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Beef Cattle Management Systems for Estrus Synchronization and Heifer Development

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Beef cattle management systems for estrus synchronization and heifer development

by

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Four experiments were conducted to evaluate estrus synchronization and heifer development systems. In the first experiment delaying AI 19 h following GnRH administration in a hybrid estrus detection and time AI protocol was evaluated. Final pregnancy rate was not different among heifers detected in estrus, AI at the time GnRH administration, or delayed AI. The second study compared the effect of melengestrol acetate (MGA) -PG and 14-d controlled internal drug release (CIDR) -PG estrus synchronization protocols on estrus response and pregnancy rates of 311 d old heifers. Final pregnancy rate was similar between CIDR and MGA treatment groups. The objective of the third study was to determine the impact of heifer development system on subsequent growth and reproductive performance in 2 breeding seasons. Heifers were offered ad libitum meadow hay (HAY) and 1.81 kg/d (29% CP, DM basis) supplement or allowed to graze meadow (MDW) and 0.45 kg/d supplement. Although ADG during the winter feeding period was greater for HAY heifers, BW was similar between treatments in the spring, summer, and at pregnancy diagnosis suggesting a compensatory growth effect for MDW heifers. Similarly, pubertal status or pregnancy rate was not different, indicating a lower input winter management system is viable to maintain heifer pubertal status and pregnancy rates in 2 breeding seasons. Finally, to determine the impact of heifer development system on pregnancy rates and feed efficiency as a pregnant first calf heifer a 3 yr study was conducted. In Yr 1, weaned heifers either grazed corn residue

(CR) or were fed in a drylot (DLHI). In Yr 2 and 3 heifers either grazed CR, upland range (RANGE), or were fed diets differing in energy, high (DLHI) or low (DLLO), in a drylot setting. Pregnancy rates to AI were similar among treatments. A subset of AI-pregnant heifers from each treatment were placed in a Calan gate system. Intake did not differ among treatments, either as DMI or as a percentage of BW.

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Introduction

Heifer development is key to the success of the beef industry. A productive cow herd provides a continuous supply of beef and as mature cows age and become less productive it is imperative that a steady supply of replacements be available to fill the place of culled cows. Cost effective heifer development resulting in optimal pregnancy rates allows producers to continue producing beef. There are many tools available to producers to improve reproductive performance in both heifers and the cow herd, including estrus synchronization and artificial insemination (AI). However only 8% of US beef producers utilize estrus synchronization and/or AI (USDA, 2009), even though the benefits of AI are well established- maintaining fewer bulls and the opportunity to utilize superior genetics for a fraction of the cost. Estrus synchronization also provides numerous benefits to producers- a more uniform calf crop, shortened calving season, tighter calving distribution, more calves born early in the calving season, causing anestrus animals to resume or begin cyclic activity. In combination with AI, estrus synchronization allows producers to consolidate the labor and time required into only a few days.

Another management tool available to producers is cost effective heifer development. The recent expansion of cost effective heifer development strategies can aid beef producers, these strategies can reduce inputs without compromising reproductive performance. Each beef producer has a unique set of resources available to them. The most cost effective method for each producer depends on their resources. There are many options in heifer development strategies, allowing producers to utilize a system that works in their specific scenario to attain an optimum number of pregnancies in a cost effective manner.

This review of literature will begin with a discussion of the estrous cycle, which will aid in understanding the attainment of puberty. Next the ways in which puberty can be advanced in heifers will be evaluated. Once the critical threshold of puberty has been attained, the mechanisms of estrus synchronization will be reviewed next. A discussion of heifer development as a system, where a single decision may impact many aspects of the system, will follow. Finally, by approaching heifer development with a systems mindset, producers can incorporate economics into their decision process.

Estrous Cycle

As with any complex physiological system, the cow's estrous cycle is best understood by first examining the individual mechanisms, hormones, in relation to the cycle and then combining the individual hormones to make sense of the entire system. In all examples ovulation occurs on d 1. The bovine estrous cycle is typically discussed in 2 phases, luteal and follicular. The luteal phase lasts 14 to 18 d, is characterized by the formation of the corpus luteum (CL), and is divided into metestrus and diestrus. The follicular phase lasts 4 to 6 d and marks the time period following the regression of the CL before ovulation; this phase is further differentiated by proestrus and estrus. A cow's estrous cycle is approximately 21 d, but can lie anywhere between 18 and 24 d.

Progesterone

Progesterone is secreted by the CL. Progesterone concentrations are low 2 d before and 3 d following ovulation, with a gradual increase observed beginning on d 4 and reaching a plateau on d 10 (Figure 1; Schams et al., 1977; Wettemann et al., 1972).

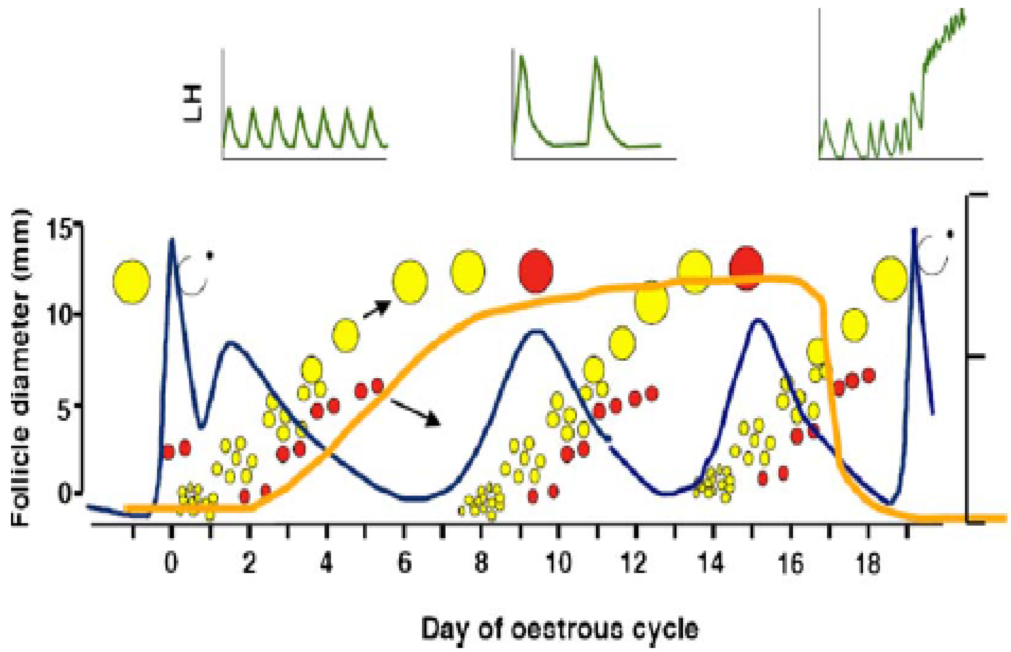

Figure 1. Illustration of the estrous cycle of the cow depicting the growth of healthy follicles (yellow) and atretic follicles (red) followed by ovulation on d 1. Concentration of FSH (blue) rise and fall with follicular development. Progesterone concentration is depicted in orange. The pattern of LH secretion during an 8 h time period is shown above for the early luteal, mid luteal, and follicular phases of the estrous cycle. (adapted from Forde et al., 2011)

Metestrus is defined as the formation of the CL from the collapsed ovulated follicle (Forde et al., 2011). As the CL grows, small and large luteal cells produce progesterone to prepare for pregnancy or a new estrous cycle, thus progesterone concentrations increase.

Estrogen

Estrogen concentrations increase beginning on d 19, during the follicular phase, and reach a maximum on d 20 (Schams et al., 1977; Wettemann et al., 1972). Estradiol is secreted by the granulosa cells of the dominant follicle on the ovary; as the follicle grows it produces an increasing amount of estradiol (Forde et al., 2011). When the elevated estradiol concentration coincide with the decreasing progesterone concentrations following luteolysis of the CL it triggers a surge in GnRH (Forde et al., 2011).

Gonadotropin Releasing Hormone (GnRH)

GnRH is a decapeptide that comes from the hypothalamus and acts on the anterior pituitary via the hypophyseal portal blood system to induce production of FSH and LH (Forde et al., 2011). When progesterone levels are low and LH pulses have occurred for 2 to 3 d every 40 to 70 minutes the dominant follicle will ovulate (Roche, 1996).

Luteinizing hormone (LH)

Basal concentrations of LH are present from ovulation to d 5, increased concentrations are seen from d 6 to 10, with below basal levels from d 11 to 13 and increasing again thereafter resulting in a pre-ovulatory surge in LH on d 20 (Schams et al., 1977). Schams et al. (1977) observed the pre-ovulatory LH peak occurring a few hours after observation of estrus, lasting a mean time of 7.4 ± 2.6 h. LH is secreted by the anterior pituitary. Figure 1 depicts LH secretion during 8 h windows for the early luteal, mid luteal, and follicular phase. The early luteal phase is characterized by frequent, low amplitude LH pulses. The mid luteal phase has less frequent, but higher amplitude LH pulses. The follicular phase has increased frequency of pulses which build up to an LH surge.

Follicle stimulating hormone (FSH)

Schams et al. first reported a wavelike function to the concentration of FSH in 1977, noting peak concentrations on d 4, 8, 12-13, 17, 18, and 20; furthermore, they observed enhanced follicular growth coinciding with these FSH peaks. Figure 1 demonstrates increased FSH concentration immediately prior to follicular growth. Like LH, FSH is secreted from the anterior pituitary. Schams et al. (1977) noticed a FSH peak on d 18 coinciding with the decrease in progesterone and proposed these opposite trending concentrations might induce final follicular growth.

Follicular waves

Follicular growth during the bovine estrous cycle nearly always occurs in a 2 or 3 wave pattern. (Adams, 1999). Figure 1 depicts a 3 wave estrous cycle. These waves are characterized by a synchronous growth of small follicles for about 4 d, when one follicle becomes the dominant follicle, continuing to grow, while the remaining follicles undergo atresia. Most cows and heifers have a non-alternating pattern (consistently having only 2 waves or only 3 waves); 70% non-alternating compared with 30% alternating (Jaiswal et al., 2009). This indicates a cow is likely to be consistent as either having a 2 or 3-wave follicular pattern. Furthermore older animals were more consistent than younger heifers, with 82% of the older cows in the study having a non-alternating pattern compared with 63% of the younger heifers (Jaiswal et al., 2009). The variability in the number of waves of follicular growth helps account for the variability between cow estrous cycle lengths.

Discussion of the Ovary

Controlled primarily by FSH, LH, and their respective receptors, the ovary is a complex organ undergoing constant change. The ovary hosts 2 or 3 follicular waves in each estrous cycle. Each wave is characterized by the recruitment of a cohort of follicles and selection of a single dominant follicle to continue growth while the remaining follicles undergo atresia (Berisha and Schams, 2005). After the pre-ovulatory LH surge, changes termed luteinization occur in the theca interna and granulosa cells of the preovulatory follicle leading to the formation of the CL. Normal CL development depends on blood flow and the growth of new blood vessels from existing ones, angiogenesis (Berisha and Schams, 2005).

Prostaglandin (PG)

Prostaglandin is naturally produced by the uterus (Forde et al., 2011). Regression of the CL, in the event the cow is not pregnant, is induced by PG. Sensing the absence of a developing embryo the endometrium secretes PG around d 17 to 19 of the estrous cycle (Sharasuna et al., 2012).

In summary, the hypothalamic-pituitary-gonadal (HPG) axis in the mature cow functions in a somewhat linear fashion with GnRH produced from the hypothalamus acting on the anterior pituitary to stimulate the production of LH and FSH, which act on the ovary. Follicles on the ovary develop and grow, producing more and more estrogen; estrogen feeds back positively on the hypothalamus to produce more GnRH. Upon ovulation of the follicle, the CL is formed and secretes progesterone, which has a negative feedback effect on the hypothalamus to inhibit stimulation of the gonadotropins.

Puberty

Establishment of puberty is the cornerstone of a females' lifetime productivity. Heifers that conceive and give birth to their first calf by 24 mo of age are more productive the rest of their lives (Cushman et al., 2014). Thus a heifer must become pregnant at 15 mo of age. Bridges et al. (2014) observed increased pregnancy rates in heifers having attained puberty prior to initiation of synchronization compared with their non-pubertal counterparts. Although historical data states a heifer's pubertal estrus is less fertile than her third estrus (Byerley et al., 1987), our more recent research found no difference in pregnancy rates between heifers who conceived on their first, second or third estrus (Vraspir, 2014). Regardless, a heifer *must* attain puberty to become pregnant.

Prior to the onset of puberty the HPG axis is controlled by negative feedback of estradiol from the ovary. Estradiol binds to its receptor in the hypothalamus, eliciting a negative effect on neurons that secrete kisspeptin. As puberty approaches, the number of estradiol receptors in the hypothalamus decreases, resulting in a potential increase in kisspeptin, effecting an increase in GnRH and thus increasing LH and FSH levels (Atkins et al., 2013). In 1998, Day and Anderson understood the hypothalamus was responding differently to estradiol pre- and post-puberty. They attributed this to structural modification of LHRH (later called GnRH) neurons (Day and Anderson, 1998).

Kisspeptin and the corresponding G protein receptor GPR54 are vital to the establishment of puberty; rodents with the gene for either kisspeptin or GPR54 removed do not go through puberty, indicating a serious role being played in the attainment of puberty (Han et al., 2005). Moreover, when kisspeptin is centrally administered, a strong GnRH response is seen, further demonstrating the key role of kisspeptin in the HPG axis (Han et al., 2005). The intensity of such a response is dependent upon age. In juvenile mice, about 25% of GnRH neurons respond to kisspeptin administration compared with about 50% in prepubertals and greater than 90% in adult mice (Han et al., 2005). In the mouse, expression of kisspeptin in the RP3V, a specific area of the hypothalamus, is nearly nonexistent at birth with a gradual increase up to puberty onset when expression takes on a pulsatile movement coinciding with cyclicity (Clarkson et al., 2010).

An amino acid transmitter, GABA, γ-aminobutyric acid, also plays a critical role in the establishment of puberty. GABA has been found to have a depolarizing effect on GnRH neurons in immature female mice, while having the inverse effect in mature mice, hyperpolarizing GnRH neurons (Hans et al., 2002). This conclusion indicates during puberty in the mouse a switch occurs, where prior to puberty GABA acts as a stimulant on GnRH secretion and in turn LH secretion. Following puberty, GABA would act in an inhibitory fashion in the mouse.

In beef heifers, the importance of estradiol feedback on LH secretion has been documented. Gasser et al. (2006d) demonstrated this by comparing 3 groups of heifers, 1) those with intact ovaries and two groups of ovariectomized heifers, 2) one group with an exogenous estradiol source, and 3) one without. Heifers with intact ovaries had very low levels of LH secretion, as did ovariectomized heifers, but receiving supplemental estradiol. Heifers with no ovaries or exogenous estradiol, however, had dramatically more frequent LH pulses (Gasser et al., 2006d). The presence of estradiol clearly has a negative impact on LH pulses in pre-pubertal heifers.

Day and Anderson (1998) documented decreasing negative estradiol feedback as estradiol levels in the heifer increased. As puberty progresses, follicle diameter increases, estradiol secretion increases, estradiol negative feedback decreases, and GnRH and LH pulse frequency increases. Immediately prior to puberty estradiol feedback becomes positive, as it will remain throughout the remainder of the heifer's life. At puberty, estradiol secretion drops, there is an LH surge, and ovulation occurs (Day and Anderson, 1998).

Often GnRH is presented as the first hormone in the HPG axis, eluding to its importance. Gonadotropin releasing hormone is important in the sense that without it the cascade of reproductive hormones comes to a screeching halt. It is also vital GnRH not only be present but must be present in a pulsatile fashion. In monkeys, it has been shown when GnRH is administered in pulses, the levels of LH and FSH secretion remains high. However, when GnRH administration is continuous the levels of LH and FSH fall dramatically and then plateau at a level of almost zero. Upon resumption of pulsatile GnRH administration, LH and FSH levels increase to reach previous pulsatile levels (Conn and Crowly, 1990).

Advancing Puberty

Given the importance of puberty attainment several methods have been developed to hasten the onset of puberty. These include genetic selection, nutrition, and progestins.

Selection

As selection tools improve, producers now have better ways to predict the value of the impact a potential sire could have on his herd. Expected progeny differences (EPD) have become an invaluable tool to producers when making herd sire decisions. Expected progeny differences evaluating carcass traits such as HCW, yield grade, and quality grade have proven to be fairly accurate. Traits considered more maternal, such as a heifer’s ability to become pregnant or a cow’s ability to stay in the herd while producing a calf every year, have been more difficult to apply a single and effective number to. One measure developed is scrotal circumference, which is well established to correlate negatively to the age at which a sires' daughters attain puberty. This is intuitive, as a bull's scrotal circumference is measured at 1 yr of age. More mature bulls will have a larger scrotal circumference and the daughters of these earlier maturing bulls are also earlier maturing. A producer striving to improve his herd will always look for the best bull; oftentimes, "best" meaning bigger. As producers have continued to choose the "best" bull, an upward trend has emerged in several breeds, including Angus and Simmental, in the scrotal circumference EPD (Eriksson et al., 2012). Perhaps as the industry strived for improvement, they unwittingly selected for increased incidence of precocious puberty.

Nutrition

Although a long-term trend towards selection for earlier maturing cattle may exist, a factor more easily managed in the short term is nutrition. It has been shown puberty can be negatively impacted as a result of energy restriction; when pre-pubertal heifers were under energy restriction LH levels decreased (Kurz et al., 1990). Conversely, Gasser et al. (2006b) were successful in inducing precocious puberty in 8 out of 9 heifers, utilizing early weaning and a high concentrate diet. Heifers were weaned early at 73 ± 3 d, fed a receiving diet for 26 d and placed on either a control or high concentrate diet. The control diet was comprised of 30% whole shell corn and had 1.70 Mcal/kg of NEm, while the high concentrate diet was 60% whole shell corn and had 2.02 Mcal/kg of NEm; both diets provided 14.1% CP. At 300 d, the cut off for heifers to be considered precociously pubertal, 88.9% of high concentrate diet heifers were pubertal, compared with no heifers fed the control diet (Gasser et al., 2006b). In a follow-up study, Gasser et al. sought to determime the role of early weaning; heifers were randomly assigned to be weaned early (104 ± 2 d of age) or weaned normally (208 ± 3 d of age). Heifers weaned early were fed a receiving diet for 3 wk before being assigned to the same control and high concentrate diets as the previous study (Gasser et al., 2006c). In the follow-up study, normally weaned heifers had a 50% incidence of precocious puberty, with heifers weaned early and fed the control diet having 56% precocious puberty incidence and 100% incidence in heifers weaned early and fed a high concentrate diet (Gasser et al., 2006c). The authors speculate the high incidence of precocious puberty in all groups of heifers in this particular study could be due to the above average forage quality available the year the study was conducted (Gasser et al., 2006c). These studies point to a clear connection between a high concentrate diet and precocious puberty.

Nutrition has been shown to be linked to serum levels of GH and IGF-1. In developing beef heifers, IGF-1 appears to be a better indicator of nutrition, with increased levels in heifers fed on a higher plane of nutrition (Granger et al., 1989). Furthermore, this same study again demonstrated puberty was hastened in heifers fed a higher plane of nutrition (Granger et al., 1989). Given that insulin and IGF-1 stimulate ovarian growth and IGF-1 increases at puberty, these findings are not surprising (Nobles, 1992; Bach et al., 1990). An increased level of nutrition results in elevated IGF-1 levels, relative to a more restrictive diet: IGF-1 levels correspond with puberty attainment, making the conclusion that higher levels of nutrition result in earlier attainment of puberty a natural one. The precise mechanism by which higher levels of energy and/or protein in the developing heifers diet lead to stimulation of the HPG axis have not yet been established and warrant further study.

