High-forage vs. high-concentrate diets fed to beef heifers during pregnancy and the impacts on blood metabolite and hormone profiles in the dam and calf and growth of the male calves through 235 days of age

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Limit-feeding a high-concentrate diet to pregnant beef heifers alters maternal and neonatal metabolic and hormonal blood profiles but does not affect calf blood parameters at weaning or postnatal growth up to 235 days after birth.

Summary

In the northern U.S., native pastures are the main feed source for beef cows, but their availability and quality vary seasonally. During winter, forage storage and delivery can be costly and impractical. In such cases, limit-feeding high-concentrate diets may provide a viable nutritional alternative for pregnant cows. 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 prebreeding through calving. Specifically, the areas of interest evaluated were the blood metabolite and hormone profiles in the dam and calf and growth of the male calves through 235 days of age. By design, there was no difference in average daily gain (ADG; $P = 0.50$) of heifers 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. Blood serum samples, collected from dams on days -2, -15, 90, 180 and 240 relative to breeding and at calving and from calves at birth and weaning, were analyzed for cortisol, insulin and insulin-like growth factor-1 (IGF-1), and blood plasma samples were analyzed for glucose, blood urea nitrogen (BUN) and nonesterified fatty acids (NEFA). In the dams, circulating concentrations of NEFA were impacted by the treatment × day interaction ($P = 0.01$), indicating differing NEFA concentrations between HF and HC groups at day -15, day 180 and calving. Additionally, dams of the HC group had greater ($P \leq 0.01$) circulating concentrations of cortisol, IGF-1 and glucose than HF dams throughout gestation. However, HC dams had decreased ($P < 0.01$) circulating concentrations of BUN compared with HF dams. Circulating concentrations of IGF-1 and NEFA were greater ($P \leq 0.03$) in the HF calves compared with the HC calves in the presuckling period following birth. However, concentrations of IGF-1, NEFA, cortisol, insulin, glucose and BUN in the calves at weaning were not influenced by maternal dietary treatment ($P \geq 0.16$). Calf body weight from birth to day 235 was not impacted by the interaction of treatment × day ($P = 0.98$; Figure 1) or the main effect of treatment ($P = 0.84$). Restricting high-concentrate diets during gestation altered the metabolic and hormonal profiles of pregnant heifers and their offspring at birth but did not compromise postnatal calf growth performance. These results support the strategic use of high-concentrate diets as a viable alternative during periods of forage scarcity or in scenarios where concentrate feeding is economically advantageous.

Introduction

In cases of limited forage availability, increasing the proportions of concentrate feeds in the diet is an alternative way to meet the energy requirements of pregnant females. Limit-feeding or restricted-feeding is the concept of feed intake management in which intake is restricted to an expected portion or

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actual portion of *ad libitum* intake (Galyean, 1999). Due to the nature of concentrates, such as corn used in this experiment, typically being high-starch and high-energy, we may expect to see alterations in the blood metabolite and hormone profiles of dams throughout gestation and their calves at birth due to the blood and nutrient exchange between dam and calf. Additionally, programming effects of dams consuming high-concentrate diets have the potential to alter postnatal growth of the calves.

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 blood metabolite and hormone profiles in the dam and calf, and growth of the male calves through 235 days of age. We hypothesized that feeding a high-concentrate diet would alter the blood metabolite and hormone profiles of the dam throughout gestation and the calf postnatally and influence growth of the male calves through 235 days of age.

Procedures

Heifers received either a high-forage diet (HF; n = 24) of 75% forage and 25% concentrate or a high-concentrate diet (HC; n = 22) of 25% forage and 75% concentrate prior to breeding (Table 1). Heifers were maintained on treatment diets through calving. Heifers in both HF and HC groups were managed strategically to target body weight (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. For further experimental design procedures, see reference (Kuzel et al., 2024).

