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Cow/Calf

Influence of maternal protein restriction in primiparous heifers during mid- and/or late-gestation on dam and suckling calf performance.

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Objective

Nutrient status in gestating beef cows has been shown to impact performance of the dam and offspring; however, most research has focused on energy or a total diet restriction and a single period of gestation. The objective of this study was to evaluate the effects of maternal metabolizable protein (MP) restriction in primiparous heifers during mid- and/or late gestation on dam and suckling calf performance through weaning.

Study Description

Two-year-old Angus × Simmental heifers (n = 108) were allocated to a randomized complete block design. Pens within each block were randomly assigned to either CON (slightly exceeding MP requirements) or RES (approximately 80% of MP requirements) treatments. Both diets were formulated to meet net energy requirements. Half of the pens on the CON treatment were reassigned to the RES treatment at the end of mid-gestation and vice versa, in a 2 MP level × 2 gestation period factorial structure. Heifer body weight (BW), body condition score (BCS), ultrasound body composition, milk production and composition, calving data, and calf weaning weights were measured.

Take home points

There was an interaction for mid-gestation treatment × time for changes in BW and BCS during mid-gestation, with heifers on the RES treatment losing BW while CON heifers maintained BW ($P < 0.01$). In a late gestation treatment × time interaction, restricted heifers gained approximately half as much BW and lost BCS compared with CON heifers ($P < 0.05$). There was a mid-gestation treatment × time interaction for longissimus muscle (LM) area, with restricted heifers losing more than twice as much LM area as CON heifers ($P = 0.04$). A mid-gestation × time interaction ($P = 0.03$) indicated a tendency ($P < 0.10$) for increased intramuscular fat loss in heifers on the RES treatment at the end of mid-gestation. In a late gestation treatment × time interaction, MP restriction in late gestation increased loss of LM area in RES vs. CON heifers ($P = 0.03$). There were no changes in 12th rib subcutaneous fat thickness ($P > 0.05$) across treatments or time. Dietary treatment did not affect calf birth or weaning weight, milk production, or subsequent cow reproductive performance ($P > 0.05$). Decreased available MP appeared to result in mobilization of maternal body reserves during the restriction; however, it

did not impact subsequent cow reproductive performance, calf birth weight or calf growth to weaning.

Keywords: cow-calf, fetal programming, gestational diet, metabolizable protein, nutrient restriction

Influence of maternal protein restriction in primiparous heifers during mid- and/or late-gestation on dam and suckling calf performance.

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Abstract
Nutrient status in gestating beef cows has been shown to impact performance of the dam and offspring; however, most research has focused on energy or a total diet restriction and a single period of gestation. The objective of this study was to evaluate the effects of maternal metabolizable protein (MP) restriction in primiparous heifers during mid- and/or late gestation on dam and suckling calf performance through weaning. Two-year-old Angus × Simmental heifers (n = 108) were allocated to a randomized complete block design. Pens within each block were randomly assigned to either CON (slightly exceeding MP requirements) or RES (approximately 80% of MP requirements) treatments. Both diets were formulated to meet net energy requirements. Half of the pens on the CON treatment were reassigned to the RES treatment at the end of mid-gestation and vice versa, in a 2 MP level × 2 gestation period factorial structure. Heifer body weight (BW), body condition score (BCS), ultrasound body composition, milk production and composition, calving data, and calf weaning weights were measured. There was an interaction for mid-gestation treatment × time for changes in BW and BCS during mid-gestation, with heifers on the RES treatment losing BW while CON heifers maintained BW ($P < 0.01$). In a late gestation treatment × time interaction, restricted heifers gained approximately half as much BW and lost BCS compared with CON heifers ($P < 0.05$). There was a mid-gestation treatment × time interaction for longissimus muscle (LM) area, with restricted heifers losing more than twice as much LM area as CON heifers ($P = 0.04$). A mid-gestation × time interaction ($P = 0.03$) indicated a tendency ($P < 0.10$) for increased intramuscular fat loss in heifers on the RES treatment at the end of mid-gestation. In a late gestation treatment × time interaction, MP restriction in late gestation increased loss of LM area in RES vs. CON heifers ($P = 0.03$). There were no changes in 12th rib subcutaneous fat thickness ($P > 0.05$) across treatments or time. Dietary treatment did not affect calf birth or weaning weight, milk production, or subsequent cow reproductive performance ($P > 0.05$). Decreased available MP appeared to result in mobilization of maternal body reserves during the restriction; however, it did not impact subsequent cow reproductive performance, calf birth weight or calf growth to weaning.

