Evaluating the impact of maternal diet during gestation on offspring energetic efficiency in finishing steers

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Maternal diet during gestation may influence growth and development of offspring, as steers from high-forage dams tended to have greater initial and final body weights. However, no significant differences were observed in feed efficiency or gas exchange during the finishing phase. Nutrient analyses are ongoing to further assess energy and nutrient utilization.

Summary

This study examined whether maternal diet during gestation influences offspring growth and feed efficiency in the finishing phase. Angus-cross heifers were fed either a high-concentrate or high-forage diet throughout pregnancy, and 40 male calves were followed through backgrounding and finishing. Steers were transitioned to a 90% concentrate finishing diet and fed for 178 days. While steers from high-forage dams tended to have greater initial and final body weights, no significant differences were observed in average daily gain, dry matter intake, gain-to-feed ratio or gas exchange. These findings suggest that maternal diet may influence growth prior to the finishing phase but has no clear effect on finishing-phase feed efficiency or metabolic gas production. Additional nutrient and energy balance analyses are ongoing and will provide further insight into potential differences in feed utilization and efficiency.

Introduction

Efficiency in cattle can be defined as their ability to utilize feed to maximize growth and performance. We know that multiple factors influence this, one of the most critical being nutrition. In the finishing phase, cattle are typically fed high-energy diets rich in grains. Over time, their rumen adapts to these diets, allowing them to more effectively digest starches and produce volatile fatty acids (VFA), which are absorbed through the rumen wall and used as energy throughout the body. Specifically, starch digestion increases propionate production, which is converted to glucose in the liver. Since ruminants cannot directly absorb glucose from the rumen, propionate becomes a key precursor to glucose and supports muscle and fat deposition (Cantalapiedra-Hijar et al. 2018). However, high-concentrate diets differ greatly from what cattle are accustomed to early in life, and a transition period is needed to avoid digestive issues such as acidosis. As cattle adjust to these diets, both their physiology and rumen microbiome change. While cattle are capable of adapting to high-grain diets, perhaps we could improve their long-term feed efficiency by initiating this adaptation earlier in life. Research has shown that the rumen microbiome of young calves is highly adaptable within the first few days after birth (Amin et al., 2021, Diddeniya et al., 2024). This raises the question of whether the microbiome could be influenced early in life, perhaps before birth as a fetus, to prepare calves to better utilize high-concentrate diets later in life.

There is growing interest in whether maternal nutrition can influence fetal development that prepares offspring for the feeding environments they will encounter later. Some studies suggest that microbial colonization may begin in utero or that maternal diet can influence organ development, metabolic function and microbial colonization after birth (Amat et al., 2022, Caton et al., 2024; Husso et al., 2021). If we can influence microbial development and energy metabolism through maternal diet, we may be able to produce more energy-efficient finishing cattle. The objective of this project is to determine whether maternal diet can influence energetic efficiency and overall performance during the finishing phase.

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Procedures

The procedures used in the experiment were approved by the North Dakota State University Institutional Animal Care and Use Committee. Crossbred Angus heifers (n = 119; initial body weight [BW] 747 ± 72.6 lb), approximately 13 months of age from the Central Grasslands Research Extension Center (CGREC), were transported to the NDSU Beef Cattle Research Complex. Heifers were stratified by BW and randomly assigned to a treatment group. Individual feed intake was determined using an electronic feed intake monitoring system (Insentec RIC, Hokofarm Group B.V., Netherlands). All heifers were adapted to the system prior to treatment assignment. Dietary treatments were high-concentrate (75% concentrate, dry matter basis) and high-forage (75% forage, dry matter basis; Table 1). Heifers were transitioned to the high-concentrate diet over four weeks. Heifers were fed treatment diets beginning 15 days before breeding. Both diets were formulated to achieve one lb/d gain up until the third trimester, and diets were adjusted to achieve 1.76 lb/d during the third trimester.

