Influence of protein and energy supplementation during mid-gestion on beef heifers and their offspring while grazing pasture

Shelby L. Sullivan[1], Jennifer L. Hurlbert[1], Leticia Bortolanza Soares[1,3], Roberta B.A. Dahlen[1], German Ramirez Zamudio[1,3], Eva Tastad[1], Kevin. K. Sedivec[2], and Carl R. Dahlen[1]

The objective of this study was to evaluate the effects of feeding a protein and energy supplement during mid-gestation on body weight, growth performance, body composition traits, blood metabolites, and offspring growth responses of grazing beef heifers. Heifers receiving a supplement had greater body weight gain, ribeye area, and fat measurements after the supplement period, and their offspring tended to be heavier through pasture turnout. In addition, their blood metabolite responses were consistent with improved nutrient status, indicating that strategic supplementation can help maintain heifer performance when forage quality is declining.

Summary

Maternal nutrition during gestation plays a central role in regulating dam performance, placental function, fetal development, and offspring productivity (Funston et al., 2010). The objective of this study was to evaluate the effects of protein and energy supplementation during mid-gestation on dam and offspring performance, including body weight (BW), blood metabolites, and body composition. The study was conducted at North Dakota State University's Central Grassland Research Extension Center (CGREC) in Streeter, North Dakota. Pregnant crossbred Angus-based heifers (n = 46) each carrying a male fetus from a single artificial insemination sire were used for the study. Heifers were randomly assigned to either a control treatment (CON; n = 22) or a supplemented treatment (SUPP; n = 24). Supplemented heifers received supplement, at 0.6% of body weight (as-fed basis; dry matter adjusted), delivered individually through SmartFeed Pro trailers (C-Lock Inc., Rapid City, South Dakota), during a 90-day grazing period. Body weight and blood samples were evaluated at four intervals throughout the trial, and body composition, including rump fat, rib fat, ribeye area (REA) and intramuscular fat (IMF), was determined via ultrasound at the beginning and end of the trial. Supplemented heifers had greater final body weight than control heifers (493.8 ± 8.35 vs. 440.0 ± 7.76 kg; $P < 0.0001$). At the end of the trial, supplemented heifers also had more ($P < 0.0001$) rump fat and rib fat and greater REA than control heifers, whereas IMF did not differ. Blood results supported these performance responses, as supplemented heifers had greater ($P < 0.0001$) glucose and blood urea nitrogen (BUN) at selected sampling times, while control heifers had greater nonesterified fatty acids (NEFA) on day 56 of the trial and tended to remain greater on day 90. Overall, these findings indicate that protein and energy supplementation during mid-gestation can potentially improve growth, body condition and metabolic status of grazing beef heifers. Calves from supplemented dams tended to be heavier at birth, at turnout and at breeding than calves from control dams, indicating potential developmental programming effects that could persist postnatally.

Introduction

In forage-based beef production systems, maternal nutrition during gestation can influence fetal development and subsequent offspring performance (Shokrollahi et al., 2025). This issue is especially relevant at the CGREC in the Missouri Coteau region of central North Dakota, where grazing cattle rely on native mixed-grass prairie and forage quality declines as the season advances. Previous work

[1]North Dakota State University Department of Animal Sciences, Center for Nutrition and Pregnancy, Fargo, ND, USA
[2]North Dakota State University, Central Grasslands Research Extension Center, Streeter, ND, USA
[3]University of São Paulo, São Paulo, Brazil

from this region has shown that advancing season is associated with increased forage fiber and reduced nitrogen and digestibility, indicating a progressive decline in nutritive value of grazed forage (Chilcoat et al., 2016). Similarly, McCarthy et al. (2023) characterized this seasonal trajectory at CGREC by tracking forage crude protein, fiber and mineral composition across a late-summer to early-fall grazing period on native mixed prairie and relating those changes to heifer performance and supplementation responses. As the grazing season progresses, forage crude protein declines and fiber increases, which may reduce forage nutritive value enough to increase the need for supplementation in grazing cattle (McCarthy et al., 2023; Chilcoat et al., 2016). For spring calving cows in North Dakota, the late-summer to early-fall pasture quality decline overlaps with mid-gestation. Inadequate maternal nutrition at this stage is broadly understood to alter fetal development and to carry over to the calf at birth and through the early postnatal period (Shokrollahi et al., 2025).

