel or to more efficiently manage labor needs of the operation. Others may be more willing to explore less traditional calving dates because a particular calving period fits into their other production enterprises. In some regions it may be reasonable to split the cowherd and manage 2 calving seasons, decreasing the number of bulls needed and spreading labor intensive periods such as calving over 2 different times of yr. In
consideration of a combination farming and beef production enterprise, calving may be
timed to alternate with labor intensive farming operations such as planting and harvest.
Producers may decide to calve when farm labor is more readily available. Producers must
also consider how calving date will influence other aspects of the production system such
as branding, weaning, and the heifer enterprise which may all require additional labor.

CONCLUSION

Timing calving during periods of seasonally high forage quality can reduce the
amount of harvested forage and supplements, reducing annual feed costs. Additionally,
calving during periods of decreased environmental stress has the potential to decrease
labor costs and increase calf survival. Annual rainfall, forage species, weather extremes,
and other environmental factors vary by location and across regions, precluding a
universal recommendation of particular calving and breeding dates. Careful consideration
should be given to the entire beef production system, including cow nutrition, heifer
development, production costs, the physical and economic environment, and the
operations marketing objectives when selecting or changing a calving date. Selecting a
calving date that fits a given production system is an extensive and challenging task
because it will affect nearly all factors of the cow-calf production system. Understanding
how calving date affects the physiological state of breeding females and interacts with the
environment and marketing conditions to affect overall ranch profitability will help
determine an optimum calving period. Calving date decisions should be based on
allocating ranch resources to insure sustained profit and/or meet overall ranch objectives.
This decision will vary across and among different production regions (Table 5; adapted
from Grings and Rusche, 2015).
LITERATURE CITED


Table 1: Least squares mean of weight, performance, pre-weaning ADG, and weaning weight of steers born in late winter (LW), early spring (ES) or late spring (LS) calving systems in Montana and weaned at one of two ages (adapted from Grings and Phillips, 2006).

<table>
<thead>
<tr>
<th>Item</th>
<th>Calving System</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LW</td>
<td>ES</td>
<td>LS</td>
<td></td>
<td>S.E.</td>
</tr>
<tr>
<td>Birth weight, kg(^a)</td>
<td>37</td>
<td>37</td>
<td>40</td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>ADG from birth to 69 d, kg/d(^b)</td>
<td>0.85</td>
<td>0.99</td>
<td>0.97</td>
<td>(2.2)</td>
<td></td>
</tr>
<tr>
<td>ADG from 69 d to first weaning, kg/d</td>
<td>1.06</td>
<td>0.92</td>
<td>1.01</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td>Age at weaning, d</td>
<td>190 240</td>
<td>190 240</td>
<td>140 190</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADG from birth to weaning, kg/d</td>
<td>1.00 0.9 3</td>
<td>0.95 0.86 0.8</td>
<td>1.01 0.8 0.8 0.6</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>Weaning weight, kg(^c)</td>
<td>227 271</td>
<td>217 255</td>
<td>180 205</td>
<td>12.4</td>
<td></td>
</tr>
<tr>
<td>ADG from first to second weaning, kg/d(^d)</td>
<td>0.87 0.7 0.64 0.50</td>
<td>0.53 0.5 0.53 0.5</td>
<td>0.11</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) LS differs from the average of the LW and ES calving systems, *P* = 0.03  
\(^b\) LW differs from ES calving system, *P* = 0.02  
\(^c\) LS differs from the average of LW and ES for 190-d weaning age, *P* = 0.08; 190- differs from 240-d weaning age for LW and ES, *P* = 0.01; 140- differs from 190-d weaning age for LS, *P* = 0.04  
\(^d\) Several treatments were assigned to the steers weaned early but treatments were consistent across calving systems.
Table 2: Nutrient composition of range and hay in each development year.\(^1\)

<table>
<thead>
<tr>
<th>Development period diet</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter Range CP, (^2) % DM</td>
<td>5.6</td>
<td>5.4</td>
<td>7.8</td>
</tr>
<tr>
<td>Winter Range TDN, (^2) % DM</td>
<td>51.7</td>
<td>52.5</td>
<td>54.4</td>
</tr>
<tr>
<td>Winter Meadow CP, (^2) % DM</td>
<td>7.7</td>
<td>10.7</td>
<td>9.9</td>
</tr>
<tr>
<td>Winter Meadow TDN, (^2) % DM</td>
<td>55.8</td>
<td>60.7</td>
<td>61.2</td>
</tr>
<tr>
<td>Hay CP, (^3) % DM</td>
<td>7.3</td>
<td>7.3</td>
<td>6.8</td>
</tr>
<tr>
<td>Hay TDN, (^3) % DM</td>
<td>54.4</td>
<td>55.9</td>
<td>48.2</td>
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</tbody>
</table>

**March-calving breeding season diet**

<table>
<thead>
<tr>
<th></th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>June Range CP, % DM</td>
<td>14.0</td>
<td>10.1</td>
<td>19.3</td>
</tr>
<tr>
<td>June Range TDN, % DM</td>
<td>64.3</td>
<td>61.5</td>
<td>79.7</td>
</tr>
</tbody>
</table>

**May-calving breeding season diet**

<table>
<thead>
<tr>
<th></th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>July Range CP, % DM</td>
<td>11.1</td>
<td>10.6</td>
<td>14.7</td>
</tr>
<tr>
<td>July Range TDN, % DM</td>
<td>61.2</td>
<td>59.6</td>
<td>71.0</td>
</tr>
<tr>
<td>Sept. Range CP, % DM</td>
<td>6.9</td>
<td>8.2</td>
<td>9.8</td>
</tr>
<tr>
<td>Sept. Range TDN, % DM</td>
<td>61.4</td>
<td>58.5</td>
<td>65.0</td>
</tr>
</tbody>
</table>

\(^1\) Collected from esophageally fistulated cattle.
\(^2\) Values for the developmental period are obtained from the previous December.
\(^3\) Hay used during the development yr was harvested the previous summer.
Table 3. Cost analysis of heifer development over-winter nutritional treatments.

<table>
<thead>
<tr>
<th>Item</th>
<th>HAY¹</th>
<th>MDW²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hay, $/hd/d</td>
<td>0.66</td>
<td>-</td>
</tr>
<tr>
<td>Meadow pasture, $/hd/d</td>
<td>-</td>
<td>0.50</td>
</tr>
<tr>
<td>Supplement (1.8kg/d), $/hd/d</td>
<td>0.77</td>
<td>0.19</td>
</tr>
<tr>
<td>Yardage, $/hd/d</td>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td>Total, $/hd/d</td>
<td>1.63</td>
<td>0.89</td>
</tr>
<tr>
<td>Treatment total, $/hd</td>
<td>146.70</td>
<td>80.10</td>
</tr>
</tbody>
</table>

¹ HAY = heifers received *ad libitum* hay and 1.81 kg/d supplement from Jan. 15 to April 15.
² MDW = heifers grazed meadow and received 0.45 kg/d supplement from Jan. 15 to April 15.
³ Hay cost assumed as $120/ton (5 kg/d).
⁴ Supplement containing 29% CP, DM priced at $385/ton, comprised of processed grain by-products, plant protein products, roughage products, calcium carbonate, molasses products, urea, vitamin A supplement, copper sulfate, zinc oxide, magnesium sulfate, and monensin.
⁵ Treatment total for 90 d treatment period.
**Table 4**: Matching genetic potential for different traits to production environments (adapted from BIF, 2010).

<table>
<thead>
<tr>
<th>Production Environment</th>
<th>Traits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Feed Availability¹</td>
</tr>
<tr>
<td>High</td>
<td>Low High</td>
</tr>
<tr>
<td></td>
<td>Low High</td>
</tr>
<tr>
<td>Medium</td>
<td>Low High</td>
</tr>
<tr>
<td></td>
<td>Low High</td>
</tr>
</tbody>
</table>

¹ L = Low; M = Medium; H = High.
² Heat, cold, parasites, disease, mud, altitude, etc.
³ Ability to store fat and regulate energy requirements with changing (seasonal) availability of feed.
⁴ Physiological tolerance to heat, cold, internal and external parasites, disease, mud, and other factors.
Table 5: Production implications for varying calving seasons (adapted from Grings and Rusche, 2015).