Cushman et al. (2014) found a negative correlation between pre-weaning BW and age at puberty, with higher gaining heifers prior to weaning attaining puberty at an earlier age; heifers' post-weaning ADG did not correlate to age at puberty. When dairy heifers were compared at the common physiological time point of puberty, body composition and backfat were similar across development treatments (Chelikani et al., 2003). Although these dairy heifers were developed on varying levels of protein and energy, they attained puberty at different ages; however BW at puberty was similar across treatments. In a separate study, heifers developed on a high nutritional plain reached puberty at a heavier BW than heifers developed on a low wintering level diet (Wiltbank et al., 1966).

To evaluate the impact of a high concentrate diet at 2 different time points heifers were weaned early and fed either a high concentrate or control diet in 2 phases, the first phase was designed to represent the pre-weaning phase of a heifer's life and the second phase representing post weaning (Gasser et al., 2006a). Precocious puberty occurred at a higher rate in heifers fed a high concentrate diet in both feeding phases compared with control diet in both feeding phases (Gasser et al., 2006a). Average age at puberty was less for heifers fed a high concentrate diet in the pre-weaning phase compared with heifers on control diet for both phases (oldest at puberty) or heifers on control diet followed by high concentrate diet (intermediate age at puberty, Gasser et al., 2006a). Heifers attaining puberty earlier than 300 d of age (precocious puberty) were at a lighter BW at puberty attainment than their contemporaries (Gasser et al., 2006a). Thus, although nutrition is very important to early puberty attainment, the mechanism by which it acts is not by altering BW.

Cordoso et al. (2014) evaluated the impact of heifer diets on puberty attainment. Heifers were weaned at approximately 3.5 mo of age and grown on a high concentrate diet (ADG = 1.0 kg), forage based diet (ADG = 0.5 kg), or 1 of 2 stair step diets alternating every 10 wk between ab libitum concentrate diet and restricted access to high-forage diet. The proportion of heifers attaining puberty at 12 mo of age was similar for heifers receiving the high concentrate diet (80%) as well as the stair step program beginning with high concentrate (70%). However heifers on forage (30%) and on the opposite stair step program, beginning with restricted forage (40%), had lower proportions of pubertal heifers at 12-mo of age (Cardoso et al., 2014). By 14 mo of age, 90% of heifers on the restriction-first stair step program had attained puberty, while forage diet fed heifers were 40% pubertal. There were insufficient numbers to evaluate BW at puberty for forage diet heifers. Stair step heifers beginning with high concentrate tended (P = 0.09) to be lighter when they reached puberty than heifers on the high concentrate diet. Pubertal BW was not different between stair step heifers beginning with restriction and high concentrate heifers or the opposing stair step program heifers (Cardoso et al., 2014). Heifers on the high concentrate diet had higher levels of leptin compared with both the forage and stair step diets. As heifers in both stair step programs were transitioned from high-concentrate diets to restricted forage diets, they experienced rapid declines in circulating leptin concentrations. Interestingly, heifers in the stair step program that began with the high concentrate diet the first 10 wk demonstrated increased leptin levels in the restriction period, while mean leptin concentrations for stair step heifers whose first 10 wk was on restricted forage diet were consistently low during periods of feed restriction (Cardoso et al. 2014). Leptin is produced by adipocytes and may act as a permissive signal to initiate puberty as an indicator of adequate nutritional status (Hausman et al., 2012). The higher levels of leptin in concentrate fed and concentrate-first fed heifers indicate a recognition by the heifer of adequate levels of nutrition to begin the establishment of puberty. Heifers fed forage throughout the development period had low levels of leptin, and consequently, a lower percentage of heifers attaining puberty. In a similar study, more heifers on a rapid growth rate, compared with a slow-then-rapid growth rate, were pubertal at 11 and 12.5 mo of age, prior to any other treatment (Hall et al., 1997).

In a 3 yr study, Roberts et al. (2009) compared restricted and ad libitum heifer development systems. The proportion of restricted heifers attaining puberty by 14 mo of age was less than heifers offered ad libitum access; 60% of restricted heifers were pubertal at the beginning of the breeding season, while 68% of ad libitum heifers had reached puberty (Roberts et al., 2009). Heifers on a restricted diet reached puberty at a lighter BW than ad libitum contemporaries; restricted heifers attained puberty at 57% of mature BW while ad libitum heifers reached puberty at 59% of mature BW (Roberts et al., 2009).

Furthermore, Roberts et al. (2009) found in the yr with the greatest proportion of heifers attaining puberty prior to the breeding season, heifers also had the lightest pre-breeding BW. For every 0.1 kg/d increase in ADG from weaning to the beginning of nutritional treatments the percentage of heifers attaining puberty prior to the breeding season increased by 3.6%, while the same increase in ADG during the pre-weaning period resulted in a 12% increase in pubertal heifers BW (Roberts et al., 2009). As previously observed (Wiltbank et al., 1966; Laster et al., 1972), this would indicate a female's growth rate prior to weaning is perhaps more important to the early attainment of puberty than the time period from weaning to breeding. Pubertal status was not found to explain the variation in final pregnancy rate (Roberts et al., 2009).

In a comparison of heifer development diets, heifers fed dried distillers grains (DDG) containing levels of RUP above NRC requirements did not impact age at puberty compared with control heifers; however, pregnancy rates were 16.9% greater in heifers developed on DDG (Martin et al., 2007). In this study Martin et al. (2007) found a 10.6 and 6.1% incidence of puberty at the initiation of development treatment at heifer ages of 250 and 230 d.

Progestins

Progestins can hasten the onset of puberty in prepubertal heifers. Crossbred heifers of either Charolais or Hereford descent demonstrated an inducement of puberty due to a progestin-based norgestomet implant at 12.5 mo of age but not at 9.5 or 11 mo of age (Hall et al., 1997). Slow LH pulse frequency in combination with low LH concentrations in younger heifers cause researchers to speculate the HPG axis of these younger animals is not capable of responding to progestins in the way we expect an older animal to, by increasing releases of LH (Hall et al., 1997). Gonzalez-Padilla et al. (1975) observed the use of norgestomet in prepubertal heifers increased pregnancy rates from 7% in control heifers to 94% in treated heifers. Furthermore, in a separate trial, 79% of treated heifers were observed in estrus within 4 d of implant removal with 84% cycling by d 25 of the breeding season whereas only 28% and 38% of control heifers had cycled by d 25 and 48, respectively (Gonzalez-Padilla et al., 1975).

Synchronizing estrus

Once a heifer has attained the critical threshold of puberty, there are 3 main ways the estrous cycle of beef cattle can be manipulated: 1) the use of PG to regress an existing CL, 2) the use of GnRH to create synchrony in a new wave of follicles and/or initiate ovulation, and 3) the use of a progestin to regulate the timing of the release of the CL. These 3 mechanisms, when used alone or in combination allow progressive managers to maximize labor while reaping the benefits of AI by successfully utilizing an estrus synchronization protocol.

Prostaglandin (PG)

When administered after d 5 of the bovine estrous cycle, PG effectively regresses the CL, causing progesterone concentrations to drop to basal concentrations within 24 h

(Roche et al., 1998). In the early part of the estrous cycle, when no CL is present, the use of PG is not effective. The effect of PG varies depending upon the stage of the luteal phase at the time of injection (Berardinelli & Adair, 1989). When PG is given during the

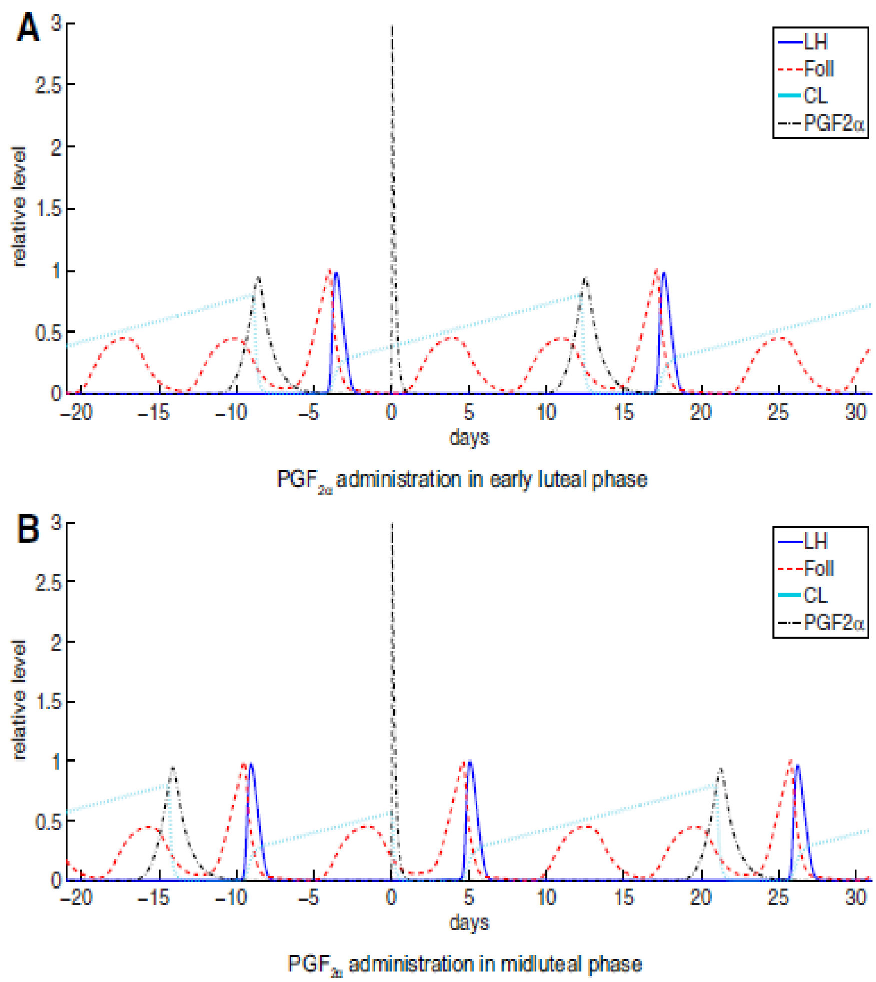

Figure 2. Computer simulation results showing the impact of PG injection on d 0 at 2 different stages of the estrous cycle. (**A**) demonstrates that ovulation does not occur when PG is given during the early luteal phase. (**B**) shows an ovulation response following PG administration 10 d following a previous ovulation. (adapted from Stotzel et al., 2012)

mid (d 10 to 14) and late (d 15 to 19) luteal phase estrous synchrony is increased (Berardinelli and Adair, 1989). This is due to increasing sensitivity of the CL to PG as the CL matures. Furthermore, in the later days of the luteal phase, endogenous PG from the uterus, which begins to produce PG on d 15 (Shemesh & Hansel, 1975) may augment the exogenous dose of PG.

Figure (2A) adapted from Stotzel et al. (2012) is a simulation of a computer generated model of the response to PG administration when given during the early luteal phase. When PG is given 4 d following ovulation, luteolysis cannot occur because a CL is not yet present, thus there is no ovulation response. Figure (2B) illustrates PG administration in the mid luteal phase, when a CL is present, and the subsequent ovulation response.

Tervit et al. (1973) observed successful synchronization utilizing a PG analogue both when given via i.m. or intra-uterine administration, but observed more precise synchrony when pretreated with pregnant mare serum gonadotropin. When administered to non-pregnant dairy cows on a weekly basis PG was shown to improve pregnancy rate over the administration of PG after confirmation of a CL via rectal palpation (Kristula et al., 1992). This is likely due to management (i.e. inefficiencies in rectal palpation).

Gonadotropin Releasing Hormone (GnRH)

Gonadotropin releasing hormone stimulates the endogenous release of FSH and LH from the anterior pituitary. Given the absence of GnRH receptors on the bovine ovary, it is clear GnRH acts through FSH and LH to stimulate follicular growth and ovulation, respectively (reviewed by Twagiramunga et al., 1995). Administration of GnRH serves to induce ovulation in follicles during the luteal phase and in females without a functioning CL; if the follicle is already on the path of atresia GnRH does not alter the outcome (reviewed by Twagiramunga et al., 1995). Thus, GnRH can be used to initiate a new wave of follicles, which increases the likelihood of the presence of a dominant follicle at the time prostaglandin is given to lyse the CL (Roche et al., 1998). By insuring a dominate follicle is present at the time of luteolysis, the variability of when estrus occurs is reduced.

Pursley et al. (1995) proposed one of the first FTAI protocols; GnRH was given at any random point in a females' cycle with a PG injection 7 d later, followed by a second GnRH injection 48 h later and AI 24 h after that. The first injection of GnRH served to bring about ovulation in 18 out of 20 cows and 13 out of 24 heifers (Pursley et al., 1995). Following luteolysis of the CL, caused by the PG injection, the second GnRH injection caused ovulation in all of the females who responded to synchronization (Pursley et al., 1995). This protocol for FTAI, utilizing GnRH, was superior to previous FTAI protocols utilizing 2 injections of PG because it more precisely timed ovulation. In a study comparing the administration of GnRH 6 h prior to CIDR implantation, at CIDR implantation, or 48 h after CIDR implantation, it was observed ovulations were reduced in cows receiving the GnRH injection 48 h following CIDR implantation (Perry and Perry, 2009). The interaction of elevated progesterone levels, as a result of the CIDR, and GnRH result in a diminished LH response (Colazo et al., 2008). In a comparison of the then traditional synchronization protocol of 2 injections of PG and protocols utilizing GnRH as a pre-treatment, Dahlen et al. (2003) observed increased pregnancy rates in lightweight, peripubertal heifers pre-treated with GnRH.

Progestins

Endogenously produced by the CL, progesterone regulates the estrous cycle length (Roche et al., 1998). As early as 1967, Woody et al. explored the possibility of using exogenous progesterone to shorten the estrous cycle. The effort was relatively successful, and what was learned laid the groundwork for modern-day use of progestins in feed additives and intra-vaginal devices. The use of progestins has been demonstrated to successfully induce non-cyclic females, both pre-pubertal heifers and anestrus cows post-partum, to ovulate (Gonzalez-Padilla et al., 1975; Lamb et al., 2001).

Norgestomet

Norgestomet was used as a progestin prior to the advent of melengestrol acetate (MGA) or controlled internal drug release devices (CIDRs). Administered as implants in the ear, norgestomet was the frontrunner of progestin research. Gonzalez-Padilla et al. (1975) observed norgestomet use in prepubertal heifers increased pregnancy rates from 7% in control heifers to 94% in treated heifers. Furthermore, a separate trial resulted in a pregnancy rate of 73% in treated heifers following a 48 d breeding season compared with 27% in the control group (Gonzalez-Padilla et al., 1975). The value of progestin-induced estrus in heifers is clearly demonstrated by these trials and led researchers to continue to develop protocols utilizing progestins to induce cyclicity in anestrus females.

Melengestrol acetate (MGA)

Melengestrol acetate was first used as a progestin feed additive in feedlot heifers to inhibit estrus and ovulation, thereby increasing heifer feedlot efficiency and performance. The minimum dosage of MGA to inhibit ovulation is 0.42 mg/d (reviewed by Patterson et al., 1989). Eventually, MGA began to be used in estrus synchronization protocols. However, the long term use of MGA results in a less fertile estrus immediately following the end of MGA administration. This is partially due to a number of physiological changes (reviewed by Patterson et al., 1989). Evaluation of ova collected from heifers given MGA for 16 d found few normal follicles, in combination with hyperplastic and atretic follicles (Lamond et al., 1971). Thus, heifer MGA + PG synchronization protocol allows for an ovulation to occur before AI. Melengestrol acetate is a cost effective synchronization method for heifers.

Controlled internal drug release (CIDR)

Similarly to MGA, a CIDR allows for prolonged progestin exposure. Although more expensive than MGA, CIDRs provide several advantages over MGA. In breeding seasons where synchronization is occurring while heifers are on green grass, managing MGA consumption can be difficult, whereas a CIDR is a more reliable source of progestin. Moreover, the individual aspect of CIDRs allows for use in cows with calves, where use of MGA has not been FDA approved.

In ovariectomized beef cows, after CIDR insertion plasma progesterone levels peaked within 24 h and decreased thereafter to d 7 (Long et al., 2009). CIDRs have been shown to be effective in a number of different protocols. Bridges et al. (2014) compared 3 CIDR protocols on heifers: 5-d CO-Synch + CIDR, PG- 6-d CIDR, and 14 d CIDR + PG and observed no difference in FTAI pregnancy rates.

The addition of a CIDR into the Co-Synch protocol increased pregnancy rates by 11% (43 vs 54%, CO-Synch vs Co-Synch + CIDR); moreover, by adding a CIDR to the Select Synch protocol pregnancy rates increased by 5% (53 vs 58%, Select Synch vs

Select Synch + CIDR; Larson et al., 2006). Although the addition of a CIDR to the Co-Synch protocol did not improve pregnancy rates in cycling cows with high levels of progesterone (58 vs 58%) it did improve pregnancy rates in non-cycling cows (40 vs 53%; Co-Synch vs Co-Synch + CIDR) and cycling cows with low progesterone levels (38 vs 66%; Co-Synch vs Co-Synch + CIDR; Lamb et al., 2001). This increase can be explained by the positive effect of the CIDR on anestrus cows, inducing estrous cycling in those cows not cycling at the beginning of the breeding season.

MGA vs CIDR

In a direct comparison of the MGA-PG and 14 d CIDR protocols variance for interval to estrus after PG injection was not different (Mallory et al., 2010). It may seem a CIDR would provide a more uniform synchrony compared with MGA, given the source of progestin is removed at nearly the exact same time upon device removal opposed to MGA, which must clear the digestive system. However, this was not the result observed by Mallory et al. (2010). Moreover, conception rate to AI was not different between MGA and CIDR synchronized heifers (Mallory et al., 2010). Furthermore, heifers synchronized with either MGA-PG or 14 d CIDR-PG protocols resulted in similar FTAI and overall pregnancy rates (Vraspir et al., 2013).

Estrous Control

The advent of FTAI protocols, which completely eliminate the need for estrus detection, increases the appeal of using AI. In a comparison of Co-Synch + CIDR (no estrus detection) and Select Synch + CIDR & TAI (requires estrus detection) there was no difference in AI pregnancy rates (54 vs 58%; Larson et al., 2006). In an effort to determine the effect of stage of estrous on estrus synchronization, Moreira et al. (2000) utilized the Ovsynch/TAI protocol, in which GnRH was administered at the initiation of the protocol, followed by PG 7 d later, a second GnRH injection 36 h after the PG injection and fixed time AI 16 h following the final GnRH injection. Heifers were grouped to begin the synchronization protocol on d 2, 5, 10, 15, or 18 of their estrous cycle. Heifers beginning synchronization on d 5, 10, 15, and 18 had successful synchronization of a new follicular wave, while heifers beginning on d 2 had already begun the follicular recruitment process and thus did not respond to the GnRH injection. This experiment eloquently demonstrates the effect of estrus synchronization protocols at different time points in the estrous cycle. The d 2 heifers, having already begun the recruitment process at initiation of the protocol, had larger follicles throughout the synchronization period and were no longer growing at the time of ovulation. Heifers in d 15 group had decreased progesterone concentrations prior to the PG injection, the point where the other groups began to decrease in progesterone levels. This was likely due to endogenous release of PG acting on both original and accessory CL. This study concluded if progesterone levels were high an induced accessory CL was capable of responding to injected PG. Heifers in group d 18 had a greater incidence of incomplete CL regression, surmised to be due to the growth of the accessory CL under a low progesterone environment, causing them to be sub-responsive to injected PG. This study concluded by noting an exogenous source of progesterone during the synchronization period would help in avoiding premature ovulation, validating use of MGA and CIDRs in synchronization protocols.

Systems

Decisions made in beef production are never singular, but always impacting other areas of the production system. Thus, decisions must consider the other components of the system. Some areas of the system are more easily altered than others, (e.g. a post weaning calf diet) and some we have little control over, such as the occurrence of a severe winter storm. The point is, these decisions and events all have an impact within the system, and because years will vary, even with the best management, it becomes very difficult to pinpoint the exact reason for performance differences across years.

