EFFECTS OF DAM NUTRITION ON GROWTH AND REPRODUCTIVE PERFORMANCE OF HEIFER CALVES

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ABSTRACT: A 3-yr study was conducted with heifers (n = 170) whose dams were used in a 2x2 factorial to determine effects of late gestation (**LG**) or early lactation (**EL**) dam nutrition on subsequent heifer growth and reproductive performance. In LG, cows received either 1 lb/d of 42% CP supplement (**PS**) or no supplement while grazing dormant winter range. During EL, cows were either fed cool-season grass hay or grazed sub-irrigated meadow. Cows were managed in a common group the remainder of the year. Heifer birth date and birth weight were not affected ($P > 0.10$) by LG or EL dam nutrition. Spring meadow grazing and PS increased ($P = 0.02$; $P = 0.07$) heifer 205-d weight. Pre-breeding weight and weight at pregnancy determination were greater ($P = 0.04$; $P = 0.03$) for heifers from PS dams, but EL nutrition did not affect ($P > 0.10$) either weight. There was no effect ($P > 0.10$) of LG or EL dam nutrition on age at puberty or percentage of heifers cyclic before breeding, and no difference ($P > 0.10$) in pregnancy rates or calving data due to EL nutrition of the dam. However, first service and overall pregnancy rates were greater ($P = 0.003$; $P = 0.05$) for heifers from PS dams. Heifers born to PS cows tended to calve earlier ($P = 0.15$) in their initial calving season, and had similar ($P = 0.94$) calf birth weights. Weight prior to the second breeding season was greater for heifers from protein supplemented dams than for heifers from unsupplemented dams ($P = 0.005$) but was unaffected by dam nutrition during early lactation ($P = 0.10$). Dam nutrition did not affect ($P > 0.10$) individually-fed heifer ADG or G:F ratio. There was an LG x EL interaction for DMI ($P = 0.09$) and residual feed intake (**RFI**; $P = 0.07$). Heifers from PS dams had greater DMI ($P = 0.09$) and RFI ($P = 0.07$) if their dams were fed hay during EL, but not if their dams grazed meadows. Protein supplementation during LG improved growth and pregnancy rate in heifer offspring.

Keywords: Protein Supplement, Fetal Programming, Heifer Development, Fertility

Introduction

The nutritional requirements of spring-calving beef cows grazing dormant Sandhills range during late gestation exceed the nutritional value of the forage (NRC, 1996). In order to maintain cow body condition, protein supplements are often fed during the last trimester of gestation. These supplements are expensive and do not always improve subsequent reproductive performance (Stalker et al., 2005). However, the additional cost of protein supplementation is recovered in improved calf performance at weaning and feedlot endpoints (Stalker et al., 2005).

Additionally, nutrient requirements of the cow are highest during early lactation (NRC, 1996), which coincides with the beginning of the breeding season. Allowing cows to graze cool-season meadows during this time improves reproductive performance and calf weaning weight compared to cows fed cool-season grass hay (Stalker et al., 2005).

Fetal programming is the concept that maternal stimuli during fetal development has lasting impacts on progeny postnatal growth and physiology (Barker et al., 1993). Primiparous heifers restricted to 65% of NRC recommended energy intake during the final 100 d of pregnancy had reduced progeny birth weight and pubertal age of the resulting heifer calves was increased by 19 d (Corah et al., 1975). In ewes, brief late-gestation nutrient restriction resulted in altered endocrine function in adult female progeny independent of differences in birth weight (Bloomfield et al., 2003). Furthermore, male lambs born to ewes energy-restricted from week 10 of pregnancy until term had reduced testicular cord volume and Sertoli cell numbers at birth (Alejandro et al., 2002) but postnatal reproductive development was not assessed. Extensive data exists concerning the effects of intra-uterine growth retardation in sheep on postnatal development (Anthony et al., 2003; Vonnahme et al., 2003). However, limited data concerning the influence of moderate differences in late-gestation nutrition of female ruminants on reproductive performance of their progeny exists. Therefore, the objectives of the current study were to determine if supplemental protein during late gestation or early lactation plane of nutrition of cows influences future growth or reproductive performance of their heifer calves.