Introduction
Nutrient status of gestating beef cows can have various long-term implications on growth, feed intake and efficiency, and performance of offspring (Funston *et al*., 2012). Research indicates developmental status of the fetus at the time of a maternal nutrient deficiency plays a role in postnatal responses of the offspring (Freetly *et al*., 2000; Morrison *et al*., 1999; Wiley *et al*., 1991). However, much of the available research has been limited to a single period of development (e.g. early or late gestation) and has evaluated the effects of an energy restriction or a reduction of total dietary dry matter intake. In many forage-based production systems, protein may be deficient in gestating beef cow diets due to increasing nutrient requirements, forage quality issues, inadequate supplementation, and/or environmental conditions (Caton

and Hess, 2010). The metabolizable protein (MP) system has been utilized for over 20 years to define protein requirements of beef cattle (NRC, 2000); however, limited data is available on the effect of a MP restriction during gestation and the subsequent developmental programming effect. It was hypothesized that MP restriction imposed during mid- and/or late gestation would impact nutrient status and result in decreased dam performance in addition to reduced calf birth weight and growth. Therefore, the objective of this study was to evaluate how maternal protein restriction from mid- to late gestation in primiparous, 2-year-old heifers affected dam nutrient status and performance and suckling calf performance through weaning.

Experimental Procedures

Two-year-old Angus x Simmental heifers (n = 108) were pen-fed at the SDSU Cottonwood Range and Livestock Field Station during the treatment period. Treatments were 2 levels of dietary MP provided during 2 stages of gestation (mid and late). Dietary MP treatments included: control (CON; slightly exceeding MP requirements) and restricted (RES; approximately 80% of MP requirements based on Level 2 of NRC (2000; Table 1). Heifers were blocked by body weight (BW) as well as age and sex of the fetus resulting in 3 blocks of 4 pens each. At the end of the mid-gestation treatment period, half of the pens on the CON treatment were crossed over to the RES treatment and half of the pens on the RES treatment were crossed over to the CON treatment, with the other half of the pens remaining on the same treatment in a Balaam's Design (Balaam, 1968) to evaluate carryover effects from mid- to late gestation. This resulted in 4 treatment combinations (CON-CON, CON-RES, RES-CON, and RES-RES).

Diets consisted of calcium hydroxide treated wheat straw, crude glycerin, and concentrates (Table 1). Both CON and RES concentrate formulations contained ground corn, ground corn cobs, a rumen-protected fat product (Energy Booster 100®, Milk Specialties Global, Eden Prairie, MN), urea, and crude glycerin. Most ingredients were chosen on the basis of energy content so diets were isocaloric and met NRC energy requirements (2000) for maintenance, growth, and pregnancy. Urea was utilized to meet bacterial N requirements and ensure fermentation capacity would not limit energy value of the diet. The CON concentrate also contained porcine bloodmeal to slightly exceed the MP requirement. Actual percentage of MP requirements supplied was 101% for CON heifers and 81% for RES heifers when averaged across the study. Immediately after calving, heifers were removed from treatments and pairs were managed as a common group through weaning. There were no further treatments applied to dams or progeny beyond gestational treatments of the dam.

