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Effects of dam nutrition on growth and reproductive performance of heifer calves[1]

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ABSTRACT: A 3-yr study was conducted with heifers (n = 170) whose dams were used in a 2 × 2 factorial arrangement of treatments to determine the effects of late gestation (LG) or early lactation (EL) dam nutrition on subsequent heifer growth and reproduction. In LG, cows received 0.45 kg/d of a 42% CP supplement (PS) or no supplement (NS) while grazing dormant Sandhills range. During EL, cows from each late gestational treatment were fed cool-season grass hay or grazed subirrigated meadow. Cows were managed as a single herd for the remainder of the year. Birth date and birth weight of heifer calves were not affected ($P > 0.10$) by dam nutrition. Meadow grazing and PS increased ($P = 0.02$; $P = 0.07$) heifer 205-d BW vs. feeding hay and NS, respectively. Weight at prebreeding and pregnancy diagnosis were greater ($P < 0.04$) for heifers from PS dams but were unaffected by EL nutrition ($P > 0.10$). There was no effect ($P > 0.10$) of LG or EL dam nutrition on age at puberty or the percentage of heifers cycling before breeding. There was no difference ($P > 0.10$) in pregnancy rates due to EL treatment. Pregnancy rates were greater ($P = 0.05$) for heifers from PS dams, and a greater proportion ($P = 0.005$) of heifers from PS dams calved in the first 21 d of the heifers' first calving season. Nutrition of the dams did not influence ($P < 0.10$) heifers' average calving date, calving difficulty, and calf birth weight during the initial calving season. Weight at the beginning of the second breeding season was greater ($P = 0.005$) for heifers from PS dams but was not affected by maternal nutrition during EL ($P > 0.10$). Dam nutrition did not affect ($P > 0.10$) heifer ADG or G:F ratio. Heifers from PS dams had greater DMI ($P = 0.09$) and residual feed intake ($P = 0.07$) than heifers from NS cows if their dams were fed hay during EL but not if their dams grazed meadows. Heifers born to PS cows were heavier at weaning, prebreeding, first pregnancy diagnosis, and before their second breeding season. Heifers from cows that grazed meadows during EL were heavier at weaning but not postweaning. Despite similar ages at puberty and similar proportions of heifers cycling before the breeding season, a greater proportion of heifers from PS dams calved in the first 21 d of the heifers' first calving season, and pregnancy rates were greater compared with heifers from NS dams. Collectively, these results provide evidence of a fetal programming effect on heifer postweaning BW and fertility.

Key words: fertility, fetal programming, heifer development, maternal nutrition, protein supplement

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INTRODUCTION

Nutritional requirements of spring-calving beef cows grazing dormant Sandhills range during late gestation typically exceed the nutrient value of the grazed forage (NRC, 2000; Jordon et al., 2002). Protein supplements are commonly fed during late gestation to maintain cow body condition. These supplements add expense and do not always improve subsequent reproductive performance of the cow herd, but the cost of supplementation is justified by increased weaning weights and a greater proportion of live calves at weaning (Stalker et al., 2006). Additionally, allowing cows to graze cool-season meadows during early lactation, when nutrient requirements are greatest (NRC, 2000), increases calf weaning weight and system profitability compared with feeding cool-season grass hay (Stalker et al., 2006).

Fetal programming is the concept that maternal stimuli during fetal development influence the physiology of the fetus and postnatal growth and health (Barker et al., 1993). There are only limited data concerning the influence of late-gestation nutrition of ruminants on reproductive performance of their female prog-

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eny. Primiparous heifers restricted to 65% of the NRC recommended energy intake during the final 100 d of pregnancy had calves with lighter birth weights and a reduced weaning percentage compared with heifers fed at NRC recommendations (NRC, 1970). Age at puberty of heifer calves from primiparous dams that were energy-restricted was increased by 19 d, but pregnancy rate of the heifer calves was not measured (Corah et al., 1975). Furthermore, energy restriction of ewes for 10 d during late gestation resulted in altered adrenal steroid production in adult female progeny (Bloomfield et al., 2003).

