The Effects of Energy Supplementation during Early Gestation on Development, Growth and Reproductive Performance in Beef Heifers

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The objectives of this study were to evaluate the impact of feeding a corn-based energy supplement to replacement heifers during the first trimester of gestation (84 days) on heifer growth and reproductive performance. Feeding the energy supplement increased heifer body weights, rib fat and rib-eye area; however, no effects were observed on fetal size at day 42, day 63 and day 84 in this study.

Summary

We hypothesized that maternal nutrition during the first trimester of gestation would affect heifer body weight gain, body composition traits and fetal measurement (biparietal distance and crown-rump length). Crossbred Angus heifers (n = 100) from the Central Grasslands Research Extension Center (**CGREC**; Streeter, N.D.) were selected from the replacement pool and transported to the Beef Cattle Research Complex (Fargo, N.D.), where they were estrus synchronized, bred via artificial insemination (AI) to sexed semen from a single sire, and assigned to one of two nutritional treatments at the time of AI for an 84-day feeding period: 1) a basal diet (**CON**) or 2) the basal diet plus energy supplement (**NRG**; Purina® Accuration® Range Supplement 33 [Land O'Lakes Inc.]).

Only heifers that became pregnant to first-service AI with a heifer calf (CON, n = 23; NRG, n = 25) remained on this study after day 42. After the 84-day feeding period, heifers were transported back to the CGREC and managed as a single group.

Body weights were analyzed using the MIXED procedure of SAS, with treatment and date as the main effects, and their interaction, whereas the GLM procedure was used for analysis of carcass traits, average daily gain, biparietal distance and crown-rump length.

During the entire 84-day period, average daily gain was 1.21 pounds per day (lb/d) greater ($P < 0.01$) in NRG heifers (1.65 ± 0.04 lb/d), compared with CON (0.44 ± 0.04 lb/d) heifers. At the end of the 84-day feeding period, NRG heifers were on average 122.1 pounds heavier than CON heifers.

After heifers were transported back to the CGREC on day 85, they were managed as one pasture group with access to free-choice mineral. The weight difference achieved during the 84-day feeding period was maintained until day 234 of gestation. Nutritional treatment affected carcass characteristics at day 84; rib fat and rib-eye area were increased ($P < 0.01$), but the percentage of intramuscular fat was not affected ($P = 0.69$).

Fetal size at day 42, 63 or 83 ($P \geq 0.20$) was not affected by nutritional treatment. In this study, heifer growth, rib fat and rib eye were influenced by energy supplementation during early gestation; however, the percentage of intramuscular fat and fetal size were not affected.

Introduction

Maternal nutrition during pregnancy plays a major role in fetal and post-natal offspring development (Wu et al., 2006; Reynolds et al., 2010). The first trimester of gestation is characterized by placental establishment and vascularization, along with fetal organ development (Wu et al., 2004; Funston et al., 2010). Therefore, during this critical developmental window, fetal growth is vulnerable to maternal dietary nutrient supply, which may alter offspring physiology and metabolism permanently (Caton et al., 2019).

Additionally, special attention should be paid to the nutritional management of pregnant heifers because animals in this category require energy for growth as well as to maintain pregnancy (Reynolds and Caton, 2012; Vonnahme et al., 2015; Caton et al., 2019). While under- or overnutrition during early gestation, followed by feeding according to recommendations during mid and late gestation, may not affect birth weights, metabolism of the offspring may be affected, leading to alterations observed later in life (Reynolds and Caton, 2012).

For pasture-based production systems that rely on forage quality and quantity to meet nutrient demands during gestation, providing supplements may improve animal performance while reducing grazing pressure when seasonal forage quality cannot meet requirements (Caton and Dhuyvetter, 1997; Caton et al., 2019). For instance, supplementing replacement heifers postweaning can improve average daily gains (ADG), as was shown by Cappellozza et al. (2014) who found that heifers supplemented with energy (cracked corn, urea and soybean meal mix) or protein (soybean meal) before breeding gained more per day than control heifers.

Because nutritional management of replacement heifers has long-term effects on cow herd performance and profitability (Caton et al., 2019), understanding how supplementation affects growth and reproductive performance in replacement heifers, with a special focus on the impact of nutrient supply on subsequent generations, is imperative. Therefore, our objectives were twofold: evaluate the impact of energy supplementation on: 1) heifer growth performance and carcass measurements and 2) fetal size and growth.