<table>
<thead>
<tr>
<th>Risk</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvested Feed</td>
<td>High</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Bad Weather</td>
<td>High</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Weaning Weight</td>
<td>High</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Labor Conflicts</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
</tr>
</tbody>
</table>
Figure 1: Matching cow biological type (weight and milk, 1 lb ≈ 0.454 kg) to range environment, with associated risk, management, and cost. Ranges in inches (12"-15", 1 in = 2.54 cm) are annual precipitation and/or represent availability of winter feed resource (adapted from Crossbreeding for Western Range Environments, 1999).
CHAPTER III:

Effects of winter supplementation on performance of May calving cows in the Nebraska Sandhills

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University of Nebraska, West Central Research and Extension Center, North Platte, 69101

ABSTRACT

A trial, conducted over 5 production cycles (2011 to 2015), evaluated the effects of winter supplementation on cow and calf performance. Pregnant, May-calving, crossbred cows (n = 255, BW = 464 ± 35 kg) grazed dormant upland range or meadow from December 1 to March 29 and received 0 or 0.45 kg/d (DM) of 32% CP supplement in a 2 × 2 factorial arrangement. Calves were weaned during the first wk of January each yr. Supplemented cows had increased (P < 0.01) BCS and BW change over winter trt compared with unsupplemented cows. Pregnancy rate was lower (P = 0.05) for cows that grazed dormant upland range without supplement (77 ± 4%) vs. cows that grazed meadow without supplement (92 ± 4%). However, neither of the previous treatments differed from cows grazing dormant meadow receiving supplement (86 ± 4%) or cows grazing dormant range receiving supplement (85 ± 4%). Calf birth BW was lower (P = 0.03) and weaning BW tended (P = 0.06) to be lower for calves born to unsupplemented cows grazing dormant range.

Key words: beef cattle, calving season, supplementation
INTRODUCTION

As part of a 5 yr beef systems study of May-calving cows in the Nebraska Sandhills, Harms et al., (2014) reported preliminary results from 3 yr of data on the effects of winter supplementation on cow performance and post-weaning management on steer and heifer progeny. The present study completes the cow herd analysis with 5 yr of production data focused on the impact of winter supplementation and grazing system on subsequent cow and calf performance.

The greatest variable cost associated with cow-calf production is feed (May et al., 1999). The amount of harvested and purchased feed required to sustain a cow herd in the Nebraska Sandhills can be reduced by calving late in the spring, better matching the cow’s nutrient requirement with grazed forage quality (Adams et al., 1996; Clark et al., 2004). Altering the calving date shifts production and market windows, which may be economically advantageous (Stockton et al., 2007). Moving the calving date may also provide flexibility to sell calves at different ages and BW (Griffin et al., 2012). Although calving in May matches nutrient requirements with peaks in forage quality, the nutritional requirements of a May-calving beef cow grazing dormant Sandhills range typically exceed the nutrient content of the grazed forage during mid to late gestation (NRC, 2000). Therefore protein is commonly supplemented to maintain cow BCS during winter grazing, which is generally more economical compared to feeding hay. Supplementing protein during this period also increases weaning BW and the proportion of live calves at weaning (Stalker et al., 2006). The Nebraska Sandhills have two distinct forage resources; native upland range and subirrigated meadow, which vary by grass species and plant growth characteristics. Meadows are dominated by cool season grasses; therefore,
forage value increases earlier than upland range and nutritive value exceeds range in both the dormant and growing season, due to greater crude protein content of active growth and stockpiled meadow forage (Lardy et al., 1997). The objective of the current study was to evaluate the effects of winter supplementation while grazing dormant Sandhills winter range or meadow on cow performance.

**MATERIALS AND METHODS**

All procedures and facilities utilized were approved by the University of Nebraska-Lincoln Institutional Animal Care and Use Committee.

**Cow Management**

A 5-yr study was conducted utilizing composite Red Angus × Simmental May-calving cows and their progeny at the Gudmundsen Sandhills Laboratory (GSL), Whitman, NE. Cows grazed either dormant upland winter range (RN) or meadow (MDW) from December 1 to March 29 and received 0 or 0.45 kg DM animal⁻¹·d⁻¹ of a 32% CP supplement (Table 1, RN + S and MDW + S). Supplement was delivered 3 times/wk on a pasture (35.6 ha) basis. Thus, creating four treatment groups replicated by yr. Cows were managed as a common group and grazed native upland pastures the remainder of the year. Cows were placed with bulls (1:20 bull to cow ratio) approximately August 1 for a 45 d breeding season. Five d after the bulls were introduced, cows were estrus synchronized with a single injection of PGF₂α (Lutalyse, Pfizer Animal Health, New York, NY). Pregnancy was determined via rectal palpation or ultrasonography at weaning in early January. Cows were removed from the study for reproductive failure, calf death, or injury.

**Replacement Heifer Management**
After January weaning, heifers grazed either meadow (MDW) with 0.45 kg/d of supplement or offered ad libitum grass hay (HAY) with 1.8 kg/d of supplement until May 15. Heifers and steers ran together during the winter supplementation period having two groups in each overwinter treatment per yr. The final year of progeny data is currently being collected for steer and heifer progeny. In the present study heifer and steer progeny performance will be presented only to weaning.

During the summer grazing period, heifers were managed as a single group and grazed native upland range during the breeding season. Heifers were estrus synchronized with a single injection of PGF$_{2\alpha}$ (Lutalyse, Pfizer Animal Health, New York, NY) 5 d after being placed with bulls (1:20 bull to heifer ratio) on approximately July 25 for a 45 d breeding season. Pregnancy was determined via transrectal ultrasonography in late October. All pregnant heifers were kept as potential replacement females to be incorporated in the study.

**Economic Analysis**

Cow winter treatments were applied on a pasture or group basis. Pasture (n = 4/yr) served as experimental unit for cow performance and reproductive data. Data were analyzed with the GLIMMIX procedure of SAS (SAS Inst., Inc., Cary, NC). Model fixed effects for cow data included winter treatment and age. Year was considered a random effect for cow and calf variables.

**RESULTS AND DISCUSSION**

Cow performance is presented in Table 2. Cows that grazed meadow or received supplement over winter had greater ($P < 0.02$) BW gain compared with cows grazing range without supplement. Following the treatment period, cow BW was 471, 480, 436,
and 463 ± 17 kg for MDW, MDW + S, RN, and RN + S, respectively. Both pasture and supplement affected winter BW gain ($P < 0.05$), and supplement had an effect ($P < 0.05$) on BCS change over winter. Additionally, unsupplemented cows in both MDW and RN treatments lost more body condition (-0.1 and –0.2 ± 0.1, respectively) during the treatment period ($P < 0.05$). Pasture treatment did not affect cow BW at prebreeding or weaning ($P > 0.10$).

Pasture trt had an effect ($P < 0.05$) on winter BW gain, pre-calving BW, lactation BW gain, pregnancy rate, as well as progeny birth and weaning BW. These data support finding from Lardy et al. (1997) suggesting nutritive value of dormant meadow exceeds dormant upland range. A pasture × supplement interaction was observed ($P = 0.05$) for conception rate. However, providing supplement to cows grazing meadow did not result in an increase in pregnancy rate (92 vs. 86 ± 4%, MDW and MDW + S, respectively); which suggests the nutritive value of meadow may support reproductive performance in May calving cows without supplemental protein. Pregnancy rate was lower for RN treatment than MDW (77 vs. 92 ± 4%, respectively, $P = 0.05$). However, neither RN nor MDW differed from observed conception rates in MDW + S (86 ± 4%, $P > 0.1$) or RN + S (85 ± 4%, $P > 0.1$). Calving difficulty and calf vigor were also not affected ($P > 0.15$) by winter treatment.

Pregnancy rate by age group is presented in Figure 1. Harms et al. (2014), reported a 21% numerical difference in pregnancy rates between 3-yo-old cows vs. mature cows, despite a lack of significance (67 vs. 88 ± 4%, respectively, $P = 0.24$). Since that initial analysis, 3-yr old cow data can be presented from females developed internally. Females developed within the May calving system have shown a numerically
increased conception rate (86 vs. 88 ± 4%, in 3-yr-old vs. mature cows, respectively). Additionally, yearling heifer and 2-yr-old conception rate was (70 vs. 79 ± 4%, respectively). At trial initiation, 3-yr-old cows originated from a March calving herd, therefore, it is possible that since then, herd adaptability has improved due to within system selection pressure as yearlings and second calving cows.

Second calving cows are generally at greater reproductive risk than older cows due to increased nutrient requirements for growth, lactation, and reproduction (Whittier, 1995). In May-calving systems the breeding season occurs in late summer, coinciding with declining forage nutrient quality, which may have a greater impact on pregnancy rates in younger growing cows (Rensiss and Scarmuzzi, 2003).

