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# Utilization of Corn Residue, Winter Range, or Dry Lot in Beef Heifer Development Systems

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# UTILIZATION OF CORN RESIDUE, WINTER RANGE, OR DRY LOT IN BEEF HEIFER DEVELOPMENT SYSTEMS

by

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Post-weaning heifer development systems that maximize reproductive efficiency and reduce input costs associated with feed is beneficial for cow/calf producers. Two research experiments were conducted to evaluate the effect of post-weaning development systems in beef heifers. In Exp. 1 heifers were developed on corn residue (CR), or dry lot (DL). Heifers developed in DL had increased BW after winter treatment until breeding. Both heifer groups were similar in percent of heifers cycling, AI conception, AI pregnancy, and final pregnancy diagnosis. A subset of AI pregnant heifers were blocked by weight and stratified by winter development system and individually fed using a Calan Gates System to measure individual feed intake. Heifers developed on CR, although lighter, had similar ADG and feed efficiency compared to DL heifers. Excess pregnant heifers were assigned to graze CR during late gestation based on previous heifer development. Late gestating heifers developed on corn CR had similar ADG compared to heifers developed in DL.

Similarly, Exp. 2 evaluated the effect of heifers grazing dormant winter range (WR) or grazing CR during post-weaning development. Heifers developed on CR were similar in ADG and BW throughout winter development and breeding. Reproductive performance indicated a similar percent of heifers cycling and final pregnancy diagnosis between groups. A portion of pregnant heifers was blocked by weight and assigned to graze one of three corn residue fields in late gestation based on previous heifer development. Late gestating heifers developed on CR had similar ADG compared to heifers developed on WR.

In summary, these experiments provide evidence to support development of heifers on dormant winter forage systems without sacrificing reproductive performance, feed efficiency, and ADG during late gestation.

# DEDICATION

I dedicate this thesis to,

my loving wife,

Brooke,

who has always loved, encouraged, and helped, during grad school and life's many trials and tribulations.

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First, I would like to thank my Father in Heaven who has led me by the hand and help me overcome the challenges I have faced.

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## Table of Contents

## List of Tables

**Impact of beef heifer development system on average daily gain, reproduction, and feed efficiency**



**Effect of heifer development system on growth, reproduction, and adaptation to corn residue during first pregnancy**

# INTRODUCTION

Currently Nebraska develops approximately 300,000 heifers annually. Heifer development systems have focused on a systems approach in Nebraska in order to measure overall productivity and sustainability. The sustainability and profitability of cow-calf operations is largely dependent on development of replacement heifers, which includes input costs associated with feed. Given the average cow-calf producer spends nearly 60% of annual costs on feed, heifer development usually requires two entire production cycles before a return on investment, in the form of a weaned calf, is recognized.

Increasing feed prices have resulted in cattle producers seeking alternative feed sources that will meet nutritional requirements during development and maintenance of heifers and cows. Many alternative feeds are by-products, co-products, or residual products, from industries processing various commodities, and consequently represent low cost feed sources. According to the Nebraska Corn Board in 2011, approximately 10 million acres were planted to corn in Nebraska, estimating production of 1.5 billion bushels. Because corn is produced in high volume in Nebraska, corn residue (CR) is readily available and considered a low quality feed alternative for ruminant animals in the winter time. For example, Adams et al. (1996) indicated an economical advantage to cattle grazing CR compared to feeding harvested forages during winter months. However, additional protein supplementation is needed for sustained CR grazing periods.

These alternative feeds are currently being incorporated into feeding programs as either primary roughage or supplemented into a regular ration. However, strategic management of weaned heifers fed low cost feed is required for optimal growth,

reproductive performance, and long term production in a cow herd. Traditional heifer development strategies depended upon feeding high levels of processed corn to heifers, leading to increased BW and body condition at time of breeding. In 2004, Funston and Deutscher reported heifer BW could be reduced from 65% to 58% of mature BW without affecting reproductive performance or production. These findings provide evidence that reducing feed quality, along with the input costs associated with heifer development, may improve profitability of replacement heifers without sacrificing production.

## FACTORS IN HEIFER DEVELOPMENT AND REPRODUCTION

### *Preweaning Development*

Maternal milk is a factor affecting the growth and development of heifers prior to weaning (Freking and Marshall, 1992; Fiss and Wilton, 1993; Mallinckrodt et al., 1993). Research has demonstrated weaning BW is positively correlated with age at puberty and AI conception as a heifer, but not final pregnancy rate (Buskirk et al., 1995). Thus, heifer selection at time of weaning has traditionally been based upon characteristics such as BW, body condition, and ADG.

Nutrition prior to heifer weaning is important and may dictate overall production and longevity of replacement heifers. At birth, heifer calves are solely dependent upon maternal milk for nutrients before the transition is made from pre-ruminant to a functional ruminant, which is not an instantaneous process. As calves grow and develop they begin to consume increasing levels of roughage, supplemented with maternal milk. Therefore, energy supplied to young ruminants transitions from glucose provided by milk to increasing levels of volatile fatty acids, which can be measured in the blood and is an indicator of rumen function and development (Quigley et al., 1991).

Excessive fat cover and condition in suckling beef heifers is reported to have lasting impacts on future milk production (Holloway and Totusek, 1973). Swanson (1960) and Holtz et al. (1961) suggested over conditioning in dairy heifers increased accumulation of adipose tissue in the mammary system, therefore decreasing future milk production. Body condition can be impacted by management systems such as creep feeding young suckling heifer calves. Prichard et al. (1989) demonstrated long term creep feeding of heifers to an over conditioned state lead to adipocyte hypertrophy in the mammary system. Hixon et al. (1982) reported creep feeding replacement heifers prior to weaning had negative effects on future milk production.

***Postweaning Development***

Postweaning nutrition impacts the timing of puberty in beef heifers. Crichton et al. (1959) indicated heifers on different planes of nutrition were pubertal at different ages, although relative stage of physical development was similar. Research has indicated age of puberty attained by heifers was decreased when winter nutrition levels were increased (Short and Bellows, 1971). Patterson et al. (1992), provided evidence for a significant negative relationship between age at puberty and length of interval to estrus after parturition. These data suggest heavier heifers at weaning reach puberty at younger ages but often experience longer intervals to estrus after calving, compared to lighter heifers.

Managing a heifer's BW prior to breeding allows for optimal pregnancy rate. Arije and Wiltbank (1971) reported weaning BW and postweaning growth rate influence age and BW at puberty. The target BW for puberty is genetically predetermined and the onset of puberty is dictated by achieving that BW (Robinson, 1990). Because BW is a useful measure to determine the onset of puberty, heifers are often fed to achieve a

certain target BW based on genotype prior to breeding (Greer et al., 1983). However, from a biological point of view, age at puberty is not determined by a specific BW, but by a large array of physiological conditions that result in a given BW (Greer et al., 1983).

Cholesterol entering the mitochondria from the cytoplasm of the cell is commonly referred to as the rate limiting step for steroidogenesis. The product of this step is pregnenolone, a precursor to androgens such as estradiol. If diet is unbalanced for energy or protein, the body will use cholesterol (lipid metabolism) to support physiological functions in the body instead of using it for reproduction. Wiltbank et al. (1969) used high and low nutrition to determine subsequent effect on reproduction and found purebred heifers consuming high nutrition levels entered puberty 191 days before purebred heifers consuming low nutrition. Furthermore, Funston and Larson (2011) used commercial Angus-based heifers to determine effects of high and low nutrition on reproduction. Heifers developed on low levels of nutrition had attained puberty at a lower percentage compared to heifers developed on high levels of nutrition (46% vs. 88%) at time of AI, although heifers had similar final pregnancy rates. In addition to heifer age, these studies indicate nutrition during the postweaning period may impact reproductive efficiency.

After weaning, replacement heifers are required to consume adequate energy for growth and development, which is usually attained by forage and protein supplementation during winter months. Prior to the onset of puberty, increased episodic levels of LH are released due to an escape from low levels of inhibitory estradiol or other gonadal steroids (Moran et al., 1989). The hypothalamic-ovarian axis is the main center responsible for the function and control of the female reproductive tract by these

hormones. Evidence suggests the hypothalamic-ovarian axis is also a site of integration between nutrition and reproduction. For example, nutrient restricted cows exhibit decreased levels of luteinizing hormone (LH) and follicle stimulating hormone (FSH) (Nolan et al., 1988; Richards et al., 1989).

The hypothalamic-axis is driven by pulses of gonadotropin- releasing hormone (GnRH) secreted into the portal system of the median eminence from neurons in various parts of the hypothalamus (Clarke and Cummins, 1982). Pulses of GnRH are required for the synthesis of FSH and LH from gonadotroph cells contained within the anterior pituitary gland. Follicle recruitment, growth, and steroidogenesis are regulated by FSH (Walters and Schallenberger, 1984). The actions of LH consist of maturation of the oocyte within the dominant follicle, ovulation, establishment of the corpus luteum (CL), and luteal and follicular steroidogenesis (Roberson et al., 1989). Synthesis of LH and pulsatile secretion are tightly coupled to GnRH secretion from the hypothalamus. Conversely, FSH secretion increases in two or three waves during the estrous cycle, initiating recruitment of multiple follicles with each surge (Adams et al., 1994; Sunderland et al., 1994). This pattern of FSH secretion is regulated by both endocrine (GnRH) and paracrine (TGFβ family) factors.

Wilmut et al. (1986) explained the function and importance of progesterone for maintaining pregnancy and embryonic development. Progesterone is a compound secreted by CL tissue after ovulation of a dominant follicle. Randel et al. (1971) noted progesterone levels in dairy heifers were higher after the second ovulation compared to the initial ovulation. Shotton et al. (1978) evaluated the effects of progesterone concentration on pregnancy. These reports indicated the first estrus period was inversely

related to pre-pubertal progesterone concentrations, and heifers with increased progesterone levels were less likely to maintain or become pregnant. It has been hypothesized increased progesterone levels may be associated with basal concentrations or secretion from short lived luteal tissue prior to the onset of puberty (Byerley et al., 1987).

