Beef heifer development systems and lifetime productivity[4]

A. J. Roberts, USDA-ARS, Fort Keogh Livestock and Range Research Laboratory, Miles City, MT; R.N. Funston, University of Nebraska West Central Research and Extension Center, North Platte; E.E. Grings, South Dakota State University, Department of Animal Science, Brookings; and M.K. Petersen, USDA-ARS, Fort Keogh Livestock and Range Research Laboratory, Miles City, MT

Introduction

Genetics and environment regulate production efficiency traits and may also influence phenotype. Furthermore, nutrition and other environmental factors encountered during intrauterine development may result in epigenetic changes altering offspring later in life (Hales and Barker, 2001; Anway et al., 2005; Wu et al., 2006). Epigenetic modifications affecting gene expression can be inherited through subsequent generations (Goldberg et al., 2007).

Research demonstrating generational impacts caused by environment arose from human populations subjected to extreme nutritional stress (reviewed in Hales and Barker, 2001). Subsequently, animals have facilitated studies to provide insight into how under and over nutrition during pregnancy affect offspring function later in life (Wu et al., 2006; Reynolds et al., 2010; Ford and Long, 2012). Relatively small nutritional differences may lead to metabolic programing that alters offspring production characteristics (Funston et al., 2012a, b; Endecott et al., 2013). This paper reviews results from 3 locations that evaluated different nutritional paradigms representative of conditions common in range beef cattle production, emphasizing how nutrition impacts lifetime reproductive performance.

Review and discussion

Lifetime productivity study

In 2001, a long-term research project began at the USDA-ARS, Fort Keogh Livestock and Range Research Laboratory (Miles City, MT), to assess lifetime productivity of cows managed with 2 harvested feed levels during postweaning development and winter grazing. It was hypothesized long-term management with lesser inputs would result in increased selection pressure against cows with greater nutritional requirements. If true, cows remaining in the population would better maintain reproductive function in nutritionally-limited environments. Two possible reasons leading to the expected result would be 1) change in genetic composition or 2) a metabolic adaptation to function with less input. Genetic change would require a relatively long period of time compared with metabolic adaptation. The adaptation process could also result in altered uterine function bringing about epigenetic changes in the offspring. When the study was initiated, evidence for either of these possibilities was scarce. Subsequently, Vonnahme et al. (2006) provided evidence that response to nutritional restriction was markedly different for ewes originating from a common genetic population, but managed under very divergent nutritional environments for several generations. Ewes from a university flock managed with diet that always met or exceeded NRC recommendations exhibited greater loss in BW and BCS, and greater suppression in placental efficiency and fetal growth in response to nutritional restriction than ewes maintained in an extensive semi-arid range environment. These results paralleled expectations in the present study.

Composite cows used in this study were developed at Fort Keogh (**CGC**; ½ Red Angus, ¼ Charolais, ¼ Tarentaise; Newman et al., 1993). Pregnant cows averaged 5.2 yr of age; 1,179 lb BW; and 5.2 BCS (1 =

[4]Adapted from: Roberts et al., 2016.

severely emaciated to 9 very obese; Herd and Sprott, 1986) at the beginning of the study in December 2001. Bred heifers averaged 980 lb BW and 5.9 BCS at 1.6 yr age. Cows and heifers were stratified by age and weight and assigned randomly to 1 of 2 supplementation levels while grazing dormant native forage from December to March. Cows in each treatment were managed separately in the winter to allow for differential feeding. Supplementation included feeding alfalfa cubes or hay at levels expected to be an adequate (4 lb/d [as-fed], **ADEQ**, n = 92 cows and 19 bred heifers) or marginal (2.4 lb/d [as-fed], **MARG**, n =138 cows and 21 bred heifers) level of protein supplementation to meet NRC (2000) requirements based on average quality and availability of the winter forage. More cows were initially assigned to the MARG treatment to accommodate expected retention rates in the 2 groups. Information concerning forage characteristics at the research site was published previously (Grings et al., 2005; Grings and Roberts 2013). Pastures used for winter grazing were not grazed during the growing season and were sufficient in size to provide available forage for grazing through the winter grazing period. When snow or ice limited forage availability, alfalfa hay was fed at a rate of 22 or 18.3 lb/d (as-fed basis) per cow in ADEQ or MARG groups, respectively. Supplement treatment was repeated annually for cows out to 10 yr of age. Cows were culled from the study if open or lost their calf prior to weaning. Heifer calves born from 2002 to 2011 retained as replacements were stratified by BW at weaning, age of dam, and dam winter supplementation treatment, and randomly assigned to 1 of 2 nutrition levels for a 140-d period after weaning: fed a corn silage-based diet to appetite (Control; n=656) or fed at 80% of that consumed by controls adjusted to a common BW basis (Restricted; n=655), as described previously (Roberts et al., 2009a). Heifers from Control and Restricted post-weaning treatments that became pregnant were subjected to the ADEQ and MARG winter supplemental feed, respectively, for all subsequent years of production as described above.

For cows used to initiate the study in 2001, differences in winter supplemental feed levels resulted in different BW changes throughout the winter, with ADEQ cows gaining more BW than MARG cows ($P < 0.05$). Cows in the ADEQ group maintained BCS during the winter treatment period, whereas MARG cows experienced a 0.12 decrease in BCS ($P < 0.04$). Pregnancy rates over the 2002 to 2007 breeding seasons were 92 and 91% for ADEQ and MARG groups, respectively ($P = 0.8$). Pregnancy rates in the MARG group were greater than was predicted based on NRC (2000) when designing the study. Forage may have been greater quality than expected during the 7-yr period (not supported by forage analyses), or the cattle performed better than NRC prediction. Evidence of cows managed under extensive semi-arid range environments functioning at greater levels than predicted by NRC is accumulating (Petersen et al., 2014), and would be consistent with pregnancy rates in cows from the MARG group not differing from ADEQ cows. A year × treatment interaction was not evident ($P = 0.9$), which supports cow adaptation to MARG level of supplement and similar trends for genetic change over time for the 2 treatment groups.

