ABSTRACT: Research emphasis has been placed on heifer development strategies in recent years, comparing traditional, more intensive systems to more extensive systems using less feed and relying on compensatory gain to reach a target BW. Recent research has indicated that developing heifers to a lighter target BW at breeding (i.e., 50 to 57% of mature BW compared with 60 to 65% BW) reduced development costs and did not impair reproductive performance. Research published through the late 1980s demonstrated greater negative effects of limited postweaning growth on age at puberty and pregnancy rates whereas more recent studies demonstrate less of a negative impact of delayed puberty on pregnancy rate. A limitation of most research concerning influences of nutrition on heifer development and cow reproductive performance is little or limited consideration of long-term implications. Longevity has relatively low heritability; therefore, heifer development and other management strategies have a greater potential to impact cow retention. Establishing the impact of heifer development protocols on longevity is complex, requiring consideration of nutritional factors after the start of breeding and through subsequent calvings. Lower-input heifer development, where all heifers are managed together after the postweaning period, did not impair rebreeding, but continued subsequent restriction in the form of marginal winter supplementation resulted in decreased retention in the breeding herd. Therefore, the compensatory BW gain period for restricted-growth heifers may be important to longevity and lifetime productivity. Adequate growth and development to ensure minimal calving difficulty can be of critical importance for longevity; however, providing additional supplemental feed during postweaning development to accomplish this may be less efficient than later in development. Restricting gain during postweaning development by limiting DMI or developing heifers on dormant winter forage resulted in increased economic advantages compared with developing heifers at greater rates of ADG to achieve a greater target BW. Implications of heifer development system on cow longevity must be considered when evaluating economics of a heifer enterprise; however, studies evaluating the effects of heifer development systems on cow longevity are extremely limited.

Key words: adaptation, beef cattle, cow longevity, feed inputs, replacement heifers

INTRODUCTION

When thinking about the appropriateness of the heifer development paradigm used over the last several decades, some critical factors need to be considered: drastic reduction in supply of relatively inexpensive feeds traditionally used in heifer development programs, genetic changes in the cattle population over the last 40 yr, and the need to understand the implication that management practices may have on lifetime production efficiency rather than on an annual production cycle. The negative impact of increases in cost of feed resources over the last decade on development protocols with substantial dependence on harvested feeds is obvious. Much of the research leading up to the paradigm of developing heifers to a
target BW was conducted during the late 1960s through the 1980s, and the impact of genetic changes that have occurred with selection based on EPD for numerous traits have not been considered. Research during the last decade has compared traditional, more intensive systems with more extensive systems using less feed and relying on compensatory gain. These studies provide evidence that developing heifers to a lighter target BW at breeding, that is, 50 to 57% of mature BW compared with 60 to 65% BW, reduced development costs and did not impair reproductive performance (Funston and Deutscher, 2004; Roberts et al., 2009; Funston and Larson, 2011; Mulliniks et al., 2012). One limitation of most research concerning influences of nutrition on heifer development and cow reproductive performance is little or limited consideration of long-term implications. Longevity has a relatively low heritability; therefore, heifer development and other management strategies have a greater potential to impact cow retention in the breeding herd. Although limited information exists about the impacts of heifer development strategies on cow longevity, data from nonruminant and nonlivestock species implies that limiting caloric intake during juvenile development can increase lifespan (Speakman and Hambly, 2007).