In sheep, uterine quiescence occurs for 6 d following fertilization as progesterone initially binds to receptors on the uterus, blocking oxytocin and preventing smooth muscle contractions (Howard et al., 1990). Progesterone is produced by the placenta during gestation in sheep and cattle during the second and third trimester of gestation, although CL tissue may be producing small amounts until parturition.

Prior to puberty, waves of ovarian follicles are growing in the absence of ovulation. During this follicular growth, theca cells secrete the hormone androstenedione, which is subsequently aromatized to 17β-estradiol by mural granulosa cells. Estrogen receptors located in the hypothalamus bind the ovarian-derived 17β-estradiol and inhibits FSH and LH synthesis and secretion. Depending upon the BW and age of the animal, follicles will steadily increase size during the adolescent period resulting in increased synthesis and expression of 17β-estradiol and estrogen receptors, respectively. When follicle size increases from waves of FSH, estrogen levels reach a threshold level to activate the GnRH surge responsible for stimulating the LH surge responsible for ovulation. Estrogen, when bound to its receptor in large concentrations, will continue to increase in amplitude and frequency of LH released into the blood.

***Puberty***

Mayer et al. (2010) hypothesized puberty depends upon coordination of two opposing central mechanisms: restricting GnRH secretion prior to the onset of puberty, followed by increased stimulation of GnRH release allowing complete reproductive maturation during puberty. Furthermore, puberty is a gradual phenomenon rather than an acute and quantitative endocrine event. Prior to attaining puberty, the gonads begin to secrete sufficient steroids to accelerate growth of the genital organs and development of secondary sexual characteristics. These secretions lead to sexual maturity and development of germ cells (i.e. oocytes) capable of fertilization and embryonic development. Rorie et al. (2002) indicates the onset of puberty is dependent on many factors including photoperiod, nutrition, and breed of heifer. Post and Reich (1980) defined puberty, in *Bos indicus* heifers in Australia, as the age at which plasma progesterone levels reaches 1.0 ng/ml. This measurement signifies elevated estrogen levels have increased stimulation of GnRH concentration resulting in synthesis of FSH and finally the LH spike responsible for ovulation. In short, measurement of 1.0 ng/ml within the plasma progesterone of a developing heifer indicates previous ovulation and the onset of puberty.

According to the "critical BW hypothesis," females cannot ovulate until they have accumulated a critical amount of fat relative to lean body tissue (Frisch and Revelle, 1970). This hypothesis has been suggested by evolution, with the need to delay pregnancy until the female has accumulated sufficient energy to sustain offspring. Research has demonstrated leptin, a hormone secreted by adipose tissue, regulates the onset of puberty in rats (Cheung et al., 1997). In addition, Spicer et al. (2001) indicated

leptin signaling stimulates GnRH secretion and the onset of puberty in livestock species. Likewise, the metabolic hormone, kisspeptin also can contribute to the stimulation of GnRH leading to the onset of puberty (Mayer et al., 2010). Finally, signaling by insulin-like growth factor-1 (IGF-1) and growth hormone also stimulates neurons secreting GnRH.

The onset of puberty is also hastened among heifers exposed to bull urine. It has been speculated the onset of puberty was due to priming pheromones present in bull urine, however later studies suggested responsiveness of pheromones was dependent upon heifer BW (Izard and Vandenburg, 1982). Research reported an interaction between growth rate and bull exposure affected the onset of puberty in heifers, where heifers on increased nutrition were more responsive to bull exposure (Roberson et al., 1991). Moreover, bull presence has been reported to stimulate the onset of puberty in some heifers (Berardinelli et al., 1978).

Other methods have been used to successfully induce puberty in heifers. For example, progestin compounds can be used to induce appropriate levels of GnRH, leading to LH synthesis and resulting in ovulation in female ruminants. Multiple studies have demonstrated melengestrol acetate (MGA), an exogenous synthetic compound structurally similar to progesterone, inhibits synthesis of GnRH, thereby changing pulses of FSH and LH from being synthesized and released. Use of MGA in prepuberal heifers has shown to induce puberty (Jaeger et al., 1992). Another method uses a controlled intra-vaginal drug releasing (CIDR) device coated with progesterone to induce puberty in some heifers (Patterson et al., 1990; Imwalle et al., 1998). Exogenous progesterone enhances follicular growth and increases estrogen levels in the blood. Increased estrogen

levels allow for binding to the receptor in the hypothalamus, thereby increasing levels of GnRH. After exogenous progestins have been removed, GnRH synthesis leads to increased levels of FSH and LH, which act directly upon ovarian tissue to generate follicle growth and ovulation of the dominant follicle. These methods lead to the first ovulation and onset of puberty in the heifer.

***Estrous Synchronization***

Synchronization protocols should be selected for heifers based on facilities and management strategy. According to Dziuk and Bellows (1983), synchronization of the estrous cycle can increase the proportion of females conceiving early in the breeding period resulting in a shorter calving season and more uniform progeny. The estrous cycle in ruminants can be separated into two separate phases. The follicular phase includes formation and growth of follicles on the ovary, followed by an LH surge causing the release of an ovum from the dominant follicle. The luteal phase occurs after ovulation and ends upon luteolysis coupled with the initiation of new follicular growth (Niswender et al., 1984). Luteal secretion of progesterone is important for gestation, ovulation of healthy oocytes, maintenance of uterine quiescence, nourishment and survival of embryo/fetus, and normal parturition (McDonald et al., 1952).

The synchronization protocol MGA/PGF is approved for use in heifers (Figure 1). This product was first marketed for use in feedlot heifers to improve feed efficiency and rate of gain by allowing ovarian follicular development while inhibiting estrus and ovulation (Bloss et al., 1966). Administration of MGA for a 14 d period causes the formation of persistent follicles on the ovaries.

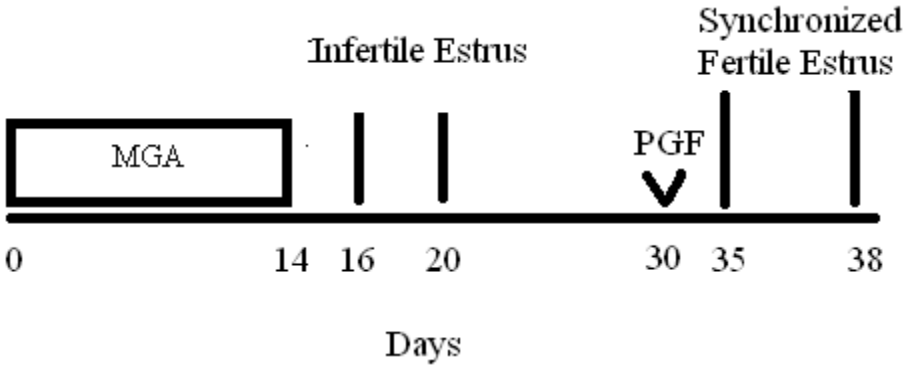


**Figure 1.** MGA-PGF protocol (adapted from Brown et al., 1988; Deutscher, 2000).

After MGA is removed from the diet, GnRH levels are increased with subsequent FSH and LH levels leading to standing heat and ovulation. However, this estrus period should not be utilized for insemination due to low fertility. Inskeep (2004) demonstrated low dose progesterone-like compounds, such as MGA, over an 18 d period caused frequent, small FSH and LH pulses in the cow due to reduced GnRH synthesis in the hypothalamus. This frequency of low FSH/LH secretion causes the formation of persistent follicles on the ovary. These large follicles produce androgens (i.e. androstenedione) and estrogen in high levels, which appears to damage the oocytes contained in the persistent follicles. Oocytes exposed to high levels of estrogen decreased ovum quality, leading to lower conception rates and fertility (Figure 2).

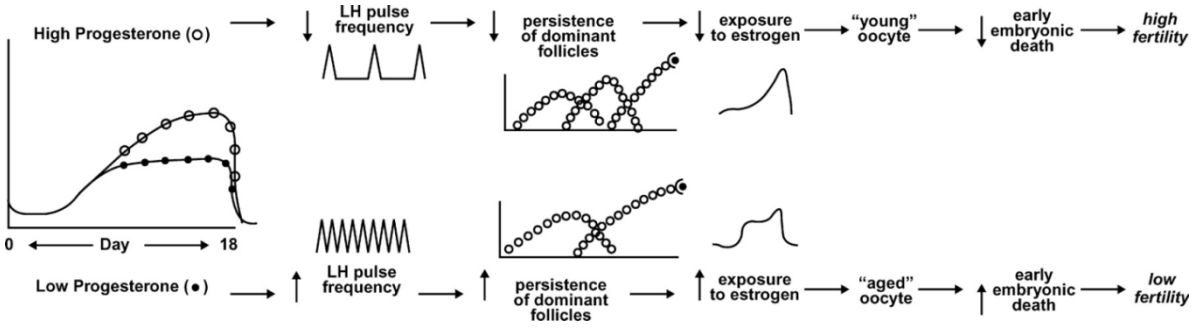


**Figure 2.** Persistent follicles caused by MGA reduce fertility of first estrus period (Inskeep, 2004).

Challenges exist to synchronize heifers with feeding MGA, as delivery and consumption need to be constant. MGA is administered 0.5 mg/head/day and usually mixed with some form of supplementation. Heifers not consuming enough MGA on a daily basis will fail to synchronize correctly. Despite these issues, feeding MGA is an attractive, low-cost synchronization method for replacement heifers compared to other synchronization protocols.

