BEEF SPECIES-RUMINANT NUTRITION CACTUS BEEF SYMPOSIUM: Influence of management decisions during heifer development on enhancing reproductive success and cow longevity¹

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ABSTRACT: Profitability of beef cattle producers can be directly tied to the productive lifespan of a cow. Management decisions influencing heifer nutrition and reproduction play a key role in establishing heifer fertility and longevity. Altering feeding strategies to utilize compensatory growth has been reported to have a positive influence on fertility during the first breeding season; however, there are discrepancies in the literature as to the impact this strategy may have on the proportion of heifers attaining puberty prior to entering their first breeding season. Ultimately, this may affect lifetime productivity as heifers born early in the calving season produce more kilograms of weaned calf over their first 6 calves, as well as, remain in the herd longer than those animals born later in the calving season. Thus, incorporation of reproductive technologies to identify fertile animals or aid in improving conception earlier in the breeding season may improve heifer reproductive

performance and longevity. Reproductive tract scores have been utilized to identify animals which are more reproductively mature, increasing the likelihood of successful artificial insemination. Antral follicle counts (AFC), which predict the number of follicles in the ovarian reserve, have not only been reported to have a moderate to high heritability, but have also been used to identify animals with greater reproductive potential. Beef heifers classified as high AFC have greater pregnancy rates and longevity than low AFC heifers. Additionally, maternal diet may play a role in influencing reproductive success and ultimately cow longevity. Improving maternal plane of nutrition has been reported to increase female offspring pregnancy rates. Overall, recent research has provided producers with a variety of methods to optimize animal performance while enhancing reproductive success and longevity to ensure profitability.

Key words: beef, heifer development, longevity

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J. Anim. Sci. 2019.97:1407–1414

doi: 10.1093/jas/sky440

¹Based on presentation given at the Beef Species-Ruminant Nutrition Cactus Beef Symposium titled “Opportunities for enhancing reproductive success and cow longevity through heifer development” at the 2018 Annual Meeting of the American Society of Animal Science held in Vancouver, BC, Canada, July 8–12, with publication sponsored by the *Journal of Animal Science* and the American Society of Animal Science.

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Received October 2, 2018.

Accepted November 16, 2018.

INTRODUCTION

Profitability for beef cow-calf producers can be directly tied to the productive life span of a mature cow. Although there are several factors that may result in a cow leaving the herd (i.e., temperament, structural issues, or age) the main reason cows leave the herd often relates to reproductive failure, whether it be failure to maintain a pregnancy or produce a live calf (Renquist et al., 2006). Improving cow longevity is a challenging

process, due in part to the multitude of factors involved. Production delays inherent in beef cattle production (cows produce their first calf at 2 yr of age), result in cows needing to produce between three and five calves in order for the producer to recoup heifer development costs (of which the opportunity cost of selling the animal as a heifer is included). Although this value will vary amongst producers due to differences in development systems, it is critical to be able to identify animals that have the potential to be most productive as early as possible.

In a review, [Hohenboken \(1988\)](#) suggested over 20 traits the “ideal” cow should possess, including: attaining puberty early as a heifer and producing her first calf by the time she is 2 yr old. Additionally, this animal should conceive at her first opportunity to mate each year and maintain a 365-d calving interval. The cow should also fit her environment, provide adequate maternal care and transmit genetic merit to her calves for an acceptable growth rate, feed efficiency, and carcass quality ([Hohenboken, 1988](#)). Obstacles associated with selecting animals to fit these important traits are challenging as selection of heifers typically occurs prior to most of these traits being displayed. Also, measurement of several of the listed traits is challenging, time-consuming, or expensive. Finally, most traits associated with fertility have a low heritability (influence of genetics on longevity reviewed by [Roberts et al., 2015](#)), suggesting that the environment may play a larger role in phenotypic expression of a trait than other production traits. This review addresses management factors which may aid in improving longevity of beef cows.

