Protein and energy supplementation during midgestation in beef heifers and the impacts on maternal performance, metabolic status, calving characteristics and offspring outcomes through weaning

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This study evaluated whether protein and energy supplementation during midgestation could improve heifer nutritional status, calving characteristics and calf growth through weaning. Strategic protein and energy supplementation during midgestation improved heifer body weight and condition and reduced reliance on body reserves for protein and energy metabolism. Calves born to supplemented heifers were heavier at birth and tended to be heavier through weaning, with the greatest weight advantage observed at pasture turn out.

Summary

Forage quality for beef cattle often declines in late summer, fall and winter, potentially limiting the protein and dietary energy available to pregnant cows and heifers. Strategic supplementation during midgestation may help meet increasing nutrient demands while supporting dam condition and calf growth. This study evaluated whether protein and energy supplementation of pregnant beef heifers from day 90 to 186 of gestation could improve dam nutritional status and calf growth through weaning. Heifers received either a forage-based diet (CON; n = 22) or a forage-based diet plus a protein and energy supplement (SUPP; n = 22) before being managed similarly after the supplementation period. Supplemented heifers gained more weight, had greater body condition scores and had lower circulating nonesterified fatty acids, indicating less reliance on body fat reserves. Calves from supplemented heifers were 5.2 lb heavier at birth and tended to be heavier through weaning, with the greatest weight advantage of 17.5 lb observed at pasture turnout. Overall, strategic protein and energy supplementation during midgestation improved maternal nutritional status and supported greater early life calf growth, although further evaluation is needed to determine whether these benefits persist beyond weaning. Further evaluation of postweaning performance and subsequent breeding season success in the cow herd will help determine the long-term production value of this management strategy.

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Introduction

Nutritive value of grazed forages for beef cattle often declines in the late summer/fall and winter months, with crude protein levels dropping below 6% in some regions (Schauer et al., 2005). During this period, pregnant heifers in the northern Great Plains, often in their second trimester of gestation for spring-calving cow herds, may struggle to meet the protein and energy demands of gestation with grazed forages alone. Strategic supplementation during midgestation therefore has the potential not only improve forage utilization and digestibility in the dam but also elicit positive outcomes on calf growth before birth and subsequently throughout postnatal life (Llewellyn et al., 2006; Cappellozza et al., 2014).

The objectives were to evaluate the impacts of providing a protein and energy supplement to beef heifers during midgestation on dam performance, calving outcomes, circulating blood metabolites in the dam and calf, and growth performance of the male offspring through weaning. We hypothesized that protein/energy supplementation would increase dam and calf body weights, enhance circulating blood metabolites, and positively influence placental and colostrum characteristics at calving and postnatal growth in the calf.

Procedures

Angus-based beef heifers (n = 143) were bred via artificial insemination (AI) using male sexed semen at the NDSU Central Grasslands Research Extension Center (CGREC). Pregnancies were confirmed on day 35 after breeding, and fetal sex was determined at day 65 after breeding. Shortly after, all heifers pregnant to AI with male fetuses (n = 44; initial body weight [BW] = = 940.9 ± 68 lb) were transported to the NDSU Beef Cattle Research Complex (BCRC) in Fargo, North Dakota, stratified by body weight and randomly assigned to receive a protein and energy supplement with a basal forage diet (SUPP; n = 22) or a basal forage diet with no supplementation (CON; n = 22) from day 90 to day 186 of gestation. The diet for SUPP heifers consisted of 30% corn silage, 45% grass hay and 25% Accuration (Land O' Lakes Purina) on a dry-matter basis, while the diet for CON heifers consisted of 40% corn silage and 60% grass hay on a dry-matter basis. All heifers received a pelleted mineral product at the company-directed rate of 1 lb per day.

