Influence of maternal protein restriction in primiparous heifers during mid- and/or late gestation on progeny feedlot performance and carcass characteristics

J.J. Block, A.D. Blair, R.N. Funston, M.J. Webb, K.R. Underwood, M.G. Gonda, A.A. Harty, R.R. Salverson and K.C. Olson

Objective

Maternal nutrient restriction in beef cows impacts developmental processes in the fetus that may influence lifetime performance. This study investigated impacts of metabolizable protein (MP) restriction in primiparous heifers during mid- and/or late-gestation on progeny feedlot performance and carcass characteristics.

Study Description

Angus × Simmental heifers (n = 108) were stratified by body weight (BW), method of conception (artificial insemination or natural service), and calf sex and allocated to 12 pens in a randomized complete block design with a 2 × 2 factorial treatment structure including 2 stages of gestation (mid- and late) and 2 levels of dietary protein (control [CON]; approximately 101% of MP requirement and restricted [RES]; approximately 80% of MP requirement). Pens were randomly assigned to CON or RES treatments within blocks during mid- and/or late gestation. Heifers were removed from treatments after calving and pairs were managed as a common group. Following weaning, progeny were finished in a GrowSafe feeding system on a typical feedlot diet. Individual carcass measurements were collected.

Take home points

No differences were observed for initial or final BW, dry matter intake, or average daily gain due to maternal nutritional treatments ($P > 0.10$). There was a tendency ($P < 0.10$) for improved gain:feed for progeny from dams restricted in late gestation. Hot carcass weight (HCW), 12th rib fat thickness, kidney pelvic heart fat, yield grade, marbling score, and proportion of carcasses in each USDA Quality Grade were not influenced ($P > 0.10$) by maternal diet. Progeny of dams on the RES treatment in late gestation had greater longissimus muscle area ($P = 0.04$) vs. progeny from CON dams, but not when adjusted on a HCW basis ($P > 0.10$). Proportion of progeny producing USDA Yield Grade 3 carcasses was least from dams restricted only in late gestation (CON-RES), and greatest from dams restricted throughout gestation (RES-RES; $P < 0.05$). Minimal differences in animal performance and carcass characteristics suggest MP restriction imposed during mid- and late gestation in this study did not have a significant developmental programming effect.

Keywords: beef, carcass, feedlot performance, fetal programming, maternal nutrient restriction, metabolizable protein

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Abstract

Maternal nutrient restriction in beef cows impacts developmental processes in the fetus that may influence lifetime performance. This study investigated impacts of metabolizable protein (MP) restriction in primiparous heifers during mid- and/or late-gestation on progeny feedlot performance and carcass characteristics. Angus × Simmental heifers (n = 108) were stratified by body weight (BW), method of conception (artificial insemination or natural service), and calf sex and allocated to 12 pens in a randomized complete block design with a 2 × 2 factorial treatment structure including 2 stages of gestation (mid- and late) and 2 levels of dietary protein (control [CON]; approximately 101% of MP requirement and restricted [RES]; approximately 80% of MP requirement). Pens were randomly assigned to CON or RES treatments within blocks during mid- and/or late gestation. Heifers were removed from treatments after calving and pairs were managed as a common group. Following weaning, progeny were finished in a GrowSafe feeding system on a typical feedlot diet. Individual carcass measurements were collected. No differences were observed for initial or final BW, dry matter intake, or average daily gain due to maternal nutritional treatments ($P > 0.10$). There was a tendency ($P < 0.10$) for improved gain:feed for progeny from dams restricted in late gestation. Hot carcass weight (HCW), 12th rib fat thickness, kidney pelvic heart fat, yield grade, marbling score, and proportion of carcasses in each USDA Quality Grade were not influenced ($P > 0.10$) by maternal diet. Progeny of dams on the RES treatment in late gestation had greater longissimus muscle area ($P = 0.04$) vs. progeny from CON dams, but not when adjusted on a HCW basis ($P > 0.10$). Proportion of progeny producing USDA Yield Grade 3 carcasses was least from dams restricted only in late gestation (CON-RES), and greatest from dams restricted throughout gestation (RES-RES; $P < 0.05$). Minimal differences in animal performance and carcass characteristics suggest MP restriction imposed during mid- and late gestation in this study did not have a significant developmental programming effect.