The objectives of the current study were to determine if feeding supplemental protein to cows during late gestation or allowing cows to graze subirrigated meadow during the postpartum period influences subsequent growth and reproductive performance of their heifer calves.

MATERIALS AND METHODS

Cow Management

The University of Nebraska—Lincoln Institutional Animal Care and Use Committee approved all procedures and facilities used for the animals in this experiment. A 3-yr study was conducted utilizing heifers born to composite Red Angus × MARC II (1/4 each Angus, Gelbvieh, Hereford, and Simmental) cows at the Gudmundsen Sandhills Laboratory (**GSL**), Whitman, NE. Heifers were born to cows in a 2 × 2 factorial treatment arrangement to determine the effects of nutrition during late gestation and early postpartum on reproductive performance and heifer growth. Pregnant, spring-calving cows (n = 136) between 3 and 5 yr of age were stratified by age and weaning weight of their previous calf and assigned randomly to treatment in yr 1. In yr 2, cows (n = 113) were switched to the opposite treatment; and in yr 3, cows (n = 113) were placed on their original treatment. Reduced numbers of cows were utilized in yr 2 and 3 due to limited forage availability. Cows were removed from the experiment for reproductive failure, failure to calve before April 20, and injury. To replace cows that were removed, 3-yr-old cows were stratified by age and weaning weight of their previous calf and assigned randomly to treatment.

During the last trimester of gestation, from December 1 through February 28, cows were divided into eight 32-ha upland pastures. Upland range sites at GSL are dominated by little bluestem [*Andropogon scoparius* (Michx.) Nash], prairie sandreed [*Calamovilfa longifolia* (Hook.) Scribn.], sand bluestem (*Andropogon hallii* Hack.), sand lovegrass [*Eragrostis trichoides* (Nutt.) Wood], and blue grama [*Bouteloua gracillis* (H.K.B.) Lag. Ex Griffiths] (Adams et al., 1998). On a pasture basis, cows received the equivalent of 0.45 kg/d of a 42% CP supplement fed 3 times/wk or no protein supplement. The supplement contained 73.3% TDN and consisted of 50.0% sunflower meal, 47.9% cottonseed meal, and 2.1% urea on a DM basis. Cows were fed hay in a drylot as a single group during the calving season, March 1 to April 20 (average calving date, March 27).

From May 1 to 31, half of the cows remained in the drylot and were fed cool-season grass hay, and the other half grazed a common, 58-ha, subirrigated meadow pasture. The primary forage species on subirrigated meadow at GSL are smooth bromegrass (*Bromus inermis* Leyss.), redtop bent (*Agrostis stolonifera* L.), timothy (*Phleum pratense* L.), slender wheatgrass [*Elymus trachycaulum* (Link) Gould ex Shinn.], quackgrass [*Elytrigia repens* (L.) Nevski.], and Kentucky bluegrass (*Poa pratensis* L.; Adams et al., 1998). On June 1, cows were again combined and were managed in a common group on upland range throughout the breeding season and the remainder of the production cycle. Each year, cows were exposed to fertile bulls for 60 d. Additional supplement composition, diet quality, cow performance, and steer feedlot performance data were reported by Stalker et al. (2006).

Heifer Management

Treatments were applied only to the dam during late gestation or early lactation, and no further treatments were applied to their heifers. Data include records from 84 heifers born to unsupplemented cows and 86 heifers born to cows supplemented with protein for the last trimester of gestation. Furthermore, 87 of the heifers' dams were fed hay in a drylot for the month of May, and 83 of the heifers' dams grazed subirrigated meadow. During yr 1, heifers (n = 66) were managed until weaning as a single group at GSL, and data from yr 1 are limited to birth and weaning information. Weaning weights for all years were adjusted for calf age, but not for age of the dam because cows were stratified by age and assigned randomly to treatment when the experiment began.

