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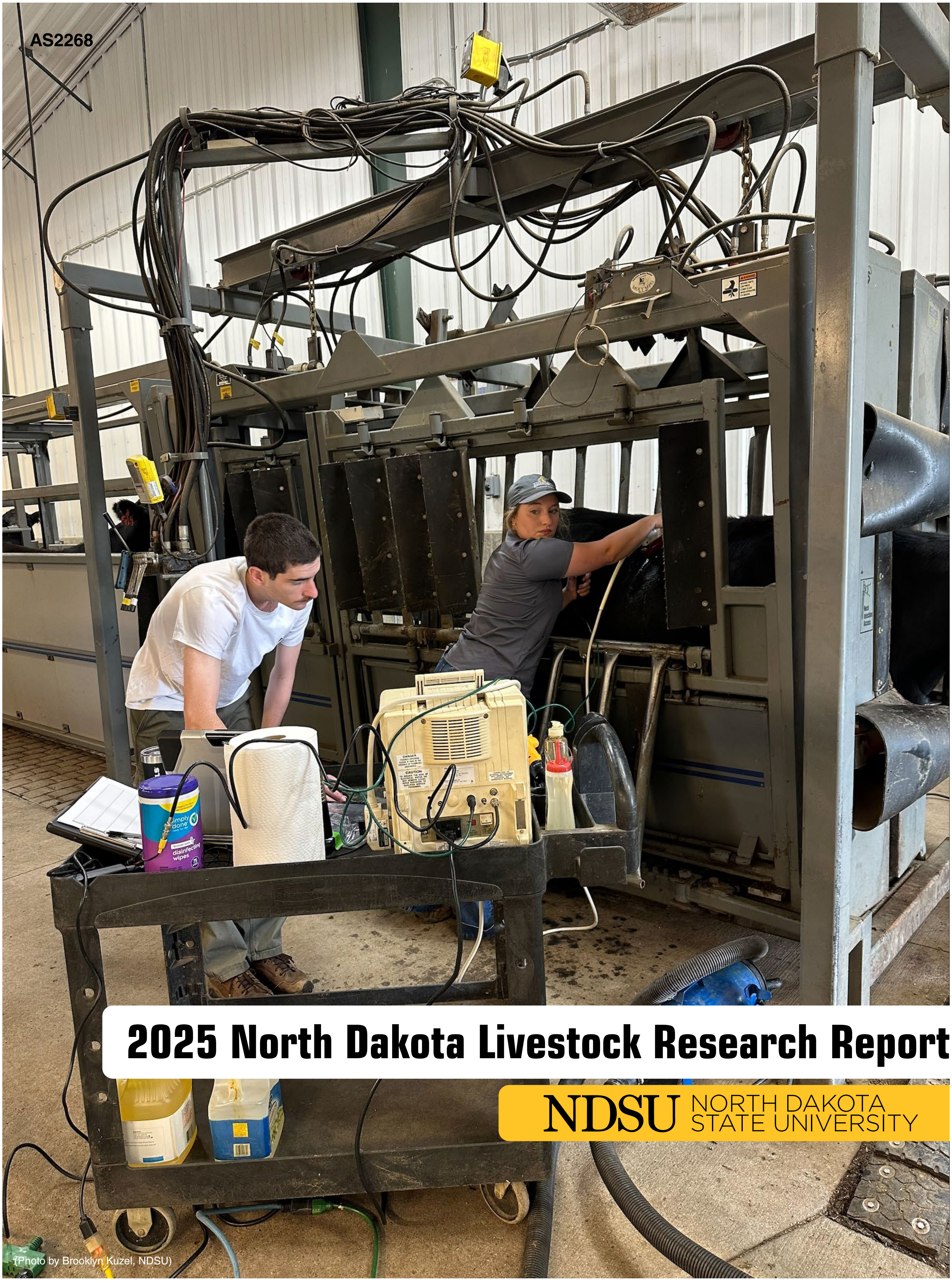

2025 North Dakota Livestock Research Report

NDSU NORTH DAKOTA STATE UNIVERSITY

(Photo by Brooklyn Kuzel, NDSU)

2025 North Dakota Livestock Research Report

It is hard for me to believe that this is the 14th year I have been the coordinator and editor of this report, which has evolved through the years as the North Dakota Beef Report, the North Dakota Beef and Sheep Report and, most recently, the North Dakota Livestock Research Report. I continue to coordinate and edit the report because I know that this is one avenue to get our research findings to producers and industry personnel in the state and region. Also, I truly enjoy helping others at NDSU, especially students, gain experience in the writing of research reports and manuscripts.

Our research ranges from discovery research, which could develop into new innovations or technologies to improve production in the future, to more applied research, which provides information that can be used immediately by producers and industry personnel. Both are equally important and often are strongly linked in our research and Extension programs. A great, or perhaps greater, outcome of our research programs is the opportunity for students to gain experience in conducting and leading research projects in livestock species and to become the next generation of animal scientists in various careers. I hope this report will continue to remind us all of the importance, quality and breadth of our livestock research and Extension programs in North Dakota.

I want to thank Monica Stensland, Dominic Erickson and Deb Tanner for their assistance in editing and formatting the reports. Also, thanks to the contributors to the report and to the staff and students who assist with livestock research, teaching and Extension activities. Finally, thanks to the funders who help support the research projects and students/staff working on the projects. We truly appreciate your contributions to our research programs. Without this support, the research and the training of the next generation of animal scientists would not be possible.

If you have any questions or thoughts about our research from this report, please do not hesitate to contact me or any of the other authors of the individual reports. Thanks for your encouragement, interest and support of livestock research in North Dakota.

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Managing mature beef bulls on divergent planes of nutrition prior to the breeding season alters activity and eating behavior

Roberta B. A. Dahlen[1], Sarah R. Underdahl[1], Matthew S. Crouse[2], Kacie L. McCarthy[3], Joel S. Caton[1], Kevin K. Sedivec[1] and Carl R. Dahlen[1]

Bulls play a critical role in determining the genetic progress of beef herds; thus, this study assessed the impact of divergent pre-breeding nutritional planes on feeding and activity behaviors in mature beef bulls. Bulls on a weight gain trajectory exhibited higher dry matter intake and greater overall and high-intensity activity levels. Conversely, bulls losing weight spent more time in behaviors classified as eating, likely reflecting increased foraging activity post-feed delivery. These findings reinforce the importance of proper nutritional management prior breeding to optimize bull performance and reproductive success.

Summary

To evaluate eating and activity behaviors, 15 mature Angus-based beef bulls (initial body weight [BW] = 1,764.2 ± 36.39 lbs.) were stratified by BW and randomly assigned to a positive (POS, n = 7) or negative (NEG, n = 8) plane of nutrition for 112 d. Bulls received a common total mixed ration delivered into Insentec feeders, which was adjusted every two weeks to achieve a targeted BW change of approximately ±12.5%. Behavior was continuously monitored using CowManager ear tags and classified as eating, ruminating, not active, active, or highly active. Data were averaged into four 28-d periods and analyzed using repeated measures in time within the MIXED procedure of SAS, with bull as the experimental unit. Due to the intended divergence in gain, POS bulls had greater ($P < 0.001$) dry matter intake (28.0 vs. 11.7 ± 2.36 lbs./d) and weight gain (2.67 vs. -2.65 ± 0.11 lbs./d) compared with NEG bulls. A treatment × period interaction ($P = 0.04$) was observed for eating behavior, with NEG bulls spending more time ($P \leq 0.001$) eating in periods 1 and 3 and tending ($P = 0.06$) to do so in period 2; no difference was observed in period 4 ($P = 0.99$). Although eating behavior increased, NEG bulls spent more time ($P \leq 0.03$) not active during periods 2 through 4; no difference was observed in period 1 ($P = 0.44$). Ruminating did not differ ($P = 0.36$) by treatment, nor treatment × period interactions ($P \geq 0.14$) were detected for ruminating, active, and highly active behaviors. However, POS bulls spent significantly more time ($P < 0.001$) in active (283.8 vs. 176.8 ± 9.03 min/d) and highly active (117.6 vs. 84.3 ± 3.29 min/d) states than NEG bulls. Thus, despite the lower feed intake, NEG bulls exhibited increased eating behavior, likely reflecting foraging from pen floors and bedding after initial allotment was consumed. Additionally, NEG bulls exhibited more not active behavior, whereas the higher energy intake of POS bulls supported elevated active and highly active behaviors.

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Introduction

Effective management of breeding bulls is as important, if not more important, than the management of cows and heifers, given the significant impact a single bull can have on the genetic and reproductive success of a cattle herd. Bulls often experience substantial weight fluctuations, even over short periods of time, due to varying nutritional strategies and workload demands. Such changes in adequate energy balance and body condition leading up to the breeding season can expose developing sperm cells to altered hormonal environments and metabolic substrates during spermatogenesis and can instigate a behavior shift from attending to females to prioritizing feed searching in pens and pastures.

Weight loss in mature bulls can often occur as outlined by a survey of producers reporting a wide range in stocking rates, from four to 80 cows per bull (Dahlen and Stoltenow, 2015). As described by Walker et al. (2009) and Hersom and Thrift (2008), bulls can lose between 100 to 400 lbs. during the breeding season. As a result, bulls that lose weight must be managed appropriately post-breeding to regain condition (Barth and Waldner, 2002). In addition to workload, undesired feeding management decisions dictate when bulls begin to lose or gain weight relative to the breeding season. In some systems, bulls begin to lose weight when the breeding season starts and are then allowed to gain weight in preparation for the following season, thus having abundant energy. In other systems, bulls may begin losing weight before the breeding season due to environmental and dietary changes after purchase or because they are offered less feed to get them into "breeding shape" after being managed to gain weight during the winter season, thus having scarce energy.

With energy levels above metabolic requirements, bulls can maintain necessary physiological processes for survival, growth, and reproduction (Schneider, 2004). However, when energy is scarce, physiological processes prioritize survival at the expense of growth, longevity, and reproductive functions, resulting in increased food-seeking behaviors while suppressing locomotion and sexual activity (Schneider, 2004). In addition, cattle are highly social animals that form strong bonds and maintain structured herd dynamics. Hence, as more individual animals shift attention to foraging, the herd as a whole may be led away from reproductive focus (Ramseyer et al., 2009). It is also important to avoid excessive energy intake, which may result in increased fat deposition and obesity which can have negative effects on reproduction, such as infertility (Schneider, 2004). Thus, this experiment was conducted to evaluate how divergent pre-breeding planes of nutrition affect eating and activity behaviors in mature beef bulls, which may consequently influence reproductive outcomes in the herd.

Procedures

All procedures were approved by the North Dakota State University Institution for Animal Care and Use Committee. Fifteen mature Angus-based beef bulls (1,764.2 ± 36.39 lbs. initial BW) were used in a 112-day study to evaluate the effects of divergent planes of nutrition on eating and activity behaviors. For details related to impacts of treatments on scrotal circumference and concentrations of hormones and metabolites, see Dahlen et al. (2021). Bulls were housed in two partially covered pens at the NDSU Beef Cattle Research Complex (BCRC; Fargo, ND). Once adapted to the Insentec feeding system (Hokofarm Group B.V., Marknesse, Netherlands), bulls were stratified by BW and randomly assigned to one of two dietary treatments: 1) in one pen, bulls were managed on a positive plane of nutrition (POS, n = 7), and 2) in another pen, bulls were managed on a negative plane of nutrition (NEG, n = 8). Bulls were fed a common total mixed ration (TMR) containing approximately 45% corn silage, 27% triticale hay, 8% cracked corn, 16% dried distillers grains plus solubles (DDGS), and 4% vitamin/mineral premix on a dry matter (DM) basis (Table 1). Water was always available. Bulls were weighed every 14 days, and the amount of feed delivered to each pen was adjusted as needed to achieve the targeted weight gain or loss of approximately 12.5% of initial BW over the feeding period. Activity data were captured using an ear tag accelerometer system (CowManager, Harmelen, Netherlands) with eating, ruminating, not active, active, or highly active behaviors monitored. To monitor behavioral changes over the course of the study, data were arranged into four 28-days periods with period 1 including days 0 to 27, period 2 including days 28 to 55, period 3 including days 56 to 83, and period 4 including days 84 to 112. Data were analyzed using the MIXED procedure of SAS (V. 9.4, Inst. Inc., Cary, NC) for effects of treatment, period, and their interaction. Day was used as a repeated measure over time and bull the experimental unit. Differences were considered significant when $P \leq 0.05$ and tendencies were noted when $0.5 < P \leq 0.10$.

Results and Discussion

Consistent with the study design, POS bulls (28.0 ± 2.43 lbs./d) consumed significantly more dry matter ($P < 0.001$) than NEG bulls (11.7 ± 2.27 lbs./d) and had greater ($P < 0.001$) BW gain (2.67 ± 0.11 lbs./d) compared with NEG bulls (-2.65 ± 0.11 lbs./d). There was a treatment × period interaction ($P = 0.04$) for eating behavior, with NEG bulls spending more ($P \leq 0.001$) time eating during periods 1 and 3 and tending ($P = 0.06$) to spend more doing so in period 2 than POS bulls; no difference ($P = 0.99$) was observed in period 4 (Figure 1). This difference in eating behavior

Table 1. Dietary ingredients and nutrient profile of diet fed to mature bulls on divergent planes of nutritio[1]

Item	Inclusion
Ingredient, % DM	
Corn silage	44.6
Triticale hay	27.4
Cracked corn	8.0
DDGS	15.6
Vitamin-mineral premix	4.4
Nutrient Composition, %	
Ash	9.16
Crude Protein	12.30
ADF	27.30
NDF	50.00
Fat	2.91
Ca	0.56
P	0.39

[1]Diets were offered and re-adjusted as needed to a target rate of 12.5% gain (POS) or loss (NEG) of original BW.

occurred even with NEG bulls having access to less feed compared with POS bulls. Under conditions of energy scarcity, physiological systems prioritize instinctive survival behaviors; thus, more time may have been spent seeking food from pen floors and bedding after initial feed allotment to bunk was consumed (Schneider, 2004). The treatment × period interaction and the main effect of treatment did not influence ($P \geq 0.14$) ruminating behavior.

Behavior categorized as not active was also influenced ($P = 0.05$) by a treatment × period interaction. Although NEG bulls spent more time exhibiting eating behavior, they spent more ($P \leq 0.03$) time not active during periods 2 through 4 compared with POS bulls; no difference ($P = 0.44$) was observed in period 1 (Figure 2). An interaction between treatment and period was not present for active ($P \geq 0.14$) and highly active ($P > 0.14$) behaviors. However, active and highly active behaviors were strongly impacted ($P < 0.001$) by treatment, with POS bulls spending almost 2 h/d more exhibiting active behavior and ½ h/d more exhibiting highly active behavior than NEG bulls, Figure 3. Under conditions of abundant food availability and low energetic demand, sufficient energy can be allocated not only to immediate survival but also to long-term physiological investments, including somatic growth, immune competence, and reproductive function (Schneider, 2004).

Our findings emphasize the importance of implementing appropriate nutritional strategies for bulls entering the breeding season. The observed increase in not active behavior, excluding foraging, relative to active and highly active behaviors, suggests suboptimal energy allocation during a period when optimal physiological readiness is critical. Reduced activity prior to breeding may carry over into the breeding season, potentially

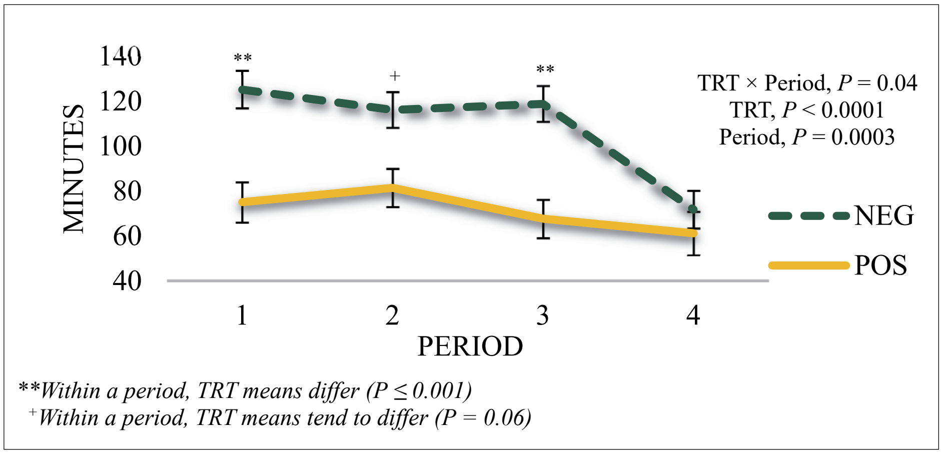

Figure 1. Effect of divergent planes of nutrition on mature bulls eating behavior.

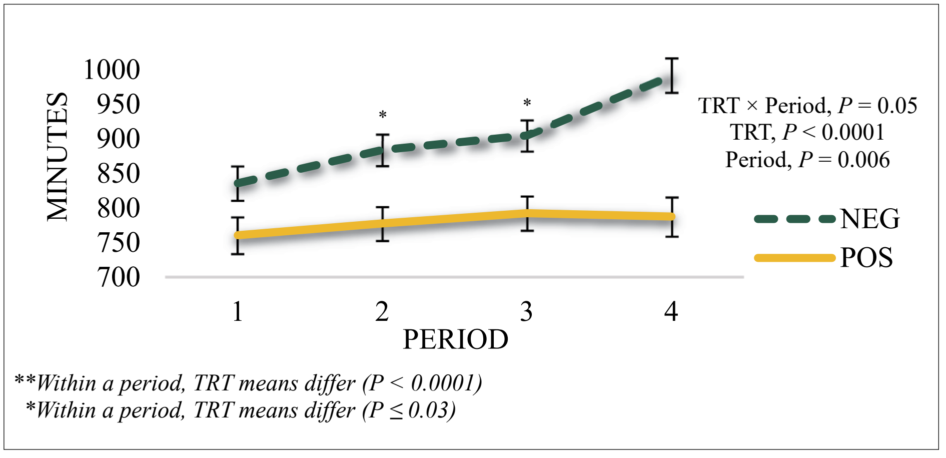

Figure 2. Effects of divergent planes of nutrition on mature bulls not active behavior.

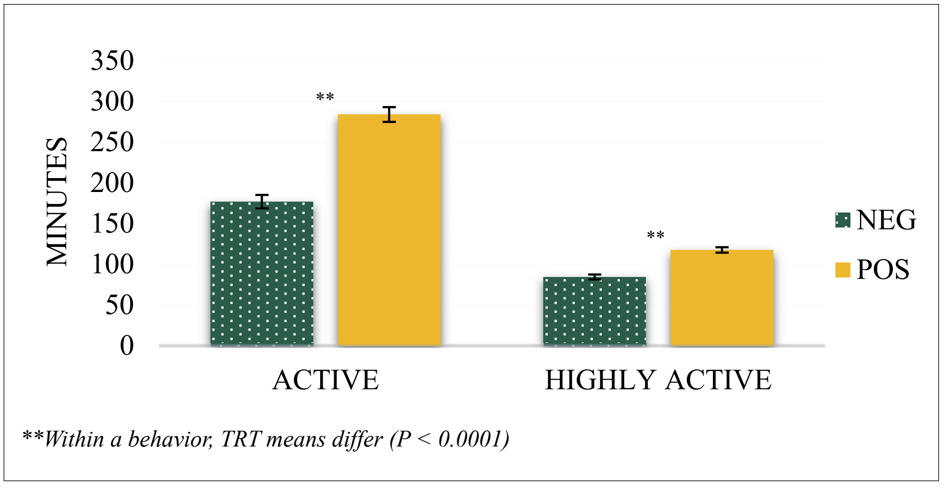

Figure 3. Effects of divergent planes of nutrition on mature bulls active and highly active behavior.

diminishing mating activity and lowering the proportion of females successfully bred. However, further research is warranted to confirm these associations. In contrast, adequate energy intake in POS bulls may enhance reproductive success. Nonetheless, overfeeding should be avoided, as excessive energy intake can exceptionally lead to obesity, which may negatively impact fertility.

Acknowledgments

We would like to thank the State Board of Agricultural Research and Education for partial funding of this project and the NDSU Central Grasslands Research Extension Center for providing bulls for this experiment. We would also like to express our gratitude to the personnel at the NDSU Beef Cattle Research Complex.

The mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the USDA. The USDA is an equal opportunity provider and employer.

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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.

Acknowledgments

Funding was provided by the USDA National Institute of Food and Agriculture grant 2022-67016-37092. We thank the staff and students at the Animal Nutrition and Physiology Center, the Beef Cattle Research Complex and the Animal Sciences Nutrition Laboratory for their assistance with the project.

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.

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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,

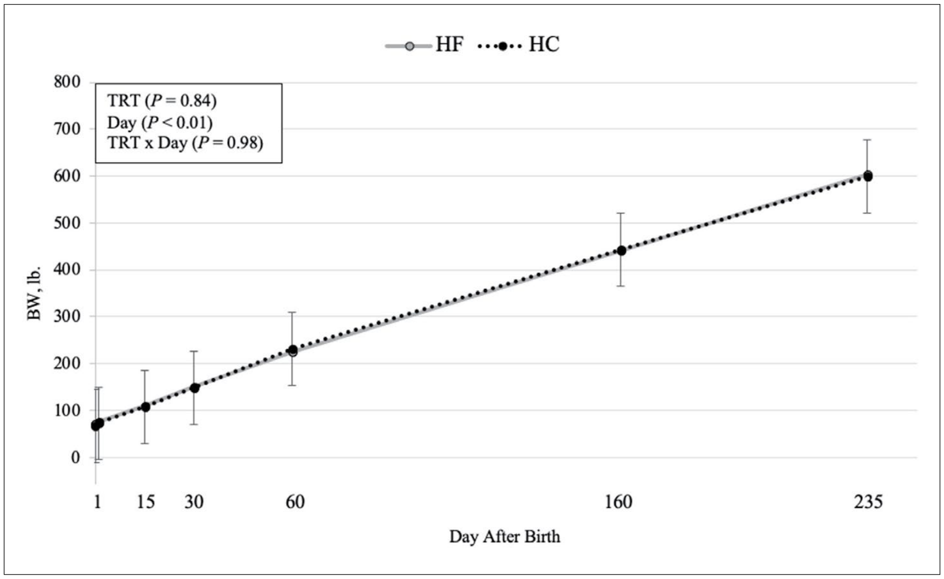

Figure 1. Body weight of calves at days 1, 15, 30, 60, 160 (weaning) and 235 (start of feedlot phase).