Procedures

All animal procedures conducted in this experiment were approved by the Institutional Animal Care and Use Committee at North Dakota State University.

One hundred cross-bred Angus-based heifers (13 to 15 months of age) were selected from the Central Grasslands Research Extension Center (**CGREC**) near Streeter, N.D., and transported to the Beef Cattle Research Complex (**BCRC**) on May 15, 2019. Heifers were trained to the Insentec Feeding System (Hokofarm B.V., Marknesse, the Netherlands) (Figure 2) for 23 days before starting the 84-day feeding trial on June 7, 2019.

All heifers were estrus synchronized using a modified Select Synch plus CIDR and TAI protocol. Briefly, heifers received a controlled internal drug release (**CIDR**; Zoetis) for seven days with an injection of 2-cc of gonadotropin-releasing hormone (**GnRH**; i.m.; Factrel; Zoetis) at CIDR insert.

At CIDR removal, heifers were injected with 5-cc of prostaglandin F2α (Lutalyze; Zoetis), and an Estrotect patch (Rockway Inc., Spring Valley, Wis.) was fitted across the tailhead for heat detection. Between 48 and 72 hours following CIDR removal, heifers were bred by artificial insemination (**AI**) to a dose of female-sexed semen from a single sire and received a 2-cc dose of GnRH.

The time of AI depended on patch activation and visual observation of estrus. At breeding, heifers were assigned randomly to one of two treatments, based on body weight and antral follicle count (determined via transrectal ultrasonography): 1) heifers received a basal total mixed ration (**TMR**) (**CON**; n = 50) or 2) the basal TMR diet with the addition of a starch-based energy supplement (**NRG**; Purina® Accuration® Range Supplement 33 [Land O'Lakes Inc.]; n = 50) (Table 1).

Target gains for CON and NRG were 0.625 pounds per day (lb/d) and 1.75 lb/d, respectively. Heifers that failed to become pregnant to first-service AI, consumed NRG treatment ration instead of their allocated CON diet, got sick or had a male or dead calf were excluded from the dataset. All remaining heifers (n = 48) stayed at the BCRC until the end of the feeding period and were transported back to the CGREC on day 85.

From this time forward, heifers were managed as one pasture group until calving in March. Heifers continued to have access to free-choice mineral supplement (Purina® Wind & Rain® Storm® All-Season 7.5 Complete Mineral [Land O'Lakes Inc.] Arden Hills, Minn.) at the CGREC.

The heifers were weighed on two consecutive days at the beginning and end of the feeding trial, and on individual days every 14 days, throughout the 84-day period prior to morning feeding. Body weights recorded on day 164 were two-day consecutive weights of heifers coming off pastures at the CGREC, whereas on day 234, the weight recorded was a single weight measurement to monitor heifer growth prior to calving.

Body composition was assessed via carcass ultrasonography (500 V Aloka with 3.5-MHz transducer, Wallingford, Conn.) at the initiation of estrus synchronization and at the end of the feeding trial. Specific measurements included rib-eye area, rib fat, rump fat and percentage of intramuscular fat. All heifers were evaluated for pregnancy on day 27, crown-rump length (**CRL**) on day 42, and fetal presence, biparietal distance (**BPD**) and fetal sex were determined on day 63 and day 83 using transrectal ultrasonography (500 V Aloka with 5.0-MHz transducer, Wallingford, Conn.).

Statistical Analysis

Daily gain, body composition traits and fetal measurements were analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, N.C.). Heifer body weight was analyzed as repeated measures in time using the MIXED procedure of SAS. Heifer was the experimental unit in all analysis and significance was set at $P < 0.05$.

Results and Discussion

As expected, feeding a corn-based energy supplement during the first 84 days of gestation impacted heifer growth (Figure 1). Heifer body weights diverged by day 14 ($P = 0.0128$) after treatment initiation and differed by 122.1 pounds at the end of the treatment period ($P < 0.01$). This divergence continued ($P < 0.01$), although to a lesser degree, until day 234 of gestation (CON 912.39 ± 12.80 pounds vs. NRG 993.20 ± 12.28 pounds). The average daily gain (ADG) of CON heifers was 0.44 ± 0.04 pounds per day (lb/d), while NRG heifers had an ADG of 1.65 ± 0.04 lb/d during the 84-day feeding trial period ($P < 0.01$). During the entire feeding period, the ADG achieved was close to the growth trajectory targets of 0.625 lb/d and 1.75 lb/d for CON and NRG heifers, respectively.