Measurements collected on heifers born 2003 to 2005 indicated growth, carcass, and reproductive performance differed due to post-weaning development treatment (Roberts et al., 2007; 2009a). Effects from post-weaning treatment from these earlier analyses are further substantiated by data analyses for all years of the study. Figure 1 illustrates growth patterns for the 2 treatments averaged over 10 yr of the study. Weight diverged ($P < 0.01$) between treatments by 28 d after initiation of restriction and remained different ($P < 0.01$) up to time winter supplementation treatments were initiated. Restricted heifers consumed 26% less feed (as-fed basis) and had 0.3 lb/d less ($P < 0.01$) ADG during the 140-d post-weaning trial than Control-fed heifers. Efficiency of gain during the 140-d trial was greater ($P < 0.01$) for Restricted than Control-fed heifers (0.251 vs. 0.239 G:F for Restricted vs Control, respectively). After the 140-d trial, all heifers were provided equal access to feed or grazing. Weight gain following the 140-d trial until pregnancy diagnosis in the fall was greater ($P < 0.01$) for Restricted than Control heifers. Although individual feed intake was not measured after the post-weaning trial, data from male cohorts of the heifers also developed on 2 levels of intake exhibited greater gain after restriction occurred with feed intake levels similar to Control-reared males (Endecott et al., 2012). Therefore, the greater BW gain observed following restriction may have occurred without differences in feed intake due to improved efficiency brought about by reduced maintenance requirements resulting from prior nutritional environment (Ferrell and Jenkins, 1985). These results, along with those reviewed previously (Funston et al., 2012a; Endecott et al., 2013), demonstrate efficiency of developing replacement heifers may be improved by nutritional environments imposed during post-weaning management.

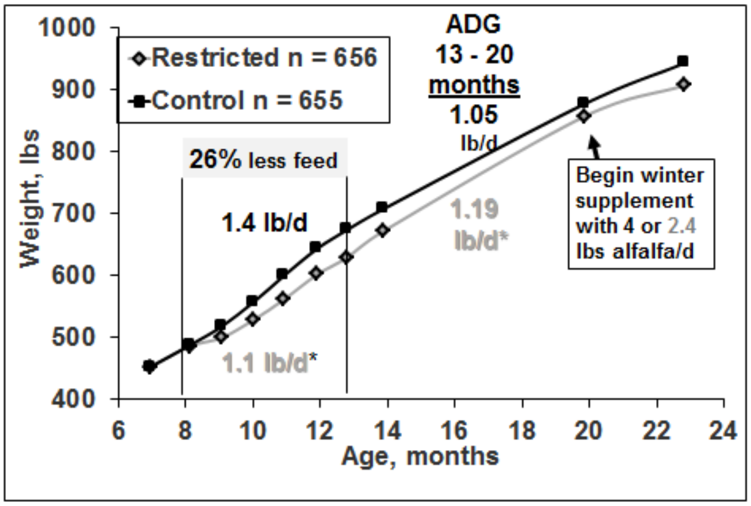

Figure 1. Growth of heifers fed to appetite (Control; n = 656) or fed at 80% of control diets adjusted to a common BW basis (Restricted; n = 655) during a 140-d period after weaning (ADG = 1.4 and 1.1 lb/d for Control and Restricted, respectively; $P < 0.05$). Restricted heifers consumed 26% less feed during the 140-d period. Heifers from both treatments were managed together from 13 to 20 mo of age (ADG = 1.05 and 1.19 lb/d for Control and Restricted, respectively; $P < 0.05$). From 20 to 23 mo of age, heifers grazed dormant winter forage and were provided an equivalent of 4 or 2.4 lb alfalfa hay (protein supplement)/d for Control or Restricted treatments, respectively.

Average heifer weight at breeding differed ($P < 0.01$) between Control (710 lb) and Restricted (672 lb) treatments. These average weights equate to 57 and 54% of the historic mature BW of the cow herd, for Control and Restricted treatments, respectively. Average pregnancy rates for Control and Restricted treatments over 10 yr were 89 and 88%, respectively ($P = 0.63$). Interval from first day of breeding to first calving date was not influenced by post-weaning treatment ($P = 0.44$). While not different due to treatment, pregnancy rates varied substantially across years (year effect, $P < 0.01$, Figure 2). Environmental factors affecting forage quality likely contribute to the annual variations in pregnancy rates.