Heifers from yr 2 (n = 46) remained at GSL, and reproduction and calving data were collected in addition to birth and weaning records. Heifers were weaned on 8 October and remained on upland range throughout development. From weaning until 20 May, heifers from yr 2 were supplemented as a group with 0.45 kg·heifer^{-1}·d^{-1} of a 28% CP (DM basis) supplement in cake form. The supplement contained 62.0% dried distillers grains plus solubles, 10.6% wheat middlings, 9.0% cottonseed meal, 5.0% dried corn gluten feed, 3.0% molasses, 3.0% calcium carbonate, and 2.0% urea on a DM basis. Additionally, the supplement was formulated to meet vitamin and trace mineral requirements of the heifers and to supply 80 mg·heifer^{-1}·d^{-1} of monensin (Rumensin, Elanco Animal Health, Indianapolis, IN). The proportion of heifers cycling before the beginning of the breeding season in yr 2 was determined by evaluating the progesterone concentration in 2 blood samples collected 10 d apart. Heifers from yr 2 were exposed to fertile bulls maintained at a ratio of approximately 1:25 (bulls:heifers) for a 45-d breeding season. Overall pregnancy rates were determined using transrectal ultrasonography at approximately 30 d after the end of the breeding season and were confirmed by calving date. Body condition score (Wagner et al., 1988) was also determined at pregnancy diagnosis. The percentage of heifers calving during the first 21 d of the calving season was calculated using the date on which the first heifer calved as the initial day of the calving season.

Birth, weaning, reproductive, and calving data were collected from heifers in yr 3. Heifers born in yr 3 (n = 58) were weaned on October 1, remained at GSL for 109 d after weaning, and were then transported 1,013 km to the North Dakota State University Animal Nutrition and Physiology Center, Fargo, ND to evaluate the efficiency of gain on an individual basis. Collection of individual intake and G:F was not feasible at GSL because of the facilities. After a 14-d adaptation and training period, heifers were individually fed for 84 d using Calan gates (American Calan, Northwood, NH). Heifers were exposed to 14 h of light and 10 h of dark each day.

The ration consisted of ad libitum consumption of cool-season grass hay (7.5% CP, 71% NDF, 52% ADF; DM basis) fed in the morning in sufficient quantity to insure that hay remained at the next feeding, and the heifers were supplemented daily with 0.90 kg of sunflower meal-based pellets (34.6% CP, 35.02% NDF, 21.71% ADF, DM basis) that were fed each afternoon. The supplement was fed in the afternoon to prevent the heifers from forcing hay out of the bunks while attempting to select for the supplement. Orts were collected twice weekly and analyzed for DM to determine DMI.

Two-day, consecutive BW and BCS were taken at the beginning and end of the feeding period, with interim BW and blood samples collected every 14 d. After completion of the individual feeding period on May 17, 2005, heifers were transported 1,034 km to the West Central Research and Extension Center, North Platte, NE. Prebreeding BW were collected 14 d later, and heifers were exposed to bulls (1:26, bulls:heifers) for a 45-d breeding season. Pregnancy diagnosis was performed via transrectal ultrasonography approximately 50 d after completion of the breeding season, and calving dates were also recorded.

Blood Collection and Assays

Blood samples were collected via coccygeal venipuncture, cooled immediately on ice, and serum was harvested via centrifugation at 1,349 × *g* and frozen at −20°C until analysis. Serum progesterone concentrations in yr 2 were determined by direct solid-phase RIA (Coat-A-Count, Diagnostics Products Corp., Los Angeles, CA) without extraction, as described by Melvin et al. (1999). Samples from yr 2 were evaluated in a single assay, with an intraassay CV of less than 10%. Samples from yr 2 were evaluated in a single assay, with an intraassay CV of less than 10%.