CALVING EARLY IN THE SEASON

Within the first 2 yr of life, heifers are expected to grow to nearly 65% to 75% of mature size, attain puberty, and produce their first viable offspring. Previous research ([Lesmeister et al., 1973](#)) reported increased lifetime productivity for cows calving at 2 compared to 3 yr of age. Additionally, it has been reported that heifers calving late increases the likelihood of the animal calving late or not calving the following year ([Burris and Priode, 1958](#)). This is important to note, as maintaining a 365-d calving interval is important for production efficiency. Thus, management strategies must be put in to place to allow heifers to reach their reproductive potential. Given the importance of reproduction and longevity on the overall profitability of a cow-calf operation, reproductive traits are three

to nine times more influential on profitability than other production traits ([Melton, 1995](#)), it is critical to identify traits or management strategies that may improve lifetime production of a cow.

To determine the influence of calving date as a heifer on lifetime productivity of beef cows, researchers at the U.S. Meat Animal Research Center in Clay Center, Nebraska analyzed the calving records of 16,549 replacement heifers born from 1980 to 2000 ([Cushman et al., 2013](#)). Animals were placed in one of three calving groups (first, second, or third 21-d period) based on calving date as a 2-yr-old heifer. Heifers that calved in the first 21 d remained in the herd longer ($P < 0.05$) than those calving for the first time in the second or third 21 d of the calving season ([Figure 1](#)). Coincidentally, age when diagnosed as open was greater for cows that calved in the first 21 d as a 2-yr old (8.2 ± 0.3 years) compared to those calving in the second (7.6 ± 0.5 years) or third 21 d (7.2 ± 0.1 yr) of the calving season ([Cushman et al., 2013](#)). Additionally, pregnancy rate was greater for cows calving in the first 21 d each year from the second breeding season through the sixth breeding season compared with cows from either the second or third 21-d calving groups. This improvement in pregnancy rate and overall increased herd retention is likely a function of improved physiological status in the cows calving in the first 21 d as a heifer. After parturition, fertility in cattle is reduced due to several physiological mechanisms, one of which is uterine involution ([Graves et al., 1968](#)). Due to type of placentation cotyledonary in a cow, involution of the placenta is a complex process involving contraction of organ size, loss of tissue and repair ([Kindahl et al., 1999](#)). Complete involution of the uterus can occur as quickly as a 3 wk; however, it is often not completed until 4 to 5 wk after calving

Figure 1. Retention rate of cows based on first calving period. Heifers calving for the first time in the first 21 d (solid line) remained in at a greater proportion compared with heifer calving for the first time in the second or third 21 d of the calving season. Adapted from [Cushman et al. \(2013\)](#).

(Kindahl et al., 1999). Due to the earlier calving date in cows that calved in the first 21 d compared to second or third 21 d, postpartum interval was 113 d compared to 92 and 71 d in second and third 21-d calving groups, respectively. This would allow a greater recovery time for cows calving earlier in the calving season prior to initiation of the breeding season.

Cushman et al. (2013) also reported increases in calf weaning weights for cows calving in the first 21 d compared to their contemporaries through the first 6 calves (Figure 2). These data agree with Funston et al. (2012a) reporting steer progeny born in the first 21 d of the calving season were ~6 and 22 kg heavier ($P < 0.01$) at weaning than steer progeny born in the second and third 21 d of the calving season, respectively. Differences in BWs among groups are maintained ($P < 0.01$) through slaughter as hot carcass weights were 6 and 18 kg greater for calves born in the first 21 d compared with calves born in the second or third 21 d, respectively. Additionally, carcass value was greatest ($P < 0.01$) for calves born during the first 21 d of the calving season (Funston et al., 2012a). Together, these data highlight the production and economic advantages of managing cows to calve early in the calving season.