Procedure

The University of Nebraska-Lincoln Institutional Animal Care and Use Committee approved the procedures and facilities used in this experiment. A 3-yr study was conducted with heifers produced at Gudmundsen Sandhills Laboratory (**GSL**), Whitman, NE. The heifers were born to cows used in a 2x2 factorial treatment design to determine effects of late gestation and postpartum nutrition on reproductive performance and calf growth (Stalker et al., 2005). During the last trimester of gestation (December 1 through February 28) cows received either the equivalent of 1 lb/d of 42% CP supplement fed three times per wk or no protein supplement. The cows were managed as a single group during the calving season, March 1 to April 30. From May 1 until May 31, half the cows were fed cool-season grass hay while the other half grazed sub-irrigated meadow. On June 1, cows were again combined and were managed in a common group throughout the breeding season and remainder of the production cycle.

During yr 1 and yr 3, heifers were managed as a single group from June 1 until the end of data collection. Data available from yr 1 is limited to birth and weaning records. In yr 2, additional reproduction and calving data was collected. The proportion of heifers cycling before the beginning of the breeding season in yr 2 was determined by progesterone concentration in two blood samples collected 10 d apart. Heifers from yr 2 were exposed to bulls for breeding, and first service and overall pregnancy rates were determined using transrectal ultrasonography approximately 30 d after the end of the breeding season and confirmed by calving date.

Heifers born in yr 3 remained at GSL for 109 d after weaning and were then transported to the North Dakota State University Animal Nutrition and Physiology Center, Fargo, ND. After an adaptation and training period, heifers from yr 3 were individually fed for 84 d using Calan gates. Heifers were housed in a climate-controlled facility with the light cycle being 14 h light, 10 h dark. All heifers were allowed ad libitum consumption of hay (7.5% CP, 71% NDF, 52 % ADF) fed in the morning and supplemented daily with 0.90 kg of 16% CP pellets in the afternoon. Orts were collected twice weekly and analyzed for DM to determine DMI. Two-day consecutive weights were taken at the beginning and end of the feeding period, with interim weights and blood samples collected every 14 d. Following completion of the individual feeding period on May 17, 2005, heifers were transported to the West Central Research and Extension Center, North Platte, NE and pre-breeding weights were recorded. Heifers were exposed to bulls for a 45 d breeding season and pregnancy status was determined via transrectal ultrasonography approximately 50 d following completion of the breeding season.

Blood samples were cooled immediately and serum harvested 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) with modifications described by Schneider and Hallford (1996). Serum progesterone concentrations in samples from yr 3 were analyzed by solid-phase, competitive chemiluminescent enzyme immunoassay (Immulite 1000, Diagnostics Products Corp., Los Angeles, CA). Progesterone concentration greater than 1 ng/mL were interpreted to indicate ovarian luteal activity.

Performance data were analyzed as a 2x2 factorial using PROC MIXED of SAS. Reproductive and calving difficulty data were analyzed using Chi-square procedures in PROC GENMOD of SAS. The model included dam treatment during late gestation and dam treatment during the spring. The interaction between gestation and spring treatments were included for data sets when significant. In multi-year analyses, year was included as a random variable. Pen was included in the random statement for heifers in the individual feeding trial.

For yr 3, RFI was calculated by regressing DMI on mid-test weight and ADG using PROC REG of SAS. 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(mid-test weight) + b_g(ADG). Residual feed intake was calculated as the difference between observed and predicted DMI; therefore, lower values indicate increased efficiency.

Results and Discussion

Birth and weaning data are summarized in Table 1. Dam nutrition did not affect ($P >$ 0.10) heifer birth date or birth weight. Supplementing cows with protein during LG tended ($P =$ 0.14) to increase subsequent heifer weaning weight, and increased ($P = 0.02$) adjusted 205 d weight. Cows that grazed sub-irrigated meadows during the spring produced heifer calves with increased actual ($P = 0.09$) and adjusted ($P = 0.07$) weaning weight compared to heifers from cows fed hay. Pre-breeding weight was greater ($P = 0.04$) for heifers from PS dams than heifers from unsupplemented dams, but EL treatment did not affect ($P > 0.10$) heifer pre-breeding weight. Overall ADG between weaning and the first breeding season was not affected by dam treatment ($P > 0.10$; data not shown).