Serum progesterone concentrations in samples from yr 3 were analyzed by solid-phase, competitive, chemiluminescent enzyme immunoassay (Immulite 1000, Diagnostics Products Corp.). Within assay variability for progesterone was determined by assaying replicate samples from a pool of serum from cycling cows to which known quantities of progesterone had been added (0.0, 0.25, 1.0, 5.0, and 25.0 ng/mL). The resulting concentrations (mean ± SEM) after subtraction of the serum blank (0.51 ± 0.03 ng/mL; n = 4) averaged 0.29 ± 0.08 (n = 4), 1.26 ± 0.01 (n = 4), 6.42 ± 0.38 (n = 4), and 26.2 ± 0.42 (n = 4) ng/mL, respectively. Coefficients of variation averaged 8.0, 13.9, 1.1, 7.8, and 2.2% for the serum blank and the samples with 0.25, 1.0, 5.0, and 25.0 ng/mL of added progesterone, respectively. A correlation of the Immulite chemiluminescent enzyme immunoassay with the Coat-A-Count RIA using 37 samples resulted in a regression of Immulite = (0.51 × RIA) + 0.92 (r = 0.95). For the current study, inter- and intraassay CV for the Immulite (n = 2 assays) were 9.8 and 7.6%, respectively, and the recovery rate was greater than 90%. Wilson et al. (1998) compared the chemiluminescent and RIA procedures used in the current study in human serum and plasma and found similar results with both methods. A progesterone concentration greater than 1 ng/mL was interpreted to indicate ovarian luteal activity.

Statistical Analysis

The statistical model was appropriate for a 2 × 2 factorial arrangement of treatments in a switchback design. Performance data were analyzed using PROC MIXED (SAS Inst. Inc., Cary, NC). Reproductive and calving difficulty data were analyzed using χ^2 procedures in PROC GENMOD of SAS. Individual heifer was considered the experimental unit, and the statistical model included dam treatment during late gestation and dam treatment during early lactation as fixed effects. The interaction between late gestation and early lactation treatments was included for data sets when significant and was removed from the final analysis if it was not significant. In multiyear analyses, year was included in the model as a random variable using the random statement. Pen was included in the random statement for heifers in the individual feeding experiment (yr 3).

Residual Feed Intake Calculation

For yr 3, residual feed intake (**RFI**) was calculated by simultaneously regressing DMI on midtest BW and ADG using PROC REG of SAS, as described by Cammack et al. (2005). The slope coefficients (b_m and b_g, respectively) from these analyses were then used to predict DMI using the following equation: Predicted DMI = average DMI of the group + [b_m × (individual midtest BW − group average for midtest BW)] + [b_g × (individual ADG − group average for ADG)]. Residual

Table 1. Effects of dam protein supplementation during the last trimester of gestation and meadow grazing vs. grass hay feeding during early lactation on growth performance of heifer calves[1]

Trait	Treatment[2]				SEM	*P*-value[3]	
	PS	NS	M	H		LG	EL
No. of heifers born	86	84	83	87			
No. exposed for breeding	45	46	46	45			
Birth date, Julian	86	84	85	86	1	0.29	0.67
Birth wt, kg	36	35	35	36	1	0.25	0.15
Wean wt, kg	212	207	212	206	7	0.14	0.09
Adj. 205-d wt, kg	226	218	225	219	7	0.02	0.07
Prebreeding wt, kg	276	266	272	270	9	0.04	0.70
BW at pregnancy diagnosis, kg	400	386	391	395	31	0.03	0.56

[1]Includes birth and weaning data from 170 heifer calves born from yr 1 to 3, and prebreeding and pregnancy diagnosis BW from 91 heifers born in yr 2 and 3.

[2]No late gestation × early lactation treatment interactions were detected ($P > 0.10$); therefore, main effects are reported. PS = dams supplemented 3 times per week with the equivalent of 0.45 kg/d of a 42% CP cake during the last trimester of gestation; NS = no protein supplement fed to dams during gestation; M = dams grazed subirrigated meadows between the end of calving and the breeding season; and H = dams fed cool-season grass hay from the end of the calving season until initiation of the breeding season.

[3]LG = late gestation treatment main effect; and EL = early lactation treatment main effect.

feed intake was calculated as the difference between observed and predicted DMI; therefore, lower values indicate greater efficiency.

RESULTS AND DISCUSSION

Dams of heifers in the current study maintained BW and BCS if they received protein supplement during the last trimester of gestation, but lost 29 kg ($P < 0.001$) and an average of 0.6 BCS ($P < 0.001$) if not supplemented during this period. At conclusion of the supplementation period, protein-supplemented cows had average BCS of 5.2, whereas unsupplemented cows had average BCS of 4.6. These data indicate differences in protein and energy status of the heifers' dams due to protein supplementation during late gestation (Stalker et al., 2006).