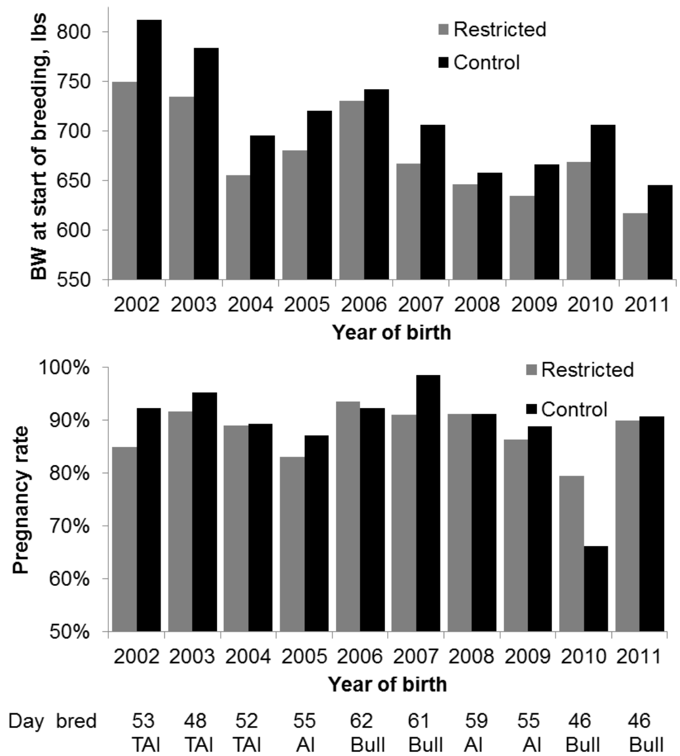

Figure 2. Pre-breeding body weight (BW; top panel) and pregnancy rates (bottom panel) for heifers fed ad-libitum (Control, black bar) or 26% less (Restricted, gray bars) during a 140-d period between weaning and start of breeding. Heifer birth year is shown on the X axis. Number of days heifers were bred each year and breeding method is shown at the bottom (TAI= estrus synchronization and timed AI followed by clean-up bulls, AI = injection of PG and AI after observed estrus and followed by clean-up bulls, Bull= natural service). Pre-breeding BW was greater ($P < 0.01$) for Control than Restricted heifers, but pregnancy rate did not differ ($P = 0.6$). Pre-breeding BW and pregnancy rate varied ($P < 0.01$) across years.

Previous research provides evidence that fetal programming may influence individual animal response to its nutritional environment later in life (Roberts et al., 2009b; Funston et al., 2012b; Endecott et al., 2013). A summary of cow retention in this study is shown in Figure 3. Interaction of dam and heifer treatment tended ($P< 0.07$) to influence pregnancy rate and percentage of cows retained in the herd at 2.2 and 5.2 years of age. These interactions arise from greater retention of heifers developed on restricted feed and fed MARG winter supplement when born from MARG dams compared with their Restricted cohorts born from ADEQ dams. Pregnancy rate at 2.2 yr of age was greater ($P = 0.01$) for the Control group (79%) than the Restricted group (72%), resulting in lower retention rates in Restricted cows at 3 and 4 yr of age. Pregnancy rates at 3.2 yr of age were greater ($P = 0.03$) for cows born from MARG supplemented dams (79%) than ADEQ dams (72%), providing another example of fetal programing. These results provide evidence the nutrition experienced during gestation can alter the developing fetus, affecting its reproductive performance later in life. Managing cows with less feed inputs may program offspring to better sustain reproductive performance when reared in a low-input environment. The greatest differences in retention rates are between Control and Restricted cows out of ADEQ dams. This agrees with data from numerous studies evaluating nutritional effects on reproduction (Richards et al., 1986; Selk et al., 1988; Spitzer et al., 1995). In contrast, retention differences between Control and Restricted heifers born from MARG dams would not be intuitive from previous research, emphasizing consideration of previous herd management when evaluating impacts on reproduction. Results from cows continuously managed to meet or exceed NRC nutritional requirements may not be indicative of results in herds managed with less inputs, as was also observed for ewes (Vonnahme et al., 2006) discussed previously.

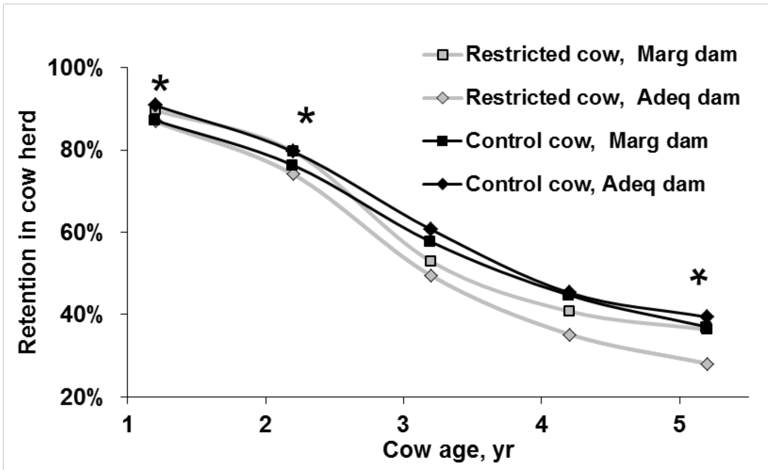

Figure 3. Impact of 2 levels of dam protein supplementation during gestation and feed level provided to daughters during post-weaning development and subsequent winter supplementation on herd retention. Dams were supplemented with either alfalfa cubes or hay at the equivalent of 4 or 2.4 lb/d (as-fed basis), providing adequate (ADEQ) or marginal (MARG) protein to meet NRC (2000) requirements based on winter forage quality and availability. Daughters of dams from each supplement level were allotted by BW to be fed to appetite (Control, n = 656 at first data point) or 80% of Control diets (Restricted, n = 655 at first data point) during a 140-d period after weaning. Animals were required to get pregnant and wean a calf each year to remain in the herd. Pregnant animals grazed dormant winter forage and were provided an equivalent of 4 or 2.4 lb/d protein supplement for Control or Restricted treatments, respectively. Asterisks indicate data points affected by interaction ($P < 0.07$) of daughter and dam treatments. Loss from 2 to 3 yr of age was greater ($P < 0.01$) for Restricted cows (gray lines) than Control cows (black lines). Loss from 3 to 4 yr of age was greater ($P < 0.03$) for cows from ADEQ dam (diamonds) than cows from MARG dams (squares).