INFLUENCE OF HEIFFER DEVELOPMENT SYSTEM ON PRODUCTIVITY

The primary goal of heifer development systems is to maximize economic efficiency, reproductive performance, and longevity. Traditionally, heifers were targeted to achieve 60% to 65% of mature BW prior to puberty and breeding (Patterson et al.,

1992). However, developing heifers to traditional target BW increased development costs compared to more extensive heifer development systems where either timing or rate of BW gain is altered. Clanton et al. (1983) reported no difference in reproductive performance in heifers developed on a constant rate of gain, late gain (with the majority of gain in the last half of the development period), or early gain (with the majority of gain achieved in the first half of the development period). This research reported timing of gain could be varied without a significant reduction in reproductive performance. In addition, it brought about the concept of compensatory gain, with late-gain heifers gaining more than predicted in each year of the 3-yr study. Therefore, altering heifer growth patterns may be a way to lower feed cost associated with heifer development.

Reduced Input Heifer Development Systems

The objective of recent research has been to maximize economic efficiency of development systems through restricting nutrient intake early in the postweaning development period or developing heifers on dormant nonharvested forages (Table 1; Lynch et al., 1997; Freetly et al., 2001; Funston and Larson, 2011; Mulliniks et al., 2013). These studies report no differences in pregnancy rates, calf birth date, and second season pregnancy rates (Table 1), although an increased age at puberty in some studies was reported. Altering rate and timing of BW gain during heifer development can result in periods of compensatory growth, which will reduce feed inputs and may be a more economically feasible way to develop heifers (Lynch et al., 1997;

Figure 2. Calf weaning weights based on heifer calving period at the U.S. Meat Animal Research Center. Heifers calving in the first 21 d of the calving season as a heifer (black bars) weaned heavier calves in the first six calving seasons compared with heifers calving for the first time in the second (gray bars) or third 21 d (open bars) as heifers (* $P < 0.05$). Adapted from Cushman et al. (2013).

Table 1. Influence of postweaning nutrition on heifer reproductive performance

Treatment	Age at puberty ¹	Heifer pregnancy rate ¹	Mean Calving date ¹	Second-year pregnancy rate ¹	Reference
Even gain vs. late gain	INCR ²	NS	—	—	Lynch et al. (1997)
Low-high vs. high	—	NS	NS	NS	Freetly et al. (2001)
Low gain vs. high gain	DECR ^{3,4}	NS	NS	NS	Funston and Deutscher (2004)
Restricted vs. control	INCR ⁵	NS	—	—	Roberts et al. (2009b)
Drylot vs. extensive	DECR ^{3,4}	NS	NS	NS	Funston and Larson (2011)
Corn residue vs. drylot	NS	NS	NS	—	Summers et al. (2014)
Low-high vs. constant	NS	NS	NS	—	Rosasco et al. (2017)

¹Effect of reduced or late nutrient intake or growth compared with control; INCR = increased compared with control; DECR = decreased compared with control; NS = not significant.

²In year 2 only $P < 0.01$.

³Reported as cyclic prior to breeding season.

⁴Means within study differ ($P < 0.05$).

⁵Means within study differ ($P < 0.10$).

Freetly et al., 2001; Funston et al., 2012b; Mulliniks et al., 2013). Lynch et al. (1997) reported similar pregnancy rates for heifers developed on restricted BW gain (0.11 kg/d) until 47 or 56 d, where gain was increased (0.91 kg/d) until the onset of the breeding season before the breeding season. In addition to altering the pattern of BW gain to reduce development costs, recent research has investigated feeding to reduced target BWs. Roberts et al. (2009a) restricted heifer dietary intake to 80% of controls resulting in a reduced ADG compared with control during the individual feeding period. However, following the feeding period, ADG was greater for restricted heifers compared with control, suggesting a period of compensatory gain was experienced by restricted heifers. At initiation of the breeding season, heifer BW was equivalent to 55% and 58% mature BW, with 60% and 68% of heifers achieving puberty prior to the breeding season for restricted and control heifers, respectively. While there was a trend for reduced AI pregnancy rates for restricted-fed heifers, final pregnancy rates were not different (Roberts et al., 2009b).