Heifer birth and growth data are summarized in Table 1. Dam nutrition did not affect ($P > 0.10$) heifer birth date or birth weight. These data agree with observations of Hough et al. (1990) who reported similar birth weights of calves born to mature cows restricted to 57% of NRC requirements for protein and energy or fed to meet nutritional requirements the last 90 d of gestation. Also in agreement with the current study, Carstens et al. (1987) fed isoenergetic diets with 91 or 55% of CP requirements to cows from 190 d of gestation until term without altering progeny birth weight. However, reduced birth weights were observed when pregnant nulliparous heifers fed approximately isonitrogenous diets were restricted to 65% of required energy intake for 100 d before calving, compared with their cohorts fed to meet energy requirements (Corah et al., 1975). Although fetal growth is maximized during the last trimester of gestation (Eley et al., 1978), maternal undernutrition during this time does not predictably reduce birth weight. Differences in protein and energy status of dams during late gestation did not influence heifer calf birth weight in the current study.

Supplementing cows with protein during late gestation tended ($P = 0.14$) to increase subsequent weaning weight of heifer calves and increased ($P = 0.02$) adjusted 205-d weight. Data from the current study agree with previous observations of increased calf weaning weight due to increased CP intake of the dam during gestation (Beaty et al., 1994). In contrast, weaning weight was not affected by nutrient restriction of cows during late gestation (Hough et al., 1990). However, energy restriction of pregnant nulliparous heifers resulted in reduced calf weight at weaning despite similar dam milk production (Corah et al., 1975), which was not measured in the current study. In the current study, heifers from cows grazing subirrigated meadows during early lactation had increased actual ($P = 0.09$) and adjusted ($P = 0.07$) weaning weight compared with heifers from cows fed hay, which agrees with previous reports indicating improved energy status of cows during early lactation increased progeny weaning weight (Houghton et al., 1990; Spitzer et al., 1995). In sheep, high levels of dam nutrition during the final 100 d of gestation and initial 100 d of lactation increased lamb weaning weights (Gunn et al., 1995), which agrees with data from protein supplemented and meadow grazing treatments reported in this study.

Prebreeding BW and BW at pregnancy diagnosis were greater ($P < 0.04$) for heifers from protein-supplemented dams than heifers from unsupplemented dams, but early lactation treatment did not affect ($P > 0.50$) either weight. Similar to the current study, 4 and 12 mo BW of progeny from ewes restricted 6 wk prepartum to 12 mo after birth (Gunn, 1977) were increased. In these studies (Gunn, 1977; Gunn et al., 1995), maternal nutrition treatments were determined by available pasture quality and supplemental feeding regimen. In con-

Table 2. Effects of dam protein supplementation during the last trimester of gestation and meadow grazing vs. grass hay feeding during early lactation on growth, BCS, and residual feed intake of heifers individually fed for 84 d[1]

	Treatment[2]					P-value[3]		
Trait	PS/M	PS/H	NS/M	NS/H	SEM	LG	EL	LG × EL
No. of heifers	11	16	11	12				
Initial wt, kg	275	260	256	259	9	0.19	0.45	0.26
Initial BCS	5.53	5.54	5.43	5.54	0.10	0.62	0.53	0.65
Final wt, kg	310	298	293	286	8	0.08	0.22	0.71
Final BCS	5.13	4.96	4.96	4.92	0.09	0.20	0.23	0.42
ADG, kg/d	0.37	0.42	0.42	0.39	0.06	0.86	0.75	0.15
DMI, kg/d	6.57[ab]	6.92[a]	6.79[ab]	6.20[b]	0.29	0.37	0.65	0.09
G:F	0.057	0.062	0.060	0.067	0.007	0.40	0.27	0.88
RFI,[4] kg/d	–0.14[ab]	0.28[a]	0.18[ab]	–0.41[b]	0.28	0.50	0.74	0.07