Therefore, the objective of this study was to evaluate the effects of maternal protein and energy supplementation during midgestation on body weight, growth performance, body composition, blood metabolites and offspring outcomes of grazing beef heifers over a 90-day feeding period. We hypothesized that supplemented heifers would have greater weight gain, heavier final BW, improved body composition and blood metabolite responses consistent with improved nutrient status compared with nonsupplemented control heifers. Along with this, we also hypothesized that calves from supplemented heifers would have improved birth weight, vigor, and early postnatal growth compared to calves from nonsupplemented control heifers.

Procedures

Pregnant crossbred Angus-based heifers located at CGREC were used to evaluate a mid-gestation supplementation program. Prior to treatment assignment, all heifers were managed together under the same conditions through breeding and early gestation. A total of 150 heifers were artificially inseminated with male-sexed semen from a single sire. After pregnancy confirmation and a two-week acclimation period to SmartFeed Pro trailers, 46 heifers carrying male fetuses were assigned to either a control treatment (CON; n = 22) or a supplemented treatment (SUPP; n = 24) and grazed pasture for 90 days (d). Supplemented heifers received a pelleted protein and energy supplement at 0.6% of their BW, delivered through SmartFeed Pro trailers. The supplement was composed primarily of wheat middlings, cracked corn, DDGS ethanol and ground fine corn. Guaranteed analysis from the manufacturer indicated a minimum of 16.0% crude protein (CP) and 7.5% crude fat, with a maximum of 5.6% crude fiber, calcium ranging from 0.01 to 0.51%, and phosphorus ranging from 0.65 to 0.74%. Nutrient analysis conducted by the NDSU Nutrition Laboratory was similar, reporting 16.12% CP, 8.29% crude fat, 5.50% crude fiber, 0.07% calcium, and 0.65% phosphorus.

During the 90-day supplementation period, heifers remained at CGREC but were managed in a separate pasture from the remainder of the herd. Body weights and blood samples were collected on days 0, 27, 56 and 90 using a two-day consecutive weighing procedure, and body weight gain and average daily gain (ADG) were calculated. Forage samples were collected at three sampling intervals during the grazing period at days 0, 27 and 56 of the trial. At each interval, forage was clipped from 16 plots within the pasture to a height of 3.75 cm above ground (Undi et al., 2008), and each sample was weighed and oven dried in a forced-air oven at 60 degrees Celsius for at least 48 hours. Dried samples were ground through a 2-mm screen using a Wiley mill (Arthur H. Thomas, Philadelphia, PA). Following grinding, 5.0-gram subsamples from each of the 16 samples were combined to form one composite sample for laboratory analysis at each collection interval. Ultrasound measurements were taken at the beginning and end of the feeding period to evaluate rump fat, rib fat, ribeye area (REA) and intramuscular fat (IMF). Blood serum samples were analyzed for glucose, blood urea nitrogen (BUN) and nonesterified fatty acids (NEFA).

Following the 90-day supplementation period, all heifers were recombined with original herd and managed together through calving. Additional body weights and blood samples were collected from dams on day 263 of gestation. Calf body weights were recorded at calving (n = 41) and again at pasture turnout (approximately 2 months of age) and at dam breeding (approximately 3 months of age) to assess early offspring performance associated with dam treatment. After calving, all cow-calf pairs were managed together as a single group until pasture turnout at day 59 postpartum (PP), body weights and blood samples were collected from dams, and body weights were collected from calves.

