High-forage vs. high-concentrate diets fed to beef heifers during pregnancy and the impacts on feeding behavior and feed efficiency in the dam and morphometric characteristics of the male offspring

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Feeding pregnant beef heifers a high-concentrate diet reduces feed intake, improves gain:feed ratio and decreases calving ease compared to a high-forage diet without affecting calf vigor at birth or calf body weight and measurements up to 60 days of age.

Summary

The study assessed the impact of feeding a high-concentrate (HC) diet compared to a high-forage (HF) diet to gestating replacement heifers from 15 days pre-breeding through calving. Specifically, the areas of interest evaluated were dam feeding behavior and feed efficiency, calf body measurements and birth weights, and calf body weight to 60 days of age. By design, there was no difference in average daily gain (ADG; P = 0.50) as HF and HC dams were strategically managed for the same targeted ADG of 1 pound/heifer/day in the first two trimesters of gestation and 1.75 pounds/heifer/day in the third trimester of gestation; however, the gain:feed ratio was greater in HC dams than HF dams ($P < 0.01$). Altered feeding events included a greater number of visits and meals in HF dams compared with HC dams ($P < 0.01$). Time eating per visit was greater in HC dams than HF dams ($P < 0.01$), but HF dams spent more time eating per meal and per day ($P \leq 0.02$) than HC dams. Dry matter intake (DMI) per day was greater in HF dams than HC dams ($P < 0.01$), but HC dams had greater DMI per visit and DMI per meal ($P < 0.01$) and an increased eating rate ($P < 0.01$) compared with HF dams. Additionally, calving ease was greater in HF dams than HC dams ($P = 0.03$). No effect of maternal diet was observed ($P \geq 0.12$) for dam body weight at calving, calf birth weights, calf vigor at birth, or calf body weights and body measurements at 24 h of age. The results may provide support for producers to make management decisions regarding development of pregnant heifers when forages are limited, and alternative feed sources are under consideration.

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Introduction

Replacement heifers are crucial to the beef production system as they provide a source of genetic improvement to the herd every year. Nutritional management of heifers during pregnancy is essential because heifers have demands for growth and maintenance while also establishing and maintaining a pregnancy, developing a fetus and producing milk for the calf after parturition (NASEM, 2016). Nutrient partitioning focuses primarily on the basal metabolism and growth of the dam and secondly on fetal development and pregnancy maintenance (Short et al., 1990). This is why proper nutrition of the dam is vital for producing healthy calves. Studies show that maternal nutrition during pregnancy can impact fetal programming (Wu et al., 2004). Fetal/developmental programming is the phenomenon in which environmental factors affecting the dam can also influence the fetus in utero, leading to molecular and physiological changes with consequences for growth, metabolism and fertility in the offspring's postnatal life (Barker, 2004; Hammer et al., 2023). This experiment evaluated how feeding a high-concentrate diet to the dam throughout pregnancy not only affected feeding behavior and feed efficiency of the dam, but also body measurements and body weights of the calves.

When forage is limited, alternative supplementation could be used in limited amounts to meet nutrient requirements. This experiment utilized two diets: one consisting of 25% concentrate and 75% forage (HF), and the other consisting of 25% forage and 75% concentrate (HC). The diets were fed to gestating beef heifers to target a specific daily gain of 1 pound/heifer/day in the first two trimesters of gestation and 1.75 pounds/heifer/day in the third trimester of gestation. The objectives were to evaluate the impacts of developing pregnant beef heifers on a high-forage or high-concentrate diet from 15 days prebreeding through calving on feeding behavior and feed efficiency of the dam and morphometric characteristics of the male calves through 60 d of age.