Calf BW was collected at day 1, day 15 and approximately days 30,

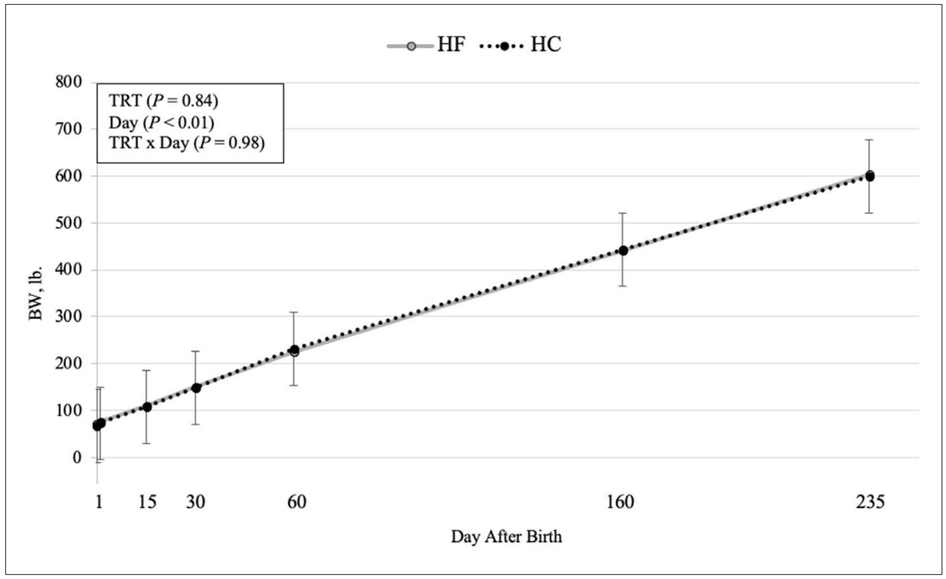

Figure 1. Body weight of calves at days 1, 15, 30, 60, 160 (weaning) and 235 (start of feedlot phase).

Table 1. Feed ingredients and nutrient profiles of diets delivered to F0 heifers receiving either the high-forage (HF) diet or the high-concentrate (HC) diet from 15 days prebreeding through calving.

	D -15 to 180		D 180 to Calving		Post-Calving	
	HF	HC	HF	HC	HF	HC
Ingredient, % DM						
Winter wheat/blended hay	65	15	60	15	23.5	
Alfalfa hay	0	0	0	0	23.5	
Corn silage	20	20	30	20	46	
Corn grain	5	55	0	55	0	
Distillers dried grains with solubles	7.7	7	7.7	7	0	
Premix[1]	2.3	3	2.3	3	7	
Chemical Composition						
Dry matter, %	95.2	95.3	95.04	95.3	94.9	
Ash, % DM	9.9	5.8	9.9	5.8	11.7	
Crude protein, % DM	15.5	13.7	15.9	13.7	18.8	
Neutral detergent fiber, % DM	63.1	36.8	61.7	36.8	55.8	
Acid detergent fiber, % DM	39.8	16.4	39.3	16.4	34.9	
Ether extract, % DM	1.79	2.67	1.85	2.67	1.89	
Ca, % DM	0.68	0.64	0.58	0.64	1.10	
P, % DM	0.31	0.37	0.32	0.37	0.34	
Total digestible nutrients. % DM	60.0	76.4	60.3	76.4	63.4	

[1]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.

60, 160 and 235 after birth. Day 160 represents the time of weaning, and day 235 represents the time before calves start the finishing phase. At approximately 61 days postcalving, pairs were transported to the Central Grasslands Research Extension Center and managed as a single group on pasture until weaning.

Blood (for separation of serum and plasma) was collected from heifers at the following timepoints relative to breeding: days -15, -2, 91, 180, 240 and at calving. Blood was collected from calves at calving and weaning. After processing, serum was analyzed for concentrations of cortisol, insulin and insulin-like growth factor 1 (IGF-1), and plasma was analyzed for concentrations of glucose, BUN (blood urea nitrogen) and NEFA (nonesterified fatty acids).

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 using repeated measures where appropriate. The CORR procedure of SAS was used to generate correlations for blood metabolite and hormone concentrations between the dams and their respective calves at calving. The PDIFF function of SAS was utilized for mean separation with a Tukey adjustment, and results are reported as least square means (LSMEANS) with the standard error of the mean (SE). Significance was considered at $P \leq 0.05$ and tendencies declared at $0.05 < P \leq 0.10$.

Results and Discussion

We previously reported that average daily gain (ADG) was similar between the HF and HC treatments (Kuzel et al., 2024). No treatment × day interactions ($P \geq 0.21$) were observed for concentrations of cortisol, IGF-1, BUN, glucose and insulin (Figure 2). Circulating concentrations of NEFA were impacted by the treatment × day interaction ($P = 0.01$), indicating differing NEFA concentrations between HF and HC groups at day -15, day 180 and calving (Figure 2). Nonesterified fatty acids are a marker of energy balance in the body, reflective of dietary energy intake and energy balance. While the impact of the interaction of day and treatment in the current study may not be well understood, it is widely supported that a shift in NEFA occurs in the time between gestation, parturition and lactation. Additionally, the diet shift to target greater ADG in the last third of gestation may have impacted NEFA concentrations in this study.