Another synchronization protocol utilizes CIDR technology whereby progesterone is released over time acting upon the reproductive axis. The 14 d CIDR-PG protocol (Figure 3) allows for quiescence of the uterine body as progesterone is inhibiting GnRH secretion in the hypothalamus. Upon CIDR removal and PGF injection, ovulation will occur. Fertile estrus will occur between 30 and 33d in the 14 d CIDR protocol. As mentioned earlier this is an attractive option for synchronizing heifers, although time and labor are increased compared to the MGA/PGF synchronization method.

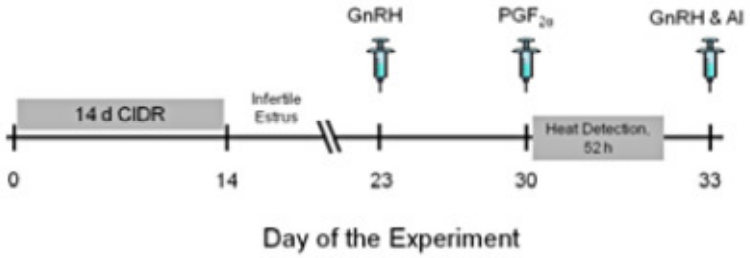


**Figure 3.** 14 d CIDR Select protocol (Bridges et al., 2009).

Synchronization in combination with natural breeding has been evaluated by Plugge et al. (1989), Landivar et al. (1985), and Short et al. (1978). These researchers determined optimal conception rates occurred using a cow to bull ratio of approximately 20 to1. Combining natural breeding and synchronization is also an attractive method for cow-calf producers to reduce calving interval. Research information used to combine these systems was conducted by Britt (1979) who demonstrated CL tissue was not yet responsive to prostaglandin $F_{2\alpha}$ (PG) 96 hrs after ovulation, which prevented luteolysis from occurring. Whittier et al. (1991) demonstrated synchronization with a single PG injection 96 hours after bull introduction increased the number of cows observed in estrus, and increased overall pregnancy rates compared to control cows treated with a saline injection. In addition to these findings, Larson et al. (2009) using a similar procedure as Whittier (1991), indicated a combination of synchronization and natural breeding increased early calving frequency leading to increased steer progeny value. This method is also used in replacement heifers; however an injection of PG will not hasten heifers to achieve puberty.

Artificial insemination (AI) in beef cattle uses the recto-vaginal technique to place 5-10 million viable sperm into the body of the uterus. This process should be performed

12 hrs after standing estrus to maximize fertilization and subsequent pregnancy rates. Although AI technology has been around for decades, it is not widely used in the beef cattle industry with less than 14% of beef cattle herds in the United States using some form of AI. In comparison, the dairy industry greatly utilizes AI breeding. It is estimated 92% of all dairy herds utilize some form of AI within their operation (USDA, 2002). Differences between beef and dairy management such as daily milking, individual lockups, and constant dry lot conditions allow for easier use of reproductive technology. Furthermore, AI technology allowed dairy breeders to select genetically superior sires to improve milk yield. Incentive for use of AI technology diminishes in beef cattle production, compared to alternative natural mating due to several critical factors including time, labor, facilities, and return on investment.

***Breeding and Gestation***

The challenge for a heifer is to conceive at 14-15 months of age, allowing for first calving by 24 months (Arije and Wiltbank, 1971; Short and Bellows, 1971; Ferrell, 1982). Cattle producers are encouraged to breed heifers three to four weeks prior to breeding the main cattle herd (Corah and Hixon, 1999). Calves born earlier in the calving season tend to have increased weaning BW. Finally, this process allows ample opportunity to rebreed after first parturition, a critical step in determining overall production and longevity of a heifer.

After ovulation of the dominant follicle, the oocyte migrates into the oviduct where fertilization takes place. After fertilization occurs, the male and female pronuclei fuse together in a process known as syngamy. This leads to the complete formation of the genome for the developing conceptus (Palmero et al., 1997). Rapid cellular division

begins after fertilization leading to the first cleavage division during the blastomere stage. Embryonic cells continue to divide and the zygote enters the uterus on day 3, as an 8-cell embryo. In order for pregnancy to be maintained luteolysis must be prevented. In the absence of pregnancy, oxytocin modulates PG secretion initiating luteolysis (Kotwica et al., 1999). If conception has occurred, luteolysis is inhibited by the developing blastocyst, which produces a protein referred to as bovine trophoblast protein 1, or interferon τ (Senger, 2003). Interferon τ acts upon the endometrial cells of the uterus inhibiting oxytocin receptors and therefore hindering synthesis of PG. Interferon τ also stimulates the production of proteins that provide nourishment for the developing blastocyst (Senger, 2003).

Embryonic loss is a major economic loss to the beef industry. Early embryonic death (EED) has been defined by the Committee of Reproductive Nomenclature (1972) as embryo death occurring between fertilization and time of cell differentiation. Roche et al. (1981) reported embryonic loss was most prevalent during the first 16 days of gestation. Dunne et al. (2000) found embryonic loss to be decreased after day 14; indicating embryonic loss is due to embryo/ovum quality. Initial heifer fertilization rates in a research setting were between 80 to 90%. Measurement of developing embryos 42 days after breeding showed only 60% of embryos were viable (Henricks et al., 1971; Diskin and Sreenan, 1980; and Roche et al., 1981).

Maternal-fetal interactions in ruminants occur within the placentome, which form during early gestation. The placentome is composed of maternal (caruncular regions of the uterus) and fetal (cotyledonary placenta) regions acting together in order to exchange metabolic nutrients and transfer waste. Nutrient transportation to the fetus is dependent

upon vascularization and blood flow of the uterus and placenta. Thus, fetal growth rates are dependent on placental size and nutrient transfer capacity, which together directly influence birth BW (Reynolds et al., 1985; Vonnahme et al., 2001; Vonnahme and Ford, 2004). Perry et al. (1999) indicated nutrient restriction during the first trimester of gestation, followed by protein supplementation during the second trimester of gestation, enhanced placental development.

Using mature cows, Khireddine et al. (1998) either restricted feed to 70% of nutritional requirements three weeks prior to breeding or fed a supplemented diet. On day 21 of gestation, supplemented cows had increased pregnancy rates compared to those who remained on diet restriction (100% vs. 20%). These findings indicate a positive effect between nutrition and embryo survival prior to breeding and during early stages of implantation and development. In agreement, prior research conducted by Short and Bellows (1971) indicated nutrient restricted heifers had a 10% increase in early embryonic death (EED) compared to heifers fed moderate to high levels of nutrition during winter months.

***Epigenetic Regulation and Maternal Nutrition***

Epigenetics is commonly defined as heritable changes in gene expression that occur without a change in DNA sequence (Kouzarides, 2007). Epigenetic differences suggest organisms with identical DNA sequences can be influenced by molecular factors causing expression of different phenotypes within a species. Current research indicates epigenetic differences during gestation and development can have a significant impact on offspring phenotype.

DNA methylation represents a direct epigenetic modification, and also one of the best characterized modifications to chromatin. The methylation of the 5' position of cytosine preceding a guanosine (also referred to as CpG) is performed by a member of the DNA methyltransferase family (Joss-Moore et al., 2010). Research (Martin, 2005; Wu et al., 2006) indicates methylation of DNA causes conformational changes in chromatin. In addition, methylation of CpG islands contained within the promoter region of DNA directly inhibits transcription factors from binding; therefore, suppressing gene expression. Histone proteins, which contain long amino acid tails, are the structure for DNA strands to wrap around. How tight or loose the DNA is wrapped is dependent on the charge of histone proteins, which can be changed by the addition or removal of modifying groups (e.g. methyl, acetyl, or phosphate groups) to the histone tails. The conformational changes in the chromatin induced by histone proteins result in different transcriptional activity by RNA polymerase, due to association of different activating or inhibitory factors.

Epigenetic-dependent regulation of gene expression is partly responsible for the differences seen when gestating cattle are supplemented with protein, resulting in pronounced growth or increased carcass quality in the offspring (Larson et al., 2009). Additions of methyl groups to DNA are cleaved from the amino acid methionine, which is consumed in the diet. Wu et al. (2006) demonstrated addition of methyl groups to DNA was derived from the methyl donor S-adenosylmethionine (SAM). During the process, active methyl donation occurs when methionine is consumed in the diet or formed by homocysteine being re-methylated by methyltetrahydrofolate, yielding two products, tetrahydrofolate and methionine (Figure 4). Methionine then binds to ATP, yielding SAM

and acts as a methyl donor for a DNA substrate acceptor. After the methyl group is donated, S-Adenosylhomocysteine is created, and then reduced into adenosine and homocysteine. This cycle is dependent upon the folate cycle (B, Figure 4) where important vitamins such as $B_{12}$ and $B_6$ are used in the creation of methyltetrahydrofolate and tetrahydrofolate. The folate cycle is essential to close the SAM cycle and allows methionine to be available for production of SAM (Cognitive Enhancement Research Institute, 1996).