Procedures

Crossbred Angus heifers (n = 119; initial body weight [BW] 748.9 ± 72.8 lbs.) approximately 13 months of age sourced from the NDSU Central Grasslands Research Extension Center (CGREC) arrived at the North Dakota State University Beef Cattle Research Complex (BCRC) in May 2023. Heifers were fitted with radio frequency identification tags (RFID) and trained to consume feed from the Insentec (Hokofarm Group B.V., Marknesse, The Netherlands) roughage intake control (RIC) bunk system. During the training period, all heifers consumed a common forage diet composed of 65% winter wheat/blended hay, 20% corn silage, 5% corn grain and 10% premix (HF; Table 1). Heifers were blocked by initial BW and randomly assigned to receive either a high-forage diet (HF; n = 60) of 75% forage and 25% concentrate or a high-concentrate diet (HC; n = 59) of 25% forage and 75% concentrate prior to breeding (Table 1). Heifers were grouped by BW and diet assignment, then placed into one of six pens. The HF heifers remained on the diet provided at the beginning of the experiment throughout gestation. Over four weeks, the HC treatment group was stepped up from the HF diet to a diet containing 75% concentrates. Both HF and HC groups received their final diets 15 days prebreeding throughout gestation. The HC diet was composed of 15% winter wheat/blended hay, 20% corn silage, 55% corn grain and 10% premix (HC; Table 1). Heifers in both HF and HC groups were managed strategically to target BW gains of 1 pound/heifer/day. This was achieved by collecting BW measurements every other week and adjusting individual feed allotments accordingly. In the third trimester of gestation through parturition, feed allocations for pregnant heifers were adjusted to achieve target BW gains of 1.75 pounds/heifer/day.

The roughage intake control (RIC) feeding system controls intake as well as monitors feeding behavior. Each bunk has a scale that monitors how much weight is being taken out as animals are eating. Electronic ear tags allow the system to track each animal for daily feed consumption, time spent eating and number of visits to the bunk. Further calculations using these variables allowed for a comprehensive evaluation of feeding behavior including visits per day, meals per day, time eating per visit, time eating per meal, time eating per day, dry matter intake (DMI) per day, DMI per visit, DMI per meal and eating rate. Calculations of gain to feed ratio (G:F) and average daily gain (ADG) throughout the experimental period were calculated using BW gains recorded every other week and feed intake data from the Insentec system. Feed intake and feeding behavior variables were averaged across the 266-d collection period that started at breeding and stopped when the first dam calved. Feed efficiency variables were calculated from 15 d prebreeding throughout gestation.

At approximately 14 months of age, heifers were synchronized using a seven-day Select Synch + CIDR protocol (Lamb et al., 2010) and artificially inseminated with male-sexed semen from a single sire in June 2023. At d 35 and d 65 after insemination, transrectal ultrasound

Table 1. Feed ingredient percentages in a high-forage and a high-concentrate diet fed to heifers 15 d prebreeding through gestation[1]

	Treatment	
Item	HF	HC
Ingredient % DM		
Winter wheat/blended hay[2]	65	15
Corn silage	20	20
Corn grain	5	55
Premix[3]	10	10

[1]Feed allotments were delivered to heifers so that targeted ADG was 1 lb/heifer/day gain in the first two trimesters of gestation and 1.75 lbs/heifer/day gain in the third trimester of gestation through parturition.
[2]Winter wheat was the sole forage used in the diet prebreeding through the second trimester. During the third trimester, a blended winter wheat and winter rye forage was utilized as the forage in both the concentrate and forage diets.
[3]The premix consists of dried distiller's grain plus soluble, limestone, salt, urea, Monvet 90 Monensin Granule, trace mineral (Feedlot Trace Hubbard), vitamin A, vitamin D, vitamin E and exclusively in the high-concentrate diet, dicalcium phosphate.

was used to determine pregnancy status and fetal sex. Forty-six heifers were confirmed pregnant with male fetuses (HC: n = 22; HF: n = 24) and subsequently maintained on treatment diets through calving in March 2024.

Dams and neonatal calves were weighed at birth prior to suckling. Calves were assigned a vigor score of 1 through 5 (1 = healthy calf and 5 = stillborn) and a calving ease score of 1 through 5 (1 = no assistance required and 5 = cesarean). Dams and calves were then paired in an indoor maternity pen for approximately 24 h. At 24 h, calves were weighed, body measurements were recorded and pairs were returned to group pens. Body measurements included chest circumference, abdominal circumference, crown rump length, shoulder hip length, hip height and hip width (Table 3). Calf BW was collected at d 15 and approximately d 30 and d 60 after birth. At approximately 61 d post-calving, pairs were transported to the CGREC and managed as a single group on pasture until weaning.