Reduced-input heifer development must be accompanied with a systems outlook, in which the continuation of a heifer's growth is accounted for after the initial development process.

Calving distribution

Perhaps one of the most important perspectives on beef systems management is calving distribution. It has long been known heifers who calve early the first time go on to wean more kg of calf throughout their lifetimes than late calving heifers (Lesmeister et al., 1973). This has been confirmed in the current century with heifers giving birth to their first calf in the first 21 d of the calving season remaining in the herd through 5 parturitions at a significantly higher rate than their contemporaries (Cushman et al., 2013). Heifers born in the first 21 d of the calving season are more likely to calve in the first 21 d of their first calving season (Funston et al., 2012). Additionally, heifers born in the first 21 d of the calving season have increased puberty attainment prior to the breeding season and increased pregnancy rates (Funston et al., 2012). Heifers calving in the first 21 d of the calving season are more productive over the remainder of their lives. They wean heavier calves each season, such that over her lifetime a heifer whose first calf was born in the first 21 d of the calving season, will have weaned the equivalent of an extra calf over her lifetime (Cushman et al., 2013). This gives producers a tool in selecting replacement heifers. By retaining only heifers carrying older fetuses or shortening the breeding season to insure all pregnancies are early pregnancies, a producer can select for fertility. Furthermore, as a selection tool, heifers that calved in the first 21 d, were born earlier in their own calving season and were heavier at their own weaning (Cushman et al., 2013).

Stages of Development

Heifer development can be divided into many stages, all of which have the potential to alter the heifer's lifetime productivity: fetal development, pre-weaning (nursing), post-weaning, and post-breeding. In theory, these stages could be broken down even further, for example fetal development could be broken down into the trimesters of pregnancy.

Fetal Programming

Although the concept of a fetus being affected by its environment *in utero* is not new and has been advocated in human medicine, the idea has been slower to develop in livestock production. Reducing maternal nutrition by 25% in mature beef cows during the second and third trimester was found to have no negative effects on either growth or reproductive performance of the daughters (Cushman et al., 2014). However in the same study, mature cows fed at a higher plane of nutrition during the third trimester resulted in a higher percentage of their daughters calving in the first 21 d of the calving season as first calf heifers (Cushman et al., 2014). Given the nature of a natural service breeding system, it is impossible to tell if this is due to conception date or if it is a function of maternal nutrition. Furthermore, dam supplementation during early gestation resulted in increased heifer progeny pregnancy rates and a greater number of calves born in the first 21 d of the calving season in heifer progeny (Martin et al., 2007).

Pre-Weaning Nutrition

Although much of the focus of heifer development has recently been on post-weaning nutrition, pre-weaning management also impacts the development of the replacement beef heifer. Research has observed heifers fed creep feed as a calf had decreased milk yield at 120 d (Hixon et al., 1982) and 52, 108, and 164 d (Sexton et al., 2004) postpartum as a first calf heifer. Furthermore, Sexton et al. (2004) observed a numerical decrease of 7 to 11% in pregnancy rate in heifers fed creep feed compared with controls. Additionally creep fed heifers have been shown to have reduced lifetime productivity, including longevity, number of calves weaned, and average calf weaning BW (reviewed by Patterson et al., 1992).

Pre-weaning nutrition may also play a role in puberty attainment. A 2 yr study found the incidence of precocious puberty to be 25% in the first year and 8.3% in the second (Wehrman et al., 1996). The authors speculated the discrepancy between yr was due to the difference in growth rates between the yr, with the yr corresponding to the higher incidence of precocious puberty having a greater growth rate in the 2 mo following weaning, because of increased forage (Wehrman et al., 1996). Additionally, Roberts et al., (2009) found increased ADG in the first 8 mo of life was associated with earlier conception and thus calving date.

Post Weaning Nutrition

The majority of heifer development research focuses on post-weaning nutritional treatments, likely because that is one of the easiest factors to manipulate and control. Treatments include differing diet qualities, diet access, nutrient availability, or a combination of differences to achieve a different target BW.

Patterson et al. (1991) first investigated the concept of developing heifers to a specific target BW based on a percentage of the expected mature BW; by developing heifers to 55% and 65% of mature BW. The conclusion of this study was nutrition was extremely important and inadequate nutrition resulted in increased incidence of dystocia and lengthened the post-partum interval (Patterson et al. 1991).

Heifers fed a restricted diet to achieve 53% of mature BW, consumed 27% less harvested feed in a 140 d trial period than their contemporaries offered ad libitum access to achieve 58% of mature BW (Roberts et al., 2009). Additionally, final pregnancy rates following a 45 d breeding season did not differ; 87% of restricted heifers and 91% of ad libitum heifers became pregnant; however pregnancies conceived in the first 21 d of the breeding season tended to be reduced in restricted heifers (Roberts et al., 2009). During the development period, heifers on restricted feed intake were more efficient than their contemporaries developed on a control diet (Roberts et al., 2007).

Development diets with increased amounts of RUP have benefited pregnancy rates. Heifers developed with a 50% RUP supplement had a 13% greater pregnancy rate than contemporary heifers developed with a 36% RUP supplement (Mulliniks et al., 2013). Heifers either developed in the drylot or supplemented on pasture with either 50%

RUP or 36% RUP supplement reached 58, 51, and 51% of mature BW prior to the breeding season, with only a tendency for increased pregnancy rate in the 50% RUP group compared with drylot or 36% RUP supplemented (Mulliniks et al., 2013).

Success or failure of a development strategy is often determined by pregnancy rate. Development treatments may have other impacts as well. Although pregnancy rates did not differ between lightweight heifers supplemented with high and low levels (3.68 vs 2.99 kg/d) of ground corn, high corn heifers did reach puberty earlier and have larger pelvic areas (Buskirk et al., 1995).

Heifers developed on either high (to achieve 65% of mature BW) or low gain (to achieve 55% of mature BW) diets from 8 mo to d 21 of the breeding season had similar pregnancy rates after 47 d of breeding, although a larger proportion of high gain heifers became pregnant in the first 21 d of the breeding period (Eborn et al., 2013). The depressed pregnancy rates in low gain heifers was not due to inhibited cyclicity as a result of diet as similar proportions of heifers were cycling prior to the breeding season regardless of nutritional treatment, breed, and yr (Eborn et al., 2013). The delay in pregnancy attainment by heifers developed to achieve 55% of mature BW prior to the breeding season may be a concern for commercial herds because early calving first calf heifers produce more calf BW in their lifetimes than later calving heifers (Lesmeister et al., 1973). Thus, by impairing a heifer's ability to attain a pregnancy in the first 21 d of the breeding season, calf BW may suffer not only in her first calf, but in all calves she produces. This may be less of an issue in a yearling based system, where calves are not sold at weaning. Furthermore, due to the market slide for lighter weight calves, this decrease in calf weaning weight may not result in diminished revenues.

Heifers developed on corn residue tended to have lower gains than heifers developed on winter range, in a comparison of 2 low-input, standing-forage systems (Larson et al., 2011). In this same study, corn residue developed heifers had similar pre-breeding BW to winter range developed heifers, indicating a compensatory gain effect prior to the breeding season (Larson et al., 2011). Heifers developed on corn residue had increased ADG as a pregnant heifer when returned to corn residue for winter grazing compared with heifers developed in the drylot or on winter Sandhills upland range (Summers et al., 2014). Behavioral retention appears to play a role in heifer performance as a pregnant female. Heifers developed in the environment they will be returned to as pregnant females appear to perform better than heifers naïve to the environment.

Compensatory gain

Developing replacement beef heifers by reducing inputs at the beginning of the development period and utilizing the compensatory gain effect to reach a target BW prior to the breeding season is an effective strategy. By altering pattern of gain from a continuous linear curve to a period of slow gain followed by a short period of fast gain near the end of development, heifers can reach a similar target BW and reduce feed inputs, resulting in similar conception rates (Clanton et al., 1983). One such development strategy is to develop heifers on a restricted diet for the majority of the development period and then feed a higher quality diet closer to breeding (Lynch et al., 1997). By concentrating the inputs of a heifer's development, a great deal of cost savings can be captured. Heifers fed at a low rate of gain until the last third of the development period, when heifers experienced compensatory gains, had similar pregnancy rates to heifers fed at an even rate throughout the feeding period (Lynch et al., 1997).

Economic Considerations

At first consideration it may seem to maximize potential profits, a heifer development system should aim to achieve as many pregnancies as possible. However, there exists a balance point at which the additional feed cost outweighs any additional pregnancies attained. With this in mind, reduced input systems of heifer development, with the intention of selling any non-pregnant heifers for a credit against the cost of a pregnant heifer, have proven to be an economical strategy.

Feuz (1992) concluded from an economic analysis the least cost alternative to develop a heifer to her first calving season is 50% of mature BW, compared to 62.5 and 70%. However when taking into account the cost of establishing a heifer's second pregnancy the 62.5% of mature BW target was the least cost alternative. Roberts et al. (2009) found a $33 per heifer advantage to restricting heifers, developing to 55% of mature BW compared with 58%. In addition, heifers developed in the drylot were found to have decreased net returns compared with heifers developed on pasture and supplemented with either 36 or 50% RUP supplement. Net return per heifer was greater by $99.71 and $87.18 for heifers fed 50 and 36% supplement and developed on pasture than their drylot contemporaries (Mulliniks et al., 2013).

In a comprehensive economic analysis, Clark et al., (2005) recommended producers evaluate the option of retaining a greater number of heifers and developing them on a low input system, with the intention of marketing the non-pregnant heifers. In a low input system, non-pregnant yearling heifers netted a substantial profit in comparison with yearling heifers developed on a high input system (Clark et al., 2005).

Objectives

- Evaluate the effect of a 19-h delayed AI following GnRH administration in a hybrid estrus detection and time AI protocol in heifers.
- Compare the effects of MGA-PG and 14-d CIDR-PG estrus synchronization protocols on estrus response and pregnancy rates of 311 d old Angus-based, crossbred heifers.
- Determine the impact of heifer development system on subsequent growth and reproductive performance in 2 breeding seasons.
- Identify the impact of heifer development system on pregnancy rates and feed efficiency as a pregnant first calf heifer a 3 yr study was conducted.

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Chapter II

Comparison of AI at estrus, TAI at GnRH injection, and 19 h delayed AI after GnRH injection of non-estrus beef heifers

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Abstract

A study evaluated the effect of a 19-h delayed AI following GnRH administration in a hybrid estrus detection and time AI protocol in heifers. Angus-based, crossbred heifers (n = 453) were managed at the Kelly Ranch (Sutherland, NE) or the University of Nebraska West Central Research and Extension Center (North Platte, NE). Estrus was synchronized utilizing the melengestrol acetate (MGA)-PG protocol, heifers received MGA for 14 d (d 1 through d 14 of the protocol). Nineteen d later, on d 33 of the protocol, heifers received a PG injection and estrus detection aids (Estrotect) were applied. Heifers were considered to have expressed estrus when greater than 50% of the rub off coating was removed from the Estrotect. Heifers (n = 319) were assigned to the first treatment group, removed from the herd, and AI 12 hours later (ESTRUS). Seventy-two h following the PG injection, heifers whose Estrotect were less than 50% activated were administered GnRH, and randomly assigned to 1 of 2 remaining treatment groups: immediately AI (n = 70 , GNRH-I) or AI 19 ± 1 h following GnRH injection (n = 64, GNRH-D). Data was analyzed using the GLIMMIX procedure of SAS (SAS Inst. Inc., Cary, NC) and the proportion of pregnant heifers was found using an odds ratio utilizing the ILINK function. Pre-breeding BW was similar (P = 0.58) between ESTRUS, GNRH-I, and GNRH-D (351, 347, and 350 ± 4 kg, respectively). Furthermore, pregnancy

diagnosis BW among the treatments was similar (*P* = 0.48; 376, 380, and 377 ± 6 kg; ESTRUS, GNRH-I, and GNRH-D, respectively). Heifers AI from estrus detection, as determined by an activated Estrotect, had higher (*P* < 0.01) pregnancy rates to AI compared with heifers in both GNRH-I and GNRH-D groups (70 vs 56, 47 ± 6%). Pregnancy rates to AI did not differ (*P* = 0.56) between GNRH-I and GNRH-D (56 vs 47 ± 6%). Heifers in all groups reached a similar (*P* = 0.59) percentage of mature BW prior to the breeding season (63 ± 1%). Final pregnancy rate was not different (*P* = 0.54) for ESTRUS, GNRH-I, and GNRH-D heifers (92, 89, 91 ± 4%). There was no significant benefit to delayed AI of non-estrus beef heifers compared with traditional timed AI at the time of GnRH injection.

Introduction

The utilization of estrus synchronization and fixed-time AI (FTAI) has dramatically improved the efficiency of AI, concentrating the labor and time requirement into only a few days, making AI more feasible for producers (Lamb et al., 2009). However, an improvement in pregnancy rates typically attained when a FTAI protocol is used would increase the appeal of such protocols to producers. In a comparison of heifers synchronized with the 14 d CIDR protocol and AI with a standard FTAI protocol or a 20 h delayed AI following GnRH administration protocol, Thomas et al., (2014a) found higher overall pregnancy rates for heifers on the delayed AI protocol (54 vs 46%). Among heifers in estrus there was no difference in pregnancy rates between standard FTAI and delayed AI. However in heifers not having expressed estrus prior to GnRH injection there was a significant advantage to delayed AI compared with standard FTAI (49 vs 34%). Thus, it was the objective of this study to determine the effect of a 19 h delayed AI following GnRH administration in non-estrus heifers as part of a hybrid estrus detection/FTAI protocol.

Materials and Methods

The University of Nebraska Animal Care and Use Committee approved the procedures and facilities used in this experiment. Yearling, angus-based crossbred heifers (n = 453) were managed as a single herd at the Kelly Ranch, Sutherland, NE (KR), grazing dormant upland Sandhills range and offered 1.3 kg/d (DM) dried distillers grains. Alfalfa was offered to each heifer at a 2.9 kg/d (DM) beginning 66 d prior to synchronization. As winter range availability decreased in the spring, alfalfa was offered ad libitum. Approximately 1 wk prior estrus synchronization, a subset of heifers (n=100) were transported to the West Central Research and Extension Center, North Platte, NE (WCREC). The balance of heifers remained at the KR (n=353) through synchronization and AI. Heifers housed at the WCREC were placed in a drylot and fed 11.6 kg/d (DM) of a diet containing 10% corn, 71% prairie hay, 16% wet corn gluten feed, and 3% supplement.

At both locations, estrus was synchronized utilizing the MGA-PG protocol (Figure 1). At each location heifers received 0.50 mg/hd/d melengestrol acetate (MGA; Pfizer Animal Health, New York, NY) for 14 d. At WCREC, MGA pellets were mixed in the ration, at KR MGA pellets were mixed with 2.1 kg/d ground hay and 0.8 kg/d wet distiller grain (DM). Nineteen d later, on d 33 of the protocol heifers received a PG (Lutalyse, Zoetis, Florham Park, NJ) i.m. injection and estrus detection aids were applied (Estrotect, Rockway Inc, Spring Valley, WI). Heifers were considered to have expressed estrus when greater than 50% of the rub off coating was removed from the Estrotect.

Heifers expressing estrus (n = 319) were assigned to the first treatment group, removed from the herd, and AI 12 h later (ESTRUS). Seventy-two hours following the PG injection heifers whose Estrotect patches were less than 50% activated were randomly assigned to 1 of 2 remaining treatment groups: administered GnRH (Fertagyl, Intervet/Schering-Plough Animal Health, Summit, NJ) and immediately AI (GNRH-I) or administered GnRH injection and AI 19 ± 1 h later (GNRH-D).

The day after TAI WCREC heifers were returned to KR, where they were comingled on upland Sandhills range, with KR heifers. Thirteen d following TAI 9 bulls were placed with heifers for a bull to heifer ratio of 1:50 for a 42 d breeding season.

A minimum of 51 d after AI, BW measurements were taken and AI pregnancies were detected via trans-rectal ultrasonography (Repro Scan XTC, Repro Scan, Beaverton, OR). Forty-five d following bull removal pregnancy was again diagnosed to determine pregnancies sired by natural service.

Statistical Analysis

All data was analyzed using the GLIMMIX procedure of SAS (SAS Institute, Inc., Cary, N.C.), accounting for origin, pen (KR was counted as a single pen), and AI technician 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

Heifer reproductive performance is presented in Table 1. Pre-breeding BW was similar (P = 0.58) among ESTRUS, GNRH-I, and GNRH-D treatments (351, 347, and

350 ± 4 kg, respectively). Furthermore, there was no difference (*P* = 0.46) in pregnancy diagnosis BW among treatments, (376, 380, and 377 ± 5 kg; ESTRUS, GNRH-I, and GNRH-D, respectively). Heifers in the GNRH-I group gained more BW (*P* < 0.01) from pre-breeding to pregnancy diagnosis compared with heifers in the ESTRUS group (0.55 vs 0.40 ± 0.06 kg/d). However, there was no difference in ADG either between GNRH-I and GNRH-D (0.55 vs 0.43 ± 0.06 kg/d, *P* = 0.18) or between ESTRUS and GNRH-D (0.40 vs 0.43 ± 0.06 lb/d, *P* = 0.80) for the same time period. Heifers in all groups reached a similar (*P* = 0.58) percentage of their mature BW prior to the breeding season (63 ± 1%).

Heifers expressing estrus, as determined by an activated Estrotect, represented 70% (n = 319) of the herd. Heifers AI on estrus, had significantly higher (*P* < 0.01) pregnancy rates to AI compared with heifers in the GNRH-I and GNRH-D groups (72 vs 56, 47 ± 6%). Echternkamp and Thallman, (2011) found cows expressing estrus prior to AI in a TAI protocol had greater pregnancy rates than contemporaries not expressing estrus. This contrasts the findings of Larson et al. (2006), who found similar first service AI pregnancy rates between estrus synchronization protocols requiring heat detection followed by a clean-up TAI and strict TAI protocols.

Pregnancy rates to AI did not differ (*P* = 0.56) between GNRH-I and GNRH-D (56 vs 47 ± 6%). In contrast, Thomas et al. (2014a) found while pregnancy rates in heifers expressing estrus prior to FTAI did not differ, a significant effect of delayed AI was found in heifers not in estrus prior to FTAI (49 vs 34%, delayed insemination vs standard). The synchronization protocol utilized in that study was a 14 d CIDR + PG while the current study utilized the MGA-PG protocol. In a comparison of MGA and

CIDR protocols, Mallory et al. (2010) found no difference in AI pregnancy rate; however, the variance for interval to estrus after PG injection tended to be larger in the heifer synchronized with a CIDR, indicating a tighter estrus synchrony in heifers synchronized with MGA. This tighter synchrony of MGA synchronized heifers may explain the lack of benefit this study found in delayed AI. Furthermore, Thomas et al., (2014a) evaluated a 20 h delay while our study assessed a 19 h delay. Thomas et al., (20014b) suggested a 20 h delay allows for a more favorable uterine environment. An injection of GnRH stimulates ovulation in large follicles (Pursley et al., 1995; Twagiramunga et al., 1995). Thus, in theory the additional time after GnRH injection before insemination allows for better alignment of ovulation and insemination. Moreover, the delay should give females more time to attain estrus, increasing the number of heifers expressing estrus at AI. Females expressing estrus prior to a time AI have higher pregnancy rates than non-estrus animals (Perry et al., 2005). Yet another possible explanation for the difference in effectiveness of a delayed AI, as suggested by Thomas et al. (2014), is a bull effect. Individual bull sperm fertility varies from bull to bull, the perfect AI time may depend upon the bull being used. The use of a single bull in the current study allows no comparisons to be made. Final pregnancy rates were not different ($P = 0.54$) among ESTRUS, GNRH-I, and GNRH-D (92, 89, and 91 ± 4%). The results of this study found no benefit to a 19 h delayed AI.