[a,b]Within a row, means without a common superscript differ, $P < 0.10$.
[1]Includes data from heifers born in yr 3.
[2]PS/M = dams supplemented 3 times per week with the equivalent of 0.45 kg/d 42% CP cake during gestation and grazed meadows from the end of the calving season until the breeding season; PS/H = dams supplemented with the equivalent of 0.45 kg/d of a 42% CP cake during gestation and were fed cool-season grass hay from the end of the calving season until the breeding season; NS/M = dams not supplemented with protein during gestation, grazed meadows between the end of calving and initiation of the breeding season; and NS/H = dams not supplemented with protein during gestation, fed cool-season grass hay between the end of calving and initiation of the breeding season.
[3]LG = late gestation treatment main effect; EL = early lactation treatment main effect; and LG × EL = late gestation × early lactation treatment interaction.
[4]Residual feed intake, the difference between the observed and predicted DMI.

trast, energy restriction of ewes for 10 or 20 d during late gestation did not affect BW of female progeny at 30 mo of age (Oliver et al., 2002; Bloomfield et al., 2003), and restricting ewes to 50% of energy requirements beginning at d 110 of pregnancy did not alter yearling weight compared with offspring of ewes fed to meet energy requirements (Gardner et al., 2005). Average daily gain between weaning and beginning of the first breeding season for heifers from yr 2 and 3 of the current study was not affected ($P = 0.32$) by dam treatment. Heifers born to protein-supplemented cows gained 0.24 ± 0.01 kg/d compared with 0.23 ± 0.01 kg/d for heifers from unsupplemented dams. Therefore, weaning weight advantage of heifers from protein-supplemented cows was maintained through their second pregnancy diagnosis.

Data from the individual feeding experiment (yr 3) are presented as simple effects due to the interaction of dam nutrition during late gestation and early lactation (Table 2). Heifers from protein-supplemented cows were heavier ($P = 0.08$) at the end of the 84-d experiment but had similar initial BW ($P = 0.19$) and similar BCS at both time points ($P > 0.20$) compared with heifers from cows that were not supplemented. Dam nutrition during early lactation did not affect BW or BCS ($P > 0.20$) of heifer calves. Neither ADG nor G:F was affected ($P > 0.25$) by maternal nutrition.

In young cattle, RFI is a measure of G:F correlated to reduced mature cow feed intake but not correlated to mature cow size, and selection for RFI is more likely to improve cow G:F than selection for feed conversion ratio alone (Arthur et al., 2004). Dry matter intake and RFI were affected ($P < 0.09$) by the interaction of maternal nutrition during late gestation and early lactation. Heifers born to protein-supplemented dams had greater DMI ($P = 0.09$) if their dams were fed hay during early lactation, but not if their dams grazed meadows in early lactation ($P > 0.10$). Similarly, heifers from protein-supplemented dams had greater RFI ($P = 0.07$) if their dams were fed hay during early lactation, but not if their dams grazed meadows during early lactation ($P > 0.10$). Greater RFI values indicate heifers from protein-supplemented cows fed hay during early lactation were less efficient than heifers from unsupplemented cows fed hay during early lactation. In this data set, it appears selecting for G:F based on RFI would result in reduced DMI, but not improved ADG, because there was not a correlation between RFI and ADG ($P = 1.0$). Previous experiments also indicate a lack of correlation between RFI and ADG (Arthur et al., 2001; Carstens et al., 2002). In fact, heifers with more favorable RFI also had numerically lower ADG, but differences were not statistically significant ($P = 0.15$). Causes for the interaction between protein supplementation during gestation and early lactation plane of nutrition on DMI and RFI are not easily explained and are not supported by feedlot ADG or G:F data from the steer mates to heifers used in the current study (Stalker et al., 2006). Gain to feed ratio was not affected by treatment ($P > 0.25$), in agreement with feedlot data from steer cohorts.