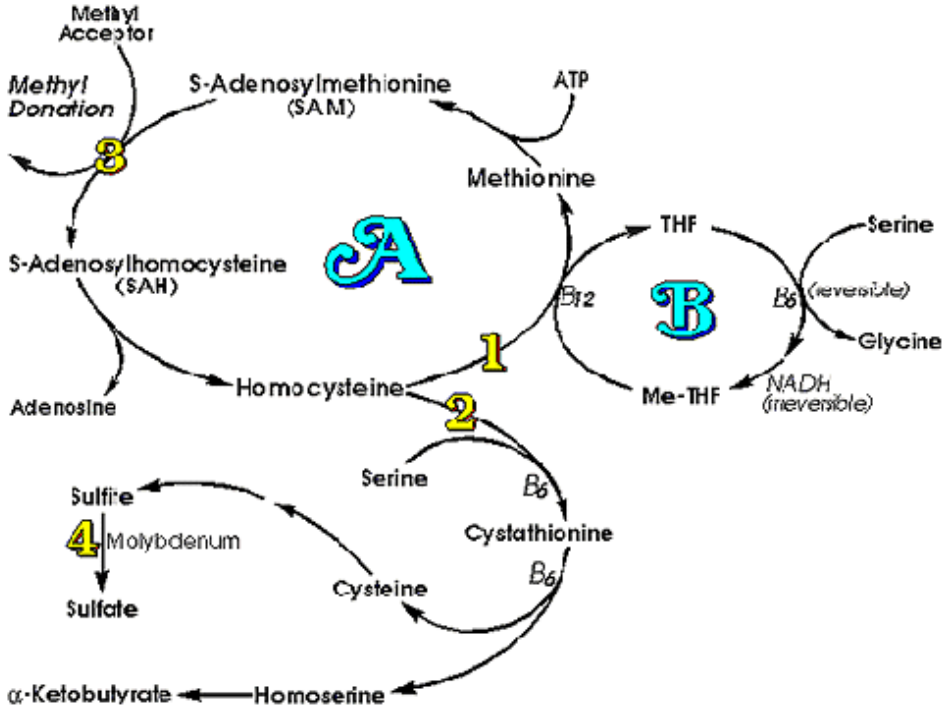


**Figure 4.** Methyl donation by SAM (Cognitive Enhancement Research Institute, 1996).

Gene regulation and modification occurring during gestation allows fetal tissue to adapt to a broad spectrum of conditions that may optimize fetal survival during gestation. Therefore, management of replacement heifers begins in utero with proper maternal

nutrition during gestation. Cow/calf operations usually supplement with varying amounts of CP, due to reduced quality of winter forages. This supplementation allows net energy requirements to be met for maintenance, gestation and lactation. Research has suggested protein supplementation during the last trimester of gestation impacts live offspring with increased immune response, carcass quality, and postweaning growth (Larson, et al., 2009).

Research conducted by Funston et al. (2010) showed cows receiving protein supplementation during late gestation gave birth to heifer progeny, which exhibited an increased percent cycling during the first breeding season, compared to heifers from cows not receiving supplement. In addition, Martin et al., (2007a) reported dams receiving maternal protein supplementation during gestation gave birth to heifer progeny more likely (77%) to calve within the first 21 d of the calving season, compared to non-supplemented dams (49%). Pregnancy data indicated heifer offspring of dams supplemented with protein had increased pregnancy rates compared to offspring of non-supplemented dams (93% vs. 80%). This research demonstrated protein supplementation can impact offspring reproductive performance. Maternal nutrition was evaluated by Gunn (1997) using the sheep model. Ewes fed to nutritional requirements during late gestation resulted in offspring with increased ovulation rate and lambs born, compared to progeny of nutrient restricted ewes. Furthermore, nutrient restriction during gestation in ewes reduced Sertoli cell numbers and testicular volume at birth (Alejandro et al., 2002). Thus it appears protein supplementation and nutrient restriction impact future progeny reproductive performance.

***Protein Supplementation***

Absorption of nutrients in the digestive system of ruminants is different for degradable intake protein (DIP) and undegradable intake protein (UIP); however both proteins are required for physiological functions in beef cattle. Protein is the first limiting nutrient when cattle are grazing dormant forage (Wallace, 1987). In addition, Fernandez-Rivera et al. (1989) found CP was the first limiting factor for developing animals while grazing CR.

Supplementation with UIP has been used in recent years to complement the supply of microbial protein to the duodenum in heifers during gestation and lactation (Straunch et al., 2001). Typically TDN values for UIP supplements range from 75 to 100%. There is some evidence where UIP supplementation hinders reproductive function. For example, Lalman et al., (1993) demonstrated fewer heifers supplemented with high levels of UIP displayed estrus at time of breeding compared to unsupplemented control heifers. In fact, heifers supplemented with high UIP exhibited a 20 d increase in age at puberty. However, pregnancy rates were not different between heifer groups.

In contrast, Martin et al. (2007b) utilized 316 spring born heifers randomly assigned and blocked by BW to consume a supplement composed of dried distillers grains (DDG) high in UIP or consume a control diet (dried corn gluten, whole corn germ, urea). Final BW, ADG, BCS, age at puberty, and synchronization rates were not affected by high UIP levels supplemented in the diet. However, AI conception rates (75% vs. 53%) and final pregnancy rates were increased in DDG heifers compared to the control group. Increased reproductive performance may be due to source of UIP supplementation. Prior to the use of ethanol byproducts for the livestock industry, animal

byproducts were used to supplement UIP. Perhaps the source of UIP provided by plant-based DDG increased reproductive performance.

Supplementation of UIP has been shown to increase feed intake and digestibility when consuming low quality forage (Owens et al., 1991). However, research conducted by Sletmoen-Olson et al. (2000) detected no differences in body BW or body condition score in high UIP supplemented cows when compared to control cattle. Thus a standard was created suggesting greater than 70g/day of UIP does not provide any advantage to beef cattle when DIP is adequate.

***Winter Development Systems***

Multiple research studies have reported postweaning development of heifers during the winter months can impact age at puberty. Lynch et al. (1997) reported heifers restricted 47 or 56 days prior to breeding were not negatively impacted in reproductive performance, but reduced the amount of feed consumed. Freetly et al. (2001) demonstrated limiting total energy intake, thereby reducing ADG, had no negative effect on calving rate, age at calving, postpartum interval, and subsequent pregnancy, although limit-fed heifers exhibited a decrease in offspring survival.

Variations in weather, time, and grazing management impact nutrient uptake for cattle, particularly during winter conditions. Corn and other crop residues offer an economic feed source for beef cattle production systems in the Midwest (Ward, 1978; Klopfenstein et al., 1987; Strohbehn, 1990). Excessive nutrient loss during winter months greatly influences the availability and quality of corn residue (Lamm and Ward, 1981; Gutierrez-Ornelas and Klopfenstein, 1991). Russell et al. (1993) found utilization of CR

during winter months was heavily dependent upon weathering losses, whereas 20 to 31% of organic matter was lost over a 56 d period.

Grings et al. (1998) developed heifers in two groups: grazing pasture re-growth for 56 d followed by dry lot development or developed only in a dry lot. Heifers developed on pasture re-growth had decreased ADG during that period; however were similar in BW, percent cycling prior to breeding, and conception rate compared to heifers developed in a dry lot. In a similar study (Marston et al., 1995), heifers developed in a dry lot reached puberty 29 days earlier than heifers developed on pasture with protein supplementation, although similar growth rates existed between heifer groups. Finally, pregnancy diagnosis and resulting age at first parturition were similar between groups. These experiments provide evidence development system can influence heifer reproduction. In addition, heifers grazing dormant winter forage may experience compensatory gains when dietary quality increases, which has been linked to alterations in IGF-1 secretion (Yambayamba et al., 1996).

***Compensatory Growth***

Compensatory growth is defined as rapid growth occurring after a period of feed restriction. Clanton et al. (1983) demonstrated delaying heifer growth until the last half of the developmental period, and upon realimentation, delayed heifers had similar conception rates compared to control heifers. Feed restriction is associated with increased GH levels and lower levels of IGF-1 (Breier and Gluckman, 1991). Upon diet realimentation no differences were detected in IGF-1 levels, although more BW was acquired in the restricted heifers during the realimentation period. In explanation for these hormone levels, Van den Brande (1986) had previously proposed low IGF-1 levels

during the restriction period could lead to increased tissue sensitivity possibly resulting in rapid tissue growth. Breier and Gluckman (1991) postulated animals consuming low nutrition feeds enhanced uncoupling of IGF-1 to its binding protein, reducing growth responses. This hormone can have multiple effects on growth and metabolism in beef heifers and appears to be correlated with economically important traits, such as residual feed intake (RFI; Johnson et al., 2002).

***Feed Efficiency***

Net feed efficiency or RFI is defined as the difference between an animal's actual feed intake and its expected feed intake required for maintenance and growth. Coined by Koch et al. (1963), RFI is considered an alternative feed efficiency trait, independent of growth. To calculate RFI, an estimated value for DMI consumption is subtracted from the actual amount of DMI consumed. Efficient animals that eat less than expected have a negative or low RFI, while inefficient animals that eat more than expected have a positive or high RFI. Regulation of feed intake and efficiency by animals involves a complex set of biological processes and metabolic pathways influenced by numerous management and environmental factors (Almeida et al., 2007).

Traditional attempts to improve feed efficiency have used the gain to feed ratio (G:F). However, since G:F is related to growth traits of an animal, selection for this ratio alone will ultimately lead to larger cattle (Herd and Bishop, 2000). Increasing mature size will directly impact the feed cost associated with maintenance of that animal and potentially reduce profitability for cattle producers. Calculating RFI overcomes the issue of increased BW by focusing on predicted DMI value subtracted from actual DMI consumption. Cattle exhibiting increased feed efficiency should be identified and utilized

to aid beef producers in achieving sustainability and increasing profitability. In addition, Basarab et al. (2003) reported feed efficiency is influenced by factors such as body composition, genotype, physiological state, and nutrition.

Kelly et al. (2010) used crossbred beef heifers in a study designed to determine the relationship between efficiency and metabolic hormones. The results concluded a positive; however, weak, interaction between IGF-1 and ADG. There was no interaction between IGF-1 and DMI, RFI, or feed conversion between crossbred heifers. Thus, research evidence portrays animal efficiency is not dictated by levels of IGF-1.

Cow size may influence feed efficiency, although many other factors may alter efficiency, one of them being animal behavior. Golden et al. (2008) conducted a study to measure the relationship between feeding behavior and feed efficiency in beef steers. Steers that spent less time at the feed bunk during the day, typically were more efficient. These findings suggest eating behavior may play some role in feed efficiency.