Daily feed intakes were managed strategically with the Insentec feeding system to target daily gains of 0.62 lb/day for heifers assigned to CON and 1.74 lb/day for heifers assigned to SUPP. Body weights were collected on the pregnant heifers every two weeks and body condition scores on a nine-point scale were recorded at the start (day 90), midpoint (day 138) and end (day 186) of the second trimester feeding trial. Following the treatment period, all heifers were transported back to the CGREC and managed on a common forage-based diet through parturition and pasture turnout. Heifers were also weighed shortly before calving (d 257), at calving (average d 279) and at pasture turnout (average 68 day postpartum). Blood samples were collected from the dams at these six major time points throughout the experiment and from their calves at birth, pasture turnout and at weaning. Blood serum samples were analyzed for concentrations of glucose, nonesterified fatty acids (NEFA) and blood urea nitrogen (BUN).

At calving and prior to suckling, BW of the dam and neonatal calf (*n* = 21 CON; *n* = 21 SUPP) were recorded, and calving date was recorded to calculate gestation length. Dams were assigned a calving ease score from 1 to 5 (1 = unassisted birth to 5 = cesarean). Additionally, a single quarter of the udder was completely milked to estimate colostrum volume and mass. The placenta was collected upon expulsion and rinsed and weighed, and total number of cotyledons were counted. In the period shortly after birth, calves were assigned a vigor score of 1 to 5 (1 = nursed independently to 5 = stillborn). At 24 hours after colostrum consumption, calf BW was recorded, and morphometric characteristics were evaluated, including chest and abdominal circumference, crown-rump length, shoulder-to-hip length, hip width and hip height. Calves continued to be weighed at pasture turnout and at weaning.

As mentioned previously, the male calves born in this experiment were weighed, and blood was collected at birth, pasture turnout and weaning to determine if maternal supplementation influenced long-term growth and metabolism.

Statistical Methods

Data were analyzed as a completely randomized design, and individual animal was considered the experimental unit for all analysis. All variables were analyzed using the MIXED procedure of SAS with repeated measures applied where appropriate. Variables were analyzed for the effect of F0 treatment, day of gestation/age and the respective interaction. Significance was considered at $P \leq 0.05$, and tendencies considered at $0.05 < P \leq 0.10$.

Results and Discussion

The actual gains recorded during the midgestation supplementation period were 0.55 lb/day and 1.66 lb/day for CON and SUPP heifers, respectively. Furthermore, SUPP heifers were heavier than CON at the end of the supplementation period and at calving ($P = 0.02$; Figure 1).

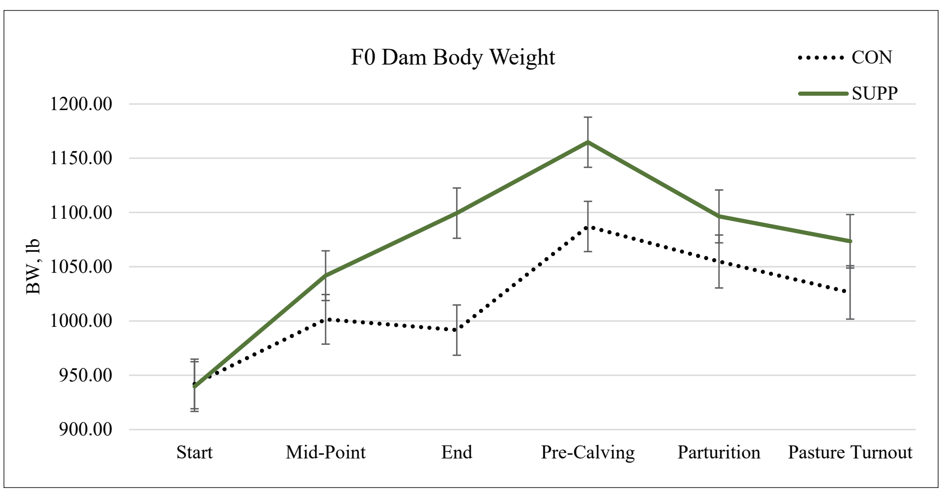

Figure 1. Body weights of pregnant (F0) beef heifers from the start of the second trimester of gestation (treatment start) to the conclusion of the second trimester (treatment end) and into late gestation and early lactation. Treatments were: F0 dams were provided with either a basal forage diet (CON) or a basal forage diet plus a protein and energy supplement (SUPP) from day 90 to 186 of gestation. * indicates significance ($P \leq 0.05$)

While heifers were similar in BW at the start of the trial (day 90 in pregnancy) by design, at day 186, we observed a 108-lb difference in BW between treatments ($P < 0.05$). Interestingly, this weight difference was sustained through late pregnancy (77-lb difference; $P < 0.05$) and pasture turnout (42-lb difference; $P < 0.10$). The body condition scores recorded during this period complement the weight differences we observed, with SUPP heifers having greater body condition scores at the end of the supplementation period than CON heifers (5.8 vs. 4.7 BCS; $P = 0.01$).