Rib fat ($P < 0.01$) and rib-eye area ($P < 0.01$) were affected by nutritional treatment at day 84. However, the percentage of intramuscular fat ($P = 0.69$) was not affected during this period (Table 3). Through time, CON heifers lost rib fat and rib-eye area, while NRG heifers increased for these measurements ($P \leq 0.01$).

While the present study assessed carcass characteristics at the beginning and end of the feeding period during early gestation, others found differences in rib fat, rib-eye area and percent of intramuscular fat at 140 days postweaning for replacement heifers fed to appetite or restricted (Roberts et al., 2007). Differences to our observations could be explained not only by time of measurement but also by differences in study design. Roberts et al. (2007) had a control and a restricted treatment, whereas in the preset study, a basal diet was compared with a basal diet plus supplement, with no loss in body weight observed.

No treatment effect was observed on fetal BPD at day 63 ($P = 0.35$) or day 84 ($P = 0.20$; Table 2). Similarly, Copping et al. (2014) observed that protein supplementation during early gestation did not affect BPD on day 36 and day 98 in female fetuses from Santa Gertrudis heifers but impacted male fetuses. These authors concluded that fetal development during early gestation may be influenced by fetal sex, with males being more susceptible to maternal nutrition (Copping et al., 2014), providing an explanation why BDP did not differ among treatment in the present study, as only heifers with female fetuses were included.

While crown-rump length was similar for fetuses from NRG and CON heifers ($P = 0.50$; Table 2), Micke et al. (2010) reported that CRL at day 39 of gestation was greater for fetuses of mixed breed heifers (*Bos taurus* x *Bos indicus*) fed a high-energy and protein supplement, compared with heifers receiving a low-energy and protein supplement. A potential reason for differences in their findings for CRL and ours could be the slight difference between time points of measurements, as Micke et al. (2010) did not find treatment differences as gestation progressed, and we measured CRL on day 42 of gestation. However, breed differences (*Bos taurus* vs. *Bos indicus)* or differences in supplement nutrient composition could be another contributing factor.

In conclusion, feeding an energy supplement during the first trimester of gestation increased heifer growth, rib fat and rib-eye area, but neither the percentage of intramuscular fat nor fetal measurements were affected. Because this study was designed to evaluate female offspring growth and reproductive performance, the next step is to calve out heifer dams and follow their heifer calves during their lifetime. This will allow us to assess the impact that maternal diet during early gestation has on heifer offspring growth and performance, and whether transgenerational impacts exist and impact future offspring pregnancies.

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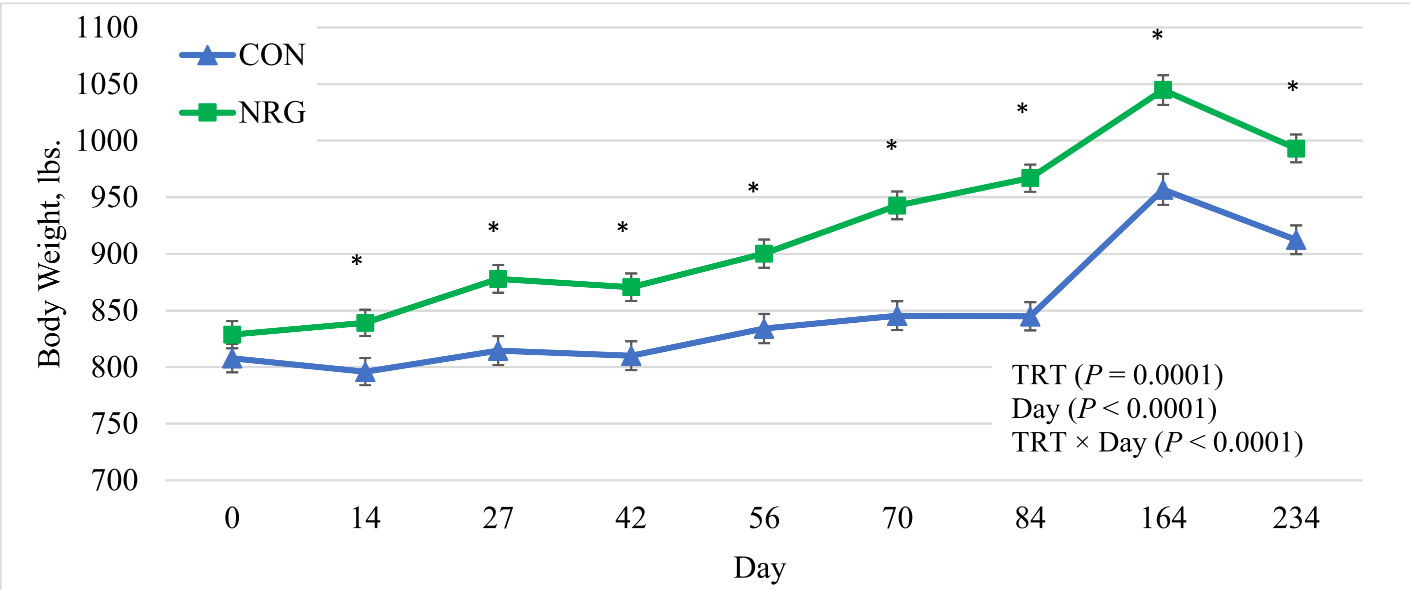