Introduction

The fetal origins hypothesis suggests that exposing the fetus to an adverse environment *in utero* leads to permanent programming of tissue function and increased risk of disease (Drake and Walker, 2004). Maternal under-nutrition at various stages of development can alter tissue development in the offspring and influence postnatal performance and feed efficiency during the finishing phase (Funston et al., 2010). Metabolizable protein (MP) is defined as true protein absorbed in the intestine, consisting of microbial protein and ruminally undegraded protein sources. Little research has been conducted investigating the effects of maternal MP restriction on progeny growth, feed efficiency, and carcass characteristics of beef cattle. The objective of this study was to investigate the impact of MP restriction in mid- and late gestation on feedlot performance and carcass characteristics of progeny.

Experimental Procedures

A detailed description of the animals, experimental design, and experimental treatments is available in the companion paper (Block et al., 2020). In brief, two-year-old Angus × Simmental heifers (n = 108) were pen-fed at the SDSU Cottonwood Range and Livestock Field Station during the treatment period. Treatments were arranged in a 2 × 2 factorial structure with 2 levels of dietary MP provided during 2 stages of gestation (mid and late) in a randomized complete block design. Dietary MP levels included: control (CON; approximately 101% of MP requirement) and restricted (RES; approximately 80% of MP requirement supplied based on Level 2 of NRC (2000). 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). Each treatment combination was randomly assigned to 1 pen per block for a total of 3 pen replicates per treatment combination.

Progeny were weaned and placed in a GrowSafe feeding system (GrowSafe Systems Ltd., Airdrie, AB Canada) to collect individual feed intake data. Progeny were adapted to a final finishing diet over 110 d using 4 step-up diets (Table 1). All progeny received the same diet throughout the feeding period because the only treatment applied in this study was maternal dietary treatment. Initial feedlot weights were collected. All calves received an initial feedlot implant of Revalor-IS (80 mg trenbolone acetate and 16 mg estradiol, Merck Animal Health, Madison, NJ) or Revalor-IH (80 mg trenbolone acetate and 8 mg estradiol; Merck Animal Health, Madison, NJ) for steers and heifers, respectively. Cattle were re-implanted with Revalor-200 (200 mg trenbolone acetate and 20 mg estradiol). Cattle were fed and managed to maintain health and achieve an industry average endpoint of approximately 0.5 inches of backfat at harvest. Individual carcass measurements included hot carcass weight (HCW), longissimus muscle (LM) area, 12th rib fat thickness, and estimated percentage of kidney pelvic heart fat (KPH). Yield Grade was calculated according to USDA guidelines, and marbling score and carcass maturity were recorded and used to determine USDA Quality Grade. Final live BW was determined as HCW divided by 0.625 (assumed dressing percentage).

Results and Discussion

There were no differences ($P > 0.10$) in initial or final BW, dry matter intake (DMI), or average daily gain (ADG) of progeny due to maternal nutritional treatment during the backgrounding and finishing phase; however, there was a tendency ($P = 0.084$) for slightly improved gain:feed (G:F) for progeny whose dams were on the RES treatment in late gestation (Table 2). Small differences in G:F were inconsistent with similar treatment means for DMI and ADG, therefore would not be considered biologically relevant. There was no influence ($P > 0.10$) of maternal diet during gestation for progeny HCW, adjusted 12^{th} rib fat thickness, KPH, USDA Yield Grade, marbling score, or proportion of carcasses in each USDA Quality Grade (Table 3). Longissimus muscle area for calves whose dams were restricted in late gestation was greater ($P = 0.039$) compared with those from dams on the control treatment; however, there was no difference among treatment groups ($P = 0.231$) when LM area was analyzed using HCW as a covariate

(Table 3). Although it may have appeared MP restriction during late gestation resulted in increased LM area of progeny, similar treatment means between groups with the HCW adjustment indicated this response was primarily a function of body mass. There was a mid- × late gestation treatment interaction (*P* = 0.049) for proportion of progeny in the USDA Yield Grade 3 category (Figure 3.1). Progeny from dams restricted throughout gestation (RES-RES) had the greatest proportion of USDA Yield Grade 3 carcasses, while progeny from dams restricted only in late gestation (CON-RES) had the least (72.1% ± 10.02 vs. 37.6% ± 10.84, respectively). Progeny from CON-CON and RES-CON treatments were intermediate (63.1% ± 10.61 and 55.9% ± 11.33, respectively) and similar to other treatments (*P* > 0.05). This response is difficult to interpret since there were no significant main effects or interactions observed for any other USDA Yield Grade category. In addition, mean yield grade and all carcass characteristics included in yield grade calculations (HCW, KPH, fat thickness) were similar (*P* > 0.10) among treatments.