Energy requirements increase 1.3 to 1.5 times maintenance in late gestation and protein requirements increase as gestation progresses. Therefore, cattle diets should contain sufficient protein and energy to support fetal growth, plus maintenance (Quigley and Drewry, 1998). An over-winter (late gestation) nutrient deficit observed in RN cows, supported by significant decreases in BW and BCS, suggests a fetal programming effect on progeny performance. A pasture × supplement interaction tended ($P = 0.07$) to effect calf birth BW. Calves born to RN cows were lighter ($P < 0.05$) at birth (34 vs. 36 ± 1kg) and tended ($P = 0.06$) to be lighter at weaning (189 vs. 198 ± 4 kg) than contemporaries. Cows grazing dormant range may need supplemental protein during mid-to-late gestation for proper fetal development, as the majority of fetal growth occurs during this period. Supplementing beef cows during late gestation can affect the lifelong productivity of the calf. Larson et al. (2009) concluded conceptus growth is sensitive to direct and indirect
effects of maternal dietary intake, observing that dam nutrition affected calf post-weaning growth, carcass composition, and calf health in the feedlot.

IMPLICATIONS

Grazing stockpiled forage on meadow over winter provides sufficient nutrients to maintain BCS without the need for supplementation. Additionally, reproductive performance data suggest meadow provided sufficient nutrients to support reproduction. Grazing dormant upland pastures during winter will require protein supplementation to avoid declines in cow BCS and BW, calf birth and weaning BW, and dam conception rate. Additionally, 3-yr old cows may require supplemental protein prior to and during breeding to compensate for a nutrient deficit caused by decreasing forage quality later in the growing season.
LITERATURE CITED


<table>
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<tr>
<th>Item</th>
<th>DM, %</th>
</tr>
</thead>
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<tr>
<td>Dried distillers grains with solubles</td>
<td>62.0</td>
</tr>
<tr>
<td>Wheat middlings</td>
<td>11.0</td>
</tr>
<tr>
<td>Cottonseed meal</td>
<td>9.0</td>
</tr>
<tr>
<td>Dried corn gluten feed</td>
<td>5.0</td>
</tr>
<tr>
<td>Molasses</td>
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</tr>
<tr>
<td>Calcium carbonate</td>
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</tr>
<tr>
<td>Trace minerals and vitamins¹</td>
<td>3.0</td>
</tr>
<tr>
<td>Urea</td>
<td>2.0</td>
</tr>
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<table>
<thead>
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</thead>
<tbody>
<tr>
<td>CP</td>
<td>31.6</td>
</tr>
<tr>
<td>Undegradable intake protein, % CP</td>
<td>47.6</td>
</tr>
<tr>
<td>TDN</td>
<td>89.4</td>
</tr>
</tbody>
</table>

¹Formulated to include 80 mg·0.45 kg monensin.
Table 2. Effects of winter grazing treatment\textsuperscript{1} on cow BW, BCS, pregnancy rate, and calf BW.

<table>
<thead>
<tr>
<th>Item</th>
<th>Meadow</th>
<th>Range</th>
<th>$P$-values</th>
</tr>
</thead>
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<tr>
<td></td>
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<td>SUP</td>
<td>NS</td>
</tr>
<tr>
<td><strong>Cow BCS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>January BCS</td>
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<td>4.6</td>
<td>4.7</td>
</tr>
<tr>
<td>Winter BCS Gain,</td>
<td>-0.1</td>
<td>0.1</td>
<td>-0.2</td>
</tr>
<tr>
<td>Pre-Calving BCS</td>
<td>4.6</td>
<td>4.7</td>
<td>4.5</td>
</tr>
<tr>
<td>Pre-breed BCS</td>
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<td>5.7</td>
<td>5.6</td>
</tr>
<tr>
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<td>-0.2</td>
<td>0.0</td>
</tr>
<tr>
<td>BCS at Weaning</td>
<td>4.5</td>
<td>4.4</td>
<td>4.5</td>
</tr>
<tr>
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<tr>
<td>January BW, kg</td>
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<td>421</td>
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<tr>
<td>Winter BW Gain, kg</td>
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<td>53</td>
<td>16</td>
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<tr>
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<td>480</td>
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<td>-1</td>
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<tr>
<td>BW at Weaning, kg</td>
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<td>437</td>
<td>435</td>
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<tr>
<td><strong>Pregnancy Rate, %</strong></td>
<td>92\textsuperscript{a}</td>
<td>86\textsuperscript{b}</td>
<td>78\textsuperscript{b}</td>
</tr>
<tr>
<td><strong>Calf BW</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calf Birth BW, kg</td>
<td>36\textsuperscript{a}</td>
<td>36\textsuperscript{a}</td>
<td>34\textsuperscript{b}</td>
</tr>
<tr>
<td>Calf Weaning BW, kg</td>
<td>198</td>
<td>199</td>
<td>189</td>
</tr>
</tbody>
</table>

\textsuperscript{1}Winter grazing treatments: Meadow = dams grazed dormant meadow, Range = dams grazed dormant range, NS = dams received no supplement, SUP = dams received 0.45 kg DM-animal\textsuperscript{1}·d\textsuperscript{-1} 32% CP supplement.

\textsuperscript{a,b}Means in rows with differing superscripts designate a pasture × supplement interaction ($P < 0.1$)
Figure 1. The effects of cow age\(^1\) on pregnancy rates in a late-spring calving system.

\(^1\)Age determined by animal date of birth. Any animals 5 years of age or greater were included in 5+ yr.
CHAPTER IV:

Comparison of timed insemination vs. modified estrus detection protocol in beef heifers

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ABSTRACT

Angus-based, crossbred heifers (n = 972, 346 kg ± 14 kg ) were assigned to either a fixed-time AI (FTAI) protocol or modified estrus detection with fixed-time AI (MTAI) to evaluate synchronization, conception, and pregnancy rates. During the pre-breeding development period, heifers were fed to achieve a target of 60 ± 5% mature BW at breeding. Heifers were synchronized via melengestrol acetate-prostaglandin F2α (MGA-PG) protocol and received an estrus detection aid (patch) at PG administration. A patch score was recorded for each heifer at AI to reflect what percentage of rub-off coating had been removed. Heifers in the FTAI treatment received 2 mL GnRH injection and were AI 72 ± 2 h following PG. Heifers in MTAI treatment were observed for estrus at 58 ± 2 and 70 ± 2 h after PG. Approximately 72 ± 2 h after PGF2α, heifers in MTAI were AI in the following order: heifers in estrus at 58 h post-PG, heifers in estrus at 70 h post-PG, and heifers not expressing estrus at either estrus observation. Heifers not expressing estrus received GnRH at AI. Pregnancy was determined via transrectal ultrasonography. Heifers exhibiting estrus had greater (P < 0.01; 71 and 66 ± 5% for FTAI vs. MTAI, respectively) AI conception rates than heifers not expressing estrus in both FTAI and MTAI treatments vs. 47 and 53 ± 9 % AI conception rates in non-estrus heifers for FTAI and MTAI,
respectively. However, overall AI conception rate (62 ± 5%, $P = 0.49$) and final pregnancy rates were similar ($P = 0.98$; 96 and 97 ± 3% for FTAI vs. MTAI, respectively). Similar AI conception rates were achieved without estrus detection.

**Key Words:** beef heifers, estrus detection, estrus synchronization, timed artificial insemination
INTRODUCTION

Using AI in replacement heifers decreases the chance for dystocia by using high accuracy calving ease sires (Bennett and Gregory, 2001). Regardless of dam age, Lamb et al. (2010) concluded synchronization of the estrous cycle can shorten the calving season, increase calf uniformity, and facilitate the use of AI. Artificial insemination allows producers to utilize superior genetics at costs less than purchasing a herd sire of similar quality.

Few beef producers have implemented AI programs, and of these producers, most produce seedstock. Estrus synchronization and AI require careful planning and additional time and labor. Consequently, adoption rates of estrus synchronization and AI have been low. Fixed-time AI (FTAI) protocols can minimize the number of times cattle are handled and eliminate estrus detection, but may provide lower conception rates than protocols involving estrus detection (Lamb et al. 2006). Melengestrol acetate (MGA) is an alternative progestin commonly used to synchronize estrus in beef heifers and has proven to be as effective as controlled internal drug release (CIDR) device in time AI protocols (Vraspir et al., 2013). Therefore, the objective of the present study was to compare modified estrus detection and FTAI vs. FTAI in a MGA-prostaglandin F₂α (PG) synchronization protocol.

MATERIALS AND METHODS

The University of Nebraska-Lincoln Animal Care and Use Committee approved the procedures and facilities used in this experiment. Yearling, Angus-based crossbred heifers (n = 972) were managed in 3 groups at the Kelley Ranch near Sutherland, NE.
Initial BW (346 ± 14 kg) was similar between treatments ($P = 0.46$). During the development period, heifers were fed to achieve a target of 60% mature BW at breeding.