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

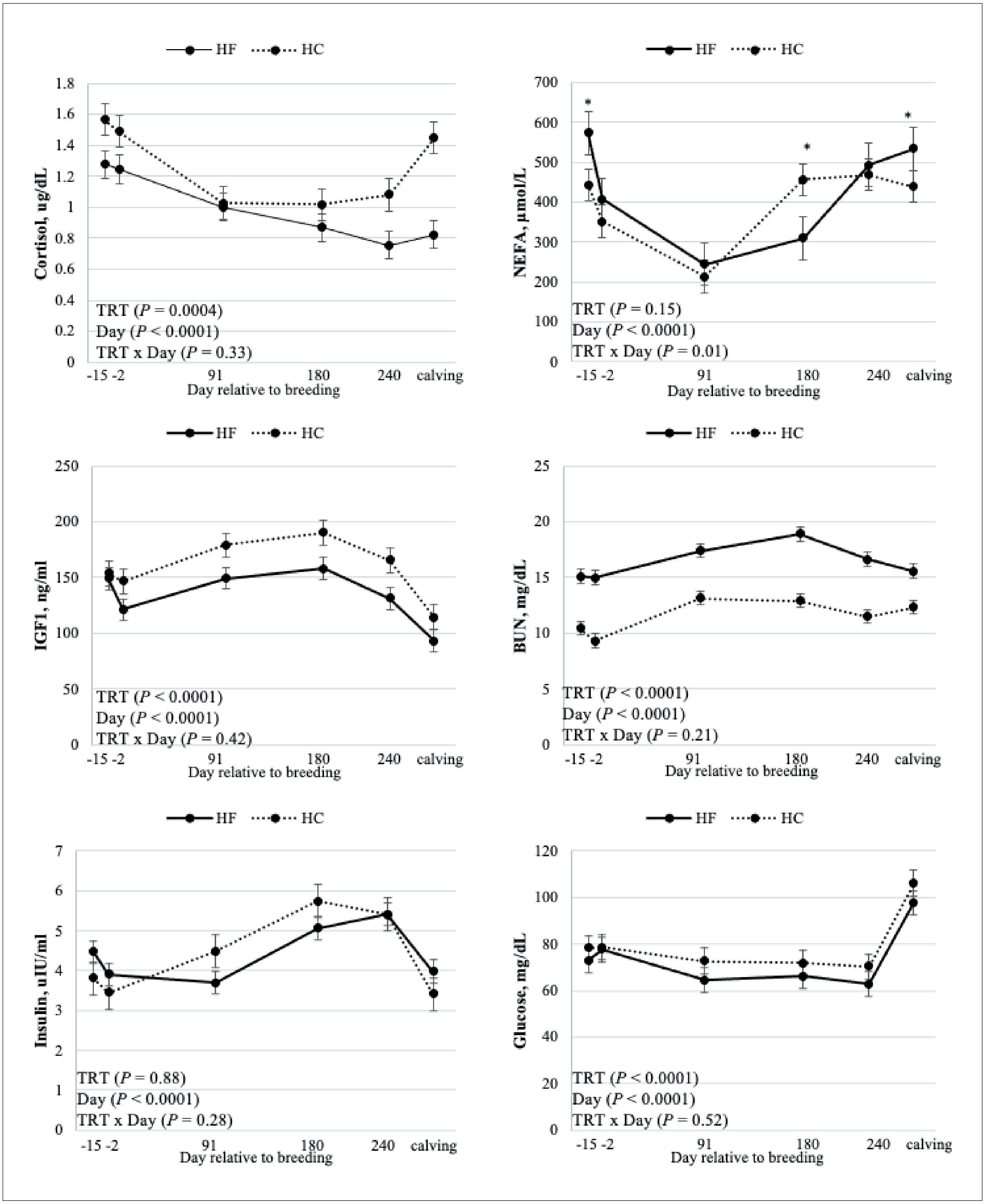

Figure 2. Serum cortisol, IGF-1, insulin, and plasma glucose, NEFA and BUN concentrations evaluated at days -15, -2, 91, 180, 240 and calving in heifers receiving either a HF diet composed of 25% concentrate and 75% forage; HC diet composed of 75% concentrate and 25% forage. Bars represent the standard 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.

Acknowledgments

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Effects of maternal nutritional supplementation during mid gestation on placental vascular development in beef heifers

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Mid gestation protein/energy supplementation in beef heifers tended to increase capillary area density and reduced capillary number density, indicating a shift toward fewer but potentially more efficient placental vessels. Supplementation did not affect Ki-67 positivity ratio or spatial cell density, suggesting no change in cell proliferation.

Summary

This study evaluated the effects of providing protein/energy supplement during mid gestation on placental vascular development in pregnant beef heifers. Heifers pregnant with male calves were assigned to either a forage-based control diet fed to gain a target of 0.62 lb/BW/d (CON); or to receive the forage-based diet with the addition of a protein/energy supplement to target 1.74 lb/BW/d (SUP) from day 90 to day 186 of gestation. After the feeding period all heifers were managed as a single group until calving. Immediately upon expulsion of the placenta, samples of cotyledon were collected and preserved in neutral buffered formalin (NBF). Tissues were subsequently analyzed using immunohistochemistry for key indicators of vascularization (using CD 31/34 stain) and cell proliferation (using Ki-67 stain) with data used to calculate capillary area density (CAD), capillary number density (CND), Ki-67 positivity ratio (PR) and spatial cell density (SCD). Data were analyzed using the GLM procedure of SAS with individual animal as the experimental unit. Results showed that CAD tended to be greater (P = 0.07) in SUP compared with CON, indicating enhanced placental vascular development and potential for improved nutrient transfer to the fetus. Conversely, CND was reduced (P = 0.02) in the SUP group, suggesting a more efficient vascular structure with fewer but possibly larger or more functional capillaries. No differences were present between treatments for PR or SCD (P = 0.27; P = 0.33), indicating that overall cellular proliferation and tissue cellularity were not markedly affected by maternal supplementation. These findings suggest that mid gestation protein/energy supplementation can enhance placental vascular features critical for fetal development, particularly by promoting vascular efficiency rather than increasing cellular proliferation.

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Introduction

In many beef production systems, nutrient demands of developing heifers are not fully met during mid gestation due to environmental constraints or management practices that often exclude targeted supplementation. During this critical period, heifers are particularly vulnerable to nutrient deficits, which can negatively impact not only their own development but also that of the fetus and associated gestational tissues (Vonnahme et al., 2018). The placenta plays a vital role in mediating nutrient, gas and waste exchange between the dam and fetus, and its proper development is crucial for fetal growth and survival (Reynolds et al., 2023). Placental efficiency is largely influenced by factors such as vascularization, surface area and nutrient transporter activity - processes that are sensitive to maternal nutrient status (Davenport et al., 2023). Indeed, maternal nutrition has been shown to impact placental morphology and angiogenesis, which may have lasting consequences for offspring outcomes as indicated in Vonnahme et al. (2018) and Davila Ruiz et al. (2024).

Despite growing evidence linking maternal nutrition and placental development, the specific impacts of mid gestation supplementation, particularly regarding protein/energy, remain incompletely understood. Few studies have directly examined how nutritional intervention during this window affects the establishment and growth of the placenta in beef heifers (Davila Ruiz et al., 2024). To address this gap, the current study evaluated the effects of mid gestation supplementation on placental development in beef heifers. We hypothesized that providing a targeted supplement during this stage would enhance placental growth and vascularization compared to unsupplemented heifers, potentially supporting improved fetal development and long-term productivity.

Procedures

Crossbred Angus heifers (n =119; initial body weight (BW) 748.9 ± 72.8 lb), approximately 13 months of age, each pregnant with a male calf from a single artificial insemination breeding, were randomly assigned to receive one of two diets from day 90 to day 186 of pregnancy. Dietary treatments were the following: 1) a forage-based diet targeting BW gains of 0.62 lb/heifer/day (CON; n = 22) or 2) a forage-based diet plus a corn-based protein/energy supplementation targeting BW gains of 1.74 lb/heifer/day (SUPP; n = 22). The placenta was collected upon expulsion, rinsed and weighed, and the largest cotyledon (COT), closest to the umbilical cord, was sampled. The COT was collected and fixed in neutral buffered formalin (NBF) for 24 hours then transferred to 70% ethanol. Fixed samples were embedded in paraffin via a tissue processor. Slides were cut on a microtome at 5-μm thickness for three-Dimensional analysis of vascularity.

As previously described by Dávila Ruiz et al. (2024), rabbit anti-CD34 and rabbit anti-CD31 were used to identify endothelial cells for quantification of vascularity, while DAPI was used for nuclear counterstaining. Sections were deparaffinized in xylene (three times × three minutes each), 100% alcohol (two times × one minute each), 95% alcohol (one time × one minute), and, finally, in distilled running water (one time × one minute) for rehydration. Epitope retrieval was performed in Na-citrate buffer for 30 minutes at 121 degrees Celsius. Antigen blocking was performed in 5% normal goat serum at room temperature for one hour. Primary CD-31 and CD-34 monoclonal antibodies were diluted at 1:50 and 1:500, respectively, in 1% bovine serum albumin (BSA) and incubated at room temperature for one hour. After incubation with the primary antibodies, the secondary Biotium CF-633 anti rabbit antibody (1:250 in 1% BSA) was incubated with the tissue sections for one hour at room temperature. Nuclear staining was performed with DAPI at room temperature for five minutes.

Staining for Ki-67 was also used to assess cell proliferation, and DAPI was used for background nuclear staining. Sections were deparaffinized, and epitope retrieval and antigen blocking were conducted as described above. Primary and secondary Ki-67 were diluted at 1:250 in 1% BSA and incubated at room temperature for one hour each, respectively. Nuclear staining for background was performed with DAPI at room temperature for five minutes.

The Mica microhub fluorescence microscope (Leica Microsystems, Wetzlar, Germany) was used to detect and quantify fluorescence intensity and spatial distribution of fluorophore-labeled targets. Specifically, fluorescence signals corresponding to endothelial markers (CD31/CD34), nuclear staining (DAPI), and the proliferation marker Ki-67 were captured at defined emission wavelengths. From these fluorescence measurements, capillary area density (CAD), capillary number density (CND), Ki-67 positivity ratio (PR), and spatial cell density (SCD) were calculated through image analysis using ImagePro-Premiere software. The measurements were quantified in terms of area (pix^2), which reflects the number of pixels exhibiting signal above threshold within a given region of interest. These pixel-based measurements were used to derive quantitative metrics representative of vascular and cellular characteristics in the placental tissue.

All statistical analyses were performed using the General Linear Model (GLM) procedure of SAS 9.4 (SAS INST. Inc., Cary, NC) with individual animal as the experimental unit. Data are reported as least squares mean (LSMEANS) ± standard error of the mean. Differences were considered statistically significant at $P \leq 0.05$, and a tendency was declared at $0.05 \leq P \leq 0.10$.

Results and Discussion

Heifers that received supplementation tended to have greater CAD values (3.72 ± 0.41) compared to control heifers (2.62 ± 0.42; $P = 0.07$). These results suggest that maternal nutritional intervention enhances placental vascular development, potentially improving nutrient delivery to the developing fetus. In contrast, CND was also influenced by maternal supplementation but in the opposite direction. Heifers in the control group had greater ($P = 0.02$) CND values (5.95 ± 0.61) compared to those in the supplemented group (3.92 ± 0.60). This suggests that supplementation during mid gestation may promote the development of fewer but more efficient blood vessels in the placenta.

There was no difference ($P = 0.27$) observed in Ki-67 PR between treatment groups. Control heifers exhibited a PR of 11.87 ± 0.86, while supplemented heifers showed a PR of 10.49 ± 0.86. These findings suggest that maternal supplementation did not markedly influence cellular proliferation rates in placental tissue (Vonnahme et al., 2018; Davila Ruiz et al., 2024). Similarly, there was no difference in SCD between the control and supplemented groups. The CON group had an average SCD of 1.39 ± 0.14, while the SUP group averaged 1.23 ± 0.13 (P = 0.33). Vonnahme et al. (2018) also reported that alterations in maternal diet influenced placental vascular characteristics without uniformly affecting placental morphology.

The present findings highlight that maternal protein and energy supplementation during gestation can influence specific aspects of placental vascular development in beef heifers. Notably, supplemented heifers had greater CAD, suggesting an enhancement in placental vascular expansion. A greater CAD may indicate increased vascular surface area for maternal-fetal exchange, potentially leading to greater efficiency in nutrient and oxygen transfer to the developing fetus. This aligns with prior work by Reynolds et al. (2023), who reported that nutritional interventions during pregnancy can modulate placental angiogenesis, supporting fetal growth trajectories and developmental

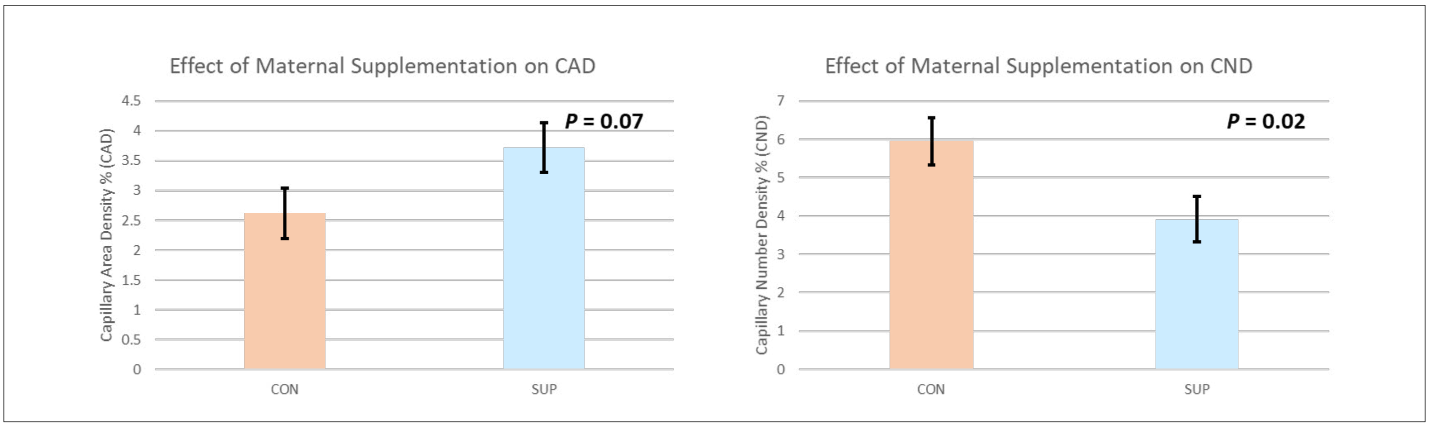

Figure 1. Capillary development in the placental cotyledon from beef heifers fed a protein/energy supplement from day 90 to day 180 of gestation. The graphs show the effect of maternal supplementation on (left) capillary area density and (right) capillary number density. This measurement was obtained through immunohistochemistry, utilizing CD-31 and CD-34 as markers for endothelial cells within blood vessels, followed by image analysis. Data are presented as mean ± SEM. CON = Control group (no supplementation); SUP = Supplemented group (received protein/energy supplement during mid-gestation); CAD = Capillary Area Density; the proportion of placental tissue area occupied by capillaries, expressed as a percentage; CND = Capillary Number Density; the number of capillaries per unit tissue area, expressed as a percentage.

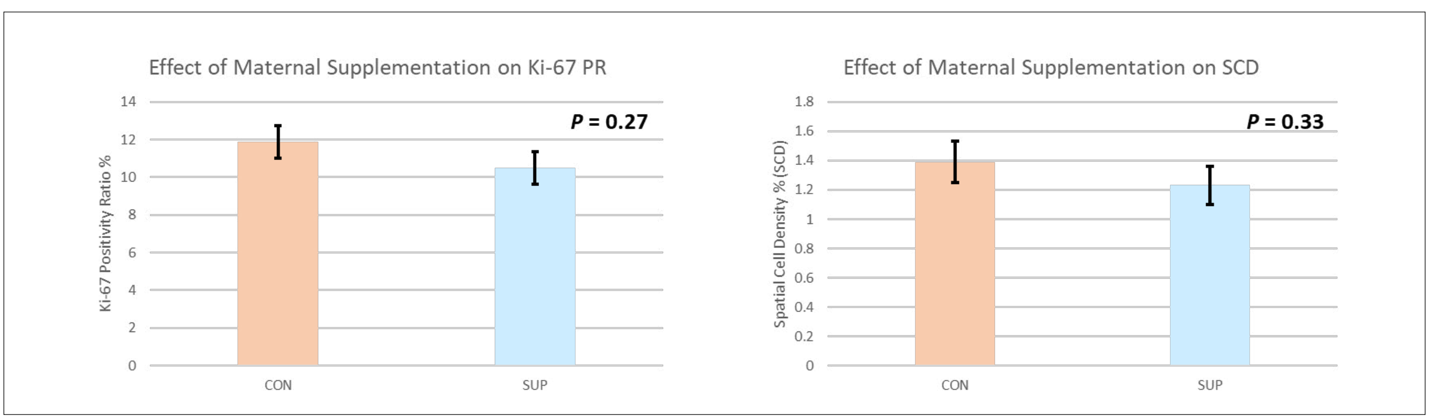

Figure 2. Cellular proliferation and density in the placental cotyledon from beef heifers fed a protein/energy supplement from day 90 to day 180 of gestation. The graphs show the effect of maternal supplementation on (left) Ki-67 Positivity Ratio and (right) Spatial Cell Density. Data are presented as mean ± SEM.
CON = Control group (no supplementation); SUP = Supplemented group (received protein/energy supplement during mid-gestation; Ki-67 PR = Ki-67 Positivity Ratio; percentage of nuclei positive for Ki-67 staining, indicating proliferating cells; SCD = Spatial Cell Density; the number of nuclei per unit tissue area, expressed as a percentage.

programming. Future research should focus on evaluating the functional consequences of these vascular changes, such as blood flow capacity, nutrient transport efficiency and fetal metabolic outcomes, to better understand how maternal supplementation translates to long-term offspring performance and health.

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Assessing the degradability of a soybean hull-based baling twine

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Incorporating soybean hulls into twine increased ruminal degradability compared to traditional plastic twine, with higher soyhull content leading to greater breakdown. While soyhull-incorporated twine is not as degradable as sisal twine, results highlight the potential for developing safer baling material for livestock.

Summary

This study investigates the ruminal digestibility of a newly developing twine made with polylactic acid and soybean hulls as a safer alternative to conventional polypropylene twine. Using in-situ rumen incubation in cannulated Jersey steers, results showed higher degradation in the rumen with greater inclusion of soybean hulls. Traditional plastic twine showed no breakdown, indicating its resistance to digestion. These findings suggest that incorporating agricultural byproducts like soybean hulls into baling materials may reduce health risks to cattle.

Introduction

The use of baling twine in the livestock industry for forage management is a common practice. Conventional twine materials often contain synthetic plastics, like polypropylene, due to their durability. These materials can pose risks to animal health and the environment. Twine that is not properly disposed of can be ingested by cattle, resulting in gastrointestinal blockages, reduced feed intake and, in severe cases, death.

In response to these issues, there is a growing interest in developing alternative twine materials that can both maintain bale storage and be safer for livestock if ingested. Agricultural byproducts, such as soybean hulls, may offer a solution for biodegradable and digestible materials that could be used in twine. Soybean hulls are rich in highly digestible neutral detergent fiber (NDF) and are already a feedstuff that can be utilized in cattle diets (Lyu et al., 2022).

The objective of this study was to evaluate the digestibility of a newly formulated soybean hull-based twine when ingested by cattle. This work aims to provide preliminary insights into incorporating plant-based materials into baling products that reduce health risks and environmental impacts while maintaining practical functionality on the farm.

Procedures

The experimental procedures were approved by the North Dakota State University Institutional Animal Care and Use Committee (IACUC#A21018). Two mature, cannulated Jersey steers were used to conduct an in-situ experiment. The steers were housed individually and fed a grass hay diet.

Experimental twine material was made of a biodegradable polylactic acid (PLA) polymer, which is produced from corn starch, with 0%, 10%, 20% and 30% soyhulls (SH) by weight (SH-0, SH-10, SH-20 and SH-30). Twine samples were produced through an extrusion process of a uniform blend of SH powder with PLA and a small amount of compatibilizer, a chemical agent added to enhance bonding between SH and PLA.

Each PLA/SH combination, a positive control (alfalfa), a negative control (commercial polypropylene twine) and an alternative product (sisal twine), was incubated ruminally in each steer. Twine samples were prepared by cutting materials into 5-gram portions. Alfalfa was ground through a 2-mm screen. Approximately 5 g of each sample, in triplicate, were sealed in in-situ bags (10 × 20 cm, Ankom Technology, Macedon, NY) using a heat sealer for each time point. Each time point also included triplicate blank bags. All samples were placed in mesh laundry bags, each containing the full set of incubation treatments for one time point. The mesh laundry bags were presoaked in water for 20 minutes and allowed to drip dry prior to insertion into the rumen. A large rock was placed in each bag to anchor it at the bottom of the rumen below the hay mat.

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Samples were incubated for 0, 24, 72, 120 and 168 hours (0, 1, 3, 5 and 7 days), placed in reverse order to allow for all bags to be pulled simultaneously. After incubation, each mesh laundry bag was rinsed carefully in a bucket to remove large particulate matter from the outside of the bags. The heat-sealed in-situ bags were then removed from the mesh bag and washed in a portable washing machine. All samples were agitated for 1 minute, drained and spun for 2 minutes; this cycle repeated five times. Each time point was washed separately due to limited space in the machine. Bags were then dried in a forced-air oven at 55 degrees Celsius for 48 hours, placed in a plastic bag and transferred to a desiccator. Once removed, samples were allowed to equilibrate to room conditions for at least 3 hours before recording equilibrated dry weights. Disappearance was calculated as loss in sample weight divided by initial sample weight using triplicate incubations. Final bag weights containing samples were corrected for changes in weight of empty incubated bags.