Evidence that restriction during post-weaning development has minimal effects on retention is provided by Funston and Deutscher (2004, Figure 4), where heifers were developed on diets differing in quality, rather than quantity. However, growth rates achieved for the low- and high-quality diets were similar to growth rates of Restricted and Control heifers depicted in Figure 1. However, heifers in the Funston and Deutscher study were treated the same after post-weaning development and retention was similar between the 2 post-weaning treatments. Comparison of retention in these studies confirms the importance of winter nutrition in young cows.

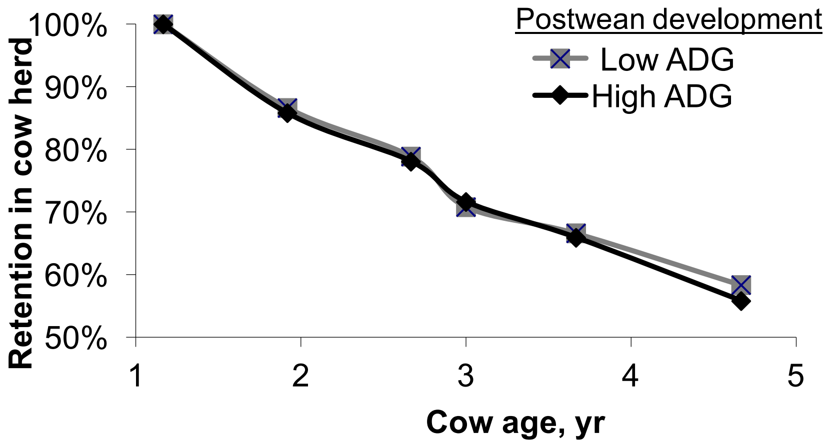

Figure 4. Growth rate between weaning and start of breeding did not affect retention beyond 4 yr of age. Heifers were fed to gain 1.10 (Low ADG) or 1.41 (High ADG) lb/d during post-weaning development resulting in 637 and 690 lb average weigh at start of breeding. Data adapted from Funston and Deutscher (2004).

How dam nutrition physiologically affects daughter reproductive performance has not been identified. The impact of dam undernutrition on subsequent reproductive performance exhibited by her daughter later in life may involve altered metabolic responses contributing to the 'thrifty phenotype' (Hales and Barker, 2001) and alternations in major organs, as well as reproductive tissues and organs (George et al., 2012; Mossa et al., 2015). Whereas these effects have been identified in undernutrition experimental models, it is unknown if the effects will also be evident with marginal nutrition. Evidence of altered metabolism was provided by evaluation of BW and BCS of a subset of cows from the lifetime productivity study (Roberts et al., 2009b). Figure 5 depicts cow and dam treatment effects on BW at start of breeding at 2 until 5 yr of age. Cows born from MARG dams weighed more ($P < 0.01$) by 3 yr of age, persisting to 5 yr of age, and had higher ($P < 0.05$) BCS at age 5 than cows from ADEQ dams. Furthermore, Restricted cows from MARG dams produced lighter calves at birth and weaning than their contemporary herd mates born from ADEQ dams (Table 1). These differences due to dam treatment, or granddam treatment, support a role of epigenetically-induced changes in metabolic pathways improving reproductive performance, which may ultimately lead to greater retention.

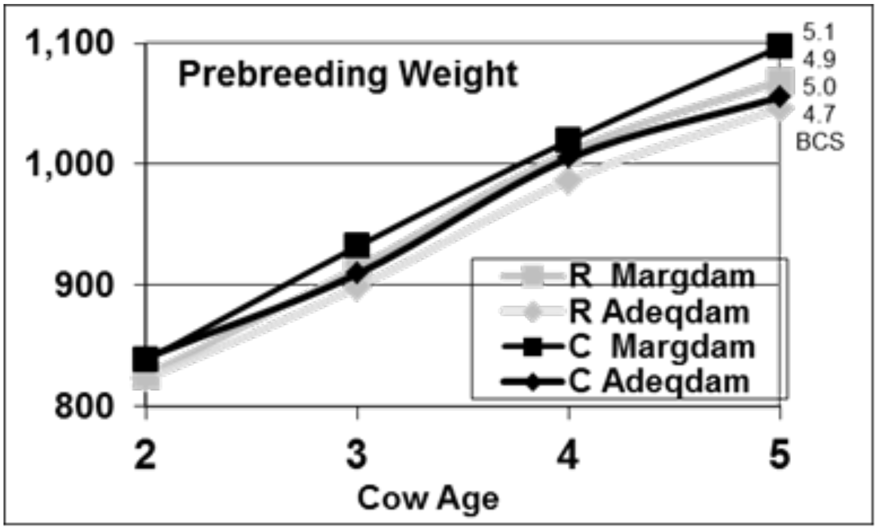

Figure 5. Impact of 2 levels of dam protein supplementation during gestation and feed level provided to daughters during post-weaning development and subsequent winter supplementation on weight (BW) at start of breeding from 2 to 5 yr of age. Supplement treatments applied to dams were feeding alfalfa at the equivalent of 4 or 2.4 lb/d (as-fed basis), expected to be an adequate (ADEQ) or marginal (MARG) level of protein supplementation to meet NRC (2000) requirements based on average winter forage quality and availability. Daughters of dams from each supplement level were fed to appetite (Control) or fed at 80 % of Control diets adjusted to a common BW basis (Restricted) during a 140-d period after weaning. Animals that became pregnant and weaned a calf each year were provided 4 or 2.4 lb/d alfalfa as protein supplement while grazing dormant winter forage for Control or Restricted treatments, respectively. Control cows were heavier than Restricted cows at all ages (black lines vs. gray lines with similar symbols). Cows born from MARG dams (squares) were heavier than cows born from ADEQ dams (diamonds) at 3, 4 and 5 yr of age. At 5 yr of age, Control cows had greater BCSthan Restricted cows and cows out of MARG dams had greater BCS than cows out of ADEQ dams.