Implications

Metabolizable protein restriction of heifers in mid- and late gestation did not substantially influence feedlot performance or carcass characteristics of progeny. Results of this study indicate offspring may be able to recover from moderate MP restriction during development when exposed to an unrestricted nutritional environment postnatally. Future investigation is warranted to determine specific impacts of maternal nutrient restriction on metabolic changes and development of specific tissues in the fetus that can impact lifetime performance and production of beef cattle.

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Table 1. Diet composition (DM basis) of backgrounding and finishing rations for progeny of heifers fed a control (CON = approximately 101% of MP requirement supplied) or restricted (RES = approximately 80% of MP requirement supplied) diet during mid- and/or late gestation[1]

Item	Step-up rations 1-4				Finishing ration
Dates fed	10/20-27	10/27-11/2	11/3-12/19	12/20-2/8	2/9-Harvest
Dry rolled corn, %	20	30	41	48	48
Grass hay, %	35	25	14	7	7
Corn gluten feed, %	35	35	35	35	40
Grow supplement[2], %	10	10	10	10	-
Finish supplement[3], %	-	-	-	-	5
Nutrient composition[4]					
DM, %	74.25	75.25	75.91	77.07	75.05
CP, %	12.91	12.99	11.48	13.13	11.47
NE_m, Mcal/lb	0.70	0.74	0.80	0.82	0.81
NE_g, Mcal/lb	0.60	0.64	0.69	0.71	0.73

[1] Dietary MP levels based on NRC (2000) predicted requirements; mid-gestation treatment applied mean d 148 through 216 of gestation; late gestation treatment applied mean d 217 of gestation through parturition

[2] Supplement formulated to provide minerals and vitamins to meet nutrient requirements (NRC, 2000) using dried distillers grains, limestone, iodized salt, ammonium chloride, trace mineral mix, Vitamins A, D, and E, monensin (Rumensin, Elanco Animal Health, Greenfield, IN), and tylosin phosphate (Tylan 40, Elanco Animal Health Greenfield, IN)

[3] Supplement formulated to provide minerals and vitamins to meet nutrient requirements (NRC, 2000) using ground corn, limestone, iodized salt, ammonium chloride, trace mineral mix, Vitamins A, D, and E, monensin (Rumensin, Elanco Animal Health, Greenfield, IN), and tylosin phosphate (Tylan 40, Elanco Animal Health Greenfield, IN)

[4] Nutrient composition for each ration based on wet chemistry analyses as reported by Ward Laboratories, Inc., Kearney, NE

Table 2. Main effect least square means for feedlot performance for progeny of heifers fed a control (CON = approximately 101% of MP requirement supplied) or restricted (RES = approximately 80% of MP requirement supplied) diet during mid- and/or late gestation[1]