Heifers in Group 1 (n = 298) were managed in 3 drylot pens and offered a diet (40% DM) containing 0.6 kg/d wet distillers grains (WDG), 2.4 kg/d grass hay, 3.2 kg/d corn silage (CS), and 0.2 kg/d balancer pellet on a DM basis. Heifers in Group 2 (n = 317) grazed dormant meadow and were offered supplement (0.8 kg/d WDG, 1.4 kg/d CS, and 0.2 kg/d balancer pellet on a DM basis; 30% DM). In early February, heifers in Group 2 were moved to 2 drylot pens and offered a diet (48% DM) containing 1.0 kg/d WDG, 4.0 kg/d grass hay, 1.8 kg/d CS, and 0.2 kg/d balancer pellet on a DM basis. Heifers in Group 3 (n = 357) were managed in 5 drylot pens and offered a diet (44% DM) comprised of 0.8 kg/d WDG, 3.3 kg mixed hay (50, 25, and 25% alfalfa, grass, and millet hay, respectively), 2.7 kg CS on a DM basis, and 0.4 kg liquid finisher supplement (as-fed).

All heifers were synchronized using a MGA-PG protocol (Vraspir et al., 2013), where on d 1 to 14 each heifer was offered 0.50 mg/d MGA (Zoetis, Florham Park, NJ) pellets mixed in their diet. On d 33, heifers received a PG (Lulatoryse, Zoetis, Florham Park, NJ) 5 mL i.m. injection and estrus detection aids (patches) applied (Estrotect, Rockway Inc, Spring Valley, WI). A patch score was recorded for each heifer at AI to reflect what percentage of rub-off coating had been removed. A score of 1 designated a patch with no rub-off coating removed, a score of 2 designated a patch with < 50% of the rub-off coating removed, a score of 3 designated a patch with ≥ 50% of the rub-off coating removed, and a score of 4 designated a missing patch. Heifers receiving a patch score of 3 were considered to have expressed estrus.
All FTAI heifers (Figure 1) received 2 mL GnRH (Fertagyl, Intervet/Merck Animal Health, Madison, NJ) i.m. injection and AI 72 ± 2 h following PG. Heifers in the modified-time AI (MTAI, Figure 2) treatment were detected for estrus at 58 ± 2 and 70 ± 2 h after PG. Heifers expressing estrus (patch score 3) were penned separately. Approximately 72 ± 2 h after PG, heifers in MTAI were AI in the following order: heifers in estrus at 58 h post-PG, heifers in estrus at 70 h post-PG, and heifers not expressing estrus at either observation time. Heifers not expressing estrus received GnRH at AI. Thirteen days following AI, bulls were placed with heifers at a bull to heifer ratio of 1:50 for a 42 d breeding season. A minimum of 51 d after AI, BW was measured and pregnancy was detected via transrectal ultrasonography (Aloka, Hitachi Aloka Medical America Inc., Wallingford, CT). Heifers not pregnant by AI were weighed and diagnosed for pregnancy 45 d following bull removal.

Statistical Analysis

All data were analyzed using the GLIMMIX procedure of SAS (SAS Institute, Inc., Cary, N.C.) accounting for group, location, treatment, and treatment x location interaction. Group, location, and AI technician were included as random variables. Pregnancy rate was analyzed using an odds ratio. Least squared means and SE of the proportion of pregnant heifers by treatment were obtained using the ILINK function.

RESULTS AND DISCUSSION

Breeding Treatment

Heifer reproductive performance is presented in Table 1. Pre-breeding BW was similar ($P = 0.48$) between FTAI and MTAI treatment groups (345 and 348 ± 14 kg, respectively). Furthermore, BW was similar ($P = 0.26$) at first pregnancy diagnosis (366
and $369 \pm 7$ kg; FTAI and MTAI, respectively). Heifers from both groups reached a similar ($P = 0.86$) percentage mature BW ($62 \pm 5\%$, based on $553$ kg mature BW) prior to breeding. At the second pregnancy diagnosis, BW ($P = 0.05$) was $411$ and $417 \pm 8$ kg for FTAI and MTAI, respectively.

The AI conception rate was similar ($62 \pm 5\%, P = 0.49$) for both treatments. Conception rates by patch score in FTAI were $42$, $48$, $71$, and $41 \pm 5\%$ for patch scores 1 ($n = 44$), 2 ($n = 144$), 3 ($n = 283$), and 4 ($n = 15$), respectively. Conception rates by patch score in MTAI were $52$, $53$, $66$, and $55 \pm 5\%$ for patch scores 1, 2, 3, and 4. Heifers exhibiting an activated patch (score 3) had greater ($P < 0.01$; $71$ and $66 \pm 5\%$ for FTAI and MTAI, respectively) AI conception rate in both FTAI and MTAI treatments vs. $47$ and $53 \pm 9\%$ AI conception rates in non-estrus heifers (score 1, 2, and 4) for FTAI and MTAI, respectively. At first estrus detection (58 h) 132 heifers exhibited a patch score of 3 ($66 \pm 5\%$ conception rate), at second estrus detection (70 h) 156 heifers exhibited a patch score 3 ($66 \pm 5\%$ conception rate), and at AI 38 additional heifers exhibited a patch score 3 for MTAI protocol ($68 \pm 5\%$ conception rate). Estrus activity at AI did not influence final pregnancy rates ($96$ and $97 \pm 3\%$ for FTAI vs. MTAI, respectively; $P = 0.97$).

Echternkamp and Thallman, (2011) found cows expressing estrus prior to TAI had greater pregnancy rates than cows not expressing estrus. This is supported by Perry et al., (2005) who suggests females expressing estrus prior to TAI have greater pregnancy rates than non-estrus animals.

Mallory et al., (2010) compared MGA and CIDR synchronization protocols, finding no difference in AI pregnancy rate. However, interval to estrus after PG injection
tended to be greater in heifers synchronized with a CIDR, which suggests the MGA-PG protocol may have an advantage over CIDR protocol in producing a tighter synchrony among heifers (as reviewed by Nielson et al., 2015). Additionally, Vraspir et al. (2013) observed similar FTAI pregnancy rates in heifers synchronized with MGA vs. 14-d CIDR. In the present study, the MGA-PG protocol synchronized the estrus cycle in FTAI treatment to allow heifers to attain estrus at or near FTAI, which is supported by the similar AI conception rate (62 ± 5%) observed for both FTAI and MTAI, suggesting proper alignment of ovulation and AI.

In a previous study on the same ranch, Nielson et al. (2015) evaluated a 19-h delayed AI following GnRH injection in a hybrid estrus detection and FTAI protocol. Heifers were synchronized, detected for estrus, and AI similar to the present study. Seventy-two h following PG, heifers not detected in estrus were administered GnRH, and randomly assigned to 1 of 2 treatment groups: 1) immediately AI or 2) AI 19 ± 1 h later. Heifers in estrus prior to AI had a greater pregnancy rate than those time AI. Delaying the time of AI did not increase pregnancy rates (70, 56, and 47 ± 6%; heifers in estrus, AI 72 h, AI 72 + 19 h later, respectively), concluding the additional labor of delaying AI was not justified.

The present study evaluated a modified estrus detection and FTAI protocol vs. a FTAI with no estrus detection, and similar to Nielson et al. (2015) there was no advantage in AI conception rates, negating the need for additional labor. Data from the present study suggests similar conception rates may be achieved by FTAI when compared with a protocol involving estrus detection.
IMPLICATIONS

Assisted reproductive technologies such as estrus synchronization and AI have limited adoption in the beef industry, partially due to added complexity, labor, and potential perceived reproductive risk. Protocols that limit labor and cattle processing have a greater potential of being adopted. The present study provided a synchronization and AI protocol that limits cattle handling and eliminates estrus detection without compromising conception rates compared with a more labor intensive protocol utilizing estrus detection.
LITERATURE CITED


Table 1. Reproductive performance of heifers on a FTAI\(^1\) or MTAI\(^2\) synchronization protocol.