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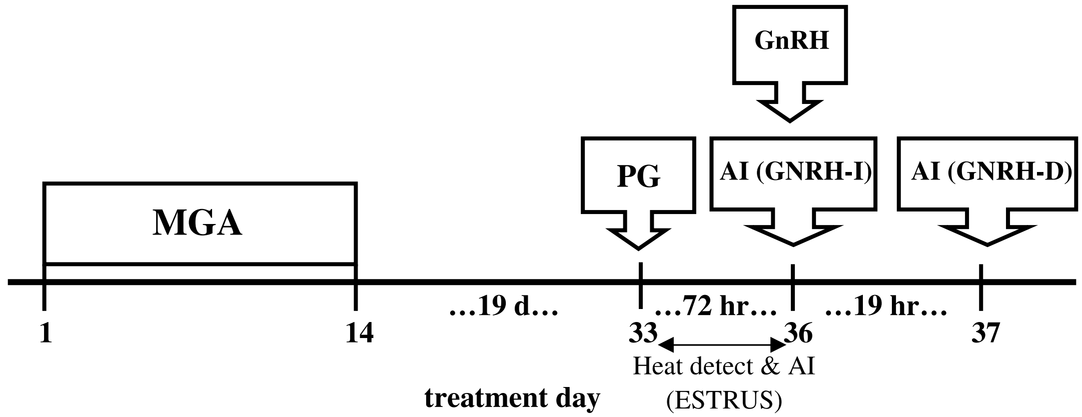

Figure 1. Modified MGA-PG estrus synchronization protocol utilized to compare AI at estrus (ESTRUS), at GnRH injection (GNRH-I), and AI 12 h following GnRH injection (GNRH-D).

Table 1. Growth and reproductive performance of heifers AI on their estrus and non-estrus heifers assigned to GNRH-I[1] or GNRH-D[2]

		Non-Estrus			
Item	ESTRUS	GNRH-I[1]	GNRH-D[2]	SEM	*P*-value
Pre-breeding BW, kg	351	347	350	4	0.58
Pregnancy Diagnosis					
BW, kg	376	380	377	5	0.46
ADG, [3] kg/d	0.40[a]	0.55[b]	0.43[a,b]	0.06	0.01
AI Pregnancy Rate, %	72[a]	56[b]	47[b]	6	< 0.01
Final Pregnancy Rate, %	92	89	91	4	0.54
Percent Mature BW, [4] %	64	63	63	1	0.58

[1] GNRH-I = non-estrus heifers were administered GnRH 72 h following PG and immediately AI.

[2] GNRH-D = non-estrus heifers were administered GnRH 72 h following PG and AI 19 h following.

[3] ADG from pre-breeding to pregnancy diagnosis (57 d).

[4] Percent mature based on 1,218 lb mature BW.

[a,b] Means in a row with different superscripts are different ($P < 0.05$).

Chapter III

Effect of MGA vs CIDR estrus synchronization on estrus response and pregnancy rates in 311 d old beef heifers

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Abstract

A study compared the effect of melengestrol acetate (MGA)-PG and 14-d controlled internal drug release (CIDR)-PG estrus synchronization protocols on estrus response and pregnancy rates of 311 d old Angus-based, crossbred heifers (n = 153). Fall-born heifers, at 10 mo of age, were randomly assigned to 1 of 2 estrus synchronization protocols in the spring. Heifers in the MGA protocol received MGA for 14 d fed through the diet beginning on d 0 of the synchronization treatment period. Heifers in the CIDR treatment received the same diet as MGA heifers and were implanted with a CIDR (Eazi-breed CIDR) on d 2 of the treatment period and removed on d 16. Following estrus synchronization, heifers from both treatments were combined and received a single PG (Lutalyse) injection on d 32. Heifers with activated heat detection aids (Estrotect) were AI 12 h following observation. All data was analyzed with the GLIMMIX procedure of SAS (SAS Inst. Inc., Cary, NC). Group BW was measured at weaning (198 kg) and prior to breeding (273 kg). Pre-breeding BW was 50.1% of predicted mature BW. Heifer age at breeding was not different ($P = 0.12$) between MGA and CIDR treatment groups. Percentage of heifers demonstrating signs of estrus was similar ($P = 0.42$) between synchronization treatment groups (CIDR vs MGA, 71.5 vs 77.4 ± 1.0%). Heifers not expressing estrus (32% of herd) were not given an opportunity to become pregnant and

removed from the herd. Pregnancy rates to AI of heifers expressing estrus (n = 115; 68% of herd) were similar (*P* = 0.27) between CIDR and MGA synchronization treatment (46.3 vs 36.1 ± 6.8%). Bulls were placed with heifers at a 1:50 ratio 4 d following AI. Final pregnancy rate was also similar (*P* = 0.96) between CIDR and MGA treatment groups (51.0 vs 51.5 ± 7.4%). Heifer BW at pregnancy diagnosis was not different (*P* = 0.45) between CIDR and MGA treatment groups (325 vs 321 ± 3.4 kg). Julian calf birth date did not differ (*P* = 0.30) between CIDR and MGA groups. Calf BW at birth was similar (*P* = 0.69) between groups as well. Approximately half of these 311 d old heifers exposed to AI and bulls became pregnant.

Introduction

For optimum lifetime productivity a beef heifer should give birth to her first calf at approximately 2 yr of age (Lesmeister et al., 1973). Thus, both traditional recommendations of developing heifers to 65% of mature BW (Short and Bellows, 1971; Patterson et al., 1992), and more recent development strategies to a lighter target BW (Funston and Deutscher, 2004; Roberts et al., 2007, 2009; Martin et al., 2008; Larson et al., 2009) have assumed an approximate breeding age of 15 mo. However, incidence of precocious puberty has been found to be higher than anticipated in several cases (Day and Anderson, 1998; Wehrman et al., 1996).

In beef cattle, precocious puberty is defined as attainment of puberty before 300 d of age (Gasser et al., 2006a; Wehrman et al., 1996). Gonzalez-Padilla et al., (1975) evaluated the use of a norgestamate implant to induce estrus in 9 and 10 mo old Angus heifers determined to be prepubertal by the absence of a CL and no visible signs of estrus. They observed 89% of treated heifers demonstrating signs of estrus within 4 d of implant removal compared to 25% of control heifers showing signs of estrus by d 18 of observation. These heifers were not given an opportunity to become pregnant, nor were they observed for more than 18 d to determine if they continued to cycle or if the induced estrus was a single occurrence.

Gasser et al. (2006a) evaluated the induction of precocious puberty in heifer calves weaned at 3 to 4 mo of age and fed a high concentrate diet (60% corn) or a control diet (30% corn). Precocious puberty occurred in 8 out of 9 heifers fed the high concentrate diet, compared with no heifers fed the control diet attaining precocious puberty.

The existence of precocious puberty gives rise to a new question, can heifers attain and maintain a pregnancy at a younger age than traditionally managed for? And if a pregnancy can be carried to term, will said heifers have the maturity to raise a calf? Furthermore, will they be able to continue to grow during pregnancy and attain a subsequent pregnancy? This study evaluated reproductive performance and subsequent calving performance of heifers exposed at 311 d of age synchronized with MGA or CIDR estrus synchronization protocols.

Materials and Methods

The University of Nebraska Animal Care and Use Committee approved the procedures and facilities used in this experiment. Angus-based, crossbred, fall-born heifers (n = 153) from 2 locations were utilized in this study. As calves, heifers and their dams received 10.3 kg of hay, 2.1 kg of dry distillers grain, and 0.02 kg of mineral (ADM Alliance Nutrition, Quincy, Illinois) per d (DM basis). At branding heifers received

Clostri Shield 7 (Novartis, St. Louis, MO), pasteurella (Colorado Serum Company, Denver, CO), and Vista 5 (Merck Animal Health, Madison, NJ). Heifers were weaned at approximately 193 d of age (Feb 18) and vaccinated with Vision 7 (Merck Animal Health, Madison, NJ), Vista 5, and pasteurella. After weaning heifers received, on a DM basis, 3.6 kg of hay, 1.4 kg of dry distillers grain, 0.6 kg of cracked corn and 0.02 kg of mineral per d (diet was 2.9% of BW) with amount increasing as heifer BW increased. Group BW was measured, heifers were drench wormed (Synanthic, Boehringer Ingelheim, St. Joseph, MO), and received BVD (Titanium 3, Elanco Animal Health, Greenfield, IN) and Brucellosis vaccinations on April 10. At approximately 10 mo of age, group pre-breeding BW was measured and heifers were randomly assigned to 1 of 2 estrus synchronization protocols in the spring. Estrus synchronization treatments are presented in Figure 1. Heifers in the MGA protocol received MGA for 14 d fed through the diet beginning on d 0 of the synchronization treatment period. Heifers in the CIDR treatment received the same diet as MGA heifers, on a DM basis, 4.8 kg of hay, 2.1 kg of dry distillers grain, 0.8 kg cracked corn and 0.02 kg of mineral (diet = 2.8% of BW), and were implanted with a CIDR (Eazi-breed CIDR, Zoetis, Florham Park, NJ) on d 2 of the treatment period and removed on d 16. Following estrus synchronization, heifers from both treatments were combined and received a single PG (Lutalyse, Zoetis, Florham Park, NJ) injection on d 32. Heifers with activated heat detection aids (Estrotect, Rockway Inc, Spring Valley, WI) were AI 12 h following observation for 3 d. Heifers not expressing signs of estrus (38/153; 25%) were not given an opportunity to become pregnant in the current trial. One week prior to AI heifers were allowed to graze irrigated rye pasture. Following AI heifers grazed irrigated millet pasture for approximately 30 d and then grazed wet hay meadow re-growth for approximately 30 d in the fall. Heifers exposed to AI (n = 115) were placed with bulls at a 1:50 bull to heifer ratio 4 d following the last d of AI for 35 d. Sixty-three d following bull removal heifers were diagnosed for pregnancy by a veterinarian. Over the winter heifers grazed deferred upland Sandhills range and were supplemented with dry distillers grain beginning at 1.0 kg/d (DM) and increasing as heifer demand increased. Hay was provided in times of deep snow cover.

At calving the following data was collected (n = 58): birth date, sex of calf, calf birth BW, calving ease score, and mothering score. Calving ease was scored according to BIF 9th Edition Guidelines (1= no difficulty, no assistance; 2= minor difficulty, some assistance; 3 = major difficulty; 4 = caesarian or very hard pull; 5 = abnormal presentation). A mothering score was assigned to each heifer at calving. Mothering score was similar to Behavioral Pen Scores described in the BIF 9th Edition Guidelines, but takes into consideration the heifer’s ability to care for her calf. The mothering score ranged from 1 to 5 wherein 1 = calm, attentive, keeps her calf with her; 2 = unremarkable, but presents no problems when moving the pair; 3 = slightly nervous or distracted; 4 = very nervous or confused, required extra time to move the pair; 5 = “crazy” or completely disinterested in the calf.

Economic Analysis

Due to the unique prices in the actual yr of this study (2014), average 5-yr price was used to conduct an economic analysis. Value of heifers was obtained from the wk heifers were weaned (USDA-AMS 2010a, 2011a, 2012a, 2013a, 2014a). Feed expenses included dry distillers grain (USDA-AMS 2010b, 2011b, 2012b, 2013b, 2014b), corn (USDA-AMS 2010b, 2011b, 2012b, 2013b, 2014b), and hay (USDA-AMS 2010c, 2011c, 2012c, 2013c, 2014c). Pasture rates were calculated as one half the pasture rental rates of a cow-calf pair, values which were obtained from the Nebraska Farm Real Estate Summary (Johnson et al., 2010, 2011, 2013; Johnson and Van Newkirk, 2012; Jansen and Wilson, 2014). Other expenses include interest calculated at 6.5% of the value of the heifer, management expense valued at $\$0.50 \cdot hd^{-1} \cdot d^{-1}$, vaccinations and other miscellaneous health expenses, and breeding expenses calculated using EstruSynch estrus synchronization planner (estrussynch.com). Total cost included value of heifer, feed cost, and other expenses. Cull heifer value at the time of pregnancy diagnosis (USDA-AMS 2010d, 2011d, 2012d, 2013, 2014d) was calculated by multiplying the value of a single cull heifer by 1 minus pregnancy rate (Feuz, 1992). The net cost of 1 pregnant heifer was calculated as the difference between total heifer cost and cull value, divided by pregnancy rate.

Statistical Analysis

All data were analyzed using the GLIMMIX procedure of SAS (SAS Institute, Inc., Cary, N.C.), accounting for origin as a random variable. Estrous response, pregnancy rate, and calf sex were 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

Group BW was measured at weaning and prior to breeding (Table 1). Pre-breeding BW was 50.1% of predicted mature BW. Heifer ages and estrous response are presented in Table 2. Heifer age at breeding was not different ($P = 0.12$) between MGA and CIDR treatment groups. Percentage of heifers demonstrating signs of estrus was similar (*P* = 0.42) between synchronization treatments (CIDR vs MGA, 71.5 vs 77.4 ± 1.0%). Heifers not expressing estrus were not given an opportunity to become pregnant and removed from the study. Pregnancy results are presented in Table 3. Pregnancy rates to AI were similar (*P* = 0.27) between CIDR and MGA synchronized heifers (46.3 vs 36.1 ± 6.8%). Final pregnancy rate was also similar (*P* = 0.96) between CIDR and MGA treatments (51.0 vs 51.5 ± 7.4%). Heifer BW at pregnancy diagnosis was not different (*P* = 0.45) between CIDR and MGA treatment groups (325 vs 321 ± 3.4 kg). Calving rate was similar (*P* = 0.72) between CIDR and MGA treatments (50.9 vs 47.5 ± 6.7).

Calving data is presented in Table 4. Julian calf birth date did not differ (*P* = 0.30) between CIDR and MGA groups. Calf BW at birth was similar (*P* = 0.69) between groups as well. Calving ease score was similar (*P* = 0.68; 1.3 ± 0.2 vs 1.2 ± 0.2, CIDR vs MGA). Mothering score was also similar (*P* = 0.79) with CIDR heifers scoring 2.1 ± 0.2 and MGA heifers scoring 2.0 ± 0.2.

Economic Analysis

Table 5 presents the economic analysis conducted using prices from the last 5 yr. Heifers began development at the same value and were developed as a single group, thus feed costs were also the same. Other expenses were numerically different due to the less expensive MGA-PG ($50.83) synchronization protocol compared with the 14-day CIDR-PG ($39.40) protocol. Given that final pregnancy rates were not different (*P* = 0.96), cull heifer values were also not different (*P* = 0.96). The net cost per pregnant heifer was similar (*P* = 0.86) between CIDR and MGA heifers.

Discussion

The heifers utilized in the current study were older than 300 d at the time of AI, but were 281 d old at the initiation of the estrus synchronization protocols. Gasser et al. (2006a,b) found heifers experiencing precocious puberty attained puberty at a lighter BW than their contemporaries not having precocious puberty. Furthermore, Gasser et al. (2006b) found precocious puberty in heifers not weaned early or fed a high concentrate diet; this was speculated to be due to the above average forage quality available to heifers and dams the yr of that particular study. Research presented by Gasser et al. (2006a,b) demonstrated the critical role of nutrition in the attainment of precocious puberty. Moreover, by decreasing energy intake immediately prior to the expected time of puberty attainment the attainment of puberty can be negatively influenced (Kurz et al., 1990).

In addition to nutrition, progestin has been shown to hasten puberty in pre-pubertal heifers (Anderson et al., 1996). Furthermore, prostaglandin has also been shown to induce ovulation in pre-pubertal heifers (Leonardi et al., 2012). It has been proposed progestins and prostaglandin may work synergistically in pre-pubertal heifers to cause an ovulation (Pfeifer et al., 2009). Both treatments in this study utilized progestin and prostaglandin. Although historic research has shown conception rates improve in heifers having experienced several estrous cycles prior to exposure (Byerley et al., 1987), more recent findings from our own lab have shown similar pregnancy rates between heifers conceiving on their 1st estrus or on their 3rd (Vraspir et al., 2013). This more recent data suggests the heifers in this study were not necessarily at a disadvantage simply because they may have not experienced an estrous cycle. Day and Nogueira (2013) proposed a way to improve efficiency in Bos indicus cattle, which traditionally calve for the first time as 3 or 4 yr olds, by exposing Nelore 12-15 mo old heifers to synchronization and

AI. Their preliminary findings indicated "precocious breeding" in Bos indicus cattle can be successful. Previous research has reported pregnancy rates of heifers developed for breeding at 15 mo in the Sandhills of Nebraska at a range from 82 to 91% (Larson et al., 2011; Martin et al., 2008; Summers et al., 2014). The pregnancy rates in the current study at 51% and 52% were not comparable with pregnancy rates of heifers exposed at a more traditional age.

Both age at weaning and pattern of growth have been shown to play an important role in puberty attainment. Heifers weaned early and fed a high concentrate diet reached puberty at the youngest age in a group of early weaned and normal weaned cattle (Moriel et al., 2014). While heifers in the current study received more dietary energy than considered normal for heifer development in the Nebraska Sandhills region; they were weaned at 193 d, which is not considered early weaning. Heifers in the present study were conceived in the fall of 2012, which was a severe drought yr in the Nebraska Sandhills. The repercussions of drought and the potential fetal impacts are undocumented. However, research has shown heifers from cows not receiving supplement throughout the winter have lower pregnancy rates than heifers born to supplemented contemporaries (Martin et al., 2007).

Historically, recommendation for heifer development has been to reach 65% of mature BW prior to the breeding season (Patterson et al., 1992). More recent data shows a lighter target BW is a cost effective way to develop heifers resulting in similar pregnancy rates (Freetly et al., 2001: Funston and Deutscher, 2004; Martin et al., 2008; Roberts et al., 2009; Funston and Larson, 2011). Heifers in this study were 50.1% of mature BW prior to the initiation of the breeding season, gaining 0.63 kg/d from weaning to breeding over a 118 d period. Approximately half of these 311 d old heifers exposed to AI and bulls became pregnant and successfully became mothers.

Implications

Although not significant, there was a numerical 10 percentage unit decrease in AI pregnancy rate in MGA compared with CIDR synchronization. Approximately half of these 311 d old heifers exposed to AI and bulls became pregnant. They went on to demonstrate adequate calving ease and mothering ability.

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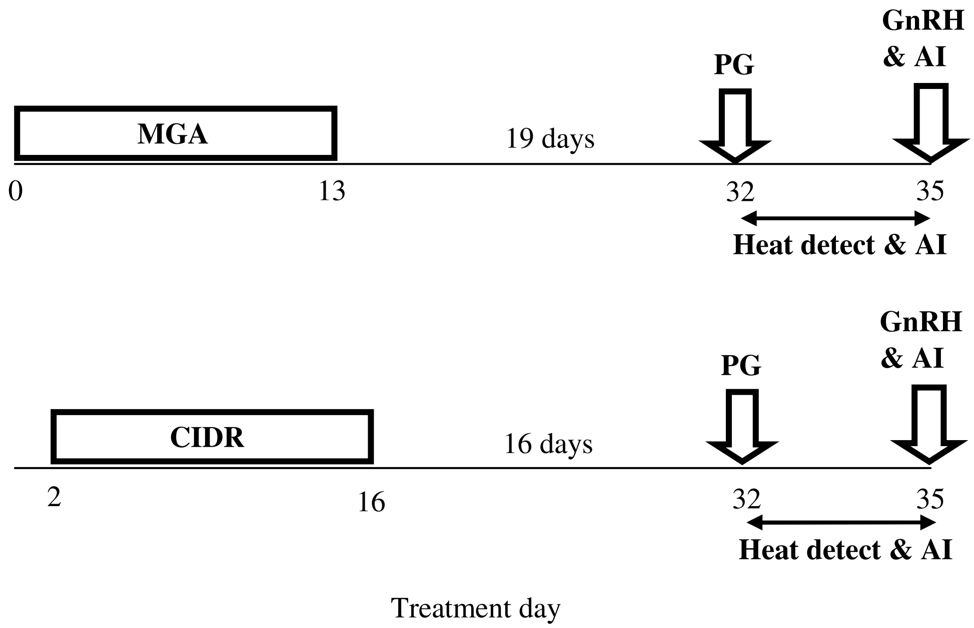

Figure 1. Treatment schedule for heifers in CIDR (n = 76) or MGA (n = 77) treatments. MGA = melengestrol acetate, CIDR = controlled internal drug release, PG = prostaglandin, GnRH = gonadotropin releasing hormone.