***Grazing Behavior and Social Interactions***

Grazing behavior has been documented in cattle by Vanzant et al. (1991), indicating pregnant heifers, prior to calving, spent less time grazing compared to non-pregnant heifers. Moreover, Putnam and Bond (1971) reported pregnant cows in dry lot conditions spent less time eating compared to non-pregnant cows with similar distribution throughout the day, one month prior to calving. It is not clear if this feeding behavior was associated with appetite or associated with pregnancy. However, anecdotal evidence suggests heifers may learn to graze CR from heifers previously developed on CR (Larson and Funston, 2009). In addition, a behavioral grazing study indicated lambs learn what to eat from their mothers and prefer those feeds after weaning (Nolte and

Provenza, 1992; Thorhallsdottir et al., 1990). In addition to these findings, Provenza et al. (1993) reported lambs also learn what not to eat from their mothers and exhibit low preference when given alternatives to feed or forage lambs are accustomed to eating. Hence, animals learn what to eat, in a foreign environment, from their contemporary group.

***Heifer Economics***

The economic component of heifer development is important with respect to feed expenses, which account for 60 to 65% of total heifer development costs. Funston and Larson (2011) developed heifers using CR as alternative low quality forage, comparing it to dry lot (DL) development. Reducing heifer development in DL by 135 d reduced development cost prior to breeding by $42/heifer. Developing heifers using low quality feed/forage alternatives typically reduces BW prior to breeding, but does not negatively impact reproductive performance. Funston and Deutscher (2004) reported reducing breeding BW from 58% to 53% of mature BW, saved $22 in development/feed costs per heifer. In complement to these findings, Martin et al. (2008) developed heifers to 50% of mature BW prior to breeding and reduced input cost by $24 /heifer compared to heifers developed to 55% of mature BW. Postweaning heifer development cost may be reduced by extending grazing. Thus it appears non-traditional utilization of winter range or crop residue may reduce expenses associated with heifer development without diminishing performance. History has determined the cattle industry is a break-even enterprise (Fuez and Umberger, 2003). Dramatic differences in development costs are apparent between high and low cost producers. Reducing amount of harvested feeds for heifer development one month prior to breeding and during late gestation may reduce development cost and

increase return on investment. However, reducing feed inputs for developing heifers is not feasible or profitable if reproduction is not maintained (Davis et al., 1994).

## SUMMARY/OBJECTIVES

Development of replacement heifers through the winter period has traditionally been costly for producers. Cost of heifer development increases by feeding high quality harvested forage, with no return on investment until first offspring is marketed. Corn is grown throughout the Midwest. After harvest, CR can be utilized as a grazing resource for cattle during the winter. Extending the winter grazing system for heifer development may allow cattle producers to decrease feed cost associated with replacement heifers prior to first calving season. However, heifers developed on dormant forage require some form of protein supplementation to achieve modest gains. Limited research has been conducted with standing winter forage compared to dry lot development. Development using dormant winter forage reduces animal growth without compromising reproductive performance. Research has linked reduced BW to smaller organ mass, possibly increasing feed efficiency. Improved feed efficiency may allow for greater profitability by reducing feed requirements. Limited research has evaluated how heifer development system affects feed efficiency, thus additional research is needed to establish development factors associated with feed efficiency.

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

### Objectives

- Evaluate the reproductive response to postweaning heifer development systems during winter months (corn residue, winter range, or dry lot).

- Determine the effects of postweaning heifer development on subsequent feed efficiency and average daily gain during late gestation.
- Compare average daily gain grazing corn residue, based on previous development on corn residue or dry lot and winter range in late gestation.

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# Chapter 1:

## Impact of postweaning beef heifer development system on average daily gain, reproduction, and feed efficiency

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**ABSTRACT:** A three year study was conducted using 299 weaned, crossbred Angus heifers to evaluate traditional dry lot **(DL)** development compared to grazing corn residue **(CR)** and winter range **(WR)**. Heifers were blocked by BW and randomly assigned to one of two treatments: graze WR then placed in a DL (248 ± 4 kg), or graze WR, then graze CR (247 ± 4 kg) followed by WR. The following year, a subset of heifers pregnant by AI from each year (yr 1 = 40; yr 2 = 38, yr 3 = 40) were stratified by BW and winter development system and randomly assigned to pens and individually fed during late gestation to determine feed intake. Heifers assigned to DL had similar ADG and BW compared to heifers assigned to CR, after grazing WR. However, prebreeding (350 vs. 313 ± 9 kg; $P = 0.02$) and breeding BW (374 vs. 350 ± 12 kg; $P = 0.03$) were greater for DL compared to CR. Percent of heifers cycling pre-breeding, AI conception, AI pregnancy, and overall pregnancy rates were similar ($P \geq 0.43$) between treatments. Individually fed heifers developed on CR had similar DMI, ADG, and G:F compared to DL heifers ($P = 0.32$) in late gestation. Final BW of CR (493 ± 3 kg) was lower ($P = 0.03$) than DL (503 ± 3 kg) approximately one month prior to calving. These data indicate heifers developed on CR have decreased ADG and BW prior to breeding; however are similar to DL developed heifers in reproductive performance. Thus,

extending winter grazing during post-weaning development reduces input costs for developing heifers without sacrificing reproductive performance.

**Keywords**: beef cattle, heifer reproduction, low-quality forage

## INTRODUCTION

Increasing harvested feed costs have producers seeking alternative feed resources for heifer development. Grazing resources such as crop residue and dormant winter range allow cattle producers to reduce input costs associated with heifer development, although heifers consuming lower quality nutrients tend to have reduced BW. Traditional targeted BW for heifer development is 60 to 65% of mature BW at time of first insemination (Short and Bellows, 1971; Patterson et al., 1992). Current research reports developing heifers to 53-58% of mature BW at time of breeding had no negative effect on conception or pregnancy rates (Funston and Deutscher, 2004; Martin et al., 2008). In addition, decreased BW has been linked to improved feed efficiency in cattle. Jenkins et al. (1986) reported lighter cows have reduced liver mass, and cows with improved feed efficiency tend to have smaller liver mass (DiCostanzo et al., 1991). The impact of heifer development system on subsequent feed efficiency has not been well established. Therefore, the objective of this study was to evaluate the effect of post-weaning development systems using corn residue compared to traditional dry lot development on reproductive performance and feed efficiency in beef heifers.

## MATERIALS AND METHODS

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

A 3 year study was conducted at the University of Nebraska West Central Research and Extension Center, North Platte, Ne., to evaluate heifer development system on subsequent reproductive performance and feed efficiency. Each year commercial crossbred Angus heifers (yr 1 = 100, yr 2 = 99, yr 3 =100) were purchased from local cattle producers. After a receiving period, weaned heifers were blocked by BW and randomly assigned to one of two developmental treatments: graze winter range (WR) then corn residue (CR) followed by WR; or graze WR and then fed in dry lot (DL). Heifers were briefly developed at WCREC grazing upland range and then distributed to treatment groups. In yr 1, CR heifers grazed WR for 26 d, grazed CR for 92 d, followed by WR for 60 d; in yr 2 heifers grazed WR for 47 d, grazed CR for 77 d, followed by WR for 61 d; and in yr 3 heifers grazed WR for 58 d, grazed CR for 60 d, followed by WR for 69 d. The CR fields (40 ha) were planted in April and harvested in October. Average annual corn yield and ear residue data was not available. Grazing rate was 2.5 heifers/ha per year based on previous research (Funston and Larson, 2011). Heifers received 0.45 kg/d protein cube (28% CP; DM basis) for the duration of CR and WR grazing. The supplement consisted of: 62% dried distillers grains plus solubles, 11% wheat middlings, 9% cottonseed meal, 5% dried corn gluten feed, 5% molasses, 3% calcium carbonate, and 2% urea on a DM basis (Table 1). The supplement provided 80 mg animal /d monensin (Rumensin, Elanco Animal Health, Indianapolis, IN) with vitamins and trace minerals to meet heifer requirements. Heifers assigned to DL grazed WR for 75 d in yr 1 followed by 103 d in DL; in yr 2 grazed WR for 97 days followed by 88 d in DL; and in yr 3 grazed WR for 118 d followed by 69 d DL feeding. Heifers in DL were offered a diet formulated to target 65% of mature BW (600 kg) at breeding. Individual feed intake for DL heifers

was 7.6 kg/d (DM basis). Diet for DL heifers, on a 3 yr average, was composed of: 9% wet corn gluten, 6% corn silage, 80% brome hay, and 4% supplement (Table 2). Diets were provided in the morning for DL heifers once daily.

Each yr blood samples were collected two times, 10 d apart, prior to estrus synchronization. Blood was collected in vacuum tubes using coccygeal venipuncture, cooled on ice, and centrifuged at 2,500 × g. Serum was isolated and stored at -20° C until analysis. Serum progesterone assays were carried out without extraction (Melvin et al., 1999) using a direct solid-phase RIA (Coat-A-Count, Diagnostics Products Corp., Los Angeles, CA). Heifers with progesterone concentrations ≥ 1.0 ng/ml were considered to have reached puberty (Henricks et al., 1971).

Prior to breeding, CR and DL heifers were managed together in a dry lot with a common diet for 50 d. Estrus was synchronized with melengestrol acetate **(MGA)** administered for 14 d at 0.5 mg/hd. Nineteen days following the completion of MGA supplementation heifers were injected i.m. with 5 ml of $PGF_{2\alpha}$ (**PGF**; Lutalyase, Pfizer Animal Health, New York, NY). Estrotect patches (Estrotect, Rockway Inc., Spring Valley, WI) were used to aid detection of standing estrus for a 5 d period. Heifers were artificially inseminated 12 hr after standing estrus. Heifers were exposed to bulls (1 bull to 50 heifers) for 60 d beginning 10 d post AI. Pregnancy was determined using transrectal ultrasonography 45 d after AI to determine AI conception, and final pregnancy rate 45 d after bull removal. Non-pregnant heifers were removed from the study and sold at market price. Pregnant heifers were managed in one group on mixed upland range for the remaining grazing period.