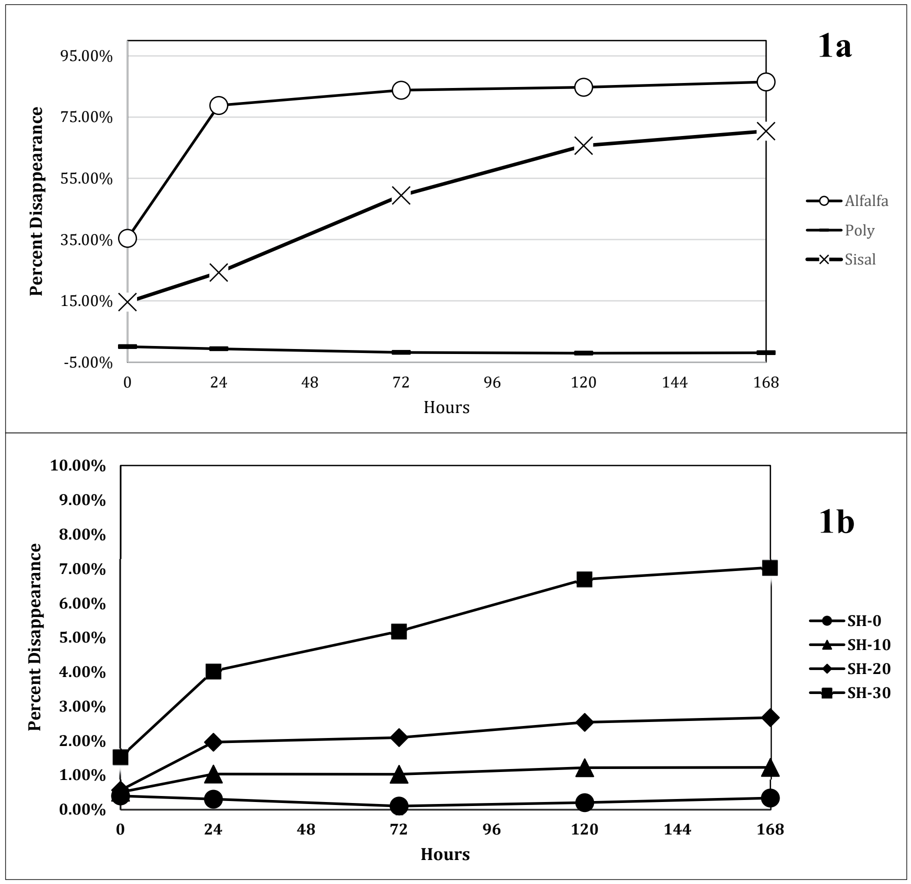

Figure 1. Comparison of degradation rates of alfalfa, sisal twine, commercial polypropylene twine (Poly) (1a) and comparing PLA/soyhull twine degradation rate (1b).

$$Disappearance = \frac{W_{initial} - (W_{incubated} - (W_{bag} - Blank\ correction))}{W_{initial}}$$

Results and Discussion

Alfalfa exhibited rapid degradation, with disappearance exceeding 80% by 72 hours and plateauing near 90% (Figure 1a). The fast rate of degradation reflects alfalfa's rich content of rumen-fermentable nutrients such as NDF, which are readily available to ruminal microbes (Van Soest, 1994). Sisal twine, which contains plant-based fibers, also demonstrated significant degradation, increasing steadily over time and reaching nearly 70% disappearance at 168 hours. The upward trend in disappearance suggests that sisal is able to be digested in the rumen environment. In contrast, the commercial polypropylene (Poly) was undegraded across all time points, with values near zero degradation, showing its resistance to microbial breakdown. This result is as expected due to its resistance to degradation (Shah et al., 2008).

Across all time points, SH-30 showed the greatest disappearance of PLA twines, reaching approximately 7% by 168 hours (Figure 1b). Lower SH levels resulted in less degradability, while SH-0 (no soyhulls) showed minimal degradation, similar to the Poly. These results indicate that incorporating SH into twine could enhance the breakdown of material by ruminal microbes due to the presence of plant-derived organic matter. Although the PLA/SH composites had greater degradation than Poly, degradability was less than that of the sisal twine, suggesting that further formulations could be developed to improve degradation of the SH twine in the cattle digestive tract.

Degradation rate and half-life provide more insights into how the PLA/SH twine breaks down in the rumen (Figure 2). The degradation rate increases nonlinearly with increasing soyhull content. SH-0, representing pure PLA twine, did not degrade, while SH-30 had the fastest rate at approximately 0.06%/hour; this is still slow compared to alfalfa (8.60%/hour) and sisal (0.88%/hour), indicating higher microbial activity and availability. The estimated half-life of the degradable fraction (the amount of

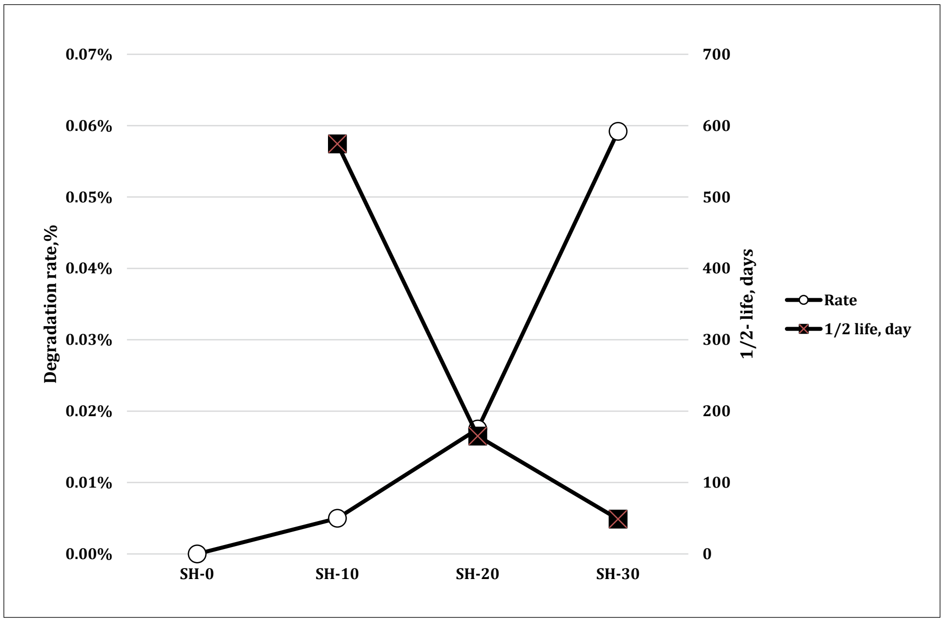

Figure 2. Ruminal degradation rate. Effect of soyhull content on the disappearance rate (%) of PLA-based twine materials in rumen incubation. A nonlinear increase in disappearance rate was observed as soyhull content increased with SH percentage.

time it takes for half of the material to degrade) decreased with increasing SH content but was still quite long. SH-10 had a half-life exceeding 575 days, while the half-life of SH-30 dropped to below 49 days. These findings suggest that the structural and nutritional contribution of SH within the PLA twine can improve overall disappearance and increase degradation efficiency.

Acknowledgments

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Economic potential of using field peas in place of corn dried distillers grains in beef heifer growing diets

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The objective was to determine the economic potential of field peas relative to corn DDGS in diets of growing heifers. Regression results revealed that total gain was not influenced (P > 0.05) by dietary treatment, allowing for a comparative ration cost analysis. Base-case results indicate the ration with field peas costs $6.89/hd more than the ration with DDGS. The breakeven price of field peas is $254.8/t, 71% of the price of DDGS; the breakeven price of DDGS was $567.2/t, 141% of the price of field peas. Results will help pea processors and feed supply dealers develop a reliable supply chain for a beef cattle quality field pea source of feed.

Summary

The objectives were to determine economic potential of field peas relative to corn DDGS in diets of growing heifers and to determine price points for competitive utilization of field peas as an alternative to corn DDGS. Animal performance data from 324 heifers were generated from a completely randomized design feeding trial replicated over two years. Mixed effects regression models revealed total gain was not influenced ($P > 0.05$) by dietary treatment, allowing for a comparative ration cost analysis. Base-case ration costs were calculated using prices of $358/t and $403/t for corn DDGS and field peas, respectively. Base-case results indicate the ration with field peas costs $6.89/hd more than the ration with DDGS. The breakeven price of field peas is $254.8/t, 71% of the price of DDGS; the breakeven price of DDGS was $567.2/t, 141% of the price of field peas. Results will help pea processors and feed supply dealers develop a reliable supply chain for a beef cattle quality field pea source of feed.

Introduction

Feed costs account for 60% to 70% of the total costs of a beef operation (Kaliel and Kotowich, 2002). Thus, reducing feed costs while optimizing animal production is essential for maintaining a profitable operation. Feed costs can be reduced through the use of cost-effective ingredients in mixed rations fed to cattle. Corn dried distillers grains with solubles (DDGS) is one of the most common supplements used across the Great Plains region of the U.S. (Swanson et al., 2014; Lardy et al., 2009). Continued utilization of corn DDGS in cattle rations will likely be affected by availability and pricing. Factors such as an increase in corn oil price can result in a drastic reduction in DDGS production and an increase in the price of DDGS. Thus, there is a need to investigate and evaluate protein and energy sources that can cost-effectively replace corn DDGS in cattle rations.

The energy content of field peas is similar to cereal grains such as corn and barley when included in high-concentrate finishing diets (Lardy et al., 2009). Field peas are primarily grown for human consumption and for the pet food industry. However, the livestock industry is a potential market for field peas in situations where there is excessive field pea production, thus saturating the pet food market or production of field peas that do not meet specifications for human consumption. Major field pea growing areas include North Dakota and Montana in the U.S. and Manitoba, Saskatchewan and Alberta in western Canada. In such areas, feeding peas to livestock presents a realistic, on-farm value-adding opportunity for pea growers.

Field peas have been successfully included in cattle finishing diets (Gilbery et al., 2007; Lardy et al., 2009). Compared to other feedstuffs, the price of field peas is likely to be a major factor in determining utilization of field peas in cattle rations. However, identifying a price for field peas as livestock feed presents a challenge since field peas for livestock do not have a formal market compared to other feeds. This provides a need for data on which to base reliable recommendations on the economic viability of utilizing field peas as a replacement of supplements such as corn DDGS in growing heifer diets. This study was conducted to determine the economic potential of feeding diets containing field peas vs. DDGS in diets of growing heifers and to identify relative price points for competitive utilization of field peas as an alternative to corn DDGS in diets of growing heifers.

Materials and Methods

This study was conducted at the Central Grasslands Research Extension Center located in Kidder and Stutsman counties in North Dakota. The two-year study was from Nov. 24, 2020, to Feb. 17, 2021 (year 1), and Nov. 8, 2021, through Feb. 24, 2022 (year 2). In the fall of each year, 162 growing Angus heifers (2020/2021, body weight [BW] = 688 ± 84 lb; 2021/2022, 624 ± 71 lb) were divided into two groups of similar average body weight and the groups were randomly assigned to six dry lot pens. Dry lot pens were surrounded by 8-foot-high wooden windbreaks on three sides of the pen. Each pen contained a 52-foot-long feed bunk and a winterized water bowl (Richie Industries Inc., Conrad, IA, USA). Three groups of heifers (27 heifers/pen) were assigned randomly to total mixed ration (TMR) diets containing either field peas or corn DDGS. Feed ingredients fed to heifers by diet and feeding period are reported in Table 1.

Heifer feeding was accomplished using a "clean bunk" feeding management. The goal of clean bunk management is for all feed delivered to a pen to be consumed daily, with bunks being empty for a certain period of time prior to the next feeding, without restricting feed intake (Erickson et al., 2003). Heifers had *ad libitum* access to fresh water. Heifer performance was assessed from averages of two-day body weights taken at the start and end of the study.

Animal performance data were analyzed using the MIXED procedure of SAS with pen as the experimental unit. The fixed effects in the model were diet (DDGS or peas), season (fall and winter) and the diet × season interaction. Year within pen was considered a random effect. Least square means were calculated and, where appropriate, differences between treatment means were tested using the Bonferroni test at a significance level of $P \leq 0.05$. Initial and final BW were collected on individual animals, and a pen value was calculated by averaging the respective individual animal values within a pen. Animal performance measures evaluated included initial and final BW, average daily gain (ADG), dry matter intake (DMI) and total gain (TG).

Economic evaluation of the feed costs for each TMR treatment (DDGS and peas) was based on the two-year average measures of DMI (lb/hd/day), TG (lb/hd) and days on feed. Because growth performance measures were not influenced by dietary treatment, a comparative ration cost analysis was conducted without the need to account for differences in animal performance. Enterprise budgeting techniques were used to calculate the two-year average costs of individual ingredients for each diet treatment. On March 1, 2022, prices of corn grain, hay and DDGS were obtained from a local farm input supplier (Farmers Coop Elevator Company, Streeter, ND) and were priced at $303, $100 and $358/t, respectively. In addition, a price of $37/t for corn silage was used and based on local production and estimated from corn production. Also, in March of 2022, based on conversations with field pea producers, the price of field peas was concluded to be in a range between $325 and $445/t ($8 to $11/bushel). For the analysis, we used the average base-case price of $403/t for field peas.

Ration costs ($\$ \text{ hd}^{-1}$) were calculated as the product of DMI (lb/hd/day) for each ingredient (DDGS vs. peas), days on feed and individual ingredient price. Individual DMI for each ingredient was calculated from feed delivered (lb/hd/day) and diet composition. Over a two-year period, an average of 4.2% DDGS and 6% field peas were used in the corn DDGS-based and field peas-based diets, respectively. At a feed intake of approximately 18 lb/hd/day for both diets, 0.73 and 1.05 lb/hd/day of corn DDGS and field peas were included in the respective diets.

Because the price of field peas as a feed source for animal production is not likely to be directly affected by the price of corn or DDGS, sensitivity analysis was conducted to calculate relative total cost of feeding peas vs. DDGS for combinations of prices ranging from ±50% of the base-case prices of $358 and $403/t for DDGS and field peas, respectively.

Table 1. Feed ingredients fed on a dry matter basis to heifers by diet and feeding period (lb/hd/day).

	DDGS			Peas		
Variable	Fall	Winter	Average	Fall	Winter	Average
Hay	6.53	7.51	7.02	6.59	7.20	6.89
Silage	6.77	7.71	7.24	6.62	7.63	7.13
Corn	2.06	2.25	2.16	1.82	2.38	2.10
Supplement	0.49	0.56	0.53	0.49	0.57	0.53
DDGS	0.68	0.79	0.73	0.00	0.00	0.00
PEAS	0.00	0.00	0.00	0.99	1.11	1.05
Total	16.54	18.81	17.67	16.51	18.90	17.70

Results and Discussion

Initial BW, final BW, DMI, ADG and TG were not influenced ($P > 0.05$) by diet, but there were seasonal differences for each ($P < 0.001$; Table 2). Initial and final BW was greater ($P < 0.001$) in winter relative to fall, which was expected since the same heifers were utilized in winter. Average DMI was greater ($P < 0.001$) in the winter relative to fall, which follows logic that animals tend to eat more when colder. Conversely, TG and ADG were greater in the fall relative to winter, which reflects the typical observation that animals do not perform as well in the extreme cold that is common to North Dakota in the winter.

Two-year average cost of feed for each ingredient on a ($/hd/day) and ($/hd) basis is reported in Table 3. The cost of hay, silage, corn grain and supplements equaled $82.09/hd (or $1.84/hd/day) over the total feeding period, accounting for 87% and 81% of the total cost of the corn DDGS-based ration and dry field peas-based ration, respectively. The total cost of feed for a representative heifer for the total (fall plus winter) feeding period for the corn DDGS-based ration is $93.89/hd (or $2.10/hd/day) and is $6.88/hd (7.3%) less than the dry peas-based ration cost of $100.77/hd (or $2.26/hd/day) for base-case prices of $358/t and $403/t for corn DDGS and field peas, respectively. For perspective, at the base-case prices, a producer interested in feeding a group of 100 heifers similar to those fed in the study, the cost of feeding field peas instead of DDGS in the TMR would cost an extra $688 over the total feeding period.

Table 4 reports differences in the total cost of field peas relative to the total cost of DDGS for alternative combinations of prices of field peas and DDGS. Price combinations that have a negative total cost indicate market situations where field pea-based rations have an economic advantage over DDGS-based rations. For a market scenario where peas can be purchased at a price that is 50% less than the base-case price of peas and the price of DDGS is priced 50% higher than the base-case price, a producer would benefit economically from buying peas and saving $8.37 head^{-1} of feed cost, holding all other feed ingredient prices constant. Overall, for a base-case average price of $358 t^{-1} for DDGS, the breakeven price for field peas was equal to $255

Table 2. Performance of growing heifers consuming field peas-based or corn DDGS-based total mixed rations.

	TMR diet			Season			*P*-values		
	DDGS	Peas	SE	Fall	Winter	SE	Diet	Season	Diet x Season
DMI, lb/d	17.4	17.6	0.20	16.8[b]	18.1[a]	0.07	0.55	<0.001	0.72
DMI, %BW	5.7	5.5	0.13	5.7[a]	5.5[b]	0.07	0.77	0.001	0.75
Initial BW, lb	655	662	21.2	617[b]	697[a]	6.4	0.71	<0.001	0.66
Final BW, lb	730	741	19.6	699[b]	770[a]	6.6	0.60	<0.001	0.69
Total gain, lb	76.5	78.7	2.7	82.5[a]	72.5[b]	1.5	0.44	<0.001	0.53
ADG, lb/d	1.70	1.65	0.11	1.85[a]	1.48[b]	0.04	0.70	<0.001	0.66

[a-b]Means with a different letter within column for diet or season differ significantly ($P \leq 0.05$).

Table 3. Two-year average cost of feed for individual feed ingredients for two total mixed rations for fall, winter and total grazing periods

	Fall		Winter		Total	
Feed ingredient	$/hd/d	$/hd	$/hd/d	$/hd	$/hd/d	$/hd
Hay	0.32	14.61	0.36	16.80	0.66	29.91
Silage	0.13	5.68	0.14	6.76	0.27	12.07
Corn grain	0.29	12.78	0.35	16.41	0.68	29.92
Supplement	0.10	4.71	0.12	5.68	0.23	10.20
Dry distiller grains (DDGS)	0.12	5.46	0.14	6.68	0.26	11.79
Total cost with DDGS included	0.96	43.24	1.11	52.32	2.10	93.89
Field peas	0.20	9.35	0.22	10.48	0.42	18.68
Total cost with field peas included	1.04	47.13	1.20	56.12	2.26	100.77
Difference in cost between rations	0.08	3.89	0.08	3.80	0.16	6.88

Table 4. Difference in total cost of field peas relative to total cost of dry distiller grains (DDGS) ($/hd) for alternative price ($/MT) combinations

			PEAS						
	% -	- $/t	-50% 202	-30% 282	-10% 363	Base* 403	10% 444	30% 525	50% 605
DDGS	-50%	180	3.42	7.15	10.88	12.76	14.65	18.38	22.10
	-30%	251	1.07	4.79	8.52	10.41	12.29	16.02	19.75
	-10%	323	-1.29	2.43	6.16	8.05	9.94	13.66	17.39
	Base*	358	-2.45	1.27	5.00	6.88	8.77	11.76	16.23
	10%	395	-3.64	0.07	3.80	5.69	7.58	11.30	15.03
	30%	466	-6.01	-2.28	1.44	3.33	5.22	8.94	12.67
	50%	538	-8.37	-4.64	0.53	2.42	2.86	6.59	10.31

*Base-case net return assuming a price of $358 and $403 per MT for DDGS and field peas, respectively.

t^{-1}, which was 36.8% less than the base-case price of $403 t^{-1} for peas and 71% of the base-case price of DDGS. Conversely, for the base-case price of field peas of $403 t^{-1}, the breakeven price of DDGS was equal to $567.3 t^{-1}, which was 58.3% more than the base-case price of $358 t^{-1} for DDGS and 141% more than the base-case price for field peas. At the respective breakeven prices, producers would be indifferent between using field peas or corn-based DDGS in their TMR.

Conclusions

Compared to a diet containing DDGS, a field peas-based diet that met nutrient requirements of growing heifers required 43% more field peas. At this level of incorporation, field peas would be an economically feasible replacement for corn DDGS in growing heifer diets when the price of the field peas is less than or equal to 71% of the price of corn DDGS. Our results offer the field pea processing industry useful economic information about the range of prices that beef cattle producers can afford to pay for peas relative to DDGS. This information will help pea processors and feed supply dealers develop a reliable supply chain for a beef cattle quality pea feed.

Acknowledgments

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Discovering performance and value in North Dakota Calves: 2024-2025 Dakota Feeder Calf Show Feedout

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The Dakota Feeder Calf Show is a feedout project where North Dakota cattle producers are identifying cattle with superior growth and carcass characteristics. For 2024-2025 feeding period, the average difference in profitability between consignments from the top five herds and the bottom five herds was $376.95 per head.

Summary

Dakota Feeder Calf Show feedout project provides North Dakota cattle producers with the actual value of their spring-born beef steer calves, comparisons among herds, and benchmark feeding and carcass performance measurements. Cattle consigned to the feedout project were delivered to the Carrington Research Extension Center Livestock Unit on Oct. 19, 2024. After a 242-day feeding period with 1.79 percent death loss, cattle averaged 1460.6 pounds (shrunk harvest weight). Feed required per pound of gain was 6.6 (dry-matter basis). Overall pen average daily gain was 3.43 pounds per head. Feed cost per pound of gain was $0.618 and total cost per pound of gain was $0.903. Profit ranged from $1,213.79 per head for pen-of-three cattle with superior growth and carcass traits to $836.84 per head. The variability between producer's herds continues to be substantial when discovering the feeding and carcass value of spring-born calves.

Introduction

Although cattle prices are trending upward, cow calf producers need to be competitive with increasing production costs and increasing returns. By determining calf value through a feedout program, cow-calf producers can identify profitable genetics under common feedlot management. Substantial marketplace premiums are provided for calves that have exceptional feedlot performance and produce a high-quality carcass.

Cost-effective feeding performance is needed to justify the expense of feeding cattle past weaning. Price premiums are provided for cattle producing highly marbled carcasses. Knowing production and carcass performance can lead to profitable decisions for ranchers raising North Dakota born and fed calves.

This ongoing feedlot project provides cattle producers with an understanding of cattle feeding and variability of cattle raised in North Dakota.

Procedures

The Dakota Feeder Calf Show was developed for cattle producers willing to consign steer calves to a show and feedout project. The calves were received in groups of three or four on Oct. 19, 2024, at the Turtle Lake Weighing Station, Turtle Lake, N.D., for weighing, tagging, veterinary processing, and display. The calves were evaluated for conformation and uniformity, with the judges providing a discussion to the owners at the beginning of the feedout. The number of cattle consigned was 112 of which 96 competed in the pen-of-three contest.

The calves then were shipped to the Carrington Research Extension Center, Carrington, N.D., for feeding. Prior to shipment, calves were vaccinated, implanted with Synovex-S, dewormed and injected with a prophylactic long-acting antibiotic.