Table 1. Heifer development BW[1] for heifers AI at 311 d of age

Item	All Heifers
n	153
Weaning BW, kg	198
Pre-breeding BW, kg	273
Development ADG[2], kg	0.64
Percent of mature BW, %	50.1

[1] Group BW of all heifers were taken and weaning and pre-breeding; group BW averages are presented here.
[2] 118 d (Feb 18 to June 16).

Table 2. Effect of CIDR or MGA estrus synchronization on estrus response of 311 d old heifers

	CIDR[1]	MGA[2]	SEM	*P*-value
n	76	77		
Estrus Response, %	71.5	77.4	1.0	0.42
Age at weaning, Julian d	196	190	5	0.12
Age at breeding, Julian d	317	311	5	0.12

[1] Heifers synchronized using the 14-day CIDR-PG protocol.

[2] Heifers synchronized using the MGA-PG protocol.

Table 3. Effect of CIDR or MGA estrus synchronization on reproductive performance of 311 d old heifers

	CIDR[1]	MGA[2]	SEM	*P*-value
n	51	53		
AI pregnancy rate,[3] %	46.3	36.1	6.8	0.27
Total pregnancy rate,[4] %	51.0	51.5	7.4	0.96
Pregnancy diagnosis BW, kg	325	321	3.4	0.45
Calving rate,[5] %	50.9	47.5	6.7	0.72

[1] Heifers synchronized using the 14-day CIDR-PG protocol.
[2] Heifers synchronized using the MGA-PG protocol.
[3] The number of AI pregnant heifers divided by total heifers exposed.
[4] The number of pregnant heifers divided by the total heifers exposed.
[5] The number of calves born divided by the total heifers exposed.

Table 4. Calving performance of heifers' exposed at 311 d old

	CIDR[1]	MGA[2]	SEM	*P*-value
n	28	30		
Birth date, Julain d	82.8	86.0	2.2	0.30
Birth Weight, kg	33.7	34.1	0.5	0.69
Calf Sex[3]	0.43	0.45	0.09	0.88
Calving Ease Score[4]	1.3	1.2	0.2	0.68
Mothering Score[5]	2.1	2.0	0.2	0.79

[1] Heifers synchronized using the 14-day CIDR-PG protocol.
[2] Heifers synchronized using the MGA-PG protocol.
[3] Bull = 1, heifer = 0.
[4] 1 = no difficulty, no assistance, 2 = minor difficulty, some assistance, 3 = major difficulty, 4 = caesarian or very hard pull, 5 = abnormal presentation.
[5] 1 = calm, attentive, keeps her calf with her, 2 = unremarkable, but presents no problems when moving the pair, 3 = slightly nervous or distracted, 4 = very nervous or confused, required extra time to move the pair, 5 = "crazy" or completely disinterested in the calf.

Table 5. Economic analyses using average 5 yr price for heifer development from weaning to pregnancy diagnosis

	CIDR[1]	MGA[2]	SEM	*P*-value
Value of heifer, $	833.50	833.50	73.54	1.00
Feed Cost, $	233.46	233.46	23.15	1.00
Other expenses[3], $	260.01	248.58	4.78	0.13
Total Expenses, $	1,326.97	1,315.54	91.40	0.93
Less: Value of cull heifers[4], $	532.29	526.86	70.62	0.96
Net Cost, $	794.68	788.68	53.41	0.94
Net cost per pregnant heifer, $	1,558.20	1,531.42	104.21	0.86

[1] Heifers synchronized using the 14-day CIDR-PG protocol.
[2] Heifers synchronized using the MGA-PG protocol.
[3] Includes interest at 6.5%, management expense, vaccine, and other miscellaneous health expenses, and breeding expense.
[4] The value of non-pregnant heifers the week of pregnancy diagnosis multiplied by 1 minus pregnancy rate.

Chapter IV

Impact of heifer development system on subsequent ADG and reproduction in two different breeding seasons.

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Abstract

The objective of this study was to determine the impact of heifer development system on subsequent growth and reproductive performance in 2 breeding seasons. In Exp. 1, over a 3 yr period, 196 May-born, crossbred (5/8 Red Angus, 3/8 Continental) heifers were stratified by BW and randomly assigned to 1 of 2 post-weaning nutritional treatments (2 pastures·treatment^{-1}·year^{-1}) beginning mid-January to mid-April. Heifers were offered ad libitum meadow hay (HAY) and 1.81 kg/d (29% CP, DM basis) supplement or allowed to graze meadow (MDW) and 0.45 kg/d supplement. Heifers were managed as a single herd prior to and following treatment. Heifers were synchronized with a single PG injection 5 d after being placed with bulls for 45 d. Heifers on HAY treatment had greater ($P < 0.01$) ADG during the treatment period compared with MDW heifers (0.63 ± 0.01 kg/d vs 0.33 ± 0.01 kg/d, respectively). However, heifers grazing meadow experienced a compensatory gain resulting in similar ($P \geq 0.12$) BW in June, July, and at pregnancy diagnosis. There was no difference ($P = 0.65$) in the proportion of heifers attaining puberty prior to the breeding season for HAY (62 ± 18%) and MDW (49 ± 18%). Pregnancy rates were similar ($P = 0.79$) between HAY vs MDW treatments (69 ± 6% vs 67 ± 6% respectively). In Exp. 2, 100 spring-born, crossbred (5/8 Red Angus, 3/8 Continental) heifers were, over 2 yr, stratified by BW and randomly assigned to HAY

or MDW treatments. Similar to Exp. 1, HAY heifers had greater ($P < 0.01$) ADG during the treatment period than MDW heifers (0.80 ± 0.02 vs 0.47 ± 0.02 kg/d). During the spring, HAY and MDW heifers had similar ($P = 0.14$) ADG and BW was similar ($P \geq 0.17$) in May and September. Pubertal status prior to breeding was not affected by treatment ($P = 0.55$). Pregnancy rates were similar for HAY (88 ± 5%) and MDW (86 ± 5%, $P = 0.78$) heifers. Although ADG during the winter feeding period was greater for HAY heifers, BW was similar in the spring, summer, and at pregnancy diagnosis suggesting a compensatory growth effect for MDW heifers. Similarly, there was no difference in pubertal status or pregnancy rate indicating a lower input winter management system is viable to maintain heifer pubertal status and pregnancy rates in 2 breeding seasons.

Introduction

Retaining replacement heifers can be a major expense to the cow-calf enterprise. The majority of this expense can be attributed to feed. Considering high feed costs, recent efforts have been made to devise more economical methods of developing heifers. One way to do this is to develop heifers in a reduced input system. Traditionally, 65% of mature BW at breeding has been the standard recommendation (Patterson et al., 1992). Heifers developed to lower target BW have comparable reproductive performance to heifers developed in higher input systems (Funston and Deutscher, 2004; Roberts et al., 2009; Funston and Larson, 2011). Martin et al. (2008) reported no significant difference in puberty attainment for heifers fed to 51% vs 57% mature BW. However, a lower percentage of heifers had reached puberty prior to the breeding season when developed on corn residue compared with winter range or drylot. Furthermore, the use of reduced-input systems decreases heifer development costs (Funston and Deutscher, 2004; Martin et al., 2008; Funston and Larson, 2011). By taking advantage of the compensatory gain effect, the majority of heifer BW gain can be shifted to later in the development period. This results in maintaining a smaller animal for a longer period of time and has been observed to be a cost effective strategy for developing beef heifers (Clanton et al., 1983; Freetly et al., 2001; Lynch et al., 1997). The objective of this study was to determine the effect of reduced overwinter supplementation on ADG and reproductive performance in beef heifers in 2 breeding seasons.

Materials and Methods

The University of Nebraska Animal Care and Use Committee approved the procedures and facilities used in this experiment. Replacement heifers from 2 calving seasons, March and May, were utilized in this study. Over a 2 yr period, 100 March-born, crossbred (5/8 Red Angus, 3/8 Continental) heifers; and over a 3 yr period, 196 May-born, crossbred (5/8 Red Angus, 3/8 Continental) heifers were utilized. Heifers were stratified by BW and randomly assigned to 1 of 2 post-weaning treatments (2 pastures·treatment^{-1}·year^{-1}) applied from mid-January to mid-April. Heifers in the HAY treatment were offered *ad libitum* meadow hay and 1.81 kg/d supplement (29% CP, DM basis). Heifers receiving MDW treatment were allowed to graze meadow and offered 0.45 kg/d supplement. Prior to and following treatment, all heifers were managed as a single herd until the respective breeding seasons. Immediately prior to each breeding season, 2 blood samples were collected 10 d apart via caudal venipuncture for progesterone analysis to determine pubertal status. Five d after being placed with bulls (1:20 bull to heifer ratio), heifers were synchronized with a single PG injection and allowed a 45 d natural service breeding season beginning May 23 for March-calving heifers and July 10 for May-calving heifers. Pregnancy diagnosis was determined by ultrasound 40 d after bulls were removed. Forage samples were collected in each year from esophageally fistulated cattle for winter range, winter meadow, June range, July range, and September range and analyzed for CP and TDN.

Statistical Analyses

Data was analyzed using the GLIMMIX procedure of SAS (SAS Institute, Inc., Cary, N.C.) evaluating year, treatment, and year × treatment. The proportions of pubertal and pregnant heifers were analyzed using an odds ratio. Least squares means and SE of the proportion of pubertal and pregnant heifers by treatment were obtained using the ILINK function.

Economic Analyses

A cost analysis of treatment was generated to compare the winter feeding cost of HAY and MDW treatments. Hay prices were extremely variable during this study, ranging from $50 to $230 per ton, with an average hay cost of $120/ton assumed. The cost of grazing meadow was one-half the cost of winter grazing for a mature cow, based upon average BW over the treatment period. Basic management and yardage per heifer was estimated at $0.20/d. A partial budget analysis was conducted using the procedure by Feuz (1992). The budget analysis was evaluated for season (March and May) and treatment (HAY and MDW). Summer grazing cost per heifer was based on $1.00/ d, basic management was $0.20/ d, with an additional fixed expense of $15.00 per heifer for the yr calculated in. Heifer value at the beginning of the study (January 15) and at pregnancy diagnosis (September 10 and October 30, March and May herds) was calculated from the Nebraska average price reported by the USDA Agricultural Marketing Service (2011, 2012, 2013) for each corresponding date and respective average heifer BW. Total breeding cost included a single PG injection at $2.80/heifer and bull expense of $37.20/heifer. Total heifer cost was calculated by adding the purchase price, treatment cost, summer grazing and management cost, breeding cost, and 6% interest on the heifer purchase price. The net cost of 1 pregnant heifer was calculated as the difference between total heifer cost and cull value, divided by pregnancy rate.

Results and Discussion

Gain and Reproductive Performance

March-born treatment effects. March-born heifer BW gain and reproductive data are presented in Table 1. A year × treatment interaction ($P = 0.04$) is noted for ADG during the January 12 to April 22 treatment period, with HAY heifers having similar ($P = 0.99$) ADG between development years 2012 and 2013 (0.81 vs 0.80 ± 0.03 kg/d, respectively), whereas MDW heifers ADG tended to differ ($P = 0.05$) between development years (2012 vs 2013, 0.42 vs 0.51 ± 0.03 kg/d).

Heifers born in March on HAY had greater ($P < 0.01$) ADG during treatment than MDW heifers (0.80 vs 0.47 ± 0.02 lb/d, respectively). However, following treatment from April 22 to May 22, MDW heifers experienced a compensatory gain resulting in ($P < 0.01$) greater ADG ($P < 0.01$) compared with HAY heifers (0.84 vs 0.43 ± 0.04 kg/d, respectively). From May 22 to Sept 10, ADG were similar ($P = 0.36$) between HAY and MDW heifers (0.43 vs 0.46 ± 0.02 kg/d, respectively). Post-treatment BW was significantly ($P < 0.01$) greater for HAY vs MDW heifers (307 vs 275 ± 3.4 kg, respectively), which carried over to pre-breeding BW (HAY vs MDW; 319 vs 300 ± 3.6

kg, respectively). At breeding, HAY heifers had reached a greater (*P* < 0.01) percent mature BW (58 vs 54 ± 7%, for HAY and MDW, respectively). Previous research has observed heifers developed to a lower percentage of mature BW are equally reproductively competent (Funston and Deutscher, 2004; Martin et al., 2008). At pregnancy diagnosis, BW was similar (*P* = 0.25) between HAY and MDW heifers, (367 vs 352 ± 4.5 kg, respectively). Heifers developed on meadow experienced a compensatory gain effect, allowing for decreased inputs during the winter and resulting in similar BW by pregnancy diagnosis. The use of compensatory gain in the development of beef heifers is not a new concept and has been shown to be a cost effective method of beef heifer development (Freetly et al., 2001; Lynch et al., 1997). The proportion of heifers attaining puberty prior to the breeding season was similar (*P* = 0.40) between HAY and MDW heifers (44 vs 52 ± 8%, respectively). Pregnancy rate was also similar for HAY (88 ± 5%) and MDW (86 ± 5%, *P* = 0.72) heifers. Calving rate was not different (*P* = 0.82) between HAY and MDW heifers (86 vs 85 ± 5%). Furthermore, the percentage of heifers calving in the first 21 d of the calving season was similar (*P* = 0.52; 70 vs 64 ± 7, HAY vs MDW).

March-born year effects. Year effects (*P* < 0.01) are noted on spring and summer ADG between heifers developed in 2012 and 2013, most likely due to severe drought in 2012. There was no difference (*P* = 0.10) in ADG during the treatment period from January 15 to April 15. There was a difference (*P* < 0.01) in spring ADG during the time period from April to May (2012 vs 2013; 0.85 vs 0.42 ± 0.04 kg/d). However this difference was inverted in summer ADG from May through September (2012 vs 2013; 0.27 vs 0.62 ± 0.02 kg/d). Neither weaning BW nor post-treatment BW were different (*P*

= 0.17 and 0.64, respectively) between development years 2012 and 2013. Pre-breeding BW was different ($P < 0.01$) between 2012 and 2013 development years (318 vs 302 ± 4 kg). This difference in BW carried over to BW at pregnancy diagnosis (2012 vs 2013; 348 vs 370 ± 4 kg; $P < 0.01$). Percent of mature BW prior to the breeding season was different ($P < 0.01$) between 2012 and 2013 (58 vs 54 ± 1 %); furthermore percent of heifers attaining pubertal status prior to the initiation of the breeding season was different ($P < 0.01$) between 2012 and 2013 (60 vs 30 ± 7 %). Pregnancy rates did not differ (P = 0.13) between 2012 and 2013 (92 vs 82 ± 6 %). The differences in ADG and BW between development yr is likely due to the dramatic difference in rainfall between 2012 and 2013. The nutrient composition of the range is presented in Table 2. In 2012, June Range CP was 10.1% (DM) compared to 2013 June Range CP at 19.3% (DM). Values for June Range TDN also varied between 2012 and 2013 at 61.5 and 79.7% (DM), respectively.

May-born treatment effects. Table 3 presents the BW and reproductive results for May-born heifers. Similar to the March-born heifers, May-born heifers on HAY treatment, had greater ($P < 0.01$) ADG during the treatment period, from January 5 to May 10, compared with MDW heifers (0.66 vs 0.35 ± 0.04 kg/d, respectively). However, heifers grazing meadow experienced greater ($P < 0.01$) ADG following treatment, from May 10 to July 9, (HAY vs MDW; 0.88 vs 1.01 ± 0.02 kg/d). Furthermore, MDW heifers continued to have greater ($P < 0.01$) ADG, from July 9 to September 10, compared with HAY heifers (0.45 vs 0.39 ± 0.01 kg/d, respectively). Post-treatment BW was greater ($P < 0.01$) for heifers on HAY treatment compared with heifers on MDW treatment (271 vs 232 ± 3 kg, respectively). This increased BW for HAY heifers continued to pre-breeding

(HAY vs MDW, 323 vs 293 ± 3 kg; $P < 0.01$) and pregnancy diagnosis (HAY vs MDW, 366 vs 342 ± 3 kg; $P < 0.01$). Heifers on the HAY treatment were 59 ± 1% of their mature BW, while MDW were 52 ± 1% of mature BW at breeding ($P < 0.01$). Although traditional recommendations are for heifers to reach 55 to 65% of mature BW prior to breeding (NRC, 2000; Patterson et al., 1992), more recent findings have demonstrated heifers developed to a lower target BW do not sacrifice pregnancy rates. One advantage to a reduced input beef heifer development system resulting in lighter BW females is a potential decreased lifetime nutrient requirement. Roberts et al. (2011) observed lighter BW through 5 yr of age in heifers developed with a nutritionally restricted diet compared with controls. Given smaller animals have less nutritional requirements (NRC, 2000), this results in decreased feed cost. The proportion of heifers attaining puberty prior to the breeding season was greater ($P = 0.03$) for HAY vs MDW heifers (68 vs 54 ± 6%, respectively). Pregnancy rate was similar ($P = 0.44$) between treatments (66 vs 61 ± 5% for HAY and MDW heifers, respectively). Similarly, Freetly et al. (2001) observed no decrease in pregnancy rates to heifers developed utilizing a compensatory gain strategy, by first restricting intake and then increasing intake. Calving rate was similar ($P = 0.52$) between HAY and MDW (63 vs 59 ± 5%), as was the percentage of heifers calving in the first 21 d of the calving season ($P = 0.52$; 51 vs 47 ± 6, HAY vs MDW). There is a difference ($P < 0.01$) in pregnancy rates between March and May heifers (87 vs 63 ± 4%). These relatively low pregnancy rates in the May calving heifers are attributed to the decreasing forage quality and availability on Sandhills range during the breeding season (July and August) for a May-calving herd. Table 2 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.

May born year effects. Effects of development yr is noted for all ADG time periods and BW (except pre-breeding BW) as a result of the extreme variability in forage quality between the relatively normal yr, 2011; the severe drought yr, 2012; and the unique post-drought recovery yr, 2013. There was a year effect on treatment ADG where 2012 was greater ($P < 0.01$) than 2013 with 2011 intermediate (2011 vs 2012 vs 2013; 0.54 vs 0.58 vs 0.40 ± 0.08 kg/d; $P < 0.01$). Spring ADG was similar ($P = 0.93$) between 2011 and 2012 (0.82 vs 0.88 ± 0.03 kg/d, respectively), which were less ($P < 0.01$) than 2013 (1.10 ± 0.03 kg/d). Summer ADG was different between all 3 yr (2011 vs 2012 vs 2013; 0.58 vs 0.31 vs 0.38 kg/d; $P < 0.01$). Weaning BW was similar ($P = 0.99$) between 2012 and 2013 (197 vs 197 ± 3 kg), which was greater ($P = 0.02$) than 2011 (186 ± 3 kg). Post treatment BW tended to differ ($P = 0.08$) between 2011 and 2012 development yr and lower ($P < 0.01$) in 2013. Pre-breeding BW did not differ ($P = 0.11$) among yr. Body weight at pregnancy diagnosis was greater ($P = 0.02$) in 2011 than 2012 or 2013 (366, 347, 351 ± 4 kg, respectively). Percent of mature BW did not differ ($P = 0.59$) among development yr. Although the percent of heifers attaining puberty prior to the breeding season was not different ($P = 0.64$) between 2011 and 2012, fewer ($P < 0.01$) heifers attained puberty prior to the breeding season in 2013. Pregnancy rates did not differ (*P* 0.29) among development yr in the May-born heifers. Again, yr differences are reflective of the variation in rainfall and subsequent range quality in the Nebraska Sandhills from 2011 to 2013. Table 2 presents the nutrient composition of the range among these yr.