A subset of AI pregnant heifers (yr 1 = 40; yr 2 = 38, yr 3 = 40) were used to measure individual ADG and DMI to determine feed efficiency during late gestation. Heifers pregnant by AI were selected to reduce variation in stage of gestation. Heifers were stratified by BW and winter development system (CR, 431 ± 3 kg; DL, 444 ± 3 kg) into pens and individually fed in a Calan Broadbent feeding system (American Calan Inc., Northwood, NH). In year 1, heifer diets contained 90% grass hay (11 % CP; DM basis) and 10% supplement , which was composed of a mixture of wet distiller's grains plus solubles (DDGS) and straw (21.8 % CP; DM basis). Years 2 and 3, heifers received ad libitum grass hay and one of three supplement treatments: no supplement, a DDGS-based supplement, or a dried corn gluten feed supplement. Corn germ was added to the corn gluten supplement to ensure supplements were isonitrogenous (29% CP, DM basis) and isocaloric, but different in undegradable intake protein (UIP).

Individual feeding started with a 25 d adaptation period, followed by approximately 80 d test period. Feed offered was recorded daily and feed refusals were measured and recorded weekly with BW measured every 14 d. Pregnant DL and CR heifers not entering the individual feeding system were managed together on upland grass during gestation until CR became available for winter grazing.

*Economic Evaluation*

Cost of grazing for weaned heifers was estimated to be one half of mature cow cost based on heifer BW at weaning. Average daily cost for weaned CR heifers grazing during the winter and spring period was estimated to be $0.46/hd, including supplement cost. Heifers developed on CR were shipped approximately 100 km to CR fields. Total shipping cost of heifers to and from CR fields was $20/hd. Daily cost of grazing WR with

supplement and DL feeding calculated to be $0.75/hd. Cost for grazing heifers in central Nebraska during the summer on upland grass was estimated to be $0.55/hd (Johnson et al., 2010). Additional development cost including feed delivery costs, estrus synchronization, breeding costs, and health/veterinarian costs were assessed to be $0.36/d. Purchase and cull prices were determined using USDA market prices reported by Overturf and Mark (2010). Net cost of one pregnant heifer was calculated using the formula developed by Feuz (1992). 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 at breeding, to determine the total cost of one heifer. Lastly, the total development cost was then divided by the final pregnancy rate, to determine the total net cost on one pregnant heifer.

*Statistical Analyses*

Data were analyzed using PROC MIXED and GLIMMIX procedures of SAS (SAS Inst. Inc., Cary, NC). Since heifers were developed utilizing 2 different treatments, replicated for 3 years (n = 3). Year was included in the model as a random effect and considered the experimental unit for heifer performance, calving data, and economic analysis; with the effect of development treatment nested within yr. Individual feed efficiency analysis included yr and pen in the model as a random variable using the random statement over the three yr trial. Differences in means separated by LSD were declared different at $P \leq 0.05$.

## RESULTS AND DISCUSSION

Heifer treatment groups were similar in ADG and BW during initial winter grazing ($P \geq 0.38$; Table 1). During the DL period, DL heifers had higher ADG compared

to CR heifers ($P < 0.01$). In addition, BW was greater for DL heifers and remained greater ($P = 0.05$) through second ultrasound. These differences in ADG and BW may be attributed to the limited amount of CP in the CR diet. Fernandez-Rivera et al. (1989) reported CP is the first limiting factor for developing cattle grazing CR. Heifers developed in DL had increased BW due to increased levels of nutrients provided (Table 2).

Number of heifers cycling between groups was similar ($P = 0.43$) prior to first breeding. Although BW was less at time of breeding for CR heifers there was similar ($P \geq 0.58$; Table 3) AI conception, AI pregnancy, and overall pregnancy rates compared to DL heifers. Synchronization using MGA/PGF did not appear to impact reproductive outcome as there were similar percent cycling prior to breeding. However, MGA/PGF synchronization has shown to induce the onset of puberty in non-cycling females (Jaeger et al., 1992).

Heifers developed on CR had similar ($P \geq 0.32$, Table 4) DMI, ADG, G:F, and residual feed intake compared to DL heifers. Heifers developed on CR had reduced ($P = 0.03$) BW one month prior to calving compared to DL heifers, however, calving ease score was similar ($P \leq 0.2$, Table 5) between treatment groups. Remaining pregnant heifers managed together on winter range and grazed CR in late gestation had similar ($P = 0.15$) BW one month prior to calving and calving ease score ($P = 0.45$; Table 6).

Heifers developed on CR prior to breeding had reduced ($P < 0.01$, Table 7) prebreeding feed cost by $31/hd compared to DL heifers. In agreement with these findings, Funston and Larson (2011) reduced heifer development cost by $42/hd by limiting development on harvested feed and utilizing dormant winter forage. Developing

heifers on dormant winter forage prior to breeding can reduce development costs without sacrificing heifer performance.

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**Table 1.** Nutrient supplement and forage analysis for heifers grazing corn residue

| | DM % |
|---|---|
| Supplement [1] | 7 |
| Dried distillers grain plus solubles | 62 |
| Wheat middlings | 11 |
| Cottonseed meal | 9 |
| Dried corn gluten feed | 5 |
| Molasses | 5 |
| Calcium carbonate | 3 |
| Urea | 2 |
| Other | 3 |
| Corn Residue | 93 |
| | |
| Nutrient Composition | |
| Crude Protein, % | 8.5 |
| UIP, % CP | 32.3 |
| Crude Fat, % | 2.5 |
| $NE_g$, Mcal/kg | 0.53 |

[1]Provided 80 mg $animal^{-1}d^{-1}$ monensin (Rumensin, Elanco Animal Health, Indianapolis, IN).

**Table 2.** Composition of diet provided to dry lot heifers from February to May

| | Year | | |
|---|---|---|---|
| Item (DM basis) | 1 | 2 | 3 |
| Brome hay, % | 77 | 69 | 71 |
| WCGF[1], % | 7.5 | 16.7 | 15.2 |
| Corn Silage, % | 11 | 0 | 0 |
| Cracked Corn, % | 0 | 10.2 | 9.2 |
| Supplement[2], % | 4.5 | 4.1 | 4.2 |
| Intake, kg/d | 7 | 7.8 | 8.5 |
| Nutrient Composition[3] | | | |
| CP, % | 10.5 | 11.9 | 11.7 |
| UIP, %CP | 22.6 | 22 | 22 |
| Crude Fat, % | 2.4 | 2.8 | 2.7 |
| $NE_g$, Mcal/kg | 0.39 | 0.46 | 0.45 |

[1]Wet corn gluten feed.

[2]Ground corn, calcium carbonate, trace mineral mix, and vitamin mix, formulated to provide 200 mg monensin (Rumensin, Elanco Animal Health, Indianapolis, IN).

[3]Wet Chemistry, Ward Laboratories Inc., Kearney, NE; RUP based on NRC (2000).

**Table 3.** Effect of winter heifer development system on growth and reproductive performance

| | Treatment[1] | | | |
|---|---|---|---|---|
| | DL | CR | SEM | *P*-value |
| n | 150 | 149 | | |
| Initial BW, kg | 248 | 247 | 4 | 0.81 |
| Dec-Feb ADG[2], kg | 0.19 | 0.10 | 0.12 | 0.47 |
| BW after winter grazing, kg | 264 | 254 | 14 | 0.38 |
| Feb-April ADG[3], kg | 1.02 | 0.51 | 0.10 | 0.05 |
| Prebreeding BW, kg | 330 | 287 | 11 | <0.01 |
| April-June ADG[4], kg | 0.49 | 0.69 | 0.10 | 0.29 |
| Breeding BW, kg | 350 | 313 | 9 | 0.02 |
| June-July ADG[5], kg | 0.47 | 0.75 | 0.09 | 0.08 |
| First ultrasound BW, kg | 370 | 350 | 12 | 0.03 |
| Aug-Sept ADG[6], kg | 0.76 | 0.82 | 0.09 | 0.08 |
| Final pregnancy BW, kg | 421 | 402 | 7 | 0.05 |
| Cycling, % | 68 | 52 | 12 | 0.43 |
| Synchronization, % | 89 | 91 | 3 | 0.60 |
| Conceived to AI, % | 67 | 71 | 6 | 0.66 |
| Pregnant to AI, % | 60 | 65 | 6 | 0.58 |
| Final pregnancy rate, % | 93 | 93 | 2 | 0.86 |

[1]DL = heifers grazed winter range then fed in dry lot; CR = heifers grazed corn residue then grazed winter range.

[2]ADG while grazing CR or grazing WR.

[3]ADG between winter development and prebreeding.

[4]ADG between prebreeding and breeding.

[5] ADG between breeding and first ultrasound.

[6]ADG between first ultrasound and final pregnancy diagnosis.

**Table 4.** Effect of winter heifer development system on individual ADG and feed efficiency in pregnant heifers during 80 d feeding period

| | Treatment[1] | | | |
|---|---|---|---|---|
| | DL | CR | SEM | *P*-value |
| n | 60 | 58 | | |
| Initial BW, kg | 444 | 431 | 3 | <0.01 |
| Final BW, kg | 503 | 493 | 3 | 0.03 |
| ADG, kg | 0.68 | 0.72 | 0.02 | 0.52 |
| DMI, kg | 10.3 | 10.2 | 0.1 | 0.42 |
| G:F | 0.06 | 0.07 | 0 | 0.32 |
| RFI[2], kg | -0.29 | -0.27 | 0.04 | 0.76 |

[1]DL = heifers grazed winter range then fed in dry lot; CR = heifers grazed corn residue then grazed winter range.