Concentrations of IGF-1 in blood samples collected prior to and after first calving, and at the start of breeding were less in Restricted cows from ADEQ dams compared with the other groups (90 vs. 98 ng IGF-1/mL; Roberts et al., 2010). The lower levels of IGF-1 coinciding with the lowest rebreeding rates in this group are consistent with IGF-1 indicating capacity to resume estrus after calving (Roberts et al., 1997; Roberts, 2008). The lack of difference in circulating IGF-1 between Restricted cows from MARG dams and Control cows from either MARG or ADEQ dams may be due to metabolic programing during uterine development, resulting in greater capacity for maintaining reproductive function under limited nutritional environments.

Table 1. Effects of feed amount provided to dam and cow on subsequent progeny performance

Dam treatment[1]	Cow treatment[2]	Calf birth wt, lb[3]	Calf wean wt, lb[3]
Adequate	Control	78.0	476
Marginal	Control	78.0	476
Adequate	Restricted	77.6	472
Marginal	Restricted	76.1*	465*
P Dam × Cow treatment		0.07	0.04

[1] Cows were provided equivalent of either 4 (Adequate) or 2.4 lb (Marginal) protein supplement/d while grazing native range each winter.

[2] Daughters of dam treated as indicated in column1. After weaning, these daughters were fed ad-lib during 140-d post-weaning development and 4 lb/d supplement each winter (Control), or were fed 80% of feed provided to control (common BW basis) during 140-d post-weaning development and 2.4 lb/d supplement each subsequent winter (Restricted).

[3] Offspring from cows described in column 2, values represent 3,106 BW measurements at birth and 2,894 BW at weaning collected on calves born from 2004 to 2014. * Differs from other numbers in same column.

Range vs feedlot heifer development study

Further evidence of improved retention rates resulting from lesser feed inputs during post-weaning development is provided by comparing heifers developed on native range or in a feedlot (Mulliniks et al., 2013). Heifers developed on native range were provided the equivalent of 2 lb/d of a 36% CP supplement, consisting of either 109 (36% ruminally undegradable protein [RUP]) or 160 (50% RUP) g/d. From January until the start of breeding in May, pasture-developed heifers gained 0.60 lb/d to achieve a pre-breeding BW of 608 lb (51% of mature BW), regardless of supplement type. In contrast, heifers developed in the feedlot gained 1.52 lb/d during this same time and weighed 694 lb by the start of breeding (58% of mature BW). At start of breeding, all heifers were combined and managed together. To compare between Mulliniks et al. (2013) and the Fort Keogh study (Figure 1), rate of gain for range heifers was approximately one-half of the Restricted heifers' rate of gain and feedlot-developed rate of gain was similar to Control heifers depicted. Whereas heifers developed on native range gained less than heifers in the feedlot, growth rate from the start of breeding to pregnancy diagnosis in September was greater in the range-developed heifers (1.76 and 1.87 lb/d for 36 and 50% RUP, respectively) than feedlot-developed heifers (1.34 lb/d), resulting in similar BW of 886, 866, and 888 lb for range + 36% RUP, range + 50% RUP, and feedlot, respectively. These BW are similar to those observed at winter pregnancy diagnosis in the Control and Restricted heifers. Whereas BW of the range and feedlot heifers were similar by fall pregnancy diagnosis, proportion retained in the herd over 4 yr was greater for the Range + 50% RUP heifers than the other 2 groups, which did not differ (Figure 6). Similar to Funston and Deutscher (2004, Figure 4), these results indicate lower growth rates during post-weaning development may not be detrimental to future retention.

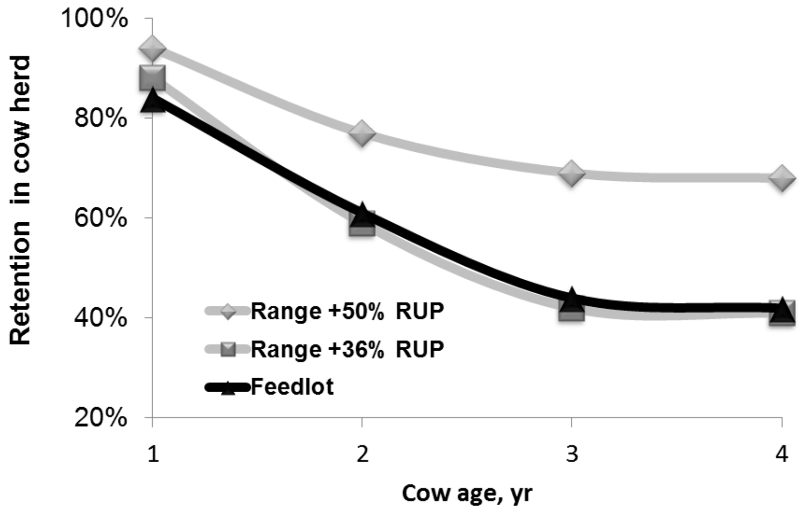

Figure 6. Retention rate of heifers grazing native dormant range provided either a 36 or 50% RUP supplementation, or fed a growing diet in a feedlot during post-weaning development. Retention tended ($P < 0.08$) to differ among treatments at 1 and 2 yr age and was greater ($P < 0.01$) for Range + 50% RUP than other 2 treatments at 3 and 4 yr age. Adapted from Mulliniks et al. (2013).

Studies discussed in the preceding paragraphs expand on previous reports demonstrating slow rates of post-weaning development can reduce harvested feed requirements, improve feed efficiency, and depending on type of supplements used, may increase reproductive performance (Funston et al., 2012a; Endecott et al., 2013).