**Heifer Development System and Pubertal Status**

In a recent review (Funston et al., 2012) of heifer development research conducted over the last several decades along with more recent research, it was indicated the association among BW, puberty, and他ifer pregnancy rate appear to have changed over time. Research published through the late 1980s demonstrated greater negative effects of limited postweaning growth on age of puberty and pregnancy rates whereas more recent studies demonstrate less of a negative impact of delayed puberty on pregnancy rate. In the previous review, it was hypothesized that changes over time may have resulted from 1) a shift from calving heifers at 3 yr of age to calving at 2 yr of age and subsequent selection pressure for decreased age at puberty, 2) the association between scrotal circumference in bulls and age at puberty in their daughters and indication of genetic change in scrotal circumference over time from several breed associations, and 3) perhaps a change in fertility of pubertal estrus compared with subsequent estrous cycles. Other factors may also contribute to the change over time. Establishment of EPD and their implementation in selection for growth, milk, and carcass characteristics would contribute to changes in reproductive performance due to genetic associations with these and other traits. Magnitude of genetic changes association with implementation of EPD is clearly evident (American Angus Association, 2012; American Hereford Association, 2012; American International Charolais Association, 2012). Insight into trends for genetic changes in BW at puberty that may correspond to genetic changes in mature size are provided by plotting data from studies conducted over time (Fig. 1). Results summarized in Fig. 1 illustrate the increased BW at time of puberty as cattle populations used in the studies progressed over time. Although information concerning mature size is not provided in most studies represented in Fig. 1, the progression of the populations from a mature size of 500 kg in the initial studies to 590 kg in the most recent studies may be reasonable. Even though different management and feeding practices were implemented within and among studies summarized in Fig. 1, a large majority of heifers would be expected to achieve puberty at or below 60% mature BW, assuming mature BW of 500, 545, or 590 kg for heifers used in the 3 time periods represented and a 20 to 30 kg SD for BW at puberty. Data in Fig. 1 also indicate that average age of puberty was before 430 d of age, which would correspond to start of breeding to begin calving at 2 yr of age. Furthermore, it is conceivable that selection and management processes imposed over time could enrich the proportion of animals capable of achieving puberty at lower target BW.

Another component of the heifer development paradigm that appears to need to be reevaluated is the theory that fertility of pubertal estrus is inferior to subsequent estrous cycles, based on data from Byerley et al. (1987) who observed a 21% lower pregnancy rate in heifers bred on their first estrus as compared with heifers bred on their third estrus. However, a limitation of these data was that mean age and BW of heifers at time of breeding were confounded by estrus status classification. Mean age at breeding for heifers bred at first estrus was 322 d whereas heifers bred on third estrus averaged 375 d old. Furthermore, age of breeding accounted for increased pregnancy in heifers classified to be bred at first estrus but not in heifers assigned to be bred on the third estrus. Therefore, further research is warranted to establish whether the young breeding age has meaningful implications for the conventional practices of today where the majority of heifers would be 13 to 15 mo of age, which is 2 to 4 mo older at breeding than heifers bred at first estrus in the study by Byerley et al. (1987). As discussed previously, studies reported in the last 2 decades demonstrate less of a negative impact of delayed puberty on pregnancy rate than earlier studies.

**Nutrition after the Start of Breeding and through Subsequent Calvings**

Establishing the impact of heifer development protocols on longevity is complex, requiring consideration
for nutritional factors after the start of breeding and through subsequent calvings. Factors to consider include the resulting maintenance requirements and behavior traits associated with development protocols. Most longer-term heifer development studies manage replacement heifers as a group on breeding pastures after development. Heifers developed extensively, that is, under conditions of dormant or scarce forage, low precipitation, undulating terrain, and large pastures, or those that are restricted-gain pen developed often exhibit compensatory gain during the summer grazing period (Olson et al., 1992; Roberts et al., 2009; Funston and Larson, 2011; Mulliniks et al., 2012). In New Mexico, (Mulliniks et al., 2012), heifers developed in a drylot had increased ADG (0.69 kg/d) from initiation of the study to breeding compared with heifers developed on a low-quality forage with protein supplementation (0.26 kg/d), resulting in 35 kg difference in BW at breeding. However, the extensively managed, range-developed heifers had greater ADG (0.83 kg/d) from the time of breeding to pregnancy diagnosis compared with drylot heifers (0.61 kg/d). Range-developed heifers compensated for their minimal prebreeding ADG and gained more BW during the breeding season than feedlot-developed heifers, due to decreased maintenance requirements and the ability to respond to a seasonal improvement in forage quality (Marston et al., 1995; Ciccioli et al., 2005). In addition, the majority of effective precipitation in New Mexico occurs in July and August. This timing of precipitation and moisture-stimulated forage growth, accompanied by increased forage quality, is reflected in ADG differences in heifer development treatments after breeding. Therefore, timing of precipitation, forage quality, and growth pattern in regard to time of breeding may alter or enhance reproductive performance especially in heifers developed on a restricted energy diet. Extensively developed heifers tended to have greater pregnancy rates than heifers developed in a drylot (91 vs. 84%; Mulliniks et al., 2012).