Calves then were sorted and placed on corn and distiller grains based receiving diets. After an eight-week backgrounding period, the calves were transitioned to a 0.62 megacalorie of net energy for gain (Mcal NEg) per pound finishing diet. Cattle were weighed every 28 days, and updated performance reports were provided to the owners. Cattle were reimplanted with Synovex-One on December 17, 2024.

An educational meeting was provided on February 5, 2025, where cattle owners could review calves, ponder performance, and discuss marketing options.

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The cattle were harvested on June 19, 2025 (110 head). The cattle were sold to Tyson Fresh Meats, Dakota City, Neb., on a grid basis, with premiums and discounts based on carcass quality. Carcass data were collected after harvest.

Ranking in the pen-of-three competition was based on the best overall score. The overall score was determined by adding the index values for feedlot average daily gain (25 percent of score), marbling score (25 percent of score) and profit (25 percent of score) and subtracting index value for calculated yield grade (25 percent of score). The Dakota Feeder Calf Show provided awards and recognition for the top-ranking pen of steers.

Results and Discussion

Cattle consigned to the Dakota Feeder Calf Show feedout project averaged 603.8 pounds upon delivery to the Carrington Research Extension Center Livestock Unit on Oct. 19, 2025. After an average 242-day feeding period, cattle averaged 1,460.6 pounds (at plant, shrunk weight). Two steers died during the feeding period.

Average daily feed intake per head was 30.7 pounds on an as-fed basis and 22.8 pounds on a dry-matter basis. Pounds of feed required per pound of gain were 8.94 on an as-fed basis and 6.64 pounds on a dry-matter basis.

The overall feed cost per pound of gain was $0.618. The overall yardage cost per pound of gain was $0.116. Bedding cost was $0.060 per pound of gain. The combined cost per pound of gain, including feed, yardage, veterinary, trucking and other expenses except interest, was $0.903.

Calves were priced by weight upon delivery to the feedlot. The pricing equation ($ per 100 pounds = (-0.172337256* initial calf weight, pounds) + 294.5797033) was determined by regression analysis on local livestock auction prices reported for the weeks before and after delivery.

Overall, the carcasses contained U.S. Department of Agriculture Quality Grades at 0.9 percent Prime, 77.3 percent Choice (including 26.4 percent Certified Angus Beef), 20.9 percent Select and 0.9 percent ungraded. The USDA Yield Grades were 0.9 percent YG1, 18.2 percent YG2, 46.3 percent YG3, 18.2 percent YG4, and 16.4 percent YG5.

Carcass value per 100 pounds (cwt) was calculated using the actual base carcass price plus premiums and discounts for each carcass. The grid price received for June 19, 2025, was $385.57 Choice YG3 base with premiums: Prime $25, CAB $6, YG1 $6.50 and YG2 $3, and discounts: Select minus $16, ungraded (dark cutter) minus $55, YG4 minus $10, YG4 minus $22 and carcasses heavier than 1100 pounds minus $15 or lighter than 650 pounds minus $20.

Results from the calves selected for the pen-of-three competition are listed in Table 1.

Overall, the pen-of-three calves averaged 448.2 days of age and 1,475.9 pounds per head at slaughter. The overall pen-of-three feedlot average daily gain was 3.60 pounds, while weight gain per day of age was 1.95 pounds. The overall pen-of-three marbling score was 517.8 (average choice, modest marbling).

Correlations between profit and average birth date, harvest weight, average daily gain, weight per day of age or marbling score are shown in Table 2. Average slaughter weight, average daily gain, average weight per day of age and marbling score had higher correlations to profitability than average birth date, or yield grade.

The top-profit pen-of-three calves with superior genetics returned $1,314.70 per head, while the bottom pen-of-three calves returned as of $749.17 per head. The profit of the five top-scoring pens of steers averaged $1,213.79 per head, while the profit of the bottom five scoring pens of steers averaged of $836.84 per head.

For the pen-of-three competition, average profit was $1,024.44 per head. The spread in profitability between the top and bottom five herds was $376.95 per head.

North Dakota calf value is improved with superior carcass and feedlot performance. Favorable average daily gains, weight per day of age, harvest weight and marbling score can be found in North Dakota beef herds. Exceptional profit per head was a result of exceptional market price improvement in 2025. Feedout projects continue to provide a source of information for cattle producers to learn about feedlot performance and individual animal differences, and discover cattle value.

Table 1. Feeding performance — 2024-2025 Dakota Feeder Calf Show Feedout

Pen of three	Best Three Score Total	Average Birth Date	Average Weight per Day of Age, lbs	Average Harvest Weight, lbs.	Average Daily Gain, lbs.	Average Marbling Score[1]	Ave Calculated Yield Grade	Ave Feeding Profit or Loss/Head
1	2.1943	8-Mar-24	1.89	1518	3.65	584	3.32	$1,165.73
2	2.1311	26-Feb-24	2.13	1708	4.19	550	4.32	$1,314.70
3	2.0175	7-Mar-24	1.97	1522	3.82	597	4.47	$1,226.69
4	2.0081	15-Mar-24	2.14	1557	4.07	515	4.19	$1,244.04
5	1.9885	5-Mar-24	2.06	1619	4.00	515	3.84	$1,117.81
Average Top 5 herds	**2.07**	**6-Mar-24**	**2.04**	**1584.7**	**3.95**	**552.3**	**4.03**	**$1,213.79**
6	1.9692	19-Apr-24	2.04	1421	3.59	551	3.51	$1,037.31
7	1.9209	28-Mar-24	2.20	1596	4.06	626	5.20	$1,174.42
8	1.9157	30-Mar-24	1.92	1490	3.52	516	3.42	$1,056.76
	1.9072	23-Mar-24	2.13	1622	3.97	574	4.83	$1,200.69
	1.8983	10-May-24	2.11	1390	3.51	438	2.64	$979.57
	1.8675	16-Mar-24	1.83	1401	3.47	553	3.79	$1,031.78
	1.8624	13-Mar-24	1.62	1355	3.08	573	3.32	$954.85
	1.8453	5-Apr-24	1.99	1485	3.60	487	3.43	$1,008.06
	1.8225	11-Mar-24	1.82	1499	3.49	549	3.68	$935.09
9	1.7768	16-Apr-24	1.96	1418	3.43	556	3.97	$981.56
10	1.7605	17-Mar-24	1.73	1425	3.26	492	3.35	$982.85
11	1.7281	28-Mar-24	2.06	1553	3.81	539	5.06	$1,101.95
12	1.6975	8-Apr-24	1.98	1534	3.56	428	3.46	$995.00
13	1.6510	5-Apr-24	2.07	1495	3.76	517	4.70	$1,043.02
14	1.6108	10-Mar-24	1.77	1439	3.40	442	3.39	$875.02
15	1.6022	9-Apr-24	2.24	1595	4.01	606	5.82	$1,021.22
16	1.5834	24-Apr-24	1.90	1335	3.30	521	4.01	$873.73
17	1.5406	23-Apr-24	1.86	1358	3.24	469	3.74	$886.03
18	1.5142	3-May-24	1.87	1275	3.17	402	2.86	$749.17
19	1.2026	3-Mar-24	1.54	1289	2.99	346	3.17	$654.05
Average bottom 5 herds	**1.49**	**12-Apr-24**	**1.88**	**1370**	**3.34**	**469**	**3.92**	**$836.84**
Overall average - pens of three	**1.80**	**28-Mar-24**	**1.95**	**1,475.93**	**3.60**	**517.89**	**3.90**	**$1,024.44**
Standard deviation		20.4	0.2	110.4	0.3	67.7	0.8	152.7
number		25	25	25	25	25	25	25

[1]Marbling score 300-399 = select, 400-499 = low choice, 500-599 = average choice, 600-699 = high choice, 700-799 = low prime

Table 2. Correlations between profit and various production measures (pen of three).

	Correlation coefficient
Profit and average birth date	-0.3646
Profit and average slaughter weight	0.8480
Profit and average daily gain	0.8654
Profit and weight per day of age	0.6769
Profit and marbling score	0.7039
Profit and yield grade	0.5132

Utilization of novel grazing technologies to implement strip grazing practices within annual grazing systems

Joshua Wianecki[1,2], Miranda Meehan[1], Christopher Byrd[1] and Kevin Sedivec[2,3]

Novel grazing technologies offer strategies to implement intensive grazing management with less labor than traditional fencing. Virtual fencing and automated gate openers effectively managed cattle with similar containment rates to polywire fencing under intensive strip grazing practices. Intensive grazing increased forage utilization, resulting in increased grazing efficiency and increased total stocking rate compared to continuous grazing.

Summary

Intensive grazing strategies offer the potential to enhance grazing efficiency by increasing forage harvest efficiency. Intensive grazing can increase labor and fencing requirements, which may not always be feasible. New technologies, such as virtual fencing and automated gate openers, have become available to aid intensive grazing practices. This study aims to determine the efficacy of virtual fencing and other grazing technologies on the containment of grazing cattle under strip grazing management as well as evaluate the impacts of intensive grazing on forage utilization and stocking rates. An annual forage pasture was established at three locations and divided into four treatments including virtual fencing, automated gate openers, manual poly-wire, and continuous graze. The virtual fencing, automated gate opener and manual poly-wire treatments were divided into eight strips. Cattle locations were recorded by GPS point data and used to determine containment. Forage utilization rates were calculated following the grazing period to determine grazing efficiency. Cattle containment rates did not differ, with 77.5% total contained points by virtual fencing, 77.4% total contained points by automated gate openers and 81.0% total contained points by manual poly-wire. No difference in forage utilization was observed across strip grazing practices; however, forage utilization was greater in manual poly-wire paddocks than continuously grazed paddocks. While stocking rates did not statistically differ between treatments, strip grazing provided an additional 0.5 AUM per acre, equating to an average of 11 more grazing days.

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Introduction

Grazing efficiency is driven by reducing waste through enhanced forage harvest efficiency and can increase the total potential stocking rate of pastures. Adoption of intensive grazing practices can lead to increased forage utilization, subsequently raising stocking rates (Davies-Jenkins et al., 2024). Intensive grazing practices, such as strip grazing, subdivide a pasture into smaller allotments and move livestock through each allotment sequentially. These smaller allotments allow more control over forage utilization and promote higher forage use by reducing selectivity and trampling waste (Smart et al., 2010). However, intensive grazing requires increased fencing and labor, which can make implementation a challenge.

Recently, novel technologies have become readily available to livestock producers to reduce labor requirements of intensive grazing. These technologies range from GPS-equipped virtual fencing devices to simpler automated gate openers that offer the potential to make convenient grazing management decisions without increasing labor. Virtual fencing utilizes a GPS-equipped device that is typically worn as a collar on a grazing animal. Pasture boundaries are remotely set within a computer or mobile-based application. When a virtual fencing-equipped animal enters a restricted boundary, an auditory or electrical stimulus is provided to discourage further movement into the restricted boundary. Virtual fencing has been shown to be effective at managing cattle within extensive grazing systems and excluding cattle from sensitive areas (Boyd et al., 2022; Mayer et al., 2025), yet the efficacy of virtual fencing technology within small grazing allotments has not been demonstrated. In addition to virtual fencing, automated gate openers have been developed to automate access to paddocks. These devices utilize a timer and retractable latch system to retract electric fence gates at a set interval. These systems still require physical fencing, but they may reduce the labor needed to move cattle into new paddocks.

New grazing technologies have great potential to enhance grazing productivity, yet little has been reported on the impacts of both virtual fencing and automated gate technologies within annual forage systems. Additionally, there is scarce literature comparing intensive and continuous grazing management in annual forage-based systems. The objective of this study is to compare the efficacy of grazing technologies within a strip grazing system and determine the impacts of intensive strip grazing on forage utilization, grazing efficiency and stocking rates.

Materials and Methods

One field composed of an annual forage mix was established each at the Central Grasslands Research Extension Center (CGREC) near Streeter, ND; the Carrington Research Extension Center (CREC) in Carrington, ND; and the Beef Cattle Research and Teaching Center (BCRT) in Fargo, ND. Each field was divided into four paddocks ranging from 4-8 acres and randomly assigned one of four treatments: strip graze with virtual fencing, strip graze with automatic gate opener, strip graze with manual poly-wire gate or continuous grazing. Water and mineral supplement were provided for each paddock. Carrying capacity and forage utilization were determined by clipping eight 5.4 square foot quadrats within each paddock to determine forage biomass both prior to and following the grazing period.

All cattle were fitted with virtual fencing collars and trained to virtual fencing cues for four days before being randomly assigned to a grazing treatment. Cattle assigned to the virtual fencing treatment continued to receive these cues during the experimental period. Virtual fence auditory and electrical boundaries were set at 0-50 ft and 50-300 ft outside the allocated strip, respectively. When cattle under virtual fencing management entered a boundary, the associated cue would be delivered. Cattle assigned to the remaining treatments did not receive virtual fencing cues during the experimental period. Stocking rates were adjusted at each location to sustain approximately one week of grazing duration within each strip. Ten first-calf heifers at CGREC, 11 cows at CREC and 9 first-calf heifers at BCRT grazed each paddock sequentially. Each paddock was grazed independently, and access to the next strip was allowed when utilization reached 60%-75% by visual assessment. GPS location data from the virtual fencing collars were used to determine if cattle were contained within the allocated grazing area. Cattle under virtual fencing management were considered successfully contained when they were inside the allocated strip or auditory boundary.

Results and Discussion

Intensive grazing strategies were equally effective at cattle containment with no difference in containment rates ($P = 0.533$). Containment rates were 77.5% for virtual fencing, 77.4% for automated gate openers and 81.4% for manual poly-wire (Figure 1). The containment rate varied among locations and individual animals. Toward the end of the grazing period within the allocated strip, containment rates often decreased as cattle seek out preferred forages on fence lines, exerting pressure on both virtual fencing and physical fences. Escapes prior to the allocation of the new strip were

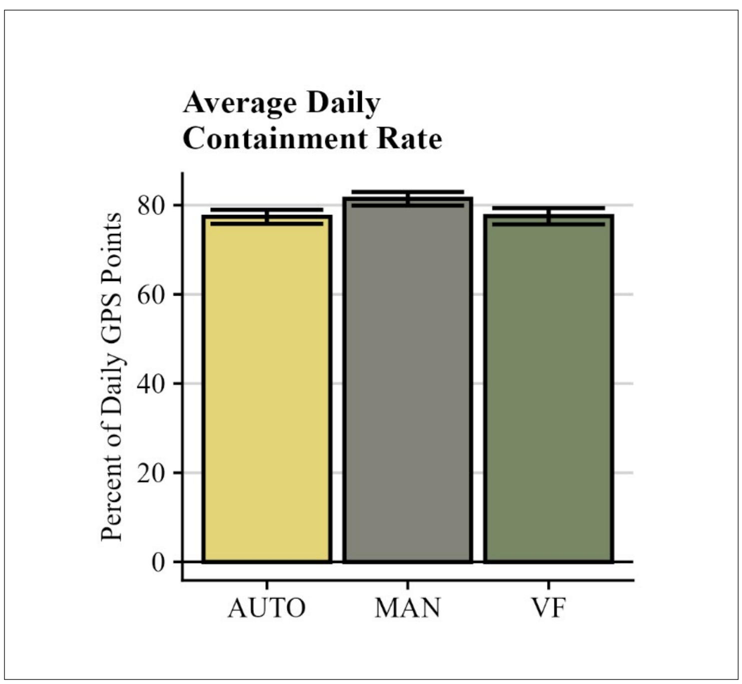

Figure 1. Average daily containment rate of each grazing technology. AUTO = Automated gate opener, MAN = Manual polywire, VF = Virtual fence.

greatest with automated gate openers. The number of virtual fencing cues increased when the virtual fencing boundary moved, as animals learned the new virtual fencing boundaries. Virtual fence containment rates were lower than the 90% or greater efficacy reported by previous literature at two of three locations (Verdon et al., 2021; Boyd et al., 2022). However, all strip grazing containment methods had similar containment rates, indicating this reduction may not be due to the fencing used.

Forage utilization was lower than anticipated across all locations and treatments. The greatest utilization was within the manual poly-wire paddocks at 34%, which differed (*P* = 0.012) from continuous grazing with the lowest utilization at -15% (Figure 2). Large quantities of trampling waste and regrowth contributed to negative utilization within continuous grazing at some locations. Utilization rates within automated gate opener and virtual fencing paddocks did not differ from manual poly-wire nor continuous grazing at 25% and 14%, respectively. Notably, all strip grazing methods provided an increase in forage utilization. Utilization rates were greater within the allocated strip sections when compared to spatially similar areas within the continuously grazed paddocks. Intensive grazing encourages grazing livestock to consume less palatable portions of the forage, as well as limits trampling when foraging. Jenkins-Davies (2024) reported an 82% increase in stocking rate by strip grazing a stockpiled oat-brassica system. This increase in forage harvest efficiency can be especially useful within annual systems when forage quality and palatability begin to diminish under grazing conditions.

Stocking rate tended (*P* = 0.094) to be higher in the manual polywire-paddocks compared to continuously grazed paddocks (Figure 2). The average stocking rates across all locations were 2.6 AUM/ac in automated gate paddocks, 2.5 AUM/ac in manual poly-wire paddocks, 2.3 AUM/ac in virtual fence paddocks and 2.2 AUM/ac in continuously grazed paddocks. Grazing duration also differed between locations. At CGREC, cattle in continuous graze and virtual fencing paddocks grazed for 37 days, while automated gate openers and manual poly-wire paddocks grazed for 48 days. All treatments at CREC grazed for 35 days, with grazing ending early due to difficulties containing cattle in all treatments. Unallocated strips in the virtual fencing paddock contained the greatest amount of standing biomass, indicating less access and trampling waste than manual poly-wire or automated gate opener paddocks at CREC. Grazing duration was greatest at BCRT with 49 days in continuously grazed paddocks and 60 days in virtual fence, automated gate opener and manual poly-wire paddocks. Across all locations, grazing duration did not vary between treatments,

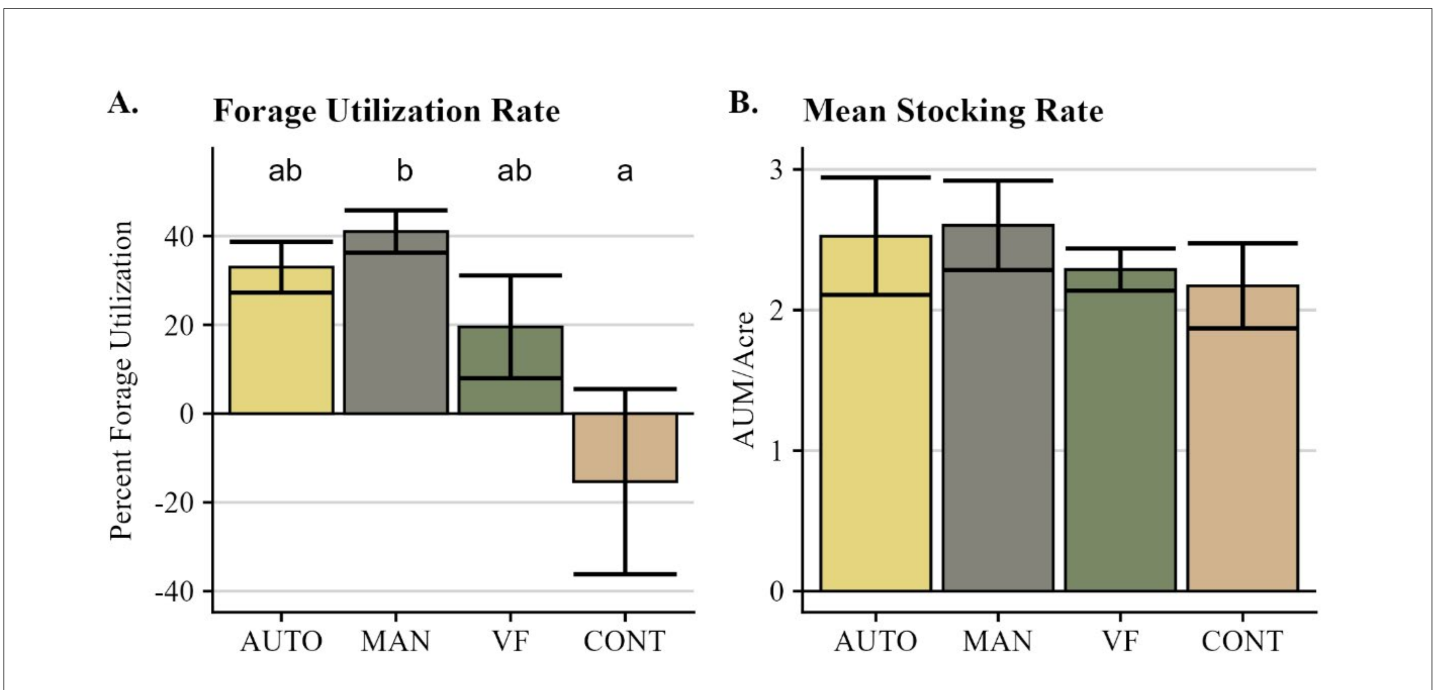

Figure 2. Forage utilization rates (A) and mean stocking rates (B) for each grazing strategy.
[ab]Means not connected by same letter are significantly different ($P \leq 0.05$)
AUTO = Automated gate opener, MAN = Manual polywire, VF = Virtual fence, CONT = Continuous graze.

although intensive grazing provided an additional 11 days of grazing or up to 0.5 AUM/ac compared to continuous grazing.

Both virtual fencing and automated gate openers can serve as effective livestock management tools to implement intensive grazing practices and improve grazing efficiency. Intensive strip grazing can increase forage utilization by reducing preferential grazing and trampling waste compared to continuous grazing practices. While containment rates were lower than previous studies, the overall effectiveness was still comparable to conventional fencing within this study. Escapes within virtual fencing paddocks were often in the form of a "filter" effect, with few animals periodically escaping the allocated strip and returning throughout the grazing period. In comparison, conventional fencing and automated gate openers had larger groups escape and often required additional labor to return the animals to the correct strip. Similar patterns of individual animals repeatedly escaping containment have been reported by previous research (Verdon et al., 2021; Boyd et al., 2022). It is important to consider that no containment method is 100% effective, and complete containment of livestock is not required to attain enhanced grazing efficiency through intensive grazing.