Impacts of alterations in prepartum dam nutrition due to winter forage type with or without protein supplement and date of weaning on offspring performance

Research at the University of Nebraska West Central Research and Extension Center, North Platte, and Gudmundsen Sandhills Laboratory, Whitman, NE, over the last decade has evaluated alternative winter feed sources and cow supplementation effects on offspring performance. The impacts of dam treatments on male and female offspring performance were reviewed recently (Funston et al., 2012b; Funston and Summers, 2013; Endecott et al., 2013). Subsequent information focuses on the effects of different forage types with or without supplementation during gestation on a calf's subsequent productivity as it relates to studies discussed in the previous sections.

Two studies evaluated offspring from spring-calving cows that were or were not provided a protein supplement during the last trimester while grazing dormant native forage in the Nebraska Sandhills. Martin et al. (2007) compared a 42% CP (DM, 33% RUP) cube containing 50% sunflower meal with a 47% cottonseed meal, each provided 3 times weekly at the equivalent of 1 lb/d. Funston et al. (2010) subsequently evaluated the provision of a 28% CP (DM, 48% RUP) supplement consisting of mostly dried distillers grains with solubles provided 3 times weekly at the equivalent of 1 lb/d. The supplements in the 2 studies delivered the equivalent of 60 g of RUP/d. Providing cows these supplements while grazing winter range increased heifer progeny BW from weaning through pregnancy diagnosis. Heifers from protein-supplemented dams attained puberty 14 d earlier than heifers from non-supplemented dams (Funston et al., 2010) and there was a trend for (Funston et al., 2010) or significant (93% vs. 80%; Martin et al., 2007) improvement in pregnancy rates of offspring from supplemented dams compared with those from non-supplemented dams. In addition, a greater proportion of heifers from protein-supplemented dams calved in the first 21 d of the calving season than heifers from dams not supplemented (Funston et al., 2010).

Whereas the studies above reported changes in heifer performance resulting from protein supplementation of dams while grazing winter range, protein supplementation to dams grazing corn crop residue during late gestation did not affect subsequent heifer fertility (Funston et al., 2010). Similarly, Warner et al. (2011) reported no differences in heifer pregnancy rates due to protein supplementation of dams grazing corn crop residue during late gestation. Thus, the impact of protein supplementation of dams during winter grazing on offspring performance may vary depending on type and quality of winter forage grazed.

In a recent study, Rolfe and coworkers (2011) evaluated offspring of March-calving cows grazing either corn crop residue or dormant winter range during the last trimester. Nutritional status for each grazing treatment was further altered by weaning in either October or December. Cows grazing winter range were provided 0, 1, or 2 lb/d of a 28% CP supplement. Cows grazing corn crop residue were not supplemented. Offspring birthweight was affected by the dam's previous weaning date and grazing treatment, with average birth weights paralleling the expected nutritional environment of the dam. Greatest calf birth weights were from dams weaned early and provided the most supplement, whereas calves from dams not provided supplement and weaned late were lightest at birth. The BW differences observed at birth were also apparent in subsequent BW throughout the first year of life. Offspring from cows that grazed corn crop residue were similar in weight to those from cows that had received either level of protein supplement while grazing winter range. Interestingly, the previous weaning date also influenced weight of subsequent offspring, being greater for offspring from dams weaned in October rather than December. Differences in offspring weight due to month of weaning in the dam were similar to differences in response to presence or absence of supplementation. These results provide evidence that altering weaning time may benefit offspring performance as much as strategies designed to supplement forage quality. However, proportion of heifers cycling and overall pregnancy rates did not differ due to maternal weaning treatment.

Fall pasture quality study

The results from the Fort Keogh lifetime productivity study prompted an additional study to evaluate how pasture quality during autumn grazing affects heifer offspring of cows calving in late winter (Grings and Roberts, 2013). The study was replicated 4 yr. Seeded pastures consisted of 2 replications of 64 ac each previously harvested for hay followed by flood irrigation in August. Forages in the seeded pasture included grasses (smooth brome, Altai wildrye, Russian wildrye and western wheatgrass) and legumes (birdsfoot trefoil, red clover, and alfalfa). Native rangeland pastures consisted of 2 replications of 175 or 222 ac. The natural rangeland vegetation is a grama-needlegrass-wheatgrass (Bouteloua-Hesperostipa-Pascopyron) mixed-grass dominant rangeland (Kuchler, 1964). Extrusa samples collected using esophageally- or ruminally-cannulated mature cows indicated CP differed ($P < 0.05$) between pasture forage types but digestibility did not ($P > 0.10$). Cannulated cows grazing seeded pastures had extrusa with 10.2% CP and 70% in vitro organic matter digestibility (IVOMD) yr 1 and 2 and 76% in vitro true digestibility yr 3 and 4 (DM basis), whereas extrusa from cows grazing native rangeland contained 6.7% CP and 67% IVOMD yr 1 and 2 and 74% in vitro true digestibility in yr 3 and 4, DM basis. Cows grazed in these pastures from September 28 to November 19 and then moved to drylots and fed a corn silage-based diet until calving. Average calving date was February 11 ± 10 d. After calving, cows were moved to dormant native pastures and fed hay (alfalfa or grass, depending on availability each year) and/or a grain-based range cake supplement until native rangeland forage was available. Cows and their calves were maintained on native range until calves were weaned at approximately 190 d of age. At weaning, calves were placed in drylots. Heifers were fed a diet of 60% corn silage, 39% hay, and 1% protein and mineral supplement (as-fed basis), as described previously (Grings et al., 2005). Heifer calves born to cows in the study retained for replacement (n = 42 and 32 for seeded and native, respectively) were returned to native range in the 1st or 2nd wk of April, and were exposed to bulls for a 35-d breeding season approximately 2 wk after return to native range. Reproductive performance of these females was evaluated.