Statistical Analysis

Data were analyzed using SAS 9.4 (SAS Inst. Inc., Cary, NC). For heifer variables, the individual heifer served as the experimental unit. Blood metabolite data were analyzed using the MIXED procedure of SAS with treatment, collection day, and the treatment × day interaction included as fixed effects. Day was treated as a repeated measure, with heifer ID as the subject and an autoregressive covariance structure [AR(1)] applied. For calf BW data, the individual calf served as the experimental unit. Calf BW was analyzed using the MIXED procedure with dam treatment, day, and the dam treatment × day interaction as fixed effects, and day treated as a repeated measure with calf ID as the subject. Denominator degrees of freedom were adjusted using the Kenward-Roger method. Results are presented as least squares means (LSMEANS) with standard error (SE). Significance was declared at $P \leq 0.05$ and tendencies at $0.05 \leq P \leq 0.10$.

Results and Discussion

Forage composition of composite pasture samples indicated changes in nutritional value across the grazing period (Table 1). Total digestible nutrients (TDN) remained relatively stable, ranging from 60.5 to 62.0%. However, crude protein (CP) declined from 9.02% in September to 7.1% in October and 6.8% in November. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were lowest in October (59.1% and 34.1% respectively), suggesting greater intake potential and digestibility in October than in September or November. In contrast, the lower CP concentration observed in November indicates that forage quality declined later in the grazing season.

Heifer body weight was impacted by a treatment × day interaction (Figure 1). Though similar at the initiation of treatments, (416.7 ± 73 vs. 426.7 ± 7.84 kg for CON and SUPP, respectively) the SUPP heifers became heavier by the end of the feeding period compared with CON heifers (493.8 ± 8.35 vs. 440.0 ± 7.76 kg; $P < 0.0001$). Average daily gain over the feeding period was greater for SUPP than CON heifers (0.73 ± 0.03 vs. 0.24 ± 0.03 kg/day; adjusted $P < 0.0001$). Daily gain over each of the individual periods showed a similar pattern: gains did not differ from day 0 to 27 (1.14 vs 1.02 kg/d; $P = 0.2041$), but SUPP heifers gained more during each of the weight intervals through the end of the experiment. Interestingly, during the period from day 57 to 90, CON heifers lost weight whereas SUPP heifers maintained a slight gain (0.09 vs. -0.64 kg/d; $P < 0.0001$). These results suggest supplementation became more important as the trial progressed

Table 1. Forage analysis of representative sample composites of pasture grazed by beef heifers during the grazing period.[1, 4]

	Grazing period[2]		
Item	September	October	November
TDN[3]	54.39	51.96	53.50
CP, %	8.80	6.90	8.11
Ash	10.57	10.72	11.00
NDF, %	67.16	74.25	72.54
ADF, %	43.68	46.76	44.81
Ca, %	0.51	0.43	0.48
P, %	0.10	0.08	0.10
S, %	0.33	0.29	0.31
N, %	1.41	1.10	1.30

[1]Clipped forage samples from 16 different locations reported herein are composite over all locations within the representative sampling dates.
[2]Values presented are mean values of the representative sampling dates within the given month: September (n = 1), October (n = 1), and November (n = 1).
[3]TDN = 88.9 – (0.79 × ADF%); Holland and Kezar, 1995
[4]SUPP = heifers grazing pasture receiving protein and energy supplementation; CON = heifers grazing pasture without supplementation.