[2]Residual Feed Intake = Predicted DMI – Actual DMI.

**Table 5.** Effect of heifer development system on calving data for individually fed heifers

| | Treatment[1] | | | |
|---|---|---|---|---|
| | DL | CR | SEM | *P*-value |
| n | 60 | 58 | | |
| Heifer calving BW, kg | 503 | 493 | 3 | 0.03 |
| Calf Julian birth date, d | 60 | 57 | 0.7 | 0.20 |
| Calf birth BW, kg | 33 | 32 | 0.6 | 0.52 |
| Calving ease score[2] | 1.3 | 1.4 | 0.1 | 0.50 |
| Death loss, % | 10 | 12 | 5 | 0.73 |

[1]DL = heifers grazed winter range (70 d) then fed in dry lot (90 d); CR = heifers grazed corn residue (75 d) then grazed winter range (90 d).

[2] Dystocia score was defined as 1 = no assistance, 2 = easy pull, 3 = hard pull, 4 = cesarean section, and 5 = abnormal presentation.

**Table 6.** Effect of postweaning heifer development system on calving data for heifers grazing corn residue during late gestation

| | Treatment[1] | | | |
|---|---|---|---|---|
| | DL | CR | SEM | *P*-value |
| n | 137 | 135 | | |
| Heifer calving BW, kg | 475 | 464 | 6 | 0.15 |
| Calf Julian birth date, d | 70 | 68 | 1.8 | 0.57 |
| Calf birth BW, kg | 34.2 | 32.4 | 0.4 | 0.67 |
| Calving ease score[2] | 1.2 | 1.3 | 0.1 | 0.45 |
| Death loss, % | 7.8 | 8.1 | 2 | 0.94 |

[1]DL = heifers grazed winter range (70 d) then fed in dry lot (90 d); CR = heifers grazed corn residue (75 d) then grazed winter range (90 d).

[2] Dystocia score was defined as 1 = no assistance, 2 = easy pull, 3 = hard pull, 4 = cesarean section, and 5 = abnormal presentation.

**Table 7.** Economic analysis for dry lot and corn residue development systems from heifer weaning to breeding

| | Treatment[1] | | | |
|---|---|---|---|---|
| | DL | CR | SEM | *P*-value |
| Initial weaned value, $/heifer | 500 | 501 | | |
| Treatment feeding cost[2], $/heifer | 137 | 84 | 1.7 | <0.01 |
| Total feeding cost, $/heifer | 205 | 152 | 0.8 | <0.01 |
| Total development cost[3], $/heifer | 849 | 816 | 46 | <0.01 |
| Cull Heifer Value, $/heifer exposed | 64 | 57 | 14 | 0.68 |
| Net Cost for 1 pregnant heifer, $ | 846 | 815 | 49 | <0.01 |

[1]DL = heifers grazed winter range (70 d) then fed in dry lot (90 d); CR = heifers grazed corn residue (75 d) then grazed winter range (90 d).

[2]Feed cost for the winter and spring period prior to breeding.

[3]All fixed and variable cost associated with initial heifer price, feed, estrus synchronization and breeding, and feed delivery.

# Chapter 2:

## Effect of heifer development system on average daily gain, reproduction, and adaptation to corn residue during first pregnancy

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**ABSTRACT:** The effect of post weaning development system was evaluated at two locations in a 3 year study to determine subsequent reproductive performance, post-weaning ADG, and ADG during late gestation. Heifers were blocked by BW and randomly assigned to graze corn residue **(CR)** and winter range **(WR)**, graze WR continually through development, or graze WR then placed in dry lot **(DL)**. A combination of AI and natural mating was used at time of breeding based on location. Pregnant heifers were assigned to one of three corn residue fields in late gestation based on previous post-weaning development. Post-weaning BW and ADG for CR were similar to WR after winter grazing. Percent cycling prior to breeding and final pregnancy rates were similar among treatments. A subset of pregnant heifers from each treatment were blocked by BW and assigned to graze one of three CR fields based on previous heifer development system. Heifers developed on CR had similar ($P \geq 0.41$) ADG during late gestation compared to WR and DL heifers. By extending the post-weaning grazing period and reducing development on harvested feeds, feed expenses for developing replacement heifers was reduced. Grazing heifers on low quality forage for extended periods during winter grazing is a suitable heifer development strategy.

**Key words**: beef cattle, heifer development, low-quality forage

## INTRODUCTION

Developing replacement heifers on dormant forage, such as corn residue (**CR**) or winter range (**WR**) is less expensive than feeding harvested forage. Dormant winter forage is low in nutrient quality (NRC, 2000) and may reduce animal performance including decreased BW. Fernandez-Rivera and Klopfenstein (1989) determined naïve cattle require an acclimation period for grazing CR. In addition, heifers grazing dormant winter forage may experience compensatory gains when diet quality increases, which has been linked to alterations of IGF-1 (Yambayamba et al., 1996). Heifers restricted at the beginning of post-weaning development, after diet realimentation, had similar conception rates compared to non-restricted heifers (Clanton et al., 1983). Effects of post-weaning heifer development systems on standing dormant winter forage and subsequent adaptation to CR during late gestation have not been well established. The objective of this study was to evaluate the effect of winter grazing systems on ADG and reproductive performance and to determine the effects of winter development system on subsequent adaptation to CR in late gestation.

## MATERIALS AND METHODS

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

Red Angus × Simmental composite heifer calves (n = 287) at Gudmundsen Sandhills Laboratory **(GSL)** near Whitman, Ne., were used to determine effect of post-weaning management on ADG and reproduction. After weaning, heifers were blocked by BW (218 ± 4 kg) and randomly assigned to two winter treatments, graze CR or WR for approximately 95 d (Table 1). Heifers assigned to CR were transported approximately

150 km to corn residue fields, whereas WR heifers were developed at GSL. Both treatment groups were offered 0.45 kg/d protein supplement (28% CP) composed of 62% dried distillers grains plus solubles, 11% wheat middlings, 9% cottonseed meal, 5% dried corn gluten feed, 5% molasses, 3% calcium carbonate, and 2% urea on a DM basis (Table 2). The supplement contained 80 mg/.45 kg monensin (Rumensin, Elanco Animal Health, Indianapolis, IN) and vitamins and trace minerals to meet heifer requirements during winter grazing. After winter treatment heifers were managed similarly on summer pasture, and then grazed mixed upland pastures at GSL for 100 d before breeding. The upland grass pastures at GSL are predominantly composed of little bluestem [*Andropogon scoparius* (Michx.) Nash], prairie sandreed [*Calamovilfa longifolia* (Hook.) Scribn.], sand bluestem (*Andropogon hallii* Hack.), sand lovegrass [*Eragrostis trichoides* (Nutt.) Wood], and blue grama [*Bouteloua gracillis* (H.K.B.) Lag. Ex Griffiths] (Adams et al., 1998).

Each yr, two blood samples were collected 10 d apart prior to breeding to determine cycling status. Blood was collected using coccygeal venipuncture then cooled on ice and centrifuged at 2,500 × g. Next, serum was removed and frozen at -20° C until analysis. Serum progesterone assays were completed without extraction (Melvin et al., 1999) and progesterone concentrations determined by direct solid-phase RIA (Coat-A-Count, Diagnostics Products Corp., Los Angeles, CA). Heifers with progesterone serum levels measuring ≥ 1.0 ng/ml were considered pubertal (Henricks et al., 1971).

Estrus was synchronized with a single 5 ml i.m. injection of $PGF_{2\alpha}$ (**PGF**; Lutalyse, Pfizer Animal Health, New York, NY) administered 108 hr after bulls were exposed to heifers. Bulls were placed with heifers (1 bull to 25 heifers) for 45 d. During

the breeding season heifers grazed summer Sandhills range until pregnancy diagnosis. A subset of pregnant heifers (n = 148) were blocked by BW and assigned to one of three CR pivots based on previous development: a naïve group composed of only WR heifers, a group previously developed on CR after weaning, and a mixture from each treatment. Heifers grazing CR in late gestation were supplemented (0.45 kg/day; 28% CP) three times weekly. Each year pregnant heifers grazed CR an average of 76 d, based on CR availability. Body BW was measured and recorded at the beginning and end of CR grazing.

In addition, weaned, Angus cross heifers (n = 159) from the West Central Research and Extension Center **(WCREC)**, North Platte, Ne. grazed CR and WR or WR and then placed in a dry lot **(DL)** during winter development. Heifers were fed melengestrol acetate (0.5 mg/d) for 14 days followed by a 5 ml PGF injection on day 33. Heat detection and AI were performed until d 38, followed by bull exposure for 60 d. A subset of pregnant heifers were also blocked by BW and assigned to one of three CR fields during mid to late gestation, based on previous winter development: DL heifers naïve to grazing CR (447 ± 9 kg; n = 53), CR heifers previously developed on CR (446 ± 9 kg; n = 52), and a mixture of heifers from both systems (442 ± 9 kg; n = 54). Pregnant heifers were transported to CR fields as dictated by CR availability and weather conditions (yr 1 = 77 d; yr 2 = 60 d; yr 3 = 86 d). Supplement (Table 2) was offered 3 times weekly at an equivalent of 0.45 kg/d (28% CP). BW was recorded at the beginning and end of CR treatment. The same three corn fields were utilized for heifers from GSL and WCREC during late gestation.

*Economic Evaluation*

Cost of winter and summer grazing for heifers was estimated to be 75% of mature cow grazing cost. Average price for weaned heifers grazing CR and WR was calculated to be $0.46/d. Transportation cost for CR heifers was $0.10/loaded km, and heifers were shipped approximately 150 km to CR fields. Daily grazing cost for summer upland grass was calculated by Johnson et al. (2010) at $0.55/d. Additional development costs including feed delivery costs, breeding costs, health and veterinarian costs were charged at $0.36/d. Heifer purchase and cull prices were based on USDA market prices reported by Overturf and Mark (2010). Net cost of one pregnant heifer was calculated using the formula developed by Feuz (1992). 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 one pregnant heifer. Total development cost was divided by the final pregnancy rate to determine the total net cost of one pregnant heifer.