Pasture type grazed in autumn did not result in differences in change of cow weight (132 vs. 142 lbs for native vs. seeded pasture; $P = 0.57$) or BCS (0.33 vs 0.31 for native vs seeded pasture, $P = 0.8$) over treatment period, or weight of offspring at birth (P = 0.9), weaning (P = 0.9), or 1 yr of age (P = 0.6). Heifer calves retained from cows that had grazed seeded pastures during the second trimester tended (P = 0.06) to remain in the herd longer than heifer calves from cows that had grazed native rangeland (1,480 vs. 1,074 d retention). Although calf BW produced by the daughters of these cows did not differ due to pasture type (434 ± 11 and 443 ± 11 lb BW at weaning for first calf of daughters of dams that grazed native and seeded pasture, respectively, P = 0.61), the daughters from cows that grazed seeded pasture produced more total lb of calf due to greater herd retention than daughters from cows that grazed native rangeland (664 vs. 526 total lbs weaned calf per cow per year). These results indicate differences in forage CP experienced during second trimester may bring about subsequent differences in female offspring retention rate.

Summary and conclusions

The nutritional environment animals are exposed to in utero and postnatally can influence traits later in life. Differences in nutrition may arise from different supplementation levels, presence or absence of supplementation, supplementation type, forage type and quality, or management (e.g., time of weaning). These nutritional differences are likely mediated through epigenetic or metabolic adaptation processes. Furthermore, these alterations appear to influence future offspring's ability to cope with nutritional stress.

References

Anway, M. D., A. S. Cupp, M. Uzumcu, and M. K. Skinner. 2005. Epigenetic transgenerational actions of endocrine disruptors and male fertility. Science 308:1466-1469.

Endecott, R. L., B. L. Shipp, M. D. MacNeil, L. J. Alexander, and A. J. Roberts. 2012. Postweaning feed restriction effects on steer feedlot performance and carcass characteristics. Proc. West. Sec. Am. Soc. Anim. Sci. 63:258-261.

Endecott, R. L., R. N. Funston, J. T. Mulliniks, and A. J. Roberts. 2013. JOINT ALPHARMA-BEEF SPECIES SYMPOSIUM: Implications of beef heifer development systems and lifetime productivity. J. Anim. Sci. 91:1329-1335.

Ferrell, C. L., and T. G. Jenkins. 1985. Cow type and the nutritional environment: Nutritional aspects J. Anim. Sci. 61:725-741. doi:10.2134/jas1985.613725x

Ford, S. P., and N. M. Long. 2012. Evidence for similar changes in offspring phenotype following either maternal undernutrition or overnutrition: potential impact on fetal epigenetic mechanisms. Reprod. Fertil. Dev. 24:105-111.

Funston, R. N., and G. H. Deutscher. 2004. Comparison of target breeding weight and breeding date for replacement beef heifers and effects on subsequent reproduction and calf performance. J. Anim. Sci. 82:3094-3099.

Funston, R. N., J. L. Martin, D. M., D. C. Adams, and D. M. Larson. 2010. Winter grazing system and supplementation of beef cows during late gestation influence heifer progeny. J. Anim. Sci. 88:4094-4101.

Funston, R. N., J. L. Martin, D. M. Larson, and A. J. Roberts. 2012a. PHYSIOLOGY AND ENDOCRINOLOGY SYMPOSIUM: Nutritional aspects of developing replacement heifers. J. Anim. Sci. 90:1166-1171.

Funston, R. N., and A. F. Summers. 2013. Epigenetics: Setting up lifetime production of beef cows by managing nutrition. Annu. Rev. Anim. Biosci. 1:339-363.

Funston, R. N., A. F. Summers, and A. J. Roberts. 2012b. ALPHARMA BEEF CATTLE NUTRITION SYMPOSIUM: Implications of nutritional management for beef cow-calf systems. J. Anim. Sci. 90:2301-2307.

George, L. A., L. Zhang, N. Tuersunjiang, Y. Ma, N. M. Long, A. B. Uthlaut, D. T. Smith, P. W. Nathanielsz, and S. P. Ford SP. 2012. Early maternal undernutrition programs increased feed intake, altered glucose metabolism and insulin secretion, and liver function in aged female offspring. Amer. J. Physiol. Regul. Integr. Comp. Physiol. 302:R795-R804.

Goldberg, A. D., C. D. Allis, and E. C. Bernstein. 2007. Epigenetics: a landscape takes shape. Cell 128:635-638.

Grings, E. E., and A. Roberts. 2013. Fall pasture quality for cows in mid-pregnancy has minimal effects on offspring growth. Proc. West. Sec. Am. Soc. Anim. Sci.64:262-265.

Grings, E. E., R. E. Short, K. D. Klement, T. W. Geary, M. D. MacNeil, M. R. Haferkamp, and R. K. Heitschmidt. 2005. Calving system and weaning age effects on cow and preweaning calf performance in the Northern Great Plains. J. Anim. Sci. 83:2671-2683. doi:/2005.83112671x

Hales, C. N., and D. J. Barker. 2001. The thrifty phenotype hypothesis. Br. Med. Bull. 60:5-20.

Herd, D., and L. S. Sprott. 1986. Body condition, nutrition, and reproduction of beef cows. Texas A&M Univ. Ext. Bull. 1526, Texas A&M AgriLife Extension Service, College Station, TX.

Kuchler, A. W. 1964. Potential natural vegetation of the coterminous United States. Am. Geogr. Soc. Spec. Pub. 36, American Geographical Society of New York, New York, NY.

Martin, J.L., K. A. Vonnahme, D. C. Adams, G. P. Lardy, and R. N. Funston. 2007. Effects of dam nutrition on growth and reproductive performance of heifer calves. J. Anim. Sci. 85:841-487.