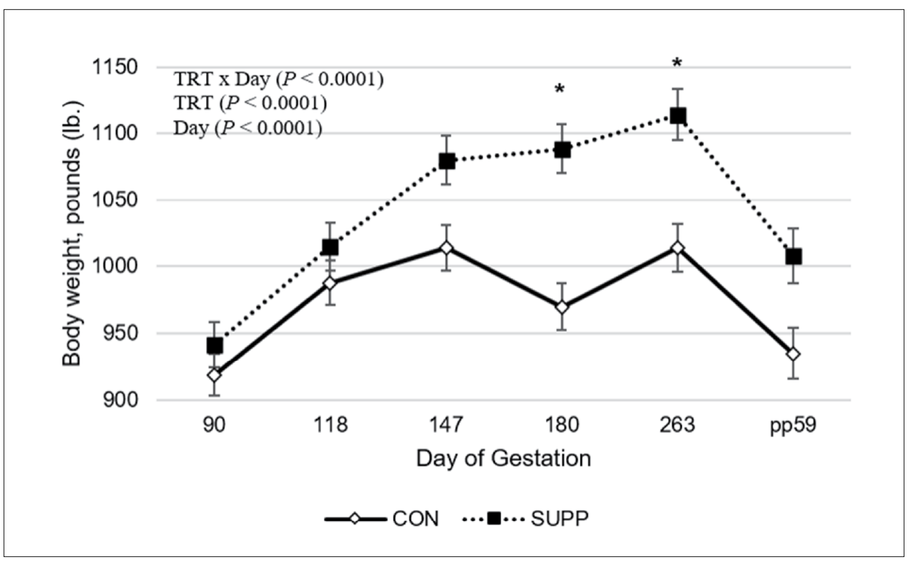

Figure 1. Body weight (lb) of the control (CON) and supplemented (SUPP) heifers measured on day 0 = 90, 27 = 118, 56 = 147, 90 = 180 of the trial through day 59 postpartum (pp). Error bars represent variability among animals.

and pasture conditions became less favorable.

Ultrasound measurements also indicated that body composition changed through the feeding period (Table 2). At the end of the trial, SUPP heifers had greater rump fat (1.93 ± 0.14 vs. 1.16 ± 0.11 cm; $P < 0.001$), rib fat (1.22 ± 0.07 vs. 0.81 ± 0.05 cm; $P < 0.0001$), and REA (67.35 ± 1.81 vs. 55.10 ± 1.42 cm^2; $P < 0.001$) than CON heifers, whereas IMF did not differ (5.18 ± 0.24 vs. 5.64 ± 0.16 %; $P = 0.113$). Changes over the feeding period followed the same pattern. Together, these results suggest that supplementation results in greater deposition of muscle and external fat during the study period, while IMF was not affected.

Blood metabolite responses were affected by treatment × day interactions for glucose, BUN, and NEFA (Figure 2). Glucose concentrations were greater in SUPP than CON heifers on day 27 (64.0 vs. 58.9 mg/dL; $P = 0.025$) and day 56 (65.5 vs 55.2 mg/dL; $P < 0.0001$) but did not differ on day 0 or 90 of the trial nor day 263 of gestation. Likewise, BUN concentrations were greater in SUPP than CON heifers on day 27 (11.4 vs. 7.2 mg/dL; $P < 0.0001$), day 56 (17.6 vs. 12.8 mg/dL; $P < 0.0001$), and day 90 (15.7 vs. 10.3 mg/dL; $P < 0.0001$), with no differences on day 0 of trial or day 263 of gestation. In contrast, NEFA concentrations were greater in CON than SUPP heifers on day 56 (408.4 vs. 189.9 mEq/L; $P < 0.0001$) and day 90 (622.4 vs. 529.0 mEq/L; $P = 0.13$) but did not differ on day 0 or 27 of trial nor 263 of gestation. These blood metabolite results suggest supplemented heifers were in a more favorable nutritional state during the trial, which is consistent with their improved BW gain and body composition.

Calf BW was not affected by dam treatment × day interaction ($P = 0.35$). Calf BW tended to be greater for calves born to SUPP dams than calves born to CON dams ($P = 0.06$). Across all calves, average BW was 34.7 kg at birth, 85.3 kg at turnout and 130.3 kg at breeding. Numerically, calves from supplemented dams were heavier at each time point, averaging 35.5 kg to 34.06 kg at birth, 87.99 kg to 82.70 kg at pasture turnout and 134.62 kg to 126.02 kg at mid-summer for SUPP and CON dams. These results suggest that maternal protein and energy supplementation during mid-gestation may have slightly improved early calf growth, but further post-natal evaluations are needed to confirm whether body weight changes persist toward sexual maturity.