Funston and Deutscher (2004) reported heifers developed to 53% mature BW prior to the breeding season had reduced BW and percentage of heifers cycling prior to the breeding season compared to heifers developed to 58% mature BW. However, pregnancy rates in the first 4 breeding seasons were not different between low- and high-gain heifers (Funston and Deutscher, 2004). In addition, developing heifers to 50% to 57% mature BW resulted in similar pregnancy rates to those developed to a greater percent mature BW (Martin et al., 2008; reviewed by Funston et al., 2012b). Moreover, a recent study conducted by Eborn et al. (2013) investigated developing heifers on a lower plane of nutrition and subsequent effects on ovarian

development and fertility. Specifically, developing heifers to 55% mature bodyweight did not influence ovarian development or follicle counts measured through transrectal ultrasound in the postweaning development period when compared with heifers developed to 64% mature BW (Eborn et al., 2013). However, heifers on extremely low planes of nutrition throughout development can experience delayed puberty (Gonzalez-Padilla et al., 1975).

Although research within the last two decades has established development of heifers to a lighter target BW utilizing extensive development systems can result in satisfactory reproductive performance, data regarding the impacts of development strategies on cow longevity are limited. The impact of development strategies on survivability and in herd retention is complex and can be influenced by nutritional and management strategies (among other factors) throughout the animal's life. In a 10-yr study, Hughes et al. (1978) suggested an advantage in retention rate for beef cows on a lower plane of nutrition compared to cows maintained on a higher level of nutrition. Based on the number of cows remaining in each treatment group in year 10, cows which were developed and maintained on a low or moderate plane of nutrition had a 77% retention rate compared to cows which were developed and maintained on a high or very high plane of nutrition which had a 63% retention rate (Hughes et al., 1978). Furthermore, Pinney et al. (1972) conducted research comparing the effect of winter supplemental feed level on survivability. Nutritional supplementation appeared to improve the average lifespan of cows receiving the low (14.65 yr) rate of supplementation compared to medium (13.07 yr) and high (10.88 yr) supplemented cows (Pinney et al., 1972). These data suggest that differences in survivability or longevity are established early in life.

In Nebraska, heifers developed on restricted gain to 53% of mature BW had similar pregnancy rates through the fourth calving season compared to heifers developed to 58% of mature BW (Funston and Deutscher, 2004). Additionally, cost of development was \$22 per heifer less for heifers developed on the restricted gain. Similarly, the net cost of producing one pregnant heifer was \$38 greater for heifers developed in a drylot compared to heifers developed grazing corn residue and winter range (Summers et al., 2014). Development of heifers on a restricted rate of gain may not only influence in herd retention, but potentially result in increased lifetime profitability.

Heifer development systems focused on preparing and adapting heifers to future production environments, specifically extensive rangeland systems, may impact survivability. Mulliniks et al. (2013) compared developing heifers in a drylot receiving a corn silage-based growing diet or on native range receiving either a 36% RUP or 50% RUP supplement. Heifers developed in the drylot had an increased ADG during the development period, resulting in an increased BW at breeding. Heifers developed on native range achieved ~51% of mature BW compared to drylot heifers at 58% of mature BW. However, pregnancy rates tended ($P = 0.10$) to be greater in heifers receiving the 50% RUP supplement while grazing native range compared to 36% RUP and drylot heifers. Heifers that were managed in an extensive grazing system had a greater ADG from the time of breeding to pregnancy diagnosis compared with drylot heifers. These results indicate that range-developed heifers may have experienced a period of compensatory gain. Heifers were managed as a group after development, and through subsequent calving seasons, in order to evaluate the influence of development strategy on longevity. Heifers receiving the 50% RUP supplement while grazing native range tended ($P = 0.10$) to have greater retention rates in breeding years 1 and 2 and had a significantly increased ($P < 0.01$) retention rates during years 3 and 4 compared to 36% RUP and drylot developed heifers. Drylot and 36% RUP developed heifers had similar retention rates from development through year 4. These data indicate that heifer development systems, as well as specific nutrient content may influence survivability.