Recent research (Funston and Larson, 2011; Larson et al., 2011) was conducted grazing heifers on corn residue or winter range as an alternative to drylot feeding. In each study, heifers grazing corn residue gained approximately 0.23 kg/d less than their...
more traditionally fed counterparts, whether winter grass or a drylot. Heifers grazing winter range or corn residue were only supplemented with the equivalent of 0.14 kg/d protein and gained between 0.19 and 0.42 kg/d during winter grazing. However, once placed on greater quality spring pasture, the heifers gained 0.54 to 0.73 kg/d during the breeding season. Heifers developed while grazing corn residue achieved 56% of their mature BW but weighed less before breeding than heifers developed in the drylot; however, they had similar pregnancy rates at the end of the breeding season and achieved similar BW before calving with a similar percentage (>60%) calving in the first 21 d of the calving season and calf birth date. Decreased winter BW gain in the more extensive development systems resulted in greater BW gain during the breeding season, which may explain similar overall pregnancy rates.

If nutrition after the start of breeding is inadequate, poor reproductive performance may result. White et al. (2001) found that acute nutrient restriction at 40% of maintenance prevented ovulation in 70% of heifers with no change in condition. Perry et al. (2009) reported decreased pregnancy success for heifers moved from feedlot to summer grazing post-AI. Postinsemination nutrition may affect embryonic survival through a variety of mechanisms. Nutritionally mediated changes to the uterine environment can occur by changing components of uterine secretions or by influencing the circulating concentrations of progesterone that regulate the uterine environment (Foxcroft, 1997). Arias et al. (2012) determined the effects of nutritional plane during the first 21 d post-AI of yearling heifers. Heifers that gained BW had greater AI pregnancy rate (77%) than heifers that maintained (56%) or lost (61%) BW during the 21-d post-AI period. In addition, no differences were found between heifers that maintained or lost BW. Therefore, nutritional plane post-AI may be as or more important than prebreeding nutritional plan in yearling heifers.

Date of calving for first calf heifers may have long-term impacts on cow longevity and productivity. Calving late in yr 1 increases the proportion of cows that calve later the next year or do not conceive (Burris and Priode, 1958). Research has indicated that heifers having their first calf earlier in the calving season had increased longevity relative to heifers that calved later in the calving season (Rogers et al., 2004; Kill et al., 2012). Therefore, date of calving has the potential to increase lifetime productivity by increased longevity in the cow herd. However, the above-mentioned studies do not demonstrate that heifer development affected date of calving or longevity. In contrast, Mulliniks et al. (2012) reported no differences in calving date between heifer development treatments with large differences in retention rate up to 5 yr of age. Results of Mulliniks et al. (2012) also illustrates that in extensive development heifer systems, attainment of puberty or date of conception is not delayed and future productivity and longevity of the female can be enhanced by extensive, low-cost development strategies.