Table 2. Ultrasound body composition characteristics at the beginning and end of the 90-day feeding period.

	Treatment[1]			
Item	CON	SUPP	SEM	*P*-value
Rump fat, in				
Beginning	0.19	0.20	0.02	0.5398
End	0.18	0.31	0.02	0.0001
Change[2]	-0.002	0.109	0.01	<0.0001
Rib fat, in				
Beginning	0.14	0.14	0.01	0.9988
End	0.13	0.19	0.01	<0.0001
Change	-0.018	0.049	0.009	<0.0001
REA, in^2				
Beginning	9.46	9.33	1.71	0.726
End	8.45	10.41	1.80	<0.0001
Change	-1.018	1.074	1.07	<0.0001
IMF, %				
Beginning	4.89	4.81	0.19	0.7655
End	5.58	5.23	0.209	0.2568
Change	0.686	0.426	0.148	0.2221

[1]Treatment
[2]Change = measurement at end of experiment – measurement at beginning of experiment

Conclusion

Overall, these results suggest that protein and energy supplementation during mid-gestation helps grazing beef heifers maintain growth, body condition, and muscle area when pasture quality is declining. Supplemented heifers finished the trial heavier, had greater ADG, and showed greater rump fat, rib fat, and REA than CON heifers, while IMF did not differ between treatments. Blood metabolite responses supported this interpretation, indicating that SUPP heifers were in a more favorable nutritional state during the trial. In addition, calves born to SUPP dams tended to be heavier through pasture turnout and mid-summer than calves born to CON dams. Together, these findings suggest that strategic supplementation during mid-gestation may be a useful management practice for producers when forage alone does not meet nutrient requirements and that impacts may extend into the postnatal period for calves gestated in this paradigm.