Table 1. Ingredient composition (% DM) of diet fed to steers[1]

Ingredients	% of DM
Corn Silage	10
Grass Hay	5
Corn Grain	60
DDGS	20
Premix	
Limestone	1.5
Salt (sodium chloride)	0.1
Urea	0.95
Fine Ground Corn	2.37
Vitamin Premix	0.01
Trace Mineral Premix	0.05
Monensin Premix	0.02

[1]Steers were stepped up to the finishing diet over 14 days and then were fed the finishing diet above until slaughter.

Heifers were AI-bred with male-sexed semen from a single sire. Pregnancy was confirmed by transrectal ultrasonography 35 days post-AI; fetal sex was determined at 65 days post-AI. A total of 46 heifers were confirmed pregnant with a male fetus (high-concentrate: 22; high-forage: 24) and remained on the assigned treatment diets throughout gestation.

After calving, dams (n = 46) were fed a common lactation diet until dams and bull calves were placed on a common pasture for grazing. Bull calves were castrated at 160 ± 4 days. Following castration, calves were weaned and transitioned to a backgrounding diet (50% forage, 50% concentrate). Five calves were removed from the experiment due to health complications (high-concentrate: 3; high-forage: 2).

Steers (n = 41; initial BW 600 ± 51 lb) were transported to the Animal Nutrition and Physiology Center (ANPC) at 236 ± 4 days of age. One steer from the concentrate treatment was removed from the trial due to health issues unrelated to the experimental treatments or study conditions. Eighteen steers were born to high-concentrate fed dams and 22 to high-forage fed dams. Steers were stratified by BW and assigned to 10 pens (nine pens with four steers per pen [two per treatment], and one pen with five steers). Pens included individual Calan gate feeders, waterers and slatted concrete flooring. Steers underwent a three-week training period on Calan gates and were fed a 60% concentrate and 40% forage diet (dry matter basis). Feed was mixed daily in a stationary ribbon mixer and offered once daily for ad libitum intake. Bunk scores were taken daily to ensure feed availability. Steers were transitioned to the finishing diet using a two-phase step-up protocol, beginning with a 70% concentrate diet for seven days, followed by an 80% concentrate diet for an additional seven days. Diets were formulated using the Beef Cattle Nutrient Requirements Model (NASEM, 2016). The adaptation period began at 261 ± 4 days of age (BW = 668.8 ± 52 lb). The final finishing diet (90% concentrate, 10% forage) was fed for 178 days.

Steers were weighed before feeding on days 0, 1, 76, 108 and two days before slaughter (155 ± 20.3 d). Twenty-two steers were subjected to a nutrient and energy balance experiment and were slaughtered on day 140 ± 5.6; the remaining steers on day 178. Average daily gain (ADG) was calculated using weight change over time. DMI was determined from feed offered and refusals. Gain-to-feed ratio (G:F) was calculated by dividing ADG by DMI.

The 22 heaviest steers (11 per treatment) were halter-broke and subjected to a nutrient and energy balance experiment. The nutrient and energy balance experiment began on day 91 ± 3.89 of the feeding periods. Steers were split into five groups of four or five animals. Groups of four were balanced (two steers per treatment), while groups of five included three from one treatment and two from the other. Collection periods were staggered to begin every other day to facilitate sample collection. Steers were placed in metabolic stanchions for five days for total collection of feces, urine and feed intake. Fecal, urine and feed samples are currently undergoing nutrient analyses. On day 6 of the collection period, steers were weighed and placed in open-circuit headboxes for 24 hours to assess gas exchange (oxygen, carbon dioxide and methane).