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Livestock integration provides return on cover crop investment in crop production systems

Katrina Kratzke[1,2], Joshua Wianecki[1,2], Miranda Meehan[1], Kevin Sedivec[2,3], Lindsay Chamberlain Malone[2] and Zachary Carlson[1]

There is potential for grazing to provide a return on cover crop investment through reducing feeding costs without negatively impacting soil health or crop performance and yield, but grazing is heavily dependent on cereal type, planting date, temperature and precipitation. The use of a winter rye cover crop may be considered as a strategy to suppress the establishment of weeds in the spring.

Summary

In the northern Great Plains, cover crops are becoming widely used for their soil health benefits, which can take years and are hard to track. Grazing cover crops has the potential to extend the grazing season and offset the costs of cover crop establishment through short-term returns in an integrated crop-livestock system. The objective of this study was to enhance the profitability of crop production and soil health through livestock integration and cover crop management. This project utilized cover crop management of winter rye, winter triticale and winter wheat and livestock integration through dual-season (fall and spring) grazing, spring grazing, no grazing or no cover crop treatments. Grazing cover crops had no impact on cash crop yield or soil health indicators. Winter rye suppressed weed establishment, and suppression was unaffected by grazing. Grazing of winter cereals provided a return on cover crop investment through lowering livestock feeding and yardage costs.

Introduction

Cover crops have gained popularity as a practice implemented by producers across the United States. In North Dakota alone, cover crop acreage has increased 107% (838,252 acres) between 2017 and 2022 (USDA NASS, 2024). Producers are incorporating cover crops to improve soil health, increase crop yields, reduce soil erosion, manage water and increase forage options for livestock. A recent national survey of farmers found that the greatest barriers to adoption of cover crops were economic return and yield reductions (CTIC 2023). Rye is the most frequently grown cover crop, with the winter cereals wheat and triticale also being common. Winter cereals are typically planted in the fall following a cash crop. They initiate growth in the fall, go through the differentiation process (change in growing point from vegetative to spikelet producing) during vernalization in the winter and regrow in the spring. Winter cereal cover crops enhance soil health by increasing organic matter, enhancing pore development for better water-holding capacity, feeding microbial communities and reducing erosion and nitrate concentrations in runoff. In addition, some winter cereals have been shown to have an allelopathic effect (suppression) on pigeon grass, kochia, pigweeds and marestail (Dhima et al. 2006).

When a winter cereal cover crop is used in conjunction with a corn cash crop, a synergistic system is created, which overcomes many weaknesses of corn in a cropping system. These benefits include reducing wind and water erosion, suppressing early-season glyphosate-resistant weeds and providing stability in saline areas. There is a significant body of research on the benefits of grass cover crops, but the impacts they have on corn production are variable, with many conflicting research results. There is currently no research evaluating the integration of livestock during a corn rotation with winter cereal cover crops in North Dakota.

Despite the ecological benefits of incorporating cover crops into a system, the economic benefits may not be realized if livestock are not incorporated into the system. In recent years, producers have expressed an increased interest in livestock integration due to the

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ecological and economic returns, yet only 24% of farmers surveyed reported grazing their cover crops (CTIC 2023).

Due to the short growing season in the northern Great Plains, it can be difficult to establish a cover crop as part of a dual crop system. Dual-purpose cover crop practices often use winter cereals, such as rye or triticale, planted in the fall and then used for spring grazing. Winter rye is commonly selected due to its winter-hardiness, high biomass production and low cost; however, winter triticale and select winter wheat varieties produce higher-quality forage. In other regions, these species are dual harvested (fall and spring) with grazing in addition to a cash crop. Currently, there is no research evaluating the potential to dual-harvest a winter cereal for livestock forage in the northern Great Plains and assessing the economic and ecological benefits of integrated crop-livestock systems.

Procedures

A research plot at the Central Grasslands Research Extension Center near Streeter, North Dakota, was selected where the grazing treatments have been implemented since fall 2022. The plot was divided into nine pastures and randomly assigned one of three treatments: dual season (fall and spring) grazing (DG), spring grazing (SG) or no grazing (NG). The NG plots were split in half to include no cover crop (NCC) treatments. Winter rye was planted as a cover crop in fall 2022 and 2023.

In the spring of 2024, plots were seeded with corn for silage. Stand counts and growth stage were recorded within each plot. A plot harvester was used to estimate yield. A representative sample of silage was collected from each pasture and submitted to the NDSU Nutrition Lab for nutrient analysis of crude protein (CP), ash, neutral detergent fiber (NDF), acid detergent fiber (ADF), in vitro organic matter digestibility (IVOMD) and in vitro dry matter digestibility (IVDMD). Corn silage was chopped on Oct. 3, and cover crops were planted the next day. Each cover crop management treatment was subdivided into winter rye, winter triticale and winter wheat. Dual-graze plots were not grazed in fall 2024 due to late seeding and limited growth.

In the spring of 2025, prior to and following grazing, forage samples of winter cover crops were collected to determine production, set stocking rates, and evaluate utilization. Samples were submitted to the NDSU Nutrition Lab for nutrient analysis of CP, ash, NDF, ADF, IVOMD and IVDMD. Ground cover was estimated pre- and postgrazing. Dual and spring graze plots were grazed for 0.56 AUMs over eight days. Two-day weights were collected from heifers pre- and postgrazing. Soil samples were taken postgrazing for analysis of total nitrogen (TN), nitrate (NO3), phosphorus (P), potassium (K), soil organic matter (OM), soil inorganic carbon (SIC), soil organic carbon (SOC), aggregate stability and bulk density. Grain corn was planted on May 24, and winter cover crops were terminated three days later. Sprinkler infiltrometers were used to evaluate infiltration rates at two points in each pasture. Soil moisture sensors were installed in every pasture during the middle of June and will be removed at harvest. Population counts and growth staging will be completed in the summer and yield data collected at harvest. At the end of the crop year, system economics will be evaluated using a partial budget.

Results and Discussion

In 2023 of this study, some trends were observed in soybean growth and yield that were likely due to soil moisture dynamics. Kelly et al. (2021) observed similar trends in soil moisture when grazing cover crops in the High Plains region. However, no research has been conducted evaluating soil moisture dynamics as they relate to cover crop management within the northern Great Plains. In 2024, a winter rye cover crop, terminated immediately after planting corn, did not affect crop performance or silage yield. Soil moisture sensors were installed in each plot in 2025 to evaluate treatment effects on soil moisture throughout the growing season.

Fall 2022 cattle grazed DG pastures for 0.6 animal unit months (AUMs). There was insufficient forage produced by winter cereals to support fall grazing in 2023 and 2024 due to late harvest and cover crop planting. Spring 2023, 2024 and 2025 DG and SG pastures were grazed for 3.36 AUMs, 0.98 AUMs and 0.56 AUMs, respectively. Spring grazing in 2025 was short due to complete winter kill of winter triticale and partial winter kill of winter wheat. Animal weights were not different between treatments pre- or postgrazing. On average, animals lost 2.5 lbs per day. This loss of gain can be attributed to the short grazing period, which did not allow animals to acclimate to the change of diet. Livestock in 2023 grazed longer, resulting in a rate of gain of 0.61lbs per day due to the longer grazing period allowing acclimation to the diet.

Spring 2025 pre- and postgrazing winter rye provided greater cover than triticale in all cover crop treatments (Figure 1). There were no differences in residue cover between treatments or cereal type, pre- and postgrazing. Bare ground was not different pregrazing, but postgrazing NCC pastures were 24.6% bare ground, which was significantly less than triticale with 56.7% bare ground and wheat with 58.3% bare ground, in NG pastures. Postgrazing weed cover was significantly lower in grazed rye at 7.7% than in NCC pastures at 37.1%. Significant weed suppression by winter rye was also seen in spring 2023 and 2024 in the same pastures (Figure 2). Winter cereals may suppress weeds through allelopathic effects (Dhima et al. 2006). The primary weed in the field was kochia, which has become a major problem for many farmers in the northern Great Plains as it is glyphosate-resistant, making it hard to combat. Notably, ground cover was not significantly affected by grazing. Rye provided the greatest cover and the highest weed suppression of the three winter cereals. The superior performance of the rye is likely due to winter kill of winter triticale and winter wheat.

Following three years of cover crop and livestock integration, there have been no changes in soil health indicators. There were no differences between treatments for soil OM, pH, TN, NO3-, P, K, TC, TOC, bulk density or soil aggregates. This is consistent with other research in semiarid regions that have documented no to little change in soil health indicators after three years of cover crop implementation; it was concluded that a longer period of cover cropping is needed to impact soil health in semi-arid environments (Wu et al. 2024).

Production economics for 2023 and 2024 have been estimated by partial budgeting that accounted for the cost of CC establishment and total savings in feed and yardage costs compared to if dry lot management were used (Figure 3). The cost of establishing a CC each year was approximately $43 per acre. Grazing either resulted in a net income or provided a return on CC investment across all years. Integrating livestock is a way to improve profitability when incorporating cover crops into a system (Kelly et al. 2021).

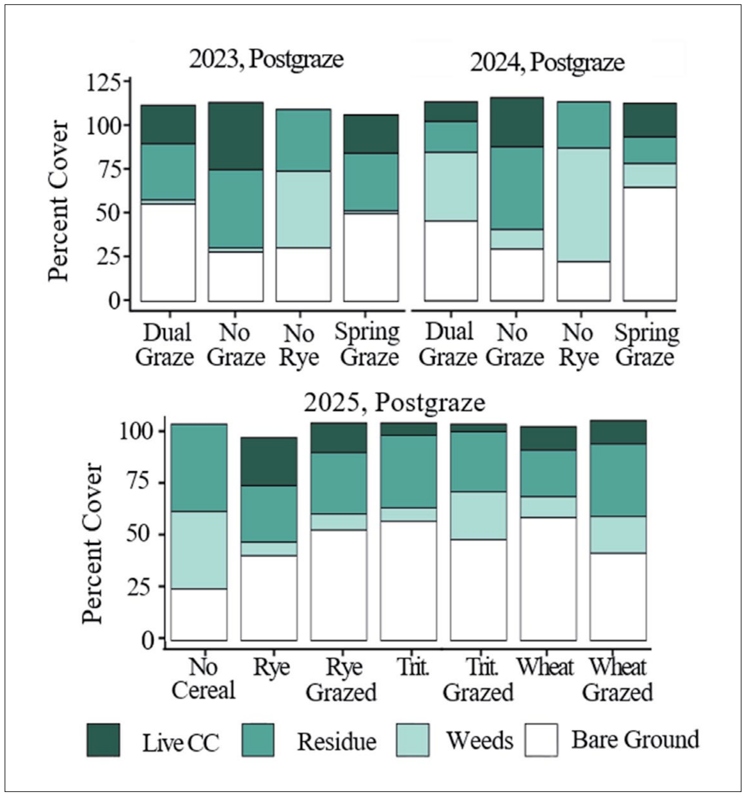

Figure 1. Post-grazing ground cover estimates for spring 2023, 2024, and 2025.

Figure 2. Differences in weed establishment within grazed winter rye (top) and fallow paddock (bottom), spring 2024.

Grazing cover crops is heavily dependent on cereal type, planting date, temperature and precipitation. There is potential for grazing to provide a return on cover crop investment through reducing feeding costs without negatively impacting soil health or crop performance and yield. As farmers continue to combat kochia, the use of a winter rye cover crop may be considered as a way to suppress the establishment of the weed in the spring. Grazing cover crops can provide a net income or return on CC investment, depending on biomass production.

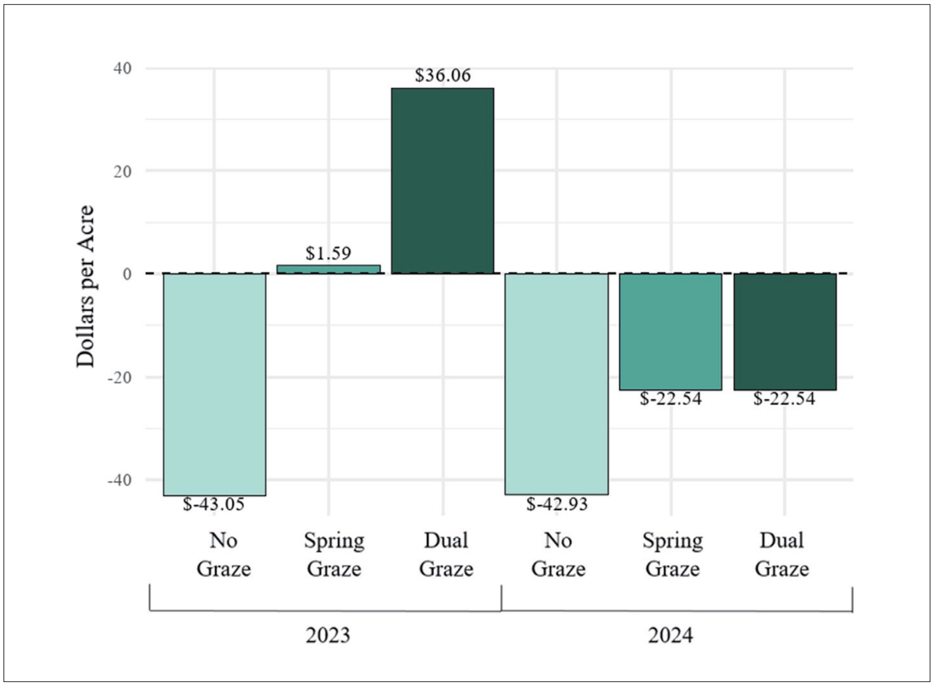

Figure 3. Estimated change to net enterprise income for 2023 and 2024. Changes to income are compared to livestock production utilizing dry lot feeding management without planting cover crops within the cropping operation.

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Evaluation of protein supplementation strategies on performance of backgrounding cattle in an extensive winter grazing system

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The objective of this experiment was to determine the influence of protein source (dried distillers grains plus solubles or soybean meal) and supplementation frequency (daily or three times weekly) on growth performance of backgrounding cattle in a winter bale-grazing system. Results from the two-year study suggest that neither protein source nor frequency of supplementation influenced growth performance. Therefore, the decision for a producer to reduce frequency of supplementation and replace dried distillers grains plus solubles with soybean meal in backgrounding beef cattle diets should be based on cost and availability.

Summary

In year 1, 72 crossbred backgrounding calves (initial body weight [BW] = 549 ± 59 lb) were utilized for 44-days, and in year 2, 65 crossbred backgrounding calves (initial BW = 593 ± 77 lb) were utilized in a 92-day winter bale-grazing study to evaluate the differences in growth performance of calves supplemented with dried distillers grains plus solubles (DDGS) or soybean meal (SBM) either daily or three times weekly. In year 1, body weights and blood were collected at day 0, 28 and 44. In year 2, body weights were collected at day 0, 28, 56, 84 and 92 and blood was collected at day 0, 56 and 92. Cattle had ad libitum access to water, hay and trace mineralized salt. Supplements were provided at an average of 0.75% of their body weight per day (dry matter basis) so that all calves would receive the same amount of supplement over a seven-day period. There were no differences ($P \geq 0.05$) in ending body weight or average daily gain between treatments. Estimated hay dry matter intake (DMI) in year 2 was higher for daily fed paddocks compared to three times weekly. This suggests that protein source and supplementation frequency have minimal effects on backgrounding cattle performance when managed in a bale-grazing system, and that choice of supplementation should be based on availability and cost of the protein supplement.

Introduction

Cattle overwintered in open dry lot pens is a common practice in the northern Great Plains (Asem-Hiablie et al., 2016). Extending the grazing season through a system such as bale grazing has become more popular with producers in recent years due to the animals' ability to harvest their own feed, which can decrease production costs (Undi and Sedivec, 2022). Much of the research on bale grazing focuses on gestating cows, and limited research has evaluated the system for backgrounding cattle. Backgrounding cattle typically have greater nutrient requirements as a percent of their diet than mature cows. Therefore, supplemental feed is usually required for cattle in a backgrounding program on pasture to achieve gains that promote continued growth (NASEM, 2016). Dried distillers grains plus solubles (DDGS) is commonly used to supplement energy and protein for cattle consuming or grazing forage. Soybean meal (SBM) supplies high concentrations of protein and is a balanced source of essential amino acids, particularly lysine, which is lower in corn and other cereal grains. However, the cost of SBM is high relative to other protein sources. Since feed costs make up a large percentage of total production costs, SBM has not been a common feed ingredient in beef cattle diets for several years. The growing interest in biodiesel has resulted in more soybeans being produced and processed in North Dakota. This growth in soybean production and processing may increase the supply and availability of SBM at potentially lower prices, which could make it useful to producers as an alternative local feedstuff. The objective of this study was to evaluate differences in growth

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performance in backgrounding cattle supplemented with DDGS or SBM daily or three times per week in an extensive winter bale-grazing system.

Experimental Procedure

A 44-day bale graaing study was conducted In year 1 (Y1) using 24 heifers (initial BW = 482 ± 98 lb) and 48 steers (initial BW = 582 ± 148 lb), followed by a 92-day study in year 2 (Y2) using 65 steers (initial BW = 593 ± 77 lb). Crossbred backgrounding cattle were grazed in a field south of the NDSU Beef Cattle Research Complex in Fargo, North Dakota. Cattle originated from the NDSU Beef Unit. This study was conducted in Y1 from Dec. 6, 2023, to Jan. 19, 2024, and in Y2 from Dec. 11, 2024, to March 13, 2025.

The study pasture was split into 15 paddocks of 40 ft × 400 ft (0.44 acres) using polywire electric fence. Grass hay round bales were individually weighed and placed in the middle of each paddock with 40 ft between each bale for a total of 10 mixed grass hay round bales per paddock. The bales for Y2 grazing were placed between the bale locations from Y1. Cattle were given access to one bale at a time by moving the polywire electric fence. Cattle were limit-fed a common diet at an estimated 2% of their BW (dry matter basis) for the five days prior to the initiation and weighed on three consecutive days (Y1) and two consecutive days (Y2) at the beginning and end of the study to equalize gut fill (Watson et al., 2013). Using the average body weight, cattle were stratified and randomly assigned to one of four treatments. The four treatments were DDGS fed daily (DDGS-d), DDGS fed three times per week (DDGS-a), SBM fed daily (SBM-d) and SBM fed three times per week (SBM-a). Each treatment was replicated three times within the year and randomly assigned to a paddock.

Table 1. Nutrient composition of feedstuff

	Year 1			Year 2		
Item[1], %	Hay[2]	DDGS[3]	SBM[4]	Hay	DDGS	SBM
DM	97.51	89.92	89.83	97.64	91.13	91.16
CP	9.97	33.24	50.77	7.65	27.77	49.35
Fat	1.94	6.20	1.16	1.51	5.19	2.11
NDF	68.90	47.81	10.95	67.10	44.12	9.62
ADF	38.60	17.80	4.55	39.14	14.20	4.27
Ash	8.73	10.29	9.95	9.36	11.33	10.73
Calcium	0.37	1.72	1.46	0.39	1.81	1.77
Phosphorus	0.22	0.99	0.69	0.24	1.10	0.75
Nitrogen	1.59	5.32	8.12	1.22	4.44	7.90
Sulfer	0.14	0.69	0.40	0.21	0.61	0.42

[1]Items: DM – dry matter; CP – crude protein; NDF – neutral detergent fiber; ADF – acid detergent fiber
[2]Fair quality mixed grass hay
[3]Dried Distillers Grains plus Solubles; 97% DDGS and 3% limestone (DM basis).
[4]Soybean Meal; 97% SBM and 3% limestone (DM basis)

Calves were allowed ad libitum access to water, hay and trace mineralized salt (American Stockman Big 6 Mineral Salt, NaCl 96-99%, Mn 2,400 ppm, Fe 2,400 ppm, Cu 260-380 ppm, Zn 320 ppm, I 70 ppm, and Co 40 ppm). Cattle that were supplemented daily received 0.75% of BW (dry matter basis), and cattle supplemented three times a week received 1.75% of BW (dry matter basis).

Body weights and blood were collected every 28 days in Y1. In Y2, body weights were collected every 28 days and blood was collected on days 0, 56 and 92. Blood was collected via jugular venipuncture, processed into serum and stored at minus 4 degrees Celsius until further analysis. Blood was analyzed for serum urea nitrogen (SUN). Weekly feed ingredient samples were collected and ground through a 1-mm screen using a Wiley Mill (Thomas Scientific, Swedesboro, NJ) and then composited into four-week composites. Dietary dry matter was determined for every new pallet delivery of feed by sampling ingredients and oven-drying at 60 degrees for 48 hours. Adjustments were made to the supplement fed to calves. Feed weigh-backs were collected over the entire experiment and stored at minus 4 degrees for dry matter analysis at a later date. The residue of one bale per paddock was collected and weighed in the spring to estimate residual hay left in the paddock and hay intake.

Data were analyzed using the MIXED procedure in SAS (SAS Inst. Inc., Cary, NC). Significance was assigned at $P \leq 0.05$, with a tendency assigned between $P < 0.10$ and > 0.05.

Results and Discussion

There were no protein source × supplementation frequency interactions ($P \geq 0.11$) in both years for average daily gain (ADG), ending bodyweight (EBW) or estimated hay dry matter intake (DMI) (Table 2). There were no differences ($P \geq 0.30$) in supplementation frequency in ADG and EBW for either year or DMI for Y1. In Y2, DMI was increased ($P = 0.002$) for the daily (10.21 lb/day) fed paddocks compared to the alternate (8.43 lb/day). There were no differences ($P \geq 0.25$) in protein source in Y1 or Y2 for ADG, EBW, and Y2 for DMI. There was a tendency ($P = 0.09$) for SBM-fed paddocks (12.07 lb/day) to have higher estimated hay DMI in Y1 compared to DDGS (10.84 lb/day).

Across all treatments and years, SUN increased as the feeding period progressed (Figure 1). In Y1, SBM-d had the highest SUN at 30 mg/dL, compared to SBM-a at 22.90 mg/dL and the DDGS treatments at roughly 18.46 mg/dL at the end of the feeding period. In Y2, the DDGS treatments had the lowest SUN at roughly 17 mg/dL; however, SBM-a had the highest levels at 41 mg/dL. Differences between years may be attributed to differences in the collection day of blood relative to when supplementation occurred.

These results agree with previous research that suggests protein supplementation can be offered on an infrequent basis to ruminants while still maintaining cattle performance (Huston et al., 1999; Bohnert et al., 2002). However, other research suggests that as supplemented crude protein increases, there is a corresponding increase in forage DMI when consuming a low-quality forage (Cappellozza et al., 2021). Similar to the Y2 results of hay DMI, research has shown that as supplement frequency decreases, forage DMI also decreases (Bohnert et al., 2002).