Dams of the HC group had greater ($P < 0.01$) circulating concentrations of glucose than HF dams (Figure 2). However, HC dams had decreased ($P < 0.01$) circulating concentrations of BUN compared with HF dams. The HF diet contained more crude protein than the HC diet, likely leading to elevated BUN concentrations in the HF heifers (Table 1). Impacts of feeding high-concentrate diets to gestating or lactating cows on blood glucose and insulin vary. However, greater blood glucose concentrations in HC dams in the current study may be attributed to the greater starch concentration in the diet, leading to greater propionate production coming from the grain. Interestingly, blood insulin concentrations were not different ($P = 0.88$) between HF and HC dams despite the difference in blood glucose.

Dams of the HC group had greater ($P < 0.01$) circulating concentrations of cortisol throughout gestation (Figure 2). Elevated cortisol concentrations in the HC dams may be attributed to the limit-feeding strategy. While HC heifers had adequate calories and nutrients to meet their dietary requirements, the nature of the HC diet was compact with little roughage to add as gut fill. Consequently, the HC heifers likely did not feel "full" and therefore did not have normal feeding behaviors.

Lastly, BW and ADG were managed to be similar between HF and HC groups; however, the HC heifers had greater ($P < 0.01$) circulating blood concentrations of IGF-1 than the HF heifers throughout gestation (Figure 2). While IGF-1 is positively related to BW gain and ADG, previous studies also reported that heifers consuming greater levels of concentrates have greater IGF-1 concentrations in the blood.

Maternal dietary treatment influenced concentrations of IGF-1 and NEFA ($P \leq 0.03$) in calves at birth; however, concentrations of cortisol, insulin, glucose and BUN at birth were not altered ($P \geq 0.14$; Table 2). Circulating concentrations of IGF-1 and NEFA were greater ($P \leq 0.03$) in the HF calves compared with the HC calves in the presuckling period. Furthermore, maternal BUN concentrations at calving were positively correlated with those in the calf at birth ($P < 0.03$; $r = 0.36$; data not shown). Contrary to the relationship between BUN concentrations in the dam and calf at birth, no correlations were observed between cortisol, IGF-1, insulin, glucose or NEFA in the dam and calf ($P \geq 0.14$). Additionally, concentrations of IGF-1, NEFA, cortisol, insulin, glucose and BUN at weaning were not influenced by maternal dietary treatment ($P \geq 0.16$; Table 2).

Calf BW from birth to day 235 was not impacted by the interaction of treatment × day ($P = 0.98$; Figure 1) or the main effect of treatment ($P = 0.84$). Expectedly, there was an increase in BW in both HF and HC calves as days progressed ($P < 0.01$; Figure 1).

Blood, nutrients and waste are exchanged across the placenta throughout gestation. Due to the intimate placental connection between a dam and her fetus, we may expect fetal blood metabolite and hormone concentrations at