Statistical Analysis

Data were analyzed using the MIXED procedure of SAS 9.4 (SAS INST. Inc., Cary, NC) with individual animal serving as the experimental unit. Repeated measures were used to evaluate dam feeding behavior and calf BW gain postnatally. No significance was found in the TRT x Day interaction of calf BW gain, so main effects of treatment and day were reported. Dam weight at calving, calf weight presuckling and calf morphometric variables recorded at 24 h were analyzed with the main effect of maternal diet at a single point in time. Results are reported as least square means (LSMEANS) with the standard error of the mean. Significance was considered at P-values ≤ 0.05 and tendencies declared at 0.05 < P ≤ 0.10.

Table 2. Feed intake and feeding behavior of gestating beef heifers averaged across the 266-d collection period during gestation.

	Treatment[1]			
Item	HF	HC	SE[2]	*P*-value
Feeding Events, per d				
Visits[3]	31.67	12.82	0.310	<0.001
Meals[4]	5.84	3.14	0.044	<0.001
Time Eating, min				
Per visit	5.57	6.68	0.085	<0.001
Per meal	22.31	21.78	0.218	0.02
Per day	113.16	55.41	0.637	<0.001
Dry matter intake				
Per day, lb	16.56	14.18	0.051	<0.001
Per visit, oz	13.80	25.84	0.275	<0.001
Per meal, oz	52.49	81.36	0.632	<0.001
Eating rate, oz/min	2.43	4.48	0.022	<0.001
Measures of feed efficiency[5]				
ADG, lb	1.28	1.30	0.033	0.50
G:F, lb:lb	0.17	0.21	0.006	<0.001

[1]Treatments were applied to heifers 15 days prebreeding and throughout gestation; HF (n = 24), diet composed of 25% concentrate and 75% forage; HC (n=22), diet composed of 75% concentrate and 25% forage.
[2]Standard error of the mean.
[3]Visit is any entry to the bunk detected by electronic ear tag.
[4]Meal is a feeding event that may consist of multiple visits but is bound by a period of 7 minutes with no feeding activity on either side.
[5]Feed efficiency calculations included average daily gain (ADG) and gain:feed ratio (G:F) 15 days prebreeding and through gestation.

Table 3. Weights of calves at birth and 24 h after birth and dams at calving, calf body measurements, and calving ease and vigor score following birth.

	Treatment[1]			
Item	HF	HC	SE	*P*-value
Weights				
Birth weight, lb	69.8	69.3	2.80	0.87
24-hour weight, lb	72.3	71.1	2.77	0.68
Dam weight at calving, lb	1046.1	1067.7	27.54	0.44
Calf morphometrics				
Chest circumference, in	29.41	29.31	0.411	0.82
Abdominal circumference, in	29.17	28.75	0.625	0.51
Crown rump length, in	30.05	30.97	0.570	0.12
Shoulder hip length, in	13.45	13.24	0.441	0.63
Hip height, in	28.05	27.50	0.340	0.12
Hip width, in	4.50	4.32	0.208	0.39
Ease and vigor score				
Calving ease[2]	1.02	1.45	0.187	0.03
Calf vigor[3]	1.46	1.64	0.330	0.59

[1]Treatments were applied to heifers 15 days prebreeding and throughout gestation; HF (n=24) diet composed of 25% concentrate and 75% forage; HC (n=22) diet composed of 75% concentrate and 25% forage.
[2]Calving ease score assigned during parturition. 1=no assistance, 2=assisted, easy pull, 3=assisted, difficult pull or mechanical assistance, 4=abnormal presentation, 5=cesarean section.
[3]Calf vigor score assigned prior to parturition. 1=normal calf, 2=weak calf that nursed without assistance, 3=weak calf assisted to nurse and lived, 4= weak calf assisted to nurse and died, 5=stillborn.

Results and Discussion

By design, there was a strategic effort to keep ADG equal between HF and HC treatments, and results indicated no difference in ADG between HF and HC dams (P = 0.50). Dry matter intake (DMI) per visit ($P < 0.001$) and DMI per meal ($P < 0.001$) were greater in HC dams compared to HF dams. However, HF dams had greater total DMI per day ($P < 0.001$) than HC dams, which can be explained by the greater number of visits to the bunk ($P < 0.001$) and meals ($P < 0.001$) the HF dams had compared to the HC dams. Although HC dams consumed less total dry matter compared to HF dams, G:F ($P < 0.001$) was greater in HC dams than HF dams. Seemingly, the nutrient-dense concentrate feed comprising the HC diet allowed HC dams to put on more weight while consuming less feed. Time eating per visit ($P < 0.001$) was greater in HC dams than HF dams; however, HF dams spent more time eating per meal (P = 0.02) and per day ($P < 0.001$) compared with HC dams. Eating rate ($P < 0.001$) was greater in HC dams than HF dams, being nearly doubled. The HC diet was less bulky than the HF diet, presumably allowing the HC heifers to consume feed faster.