Our results suggest that a producer can utilize an extended

Table 2. Growth performance and estimated dry matter intake of backgrounding cattle in a bale-grazing system

	Treatment[1]					P-Value[2]		
Item	DDGS-d	DDGS-a	SBM-d	SBM-a	SEM	TRT	FREQ	TRT x FREQ
Year 1								
Calves, n	18	18	18	18	-	-	-	-
Initial BW[3], lb	531.77	533.32	532.55	531.99	2.60	0.92	0.85	0.69
Ending BW, lb	629.57	623.4	623.57	621.68	4.85	0.44	0.34	0.50
ADG, lb/day	2.23	2.05	2.07	2.04	0.09	0.43	0.32	050
DMI[4], lb/day	10.84	10.83	12.19	11.94	10.64	0.09	0.84	0.85
Year 2								
Calves, n	17	17	14	17	-	-	-	-
Initial BW, lb	599.22	587.53	591.72	592.60	20.13	0.95	0.79	0.76
Ending BW, lb	714.30	716.50	718.49	703.05	6.25	0.47	0.30	0.17
ADG, lb/day	1.32	1.32	1.37	1.19	0.08	0.65	0.30	0.27
DMI, lb/day	10.32	7.85	10.10	9.02	0.17	0.25	**0.002**	0.11

[1]Treatments; DDGS-d: dried distillers grains plus solubles fed daily; DDGS-a: dried distillers grains plus solubles fed 3 times per week; SBM-d: soybean meal fed daily; SBM-a: soybean meal fed three times per week
[2]P-values: TRT – Treatment (DDGS vs SBM) and FREQ (daily vs three times per week)
[3]BW: body weight
[4]Dry Matter Intake: estimated hay intake as individual was not monitored

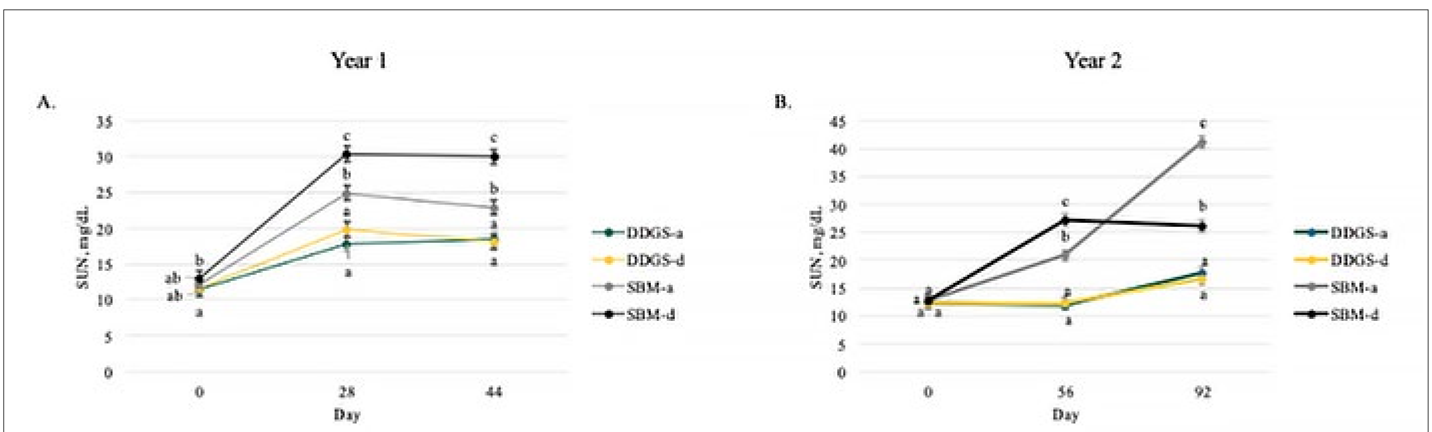

Figure 1. A) Serum urea nitrogen (SUN) concentrations for year 1. B) SUN concentrations for year 2. Treatments; DDGS-d: dried distillers grains plus solubles fed daily; DDGS-a: dried distillers grains plus solubles fed three times per week; SBM-d: soybean meal fed daily; SBM-a: soybean meal fed three times per week.[a-c]Letters denote significant difference ($P \leq 0.05$) within each time point.

winter bale-grazing system with backgrounding cattle while supplementing DDGS or SBM as few as three times a week. The decision to use SBM rather than DDGS will most likely be made based on supplement cost, transportation cost and availability.

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Impact of an extensive winter grazing system on soil health, forage production and forage quality

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The objective of this experiment was to determine the impacts of winter bale grazing on soil physical and chemical properties, forage production and forage quality. Results from the first growing season after grazing suggest that not only does winter bale grazing increase soil chemical and forage quality parameters, but soybean meal supplementation resulted in greater increases of soil nitrogen and the crude protein in the forage produced.

Summary

In year one, 72 crossbred backgrounding calves (initial body weight [BW] = 549 ± 233 lb) were utilized for a 44-day winter bale grazing study that evaluated the impacts on soil health (physical and chemical properties), forage production and forage quality. Calves were supplemented with dried distillers grains plus solubles (DDGS) or soybean meal (SBM) either daily or three times weekly. Soil and forage samples were collected at 0, 5, 10 and 15 ft from the bale center from three bales in each paddock; soils were collected at 0-6 and 6-12 inches. There was an increase ($P \leq 0.04$) in soil total nitrogen (TN), total carbon (TC) and total organic carbon (TOC) for SBM daily paddocks compared to the other three treatments. There was a decrease ($P = 0.005$) in the C:N ratio for SBM paddocks compared to control. There was no difference ($P = 0.104$) in average forage biomass yields between the bale-grazed paddocks and the ungrazed control. When evaluating the quality of the forage biomass, there was an increase ($P = 0.04$) in forage CP for SBM paddocks (13.20%) compared to DDGS paddocks (11.52%).

Introduction

Extended grazing systems, such as bale grazing, have started to gain popularity with producers in recent years due to the potential to be more efficient in nutrient recycling compared to drylotting (Jungnitsch et al., 2011). Research shows that bale grazing introduces higher nitrogen and phosphorus into the soil, and there is a positive relationship between bale grazing and nitrogen capture (Brummer et al., 2018). These extended grazing systems also allow producers to decrease production costs while enhancing profitability through reduced labor and feed costs (Undi and Sedivec, 2022). Feed costs make up a large portion of total production costs. Soybean meal has a higher cost relative to other protein sources, but it has a high concentration of protein and is a balanced source of essential amino acids, while dried distillers grains plus solubles is a cheaper feed source but lower in protein. When implementing an extended grazing system, not only are producers able to lower feed costs, but they also have the potential to improve soil health, forage production and forage quality. The objective of this study was to determine the impacts of winter bale grazing on soil health (both physical and chemical properties), forage production and forage quality.

Experimental Procedure

In the winter of 2023-2024, 72 crossbred backgrounding calves (initial BW = 549 ± 233) were used in a 44-day winter bale grazing study evaluating two protein sources and two supplementation frequencies on a field south of the NDSU Beef Cattle Research Complex in Fargo, North Dakota.

The study pasture was split into 15 paddocks of 40 ft × 400 ft (0.44 acres) using polywire electric fence. Grass hay round bales were individually weighed and placed in the middle of each paddock with 40 ft between each bale (10 bales per paddock). Cattle were given access to one bale at a time by moving the polywire electric fence. Cattle were assigned to one of four treatments: DDGS fed daily (DDGS-d), DDGS fed three times per week (DDGS-a), SBM fed daily (SBM-d) and SBM fed three times per week (SBM-a). There was also a non-grazed control to evaluate the impact of bale grazing on soil chemical properties, forage

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production and forage quality. Each treatment was replicated three times and randomly assigned to a paddock.

Before the start of the trial, baseline soil samples were collected at 0-6 and 6-12-inch depths. Five samples were taken for each depth in each paddock and then composited into one sample for each depth per paddock. At the end of the trial, soil samples were collected at 0, 5, 10 and 15 ft from the bale center from three bales in each paddock. Three samples were collected at random in the control paddocks. Samples were sent to AgVise Laboratories in Northwood, North Dakota, for chemical analysis (pH, total carbon [TC], total organic carbon [TOC], total nitrogen [TN], phosphorus [P], potassium [K], nitrate nitrogen [NN] and organic matter [OM]). Three bulk density samples were taken at the edge of three random bale site locations in each paddock, with the control paddock sample sites being chosen at random.

Forage biomass samples were collected by clipping 0.25 m^2 frames 0, 5, 10 and 15 ft from bale center. This was done from the three bale locations where we took soil samples. Samples were oven-dried at 50 degrees Celsius and weighed. Samples were ground through a 1-mm screen and analyzed by the NDSU Nutrition Laboratory for crude protein (CP), ash, acid detergent fiber (ADF), neutral detergent fiber (NDF), calcium (Ca), phosphorus (P) and ether extract (EE).

Data were analyzed using the MIXED procedure in SAS (SAS Inst. Inc., Cary, NC). Significance was assigned at $P \leq 0.05$ with tendency between $0.10 \leq P > 0.05$.

Results and Discussion

Following bale grazing, there was an increase ($P \leq 0.04$) in TN, TC and TOC for SBM-d paddocks compared to the other three treatments (Table 1). Total nitrogen was as much as 0.10% higher in SBM-d, while TC and TOC were increased by as much as 0.82% and 0.81%, respectively. There was an increase ($P = 0.04$) in pH for SBM paddocks and daily (7.9 vs 7.8) supplemented paddocks, with pH being increased ($P = <0.0001$) at bale center (7.99) and 5 ft out (8.04) compared to 10 ft (7.75) and 15 ft (7.67). There was a decrease ($P = 0.005$) in the C:N ratio for SBM (9.97) paddocks compared to DDGS (10.41). There was also a decrease ($P = <0.0001$) in K concentrations moving out from bale center from 955.69 ppm at 0′ to 763.75 ppm at 15′. There was no difference ($P = 0.96$) in post grazed soil bulk density between the bale-grazed (0.92) and ungrazed control (0.92) paddocks.

Average forage biomass yields were not significant ($P = 0.104$) between the bale-grazed treatments and the ungrazed controls. However, when evaluating forage biomass yields for each distance from bale center within the bale-grazed paddocks, forage biomass decreased ($P = <0.0001$) at bale center and out to 5 ft from center. When evaluating the quality of the forage biomass, there was an increase ($P = 0.04$) in CP for SBM paddocks (13.20%) compared to DDGS paddocks (11.52%).

Previous studies show similar results as the current study. Chen et al. (2017), Donohoe et al. (2021) and Brummer et al. (2018) all saw increases in P and K in bale-grazed paddocks compared to ungrazed controls. Soybean meal paddocks had a decreased C:N ratio compared to the control. This is likely due to the increased concentrations of N in SBM compared to DDGS. Inclusion of N to the soil is important in the semiarid Great Plains as plant available N is often limited (Schuman et al., 1999). The freeze/thaw cycle that occurs in the northern Great Plains may be why there were no observed differences in soil bulk density (Liebig et al., 2011) single-enterprise production systems. However, concerns exist regarding the effect of livestock in integrated systems to cause soil compaction, thereby decreasing infiltration of water into soil. Such concerns are compounded by projections of more frequent high-intensity rainfall events from anticipated climate change, which would act to increase surface runoff and soil erosion. A study was conducted to evaluate the effects of residue management, frequency of hoof traffic, season, and production system (e.g., integrated annual cropping versus perennial grass. The decrease in forage production near bale center is also supported by research that has reported a decrease in production at and near bale center (Donohoe et al., 2021). Heavy accumulation of bale residue likely contributes to this decrease in production. Heavy accumulation of residue and continued decomposition can lead to potential increases in forage production in subsequent growing seasons (Brummer et al., 2018). Similar to both Brummer et al (2018) and Donohoe et al (2021), we also observed an increase in CP of forage biomass at bale center and a decrease moving out from bale center.

Our results suggest that producers can utilize an extended winter bale grazing system with backgrounding cattle while supplementing DDGS or SBM as few as three times per week and see improvements in soil health and forage quality parameters. Due to increased N concentration in SBM, there is an increase in soil N, which decreases the C:N ratio of the soil. Despite the decrease in year one forage biomass near bale center, there is research that supports an increase in production in subsequent growing seasons.

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Table 1. Post bale-grazing soil chemical analysis of bale-grazed treatments for depth 0-15 cm

Source	Freq	Distance, m	pH	NN, ppm	K, ppm	TN, %	TC, %	TOC, %	C:N
DDGS	A	0	$7.92^{A,a}$	11.17	899.00^{a}	0.36	3.82^{A}	3.64^{A}	$10.22^{b,c}$
		1.5	$7.87^{A,a}$	29.50	982.33^{a}	0.38	3.99^{A}	3.87^{A}	10.03^{c}
		3	$7.62^{A,b}$	10.22	805.44^{b}	0.38	4.09^{A}	3.99^{A}	$10.44^{a,b}$
		4.5	$7.66^{A,b}$	7.67	787.56^{b}	0.36	3.82^{A}	3.72^{A}	10.46^{a}
DDGS	D	0	$7.97^{B,a}$	11.83	940.44^{a}	0.38	4.12^{B}	3.94^{B}	$10.31^{b,c}$
		1.5	$8.02^{B,a}$	11.06	921.67^{a}	0.38	4.08^{B}	3.92^{B}	10.34^{c}
		3	$7.82^{B,b}$	7.89	809.67^{b}	0.36	4.08^{B}	3.92^{B}	$10.70^{a,b}$
		4.5	$7.70^{B,b}$	4.56	768.44^{b}	0.33	3.68^{B}	3.56^{B}	10.76^{a}
SBM	A	0	$8.00^{A,a}$	8.44	995.56^{a}	0.38	3.67^{A}	3.61^{A}	$9.57^{b,c}$
		1.5	$8.07^{A,a}$	4.83	997.11^{a}	0.39	3.81^{A}	3.73^{A}	9.58^{c}
		3	$7.83^{A,b}$	15.78	853.22^{b}	0.37	3.68^{A}	3.61^{A}	$9.94^{a,b}$
		4.5	$7.61^{A,b}$	7.44	788.67^{b}	0.35	3.81^{A}	3.70^{A}	10.57^{a}
SBM	D	0	$8.10^{B,a}$	7.94	987.78^{a}	0.40	4.12^{B}	3.99^{B}	$9.97^{b,c}$
		1.5	$8.19^{B,a}$	8.00	994.22^{a}	0.43	4.17^{B}	4.00^{B}	9.28^{c}
		3	$7.71^{B,b}$	21.33	873.67^{b}	0.42	4.49^{B}	4.37^{B}	$10.37^{a,b}$
		4.5	$7.70^{B,b}$	12.22	710.33^{b}	0.41	4.42^{B}	4.28^{B}	10.52^{a}
		SEM	8.19	29.50	997.11	0.43	4.49	4.37	10.76
	***P*-values**								
	Main effect	**SUPP**	**0.04**	0.70	0.24	**0.02**	0.58	0.40	**0.005**
		FREQ	**0.04**	0.62	0.67	0.10	**0.008**	**0.02**	0.22
		DIS	**<0.0001**	0.32	**<0.0001**	0.21	0.73	0.65	**0.003**
	Interactions	**SUPP x FREQ**	0.40	0.08	0.89	**0.04**	**0.03**	**0.04**	0.68
		SUPP x DIS	0.27	**0.02**	0.66	0.96	0.45	0.57	0.40
		FREQ x DIS	0.81	0.55	0.83	1.00	0.91	0.90	0.86
		SUPP x FREQ x DIS	0.26	0.47	0.89	0.52	0.62	0.52	0.64

[1]Source – DDGS: dried distillers grains plus solubles; SBM: soybean meal

[2]Freq (supplementation frequency) – a: three times per week; d: daily

[3]Distance – distance from bale center

[4]Items - OM: organic matter; NN: nitrate-nitrogen; P: Olsen-phosphorus; K: potassium; TN: total nitrogen; TC: total carbon; TOC: total organic carbon; C:N: carbon:nitrogen ratio

[5]SEM – largest standard error of the least squares means

[6]*P*-values - SUPP: protein source; FREQ: supplementation frequency; DIS: distance from bale center and their interactions.

[A-B] Uppercase letters denote significance ($P \leq 0.05$) for the main effect of supplementation frequency (FREQ). [a-b] Lowercase letters denote significance ($P \leq 0.05$) for the main effect of distance (DIS)

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Protein supplement source and processing for cattle fed forage-based diets: Effects on nutrient intake and digestibility

Pauliane Pucetti[1], Christy A. Finck[1], Zachary E. Carlson[2], Julia T. da Silva[3] and Kendall C. Swanson[1]

Protein supplements improve total-tract digestibility without increasing total intake. Both dried distillers grains with solubles (DDGS) and soybean-based options are effective. Pelleting protein supplements improves nutrient digestibility.

Summary

This study evaluated the effects of protein supplementation and pelleting on nutrient intake and digestibility in cattle fed medium-quality hay. Supplementation at 0.5% of body weight increased crude protein intake and improved apparent total-tract digestibility of dry matter, organic matter and crude protein. Total-tract NDF digestibility was greater for DDGS-based than soybean-based supplements and was also improved by pelleting. Ruminal fermentation profiles differed between supplements, but total VFA concentrations remained similar. These findings support the benefits of protein supplementation and suggest that pelleting of supplements can enhance nutrient utilization in forage-based diets.

Introduction

Protein is often a limiting nutrient in beef cattle diets, especially during winter or drought, when forage crude protein (CP) drops below 9-10%. Inadequate CP supply impairs fiber digestion, reduces intake and increases tissue mobilization and nitrogen excretion (NASEM, 2016). Protein supplementation is known to improve forage utilization, but its effectiveness depends not only on the nutrient composition of the supplement but also on its physical form and how it interacts with digestion dynamics.

Pelleted protein supplements, commonly known as "range cubes," are widely preferred by producers in extensive systems due to their ease of handling and distribution. However, little is known about how pelleting affects nutrient intake and digestibility.

Dried distillers grains with solubles (DDGS) and soybean-based products are two common protein sources in beef systems. Most supplementation studies have used DDGS as the benchmark, reflecting regional practices — in the northern Great Plains, high-protein range cubes (≥30% CP) are typically formulated with DDGS (Mueller, 2024). Importantly, soybean processing capacity in North Dakota has expanded significantly since 2023, creating new opportunities for the local use of soybean meal and hulls as livestock feed. This shift highlights the need for updated information on the efficacy of soybean-based supplements in beef cattle diets. Therefore, the objective of this study was to evaluate the effects of protein source (DDGS vs. soybean-based) and physical form (meal vs. pellet) on intake, ruminal, intestinal and total-tract digestibility in cattle fed a forage-based diet.

Experimental Procedures

Five Jersey steers (initial body weight [BW] = 994 ± 20 lb), fitted with ruminal, duodenal and ileal cannulas, were used in a 5 × 5 Latin square design with a 2 × 2 + 1 factorial arrangement of treatments. Factors included two protein sources: DDGS or a soybean-based supplement (52.5% soybean meal, 47.5% soyhulls), each in meal or pelleted form, and a negative control with no supplementation. Supplements were offered daily at 0.5% of BW. All animals received free-choice access to grass hay, mineral supplement and water. Animals were fed supplements at 7:30 a.m. and hay at 8:00 a.m., adjusted daily to maintain ~5% refusals.

Each period lasted 14 days, with seven days of adaptation and seven days of data collection. Samples of feed and refusals were collected daily and composited by steer and period. Chromic oxide (16 g/d) was dosed intraruminally from days 5 to 12 as a marker for digesta flow. Total feces were collected from days 8 to 12. Ruminal fluid was collected at multiple time points on day 9 for measurement of pH, ammonia, VFA and ruminal fluid kinetics using Co-EDTA. Duodenal and ileal digesta

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Table 1. Nutrient composition (% of DM) of the feed ingredients used in experimental diets

		Protein Supplements[1]			
Items	Hay	DDGS	DDGSP	SB	SBP
Organic matter	90.5	92.9	92.6	94.3	94.5
Crude protein	8.66	32.5	32.4	27.5	27.9
Neutral detergent fiber	68.2	47.5	43.8	31.6	33.0
Acid detergent fiber	36.9	16.2	15.0	21.3	21.9

[1]DDGS = dried distillers grains with solubles in meal form; DDGSP = dried distillers grains with solubles in pellet form; SB = soybean-based supplement (52.5% soybean meal and 47.5% soyhulls) in meal form; SBP = soybean-based supplement in pellet form.

were collected across three days, at nine-hour intervals, composited and analyzed to estimate nutrient flow and microbial protein synthesis. On day 14, ruminal contents were collected and processed to isolate bacteria for estimating microbial protein synthesis.

Data were analyzed using the MIXED procedure in SAS (SAS Institute Inc., Cary, NC). The model included treatment as a fixed effect, with steer and period as random effects. Preplanned contrasts evaluated supplementation (control vs. supplemented), protein source (soybean vs. DDGS), physical form (meal vs. pellet) and source × form interaction. Statistical significance was declared at $P < 0.05$ and tendencies at $P < 0.10$.

Results and Discussion

Supplementation did not affect total DM or OM intake ($P > 0.05$; Figure 1), but reduced hay DM intake ($P < 0.001$), suggesting a substitution effect. This effect is commonly observed with nutrient-dense supplements and may result from physical or metabolic intake limits. However, in forage-based systems, such substitution may be undesirable, as it can reduce the utilization of available roughage. Therefore, lower inclusion rates should be explored to maintain supplementation benefits without compromising forage intake.

Crude protein intake was higher in supplemented animals ($P < 0.001$), particularly with DDGS-based supplements compared to soybean-based ones ($P = 0.001$), reflecting their greater crude protein content. Intake of NDF tended to be lower with soybean-based supplementation ($P = 0.069$), consistent with their higher soyhull content, which is more digestible but less fibrous than DDGS.

Duodenal DM flow tended to be greater with DDGS ($P = 0.088$), and the feed-derived portion was significantly greater ($P = 0.045$). Supplementation reduced fecal DM flow ($P = 0.046$). Similar trends were observed for OM, with duodenal OM flow tending to increase with DDGS ($P = 0.072$) and the feed portion significantly greater ($P = 0.031$). Fecal OM tended to be lower in supplemented animals ($P = 0.070$). Duodenal CP flow increased with supplementation ($P = 0.003$) and with DDGS ($P = 0.005$). Fecal CP flow was also greater with supplementation ($P = 0.050$) and with DDGS ($P < 0.001$) but tended to be reduced with pelleting ($P = 0.089$), suggesting improved nitrogen digestion with the pelleted form. Duodenal NDF flow was greater with DDGS ($P = 0.020$), while fecal NDF flow tended to be reduced by supplementation ($P = 0.054$).