<table>
<thead>
<tr>
<th>Item</th>
<th>FTAI</th>
<th>MTAI</th>
<th>SEM</th>
<th>P-Value</th>
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<td>344</td>
<td>14</td>
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<td>369</td>
<td>7</td>
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<tr>
<td>2(^\text{nd}) Pregnancy test BW(^3), kg</td>
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<td>417</td>
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<td>63</td>
<td>5</td>
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<tr>
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<td>62</td>
<td>5</td>
<td>0.49</td>
</tr>
<tr>
<td>Final Pregnancy Rate, %</td>
<td>96</td>
<td>97</td>
<td>3</td>
<td>0.98</td>
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</table>

<table>
<thead>
<tr>
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<th>2</th>
<th>3</th>
<th>4</th>
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</thead>
<tbody>
<tr>
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<td>48(^b)</td>
<td>71(^a)</td>
<td>40(^b)</td>
</tr>
<tr>
<td></td>
<td>52(^b)</td>
<td>53(^b)</td>
<td>66(^a)</td>
<td>55(^b)</td>
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<tr>
<td>Final Pregnancy Rate, %</td>
<td>96</td>
<td>96</td>
<td>97</td>
<td>86</td>
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</tbody>
</table>

\(^1\) FTAI = synchronized using melengestrol acetate-prostaglandin F\(_{2a}\) (MGA-PG) protocol, d 1 to 14 heifers offered 0.50 mg/(hd ∙ d) MGA (Zoetis, Florham Park, NJ), d 33, PG (Lutalyse, Zoetis, Florham Park, NJ) 5 mL i.m. injection and estrus detection aids (Estrotect, Rockway Inc, Spring Valley, WI). Approximately 72 ± 2 h after PG heifers received GnRH and AI.

\(^2\) MTAI = synchronized using MGA-PG protocol. Approximately 72 ± 2 h after PG, heifers were AI in the following order: heifers in estrus 58 h post-PG, heifers in estrus 70 h post-PG, and heifers not expressing estrus given GnRH.

\(^3\) Second pregnancy diagnosis BW occurred at a minimum 50 d following first pregnancy diagnosis.

\(^4\) ADG from pre-breeding to pregnancy diagnosis (57 d).

\(^5\) Based on 553 kg mature BW.

\(^6\) Patch score 1 = not rubbed; 2 = ≤ 50% rubbed; 3 = ≥ 50% rubbed; 4 = missing estrus detection patch.

\(^7\) Means\(^a\),\(^b\) in a row with differing superscripts are different (P < 0.05)
Figure 1. Fixed-time AI melengestrol acetate (MGA) - PGF$_{2\alpha}$ synchronization protocol.
**Figure 2.** Modified melengestrol acetate (MGA) - PGF$_{2\alpha}$ synchronization protocol

- **GnRH** (non-estrous)
- **PG$_{2\alpha}$**
- **AI**
- Estrus detect at 58 and 70 h

MGA

---

1  14  ...19 d...  33  72 hr  36
CHAPTER V: Growth and reproductive performance of yearling beef heifers implanted with Revalor G in the Nebraska Sandhills

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ABSTRACT

Crossbred beef heifers (n = 3,242), approximately 12 mo of age, were managed at 3 locations in the Nebraska Sandhills and randomly assigned to be implanted with trenbolone acetate + estradiol (TBA + E2; 40 mg of trenbolone acetate plus 8 mg estradiol, IMP), while the control group (CON) did not receive an implant. Heifers (238 ± 2 kg) grazed native Sandhills range for the duration of the trial (164 ± 4 d). Eighty-two ± 2 d following trial initiation, heifers were synchronized for estrus and AI followed with clean-up bulls as part of a 25 d breeding season. Body weight was measured at the beginning and end of trial. Pregnancy detection occurred 45 d following bull removal at the conclusion of the summer grazing period. Implanted heifers gained more and were heavier (P < 0.05; 0.68 vs. 0.64 ± 0.01 kg/d and 347 vs. 340 ± 3 kg, IMP vs. CON, respectively) at the end of the trial. However, pregnancy rate was greater (P < 0.01) for CON vs. IMP (64 vs. 46 ± 3% respectively). Implanted heifers also had a lower pregnancy rate in their second breeding season (P = 0.02; 93 vs. 96 ± 2%, IMP vs. CON, respectively). Implanting beef heifers with TBA + E2 at approximately 12 mo of age increased ADG and summer BW gain; however, it decreased initial and subsequent pregnancy rate compared with heifers not implanted.

Key words: beef heifers, fertility, growth implants
INTRODUCTION

Administering growth implants in stocker systems results in increased growth, improved efficiency, and increased profitability (Barham, 2003). Initially, growth implants were utilized in the finishing phase of production, but over the past several decades, growth implants have been incorporated at earlier stages of growth and development. Anabolic implants increase stocker cattle BW gains by 8 to 18% or 7 to 18 kg during the grazing season (Kuhl, 1997; Selk, 1997). Kuhl (1997) reported data from 3 studies (n = 494), in which stocker heifers receiving a trenbolone acetate plus estradiol (TBA + E2) implant gained 12 kg more than non-implanted controls, which was 4.6% greater than responses to Zeranol (ZER; 36 mg of zeranol) during a 116-d grazing period. However, growth implants have not been widely used in heifer calves, due to subsequent reproductive concerns (Selk, 1997). Consequently, less research has been conducted with heifers. Reproductive performance has been variable; however, several studies have shown decreased reproductive performance of beef heifers implanted once with ZER at weaning (Nelson et al., 1972; Pruitt et al., 1980; Pritchard et al., 1989).

Traditional heifer development programs focus on maximizing reproductive rates. However, if excess beef females are retained after weaning, a management strategy may be to implant heifers and accept a decreased conception rate; and increase stocker gains, provided an adequate number of replacements are achieved. Increased growth responses to implants are consistent, but reproductive performance in beef heifers has been variable.

Therefore, objectives of the present study were to evaluate effects of a single stocker implant (TBA + E2) on growth and reproductive performance of yearling beef heifers in the Nebraska Sandhills.
MATERIALS AND METHODS

In 2011, 12 mo old crossbred beef heifers grazing native Sandhills range at 3 locations were randomly assigned to be implanted (IMP) with 40 mg of trenbolone acetate plus 8 mg estradiol (TBA + E2, Revalor G, Merck Animal Health, Summit, NJ) or not implanted (control, CON). Heifers were implanted at the beginning of the grazing period (May 1). Initial heifer BW was similar ($P = 0.03$) between treatments (238 ± 2 kg). At the time of implant, all heifers were vaccinated (Pyramid 5, Boehringer Ingelheim, St. Joseph, MO; and VL5 Staybred, Zoetis, Florham Park, NJ) and treated with a topical endectocide (Ivermax, RXV Products, Westlake, TX). At each location, heifers grazed common upland pastures for 164 ± 4 d.

A 25 d breeding season began 82 ± 2 d following trial initiation. Heifers at location 1 (L1; n = 942) were synchronized with 2 prostaglandin F$_{2\alpha}$ (PG) injections administered 17 d apart (5 ml, Lutalyse, Zoetis, Florham Park, NJ) followed by 5 d of estrus detection and AI. Mature bulls were then placed with heifers at a 1:52 bull to heifer ratio for 20 d to conclude a 25 d breeding season. At location 2 (L2; n = 1,184) and 3 (L3; n = 1,116), mature bulls were placed with heifers at a 1:82 bull to heifer ratio 6 d before heifers received a single PG injection followed by 6 d of estrus detection and AI. Estrus detection aids were utilized at all 3 locations (Estrotect, Rockway Inc., Spring Valley, WI) at PG injection. Heifers were considered to have expressed estrus when greater than 50% of the rub-off coating had been removed from the Estrotect patch and were AI 12 h later. Following the AI period, mature bulls were then placed with heifers at ratios of 1:49 and 1:35 at L2 and L3, respectively, for 19 d to conclude a 25 d breeding season.
Heifers were managed on native Sandhills range throughout the summer grazing period. Pregnancy diagnosis was conducted via transrectal palpation approximately 45 d following bull removal and ending BW measured. Non-pregnant heifers were marketed as stocker cattle. During the second production year, heifers (n = 1,667; 706 and 961, IMP and CON, respectively) retained as replacements were managed in 3 groups and grazed native upland range throughout the year without further treatment. Cows were offered 0.45 kg/d of a 32% CP supplement range cube for 30 days (15 d prior to breeding until 15 d following bull turnout (July 25). Pregnancy diagnosis was performed via transrectal palpation approximately 45 d following bull removal.

**Economic Evaluation**

Heifer development economic analysis was performed similar to Summers et al. (2014), and is presented in Table 2. Winter grazing cost was estimated to be one-half the grazing costs for a mature cow ($0.46/d) based on heifer BW at weaning, as previously established (Larsen et al., 2011). Winter range with supplement was valued at $0.75/d. Summer grazing costs, $0.55/d for upland grass, were based on Johnson et al., (2010). Additional development costs, including feed delivery costs, breeding costs, and health and veterinarian costs, were charged at $0.36/d. Average heifer purchase and cull prices were based on USDA Agricultural Marketing Service prices reported in Nebraska for each date (USDA-AMS, 2008). Net cost of 1 pregnant heifer was calculated using the formula developed by Feuz (1992). The total value of cull heifers was subtracted from the total cost of all developed heifers. Total costs were then divided by the number of heifers exposed to determine the total cost of 1 pregnant heifer. This value was divided by final pregnancy rate to determine the total net cost of 1 pregnant heifer.
Statistical Analysis

Data were analyzed using the GLIMMIX procedure of SAS (SAS Institute, Inc., Cary, N. C.). Individual heifer was the experimental unit and synchronization protocol was included as a random variable in the model. Location was experimental unit for economic analysis and in Table 2 where data are presented by location. Least squares mean and SE for ADG, BW, and pregnancy rate were obtained using the Tukey function of SAS.