Calving ease was greater in HF dams than HC dams (P = 0.03); however, there was no difference in calf vigor (P = 0.59) between HF and HC calves. Calf BW through 60 d of age was not impacted by the interaction of maternal diet x day (P = 0.45; Figure 1). Additionally, maternal gestational diet did not cause differences in BW between calves born to HF and HC dams (P = 0.71). Expectedly, there was an increase in BW in both HF and HC calves with time ($P < 0.001$). However, BW of HC and HF dams was not impacted at time of calving (P = 0.44; Table 3). There were no differences in calf body measurements at 24 h of age, including chest circumference, abdominal circumference, crown-rump length, shoulder-hip length, hip height and hip width ($P \geq 0.12$).

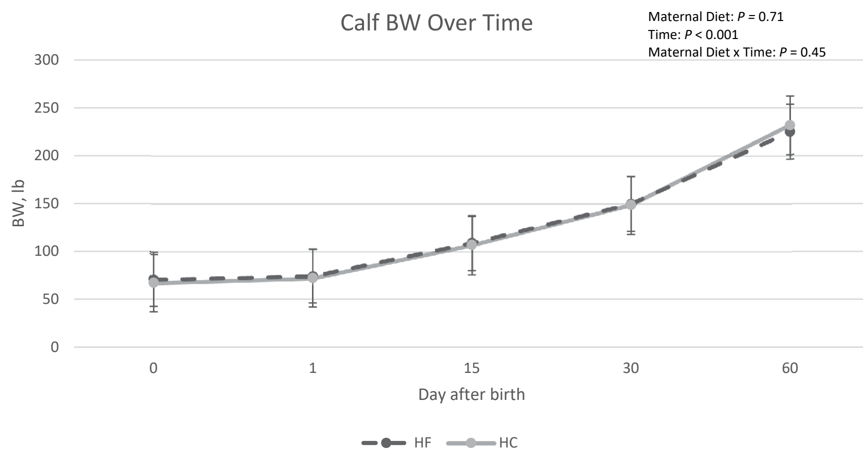

Figure 1. Calf weights at day 0, 1, 15, 30 and 60 of bull calves born to dams fed a HF or HC diet.

These data show that a HC diet can be implemented in feeding replacement beef heifers throughout gestation. Feeding a HC diet improves feed efficiency, indicating heifers are reaching their gains while consuming less feed. The improvement in feed efficiency is highlighted by the equal ADG in HF and HC dams but a greater G:F in HC dams. Depending on the availability and cost of forage and concentrate feeds, limit-feeding concentrates in the diet may be a cost-effective method to reach nutrient requirements for gestating beef heifers. As seen in the results, feeding a HC diet does not impact calf BW or calf body measurements, but there is a decrease in calving ease in HC dams, which may be a concern depending on producer calving systems. Continuing to study effects on male calves later in life is important for further understanding of feeding strategies that may allow producers to make decisions regarding feed efficiency in dams and offspring.

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Literature cited

Barker, D. J. P. 2004. The developmental origins of well-being. Phil. Trans. R. Soc. B Biol. Sci. 359:1359–1366.

Hammer, C. J., J. S. Caton, C. R. Dahlen, A. K. Ward, P. P. Borowicz, L. P. Reynolds. 2023. Large animal models of developmental programming: Sustenance, stress, and sex matter. Reproduction. 165:F1-F13.

Lamb, G. C., C. R. Dahlen, J. E. Larson, G. Marquezini, J. S. Stevenson. 2010. Control of the estrous cycle to improve fertility for fixed-time artificial insemination in beef cattle: a review. J. Anim. Sci. 88:E181-E192.

Short, R. E., R. A. Bellows, R. B. Staigmiller, J. G. Berardinelli, E. E. Custer. 1990. Physiological mechanisms controlling anestrus and infertility in postpartum beef cattle. J. Anim. Sci. 68:799-816.

Wu, G., F. W. Bazer, T. A. Cudd, C. J. Meininger, and T. E. Spencer. 2004. Maternal nutrition and fetal development. J. Nutr. 134:2169-2172.