At calving, we observed no differences in gestation length ($P = 0.13$) between CON and SUPP (280 vs. 278 days, respectively), calving ease ($P = 0.32$) or calf vigor scores ($P = 0.68$). Colostrum production and mass were also not different ($P \geq 0.16$) between CON and SUPP, and placental characteristics (weight, number of cotyledons and weight of cotyledons) were not different ($P \geq 0.50$) between treatments. However, the F1 bull calves born to SUPP heifers were 5.2 lb heavier ($P = 0.04$) than calves born to CON heifers prior to suckling (Figure 2). Also at birth, SUPP calves had greater chest circumference ($P = 0.05$) and tended to have greater abdominal circumference and greater hip height measurements ($P < 0.10$) compared with CON. Despite a difference in birth weights of SUPP and CON calves, the long-term growth performance of the F1 bull calves was not impacted by the interaction of treatment and day ($P = 0.36$; Figure 2). However, postnatal bull calf growth performance tended ($P = 0.10$) to be greater in SUPP calves compared with CON, which was driven by a 17.5-lb weight advantage in SUPP calves at pasture turnout but only a 1-lb advantage in SUPP calves at weaning. Calf body weight was also impacted by the effect of day ($P < 0.01$), which is expected as calf weights increased from birth to weaning.

We observed no impact ($P \geq 0.18$) of the interaction of treatment and day on circulating blood metabolites in the dam for glucose or BUN. However, we observed a tendency ($P = 0.08$) for concentrations of NEFA in the F0 dam to be influenced by the interaction of treatment and day. We also observed that both NEFA and BUN were impacted ($P \leq 0.05$) by protein/energy supplementation during midgestation (Table 1), in which concentrations of NEFA were lower ($P = 0.02$) for SUPP heifers compared with CON and concentrations of BUN were greater ($P = 0.05$) in SUPP compared with CON heifers. We observed no impact ($P = 0.34$) of treatment during midgestation on circulating concentrations of glucose in the dam. The effect of day was also observed ($P \leq 0.01$) for glucose, NEFA and BUN in SUPP and CON dams (Table 1).

In the F1 bull calves born to CON and SUPP dams, we observed an interaction of treatment and day ($P = 0.04$) for concentrations of NEFA in the calf, indicating greater concentration of NEFA in SUPP calves at birth and pasture turn out ($P \leq 0.05$) compared with CON calves. We also observed an effect of day for concentrations of glucose and BUN in the F1 calf ($P \leq 0.01$). However, concentrations of glucose and BUN in the F1 calf were not influenced by the main effect of F0 maternal treatment ($P \geq 0.11$; Table 2).

Most fetal growth and increases in nutrient demand for the pregnant cow occur between mid- and late gestation. Because of this, the level of protein and energy provided to cows during midgestation can influence both cow condition and early calf performance. In the current study, protein and energy supplementation increased cow body weight, body condition score, and improved metabolic indicators of energy and protein status during pregnancy. Supplemented cows had lower circulating NEFA, indicating less reliance on body fat mobilization, and slightly greater BUN, reflecting improved protein intake and nitrogen availability (Silva et al., 2019). These results suggest that strategic supplementation helped cows meet pregnancy demands using dietary nutrients rather than body reserves.