RESULTS AND DISCUSSION

Heifer growth and reproductive performance are presented in Table 1 and presented by location in Table 2. Implanted heifers had greater ADG and ending BW ($P < 0.05$; 0.68 vs. 0.64 ± 0.01 kg/d and 347 vs. 340 ± 3 kg for IMP and CON, respectively). Summer gains were greater ($P = 0.03$) for IMP (110 ± 3 kg) vs. CON (104 ± 3 kg). Kuhl (1997) reported response to growth implants to be 7 to 18 kg during the summer grazing period for stocker cattle. Implanted heifers gained an average of 6 kg more than CON heifers, which is slightly lower than reported by Kuhl (1997). Heifers in the current study grazed native upland Sandhills pasture during the trial without supplement. Forage quality of Sandhills rangeland early in the grazing period is high, but decreases with increasing plant maturity (Lamb, 1996). Therefore, heifers on a higher plane of nutrition for the entire grazing period would likely have a greater growth response to implants. Additionally, a synergistic growth response for implanting in combination with supplementation is commonly observed in stocker cattle, where nutrient deficiencies are corrected, or forage resources extended, via supplementation strategies (Kuhl, 1997). In a
Missouri study, providing late-season supplementation to stocker calves improved ADG in re-implanted yearlings (Sewell, 1983).

In a 2-yr Montana study, weaned heifers were separated into 2 weight classes and divided between implant and non-implanted control. Heifers were developed in a drylot until 1 mo prior to breeding season. Weaned heifers were implanted with ZER at 8 and 11 mo of age. Rates of gain in the drylot were greater for implanted vs. control heifers in both Trial 1 (0.53 vs. 0.48 kg/d) and Trial 2 (0.70 vs. 0.63 kg/d). Pregnancy rate was 16 percentage points lower in implanted heifers vs. control (62 vs. 78%) in Trial 1, but did not differ (88 vs. 87%; implant vs. control, respectively) in Trial 2 (Staigmiller et al., 1983).

In a similar study, ZER implants were administered to crossbred beef heifers at 1, 6, or 9 mo, or at multiple intervals. Heifers receiving a combination of 2 implants had greater ADG from weaning to breeding than control or heifers implanted 3 times. Conception rates in a 62-d breeding season were comparable for implanted vs. non-implanted control heifers (93 vs. 96%), with the exception of heifers receiving implants at both 1 and 6 mo of age (56%). Calf birth weight, dystocia score, cow re-breeding rate, and calf weaning weight were not affected by implant treatment (Deutscher et al., 1984). Moran et al. (1990) observed decreased pregnancy rates when heifers were repeatedly implanted with trenbolone acetate (TBA; 200 mg of TBA), ZER, or TBA + E2.

In the present study, pregnancy rate was greater \( (P < 0.01) \) for CON vs. IMP heifers (64 vs. 46 ± 3%). This is consistent with results from Trial 1 in Staigmiller et al. (1983), which demonstrated a 16 percentage point reduction in pregnancy rate in implanted heifers. However, data from the present study contrasts Staigmiller et al.
(1983) Trial 2, where similar pregnancy rates were observed regardless of implant
treatment. In Trial 2, heifers were fed to reach greater pre-breeding BW (293 kg vs. 341
kg, Trial 1 vs. Trial 2, respectively), which may explain differences in pregnancy rates. In
the present study, heifers were developed to a similar pre-breeding BW (294 vs. 290 kg
in IMP and CON, respectively) as Trial 1. Additionally, age at implant may also explain
differences observed between previous research and the present study. Staigmiller et al.,
(1983) implanted heifers at 8 and 11 mo of age; in the present study, heifers were
implanted at 12 mo of age. Additionally, Deutscher et al. (1984) reported similar
conception rates among non-implanted controls and heifers implanted at 1, 6, or 9 mo of
age, earlier than the present study. In addition to age, chemical composition of implant
may also contribute to variation in pregnancy rates. Zeranol was administered in both
Staigmiller et al. (1983) and Deutscher et al. (1984) studies, whereas TBA + E2 was used
in the present study. This is supported by a recent study performed by Devine et al.
(2015), where heifers were implanted at 255 ± 12 d with TBA, TBA + E2, and ZER, and
the TBA treatment reduced AI conception rates 40 percentage points and collectively, all
implants reduced final pregnancy rates from 17-23 percentage points, however, due to
small numbers, these differences were not statistically significant. F Trenbolone acetate
mimics testosterone and elicits a similar response to testosterone in the animal. Zeranol
acts similar to estrogen, which could explain why varying effects on reproduction have
been observed.

Subsequent pregnancy rate after the first calving season was also lower ($P = 0.02$)
in IMP (93%) vs. CON (96%) heifers, which suggests implanting heifers may have a
residual or development effect on growing heifers beyond the production yr the implant
was administered.

**Economic Analysis**

The economic analysis is presented in Table 3. Heifers were developed together
by location; therefore, winter and summer feed costs and total development costs were
similar between treatments ($P = 1.0$). Additionally, the net cost of 1 pregnant heifer
tended ($P = 0.13$) to be greater in CON heifers. Cull value did not differ ($P = 0.66$)
despite a $21 numerical advantage for IMP heifers.

Stocker enterprises commonly market cattle in late summer when pasture
availability or forage quality may be declining. A disadvantage to the present study is the
expense and resource allocation associated with retaining heifers until pregnancy
determination. It’s likely that heifers continued to gain during the extended period prior
to pregnancy detection; however, the increased gain due to implant had presumably
diminished due to implant potency and declining forage quality.

In recent years, the beef industry has seen a decline in cattle numbers and high
demand for replacement females. Some beef stocker enterprises have utilized their
resources to market pregnant replacement females. Many cow-calf producers have
retained all heifers for breeding and marketed excess pregnant females in response to
market demand. When pregnant heifer value exceeds feeder heifer value, it is unlikely the
additional BW gain in cull females will compensate for the decreased pregnancy rate.
However, when pregnant heifer value is comparable to feeder heifer value, the additional
BW gain from the implant increases the value and efficiency of stocker heifers.

**IMPLICATIONS**
Implanting beef heifers at approximately 12 mo of age with TBA + E2 increased heifer ADG and BW; however, implant also decreased pregnancy rate by approximately 18 percentage points. When deciding to implant replacement females, the current (or expected) market conditions for pregnant heifers and feeder heifers must be considered.
LITERATURE CITED


**Table 1.** Effects of Revalor-G on reproduction and summer BW gain of beef heifers grazing native Sandhills rangeland

<table>
<thead>
<tr>
<th>Item</th>
<th>CON(^1)</th>
<th>IMP(^2)</th>
<th>SEM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>1,621</td>
<td>1,621</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring BW, kg</td>
<td>237(^b)</td>
<td>238(^a)</td>
<td>2</td>
<td>&gt; 0.1</td>
</tr>
<tr>
<td>Fall BW, kg</td>
<td>340(^b)</td>
<td>347(^a)</td>
<td>3</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Summer Gain, kg</td>
<td>104(^b)</td>
<td>110(^a)</td>
<td>3</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>ADG(^3), kg</td>
<td>0.63(^b)</td>
<td>0.67(^a)</td>
<td>0.01</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Pregnancy Rate, %</td>
<td>64(^a)</td>
<td>46(^b)</td>
<td>3</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>2nd Preg. Rate, (^4) %</td>
<td>96(^a)</td>
<td>93(^b)</td>
<td>2</td>
<td>0.02</td>
</tr>
</tbody>
</table>

\(^1\)CON = Heifers did not receive a growth implant prior to breeding season.

\(^2\)IMP = Heifers received 40 mg of trenbolone acetate plus 8 mg estradiol implant (Revalor G, Merck Animal Health, Summit, NJ) 82 ± 2 d prior to breeding season.

\(^3\)Grazing season ADG (Location 1-162 d, Location 2-160 d, Location 3-168 d).

\(^4\)Second season pregnancy rates (n = 1667).