Economic Analysis

Treatment cost analyses are presented in Table 4. The over-winter daily cost for HAY heifers was \$1.63/heifer compared with MDW heifers at \$0.89/heifer, resulting in a \$0.74/d savings. Over the 3 mo treatment period, this equates to a difference ($P < 0.01$) in cost; \$146.70 treatment cost for HAY heifers compared with \$80.10 treatment cost for MDW heifers. Therefore, there was a \$66.60/heifer savings by grazing meadow with 0.45 kg of supplement compared with *ad libitum* hay and 1.81 kg of supplement.

The partial budget analyses (Table 5) reveals the cost per pregnant heifer is \$65.92 greater for March-born heifers on HAY compared with MDW treatment. May-born heifers on HAY had \$49.57/pregnant heifer greater cost than their contemporaries on MDW treatment. This is similar to previous research findings where heifers developed with limited input at the beginning of the development period and utilizing compensatory gain to reach the desired target BW eat less than heifers developed to gain uniformly throughout the development time period, resulting in decreased development costs (Clanton et al., 1983; Lynch et al., 1997). Furthermore, developing heifers to a lower target BW has been shown to be an effective strategy to produce beef replacement heifers in a cost effective manner (Clark et al., 2005; Feuz, 1992).

Heifers on the HAY treatment had greater ADG during the winter feeding period resulting in greater pre-breeding BW for HAY heifers compared with MDW heifers resulting in HAY heifers reaching a greater percentage of their mature BW at breeding. There was no difference in pubertal status or pregnancy rate between HAY and MDW heifers, indicating a lower input winter management system is viable to maintain heifer pubertal status and pregnancy rates in 2 breeding seasons. A \$66.60/heifer savings from

January to April in the MDW treatment indicates an economic advantage to the grazed meadow heifer development system.

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Table 1. Effect of over-winter treatment on developing March-born heifer ADG, BW, and reproductive performance

Item	Development Year 2012	Development Year 2013	SEM	*P*-value	Treatment HAY[1]	Treatment MDW[2]	SEM	*P*-value
n	50	50			50	50		
ADG								
Treatment ADG,[3] kg/d	0.62	0.65	0.02	0.10	0.80	0.47	0.02	<0.01
Spring ADG,[4] kg/d	0.85	0.42	0.04	<0.01	0.43	0.84	0.04	<0.01
Summer ADG,[5] kg/d	0.27	0.62	0.02	<0.01	0.43	0.46	0.02	0.36
Body Weight								
Weaning BW, kg	192	186	3	0.17	188	191	3	0.63
Post-treatment BW, kg	292	290	3	0.64	307	275	3	<0.01
Pre-breeding BW,[6] kg	318	302	4	<0.01	319	300	4	<0.01
Percent Mature BW,[7] %	58	54	1	<0.01	58	54	1	<0.01
Pregnancy Diagnosis BW, kg	348	370	4	<0.01	367	352	5	0.25
Pubertal,[8] %	60	30	7	<0.01	44	52	8	0.40
Pregnancy Rate, %	92	82	6	0.13	88	86	5	0.72
Calving Rate, %	90	80	6	0.16	86	85	5	0.82
Calved in 1st 21 d, %	74	60	7	0.14	70	64	7	0.52

[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] Treatment ADG from January 16 to April 22 (96 d), includes the treatment period.

[4] Spring ADG from April 22 to May 22 (30 d).

[5] Summer ADG from May 22 to Sept 10 (111 d).

[6] Pre-breeding BW determined May 22.

[7] Percent of mature BW at breeding based on mature cow size of 552.5 kg.

[8] Considered pubertal if blood serum progesterone concentration >1 ng/mL.

Table 2. Nutrient composition of range and hay in each development year[1]

	2011	2012	2013
Development period diet			
Winter Range CP, [2] % DM	5.6	5.4	7.8
Winter Range TDN, [2] % DM	51.7	52.5	54.4
Winter Meadow CP, [2] % DM	7.7	10.7	9.9
Winter Meadow TDN, [2] % DM	55.8	60.7	61.2
Hay CP, [3] % DM	7.3	7.3	6.8
Hay TDN, [3] % DM	54.4	55.9	48.2
March-calving breeding season diet			
June Range CP, % DM	14.0	10.1	19.3
June Range TDN, % DM	64.3	61.5	79.7
May-calving breeding season diet			
July Range CP, % DM	11.1	10.6	14.7
July Range TDN, % DM	61.2	59.6	71.0
Sept. Range CP, % DM	6.9	8.2	9.8
Sept. Range TDN, % DM	61.4	58.5	65.0

[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. Effect of over-winter treatment on developing May born heifer ADG, BW, and reproductive performance

	Development Year					Treatment			
Item	2011	2012	2013	SEM	*P*-value	HAY[1]	MDW[2]	SEM	*P*-value
n	65	65	66			97	99		
ADG									
Treatment ADG,[3] kg/d	$0.54^{a,b}$	0.58^{a}	0.40^{b}	0.08	<0.01	0.66	0.35	0.04	<0.01
Spring ADG,[4] kg/d	0.82^{a}	0.88^{a}	1.10^{b}	0.03	<0.01	0.88	1.01	0.02	<0.01
Summer ADG,[5] kg/d	0.58^{a}	0.31^{b}	0.38^{c}	0.01	<0.01	0.39	0.45	0.01	<0.01
Body Weight									
Weaning BW, kg	186^{a}	197^{b}	197^{b}	3	<0.01	193	193	2	0.91
Post-treatment BW, kg	253^{a}	264^{a}	238^{b}	3	<0.01	271	232	3	<0.01
Pre-breeding BW,[6] kg	305	315	305	5	0.11	323	293	3	<0.01
Percent Mature BW,[7] %	58	71	62	1	0.59	59	52	1	<0.01
Pregnancy Diagnosis BW, kg	366^{a}	347^{b}	351^{b}	4	<0.01	366	342	3	<0.01
Pubertal,[8] %	69^{a}	77^{a}	37^{b}	8	<0.05	68	54	6	0.03
Pregnancy Rate, %	58	71	62	6	0.29	66	61	5	0.44
Calving Rate, %	57	68	57	6	0.31	63	59	5	0.52
Calved in 1st 21 d, %	46	55	45	7	0.55	51	47	6	0.52

[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] Treatment ADG from January 5 to May 10 (125 d), includes the treatment period.
[4] Spring ADG from May 10 to July 9 (60 d).
[5] Summer ADG from July 9 to Sept 10 (63 d).
[6] Pre-breeding BW determined Sept 10.
[7] Percent of mature BW at breeding based on mature cow size of 552.5 kg.
[8] Considered pubertal if blood serum progesterone concentration >1 ng/mL.
[a,b,c] Means in a row with different superscripts are different ($P < 0.01$).

Table 4. Cost analysis of heifer development over-winter nutritional treatments

Item	HAY[1]	MDW[2]
Hay,[3] $/hd/d	0.66	-
Meadow pasture, $/hd/d	-	0.50
Supplement (4 lb/d),[4]	0.77	0.19
Yardage, $/hd/d	0.20	0.20
Total, $/hd/d	1.63	0.89
Treatment total,[5] $/hd	146.70	80.10

[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 5. Partial budget analysis of heifer development calving season and over-winter nutritional treatments

	March-calving		May-calving	
Item	HAY[1]	MDW[2]	HAY[1]	MDW[2]
Value of Heifer, Jan 15, $	775.52	777.06	700.52	707.20
Feed Cost:				
Winter Treatment Period,[1,2] $	146.70	80.10	146.70	80.10
Summer grazing,[3] $	148.00	148.00	198.00	198.00
Breeding Expense,[4] $	40.00	40.00	40.00	40.00
Fixed Expenses, $	25.00	25.00	25.00	25.00
Management Expense,[5] $	29.60	29.60	39.60	39.60
Interest @ 6.0%, $	46.53	46.62	42.03	42.43
Total cost, $	1,211.35	1,146.38	1,191.85	1,132.33
Less: Value of cull heifers,[6] $	147.21	163.51	386.38	418.12
Net Cost, $	1,064.14	982.87	805.47	714.21
Net cost per pregnant heifer, $	1,195.66	1,129.74	1,220.41	1,170.84

[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] Summer grazing calculated at $1.00/hd/d.
[4] Breeding expense includes cost of bull use and a single injection of PG.
[5] Management expense calculated at $0.20/hd/d.
[6] Heifer cull value calculated from prices the week of pregnancy diagnosis.

Chapter V

Effect of post-weaning heifer development on pregnancy rates and subsequent feed efficiency as a pregnant first-calf heifer

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Abstract

To determine the impact of heifer development system on pregnancy rates and feed efficiency as a pregnant first calf heifer a 3 yr study was conducted. In Yr 1, weaned heifers either grazed corn residue (CR) or were fed in a drylot (DLHI). In Yr 2 and 3 heifers either grazed CR, upland range (RANGE), or were fed diets differing in energy, high (DLHI) or low (DLLO), in a drylot setting. Percent of mature BW prior to the breeding season was similar among treatments except DLHI, which was greater (P = 0.04) at 66.7% compared with 59.4, and 60.7% for RANGE and CR treatments, with DLLO intermediate at 61.6%. Pregnancy rates to AI were similar (P = 0.70) among treatments (58.7, 66.3, 60.4, 52.7 ± 9.7%; RANGE, CR, DLHI, DLLO). A subset of AI-pregnant heifers from each treatment were placed in a Calan gate system. Heifers were allowed a 20 d acclimation and training period before beginning the 90 d ad libitum hay treatment period on approximately gestational d 170. Offerings were recorded daily and orts collected weekly. Initial BW was not different (P = 0.62) among treatments (458, 468, 473, 464 ± 9 kg; RANGE, CR, DLHI, DLLO). Body weight at the end of the treatment period was also not different ([P = 0.55] 458, 497, 503, 491 ± 16 kg; RANGE, CR, DLHI, DLLO). Intake did not differ among treatments, either as DMI ([P = 0.59] 9.24, 9.37, 9.53, 9.39 ± 0.65 kg; RANGE, CR, DLHI, DLLO) or as a percentage of BW

([*P* = 0.98] 1.96, 1.95, 1.95, 1.96 ± 0.15 %; RANGE, CR, DLHI, DLLO). There was no difference (*P* = 0.58) in ADG (0.28, 0.33, 0.32, 0.28 ± 0.17; RANGE, CR, DLHI, DLLO) or residual feed intake ([*P* = 0.41] -0.095, -0.096, 0.144, 0.113 ± 0.156; RANGE, CR, DLHI, DLLO) among treatments. Although there was no difference (*P* = 0.41) in the 3-mo-development cost among treatments ($166.06, 141.66, 160.63, 171.80 ± 12.52; RANGE, CR, DLHI, DLLO), there was a $30.14 numerical difference between the most expensive treatment, DLHI, and the least costly treatment, CR. Post-weaning heifer development system did not impact heifer pregnancy rate or feed conversion as pregnant first calf heifers.

Introduction

Retaining and developing replacement heifers presents one of the largest expenses to the cow-calf producer, only surpassed by the feed expense of maintaining the cow herd. Recent efforts have been made to minimize the cost of replacement heifer development. Altered strategies of gain, utilizing the compensatory gain effect to reach a similar target weight, have lessened development costs and result in similar reproductive performance (Lynch et al., 1997; Freetly et al., 2001). Furthermore, developing heifers to a lower target BW than previously recommended has been shown to significantly reduce development cost, negating any pregnancy rate reduction (Feuz, 1992; Clark et al., 2005). This concept presents an alternate management strategy for developing more heifers with the intention of selling non-pregnant heifers as yearlings.

Resource availability and cost are often dependent upon year and a producers' location. As corn prices have recently been at record highs and more marginal land has been converted to crops, the availability of corn residue as a winter grazing forage has increased. Developing heifers on corn residue has been shown to be a successful alternative to more traditional development methods (Funston and Larson, 2011; Summers et al., 2014). With more native range being converted to cropland, the cost of range grazing has increased. However, in times of high hay prices a drylot system is less cost effective. Management considerations must also play into a development strategy decision. An intensive management system in the drylot may work well for some producers with the appropriate infrastructure, while an extensive management system grazing winter range or corn residue is more applicable to other producers. Previous research comparing corn residue and drylot systems has found heifers in the drylot gain more during the development period than their contemporaries on corn residue (Summers et al., 2014). However heifers developed on corn residue experience increased post AI ADG while on summer range, compared to heifers developed in confinement. It remains unclear if this difference is a result of compensatory gain or retained learned grazing behavior as suggested by Summers et al. (2014). To evaluate this difference 2 drylot diets were utilized in the current study, a traditional heifer development diet, and a lower energy diet to mirror the diets available in range and corn residue grazing situations. By comparing extensive grazing systems (range and corn residue), a confinement system of comparable nutritional quality, and a higher energy confinement system, the effects of grazing and confinement systems can be observed.

The second aspect of this study sought to determine if heifer development system impacted feed efficiency as a pregnant first calf heifer. The most expensive aspect of beef production is the feed cost associated with maintaining the cow herd, which accounts for approximately 50% of the total cost of beef production (Lamb and Maddock, 2009).

Recently, greater effort has been made to select feed efficient animals. However, it remains unclear if selection for greater efficiency results in decreased DMI in the mature cow (Meyer et al., 2008). Understanding the long term effects of heifer development on cow feed efficiency will allow producers to make better management decisions. Whether a difference lies in behavioral effects as suggested by Summers et al. (2014) or previous diet quality; any effects on mature cow intake as a result of developmental system have the potential to impact beef producers' profitability.

Materials and Methods

Post-weaning development

The University of Nebraska Animal Care and Use Committee approved the procedures and facilities used in this experiment. Angus-based, crossbred, spring born heifers purchased from the same ranch all 3 yr were weaned and delivered to the University of Nebraska West Central Research and Extension Center (WCREC) in North Platte, NE.

In Yr 1, weaned heifers either grazed combination of corn residue and upland winter range (CR) or were fed in a drylot (DLHI). In Yr 2 and 3 heifers either grazed CR, upland winter range (RANGE), or were fed, in a drylot setting, diets differing in energy, high (DLHI) or low (DLLO). Treatments are presented in Figure 1. Heifers on the CR (n = 100) treatment grazed corn residue from mid-November through mid-February, when they were placed on upland range until brought into the drylot for synchronization. In Yr 1, heifers in DLHI (n = 50) grazed winter range for half the treatment period before being placed in the drylot. RANGE heifers (n =50) grazed winter range throughout the treatment period. In Yr 2 and 3, DLHI (n = 50) and DLLO (n = 50) heifers were placed in the drylot for the duration of the treatment period. In treatments CR, RANGE, and during the first half of the treatment period for DLHI heifers in Yr 1, heifers received the equivalent of 0.45 $kg \cdot hd^{-1} \cdot d^{-1}$of a 29% CP, dry distiller grain-based supplement containing monensin, with hay provided in times of deep snow. Drylot diets are presented in Table 1, with drylot supplement presented in Table 2.

Prior to estrus synchronization blood samples were collected 10 d apart via caudal venipuncture and analyzed by RIA (Coat-A-Count Technologies, Diagnostics Products Corp., Los Angeles, CA) to determine pubertal status. Heifers with greater than 1 ng of progesterone per ml at either collection were considered pubertal. For this thesis pubertal status data from Yr 1 and 2 are included. Heifers were synchronized using the MGA-PG protocol as a single group. Heat detection aids (Estrotect, Rockway Inc, Spring Valley, WI) were applied at the time of PG injection (Lutalyse, Zoetis, Florham Park, NJ) and heifers in standing estrus were removed from the herd and AI 12 h later by an experienced technician. Heifers were detected for estrus for 4 d. Heifers not expressing estrus received a second PG injection 6 d following the first PG injection and immediately turned out with bulls. The remainder of heifers were combined with the non-estrus heifers and bulls 10 d following AI on upland range for the summer at a 1:50 bull to heifer ratio for 60 d. Pregnancy diagnosis for determination of AI conceptions was conducted via trans-rectal ultrasonography (ReproScan, Beaverton, OR) 45 d following AI. Forty-five d after bull removal a second pregnancy diagnosis was conducted to determine final pregnancy rate.

Pregnant Heifer Feed Efficiency

Following pregnancy diagnosis, a subset of AI-pregnant heifers from each development treatment (RANGE, n = 20; CR, n = 38; DLHI, n = 39; DLLO, n = 17) were placed in a Calan gate system in mid-October. Heifers were allowed a 20 d acclimation and training period before beginning the 90 d ad libitum hay (CP: Yr 1- 8.5%, Yr 2- 7.6%, Yr 3 7.0% [DM]) treatment period on approximately gestational d 170. Individual offerings were recorded daily and orts collected weekly.

Economic Analysis

Due to the extreme price fluctuations in the actual years this experiment was conducted, average 5 yr price was used to conduct an economic analysis. Value of heifers was obtained for the week heifers were received (USDA-AMS, 2010a, 2011a, 2012a, 2013a, 2014a). Pasture values were calculated as one half the cost of a cow-calf pair in the Southwest region of Nebraska and were obtained for the study years from the Nebraska Farm Real Estate Market Highlights (Johnson et al., 2010, 2011, 2013; Johnson and Van Newkirk, 2012; Jansen and Wilson, 2014). Wet corn gluten feed prices were obtained from the National Weekly Feedstuffs report from USDA AMS from the third week in September using the Kansas City values (USDA-AMS, 2010b-2014b). Hay prices were also obtained from the third week of September in the Platte Valley from the Nebraska and Iowa Hay report (USDA-AMS, 2010c-2014c). Actual costs of heifer supplement included in WCREC drylot diets, and cube supplement, fed to RANGE and CR heifers, were used. Other expenses include 6.5% interest of value of heifer, vaccine, yardage, trucking for CR heifers, breeding expenses, and other miscellaneous expenses. Cull values of non-pregnant heifers were obtained for the week of final pregnancy diagnosis (USDA-AMS, 2010d-2014d). The net cost of 1 pregnant heifer was found using the calculation put forth by Feuz (1992). The value of 1 non-pregnant heifers was divided by 1 minus pregnancy rate to determine the value of cull heifers per pregnant heifer. This value was subtracted from the total development cost. Then the adjusted cost of development is divided by pregnancy rate to find the net cost of 1 pregnant heifer.

Statistical Analysis

Treatment was heifer development system in which CR and DLHI was replicated in 3 yr and RANGE and DLLO was replicated in 2 yr. Year was considered the experimental unit for this study, with development treatment the fixed effect. Data was analyzed using the GLIMMIX procedure of SAS (SAS Inst. Inc., Cary NC). Pregnancy analyses included AI technician as a random effect. Pregnant heifer feed efficiency analyses included pen as a random effect. A P-value ≤ 0.05 was considered significant, with P-values between 0.05 and 0.1 considered tendencies. Least square means and SE of the proportion of pubertal and pregnant heifers by treatment were obtained using the ILINK function.

Results and Discussion

Post Weaning Development Treatment

Data in Table 3 represent heifer performance through development to pregnancy diagnosis. Year × treatment interactions are presented where significant. In all other variables yr and treatment effects are presented separately. Heifers began the study at a similar (P = 0.83) BW. During the treatment period, DLHI heifers had higher (P = 0.01) ADG than RANGE and CR treatments, additionally DLHI (P = 0.08) tended to have greater ADG than DLLO heifers. Differences in ADG resulted in a similar trend in post-treatment BW, where DLHI heifers were heavier (*P* = 0.01) than RANGE and CR heifers and tended (*P* = 0.05) to be heavier than DLLO heifers. This variation in BW carried over to pre-breeding BW; DLHI were heavier (*P* = 0.04) than RANGE and CR heifers, with DLLO similar to all other treatments. Thus, percent of mature BW prior to the breeding season was also greater (*P* = 0.04) for DLHI at 66.7% compared with RANGE and CR, at 59.4 and 60.7% with DLLO similar to all other treatments at 61.6%. Average daily gain following AI to the first pregnancy diagnosis, was similar between RANGE, CR, and DLLO; also similar was DLHI and DLLO. RANGE heifers tended (*P* = 0.08) to gain more than DLHI heifers; moreover, CR heifers gained more (*P* = 0.02) than DLHI heifers. Although DLHI heifers had the lowest ADG following AI, BW at the first pregnancy diagnosis tended (*P* = 0.05) to be greatest for DLHI heifers compared with all other treatments. Final pregnancy diagnosis BW also tended to be different (*P* = 0.08) with DLHI tending be heavier than DLLO (*P* = 0.10; 448 vs 427 ± 5 kg) with RANGE and CR intermediate (428 and 436 ± 5 kg).