Heifer development systems focused on acclimation of heifers to extensive production systems may allow for heifers to be more prepared for future challenges facing the grazing animal. Early exposure and adaptation to their grazing environment may allow animals to gain crucial grazing

experience and impact grazing behavior throughout the animal's life. It has been suggested that animals can form grazing preferences based on positive and negative digestive feedback (Launchbaugh et al., 1999). Therefore, heifers developed in a range setting may be better adapted to fit their future production environment compared with cohorts reared in a drylot or on a greater rate of gain, potentially increasing longevity. While limited, current research evaluating the influence of heifer development protocols on longevity, suggest developing heifers to lighter target BWs and (or) in grazing environments may be advantageous and positively impact heifer performance and survivability.

Managing Heifers Postbreeding

Vastly, altering the management strategy or environment of the developed heifer can impact AI pregnancy rates (Arias et al., 2012; Mulliniks et al., 2013; Summers et al., 2014). Altering nutrient intake from maintenance to 80% of NRC requirements from 6 d prior to breeding through 2 wk postinsemination resulted in delayed embryo development, decreased embryo survival and pregnancy rates (Dunne et al., 1999; Bridges et al., 2012). Perry (2015) reported heifers developed in a drylot and placed on spring forage pastures after insemination had reduced AI pregnancy rates compared with heifers developed in a drylot, then placed on spring pastures after AI and supplemented 2.2 kg·animal⁻¹·d⁻¹ dried distillers grains with solubles for 42 d. Similarly, Summers et al. (2014) developed heifers in a drylot or grazing corn residue and winter range during the development period and offered the equivalent of 0.45 kg/d of 32% CP supplement. Heifers developed in an extensive grazing system were placed in the drylot with drylot heifers for 40 d prior to the beginning of the breeding season for estrous synchronization, during which time ADG tended to be greater for corn residue heifers compared with drylot developed heifers. Heifers developed utilizing an extensive grazing system grazing corn residue and winter range had an 11 percentage point increase in AI pregnancy rates compared to contemporaries developed in the drylot, despite being developed to a reduced proportion of mature BW. Increases in AI pregnancy rate may be attributed to increased nutrient intake and BW gain by corn residue heifers during the period immediately before breeding, potentially resulting in a compensatory gain effect (Summers et al., 2014). However, 5 d following AI heifers were placed on summer pastures, leading to a decreased ADG for drylot

developed heifers compared to extensively developed heifers during the breeding season. This transition in nutrient quality during a critical stage of gestation could have led to the decreased conception rates (Summers et al., 2014). Factors impacting reproductive success in these animals may be related to the lack of grazing skills and dietary habits reducing grazing effectiveness in drylot developed heifers returned to native pasture grazing (Perry et al., 2016). Decreases in ADG for drylot developed heifers being returned to native range in several studies (Perry et al., 2013; Summers et al., 2014) compared to range developed heifers would support this hypothesis.

Perry et al. (2016) investigated the influence of postbreeding management on native range developed heifers. Heifers were randomly assigned to one of three treatments: (i) placed in a drylot; (ii) returned to native range and supplemented 2.2 kg·animal⁻¹·d⁻¹ dried distillers grains with solubles; or (iii) returned to native pastures and not supplemented following AI for a 42-d breeding season. There were no differences in AI pregnancy rate among treatments, although heifer BCS increased in the drylot and native range plus supplement groups. It is likely that AI pregnancy rates did not vary among treatments in due to the non-supplemented heifers being returned to a forage-based system in which they were acclimated and accustomed to (Provenza and Balph, 1988; Provenza et al., 1993). Together these data indicate heifers developed in an extensive development system may have been better adapted to an extensive production environment. Management of heifer BW gain prior to the breeding season is critical for maximizing puberty attainment and pregnancy rates. Furthermore, postweaning management focused on adaptation of heifers to extensive grazing systems may allow heifers to increase in longevity when compared to heifers developed in confinement.