Results and Discussion

Steers born to heifers fed a high-forage diet tended to have greater slaughter weights compared to steers born from the high-concentrate group (1,349 vs. 1,311 lb; $P = 0.09$). Initial BW at the start of the finishing phase was greater ($P = 0.03$) in high-forage steers (Table 2). These findings

support previous studies showing that maternal diet can influence offspring growth performance after birth (Funston et al., 2010). However, no differences were observed between treatments for ADG, DMI or G:F during the finishing period. Oxygen consumption, carbon dioxide and methane production and respiratory quotient (RQ) did not differ between treatment groups. These findings suggest that while maternal diet may influence early offspring growth, no differences were observed in finishing-phase gain or metabolic gas exchange. Further ongoing nutrient analyses will be used to quantify nutrient and energy intake, losses and retention, which will provide more information on whether cattle born to dams fed concentrate vs. forage-based diets utilize feed more efficiently for growth.

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Table 2. Influence of feeding high- or low-concentrate diet to pregnant heifers on growth performance of steer offspring.

Item	Concentrate	Forage	SEM	*P*-value
Start weight, lb	660	675	3.1	0.03
Final weight, lb	1315	1352	9.5	0.09
Average daily gain, lb	4.19	4.30	0.06	0.45
Dry matter intake, lb	22.31	22.79	0.23	0.36
Gain:Feed	0.41	0.42	0.001	0.93

Table 3. Effect of maternal diet on gas exchange in steer progeny subjected to a nutrient and energy balance experiment during the finishing phase.

	Treatment			
Item	Concentrate	Forage	SEM	*P*-value
Oxygen, Liters	660	675	3.1	0.03
Carbon dioxide, Liters	1315	1352	9.5	0.09
Methane, Liters	4.19	4.30	0.06	0.45
Respiratory quotient, CO_2/O_2	4.19	4.30	0.06	0.45

Oxygen (O_2), carbon dioxide (CO_2), and methane (CH_4) measurements reflect metabolic gas exchange during the 24-hour headbox collection.

Literature Cited

Amat, S., C. R. Dahlen, K. C. Swanson, A. K. Ward, L. P. Reynolds, and J. S. Caton. 2022. Bovine animal model for studying the maternal microbiome, in utero microbial colonization and their role in offspring development and fetal programming. Front. Microbiol. 13:854453.

Amin, N., S. Schwarzkopf, A. Kinoshita, J. Tröscher-Mußotter, S. Dänicke, A. Camarinha-Silva, K. Huber, J. Frahm, and J. Seifert. 2021. Evolution of rumen and oral microbiota in calves is influenced by age and time of weaning. Anim. Microbiome. 3:31

Cantalapiedra-Hijar, G., M. Abo-Ismail, G. E. Carstens, L. L. Guan, R. Hegarty, D. A. Kenny, M. McGee, G. Plastow, A. Relling, and I. Ortigues-Marty. 2018. Review: Biological determinants of between-animal variation in feed efficiency of growing beef cattle. animal. 12:s321–s335.

Caton, J. S., M. S. Crouse, C. R. Dahlen, A. K. Ward, W. J. S. Diniz, C. J. Hammer, R. M. Swanson, K. M. Hauxwell, J. G. Syring, K. S. Safain, and L. P. Reynolds. 2024. International symposium on ruminant physiology: Maternal nutrient supply - impacts on physiological and whole animal outcomes in offspring. J. Dairy Sci. 108:7696-7709.

Diddeniya, G., M. Hosseini Ghaffari, E. Hernandez-Sanabria, L. L. Guan, and N. Malmuthuge. 2024. Invited review: Impact of maternal health and nutrition on the microbiome and immune development of neonatal calves. J. Dairy Sci. 107:7504–7519.

Funston, R. N., D. M. Larson, and K. A. Vonnahme. 2010. Effects of maternal nutrition on conceptus growth and offspring performance: Implications for beef cattle production. J. Anim. Sci. 88:E205–E215.

Husso, A., L. Lietaer, T. Pessa-Morikawa, T. Grönthal, J. Govaere, A. Van Soom, A. Iivanainen, G. Opsomer, and M. Niku. 2021. The Composition of the microbiota in the full-term fetal gut and amniotic fluid: A Bovine cesarean section study. Front. Microbiol. 12:626421/.