Individual gestating heifer BW and body condition score (BCS; using a 9-point scale (1 = extremely emaciated to 9 = extremely obese; Wagner et al., 1988) were recorded at trial initiation, treatment crossover, and about 3 weeks before calving. Ultrasound images were recorded at the same time points and analyzed to determine 12th rib subcutaneous fat thickness, percent intramuscular fat (% IMF), and longissimus muscle (LM) area for each heifer using an Aloka 500V (Aloka, Wallingford, CT) Calves were weighed at birth and weaning. A sub-set of 34 heifers representing each treatment combination were selected for a single measure of milk production using a portable milking machine (Porta-Milker, The Coburn Company, Inc., Whitewater, WI). Milk samples were analyzed for fat, protein, somatic cell count, lactose, total solids, and milk urea nitrogen at the Heart of America Dairy Herd Improvement Association laboratory (Manhattan, KS). To evaluate subsequent return to estrous cyclicity, blood samples were collected via venipuncture on d -10 and 0 relative to initiation of an estrus synchronization protocol. Serum was analyzed for progesterone concentration; heifers were considered cycling if serum progesterone concentrations were > 1 ng/ml in either sample. Heifers were synchronized utilizing a modified 7-day controlled internal drug release (CIDR) CO-Synch protocol. Heifers were artificially inseminated (AI), followed by exposure to a bull to complete a 60-d breeding season. Pregnancy rates were determined via ultrasound 117 d post-AI.

Results and Discussion

Heifer response. Metabolizable protein restriction during mid-gestation affected ($P = 0.02$) BW, with RES heifers weighing less than CON heifers throughout the study (430 vs. 442 ± 8.5 kg). A mid-gestation treatment (CON vs. RES) × time (treatment crossover and end of study) interaction was observed for change in heifer BW ($P = 0.002$; Table 2). Mid-gestation CON lost less BW than mid-gestation RES, with no carryover effect on weight change during late gestation. However, there was no difference for BCS between CON and RES treatments (4.83 vs. 4.80 ± 0.037 respectively; $P = 0.60$), even though a mid-gestation treatment (CON vs. RES) × time interaction was observed for change in heifer BCS ($P = 0.027$; Table 2). There tended to be a greater BCS loss ($P = 0.08$) in heifers on the RES treatment during mid-gestation. Similar change in BCS at the end of the study indicated no carryover effect of mid-gestation treatment into the late gestation period. Late-gestation treatment (CON vs. RES) × time interactions were also observed for BW, BCS, and changes in both of these variables ($P < 0.05$; Table 2). All heifers gained BW during the late gestation period; however, the interaction for BW change indicated the MP restriction resulted in lower BW gains ($P = 0.001$). In addition, restricted heifers lost BCS in the late gestation period whereas heifers on the CON treatment maintained BCS ($P = 0.007$). There was a tendency ($P = 0.06$) for an interaction between mid- and late gestation treatments for BW change, with heifers on the CON diet throughout mid- and late gestation (CON-CON) gaining slightly more BW than heifers on any other treatment combination (CON-RES, RES-CON, and RES-RES; mean gain 11.9 vs. 4.0, 2.3, and 4.2 ± 5.75 kg, respectively).

A tendency ($P = 0.06$) was observed for influence of mid-gestation treatment on LM area. Heifers on the CON treatment in mid-gestation had greater LM area compared with the RES treatment (47.8 vs. 47.0 ± 0.336 cm^2). A mid-gestation treatment (CON vs. RES) × time interaction ($P = 0.04$) was observed for changes in LM area (Table 2). From the beginning of the study to the end of the mid-gestation period, RES heifers lost over twice as much LM area as heifers on the CON treatment. There was no carryover effect of mid-gestation treatment on LM area change from treatment crossover to the end of the study. There was an interaction ($P < 0.01$; Table 2) for late gestation treatment (CON vs. RES) × time for LM area; however, there were no differences ($P > 0.10$) between treatment means due to the late gestation dietary treatments. A late gestation treatment × time interaction was also observed ($P = 0.03$) for LM area change. From treatment crossover to the end of the study, heifers restricted in late gestation lost over 4-fold the amount of LM area as CON heifers.