Nutrition through subsequent calvings after heifer development may also have an impact on cow longevity. Heifers in the Nebraska and New Mexico datasets are managed in common after heifer development whereas heifers in the Montana dataset continue on their heifer development treatment assignments throughout their lifetime. Heifers developed on unlimited feed are provided adequate supplemental harvested feed from early December through calving whereas restricted developed heifers are fed a marginal level of supplemental harvested feed, that is, 20 to 45% less harvested feed December through calving. Pregnancy rates through the fourth calf remained similar between high- and low-BW gain heifers developed in the Nebraska system (Funston and Deutscher, 2004). In New Mexico, Mulliniks et al. (2012) reported 68% retention in the breeding herd through 5 yr of age for range-developed heifers fed a high-RUP supplement compared with 41% retention for range-raised counterparts fed a lower-RUP cottonseed meal-based supplement and 42% retention for heifers developed in a feedlot. This relationship tended to be significant as early as 2 and 3 yr of age, respectively. These data indicate that not only where a heifer is developed (i.e., extensive versus feedlot) but also what she is fed when developed extensively (i.e., high-RUP supplement vs. lower-RUP supplement) may influence her longevity in the cow herd. In contrast to the Nebraska and New Mexico data sets, data from Montana indicate that heifers that were developed on a restricted plane of nutrition and that continued to receive marginal supplementation of harvested feeds in subsequent years dropped out of the herd at a greater rate between 2 and 3 yr of age and had decreased retention rates at 3 and 4 yr of age than nonrestricted heifers provided greater levels of supplemental feed during the winter (Fig. 2; A. J. Roberts, unpublished data). Collectively, rebreeding results from New Mexico and Nebraska would indicate that lower-input heifer development where all heifers are managed together after the postweaning period did not impair rebreeding, but continued subsequent restriction in the form of marginal winter supplementation, as experienced by the Montana heifers, resulted in decreased retention rates. Furthermore, restricting heifer growth before breeding may have an impact on mature cow size resulting in decreased reproductive performance. Restricted heifers that failed to rebreed were lighter before calving (395 vs. 403 kg) and before start of breeding (371 vs. 382
kg) as 2 yr olds compared with pregnant heifers from both development groups and nonpregnant heifers developed on ad libitum feed. This primary difference between lower-input heifer development programs emphasizes the importance of managing extensively developed heifers for continued growth after lower inputs during postweaning development. In support of continued growth postdevelopment, data from New Mexico (J. T. Mulliniks, unpublished data) indicate that rate of BW gain before breeding does not affect cow mature size up to 4 yr of age (Table 1). Therefore, the compensatory BW gain period for restricted-growth heifers may be extremely important to the longevity and lifetime productivity.

Heifer development protocols may influence resulting behavior traits associated with the environment in which the heifer was developed. Range-developed heifers may retain better grazing skills and be more productive during the subsequent summer (Olson et al., 1992; Perry et al., 2009). In a recent study at 2 locations in Nebraska (Summers et al., 2013), heifers were either developed on winter range vs. corn residue or drylot vs. corn residue. There were no differences in pregnancy rate based on heifer development system; however, heifers that were developed on corn residue exhibited greater ADG when placed on corn residue as pregnant heifers compared with either winter range or drylot developed heifers (Summers et al., 2013), supporting the hypothesis of a learned behavior for grazing corn residue. However, drylot-developed heifers that graze dormant forage during the winter before development in a pen may not exhibit a change in grazing skills on returning to a grazing environment. Mulliniks et al. (2012) reported similar ADG in drylot-developed heifers between the drylot phase (0.69 kg/d) and grazing phase (0.61 kg/d). Data from other species indicates that the environment experienced during development can have lifetime impacts. A single generation in captivity resulted in genetic adaptation in Hood River steelhead (Christie et al., 2012), where wild-born broodstock with the greatest fitness in a captive environment produced offspring that performed the worst in the wild.