There was no effect ($P > 0.15$) of dam nutrition on the proportion of heifers from yr 2 and 3 exhibiting ovarian luteal activity before the breeding season, nor was there a difference in age at puberty of heifers born in yr 3 ($P > 0.45$; Table 3). This is in agreement with

Table 3. Effects of dam protein supplementation during the last trimester of gestation and meadow grazing vs. grass hay feeding during early lactation on reproductive and calving performance of heifers[1]

	Treatment[2]					*P*-value[3]	
Trait	PS	NS	M	H	SEM	LG	EL
Age at puberty, d	339	334	341	332	10	0.70	0.48
Cycling at beginning of breeding season, %	61	67	56	73	—	0.45	0.15
Calved in first 21 d, %	77	49	63	63	—	0.005	0.89
Overall pregnancy rate, %	93	80	83	91	—	0.05	0.18
Calving date, Julian	71	75	73	73	3	0.15	0.94
Calf birth wt, kg	33	33	32	33	1	0.94	0.25
Unassisted births, %	78	64	76	66	—	0.24	0.21

[1]Includes puberty data from 50 heifers born in yr 3, cyclicity and pregnancy data from 91 (PS = 45, NS = 46, M = 46, H = 45) heifers born in yr 2 and 3, and calving data from 77 heifers born in yr 2 and 3.

[2]No late gestation × early lactation treatment interactions were detected ($P > 0.10$); therefore, only main effects are reported. PS = dams supplemented 3 times per week with the equivalent of 0.45 kg/d of a 42% CP cake during the last trimester of gestation; NS = no protein supplement fed to dams during gestation; M = dams grazed subirrigated meadows between the end of calving and the breeding season; and H = dams fed cool-season grass hay from the end of the calving season until initiation of the breeding season.

[3]LG = late gestation treatment main effect; and EL = early lactation treatment main effect.

Corah et al. (1975) who also did not detect a difference in age at puberty in female progeny of primiparous heifers restricted to approximately 65% of NRC recommended energy intake for the final 100 d of gestation. The severity of restriction imposed by Corah et al. (1975), and the moderate negative energy balance experienced by mature cows used in this study indicate dam energy deficiency during late gestation is unlikely to influence attainment of puberty in heifer progeny.

The percentage of heifers that calved in the initial 21 d of the calving season was 77% for heifers from protein-supplemented dams and 49% for heifers born to unsupplemented cows (Table 3; $P = 0.005$). Overall pregnancy rate was 93 vs. 80% ($P = 0.05$) for heifers from protein-supplemented or unsupplemented dams, respectively. This is independent of age at puberty or estrous cyclicity immediately before the breeding season and suggests a fetal programming effect of late gestation dam nutrition on subsequent heifer fertility. In ruminant animals, ovarian folliculogenesis and endometrial gland development is completed late in gestation (Gray et al., 2001; Rhind et al., 2001). Therefore, these tissues may be involved in the programming of fertility observed in the current study.

First parity average calving date, calving difficulty, and calf birth weight were similar for heifers born to protein-supplemented and unsupplemented cows ($P > 0.15$; Table 3). Furthermore, there was no difference ($P > 0.18$) in pregnancy rates, calving date, calving difficulty, or calf birth weight during the initial calving season due to early lactation dam treatment. Weight before the second breeding season for heifers born in yr 2 and 3 was 446 ± 6 kg for heifers from protein-supplemented dams, compared with 422 ± 6 kg for heifers from unsupplemented dams ($P = 0.005$) but was unaffected by dam nutrition during early lactation ($P = 0.10$; data not shown). Weight records before second breeding include only females that became pregnant during the first breeding season, so more heifers from protein-supplemented cows are represented than daughters of unsupplemented cows. In a related study, Stalker et al. (2006) reported increased weaning and initial feedlot BW of steers born to protein-supplemented dams but similar final BW compared with steers from unsupplemented dams. Based on weight before the second breeding season, it appears greater postweaning BW of heifers from protein-supplemented cows are maintained through 3 yr of age. Protein supplementation of cows grazing dormant Sandhills range during late gestation resulted in heifer progeny with increased BW from weaning through 3 yr of age. Perhaps more importantly, heifers from protein-supplemented cows had greater pregnancy rates and were more likely to calve in the initial 21 d of their first calving season.

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