Pubertal status prior to synchronization was not different (*P* = 0.20) among treatments (28.5, 41.3, 86.1, 77.2 ± 10.0%; RANGE, CR, DLHI, DLLO). Pregnancy rates to AI were similar (*P* = 0.70) among treatments (58.7, 66.3, 60.4, 52.7 ± 9.7 %; RANGE, CR, DLHI, DLLO). Furthermore, final pregnancy rates were also similar (*P* = 0.42) among treatments (82.6, 90.4, 92.6, 94.7 ± 7.5 %; RANGE, CR, DLHI, DLLO); although a 12.1% numerical difference does exist between the RANGE heifers, the lowest final pregnancy rate, and DLLO, the highest final pregnancy rate. Numerically, there is little variation in pregnancy rates within the extensive development systems, RANGE and CR; or within the intensive development systems, DLHI and DLLO.

Heifers fed a restricted diet, to achieve 53% of mature BW, consumed 27% less harvested feed in a 140 d trial period than their contemporaries offered ad libitum access, to achieve 58% of mature BW (Roberts et al., 2009). Additionally, final pregnancy rates following a 45 d breeding season did not differ; restricted heifers were 87% and ad libitum heifers were 91%. However, pregnancies conceived in the first 21 d of the breeding season tended to be reduced in restricted heifers (Roberts et al., 2009). Heifers developed on either high (to achieve 65% of mature BW) or low gain (to achieve 55% of mature BW) diets from 8 mo to d 21 of the breeding season had similar pregnancy rates after 47 d of breeding, although a larger proportion of high gain heifers became pregnant in the first 21 d of the breeding period (Eborn et al., 2013). The decreased pregnancy rates in low gain heifers were not due to decreased cyclicity as a result of diet because a similar proportion of heifers were cycling prior to the breeding season across nutritional treatment, breed, and yr (Eborn et al., 2013).

Pregnant Heifer Feed Efficiency

An additional potential impact of heifer development strategy is cow feed efficiency. If the strategy used to develop heifers has an impact on lifetime efficiency, beef producers could benefit greatly as a result of cost savings in maintaining the mature cow herd. Table 4 presents performance and feed efficiency data collected from a subset of AI pregnant heifers placed in the Calan gate system. Initial BW was not different (P = 0.62) among treatments (458, 468, 473, 464 ± 9 kg; RANGE, CR, DLHI, DLLO). Body weight at the end of the treatment period was also not different (P = 0.55; 485, 497, 503, 491 ± 16 kg; RANGE, CR, DLHI, DLLO). Intake did not differ among treatments, either as DMI (P = 0.59; 9.24, 9.37, 9.53, 9.39 ± 0.65 kg; RANGE, CR, DLHI, DLLO) or as a percentage of BW (P = 0.98; 1.96, 1.95, 1.95, 1.96 ± 0.15 %; RANGE, CR, DLHI, DLLO). There was no difference (P = 0.58) in ADG (0.28, 0.33, 0.32, 0.28 ± 0.17; RANGE, CR, DLHI, DLLO) or residual feed intake (P = 0.41; -0.095, -0.096, 0.144, 0.113 ± 0.156; RANGE, CR, DLHI, DLLO) among treatments. In a comparison of intensive and extensive heifer development systems Summers et al. (2014) suggest learned grazing behavior during the development period may impact future heifer ADG. Meyer et al. (2008) determined RFI of heifers fed a forage only diet. Then heifers were divided into high and low RFI groups. As cows, pasture DMI, determined using a rising plate meter, was similar between high and low RFI groups.

Recent emphasis on genetic selection for feed efficient cattle to optimize profit in the feed yard has led to the idea of increased feed efficiency in the cow herd. Although potential exists for great feed cost savings by increasing feed efficiency, reproductive efficiency in the cow herd should be priority. Hughes and Pitchford (2004) evaluated mice divergently selected for efficiency when not pregnant or lactating, and found highly efficient mice became less efficient, similar in efficiency to less efficient mice, when pregnant and lactating. The authors suggested the less efficient mice could repartition feed resources during pregnancy and lactation previously being wasted, while highly efficient mice do not have that reserve of energy and must consume more to meet the increasing requirements of pregnancy and lactation. Basarab et al. (2011) found heifers selected for high feed efficiency had lower pregnancy (P = 0.09) and calving (P = 0.05) rates than low efficiency contemporaries. In the current study, development treatment had no impact on feed efficiency as a pregnant first calf heifer. Further research investigating the impacts of heifer development system on lifetime feed efficiency is needed.

Economic Analysis

Heifers began development with the same value and receiving diet expense. The diet cost was different ($P < 0.01$) among treatments, with all treatments differing ($P < 0.05$) from one another with the exception of RANGE and CR treatments, which had similar ($P = 0.56$) treatment costs (Table 5). There was a $41.12 difference between the most expensive treatment diet, DLHI, and the mean of the 2 least expensive treatment diets, RANGE and CR. Summer pasture and additional expenses were the same across treatment groups. Due to numerical differences in pregnancy rates and differences in BW at pregnancy diagnosis value of cull heifers was different ($P < 0.01$) among treatment groups wherein RANGE heifers, with the numerically lowest pregnancy rate netted the greatest value of cull heifers. Numerically higher final pregnancy rates resulted in lower value of cull heifers for DLHI and DLLO heifers. Net cost per pregnant heifer was not different ($P = 0.99$) between treatment groups using prices from a 5 yr average.

Implications

Heifer development strategy did not impact AI or final pregnancy rates. Cost per pregnant heifer was not different among development treatments. Nor was feed efficiency as a pregnant first calf heifer impacted by development system. These results indicate producers are able to utilize the resources most cost effective and readily available to them with no detriment to pregnancy rates or impacts on long-term efficiency.

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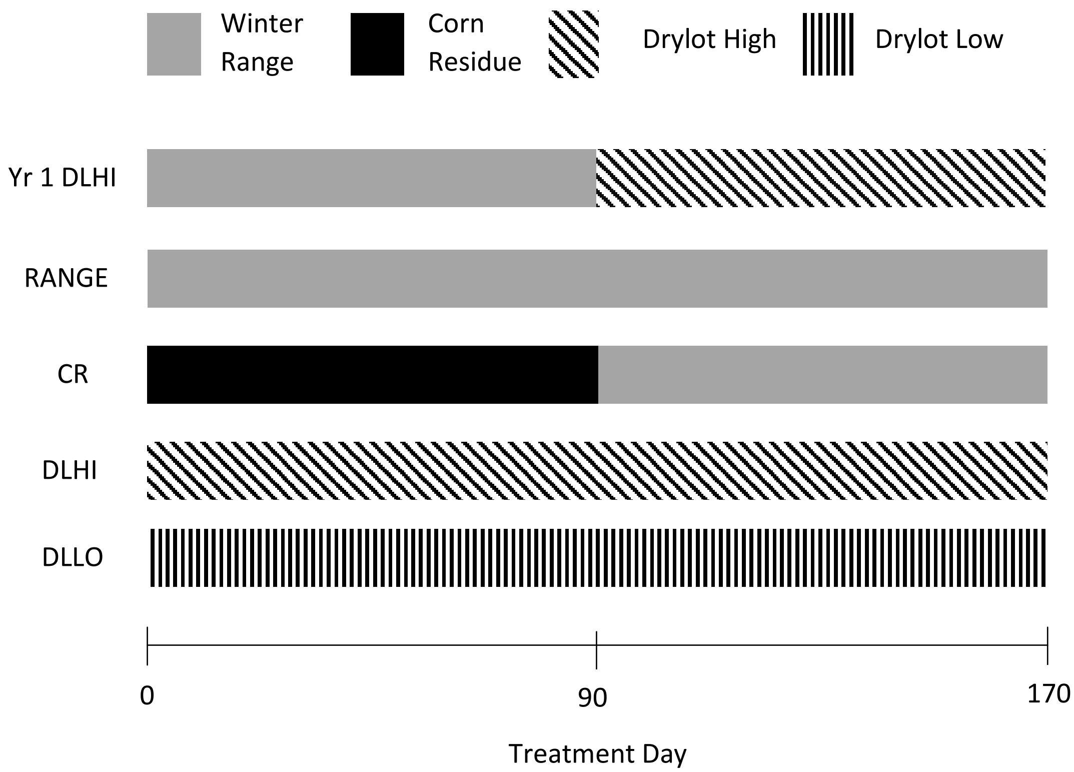

Figure 1. Illustration of time (d) heifers spent grazing winter range (grey), on corn residue (black), on the higher energy drylot diet (diagonal lines), or on the lower energy drylot diet (vertical lines) during the treatment period following a 30 d receiving period to co-mingling in the drylot for estrus synchronization. In Yr 1, heifers in DLHI grazed winter range for half the treatment period before being placed in the drylot. RANGE heifers grazed winter range throughout the treatment period. CR heifers grazed corn residue for the first half of the treatment period and then were moved to winter range. DLHI and DLLO heifers, in Yr 2 and 3 were placed in the drylot for the duration of the treatment period.

Table 1. Composition of drylot diets fed to developing heifers

	% of diet DM		
Ingredient	DLHIYr1[1]	DLHI[2]	DLLO[3]
Hay	78	74	83
Wet CGF	18	21	12
Heifer Supplement	4	5	5

[1] DLHIYr1 = heifers in Yr 1 were fed this diet for 80 d.
[2] DLHI = heifers in Yr 2 and 3 received a high-energy diet in the drylot for 170 d.
[3] DLLO = heifers received a low-energy diet in the drylot for 170 d.

Table 2. Composition of drylot supplement included in DLHI[1] and DLLO[2] diets fed to heifers

Ingredient	% of Supplement, DM
Ground corn	81.35
Limestone	11.11
Iodized salt	5.55
Trace mix	1.39
Rumensin-90	0.37
Vitamin A-D-E	0.22

[1] DLHI = heifers in Yr 1 were offered the equivalent of 0.45 $kg \cdot hd^{-1} \cdot d^{-1}$ while grazing winter range for 90 d before entering the drylot and receiving a high energy diet through estrus synchronization and AI. In Yr 2 and 3 heifers were housed in the drylot for 170 d and through estrus synchronization and AI.

[2] DLLO = heifers received a low-energy diet in the drylot for 170 d through estrus synchronization and AI.

Table 3. Effect of heifer development system on gain and reproductive performance

Item	RANGE[1]	CR[2]	DLHI[3]	DLLO[4]	SEM	*P* - value
n	50	100	100	50		
Initial BW, kg	237	240	239	236	5	0.83
Post-Treatment BW, kg	303[a]	305[a]	344[bx]	314[ay]	8	0.01
Treatment ADG, kg	0.43[a]	0.41[a]	0.66[bx]	0.49[ay]	0.05	0.01
Pre-breeding BW, kg	328[a]	335[a]	368[b]	340[ab]	9	0.04
Percent of Mature BW, %	59.4[a]	60.7[a]	66.7[b]	61.6[ab]	1.6	0.04
Pubertal Status, %	28.5	41.3	86.1	77.2	10.0	0.20
Synchronization ADG, kg	0.72	0.80	0.66	0.76	0.15	0.44
AI pregnancy diagnosis BW, kg	366[x]	377[x]	396[y]	371[x]	6	0.05
Post-AI ADG, kg	0.75[ay]	0.80[a]	0.53[bcx]	0.62[ac]	0.13	0.02
Final pregnancy diagnosis BW, kg	428[xy]	436[xy]	448[y]	427[x]	5	0.08
AI Pregnancy, %	58.7	66.3	60.4	52.7	9.7	0.70
Final Pregnancy, %	82.6	90.4	92.6	94.7	7.5	0.42
Calving rate, %	74.0	87.0	87.0	90.0	6.2	0.11
Calved in first 21 d, %	58.0	60.0	58.0	58.0	6.9	0.99

[1] RANGE = heifers were offered the equivalent of 0.45 kg·hd^{-1}·d^{-1} while grazing winter range for 170 d before entering the drylot for estrus synchronization and AI.

[2] CR = heifers were offered the equivalent of 0.45 kg·hd^{-1}·d^{-1} while grazing corn residue for 90 d and winter range for 80 d before entering the drylot for estrus synchronization and AI.

[3] DLHI = heifers in Yr 1 were offered the equivalent of 0.45 kg·hd^{-1}·d^{-1} while grazing winter range for 90 d before entering the drylot and receiving a high energy diet through estrus synchronization and AI. In Yr 2 and 3 heifers were housed in the drylot for 170 d and through estrus synchronization and AI.

[4] DLLO = heifers received a low-energy diet in the drylot for 170 d through estrus synchronization and AI.

[a,b,c] Means in a row with different superscripts are different ($P \leq 0.05$).

[x,y] Means in a row with different superscripts are different ($0.05 \leq P < 0.1$).

Table 4. Effects of heifer development system on feed efficiency as a pregnant first-calf heifer

	RANGE[1]	CR[2]	DLHI[3]	DLLO[4]	SEM	*P*-value
n	20	38	39	17		
DM intake as % of MBW	1.96	1.95	1.95	1.96	0.15	0.98
Initial BW, kg	458	468	473	464	9	0.62
Mid BW, kg	471	482	488	477	11	0.59
Final BW, kg	485	497	503	491	16	0.55
DMI, kg	9.24	9.37	9.53	9.39	0.65	0.59
ADG, kg	0.28	0.33	0.32	0.28	0.17	0.61
RFI	0.0062	-0.0191	0.0042	0.0392	0.1281	0.98
F:G	-75.43	-1.77	43.74	-326.44	156.01	0.36

[1] RANGE = heifers were offered the equivalent of 0.45 $kg{\cdot}hd^{-1}{\cdot}d^{-1}$ while grazing winter range for 170 d before entering the drylot for estrus synchronization and AI.

[2] CR = heifers were offered the equivalent of 0.45 $kg{\cdot}hd^{-1}{\cdot}d^{-1}$ while grazing corn residue for 90 d and winter range for 80 d before entering the drylot for estrus synchronization and AI.

[3] DLHI = heifers in Yr 1 were offered the equivalent of 0.45 $kg{\cdot}hd^{-1}{\cdot}d^{-1}$ while grazing winter range for 90 d before entering the drylot and receiving a high energy diet through estrus synchronization and AI. In Yr 2 and 3 heifers were housed in the drylot for 170 d and through estrus synchronization and AI.

[4] DLLO = heifers received a low-energy diet in the drylot for 170 d through estrus synchronization and AI.

Table 5. Five-year-average economic analysis (2010-2014) of heifer development nutritional treatments.

Item	RANGE[1]	CR[2]	DLHI[3]	DLLO[4]	SEM	*P*-value
Value of Heifer, $/heifer	876.81	876.81	876.81	876.81	137.91	1
Feed Cost:						
Receiving Diet,[5] $/heifer	32.16	32.16	32.16	32.16	3.43	1
Treatment Diet, $/heifer	113.18[a]	109.08[a]	152.25[b]	137.15[c]	4.87	<.01
Summer Pasture,[6] $/heifer	68.06	68.06	68.06	68.06	3.69	1
Other Expenses,[7] $/heifer	310.96	318.67	310.96	310.96	8.96	0.91
Total Development Cost	1,401.17	1,404.79	1,440.24	1,425.15	152.16	0.99
Less: Value of cull heifers	228.10[a]	127.32[b]	100.15[b,c]	69.24[c]	18.64	<0.01
Net cost	1,173.07	1,277.47	1,340.09	1,355.91	135.57	0.77
Net cost per pregnant heifer, $	1,420.18	1,413.13	1,447.18	1,431.8	150.28	0.9986

[1] RANGE = heifers were offered the equivalent of 0.45 kg·hd^{-1}·d^{-1} while grazing winter range for 170 d before entering the drylot for estrus synchronization and AI.

[2] CR = heifers were offered the equivalent of 0.45 kg·hd^{-1}·d^{-1} while grazing corn residue for 90 d and winter range for 80 d before entering the drylot for estrus synchronization and AI.

[3] DLHI = heifers in Yr 1 were offered the equivalent of 0.45 kg·hd^{-1}·d^{-1} while grazing winter range for 90 d before entering the drylot and receiving a high energy diet through estrus synchronization and AI. In Yr 2 and 3 heifers were housed in the drylot for 170 d and through estrus synchronization and AI.

[4] DLLO = heifers received a low-energy diet in the drylot for 170 d through estrus synchronization and AI.

[5] Heifers received a common receiving diet for 30 d prior to the initiation of the treatments.

[6] Summer pasture was calculated as one half the cost of a cow-calf pair.

[7] Other expenses included breeding expense, interest at 6.5%, yardage, trucking for heifers on CR, vaccinations and other miscellaneous health expenditures.

[a,b,c] Means in a row with different superscripts are different ($P \leq 0.05$).

Appendix A

How many clean-up bulls are needed after estrus synchronization and artificial insemination?

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Abstract

To evaluate the ideal number of bulls to use following estrus synchronization and artificial insemination (AI) research reporting AI and final pregnancy rates and bull to female ratio in Bos taurus cattle was reviewed and summarized. Pregnancy rate means were weighted based on the number of females in each study. Final pregnancy rates for a normal bull to female ratio (1:20 to 30) in a natural service setting were 87.8%. In comparison, final pregnancy rates following estrus synchronization and AI for a normal, intermediate (1:31 to 49), and half the number of bulls (1:50 to 60) was 87.8, 82.6, and 89.2%, respectively.

Introduction

One of the benefits of estrus synchronization and AI is purchasing and maintaining fewer bulls. However, an idea has been circulating that synchronized females not becoming pregnant to AI will return to estrus at the same time and require the same number of bulls as a natural service pasture would require.

Larson et al. (2009) observed cows not conceiving to AI will return to estrus over a 12 d period following a single timed AI. The most active d had 18% of the herd in estrus, with the remainder of the distribution a bell curve (Figure 1). Each cow's estrous cycle is slightly different. Some cows have 2 follicular waves during the estrous cycle, while others have 3. This results in a natural variation in cycle length, causing the non-pregnant cows' return to estrus to vary more than may be anticipated.

No effect of bull to female ratio or number of females expressing estrus per bull on pregnancy rate was found when comparing bull to heifer ratios ranging from 1:7 to 1:51 in heifers synchronized with Synchro-Mate B (Pexton et al., 1990). In a comparison of bull to heifer ratios ranging from 1:16 to 1:50 in herds of 100 heifers synchronized with MGA-PG and immediately exposed to bulls, the optimal bull to heifer ratio for synchronized heifers was 1:25 based on both biological and economic criteria (Healy et al., 1993). If the optimal bull to heifer ratio in a synchronized natural service setting is 1:25, it can be extrapolated with a hypothetical AI pregnancy rate of 50%, the number of clean-up bulls needed is decreased by 50%.

A study comparing bull to female ratios following estrus synchronization and AI is needed. However, considering the breadth of research documenting bull to female ratios, AI pregnancy rates, and final pregnancy rates and the need for this information as soon as possible; the authors have chosen to summarize available data to provide a preliminary answer to this industry-relevant question.

Materials and Methods

Data was collected from published studies reporting AI and final pregnancy rates, and bull to female ratio. The synchronization protocol utilized, number of females in the herd, and breeding season length were also collected. The studies collected were limited to those evaluating *Bos taurus* cattle. Of the data collected, studies were divided into bull to female ratio groups including Normal-Natural Service (NS, 1:20 to 30 bull to female ratio), and 3 groups following estrus synchronization and AI; Normal (1:20 to 30), Intermediate (1:31 to 49), and Half (1:50 to 60). A summary of the mean AI and final pregnancy rates, weighted by number of females in each study, are presented.