Adequate heifer growth and development to ensure minimal calving difficulty can be of critical importance for longevity; however, providing additional supplemental feed during postweaning development to accomplish this may be less efficient than later in development. Similar calving difficulty has been observed between low- and high-gain heifers developed in confinement (Funston and Deutscher, 2004), between heifers developed extensively on corn residue and winter range and feedlot-developed heifers (Funston and Larson, 2011), and between extensively developed heifers grazing either winter range or corn residue (Larson et al., 2011). Within study, all heifers were exposed to a low-birthweight EPD bull battery in the same breeding pastures.
Table 3. Enterprise budget for costs and returns, Montana data

<table>
<thead>
<tr>
<th>Item</th>
<th>Control</th>
<th>Restricted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross returns, $</td>
<td>$7,079.52</td>
<td>$11,262.16</td>
</tr>
<tr>
<td>Nonpregnant heifers</td>
<td>$96,600.00</td>
<td>$91,350.00</td>
</tr>
<tr>
<td>Pregnant heifers</td>
<td>$103,679.52</td>
<td>$102,612.16</td>
</tr>
<tr>
<td>Total</td>
<td>$17,967.60</td>
<td>$13,176.24</td>
</tr>
<tr>
<td>Costs</td>
<td>$71,095.60</td>
<td>$66,304.24</td>
</tr>
<tr>
<td>Heifer purchase cost</td>
<td>$53,128.00</td>
<td>$53,128.00</td>
</tr>
<tr>
<td>Feed</td>
<td>$32,583.92</td>
<td>$36,307.92</td>
</tr>
<tr>
<td>Net returns, $</td>
<td>$325.84</td>
<td>$363.08</td>
</tr>
<tr>
<td>Net returns, $/heifer developed</td>
<td>$325.84</td>
<td>$363.08</td>
</tr>
</tbody>
</table>

1Corn silage-based diet, either ad libitum (control) or 20% less at similar BW (restricted).

Economic Analysis of Heifer Development Systems

Mulliniks et al. (2012) evaluated enterprise budgets for the 3 New Mexico heifer development treatments. Assumptions included comparing 100 heifers in each treatment, and all heifers would be sold in the fall of their yearling year, regardless of pregnancy status. Gross returns were greatest for the RUP-supplemented range heifers and least for heifers developed in the feedlot, and feed costs were greatest for feedlot-developed heifers. Compared with feedlot-developed heifers, net returns were US$99.71 and $87.18 greater per heifer developed for the high-RUP- and cottonseed meal-supplemented heifers grazing dormant native range, respectively. The increase in net returns for range-raised heifers was due to greater pregnancy rates and decreased development costs.

A similar approach was used to evaluate the heifer development protocols in the Montana dataset. Assumptions and input costs used are detailed in Table 2, and an enterprise budget comparing the 2 heifer development methods on their economic impacts is listed in Table 3. Gross returns were greater for control heifers, but restricted heifers had lower feed costs. This resulted in an increase of $37.24 in net returns per developed heifer for the restricted group.

Research from the University of Nebraska reports similar savings in development costs, where developing heifers on dormant winter forage resulted in a $45 savings per pregnant heifer compared with drylot development (Funston and Larson, 2011) and a similar development cost comparing 2 extensive development systems, winter range vs. corn residue (Larson et al., 2011). Studies from New Mexico, Montana, and Nebraska illustrate that restricting gain during postweaning development by limiting DMI or developing heifers on dormant winter forage resulted in increased economic advantages compared with developing heifers at greater rates of ADG to achieve a greater target BW.

SUMMARY AND CONCLUSIONS

Developing heifers to lighter target BW may be advantageous in maintaining positive energy balance or adapting to negative energy balance through the breeding season in many range settings. Likewise, heifers developed under a range setting may be better adapted to maintain desired metabolic status during breeding than heifers reared in a pen or developed at a high rate of gain. Implications of heifer development system on cow longevity must be considered when evaluating economics of a heifer enterprise; however, studies evaluating the effects of heifer development systems on cow longevity are extremely limited.

LITERATURE CITED


Beef heifer development and lifetime productivity