True ruminal digestibility of DM, OM and NDF was unaffected ($P > 0.10$), but CP digestibility was greater for soybean-based supplements ($P = 0.023$). Apparent small intestinal digestibility of

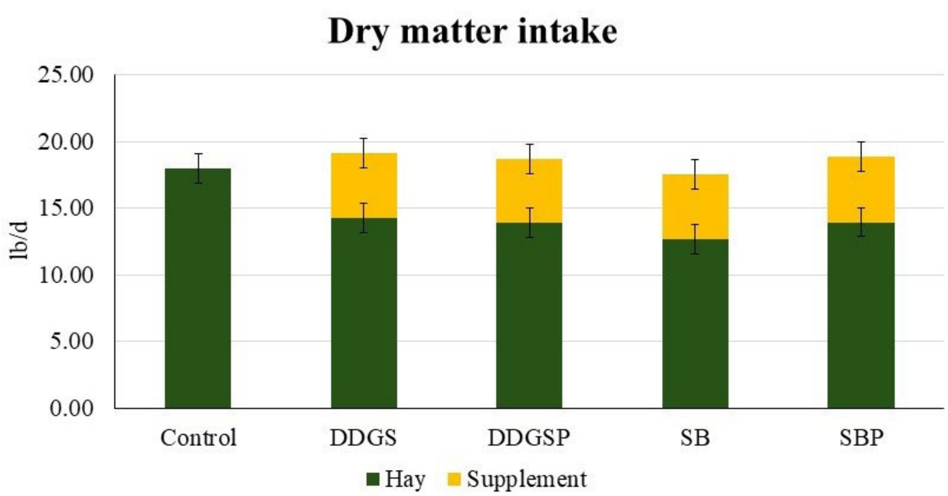

Figure 1. Dry matter (DM) intake (lb/day) in steers fed grass hay and supplemented at 0.5 % of body weight with or without either soybean-based or DDGS-based protein supplements, offered in meal or pelleted form. Control = hay only; DDGS = hay supplemented with dried distillers grains with solubles in meal form; DDGSP = hay supplemented with dried distillers grains with solubles in pellet form; SB = hay supplemented with soybean-based supplement (52.5% soybean meal and 47.5% soyhulls) in meal form; SBP = hay supplemented with soybean-based supplement in pellet form.

DM, OM and CP increased with supplementation ($P < 0.05$). Pelleting tended to reduce DM and NDF digestibility in the small intestine ($P = 0.074$ and $P = 0.047$, respectively). Large intestine digestibility was not affected, except for CP, which increased with supplementation when expressed relative to ileal flow ($P = 0.018$), suggesting more efficient absorption earlier in the tract.

Apparent total-tract digestibility of DM, OM and CP increased with supplementation ($P < 0.001$, Figure 2) and pelleting ($P < 0.01$), with no effect of protein source. For NDF, total-tract digestibility was greater with DDGS ($P = 0.006$) and with pelleting ($P = 0.004$), but was unaffected by supplementation. Despite similar NDF ruminal digestibility, this improvement in total-tract NDF digestibility may be due to post-ruminal effects or better synchronization between nutrient availability and microbial activity.

Ruminal VFA concentrations were mostly unchanged, although acetate concentration ($P = 0.037$) and acetate-propionate ratio ($P = 0.004$) were greater with soybean-based supplements, while butyrate was greater with DDGS ($P = 0.009$). Pelleting tended to lower the acetate-propionate ratio ($P = 0.055$), suggesting subtle shifts in fermentation.

In conclusion, protein supplementation increased crude protein intake and total-tract digestibility of DM, OM and CP without affecting total DM intake. However, supplementation reduced hay intake, indicating a substitution effect that may require attention in forage-based systems.

Differences in nutrient intake and flow were observed between supplement sources, likely reflecting their distinct protein levels and composition. While DDGS-based supplements increased CP intake and duodenal NDF flow, soybean-based treatments led to greater ruminal CP digestibility and shifts in fermentation profile. Pelleting enhanced total-tract digestibility but tended to reduce small intestine NDF digestion. These results highlight the importance of considering both composition and physical form when evaluating protein supplements for cattle fed forage-based diets.

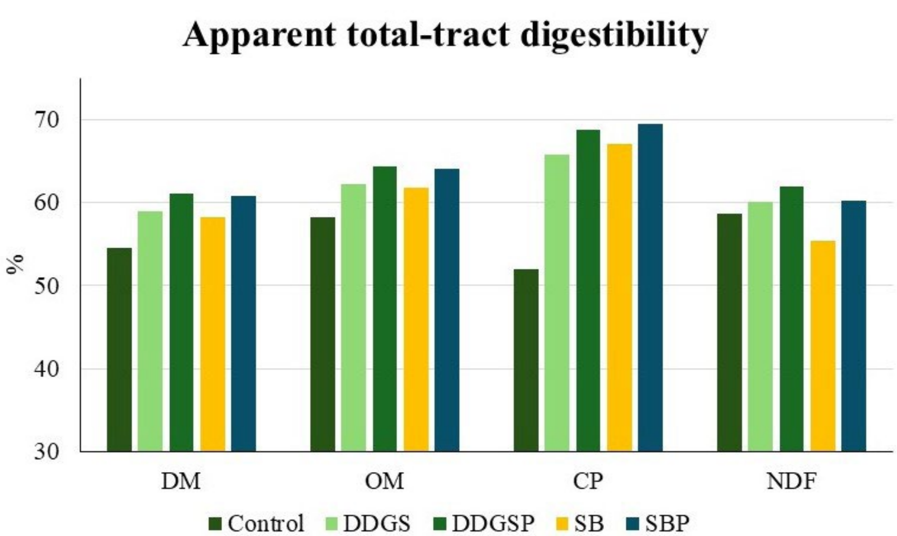

Figure 2. Nutrient apparent total-tract digestibility (% of intake) fed grass hay and supplemented at 0.5 % of body weight with or without either soybean-based or DDGS-based protein supplements, offered in meal or pelleted form. Control = hay only; DDGS = hay supplemented with dried distillers grains with solubles in meal form; DDGSP = hay supplemented with dried distillers grains with solubles in pellet form; SB = hay supplemented with soybean-based supplement (52.5% soybean meal and 47.5% soyhulls) in meal form; SBP = hay supplemented with soybean-based supplement in pellet form.

Acknowledgments

The authors thank the North Dakota Soybean Council for providing financial support and the staff and students at the NDSU Animal Nutrition and Physiology Center and the Animal Sciences Nutrition Laboratory for their assistance.

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Protein supplement source and processing for cattle fed forage-based diets: Effects on nitrogen and energy use and methane emissions

Pauliane Pucetti[1], Christy A. Finck[1], Zachary E. Carlson[2], Julia T. da Silva[3] and Kendall C. Swanson[1]

Protein supplementation improves nitrogen retention, reduces methane losses and enhances energy use efficiency regardless of supplement source or processing. Supplementation with distillers grains led to greater nitrogen retention due to their higher protein content. Pelleting altered nitrogen and energy metabolism, which warrants further investigation.

Summary

This study tested how protein source (DDGS vs. soybean-based) and supplement form (meal vs. pellet) affect nitrogen and energy use in steers. Protein supplementation increased nitrogen intake and retention, reduced methane emissions and improved overall energy efficiency. Supplementing DDGS led to greater nitrogen retention than a soybean-based supplement, mainly due to its higher protein content. Pelleting changed how nitrogen and energy were used, including increased urinary nitrogen losses and reduced fecal energy losses. These results show that protein supplementation improves nutrient utilization, reduces methane output and supports more efficient energy use in forage-fed cattle. Pelleting may further influence these responses and warrants more investigation.

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Introduction

Forage-based diets often fail to meet the protein requirements of beef cattle, especially during winter or drought conditions. When crude protein (CP) levels drop below 9-10%, fiber digestion is impaired, feed intake declines and nutrient imbalances can lead to increased nitrogen excretion and greater methane emissions (NASEM, 2016). Protein supplementation is a well-established strategy to improve nutrient utilization and support animal performance, but its impact extends beyond digestion; it also influences nitrogen and energy partitioning and contributes to the environmental footprint of cattle production.

The form and composition of protein supplements can influence digestion dynamics and affect energy and nitrogen utilization. Pelleted supplements, or "range cubes," are widely adopted in extensive grazing systems due to their ease of handling and distribution, but how pelleting affects nitrogen use efficiency, methane production and energy metabolism remains unclear. The use of DDGS has traditionally dominated supplementation programs in the northern Great Plains (Mueller, 2024). However, since 2023, North Dakota has expanded its soybean processing capacity, increasing the interest in soybean-based protein supplements as alternatives to DDGS sources. This study aimed to evaluate how protein supplementation, source (DDGS vs. soybean-based) and processing method (meal vs. pellet) affect methane emissions and how nitrogen and energy use in cattle fed a forage-based diet.

Experimental Procedures

All procedures involving animals were approved by the North Dakota State University Institutional Animal Care and Use Committee. Five Jersey steers (initial body weight [BW] = 994 ± 20 lb), fitted with ruminal, duodenal and ileal cannulas, were used in a 5 × 5 Latin square design with a 2 × 2 + 1 factorial arrangement of treatments. Factors included two protein sources — distillers dried grains with solubles (DDGS) or a soybean-based supplement (52.5% soybean meal, 47.5% soyhulls) — each in meal or pelleted form and a negative control with no supplementation. Supplements were offered daily at 0.5% of BW. All animals received free-choice access to grass hay, mineral supplement and water. Supplements were fed at 7:30 a.m. and hay at 8:00 a.m., adjusted daily to maintain ~5% refusals.

Each period lasted 14 days, with seven days of adaptation and seven days of data collection. Offered feed (hay and supplements) and refusals were weighed and sampled daily during the collection phase. Total feces and urine were collected over five consecutive days (days 8 to 12). Feces were collected using fecal bags, weighed and sampled twice daily. Feed, refusals and fecal samples were composited by steer and period, dried, ground and analyzed for nutrient and energy content. Urine was collected using funnels and vacuum systems, preserved in HCl and subsampled daily. Total volume was recorded, and aliquots were frozen for nitrogen and energy analysis.

Methane emission was measured using headbox respiration chambers over 24 hours on day 13 of each period. Heat production was estimated by indirect calorimetry. Steers were tethered comfortably and had ad libitum access to hay and water. Air samples were collected from the inlet and outlet of the chambers and analyzed with a Siemens Ultramat 23 gas analyzer for oxygen, carbon dioxide and methane. Total air flow was recorded using a wet gas meter and corrected for temperature and humidity. Methane energy loss was calculated by multiplying CH_4 volume by 9.45 kcal/L. Energy balance was calculated from gross energy intake and energy losses via feces, urine, methane and heat. Data were analyzed using the MIXED procedure in SAS (SAS Institute Inc., Cary, NC). The model included treatment as a fixed effect and steer and period as random effects. Preplanned orthogonal contrasts were used to test effects of supplementation (control vs. supplemented), source (DDGS vs. soybean), processing (meal vs. pellet) and source × form interaction. Significance was declared at $P < 0.05$ and tendencies at $0.05 \le P \le 0.10$.

Results and Discussion

Protein supplementation increased nitrogen (N) intake ($P < 0.001$; Figure 1), with greater values for the DDGS-based compared to the soybean-based supplement ($P = 0.001$). Fecal N excretion followed a similar pattern, increasing with supplementation ($P = 0.005$) and being greater for DDGS-based supplements ($P < 0.001$); a tendency for lower fecal N was observed with pelleting ($P = 0.071$). Urinary N excretion also increased with supplementation ($P < 0.001$) and was greater for soybean-based supplements ($P = 0.041$), likely due to greater ruminal ammonia production from the more degradable protein. Without sufficient fermentable energy from the hay to support microbial uptake, excess ammonia was likely absorbed and excreted as urea in the urine. Pelleting increased urinary N excretion ($P = 0.043$), demonstrating that processing affects N metabolism. Nitrogen retention was increased by

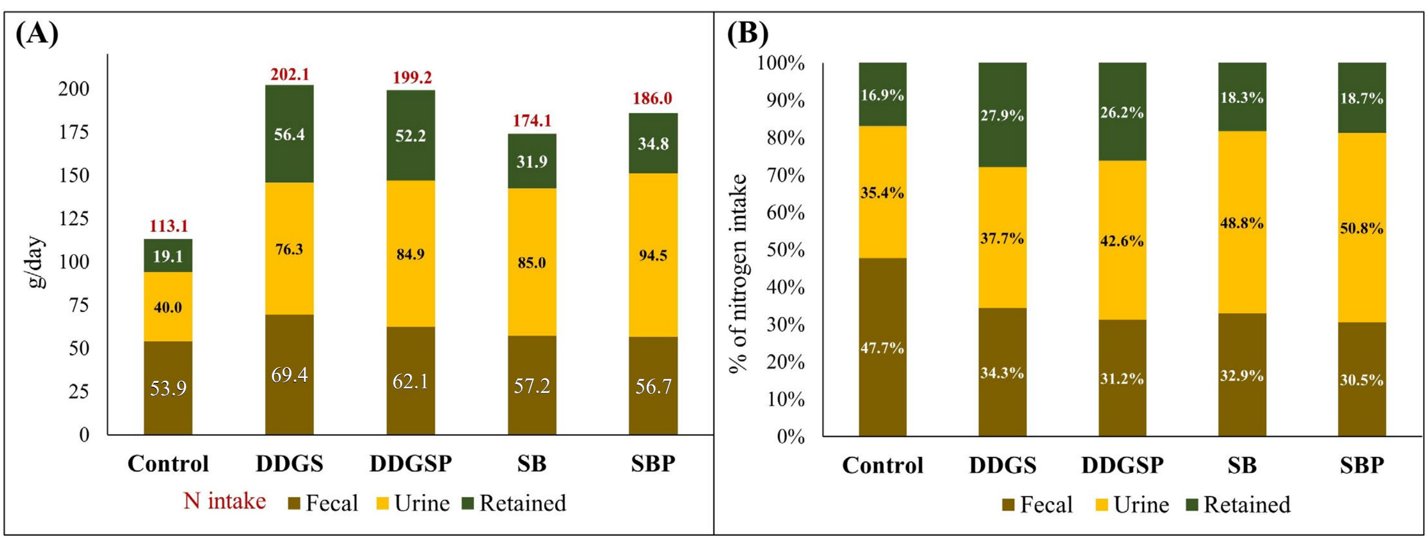

Figure 1. (A) Daily nitrogen (N) intake and partitioning (g/day) and (B) N partitioning as percentage of intake in steers fed grass hay and supplemented or not at 0.5 % of body weight with a soybean-based or DDGS-based protein supplement, offered in meal or pelleted form. Control = hay only; DDGS = hay supplemented with DDGS in meal form; DDGSP = hay supplemented with DDGS in pellet form; SB = hay supplemented with soybean-based supplement (52.5% soybean meal and 47.5% soyhulls) in meal form; SBP = hay supplemented with soybean-based supplement in pellet form. Standard error mean (g/day) for panel A variables were: intake = 11.4, fecal = 4.20, urine = 6.86, digested = 7.99, retained = 7.09. *P*-values (supplementation, source, and processing, respectively) were <0.001, 0.001, and 0.409 for N intake; 0.005, <0.001, and 0.071 for fecal N; <0.001, 0.041, and 0.043 for urinary N; and <0.001, 0.001, and 0.892 for retained N. No interaction effect was detected (*P* > 0.10).

supplementation ($P < 0.001$) and was greater with DDGS supplementation ($P = 0.001$), reflecting their higher crude protein content. Nitrogen retention as a percentage of intake also increased with supplementation ($P = 0.016$) and was greater for DDGS ($P < 0.001$), with no effects of pelleting or the interaction ($P > 0.10$).

Methane (CH_4) production in liters per day was not affected by treatment ($P > 0.10$). However, when expressed per kg of DM intake, CH_4 tended to decrease with supplementation ($P = 0.052$), and was reduced when expressed per kg of digested DM ($P = 0.016$), suggesting improved fermentation efficiency. No effects of source, pelleting or interaction were observed for CH_4 production ($P > 0.10$). These results indicate that protein supplementation reduces CH_4 emissions per unit of digested feed.

Gross energy (GE) intake was not affected by treatment ($P > 0.10$), but supplementation reduced fecal energy losses ($P = 0.041$) and increased urinary energy losses ($P < 0.001$), consistent with greater N intake and excretion. Methane energy losses were reduced with supplementation ($P = 0.012$), while heat production increased ($P = 0.003$). Retained energy increased with supplementation ($P = 0.025$), indicating improved energy utilization. When expressed as a percentage of GE intake, supplementation reduced fecal ($P < 0.001$, Figure 2) and methane ($P < 0.001$) losses, and it increased urinary losses ($P < 0.001$) and energy retention ($P = 0.016$). Pelleting reduced fecal energy losses ($P = 0.048$), and methane energy losses tended to be greater with soybean-based supplements than with DDGS ($P = 0.096$). Retained energy was not affected by protein source, pelleting or their interaction ($P > 0.10$).

In conclusion, protein supplementation improved nitrogen retention and reduced methane emissions per unit of digested dry matter, indicating more efficient nutrient use. Supplement with DDGS led to greater nitrogen retention than soybean-based supplementation, likely due to higher protein content and a greater proportion of rumen-undegradable protein. In contrast, the soybean-based supplement increased urinary nitrogen losses, likely due to excess rumen ammonia being converted to urea and excreted. Pelleting reduced fecal energy losses but increased urinary nitrogen, showing that supplement processing affects nutrient partitioning. Properly formulated soybean-based pellets may offer a practical alternative to DDGS for forage-based systems.

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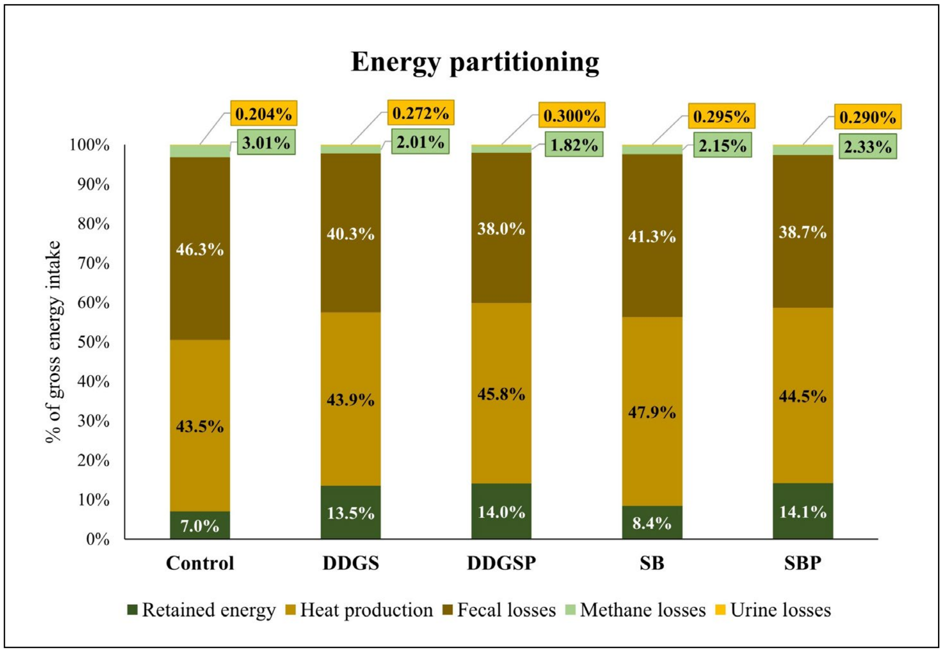

Figure 2. Energy partitioning as percentage of gross energy intake in steers fed grass hay and supplemented or not at 0.5 % of body weight with a soybean-based or DDGS-based protein supplement, offered in meal or pelleted form. Control = hay only; DDGS = hay supplemented with DDGS in meal form; DDGSP = hay supplemented with DDGS in pellet form; SB = hay supplemented with soybean-based supplement (52.5% soybean meal and 47.5% soyhulls) in meal form; SBP = hay supplemented with soybean-based supplement in pellet form. Standard error mean values (%) were: fecal = 1.03, urine = 0.0190, methane = 0.404, heat = 2.23, retained = 2.955. *P*-values (supplementation, source, and processing, respectively) were <0.001, 0.251, and 0.005 for fecal losses; <0.001, 0.614, and 0.410 for urinary losses; <0.001, 0.096, and 0.980 for methane losses; 0.248, 0.396, and 0.647 for heat production; and 0.016, 0.178, and 0.101 for retained energy. No interaction effect was detected ($P > 0.10$).

Lubabegron and betaine for finishing steers: Impacts on growth performance and carcass traits

Pauliane Pucetti[1], Christy A. Finck[1], Kasey R. Maddock-Carlin[1], Zachary E. Carlson[2], Nathan Pyatt[3] and Kendall C. Swanson[1]

Lubabegron (Experior®) improved feed efficiency and carcass yield in finishing steers without increasing feed intake, supporting its potential for enhancing profitability. Trends for interactions with betaine (Betafin®) suggest that combining both additives may provide additional carcass benefits worth further investigation.

Summary

This study evaluated the effects of lubabegron (Experior®, 0.032% DM for 56 days) and betaine (Betafin®, 0.28% DM for seven days) on feedlot performance and carcass traits of finishing steers. Lubabegron improved feed efficiency and increased hot carcass weight without affecting feed intake. Betaine alone had no effect, but a trend for an interaction with lubabegron on dressing percentage suggests possible additive benefits. These results indicate that lubabegron may be an effective nutritional strategy to enhance carcass yield and nutrient utilization in finishing cattle.

Introduction

Improving the productivity, efficiency and sustainability of beef cattle production is an ongoing priority for both producers and the livestock industry. One strategy to support this goal is the use of feed additives that can enhance growth performance, improve feed efficiency and increase carcass yield.

Lubabegron (Experior®; Elanco Animal Health), approved by the FDA in 2018, is a β-adrenergic modulator used during the final 14-91 days of finishing. Unlike traditional β-agonists, lubabegron stimulates β_3-receptors while blocking β_1 and β_2, promoting lean tissue accretion with fewer cardiovascular side effects. Research has shown that lubabegron improves feed efficiency, increases hot carcass weight (HCW) and reduces ammonia emissions (Kube et al., 2021).

Betaine (Betafin®; Danisco Animal Nutrition and Health) is another additive that can influence growth performance and nutrient utilization. It acts as an osmolyte, maintaining cellular hydration and preserving enzyme function, and as a methyl donor in one-carbon metabolism, aiding in protein synthesis, liver function and growth. In beef cattle, betaine supplementation has been linked to improvements in dry matter intake and sometimes carcass yield, although results vary depending on diet and environment (Abhijith et al., 2024).