Results

The weighted means of each bull ratio group are presented in Table 1. The final pregnancy rate of a normal bull to heifer ratio in a natural service setting was 87.8%. Pregnancy rate to AI in the Normal group was 56.1% and final pregnancy rate was 87.7%. The Intermediate AI pregnancy rate was 46.5% with a final pregnancy rate of 82.6%. Pregnancy rate to AI in the Half group was 55.6% and had a final pregnancy rate of 89.2%. Bulls turned in at half the normal bull to female ratio following estrus synchronization and AI resulted in final pregnancy rates similar to normal bull to female ratio both in a natural service situation and following estrus synchronization and AI.

A consideration to make prior to choosing a bull to female ratio is bull age. Experienced bulls are more efficient breeders, while yearling bulls are less experienced. Another consideration is pasture size and terrain; a rugged, multi-windmill pasture may demand more from a bull than a flat single-windmill pasture. In conclusion, producers utilizing estrus synchronization and AI should keep in mind the similarity between final pregnancy rates when using a 1:25 bull to female ratio and 1:50 bull to female ratio. Producers need to evaluate the cost difference of purchasing and maintaining twice as many bulls to maintain a 1:25 bull to female ratio following estrus synchronization and AI.

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Table 1. Summary of AI and final pregnancy rates of varying bull to female ratios obtained in cited studies[1]

Synchronization Protocol	AI Method[2]	Female age[3]	Number of females	Breeding Season Length	AI Preg Rate,[4] %	Final Preg Rate,[5] %	Reference
NORMAL-NS[6]							
1 shot PG	NS	cows	201	64	-	89.0	Engle et al., 2008
None	NS	cows	72	60	-	81.0	Sanson and Coombs, 2003
None	NS	cows	295	90	-	91.5	Whitworth et al., 2008
None or CIDR for 7 d	NS	cows	2,033	90-120	-	88.8	Lamb et al., 2008
None	NS	heifers	1,381	85	-	85.8	Gutierrex et al., 2015
NORMAL-NS Mean			3,982		NA	87.8	
NORMAL[7]							
7 day CIDR+PG(no GnRH)	HD	cows	96	30	43.1	76.4	Lake et al., 2005
16 d CIDR +GnRH (2d) +PG(1wk)	HD	heifers	65	28	40.8	72.8	Devine et al., 2015
SynchomateB	HD	cows	89	65	52.7	79.7	Fanning et al., 1995
MGA+PG	HD	cows	50	62	44.3	87.3	Berke et al., 2001
Select Synch	HD+ TAI	heifers and cows	80	46	56.3	92.1	Ahola et al., 2005
Co-Synch + CIDR	TAI	cows	194	50	NR[10]	91.7	Cooke et al., 2012
Co Synch + CIDR	TAI	heifers	88	50	NR[10]	82.5	Cooke et al., 2012
SynchomateB	TAI	heifers	239	42	NR[10]	73.5	Mulliniks et al., 2013
Co Synch + CIDR	TAI	cows	188	50	47.5	97.4	Thomas et al., 2009
MGA of 14 day CIDR	TAI	heifers	1,385	50	61.5	91.5	Vraspir et al., 2013
Co-Synch + CIDR	TAI	heifers	80	53	48.0	91.5	Bryant et al., 2011
Co-Synch + CIDR	TAI	cows	102	-	41.4	70.2	Moriel et al., 2012
Norgestomet + estrodiol valerate	TAI, TAI+HD, NS	cows	150	90	52.5	88.2	Sa Filho et al., 2013
NORMAL Mean			2,806		56.1	87.8	

Table 1. Summary of AI and final pregnancy rates of varying bull to female ratios obtained in cited studies[1] cont.

Synchronization Protocol	AI Method[2]	Female age[3]	Number of females	Breeding Season Length	AI Preg Rate, %[4]	Final Preg Rate, %[5]	Reference
INTERMEDIATE[8]							
MGA-PG	HD	heifers	104	60	67.0	92.0	Harris et al., 2008
5 or 7 d CIDR	TAI	cows	138	40	55.8	77.5	Gunn et al., 2011
MGA-PG	HD+TAI	heifers	500	61	49.7	93.0	Funston and Meyer, 2012
2 shot PG	HD	cows	34	30	54.5	90.9	Alexander et al., 2002
8d half-cuemate	TAI	heifers	316	50	29.8	64.6	Butler et al., 2011
INTERMEDIATE Mean			1,092		46.5	82.6	
HALF[9]							
MGA-PG	HD	heifers	399	60	72.5	94.0	Summers et al.2014
Co Synch + CIDR	TAI	heifers	191	45	NR[10]	88.7	Mulliniks et al., 2013
MGA-PG	HD	heifers	100	60	46.0	90.0	Harris et al., 2008
MGA-PG	HD	heifers	100	60	59.0	90.0	Harris et al., 2008
MGA -PG	TAI or HD	heifers	299	60	59.0	93.0	Funston and Larson, 2011
MGA-PG	HD	heifers	1,005	60	58.7	91.0	Vraspir et al., 2013
MGA-PG	HD+TAI	cows	121	60	48.5	87.0	Post et al., 2005
MGA-PG	HD	heifers	64	29	NR[10]	82.1	Sexten et al., 2005
MGA+2 shots EB	TAI	heifers	118	39	37.2	73.5	Baptiste et al., 2005
5 or 7 d CO synch + CIDR	TAI or HD	heifers	2,660	85	52.8	88.3	Gutierrex et al., 2014
HALF Mean			5,057		55.6	89.2	

[1] Studies reporting bull to female ratio, AI and final pregnancy rates evaluating *Bos Taurus* cattle we utilized.
[2] NS = natural service; HD = heat detect; TAI = time artificial insemination.
[3] Female age reported as either heifers or cows.
[4] Percentage of females that conceived to AI.
[5] Percentage of females determined pregnant at the end of the breeding season.
[6] NORMAL-NS = bull to female ratio was 1:20 to 30 in a natural service setting.
[7] NORMAL = 1:20 to 30 bull to female ratio following estrus synchronization and AI.
[8] INTERMEDIATE =1:31 to 49 bull to female ratio following estrus synchronization and AI.
[9] HALF = 1:50 to 60 bull to female ratio following estrus synchronization and AI.
[10] NR = AI pregnancy rates not reported.

Appendix B

A Comparison of Two Implant Protocols; Synovex-Choice/Synovex-Plus vs Synovex-S/Revalor-S on Steer Feedlot Performance and Carcass Characteristics

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ABSTRACT

An experiment was conducted to determine the impact of 2 implant protocols on steer feedlot performance and carcass characteristics. Over a 2-yr period, 109 crossbred (5/8 Red Angus, 3/8 Continental; approximately 205 d of age; 242 ± kg) steers were randomly assigned to 1 of 2 implant protocols: 1) Synovex-Choice (100 mg of trenbolone acetate [TBA] and 14 mg of estradiol benzoate [EB]) implanted at the beginning of the feeding period, followed by Synovex-Plus (200 mg of TBA and 28 mg of EB) approximately 100 d later (CHPL), or 2) Synovex-S (200 mg of progesterone and 20 mg of EB) as initial implant, followed by Revalor-S (120 mg of TBA and 24 mg of estradiol) approximately 100 d later (SS). Average daily gain was similar (*P* = 0.39) for CHPL (1.75 ± 0.08 kg/d) and SS (1.70 ± 0.08 kg/d) steers. Yield grade was also not affected (*P* = 0.16) by treatment, 2.5 and 2.7 ± 0.3 for CHPL and SS, respectively. Marbling score was similar (*P* = 0.19) between treatments (501 vs 525 ± 13, CHPL and SS, respectively) resulting in a similar percentage of steers grading USDA Choice (CHPL vs SS, 93 vs 96 ± 3% [*P* = 0.42]) and upper 2/3 USDA Choice (CHPL vs SS; 47 vs 54 ± 7% [*P* = 0.51]).

Net revenue was similar ($P = 0.59$) between CHPL ($1,255.97 ± 23.13) and SS ($1,237.78 ± 23.13) steers. Both implant regimens utilized in the current experiment resulted in similar feedlot performance and carcass characteristics.

Keywords: carcass characteristics, feedlot performance, implants

INTRODUCTION

Implants are commonly used in the United States to increase muscling in cattle without adding excess backfat. The use of growth enhancement technologies, such as implants, allows the beef industry to continue sustainable beef production. If these technologies were to be withdrawn from the production system, carbon emissions, use of fossil fuels, and total production cost would increase (Capper and Hayes, 2012). Trenbolone acetate (TBA) and estradiol have a synergistic effect when used together, with increases in ADG and improvement in feed efficiency without affecting fat deposition (Johnson et al., 1996).

However, the use of high dosage implants has been linked to decreased marbling scores (Herschler et al., 1995; Roeber et al., 2000) resulting in lower QG grades and lost premiums when sold on a grid pricing system. The use of lower dosage implants to capture the benefits of increased ADG and G:F without sacrificing QG has been suggested as a profitable compromise (Cleale et al., 2013). The objective of this experiment was to compare the effects of using the higher dosage implant strategy, Synovex-Choice (Zoetis; Florham Park, NJ) and Synovex-Plus (Zoetis; Florham Park, NJ), with the lower dosage strategy, Synovex-S (Zoetis; Florham Park, NJ) and Revalor-

S (Merk Animal Health; Madison, NJ), on steer feedlot performance and carcass characteristics.

MATERIALS AND METHODS

The University of Nebraska Animal Care and Use Committee approved the procedures and facilities used in this experiment. Over a 2 yr period, 109 crossbred (5/8 Red Angus, 3/8 Continental; approximately 205 d of age; 242 ± 11 kg) spring-born steers were blocked by BW and assigned randomly to pen. Each pen was assigned 1 of 2 implant protocols: Synovex-Choice (100 mg of trenbolone acetate [TBA] and 14 mg of estradiol benzoate [EB]) implanted at the beginning of the feeding period, followed by Synovex-Plus (200 mg of TBA and 28 mg of EB) 103 and 101 d later, in Yr 1 and 2, respectively (CHPL), or Synovex-S (200 mg of progesterone and 20 mg of EB) as initial implant, followed by Revalor-S (120 mg of TBA and 24 mg of estradiol) 103 and 101 d later, in yr 1 and 2, respectively (SS). Nine steers were housed in each pen with 2 and 4 pens/treatment in Yr 1 and Yr 2, respectively. Steers were fed a growing diet from the beginning of treatment in mid-December to early March at which time they were transitioned to a finishing diet (Table 1). At 209 and 213 (Yr 1 and Yr 2, respectively) d on feed, steers were shipped to a commercial abattoir for slaughter. Individual carcass characteristics including LM area, KPH, 12th rib fat cover, HCW, and marbling score were collected by USDA graders. Final YG was calculated by using the USDA regression equation (USDA, 1997). Hot carcass weight was determined on d of slaughter; carcass characteristics were evaluated 24 h following slaughter. Final BW was calculated from HCW, based on an average dressing percentage of 63%. Means for DMI and F:G were based on actual pen DMI and the average pen ADG.

Economic analysis

Individual expense and revenue was calculated for each steer. Treatment cost per steer was $5.25 for CHPL and $3.92 for SS, based on actual implant costs and labor. Based on the average pen DMI and actual feed costs, feed cost was $0.13/kg, and a daily yardage charge of $0.50/steer was included. Revenue was calculated on the base grid price for the week steers were slaughtered. Premiums and discounts for QG, YG, and HCW were also calculated for those week.

Statistical analysis

The GLIMMIX procedure of SAS (SAS Institute, Inc., Cary, N.C.) was used to analyze data with steer as the experimental unit, with the exception of average DMI and F:G, where pen was the experimental unit. The model included year, pen, implant strategy, and year × implant strategy interaction. Differences in the proportion of Choice and upper two-thirds Choice USDA QG were analyzed using an odds ratio. Economic data was analyzed with pen as the experimental unit. Least squares means and SE of the proportion of Choice and upper two-thirds Choice by treatment were obtained using the ILINK function.

RESULTS AND DISCUSSION

Feedlot performance data

Feedlot data performance are presented in Table 2. Steers began the feeding period at a similar ($P = 0.94$) BW, 242 vs 242 ± 11 kg for CHPL and SS, respectively. Average daily gain was similar ($P = 0.39$) for CHPL (1.75 ± 0.08 kg/d) and SS (1.70 ± 0.08 kg/d) steers. There was no difference ($P = 0.59$) in average pen DMI between CHPL (9.90 ± 0.26 kg/d) and SS (9.76 ± 0.26 kg/d). In a comparison of no implant and increasing levels of TBA and EB, Bartle et al. (1992) observed an improvement in ADG and feed efficiency as dosage increased with the optimum TBA to EB dosage (in mg) concluded to be 140/28, respectively, compared to lower levels of 80/16 and 20/4. The difference between these values and the values in our experiment are similar; CHPL is comprised of Synovex Choice which contains 100/14 TBA/EBA, respectively, and Synovex Plus containing 200/28 while SS is comprised of Synovex S containing 200/20 (progesterone and EB) and Revalor S containing 120/24. However, we noted improvement in feedlot performance as a result of using a higher potency implant.

Steer carcass characteristics

Carcass characteristics are presented in Table 3. There was no difference (P = 0.37) in HCW for CHPL compared with SS steers (380 vs 374 ± 7 kg, respectively). Conversely, Parr et al. (2011) observed a tendency for increased TBA and EB dosage to increase ADG and BW. Increasing TBA and EB dosage had no impact on BW in this experiment. Yield grade was also not affected (P = 0.16) by treatment (2.5 and 2.7 ± 0.3 for CHPL and SS, respectively). Additionally, there was no difference in LM area (P = 0.98) between CHPL and SS (90.5 vs 90.5 ± 2.3 cm^2), and back fat thickness was also similar (P = 0.13) between the treatments (1.37 vs 1.50 ± 0.15 cm, CHPL vs SS, respectively). Marbling score was similar (P = 0.19) between treatments (501 vs 525 ± 13, CHPL and SS, respectively) resulting in a similar percentage of steers grading USDA Choice (CHPL vs SS, 93 vs 96 ± 3%; P = 0.42) and upper 2/3 USDA Choice (CHPL vs SS, 47 vs 54 ± 7%, P = 0.50). Hunt et al. (1991) observed no differences in marbling scores in implanted steers and bulls compared to non-implanted contemporaries.

Conversely, Bartle et al. (1992) noted a linear decrease in marbling score as implant dosage of TBA and EB increased.

Economic analysis

Feed expense was similar (P = 0.62) between CHPL and SS ($265.86 vs $262.18 ± 5.15). Although net revenue was similar (P = 0.59) between CHPL ($1,255.97 ± 23.13) and SS ($1,237.78 ± 23.13) steers, a numerical difference in net revenue of $18.19/steer is noted between the 2 treatments.

IMPLICATIONS

Feedlot performance and carcass characteristics were similar between steers implanted with Synovex Choice and Synovex Plus compared with Synovex S and Revalor S. Percentage of steers grading USDA Choice or in the upper 2/3 of USDA Choice did not differ between the treatments. Furthermore, net revenue was also similar between steers implanted with Synovex Choice and Synovex Plus and steers implanted with Synovex S and Revalor S. Both implant protocols evaluated in this experiment provide cattle feeders with viable options when choosing their implant strategy.

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Table 1. Composition of calf and yearling diets

	DM, %	
Ingredient	Growing diet	Finishing diet
Dry-rolled corn	35	37
Prairie hay	10	6
Wet corn gluten feed	47	53
Supplement[1,2]	8	4
Calculated Composition		
CP, %	17.7	17.9
TDN, %	78.9	81.1
Ca, %	0.50	0.28
P, %	0.62	0.65

[1]Growing diet supplement included 71.74% dried distillers grain plus soluble, 14.90% limestone, 2.85% iodized salt, 2.35% ammonium chloride, and 1.06% trace mineral mix, Rumensin 90 (28g/ton), thiamine, Tylan 40 (10 g/ton), and Vitamin A,D and E.
[2]Finishing diet supplement included 51.26% ground corn, 29.57% limestone, 5.59% iodized salt, 4.65% ammonium chloride, and 1.94% trace mineral mix, Rumensin 90 (28g/ton), thiamine, Tylan 40 (10 g/ton), and Vitamins A,D and E.

Table 2. Feedlot performance of steers on CHPL[1] and SS[2] implant protocols

Item	CHPL[1]	SS[2]	SEM	*P*-value
Initial BW, kg	242	242	11	0.94
Final BW,[3] kg	602	593	12	0.37
ADG, kg	1.75	1.70	0.08	0.39
DMI,[4] kg/d	9.90	9.76	0.26	0.59
F:G	5.64	5.71	0.15	0.73

[1]CHPL = steers received Synovex Choice (Zoetis; Florham Park, NJ) as initial implant in mid-December and were re-implanted with Synovex Plus (Zoetis; Florham Park, NJ) 100 d later.
[2]SS = steers received Synovex S (Zoetis; Florham Park, NJ) as initial implant in mid-December and re-implanted with Revalor S (Merk Animal Health; Madison, NJ) 100 d later.
[3]Final BW calculated from HCW based on a common dressing percentage of 63%.
[4]F:G calculated as the average pen DMI.

Table 3. Carcass characteristics of steers on CHPL[1] and SS[2] implant protocols

Item	CHPL[1]	SS[2]	SEM	P-value
HCW, kg	380	374	7	0.37
YG	2.5	2.7	0.3	0.16
LM Area, cm^2	90.5	90.5	2.3	0.98
Marbling score[3]	501	525	13	0.19
Fat thickness, cm	1.37	1.50	0.15	0.13
USDA Choice, %	93	96	3	0.42
Md[4] or greater, %	47	54	7	0.51

[1]CHPL = steers received Synovex Choice (Zoetis; Florham Park, NJ) as initial implant in mid-December and were re-implanted with Synovex Plus (Zoetis; Florham Park, NJ) 100 d later.
[2]SS = steers received Synovex S (Zoetis; Florham Park, NJ) as initial implant in mid-December and re-implanted with Revalor S (Merk Animal Health; Madison, NJ) 100 d later.
[3]Marbling score: Slight^{00} = 400, Small^{00} = 500, etc.
[4]Md = Modest QG, USDA average Choice.

Table 4. Economic analysis of steers on CHPL[1] and SS[2] implant protocols

Item	CHPL[1]	SS[2]	SEM	*P* -value
Implant, $	5.25	3.92		
Yardage,[3] $	105.50	105.50		
Feed Expense,[4] $	265.86	262.18	5.15	0.62
Carcass Return,[5] $	1,628.08	1,604.19	25.31	0.52
Net Revenue,[6] $	1,255.97	1,237.78	23.13	0.59

[1]CHPL = steers received Synovex Choice (Zoetis; Florham Park, NJ) as initial implant in mid-December and were re-implanted with Synovex Plus (Zoetis; Florham Park, NJ) 100 d later.

[2]SS = steers received Synovex S (Zoetis; Florham Park, NJ) as initial implant in mid-December and re-implanted with Revalor S (Merk Animal Health; Madison, NJ) 100 d later.

[3]Yardage calculated at $.50/hd/d at 213 d (Yr 1) and 209 d (Yr 2).

[4]Feed Expense calculated at $0.13/kg of pen average DMI for 213 d (Yr 1) and 209 d (Yr 2).

[5]Carcass return calculated using the base grid price ($190.71/cwt and $194.65/cwt in yr 1 and 2,respectively) and premiums and discounts for quality grade ($22.34/cwt-Prime and $-15.85/cwt-Select, $13.45/cwt-Prime and $-11.15/cwt-Select, in yr 1 and 2, respectively), yield grade ($-10.30/cwt YG-4s and 5s and $2.12/cwt YG-2s and $-9.25/cwt YG-4s and 5s and $2.24/cwt YG-2s, in yr 1 and 2,respectively), and HCW ($-0.23/cwt and $-0.24/cwt 477 kg discount, in yr 1 and 2, respectively) for the weeks steers were harvested.

[6]Net revenue = carcass return – (implant expense + yardage + feed expense).