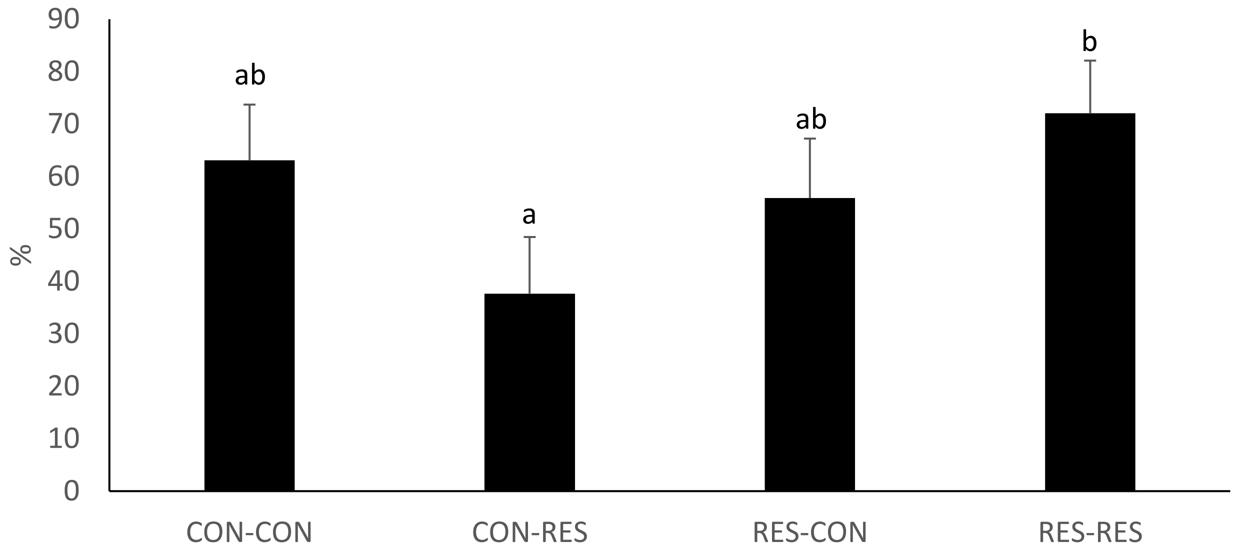
	Mid-gestation			Late gestation				*P*-value	
Item	CON	RES		CON	RES		SEM	Mid	Late
Initial BW[2], lb	571	560		562	571		11.0	0.434	0.550
Final BW[3], lb	1263	1246		1239	1268		20.5	0.401	0.225
DMI[4], lb	22.18	22.18		22.18	22.18		0.315	0.984	0.972
ADG[5], lb	4.01	3.97		3.95	4.06		0.064	0.557	0.176
G:F[6]	0.182	0.179		0.178	0.183		0.002	0.369	**0.084**

[1] Dietary MP levels based on NRC (2000) predicted requirements; mid-gestation treatment applied mean d 148 through 216 of gestation; late gestation treatment applied mean d 217 of gestation through parturition
[2] Body weight (BW) based on average of 2-day weights
[3] BW based on HCW/0.625 (assumed dressing percentage)
[4] Dry matter intake (DMI)
[5] Average daily gain (ADG)
[6] Gain:feed (G:F)

Table 3. Main effect least square means for carcass characteristics for progeny of heifers fed a control (CON = approximately 101% of MP requirement supplied) or restricted (RES = approximately 80% of MP requirement supplied) diet during mid- and/or late gestation[1]

	Mid-gestation			Late gestation				*P*-value	
Item	CON	RES		CON	RES		SEM	Mid	Late
HCW, lb	789	778		776	791		12.8	0.400	0.222
12th rib FT[2], in	0.63	0.61		0.64	0.59		0.029	0.661	0.248
LM area[3], in^2	14.21	14.15		13.95	14.40		0.253	0.774	**0.039**
Adj LM area[4], in^2	14.15	14.21		14.04	14.31		0.291	0.756	0.231
KPH, %	2.24	2.13		2.14	2.23		0.085	0.230	0.342
Yield grade	2.76	2.67		2.79	2.65		0.135	0.597	0.443
Marbling score[5]	514	515		520	509		22.8	0.982	0.601
USDA Quality Grade									
Choice, %	81.0	86.1		80.7	86.4		5.82	0.622	0.588
Prime, %	19.0	13.9		19.3	13.6		5.82	0.622	0.588
USDA Yield Grade[6]									
Yield grade 2, %	20.5	15.6		15.0	21.1		6.18	0.650	0.581
Yield grade 3, %	50.4	64.4		59.6	55.5		9.18	0.181	0.695
Yield grade 4, %	19.3	16.0		21.6	14.2		10.33	0.671	0.341

[1] Dietary MP levels based on NRC (2000) predicted requirements; mid-gestation treatment applied mean d 148 through 216 of gestation; late gestation treatment applied mean d 217 of gestation through parturition
[2] 12th rib fat thickness
[3] longissimus muscle (LM) area
[4] Adj. LM area determined using HCW as a covariate in the model
[5] 400 = Small[00]; 500 = Modest[00]; 600 = Moderate[0]
[6] Only 1 animal was Yield Grade 1 and 2 animals were Yield Grade 5



[a,b] Means lacking a common superscript differ ($P < 0.05$)

Figure 1. Least square means for mid-gestation treatment × late gestation treatment interaction ($P = 0.049$) for proportion of USDA Yield Grade 3 carcasses of progeny from heifers receiving a control (CON; slightly exceeding MP requirement) or restricted (RES; approximately 80% of MP requirement supplied) diet during mid- and/or late gestation