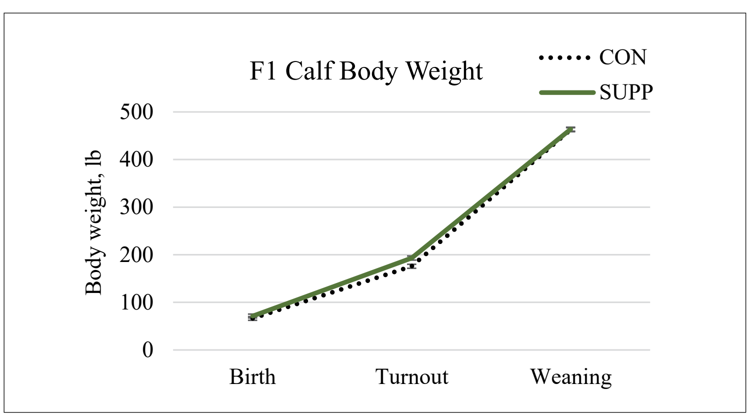

Figure 2. Body weights for the F1 bull calves from birth to weaning. Treatments of the F0 dams during midgestation were the following: F0 dams were provided with either a basal forage diet (CON) or a basal forage diet plus a protein and energy supplement (SUPP) from day 90 to 186 of gestation. Dams were managed as a single group from the end of the second trimester through weaning the next fall. Sampling timepoints were birth (average 279-day gestation length); pasture turnout (average 68 days of age), and weaning (average 174 days of age).

Table 1. Blood metabolites in F0 beef heifers during the supplementation period (day 90 to 186) through calving and pasture turnout.

	Treatment[1]			*P*-Values		
Item[3]	CON	SUPP	SEM[2]	TRT	Day	TRT×Day
Glucose, mg/dL				0.34	<0.01	0.79
Start	66.0	69.3	3.10			
Midpoint	60.0	64.0	3.07			
End	63.7	63.1	3.10			
Precalving	68.5	71.2	3.18			
Parturition	96.1	95.8	4.73			
Pasture Turnout	59.9	58.7	3.31			
NEFA, μmol/L				0.02	<0.01	0.08
Start	268.8	211.1	39.51			
Midpoint	264.7	270.9	38.97			
End	606.3	428.8	40.18			
Precalving	977.9	716.5	45.70			
Parturition	662.8	600.2	40.94			
Pasture Turnout	334.5	404.6	41.51			
BUN, mg/dL				0.05	<0.01	0.77
Start	7.6	7.7	0.56			
Midpoint	10.8	11.5	0.56			
End	11.1	11.8	0.57			
Precalving	9.6	9.4	0.57			
Parturition	6.7	7.5	0.59			
Pasture Turnout	8.9	9.7	0.61			

[1]Heifers were assigned to receive a basal forage diet with target body weight gains of 0.28 kg/hd/d (CON, n = 22) or a basal forage diet plus a protein and energy supplement with target body weight gains of 0.79 kg/hd/d (SUPP, n = 22).
[2]Standard error of the mean.
[3]Metabolites evaluated included glucose, nonesterified fatty acids (NEFA) and blood urea nitrogen (BUN).

Table 2. Blood metabolites in F1 male offspring born to dams provided with a basal diet (CON) or to dams provided with a basal diet plus a protein/energy supplement (SUPP).

	Treatment[1]			*P*-Values		
Item[3]	CON	SUPP	SEM[2]	TRT	Day	TRT×Day
Glucose, mg/dL				0.11	<0.01	0.61
Birth	70.4	63.3	4.01			
Turnout	97.8	89.8	4.23			
Weaning	81.5	80.8	4.12			
NEFA, μmol/L				0.01	0.03	0.14
Birth	172.2	252.6	27.51			
Turnout	92.5	194.2	29.29			
Weaning	209.4	208.8	26.74			
BUN, mg/dL				0.56	<0.01	0.19
Birth	9.1	10.3	0.48			
Turnout	8.9	8.9	0.52			
Weaning	16.4	15.9	0.50			

[1]F0 Heifers were assigned to receive a basal forage diet with target body weight gains of 0.28 kg/hd/d (CON, n = 22) or a basal forage diet plus a protein and energy supplement with target body weight gains of 0.79 kg/hd/d (SUPP, n = 22). The F1 offspring were managed on a common diet from birth through weaning.
[2]Standard error of the mean.
[3]Metabolites evaluated included glucose, nonesterified fatty acids (NEFA) and blood urea nitrogen (BUN).