Mossa, F., S. W. Walsh, J. J. Ireland, and A. C.O. Evans. 2015. Early nutritional programming and progeny performance: Is reproductive success already set at birth? Anim. Frontiers 5:18-24. doi:10.2527/af.2015-0004.

Mulliniks, J. T., D. E. Hawkins, K. K. Kane, S. H. Cox, L. A. Torell, E. J. Scholljegerdes, and M. K. Petersen. 2013. Metabolizable protein supply while grazing dormant winter forage during heifer development alters pregnancy rate and subsequent in-herd retention rate. J. Anim. Sci. 91:1409-1416.

Newman, S., M. D., MacNeil, W. L.Reynolds, , B. W. Knapp, and J. J. Urick, 1993. Fixed effects in the formation of a composite line of beef cattle.1. Experimental design and reproductive performance. J. Anim. Sci. 71:2026-2032.

NRC. 2000. Nutrient requirements of beef cattle. 7th 514 rev. ed. Update 2000. Natl. Acad. Press, 515 Washington, DC.

Petersen, M. K., C. J. Mueller, J. T. Mulliniks, A. J. Roberts, T. DelCurto, and R. C. Waterman. 2014. BEEF SPECIES SYMPOSIUM: Potential limitations of NRC in predicting energetic requirements of beef females within western U.S. grazing systems. J. Anim. Sci. 92:2773-2774.

Reynolds, L. P., P. P. Borowicz, J. S. Caton, K. A. Vonnahme, J. S. Luther, C. J. Hammer, K. R. Maddock Carlin, A. T. Grazul-Bilska, and D. A. Redmer. 2010. Developmental programming: The concept, large animal models, and the key role of uteroplacental vascular development. J. Anim. Sci. 88(E. Suppl.):E61- E72.

Richards, M. W., J. C. Spitzer, and M. B. Warner. 1986. Effect of Varying Levels of Postpartum Nutrition and Body Condition at Calving on Subsequent Reproductive Performance in Beef Cattle. J. Anim. Sci. 84:3451-3459.

Roberts A. J., R. A. Nugent, III, J. Klindt, and T.G. Jenkins. 1997. Circulating insulin-like growth factor I, insulin-like growth factor binding proteins, growth hormone, and resumption of estrus in postpartum cows subjected to dietary energy restriction. J. Anim. Sci. 75:1909-1917.

Roberts, A. J., S. I. Paisley, T. W. Geary, E. E. Grings, R. C. Waterman, and M. D. MacNeil. 2007. Effects of restricted feeding of beef heifers during the postweaning period on growth, efficiency, and ultrasound carcass characteristics. J. Anim. Sci. 85:2740-2745.

Roberts, A. J. 2008. Assessment of insulin-like growth factor-1 as an indicator of competence for rebreeding in first calf heifers. . Proc. West. Sec. Am. Soc. Anim. Sci. 59:257-260.

Roberts, A. J., T. W. Geary, E. E. Grings, R. C. Waterman, and M. D. MacNeil. 2009a. Reproductive performance of heifers offered ad libitum or restricted access to feed for a 140-d period after weaning. J. Anim. Sci. 87:3043-3052.

Roberts, A. J., E. E. Grings, M. D. MacNeil, R. C. Waterman, L. Alexander, and T. W. Geary. 2009b. Implications of going against the dogma of feed them to breed them. Proc. West. Sec. Am. Soc. Anim. Sci. 60:85-88.

Roberts, A. J., R. C. Waterman, T. W. Geary, L. J. Alexander, and M. D. MacNeil. 2010. Level of maternal winter supplement and feed restriction during postweaning development influences circulating concentrations of IGF-I in heifers during the peripartum and rebreeding period. Proc. West. Sec. Am. Soc. Anim. Sci. 61:194-196.

Roberts, A. J., R.N. Funston, E. E. Grings, and M. K. Petersen. 2016. Triennial Reproduction Symposium: Beef heifer development and lifetime productivity in rangeland-based production systems. J. Anim. Sci. 94:2705-2715.

Rolfe, K. M., L. A. Stalker, T. J. Klopfenstein, J. A. Musgrave, and R. N. Funston. 2011. Influence of weaning date and pre-partum plane of nutrition on cow-calf productivity. Proc. West. Sec. Am. Soc. Anim. Sci. 62:375-378.

Selk, G. E., R. P. Wettemann, K. S. Lusby, J. W. Oltjen, S. L. Mobley, R. J. Rasby, and J. C. Garmendia. 1988. Relationships among Weight Change, Body Condition and Reproductive Performance of Range Beef Cows. J. Anim. Sci. 66:3153-3159.

Spitzer, J. C., D. G. Morrison, R. P. Wettemann, and L. C. Faulkner. 1995. Reproductive responses and calf birth and weaning weights as affected by body condition at parturition and postpartum weight gain in primiparous beef cows. J. Anim. Sci. 73:1251-1257.

Vonnahme, K. A., B. W. Hess, M. J. Nijland, P. W. Nathanielsz, and S. P. Ford. 2006. Placentomal differentiation may compensate for maternal nutrient restriction in ewes adapted to harsh range conditions. J. Anim. Sci. 84:3451-3459.

Warner J. M., J. L. Martin, Z. C. Hall, L. M. Kovarik, K. J. Hanford, and R. J. Rasby. 2011. The effects of supplementing beef cows grazing cornstalk residue with a dried distillers grain based cube on cow and calf performance. Prof. Anim. Sci. 27:540-546.

Wu, G., F. W. Bazer, J. M. Wallace, and T. E. Spencer. 2006. Board invited review. Intrauterine growth retardation: Implications for the animal sciences. J. Anim. Sci. 84:2316-2337.