*Statistical Analysis*

Data were analyzed with SAS (SAS Inst. Inc., Cary, NC). Heifers were developed at two different locations. At each location, two development systems were used and replicated for 3 years (n = 3). Heifer ADG and BW was analyzed using PROC MIXED, and reproductive data analyzed with PROC GLIMMIX. Experimental unit was year, with heifer development treatment analyzed as the fixed effect. Additionally, year was also included as a random variable. Differences in data were considered significant at $P \leq 0.05$.

## RESULTS AND DISCUSSION

Historically, beef cows in the Nebraska Sandhills have been wintered grazing dormant forage or fed harvested feed. In the last 20 years corn production has increased by more than 15% (USDA-NASS, 2011). In the current study, heifers grazing CR had similar ADG and BW during winter treatment, compared to WR heifers ($P \geq 0.11$; Table 3). Perhaps, differences in BW were not apparent due to similar CP values in both dormant winter forages (Table 1). Heifers grazing CR or WR had similar ADG, BW, percent cycling before breeding season, and pregnancy rate ($P \geq 0.31$, Table 3). Hence, increased corn production can provide residue as a substitute winter feed resource similar to historic winter range development.

Cost of winter grazing and total feeding cost was similar (P= 0.84; Table 4) between groups, as cost of grazing WR and CR were similar. Cost of shipping heifers to CR fields increased total development cost of CR by $30/hd, compared to WR heifers remaining at GSL. Thus, developing heifers on CR may be a suitable development alternative to WR, without compromising ADG and reproductive performance. However, grazing CR may incur additional costs, reducing the profitability of grazing heifers on CR.

In late gestation, heifers developed on WR naïve to grazing CR had similar ($P$ = 0.41) ADG and BW compared to heifers previously developed on CR (Table 5). In addition, the mixture of heifers from each development system was also similar ($P$ = 0.41) in ADG compared to WR and CR heifers. Thus, developing heifers postweaning on dormant WR may not impair animal performance in late gestation when heifers graze CR. Heifer ADG during CR grazing in late gestation were not different, perhaps due to

similar postweaning development CP values. During the calving season there were no differences ($P \geq 0.45$) in calving ease or calf birth BW, between heifers developed on WR or CR (Table 6).

Post-weaning ADG and reproductive performance for DL and CR heifers are reported previously in Chapter 1 (Impact of post-weaning beef heifer development system on average daily gain, reproduction, and feed efficiency). Heifer adaptability to CR was measured using ADG in late gestation for DL and CR heifers (Table 7). Heifers previously developed on CR had a twofold ADG increase, compared to naïve heifers previously developed in DL; however, neither ADG nor final BW were different (P = 0.42). No differences in birth BW, calving ease, and calf vigor were observed when comparing heifers developed on CR vs. heifers developed in DL (Chapter 1, Impact of post-weaning beef heifer development system on average daily gain, reproduction, and feed efficiency, Table 6).

In the present study grazing heifers on WR and CR during the postweaning period resulted in successful development. These findings agree with previous research from our group that CR and WR are an acceptable source of winter forage for mature, lactating, and pregnant cows (Stalker et al., 2006; Larson et al., 2009; Funston et al., 2010). Utilization of low cost winter forage may represent a management strategy for heifer development to minimize feed costs prior to breeding.

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**Table 1.** Nutrient analysis of corn residue and winter range during postweaning heifer development

| | CP, % | RUP, % | Intake, kg/d |
|---|---|---|---|
| Corn residue[1] | 6.5 | 31.0 | 6.43 |
| Upland winter range[1] | 4.7 | 37.0 | 6.43 |

[1]National Research Council values (NRC, 2000).

**Table 2.** Nutrient analysis of supplement provided to heifers grazing corn residue

| | DM % |
|---|---|
| Supplement [1] | 7 |
| Dried distillers grain plus solubles | 62 |
| Wheat middlings | 11 |
| Cottonseed meal | 9 |
| Dried corn gluten feed | 5 |
| Molasses | 5 |
| Calcium carbonate | 3 |
| Urea | 2 |
| Other | 3 |
| Corn Residue | 93 |
| | |
| Nutrient Composition | |
| Crude Protein, % | 8.5 |
| UIP, % CP | 32.3 |
| Crude Fat, % | 2.5 |
| $NE_g$, Mcal/kg | 0.53 |

[1]Provided 80 mg animal$^{-1}$d$^{-1}$ monensin (Rumensin, Elanco Animal Health, Indianapolis, IN).

**Table 3.** Effect of post weaning heifer development on ADG and reproductive performance

| | Treatment[1] | | | |
|---|---|---|---|---|
| | CR | WR | SEM | *P*-value |
| n | 144 | 143 | | |
| Initial BW, kg | 218 | 220 | 4 | 0.56 |
| Dec. - Feb. ADG[2], kg | 0.22 | 0.30 | 0.06 | 0.21 |
| BW after winter grazing, kg | 237 | 244 | 6 | 0.11 |
| Feb. - April ADG[3], kg | 0.46 | 0.37 | 0.07 | 0.14 |
| Spring BW, kg | 274 | 279 | 4 | 0.36 |
| April - June ADG[4], kg | 0.52 | 0.47 | 0.05 | 0.18 |
| Breeding BW, kg | 287 | 289 | 3 | 0.40 |
| June - Sept. ADG[5], kg | 0.73 | 0.74 | 0.07 | 0.84 |
| Pregnant BW, kg | 354 | 358 | 2 | 0.38 |
| Cycling, % | 52 | 46 | 6 | 0.31 |
| Pregnant, % | 85 | 86 | 2 | 0.80 |
| Pregnant BCS | 5.8 | 5.8 | 0.02 | 0.46 |

[1]CR = heifers developed on corn residue; WR= heifers developed on winter range.

[2]ADG while grazing CR or WR.

[3]ADG between winter development and prebreeding.

[4] ADG between prebreeding and breeding.

[5] ADG between breeding and pregnancy diagnosis.

**Table 4.** Economics of grazing winter range or corn residue

| | Treatment[1] | | | |
|---|---|---|---|---|
| | WR | CR | SEM | P-value |
| Initial weaned value, $/heifer | 523 | 526 | | |
| Treatment feeding cost[2], $/heifer | 84 | 84 | 0.5 | 0.96 |
| Total feeding cost, $/heifer | 135 | 135 | 0.4 | 0.98 |
| Total development cost[3], $/heifer | 744 | 775 | 26 | <0.01 |
| Cull Heifer Value, $/heifers exposed | 114 | 126 | 12 | 0.49 |
| Net Cost for 1 pregnant heifer, $ | 732 | 768 | 29 | 0.01 |

[1]WR = heifers grazed winter range (180 d); CR = heifers grazed corn residue (75 d) then grazed winter range (105 d).

[2]Feed cost for the winter and spring period prior to breeding.

[3]All fixed and variable cost associated with initial heifer price, feed, breeding, feed delivery, and supplement.

**Table 5**. Effect of heifer development on winter range or corn residue on animal performance during corn residue grazing as pregnant heifers*

| | Treatment[1] | | | | |
|---|---|---|---|---|---|
| | WR | CR | MIX | SEM | *P*-value |
| n | 51 | 50 | 47 | | |
| Initial BW, kg | 387 | 387 | 382 | 7 | 0.75 |
| Final BW, kg | 414 | 420 | 409 | 9 | 0.41 |
| ADG, kg | 0.36 | 0.42 | 0.35 | 0.1 | 0.41 |
| BCS | 5.1 | 5.3 | 5.2 | 0.1 | 0.24 |

[1]WR = heifers grazed winter range that were naïve to grazing CR; CR = heifers who had previously grazed corn residue; MIX = mixture of heifers from CR and WR treatments.
*Heifers developed at Gudmundsen Sandhills Laboratory, Whitman, NE.

**Table 6.** Effect of postweaning heifer development system on calving characteristics

| | Treatment[1] | | | |
|---|---|---|---|---|
| | WR | CR | SEM | *P*-value |
| n | 75 | 72 | | |
| Heifer Calving BW, kg | 412 | 417 | 9 | 0.50 |
| Calf Julian Birth Date, d | 70 | 70 | 1.4 | 0.90 |
| Calf Birth BW | 30 | 30 | 0.5 | 0.83 |
| Calving Ease[2] | 1.3 | 1.4 | 0.0 | 0.45 |
| Sex, % male | 45 | 56 | 5 | 0.34 |

[1]WR = heifers grazed winter range (180 d); CR = heifers grazed corn residue (75 d) then grazed winter range (105 d).

[2] Dystocia score was defined as 1 = no assistance, 2 = easy pull, 3 = hard pull, 4 = cesarean section, and 5 = abnormal presentation.

**Table 7.** Effect of dry lot or corn residue heifer development system on ADG and BW during corn residue grazing as pregnant heifers*

| | Treatment[1] | | | | |
|---|---|---|---|---|---|
| | DL | CR | MIX | SEM | *P*-value |
| n | 53 | 52 | 54 | | |
| Initial BW, kg | 439 | 434 | 441 | 9 | 0.81 |
| Final BW, kg | 448 | 452 | 452 | 14 | 0.94 |
| ADG, kg | 0.12 | 0.24 | 0.12 | 0.14 | 0.42 |

[1]DL = heifers developed in dry lot that were naïve to grazing CR; CR = heifers who had previously grazed corn residue; MIX = mixture of heifers from CR and DL.

*Heifers developed at West Central Research and Extension Center, North Platte, NE.