No differences ($P > 0.05$) were detected for 12th rib fat thickness or change in fat thickness due to main effect of treatment or any treatment × period of gestation interactions. A mid-gestation treatment × late gestation treatment × time interaction was observed for IMF ($P = 0.01$; Figure

1). For ultrasound measurements conducted at treatment crossover (end of mid-gestation treatments), the percentage of IMF tended (*P* < 0.10) to be greatest for the CON-CON treatment and least for RES-CON and RES-RES, with CON-RES intermediate and not different from any other treatment combination. For ultrasound measurements conducted at the end of the study, the percentage of IMF was similar (*P* > 0.10) for heifers from CON-CON, RES-CON, and RES-RES treatments. Heifers on the CON-RES treatment had the lowest amount of IMF and tended to be different (*P* < 0.10) from the CON-CON treatment but similar to other treatments. A mid-gestation treatment × time interaction was observed for IMF change (*P* = 0.03), with a tendency (*P* < 0.10) for increased IMF loss in heifers on the RES treatment at treatment crossover. There were no differences (*P* > 0.10) between treatments for this interaction at the end of the study, indicating no carryover effect from mid- to late gestation. There was also a tendency (*P* = 0.08) for an interaction between mid- and late gestation treatments; however, there were no differences (*P* > 0.10) among any treatment combinations (CON-CON, CON-RES, RES-CON, and RES-RES) when means were separated.

***Calf birth weight and performance*.** Nutritional treatments experienced by heifers during mid- and/or late gestation did not affect calving difficulty, calf vigor, calf birth weight, or calf weaning weight (*P* > 0.20; Table 3).

Dam milk production and composition. There were no differences (P > 0.05) for peak milk production or composition in terms of fat content, protein content, or total solids (mean 3.27 ± 0.148%, 3.29 ± 0.086%, and 9.30 ± 0.074%, respectively; Table 3)). Heifers on the RES treatment in mid-gestation had reduced (P = 0.02) milk urea nitrogen compared with CON heifers (14.62 vs. 15.56 ± 1.100%, respectively). Milk from heifers restricted in late gestation had increased lactose content compared with the CON treatment (P = 0.04; mean 5.17 vs. 4.92 ± 0.106%, respectively).

Subsequent dam reproductive responses. The proportion of heifers returning to cyclicity by the beginning of the breeding season following calving was not influenced by MP restriction during mid- or late gestation (P > 0.05; Table 3). Heifer BW and BCS were similar (P > 0.60) at breeding (Table 3). All treatments had virtually 100% overall pregnancy rate.

Implications

This study provides evidence that heifers exposed to a MP restriction during mid- and late gestation lost weight and body condition and mobilized muscle tissue; however, treatments did not influence fat tissue depots. Gestational treatments did not impact calf birth or weaning weight, milk production or composition, or subsequent reproductive performance. Results suggest that heifers were able to buffer consequences of a MP restriction to the fetus given sufficient dietary energy. Considered with results from other studies, energy restriction may have more influence on dam and offspring responses than a MP restriction.

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Table 1. Dietary components and nutrients consumed by heifers receiving a control (CON = slightly exceeding MP requirement) or restricted (R = approximately 80% of MP requirement supplied) diet during mid- and/or late gestation based on NRC (2000) calculations[1]

	Diet formulation 1[2]		Diet formulation 2[2]		Diet formulation 3[2]	
	CON	RES	CON	RES	CON	RES
Item	---- % DM basis ----					
$Ca(OH)_2$ treated wheat straw[3]	59.81	59.62	54.14	53.65	51.22	51.28
Crude glycerin[4]	15.66	17.97	13.27	15.27	14.52	14.54
Dry supplement[5]						
Ground corn	-	-	10.27	10.02	10.79	11.03
Ground corn cobs	16.77	16.56	11.33	11.43	11.84	12.51
Energy Booster 100®[6]	3.42	3.06	7.38	7.46	7.74	8.20
Porcine bloodmeal	1.62	-	1.65	-	1.54	-
Sodium phosphate (XP 40)	1.57	1.56	1.39	1.43	1.73	1.62
Urea, 46%	1.08	1.18	0.51	0.67	0.54	0.75
Magnesium oxide, 54%	0.032	0.034	0.032	0.031	0.034	0.034
TM Green[7]	0.015	0.014	0.020	0.019	0.010	0.010
Selenium, 0.06% yellow	0.009	0.012	0.011	0.013	0.013	0.015
Vitamin AD 10:1	0.004	0.004	0.004	0.004	0.005	0.005
Nutrient composition of diet predicted by NRC (2000) based on actual intake						
Bacterial N balance, g/d	11	11	-1	-1	2	2
MP, %	108.7	88.4	101.4	78.3	93.2	77.2
NE_m, Mcal/lb	0.56	0.53	0.62	0.64	0.65	0.65
NE_g, Mcal/lb	0.30	0.28	0.36	0.37	0.39	0.39

[1] Diets formulated based on NRC (2000) Level 2 predictions for MP, NE_m, and NE_g requirements for heifers throughout gestation

[2] Diet formulation 1 fed from 2Nov2013 – 14Dec2013, diet formulation 2 fed from 15Dec2013 – 18Jan2014, and diet formulation 3 fed from 19Jan2014 – calving.