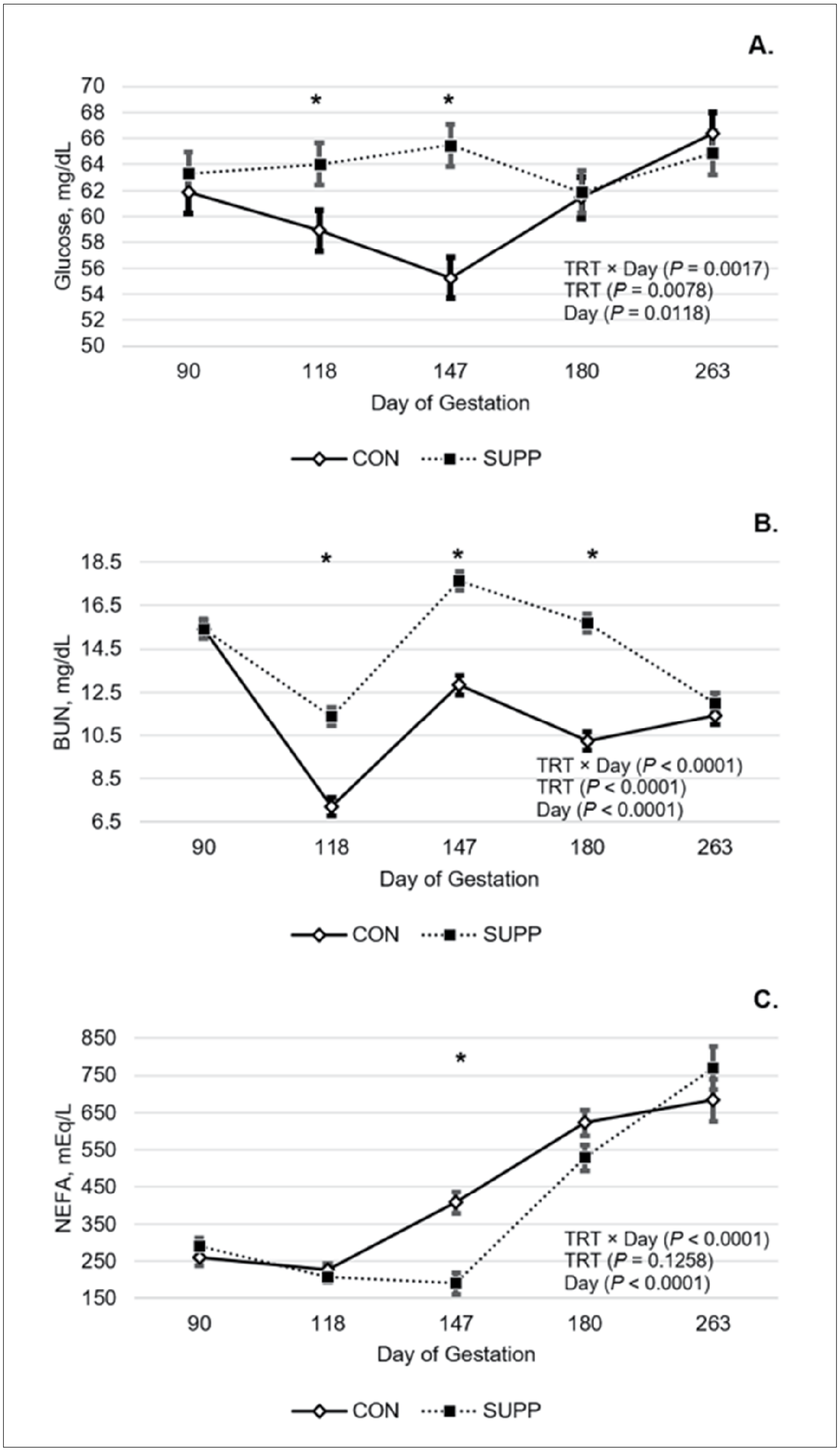

Figure 2. Concentrations of glucose (A), blood urea nitrogen (BUN; B), and nonesterified fatty acids (NEFA; C) during gestation in control (CON) heifers maintained on pasture only and supplemented (SUPP) heifers receiving protein and energy supplementation at 0.6% of BW on pasture. Values are least squares means ± SE. Significance was declared at $P \leq 0.05$ and tendency at $0.05 < P < 0.10$. Trial days correspond to gestation days as follows: d 0 = 90, d 27 = 118, d 56 = 147, and d 90 = 180 of gestation.

References

Chilcoat, K. E., M. S. Crouse, B. W. Neville, and J. S. Caton. 2016. effects of grazing intensity and advancing season on dietary chemical composition and in vitro organic matter digestibility in steers grazing mixed-grass prairie. J. Anim. Sci. 87:375–383.

Funston, R.N., Martin, J.L., Adams, D.C., & Larson, D.M. (2010). Winter grazing system and supplementation of beef cows during late gestation: Effects on progeny performance. J. Anim. Sci. 88:4094–4101.

McCarthy, K. L., S. R. Underdahl, M. Undi, and C. R. Dahlen. 2023. Using precision tools to manage and evaluate the effects of mineral and protein/energy supplements fed to grazing beef heifers. Transl. Anim. Sci. 7:txad013.

Shokrollahi, B., M. Park, G. S. Jang, S. Jin, S. J. Moon, K. H. Um, S. S. Jang, and Y. C. Baek. 2025. Maternal overnutrition in beef cattle: effects on fetal programming, metabolic health, and postnatal outcomes. Biology (Basel). 14:14060645.

Undi, M., C. Wilson, K. H. Ominski, K. M. Wittenberg, and K. Wittenberg. 2008. Comparison of techniques for estimation of forage dry matter intake by grazing beef cattle. Can. J. Anim. Sci. 88:693-701.