There was no effect ($P > 0.10$) of dam nutrition on the proportion of heifers from yr 2 exhibiting ovarian luteal activity prior to the breeding season, nor was there a difference in age at puberty of heifers born in yr 3 (Table 2). The difference of 5 d in age at puberty for heifers from PS or unsupplemented dams in this study is less than the 19 d difference in age at puberty that Corah et al. (1975) documented in female progeny of primiparous heifers restricted to approximately 70% of NRC recommended energy intake. However, there was not a statistical difference in age at puberty for heifers born to cows in either study. Furthermore, there was no difference ($P > 0.10$) in pregnancy rates or calving data due to EL dam treatment. The proportion of heifers calving in the initial 21 d of their first calving season was 77% for heifers from PS dams and 49% for heifers born to unsupplemented cows ($P = 0.003$). Overall pregnancy rate was 93% versus 80% ($P = 0.05$) for heifers from PS or unsupplemented dams, respectively. The mechanism responsible for the differences in first service and overall pregnancy rates between heifers from PS and unsupplemented dams is not clear from this study but is independent of age at puberty or estrous cyclicity immediately prior to the breeding season. Heifers born to PS cows tended to calve earlier in their first calving season (*P* = 0.15; Table 2) and had a similar proportion of unassisted births (*P* = 0.24) than heifers whose dams were not supplemented with protein during LG. However, no differences (*P* = 0.94) in calf birth weight were detected. Weight prior to the second breeding season for heifers born in yr 2 and 3 was 983 ± 13 lbs. for heifers from protein supplemented dams, compared to 930 ± 13 lbs. for heifers from unsupplemented dams (*P* = 0.005) but was unaffected by dam nutrition during early lactation (*P* = 0.10; data not shown).

Data from the individual feeding trial (yr 3) are presented as simple effects (Table 3). Heifers from PS cows were heavier (*P* = 0.08) at the end of the 84 d trial but had similar initial weights (*P* > 0.10), and similar BCS at both time points (*P* > 0.10) compared to heifers from cows that were not supplemented. Dam nutrition during EL did not affect weight nor BCS (*P* > 0.10). Neither ADG nor the ratio of gain to feed was affected (*P* > 0.10) by maternal nutrition.

In young cattle, RFI is a measure of feed efficiency correlated to reduced mature cow feed intake but not mature cow size, suggesting that selection for RFI is more likely to improve cow feed efficiency than selection for feed conversion ratio alone (Arthur et al, 2004). Dry matter intake and RFI were affected (*P* = 0.09, *P* = 0.07, respectively) by the interaction of maternal nutrition during LG and EL. Heifers born to PS dams had greater DMI (*P* = 0.09) if their dams were fed hay during EL, but not if their dams grazed meadows in EL (*P* > 0.10). Similarly, heifers from PS dams had higher RFI (*P* = 0.07) if their dams were fed hay during EL, but not if their dams grazed meadows during EL (*P* > 0.10). Higher RFI values indicate that heifers from PS cows fed hay during EL were less efficient than heifers from unsupplemented cows fed hay during EL. In this data set, it appears that selecting for feed efficiency based on RFI would result in reduced DMI, but not improved ADG. In fact, the heifers with more favorable RFI also had numerically lower ADG, but the differences were not statistically significant. Gain to feed ratio was not affected by treatment.

Literature Cited

Alejandro, B., R. Perez, G. Pedrana, J. T. Milton, A. Lopez, M. A. Blackberry, G. Duncombe, H. Rodriguez-Martinez, and G. B. Martin. 2002. Low maternal nutrition during pregnancy reduces the number of Sertoli cells in the newborn lamb. Reprod. Fertil. Dev. 14:333-337.

Anthony, R. V., A. N. Scheaffer, C. D. Wright, and T. R. Regnault. 2003. Ruminant models of prenatal growth restriction. Reprod. Suppl. 61:183-194.

Arthur, P. F., J. A. Archer, A. Reverter, D. J. Johnston, and R. M. Herd. 2004. Genetic correlations between postweaning feed efficiency and cow traits. J. Anim. Sci. 82(Suppl. 1):449.

Barker, D. J. P., C. N. Martyn, C. Osmond, C. N. Hales, and C. H. D. Fall. 1993. Growth in utero and serum cholesterol concentration in adult life. Br. Med. J. 307:1524-1527.

Bloomfield, F. H., M. H. Oliver, C. D. Giannoulias, P. D. Gluckman, J. E. Harding, and J. R. Challis. 2003. Brief undernutrition in late-gestation sheep programs the hypothalamic-pituitary-adrenal axis in adult offspring. Endocrinology 144:2933-2940.

Corah, L. R., T. G. Dunn, and C. C. Kalthenbach. 1975. Influence of prepartum nutrition on the reproductive performance of beef females and the performance of their progeny. J. Anim. Sci. 41:819-824.

NRC. 1996. Nutrient Requirements of Beef Cattle (7th Ed.). National Academy Press, Washington, DC.

Schneider, F. A., and D. M. Hallford. 1996. Use of a rapid progesterone radioimmunoassay to predict pregnancy and fetal numbers in ewes. Sheep and Goat Res. 12:33-42.