[3] Nutrient composition of wheat straw: 49.39% DM; 4.75% CP; 57.48% ADF; 66.78% NDF; 3.17% Ca; 0.07% P; 49.75% TDN; 0.95 Mcal/kg NE_m; 0.40 Mcal/kg NE_g

[4] Crude glycerin contained 82.3% glycerol, 9.5% water, 0.56% CP, 0.04% methanol, 8.07% ash, and 0.90% MONG [matter organic non-glycerol; defined as 100 – glycerol content (%) + water content (%) + ash content (%)]. Crude glycerin sourced from Minnesota Soybean Processors, Brewster, MN

[5] Dry supplement formulated and mixed by Hubbard Feeds Inc., Mankato, MN

[6] Milk Specialties Global, Eden Prairie, MN

[7] TM Green mineral mix contained 6.6% Ca; 15.2% S; 330 ppm Co; 33,000 ppm Cu; 1,650 ppm I; 132,000 ppm Mn and 99,000 ppm Zn

Table 2. Least square means for mid- and late gestation treatments (CON = slightly exceeding MP requirements; RES = approximately 80% of MP requirements) × time (treatment crossover and end of study) interactions for heifer BW, BW change, body condition score (BCS), BCS change, and ultrasound measurements

	Treatment crossover		End of study			
Item	CON	RES	CON	RES	SEM	*P-value*
	Mid-gestation treatment × time interaction					
BW, lb	950	922	999	977	19.0	0.295
BW change, lb	-11[a]	-42[b]	46	57	12.7	0.002
BCS	4.92	4.82	4.74	4.78	0.046	0.106
BCS change	-0.30[c]	-0.46[d]	-0.18	-0.04	0.081	0.027
LM area, in^2	7.47	7.33	7.33	7.24	0.0539	0.208
LM area change, in^2	-0.11[a]	-0.25[b]	-0.14	-0.09	0.0423	0.042
12th rib fat thickness, in	0.21	0.20	0.18	0.18	0.0079	0.477
12th rib fat thickness change, in	0.00	-0.01	-0.03	-0.02	0.0067	0.235
IMF change, %	-0.06[c]	-0.20[d]	-0.07	0.06	0.054	0.026
	Late gestation treatment × time interaction					
BW, lb	928	944	994	981	19.0	0.011
BW change, lb	-35	-20	66[a]	37[b]	12.6	0.001
BCS	4.81	4.93	4.81	4.71	0.046	0.022
BCS change	-0.46	-0.30	0.00[a]	-0.22[b]	0.081	0.007
LM area, in^2	7.37	7.43	7.33	7.24	0.0539	0.006
LM area change, in^2	-0.21	-0.15	-0.04[a]	-0.19[b]	0.0423	0.031
12th rib fat thickness, in	0.21	0.20	0.18	0.18	0.0079	0.903
12th rib fat thickness change, in	0.00	0.00	-0.02	-0.03	0.0067	0.538
IMF change, %	-0.09	-0.18	-0.03	0.03	0.058	0.184

[1] Statistical analysis was not conducted for initial BW and BCS measurements because these values were utilized as covariates for analysis of midpoint and final ultrasound measurements
[a,b] Within gestation period, means lacking a common superscript differ ($P < 0.05$)
[c,d] Within gestation period, means lacking a common superscript tend to differ ($P < 0.10$)