INCORPORATION OF REPRODUCTIVE TECHNOLOGIES

Estrus Synchronization and Artificial Insemination

Although estrus synchronization and artificial insemination are tools that have been available for producer utilization for decades, incorporation of these tools has been limited in the beef cattle sector. Reports suggest producers have greater concerns about the difficulty of the procedure (17.8% surveyed) and labor/time involved (37.3%) than those concerned with the efficacy of estrus

synchronization (2.1%; NAHMS, 2009). Utilization of estrus synchronization has been reported to shorten the breeding season, initiate cyclicity in some anestrus animals, and increase the number of animals bred early in the breeding season (Lucy et al., 2001; Larson et al., 2009). Although synchronization did not influence overall pregnancy rates, Larson et al. (2009) reported a 13% increase in the proportion of heifers calving in the first 21 d of the calving season when a single injection of prostaglandin was administered ~108 h after bull turn-in. Weaning weights did not differ ($P = 0.58$); however, due to calving earlier in the calving season, postpartum interval would have been greater in the synchronized group of heifers, increasing recovery time, which would likely aid in improving the proportion of the synchronized heifers becoming pregnant in the subsequent breeding season.

Antral Follicle Counts and Fertility

Another reproductive technology that could potentially aid producers in improving early breeding success, and thus improve herd longevity includes antral follicle count (AFC). Antral follicle count has been positively associated with fertility in *Bos taurus* cattle (Cushman et al., 2009; Mossa et al., 2013), with moderate-to-high heritability (Snelling et al., 2012; Walsh et al., 2014). Given that reproductive traits typically display low heritability, AFC may be an appropriate selection criterion to aid in improving reproductive performance of a population. Additionally, AFC is highly repeatable within an animal, but varies among individuals (reviewed by Ireland et al., 2011). Classifications are made based on the number of antral follicles identified by ultrasonography with animals having ≤15 being classified as low, 16 to 24 moderate, and ≥25 classified as high follicle count groups (Ireland et al., 2008). Typically, ~15% to 20% of individuals in a herd are classified as low or high AFC while the remainder of the herd classified as moderate AFC (reviewed by Ireland et al., 2011). Antral follicle counts are typically conducted in heifers prior to their first breeding season (13 to 15 mo of age). Previous studies report low AFC heifers had lower pregnancy rates and reduced numbers of morphologically healthy oocytes and follicles (Ireland et al., 2008; Cushman et al., 2009; Mossa et al., 2013) compared with high AFC heifers. Moreover, dairy cows classified as high AFC had 3.34 times greater ($P < 0.05$) odds ratio of getting pregnant compared with low-AFC animals (Mossa et al., 2013). Additionally, Cushman et al. (2013) reported

heifers calving in the first 21 d of the calving season had larger AFC than heifers calving in the second or third 21 d of the calving season. McNeel et al. (2015) reported similar findings, with AFC being significantly greater in heifers calving early in the calving season compared with those calving late, regardless of the use of estrus synchronization (PGF_{2α}). Due to earlier calving, McNeel et al. (2015) also reported heavier weaning weights for heifers with higher

SUMMARY AND CONCLUSIONS

Cow longevity is vital for producer profitability. Although several factors can contribute to the ability of an animal to reproduce, management decisions can play a large role in allowing animals to reach their genetic potential. Although reproductive traits typically have low heritability, identifying traits that may aid in selecting animals which could increase longevity are important. Calving early as a heifer appears to be one of the greatest factors influencing overall productivity and longevity of a cow, thus incorporating this trait as a measurement to help in management decisions may be of interest to producers. Reproductive technologies can be utilized to increase the probability of an animal being bred early in the breeding season, and consequently, calving earlier in the calving season. Year-round nutrition programs and proper heifer development programs are also critical in establishing the foundation of reproduction and longevity in a beef herd. Although there is no specific trait or management tool that will identify the perfect cow, producers must identify management strategies that will allow for optimal animal performance while enhancing reproductive success and longevity to ensure profitability.

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