Stalker, L. A., D. C. Adams, and T. J. Klopfenstein. 2005. Effects of supplemental protein during gestation and grazing sub-irrigated meadow during the postpartum interval on pregnancy rates of spring calving cows and calf growth. Nebraska 2005 Beef Cattle Report. University of Nebraska-Lincoln, Lincoln, NE.

Vonnahme, K. A, B. W. Hess, T. R. Hansen, R. J. McCormick, D. C. Rule, G. E. Moss, W. J. Murdoch, M. J. Nijland, D. C. Skinner, P. W. Nathanielsz, and S. P. Ford. 2003. Maternal undernutrition from early- to mid-gestation leads to growth retardation, cardiac ventricular hypertrophy, and increased liver weight in the fetal sheep. Biol. Reprod. 69:133-140.

Table 1. Effects of dam protein supplementation during the last trimester of gestation and grazing sub-irrigated meadow or fed grass hay during early lactation on growth performance of heifer calves[a]

	Treatment[b]					P-values	
Item	Prot	NoProt	Meadow	Hay	SEM	Gest	Spring
Birth date, Julian d	86	84	85	86	1	0.29	0.67
Birth wt, lb	79	77	77	79	2	0.25	0.15
Act wn wt, lb	467	456	467	454	15	0.14	0.09
Adj 205 d wt, lb	498	481	496	483	15	0.02	0.07
Pre-breeding wt, lb	608	586	600	595	20	0.04	0.70
Weight at first pregnancy check, lb	882	851	862	871	68	0.03	0.56

[a] Includes birth and weaning (wn) data from 170 heifer calves born from yr 1 to yr 3 , and pre-breeding and pregnancy check weights from 91 heifers born in yr 2 and yr 3.

[b] No gestation by lactation treament interactions were detected, therefore main effects are reported. Prot = dams supplemented three times per week with the equivalent of 1 lb/d 42%CP cake during the last trimester of gestation; NoProt = no protein supplement fed to dams during gestation; Meadow = dams grazed sub-irrigated meadows between the end of calving and the breeding season; Hay = dams fed cool-season grass hay from the end of the calving season until initiation of the breeding season.

Table 2. Effects of dam protein supplementation during the last trimester of gestation and grazing sub-irrigated meadow or fed grass hay during early lactation on reproductive and calving performance of heifers[a]

	Treatment[b]					P-values	
Item	Prot	NoProt	Meadow	Hay	SEM	Gest	Spring
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 d	71	75	73	73	3	0.15	0.94
Calf birth wt, lb	73	73	71	73	2	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 heifers born in yr 2 and 3, and calving data from 77 heifers born in yr 2 and yr 3.

[b] No gestation by spring treatment interactions were detected, therefore only main effects are reported. Prot = dams supplemented three times pre week with the equivalent of 1 lb/d 42%CP cake during the last trimester of gestation; NoProt = no protein supplement fed to dams during gestation; Meadow = dams grazed sub-irrigated meadows between the end of calving and the breeding season; Hay = dams fed cool-season grass hay from the end of the calving season until initiation of the breeding season.

Table 3. Effects of dam protein supplementation during the last trimester of gestation and grazing sub-irrigated meadow or fed grass hay during early lactation on growth, BCS, and residual feed intake of heifers individually-fed for 84 d[a]

	Treatment Effects[b]					P-values		
Item	P/M	P/H	NP/M	NP/H	SEM	G	Sp	G*Sp
Initial wt, lb	606	573	564	571	20	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, lb	683	657	646	631	18	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, lb/d	0.82	0.93	0.93	0.86	0.13	0.86	0.75	0.15
DMI, lb/d	14.48^{de}	15.26^{d}	14.97^{de}	13.67^{e}	0.64	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, lb/d[c]	-0.31^{de}	0.62^{d}	0.40^{de}	-0.90^{e}	0.62	0.50	0.74	0.07

[a] Includes data from 50 heifers born in yr 3.

[b] P/M = dams supplemented with the equivalent of 1 lb/d 42% CP cake during gestation and grazed meadows from the end of the calving season until the breeding season; P/H = dams supplemented with the equivalent of 1 lb/d 42% CP cake during gestation and were fed cool-season grass hay from the end of the calving season until the breeding season; NP/M = dams not supplemented with protein during gestation, grazed meadows between in the interval between the end of calving and initiation of the breeding season; NP/H = dams not supplemented with protein during gestation, fed cool-season grass hay between in the interval between the end of calving and initiation of the breeding season.

[c] Residual feed intake, the difference between observed DMI and predicted DMI.

[de] Within a row, means without a common superscript differ.