\(^a,b\) Means in a row with different superscripts differ (P < 0.05).
**Table 2.** Effects of Revalor G on reproduction and summer BW gain of beef heifers grazing native Sandhills rangeland by location

<table>
<thead>
<tr>
<th>Item</th>
<th>CON&lt;sup&gt;1&lt;/sup&gt;</th>
<th>IMP&lt;sup&gt;2&lt;/sup&gt;</th>
<th>SEM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L1</td>
<td>L2</td>
<td>L3</td>
<td>L1</td>
</tr>
<tr>
<td>Spring BW, kg</td>
<td>232</td>
<td>235</td>
<td>245</td>
<td>232</td>
</tr>
<tr>
<td>Fall BW, kg</td>
<td>326</td>
<td>351</td>
<td>359</td>
<td>332</td>
</tr>
<tr>
<td>Summer Gain, kg</td>
<td>94</td>
<td>116</td>
<td>113</td>
<td>99</td>
</tr>
<tr>
<td>ADG, kg&lt;sup&gt;4&lt;/sup&gt;</td>
<td>0.58</td>
<td>0.72</td>
<td>0.67</td>
<td>0.61</td>
</tr>
<tr>
<td>Pregnancy Rate, %</td>
<td>59</td>
<td>64</td>
<td>67</td>
<td>44</td>
</tr>
</tbody>
</table>

<sup>1</sup>CON = Heifers did not receive a growth implant prior to breeding season.

<sup>2</sup>IMP = Heifers received 40 mg of trenbolone acetate plus 8 mg estradiol implant (Revalor G, Merck Animal Health, Summit, NJ) 82 ± 2 d prior to breeding season.

<sup>3</sup>Grazing season ADG (Location 1, 162 d; Location 2, 160 d; Location 3, 168 d).
Table 3. Economics of implanting beef heifers with Revalor G at 12 mo of age\(^1\)

<table>
<thead>
<tr>
<th>Item</th>
<th>CON(^2)</th>
<th>IMP(^3)</th>
<th>SEM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter feed costs /$heifer(^4)</td>
<td>102</td>
<td>102</td>
<td>.02</td>
<td>1.0</td>
</tr>
<tr>
<td>Summer feed cost /$heifer</td>
<td>91</td>
<td>91</td>
<td>.1</td>
<td>1.0</td>
</tr>
<tr>
<td>Total feed costs, $/heifer</td>
<td>193</td>
<td>193</td>
<td>.02</td>
<td>1.0</td>
</tr>
<tr>
<td>Total development cost $/heifer</td>
<td>1,019</td>
<td>1,019</td>
<td>3</td>
<td>1.0</td>
</tr>
<tr>
<td>Avg. Cull heifer value $</td>
<td>1,102</td>
<td>1,123</td>
<td>46</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Cull heifer value $/heifer exposed</td>
<td>402</td>
<td>601</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Net cost of 1 pregnant heifer(^5), $</td>
<td>969</td>
<td>901</td>
<td>36</td>
<td>0.13</td>
</tr>
</tbody>
</table>

1 Heifers developed at Rex Ranch on native Sandhills rangeland (Ashby, NE).
2 CON = Heifers did not receive a growth implant prior to breeding season.
3 IMP = Heifers received 40 mg of trenbolone acetate plus 8 mg estradiol implant (Revalor G, Merck Animal Health, Summit, NJ) 82 ± 2 d prior to breeding season.
4 Heifers grazed winter range for 135 d and were offered the equivalent of 0.45 kg/d 32% CP supplement 3 times per wk.
5 Includes all fixed and variable cost associated with initial heifer price, feed, feed delivery, breeding, transportation, and supplement.
6 Total value of cull heifers was subtracted from the total cost of all developed heifers. Total costs were then divided by the number of heifers exposed to determine the total cost of 1 pregnant heifer.
CHAPTER VI:

Effects of supplemental energy and protein source on performance of steers grazing irrigated corn residue


*University of Nebraska-Lincoln, Lincoln 68583; and †University of Nebraska West Central Research and Extension Center, North Platte 69101

ABSTRACT

Seventy-five crossbred steer calves (235 kg, SD = 3.5) grazing irrigated corn residue were blocked by BW and randomly assigned to 5 treatment groups (n = 15) to evaluate the effects of protein and energy supplementations on steer performance. Treatment supplements consisted of 60% soy-pass + 40% soybean meal (SP), dried distillers grains (DDG), 89% whole corn/6% molasses/5% urea (C + RDP), whole corn only (CRN), and control (NS) fed at 1.59, 1.36, 1.82, 1.7, and 0.0 kg DM/d respectively. Supplements were fed at different DM amounts to provide equal TDN intake. Estimated TDN values by supplement were 87% (SP), 104% (DDG), 87% (C + RDP), and 83% (CRN). Steers were individually supplemented daily at 1100-1200 via a Calan gate system and grazed the remainder of the day for 86 d. Ending BW differed (P < 0.05) among treatments and was 291, 286, 254, 245, and 229 ± 4.9 kg for SP, DDG, C + RDP, CRN, and NS respectively. Average daily gain among treatments was 0.67, 0.60, 0.24, 0.14, and - 0.08 kg ± 0.03 for SP, DDG, C + RDP, CRN, and NS respectively and was significantly (P < 0.05) different among all treatments. Treatment groups supplemented with SP and DDG achieved ADG above 0.5 kg, while C + RDP, CRN, and NS treatment groups achieved ADG less than 0.5 kg. The SP treatment provided a combination of RDP
and RUP which resulted in the greatest ADG among treatments when supplement TDN
was similar.

**Keywords**: beef steers, corn residue grazing, protein supplementation
INTRODUCTION

Corn residue grazing, an abundant feed resource for some Nebraska beef producers, extends the grazing period, and decreases the amount of harvested feed needed per animal. Additionally, increased conversion of pasture to farmland observed in recent years has increased the number of acres planted in corn, which has increased the amount of corn residue available (Watson et al. 2015. Corn residue contains CP and energy concentrations sufficient to support mature, non-lactating, beef females (NRC, 2000), but those nutrients may not meet the requirements for growing animals. Dried distillers grains plus solubles (DGS) is high in protein (30% CP) and is a good source of rumen undegradable protein (RUP) (NRC, 2000). Additionally, DGS is a good source of energy, having a TDN value estimated by Ahern et al. (2015) to be 112%. Previous work has shown DGS to be an effective supplement to increase ADG of steers grazing corn residue (Jones, 2015). However, DGS price is variable and may not always be the most economical supplement choice. Therefore, the objective of this experiment was to determine the effects of supplementing growing calves grazing corn residue with corn grain to determine its viability as a supplement in back-grounding systems. Additionally, to compare DGS to alternative protein and energy supplement sources on performance of steers grazing corn residue.

MATERIALS AND METHODS

All procedures and facilities utilized are in accordance with the approval of the University of Nebraska-Lincoln Institutional Animal Care and Use Committee. Seventy-five (7-9 mo) crossbred steer calves (235 kg, SD = 3.5) grazed irrigated corn residue for 86 d at the University of Nebraska – Lincoln Agricultural Research and
Development Center near Mead, Nebraska. Treatments were arranged in a randomized complete block design. Steers were blocked by BW and assigned to 1 of 5 treatments (n = 15) to evaluate the effects of protein supplementation on steer performance. All steers grazed residue from the same paddock throughout the study, and individual supplementation was provided daily for 1 hour from 1100 to 1200 hr via a Calan gate system (American Calan Inc. Northwood, NH). In addition to an un-supplemented control group (NS), supplements fed were 1) 60% SoyPass (Borregaurd Lignotec, Rothchild, WI) + 40% soybean meal (SP), 2) dried distillers grains plus solubles (DGS), 3) 89% dry rolled corn, 6% molasses, 5% urea (C + RDP), and 4) dry rolled corn only (CRN), fed at 1.59, 1.36, 1.82, and 1.70 kg DM/d, respectively. Estimated TDN values of supplement were 90% (SP), 112% (DGS), 78% (C + RDP), and 83% (CRN). Supplements were formulated to provide 1.42 kg of TDN, which is the amount of TDN provided by 1.36 kg DM of DGS. In order to provide an equal amount of TDN in each supplement, DM amounts of each supplement varied. Un-supplemented calves were separated prior to other treatments entering the Calan gate system. Therefore, non-supplemented steers did not have access to supplement or residue until all steers consumed their supplement. After individual supplementation, all steers were returned to the paddock to continue grazing.

Steers were limit-fed a 50:50 diet of alfalfa hay and Sweet Bran (Cargill Corn Milling, Blair, NE) at 2% of BW on a DM basis for 5 d before the trial. Body weight was measured on 3 consecutive days to reduce variation from gut fill (Watson et al., 2013). Steers were blocked by initial BW and assigned to 1 of 5 treatments. At the conclusion of
the trial, steers were again limit-fed a 50:50 diet of alfalfa hay and Sweet Bran at 2% of BW on a DM basis and ending BW was measured on 3 consecutive days.