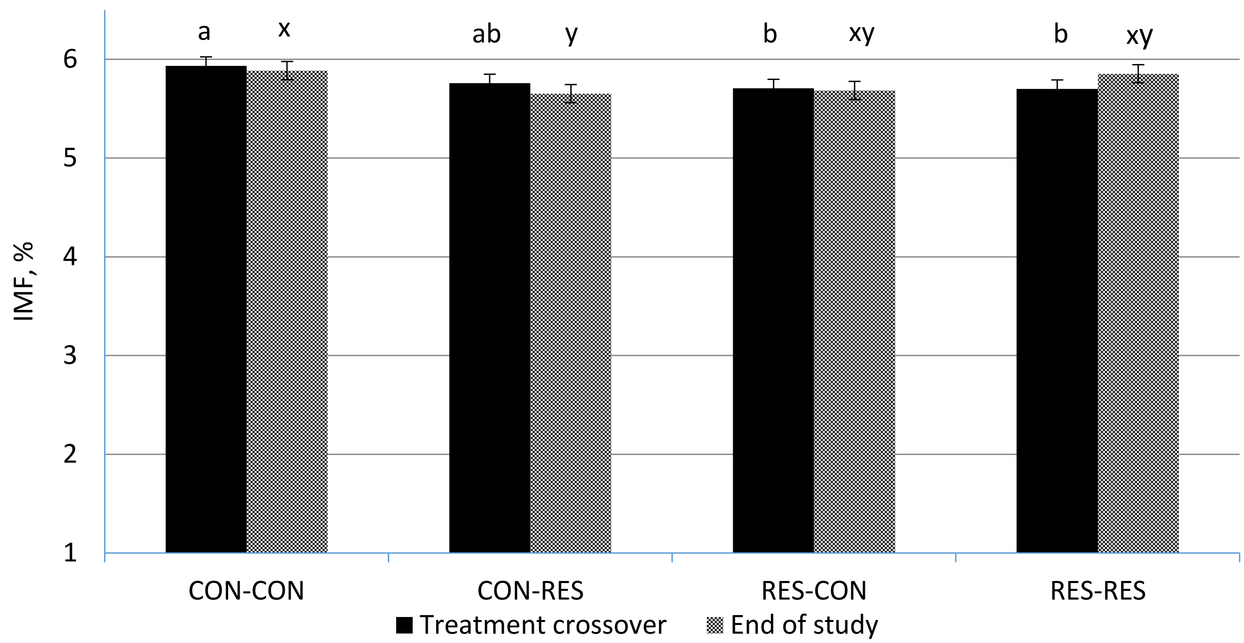
Table 3. Least square means for main effects of mid- and late gestation treatments (CON = slightly exceeding MP requirements; RES = approximately 80% of MP requirements) on calf performance from birth to weaning, milk production, and subsequent heifer reproductive responses

	Mid-gestation		Late gestation			Mid	Late
Item	CON	RES	CON	RES	SEM	*P*-value	*P*-value
Calving difficulty score	1.07	1.07	1.13	1.00	0.060	1.000	0.132
Calf vigor score	1.05	1.13	1.16	1.02	0.062	0.347	0.127
Calf birth BW[1], lb	66.1	63.9	63.9	66.1	4.01	0.282	0.247
Calf weaning BW, lb	465	450	456	459	19.8	0.221	0.926
Peak milk production, lb	22.1	20.5	22.3	20.4	2.45	0.607	0.549
Return to cyclicity, %	91	87	89	89	5.33	0.523	0.945
Heifer BW at rebreeding	979	974	981	972	35.3	0.646	0.489
Heifer BCS[2] at rebreeding	4.7	4.7	4.8	4.7	0.072	0.893	0.248
Overall pregnancy rate[3]	96	100	98	98	-	-	-

[1] BW = body weight

[2] BCS = body condition score

[3]Data shown are means for each treatment group. Statistical analysis of pregnancy rates did not converge because only 2 heifers failed to become pregnant



[a,b] At treatment crossover, means lacking a common superscript tend to differ ($P < 0.10$)
[x,y] At end of study, means lacking a common superscript tend to differ ($P < 0.10$)

Figure 1. Least square means for mid-gestation treatment × late gestation treatment × time (treatment crossover and end of study) interaction for % IMF based on ultrasound measurements for heifers receiving a control (CON; approximately 101% of MP requirement) or restricted (RES; approximately 80% of MP requirement supplied) diet during mid- and/or late gestation