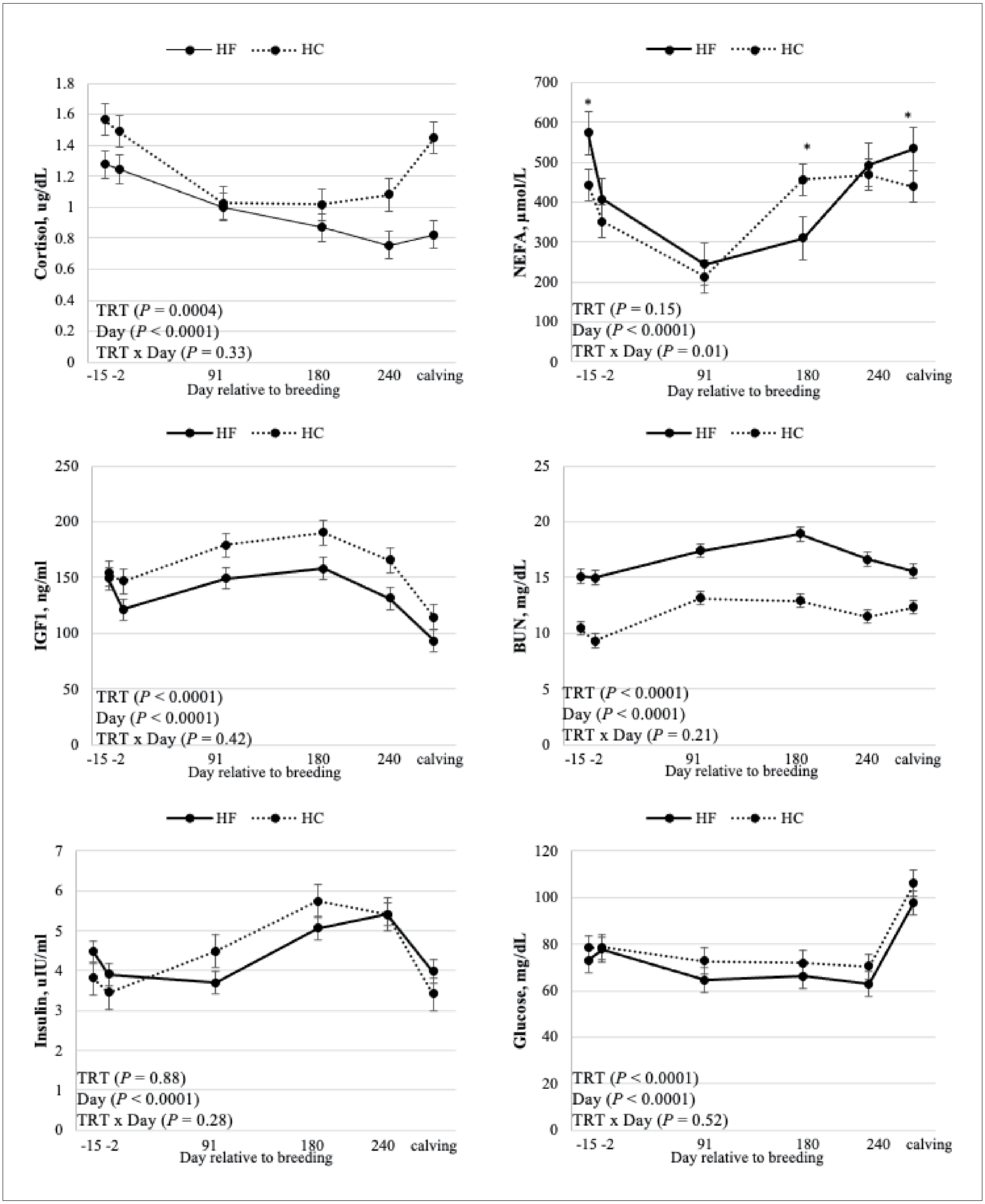

Figure 2. Serum cortisol, IGF-1, insulin, and plasma glucose, NEFA and BUN concentrations evaluated at days -15, -2, 91, 180, 240 and calving in heifers receiving either a HF diet composed of 25% concentrate and 75% forage; HC diet composed of 75% concentrate and 25% forage. Bars represent the standard error of the mean. TRT: treatment effect; Day: Day effect; TRT x Day: interaction between main effects of TRT and Day. * indicates the mean concentration within day differs between treatments ($P \leq 0.05$).

birth to mimic or be correlated with those of the mother. After the dams returned to a common lactation diet and a common diet on pasture, all blood metabolites and hormones measured were similar between HF and HC calves. Calves of both treatment groups were also growing at a uniform rate, having similar BW, which likely contributes to similar blood metabolite and hormone profiles. Though blood metabolite and hormone profiles of HF and HC calves were similar at the time of weaning, it's important to evaluate long-term effects that may be the result of altered IGF-1 and NEFA concentrations at birth that stem from the uterine environment of the calves throughout gestation.

Conclusion

These data show that feeding a high-concentrate diet alters blood metabolite and hormone profiles of heifers throughout gestation and of their calves at birth, suggesting possible alterations in nutrient utilization. However, blood metabolite and hormone profiles of calves at weaning and calf BW up to 235 days after birth are not affected. Depending on the availability and cost of forage and concentrate feeds, limit-feeding concentrates in the diet may be a cost-effective method to meet nutrient requirements for gestating beef heifers with minimal effects on calves postnatally. However, 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 feeding management of dams and offspring.

Table 2. Serum cortisol, IGF-1, insulin, and plasma glucose, NEFA and BUN concentrations evaluated at birth and weaning in F1 male offspring.

	Treatment[1]			*P*-values
Item	HF	HC	SE[2]	TRT
Birth				
Cortisol, ug/dL	4.37	4.48	0.320	0.74
IGF-1, ng/mL	36.5	26.6	4.25	0.03
Insulin, uIU/mL	5.9	7.8	1.22	0.14
Glucose, mg/dL	79.3	86.2	5.53	0.22
NEFA, µmol/L	985.4	662.8	129.45	0.02
BUN, mg/dL	20.1	19.2	1.35	0.51
Weaning				
Cortisol, ug/dL	1.01	0.84	0.117	0.16
IGF-1, ng/mL	137.6	136.7	12.15	0.94
Insulin, uIU/mL	2.9	2.5	0.31	0.18
Glucose, mg/dL	90.8	88.5	5.18	0.65
NEFA, µmol/L	695.9	612.2	65.62	0.21
BUN, mg/dL	15.0	14.2	0.76	0.28

[1]Treatments were applied to heifers 15 days prebreeding and throughout gestation; HF diet composed of 25% concentrate and 75% forage; HC diet composed of 75% concentrate and 25% forage.
[2]Standard error of the mean.

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