Figure 1. Impact of nutritional treatment on mean body weights and SEM from initiation of the 84-day feeding period until pre-calving. Asterix denote days at which effect of treatments on body weights is significant ($P < 0.01$).

Table 1. Ingredient composition of the rations fed to heifers during the first 84 days of gestation.

	Treatment	
Item	**CON[1]**	**NRG[2]**
Ingredient, % of DM		
Corn silage	37	29
Prairie hay	53	41
DDGS	10	5
NRG supplement[2]	–	25

[1]Basal TMR contained a commercially available mineral supplement ((Purina® Wind & Rain® Storm® All-Season 7.5 Complete Mineral, Land O'Lakes Inc., Arden Hills, Minn.) fed at a rate of 4 ounces per head per day.

[2]NRG supplement fed was Purina® Accuration® Range Supplement 33 [Land O'Lakes Inc.] mixed with ground corn.

Table 2. Impact of nutritional treatment on ADG and fetal measurements of replacement heifers during early gestation.

	Treatment[1]			
Item	**CON**	**NRG**	**SEM[2]**	***P*-Value**
No. of heifers	23	25		
ADG[3]	0.44	1.65	0.04	<0.01
Fetal size				
CRL[4], mm	21.71	21.95	0.25	0.50
BPD[5] at d 63, mm	15.37	15.56	0.15	0.35
BPD at d 84, mm	25.37	25.71	0.19	0.20
BPD change[6], mm	10.00	10.14	0.23	0.66

[1]Treatment: CON, basal diet; NRG, basal diet plus energy supplement.
[2]SEM = Standard error of the mean (n = 48).
[3]ADG = Average daily gain.
[4]CRL = Crown-rump length evaluated at day 42 of gestation.
[5]BPD = Biparietal distance; measure of skull width taken via ultrasonography.
[6]BPD change = BPD at day 84 – BPD at day 63; to calculate fetal growth rate.

Table 3. Impact of nutritional treatment on carcass ultrasonography measurements on replacement heifers at the beginning and end of the feeding period.

	Treatment[1]			
Item	**CON**	**NRG**	**SEM[2]**	***P*-Value**
No. of heifers	23	25		
Rib fat[3], in				
Beginning	0.16	0.16	0.010	0.67
End	0.13	0.21	0.009	<0.01
Change[6]	-0.021	0.053	0.007	<0.01
Rib-eye area[4], in^2				
Beginning	8.90	9.34	0.170	0.07
End	8.63	9.97	0.200	<0.01
Change[6]	-0.28	0.63	0.159	0.01
Intramuscular fat[5], %				
Beginning	4.64	4.56	0.207	0.79
End	4.51	4.61	0.178	0.69
Change[6]	-0.13	0.05	0.153	0.41

[1]Treatment: CON, basal diet; NRG, basal diet plus energy supplement.
[2]SEM = Standard error of the mean (n = 48).
[3] Rib fat (measured at 12th rib).
[4]Rib-eye area (measured at 12th rib).
[5]% intramuscular fat (measured at 12th rib).
[6]Change = measurement at end of feeding – measurement at beginning of feeding.

Figure 2. Insentec Feeding System (Hokofarm B.V., Marknesse, the Netherlands) at the BCRC, Fargo.