Calves born to supplemented cows were 5.2 lb heavier at birth and 17.5 lb heavier at pasture turnout (approximately 70 days of age), demonstrating a short-term growth advantage. However, body weight differences did not persist through weaning, likely due to similar postnatal grazing conditions across treatment groups and catch-up growth exhibited by CON calves. Although long-term weight differences were not observed, calves from supplemented cows showed greater circulating NEFA early in life, suggesting differences in energy use or fat metabolism during the preweaning period. Because midgestation coincides with critical periods of muscle and fat tissue development, improved maternal nutrition during this window may influence early tissue growth and metabolic function in the calf.

Similar responses have been observed in related work from our laboratory, where protein and energy supplementation during early gestation in beef heifers resulted in sustained improvements in cow body weight and modest, short-term increases in calf birth weight, observed as a 2-lb birth weight advantage in calves born to supplemented dams (Baumgaertner et al., 2024). In that study, body weight differences in female offspring were negligible at weaning, but re-emerged after puberty, suggesting that gestational nutrition may have longer-term impacts on animal performance that are not immediately evident at weaning.

Overall, these findings indicate that strategic protein and energy supplementation during midgestation can improve cow condition, reduce reliance on body reserves and enhance early calf growth. While postweaning management may minimize visible weight differences, improved maternal nutrition during pregnancy may still provide long-term benefits for offspring performance and productivity. Additional evaluation of postweaning growth and carcass traits will help determine the full production value of midgestation supplementation programs for offspring developed for terminal or breeding markets.

Conclusions

These data show that providing supplemental protein and energy and greater rates of gain during the second trimester of pregnancy supported increased birth weight and body measurements in the neonatal calf, but did not impact maternal BW at calving, colostrum production or placental characteristics. Further evaluation of growth performance and metabolic phenotype in the F1 male offspring at later postnatal time points will help determine whether maternal nutritional management during gestation induces long-term programming outcomes that could enhance offspring productivity and contribute to global food security.

Funding Acknowledgements

The authors express their appreciation to the North Dakota Corn Utilization Council, Purina Animal Nutrition, and USDA-NIFA Predoctoral Fellowship #2024-67011-43015 for funding support of this project and the personnel involved in this effort. Appreciation is also given to the staff and students at the NDSU Beef Cattle Research Complex, Central Grasslands Research and Extension Center, and the NDSU Nutrition Lab.

Literature Cited

Baumgaertner, F., A. C. B. Menezes, W. J. S. Diniz, J. L. Hurlbert, K. A. Bochantin, S. R. Underdahl, J. D. Kirsch, S. T. Dorsam, K. L. McCarthy, G. D. Ramirez-Zamudio, K. K. Sedivec, J. S. Caton, and C. R. Dahlen. 2024. Effects of rate of body weight gain during the first trimester of gestation on beef heifer and offspring performance, concentrations of hormones and metabolites, and response to vaccination. *J. Anim. Sci*. 102:skae193.

Cappellozza, B. I., R. F. Cooke, M. M. Reis, P. Moriel, D. H. Keisler, and D. W. Bohnert. 2014. Supplementation based on protein or energy ingredients to beef cattle consuming low-quality cool-season forages: II. Performance, reproductive, and metabolic responses of replacement heifers. *J. Anim. Sci.* 92:2725–2734.

Llewellyn, D. A., R. C. Cochran, T. T. Marston, D. M. Grieger, C. G. Farmer, and T. A. Wickersham. 2006. Influence of limited fall protein supplementation on performance and forage utilization by beef cattle grazing low-quality native grass pastures. *Anim. Feed Sci. Technol*. 127:234–250.

Schauer, C. S., D. W. Bohnert, D. C. Ganskopp, C. J. Richards, and S. J. Falck. 2005. Influence of protein supplementation frequency on cows consuming low-quality forage: Performance, grazing behavior, and variation in supplement intake. *J. Anim. Sci.* 83:1715–1725.

Silva, L. F. P., R. M. Dixon, and D. F. A. Costa. 2019. Nitrogen recycling and feed efficiency of cattle fed protein-restricted diets. *Anim. Prod. Sci.* 59:2093–2107.