Stocking rate was calculated based on grain yield at harvest and previous research estimating the amount of residue available for grazing per bushel of grain yield (Gardine, et al., 2016). Available forage was determined by multiplying grain yield, estimated forage availability (3.6 kg/bu), and number of acres, to produce the total available forage in the paddock. Total available forage was then divided by the estimated DMI (4.5 kg) of all steers to determine the length of grazing period available in the paddock (Jones, 2015). Supplement refusals were collected and weighed each week. Samples were analyzed for DM by drying at 60°Celsius for 48 hours in a forced air oven and weighed using a digital scale.

Statistical Analysis

Data were analyzed using the GLIMMIX procedures of SAS (SAS Inst. Inc., Cary, NC). Individual animal was considered the experimental unit, with supplement treatment and block considered as fixed effect.

RESULTS AND DISCUSSION

Results from the trial are shown in Table 1. Ending BW and ADG differed (P < 0.01) among treatments. Average daily gain among treatments was 0.67, 0.6, 0.24, 0.14, and -0.08 ± 0.06 kg/d for SP, DDG, C+RDP, CRN, and NS respectively. Both SP and DDG provided supplemental metabolizable protein as RUP. The growth response to DGS (0.6 kg/d) in the present study was consistent with Jones, et al., (2015), which observed steers grazing irrigated corn residue at the same location supplemented at 1.34 kg/d of DGS, had similar ADG (0.62 kg/d) as the steers in the present study.
The TDN value assigned to the SP supplement (90%) may have been underestimated initially. When the NRC is utilized and a supplement TDN value of 95% instead of 90% is modeled for the SP supplement, the DM amount fed decreases to 1.5 kg instead of 1.6 kg, and the estimated TDN amount is 1.42 kg. Under this scenario, a predicted ADG is 0.6 kg/d, which is equal to the actual ADG of the DGS treatment. Therefore, if a greater TDN value had been used for SP, steer performance between SP and DGS would have likely been similar (NRC, 2000). Alternatively, the DGS treatment may have been deficient in RDP. Treatments with negative RDP values did not have sufficient MP as predicted by the NRC because BCP was limited. In order to reflect the reduction in bacterial crude protein flow due to limited RDP, MP balance was reduced by 64% of the negative RDP balance.

Steers supplemented with C + RDP were the only treatment group to refuse feed each week, likely due to the palatability and inclusion level of urea. Due to feed refusal, calves supplemented with C + RDP consumed less TDN than other treatment groups. The average daily DMI for C + RDP was 1.47 kg/d, which is 80% of the supplement offered. Differences in DMI (1.47 vs. 1.82 kg) and TDN (1.15 vs 1.41 kg) likely had an impact on performance of the C + RDP treatment group. When the NRC model is used and reflects the scenario of consuming 80% of C + RDP supplement, it projects an ADG of 0.45 kg/d, which is 0.23 kg above actual ADG. It is not likely the decrease in DMI and TDN consumption accounts for the entire deficit in performance observe between predicted gains from the NRC, and the actual gains achieved in the trial. While the NRC model did not predict a metabolizable protein deficiency in CRN + RDP at the observed ADG, we concluded that corn did not provide adequate metabolizable protein to achieve ADG
similar to DDG, even when balanced for RDP. However, even though steers consumed 
less energy in C + RDP, adding urea did elicit a growth response over the supplement 
offering only corn grain. Additionally, steers fed CRN were clearly affected by a 
deficiency in RDP, contributing to the reduced ADG compared to C + RDP. As observed 
in previous research (Ahern et al., 2011), a negative associative effect of starch digestion 
on fiber digestibility of corn residue may have affected both CRN and CRN + RDP 
treatments.

Supplementing growing animals grazing corn residue with protein in the form of 
RDP and RUP is needed to optimize gain and growth performance. Wilson et al., (2004), 
in review recommended 0.16 kg/d of RUP supplementation to calves grazing corn 
residue in order to optimize gain. In the present study, RUP amount provided by 
supplement was 0.46, 0.29, 0.10, and 0.09 kg/d for SP, DGS, CRN + RDP, and CRN 
respectively. Calves supplemented with DGS and SP had significantly better growth 
performance than CRN or C + RUP suggesting CP needs were met. The lack of 
performance in CRN and C + RDP suggests a CP deficiency in those treatments, which 
deficiency is likely caused by an insufficient RUP concentration in those diets.

**IMPLICATIONS**

The present study demonstrates the importance of protein supplementation of 
growing calves grazing corn residue as well as the importance of supplementing protein 
in the form of both RDP and RUP. Supplements high in RDP and RUP (SP, DGS) will 
produce greater growth response in growing cattle even when TDN amount of other 
supplement sources (CRN, C + RDP) is similar. Meeting CP requirements with a 
combination of RDP and RUP will optimize gain and growth performance in steers
grazing corn residue. Additionally, supplementing with corn grain, with or without urea, will produce low winter gains. Supplements should contain protein, both RUP and RDP, at greater amounts than what is supplied by corn and urea.
LITERATURE CITED


Means within a row with differing superscripts are different.

Calves did not receive suppl. throughout feeding period.

Suppl. contained 1.7 kg DM, whole corn.

Suppl. contained 1.8 kg DM, 89% whole corn, 6% molasses, 5% urea.

Suppl. contained 1.4 kg DM, dried distillers grains + solubles.

Suppl. contained 1.6 kg DM, 60% soy-pass + 40% soybean meal.

Suppl. was formulated to provide 1.42 kg TDN intake, which is the TDN amount supplied by 1.36 kg dried distillers grains + solubles. This formulation requires differing DM amounts.

Metabolizable protein balance was reduced by 64% of the negative RDP balance to reflect the reduction in bacterial crude protein flow due to limited RDP.

<table>
<thead>
<tr>
<th></th>
<th>No Suppl.</th>
<th>Corn&lt;sup&gt;2&lt;/sup&gt;</th>
<th>Corn/Urea&lt;sup&gt;3&lt;/sup&gt;</th>
<th>DDGS&lt;sup&gt;4&lt;/sup&gt;</th>
<th>Soypass&lt;sup&gt;5&lt;/sup&gt;</th>
<th>SEM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial BW, kg</td>
<td>235</td>
<td>235</td>
<td>235</td>
<td>235</td>
<td>235</td>
<td>1.6</td>
<td>0.1</td>
</tr>
<tr>
<td>Ending BW, kg</td>
<td>230&lt;sup&gt;a&lt;/sup&gt;</td>
<td>245&lt;sup&gt;b&lt;/sup&gt;</td>
<td>254&lt;sup&gt;c&lt;/sup&gt;</td>
<td>286&lt;sup&gt;d&lt;/sup&gt;</td>
<td>291&lt;sup&gt;e&lt;/sup&gt;</td>
<td>2.2</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>ADG, kg</td>
<td>- 0.08&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.14&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.24&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.6&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.67&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.03</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Suppl. DMI, kg/d&lt;sup&gt;6&lt;/sup&gt;</td>
<td>-</td>
<td>1.7</td>
<td>1.5</td>
<td>1.4</td>
<td>1.6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>TDN, %</td>
<td>-</td>
<td>83%</td>
<td>78%</td>
<td>104%</td>
<td>90%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>TDN intake kg/d</td>
<td>-</td>
<td>1.4</td>
<td>1.1</td>
<td>1.4</td>
<td>1.4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>RDP balance</td>
<td>-144</td>
<td>-253</td>
<td>7</td>
<td>-161</td>
<td>-1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(g/day)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP balance&lt;sup&gt;7&lt;/sup&gt;</td>
<td>-110</td>
<td>-36</td>
<td>93</td>
<td>41</td>
<td>257</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<sup>a-c</sup>Means within a row with differing superscripts are different.

<sup>1</sup>Calves did not receive suppl. throughout feeding period.

<sup>2</sup>Suppl. contained 1.7 kg DM, whole corn.

<sup>3</sup>Suppl. contained 1.8 kg DM, 89% whole corn, 6% molasses, 5% urea.

<sup>4</sup>Suppl. contained 1.4 kg DM, dried distillers grains + solubles.

<sup>5</sup>Suppl. contained 1.6 kg DM, 60% soy-pass + 40% soybean meal.

<sup>6</sup>Suppl. was formulated to provide 1.42 kg TDN intake, which is the TDN amount supplied by 1.36 kg dried distillers grains + solubles. This formulation requires differing DM amounts.

<sup>7</sup>Metabolizable protein balance was reduced by 64% of the negative RDP balance to reflect the reduction in bacterial crude protein flow due to limited RDP.