Because lubabegron and betaine act through different mechanisms, they may offer complementary benefits. However, little is known about their combined effects in finishing cattle. Therefore, this study was conducted to evaluate the individual and combined effects of lubabegron and betaine on dry matter intake, feed efficiency, HCW and carcass dressing percentage in finishing steers.

Experimental Procedures

All procedures were approved by the North Dakota State University Institutional Animal Care and Use Committee. Sixty steers (initial body weight [BW] = 1050 ± 11.6 lbs; commercial crossbred and Angus) were housed at the NDSU Beef Cattle Research Complex (Fargo, ND) and stratified by BW into two blocks: a heavier group (n = 38; 119-day feeding period; BW = 1101 ± 10.0 lbs) and a lighter group (n = 22; 147-day feeding period; BW = 966 ± 12.4 lbs). Steers were randomly assigned to one of four treatments in a 2 × 2 factorial arrangement: the control group (no additive; n = 16), Lubabegron (0.032% of dietary dry matter [DM] for 56 days, followed by a seven-day withdrawal; n = 14) and Betaine (0.28% of dietary DM for the final seven days; n = 15) and Lubabegron + Betaine (n = 15).

Diets were formulated using the empirical solutions model of the Beef Cattle Nutrient Requirements Model, 2016 (NASEM, 2016) to contain approximately 10% roughage and 90% concentrate on a dry matter basis with the following ingredients: corn grain (60%), DDGS (20%), corn silage (10%), grass hay (5%), limestone (1.5%), urea (0.95%), salt (0.10%), fine

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ground corn (2.1-2.3%), monensin (0.02%), vitamin premix (0.01%) and trace mineral premix (0.05%). Both additives were incorporated by partially replacing fine-ground corn in the supplement premix.

Steers were weighed at trial initiation (two consecutive days), every 28 days and at key time points during supplementation (days -1, 0, 28, 55 and 56 for Lubabegron; days -1, 0, 6 and 7 for Betaine). On day one, steers were implanted with 200 mg trenbolone acetate + 20 mg estradiol-17β (Component™ TE-200, Elanco, Greenfield, IN). Individual daily feed intake was measured using an automated feed system (Insentec Roughage Intake Control, Hokofarm B.V., Marknesse, Netherlands). Weekly ingredient samples were dried (60 degrees Celsius, 48 hours), ground (1-mm screen, Wiley mill), composited and analyzed for nutrient composition. At the end of the trial, steers were transported to a federally inspected slaughter facility.

Data were analyzed using the MIXED procedure of SAS (SAS Institute, Cary, NC) as a randomized complete block design with a 2 × 2 factorial arrangement. Marketing group was included as a random blocking factor, and initial BW at the start of supplementation was included as a covariate. Isolated additive effects and their interaction were tested, with significance at $P \leq 0.05$ and trends at $0.05 < P \leq 0.10$.

Results and Discussion

There were no treatment effects on initial BW, presupplementation BW or final BW ($P > 0.10$; Table 1), confirming that steers were well balanced at the beginning of the trial and that final live weight was not influenced by the additives. Hot carcass weight was greater in steers receiving lubabegron ($P = 0.035$; Figure 1), and a tendency for a lubabegron × betaine interaction was observed ($P = 0.071$). This suggests a potential additive or synergistic effect, although the interaction was not statistically significant. The increase in HCW with lubabegron is consistent with its β_3-adrenergic activity, which promotes lean tissue accretion. A similar pattern was observed for carcass dressing percentage, which tended to be greater in lubabegron-fed steers ($P = 0.079$), with a trend for an interaction ($P = 0.062$).

Table 1. Body weight, dry matter intake and average daily gain of finishing steers supplemented with Lubabegron (Experior®) and/or Betaine (Betafin®).

Item	Control	Betaine	Lubabegron	Lubabegron + Betaine	SEM[1]	*P-value*[2] Lubabegron	Betaine	Interaction
***Body weight*[3], lb**								
Initial	1039	1028	1028	1034	70	0.894	0.887	0.613
Pre-Supplementation	1322	1336	1307	1322	19	0.463	0.463	0.967
Final	1584	1581	1587	1600	40	0.316	0.652	0.468
***Dry matter intake*[4], lb/d**								
Pre-Supplementation	26.8	28.0	27.9	27.8	0.85	0.292	0.194	0.144
Lubabegron + Betaine	31.6	32.5	30.9	31.8	0.89	0.239	0.148	0.977
Lubabegron	31.6	32.6	30.8	31.8	0.83	0.220	0.123	0.988
Total	29.1	30.2	29.3	29.7	1.04	0.749	0.138	0.532
***Average Daily Gain*[4], lb/d**								
Pre-Supplementation	4.01	4.32	3.98	4.03	0.13	0.261	0.211	0.34
Lubabegron + Betaine	4.15	4.10	4.20	4.41	0.64	0.315	0.645	0.467
Lubabegron	4.32	4.27	4.47	4.74	0.44	0.052	0.493	0.309
Total	4.12	4.26	4.13	4.27	0.29	0.962	0.253	0.984
Gain:feed								
Pre-Supplementation	0.150	0.155	0.143	0.146	0.0078	0.085	0.472	0.777
Lubabegron + Betaine	0.131	0.125	0.136	0.138	0.0166	0.038	0.713	0.352
Lubabegron	0.137	0.131	0.145	0.149	0.0105	<0.001	0.749	0.156
Total	0.141	0.141	0.141	0.144	0.0050	0.784	0.644	0.585

[1]Standard error of the mean
[2]*P*-values represent the main effects of Lubabegron (Experior®), Betaine (Betafin®), and their interaction (Lubabegron × Betaine
[3]Body weight is presented at three timepoints: initial (trial start), pre-supplementation (start of additive feeding), and final (end of finishing period)
[4]Reported for the pre-supplementation period, during the Lubabegron and Betaine supplementation (last 63 days), during Lubabegron supplementation (56 days), and for the total finishing period.

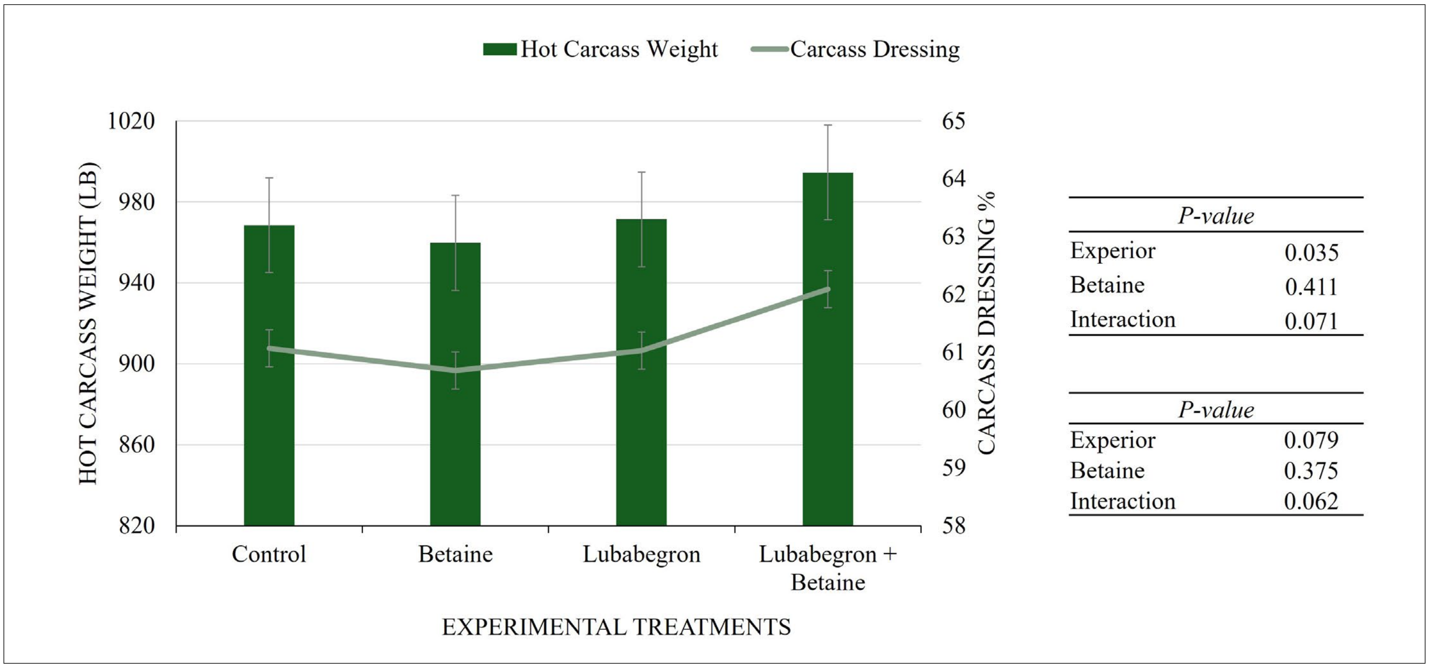

Figure 1. Hot carcass weight and carcass dressing percentage of finishing steers fed diets with or without Lubabegron (Experior®) and/or Betaine (Betafin®). *P*-values represent the main effects of Lubabegron, Betaine and their interaction.

Dry matter intake was not affected by treatment during the presupplementation period, the lubabegron supplementation phase or the total finishing period ($P > 0.10$; Table 1). These results indicate that performance responses were not driven by changes in feed intake, but rather by differences in nutrient utilization.

Lubabegron tended to increase ADG during the 56-day supplementation period ($P = 0.052$; Table 1), suggesting a potential improvement in growth performance associated with its β_3-adrenergic activity. No effects on ADG of betaine or the lubabegron × betaine interaction were observed during this period ($P > 0.10$). During the presupplementation period, no effects of lubabegron, betaine or their interaction were detected ($P > 0.10$). Similarly, total ADG across the entire feeding period was not influenced by either additive or their interaction ($P > 0.10$).

The gain-feed ratio tended to be lower for steers assigned to the lubabegron group during the presupplementation period ($P = 0.085$; Table 1). Although the cause for this reduction is unclear, the effect was not sustained after supplementation began. Lubabegron supplementation increased gain:feed during the 56-day treatment window ($P < 0.001$) and also during the last 63 days of the finishing period ($P = 0.038$). No effects of betaine or the lubabegron × betaine interaction were observed on gain:feed in any period ($P > 0.10$).

In conclusion, lubabegron improved feed efficiency and hot carcass weight without increasing intake. Although betaine alone had no effect, a trend for an interaction with lubabegron suggests additive potential. Additional studies are needed to clarify these responses and optimize combined supplementation.

Acknowledgments

We thank Elanco Animal Health for providing Experior® (lubabegron) and Component™ TE-200 implants and Danisco Animal Nutrition (IFF) for providing Betafin® (betaine) for use in the study. We also thank the staff and students at the NDSU Beef Cattle Research Complex and Animal Sciences Nutrition Laboratory for their assistance.

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Lubabegron and betaine for finishing steers: Impacts on carcass measurements, meat quality and yield

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Lubabegron (Experior®) improved USDA Yield Grade through increased hot carcass weight and ribeye area and decreased 12th rib backfat measurements. However, lubabegron also decreased USDA Quality Grade due to lower marbling scores, which also resulted in slightly lower tenderness measurements in strip steaks on day 21 of aging. Lubabegron also increased purge in wholesale strip loins during refrigerated storage. Betaine (Betafin®) increased USDA Yield Grade in beef carcasses, which was due to increased 12th rib backfat measurements while not impacting USDA Quality Grade. However, betaine, when supplemented with lubabegron, prevented the loss of water due to purge that was observed when lubabegron was supplemented alone.

Summary

This study evaluated the effects of lubabegron (Experior®, 0.032% DM for 56 days) and betaine (Betafin®, 0.28% DM for seven days) on carcass yield and quality, as well as meat quality measurements related to tenderness and water-holding capacity. While lubabegron improved upon USDA Yield grades through greater lean yield and less fat, there was also decreased tenderness and water-holding capacity. While betaine was detrimental to USDA Yield Grade by increasing the percentage of carcasses grading in Yield Grade 4 and 5, it decreased drip loss in strip steaks and prevented the purge loss that was observed when lubabegron was supplemented alone.

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Introduction

Lubabegron fumarate is the newest beta-adrenergic agonist approved for use in finishing cattle (Experior®; Elanco Animal Health) and is labeled primarily for reduction of ammonia emissions. Although the use of lubabegron has become widespread, little is known about potential impacts on meat quality. Vogel et al. (2023) reported that lubabegron supplementation increased carcass weights and ribeye area in crossbred steers, and they observed a decrease in marbling score, resulting in a USDA quality grade shift from USDA Choice to USDA Select.

Betaine (Betafin®; Danisco Animal Nutrition and Health) is an amino acid derivative that serves as a methyl donor for the conversion of homocysteine to methionine, and it is considered a zwitterionic molecule with antioxidant properties that protect cells from osmotic and ionic stresses (Lipinski et al., 2012). Although there is little information on the impact of betaine on beef quality, research on rumen-protected betaine in lambs showed that it increases pH in the semimembranosus and gluteus medius and decreases shear force values and drip loss (Dong et al., 2020). A recent study (Soares et al., 2022) evaluated betaine supplementation in combination with the beta-agonist ractopamine hydrochloride in finishing pigs and observed a decrease in cooking water loss when the combination of the two supplements were fed, as well as a decrease in shear force value and an increase in intramuscular fat in the longissimus muscle when betaine was supplemented without ractopamine.

The impacts of supplementation of beta-agonists in beef feedlot diets on meat quality have been well researched with consistent themes of increased carcass weight, yield and efficiencies, but also detriments related to meat quality traits of tenderness and marbling scores. Preliminary research with lubabegron fumarate is showing similar tendencies to previously well-researched beta-agonists such as ractopamine hydrochloride. The osmotic and antioxidant protections of betaine — resulting in increased water-holding ability, decreased shear force values and increased intramuscular fat observed in some meat animal species (lamb and pork) — could potentially help to mitigate the detrimental changes observed in beef quality when supplementing lubabegron. Therefore, the objectives of this study were to evaluate the impacts of lubabegron fumarate (LUB) and betaine (BET) supplementation on carcass characteristics and strip loin meat quality traits of finishing steers.

Procedures

All animal procedures were reviewed and approved by the North Dakota State University Institutional Animal Care and Use Committee (IACUC Protocol #: 20240033). Sixty steers (initial body weight [BW] 1050 ± 11.6 lbs), predominantly of Angus and Simmental breeding, were stratified by weight into two groups: heavy (fed for 119 days before slaughter, n = 38) and light (fed for 147 days before slaughter, n = 22). Steers were randomly assigned to one of four treatments in a 2 × 2 factorial arrangement: the control treatment (no additive; n = 16), Lubabegron (0.032% of dietary dry matter [DM] for 56 days, followed by a seven-day withdrawal; n = 14), Betaine (0.28% of dietary DM for the final 7 days; n = 15) and Lubabegron + Betaine (n = 15).

All steers received a growth-promoting implant (200 mg trenbolone acetate, 20 mg estradiol 17β+, and 29 mg tylosin tartrate; Elanco Animal Health) and were fed a diet containing 10% forage (corn silage and grass hay) and 90% concentrate (dry-rolled corn, DDGS, urea, limestone, salt, vitamin and trace mineral mix and monensin). Individual feed intake was monitored using the Insentec feeding system, and steer served as the experimental unit. Steers were weighed on two consecutive days at the beginning and end of the experiment, during Lubabegron and Betaine supplementation periods and every 28 days throughout the experiment. Steers were transported to a commercial beef processing plant on two different days. Carcass data were collected, and strip loins (IMPS 180, n = 53) were transported to the NDSU Meat Science Laboratory for further fabrication and analyses. Loins not collected were either lost in the packing plant due to sorting, or their fabrication was delayed and could not be collected within the time that personnel were at the plant. The loins were aged in vacuum packaging for 14 days at 4 degrees Celsius. Loins were fabricated into four 2.5-cm thick steaks for further analysis. Tenderness was evaluated by Warner-Bratzler Shear Force (WBSF) on 14- and 21-day-aged steaks, with cook loss percentage calculated. Drip loss was measured with 14-day-aged samples with 50 g samples that were either suspended for 48 hours or were stored in plastic storage bags for six days. Simulated retail display was evaluated on 14-day-aged steaks placed on Styrofoam trays overwrapped with PVC and displayed in a retail cooler for 14 days, where daily measurements of L*, a* and b* were taken with a Minolta colorimeter. Data were analyzed using PROC MIXED in SAS as a randomized complete block design for effects of treatments and their interaction. For performance data including hot carcass weight, marketing date was included as the block and initial BW was used as a covariate. For carcass and meat quality data, marketing date was used as a covariate. Significance was declared at $P \leq 0.05$, and trends were considered for $0.05 < P \leq 0.10$.

Results

Supplementation with LUB decreased ($P < 0.006$; Table 1) marbling score and USDA yield grade and increased ($P = 0.04$) ribeye area. Supplementing BET increased ($P < 0.009$) 12th rib backfat and, therefore, also USDA Yield Grade ($P < 0.002$). Kidney, pelvic and heart fat percentages were not impacted by treatment.

Supplementing LUB increased ($P < 0.02$; Table 2) 14-day purge loss in vacuum-package boneless strip loins. Supplementing BET tended ($P < 0.06$) to decrease purge loss and drip loss. Neither supplementation with LUB nor BET impacted cook loss or water loss. However, numerical values for cook loss and water loss are consistently lower for BET compared to no-BET, although statistical significance was not found. Fu et al. (2023) determined that long-term supplementation of betaine to finishing pigs decreased cooking loss.

Strip loins aged for 14 days were not impacted by LUB or BET supplementation for WBSF; however, 21-day strip loins had greater ($P < 0.01$) shear force values when LUB was fed. When observing the improvement in shear force value from day 14 to day 21, LUB steaks did not have the same magnitude of reduction in shear force values as non-LUB steaks, indicating that less aging occurred. Corona et al. (2025) observed that LUB increased shear force on day 14 of aging at a higher dose of LUB; however, the lowest dose of LUB was not different from controls, and by day 21 of aging, the magnitude of reduction of shear force was not different between LUB and controls, indicating continuing improvements in shear force values. It's important to note that all shear force values were within the threshold of acceptability for tenderness.

Supplementation with LUB and BET did not affect L* values (lightness) on steaks displayed for 14 days. However, supplementation with LUB decreased a* values (redness; Figure 1) after d 10 of display. This decrease in redness occurred well after a typical retail display time for fresh beef in overwrap packages (two to seven days), so it would have limited implications on purchasing decisions at the retail level. When LUB was

Table 1. Least-squares means (interactive means) of the effects of lubabegron and betaine supplementation of beef cattle on hot carcass weight, dressing percentage, final USDA yield grade, ribeye area, marbling, 12th rib backfat and KPH

Item	Control	Betaine	Lubabegron	Lubabegron + Betaine	SEM	*P-value* Lubabegron	*P-value* Betaine	*P-value* Interaction
USDA Yield Grade	3.7[bc]	4.2[a]	3.3[c]	3.9[ab]	0.2	0.04	**0.002**	0.83
Ribeye area (in^2)	14.5[ab]	13.8[b]	15.0[a]	14.8[ab]	2.3	0.04	0.17	0.46
Marbling[2]	525.1[ab]	567.1[a]	465.2[c]	481.2[bc]	26.3	0.006	0.26	0.61
12[th] rib backfat (in)	0.72[ab]	0.79[a]	0.64[b]	0.77[a]	0.1	0.18	**0.009**	0.40
KPH[3] (%)	1.9	1.9	1.8	1.9	0.03	0.19	0.33	0.61

[1]Dressing percentage = Hot carcass weight/Live weight x 100
[2] Marbling scores = Small 400-499; Modest 500-599
[3]Kidney, Pelvic, and Heart fat as a percentage of total carcass weight

Table 2. Least-squares means (interactive means) of the effects of lubabegron and betaine supplementation of beef cattle on purge loss, drip loss, water loss, cook loss and Warner-Bratzler shear force values (WBSF)

Item	Control	Betaine	Lubabegron	Lubabegron + Betaine	SEM	*P-value* Lubabegron	*P-value* Betaine	*P-value* Interaction
Purge[1], %	1.25[b]	1.01[b]	1.88[a]	1.33[b]	0.18	**0.02**	**0.08**	0.55
Drip loss[2], %	0.65	0.46	0.72	0.52	0.09	0.81	**0.06**	0.67
Water loss[3] D1, %	1.08	0.92	1.20	1.04	0.18	0.48	0.34	0.99
Water loss[3] D6, %	2.78	2.58	3.10	2.72	0.32	0.44	0.33	0.76
Cook loss[4] D14, %	17.43	17.09	16.83	16.47	0.57	0.25	0.51	0.99
Cook loss[4] D21, %	18.58	17.62	17.85	16.72	0.83	0.29	0.17	0.92
WBSF[5] D14, kg	2.55	2.34	2.58	2.58	0.14	0.29	**0.39**	0.38
WBSF[5] D21, kg	2.40[ab]	2.11[b]	2.53[a]	2.52[a]	0.11	**0.01**	0.14	0.18

[1]Percentage of weight lost in primal beef loins stored for 14 days in vacuum packages.
[2] Percentage of weight lost in 50-g samples after suspension for 48 hours.
[3]Percentage of weight lost in 50-g samples stored in storage bags.
[4]Percentage of weight lost in 2.5-cm steaks after cooking.
[5]Warner-Bratzler shear force values

supplemented, BET decreased ($P < 0.03$) a* and b* values (yellowness) on day 2 of retail display, but this difference was not observed on any other day of display. Corona et al. (2025), who evaluated the effects of LUB supplementation duration and dose, also did not observe changes in L*; however, they did observe that as LUB dose increases, a* and b* values decrease on unaged *Longissimus lumborum* muscle. In this study, instrumental color was not measured until after 14 days of aging, and there was only one dose concentration when compared to control. Previous research with other beta-agonists has had mixed results on impacts on redness (a*) or yellowness (b*; Quinn et al., 2008).

In conclusion, supplementation with LUB improved carcass yield but decreased measurements of tenderness and purge. However, supplementation with BET tended to decrease purge and may be able to mitigate some of the purge loss due to LUB supplementation. However, BET supplementation increased backfat, which increased USDA Yield Grades. Although LUB supplementation decreased the redness of steaks in simulated retail display, this was not observed until after 10 days of display, which is outside of typical retail display times.

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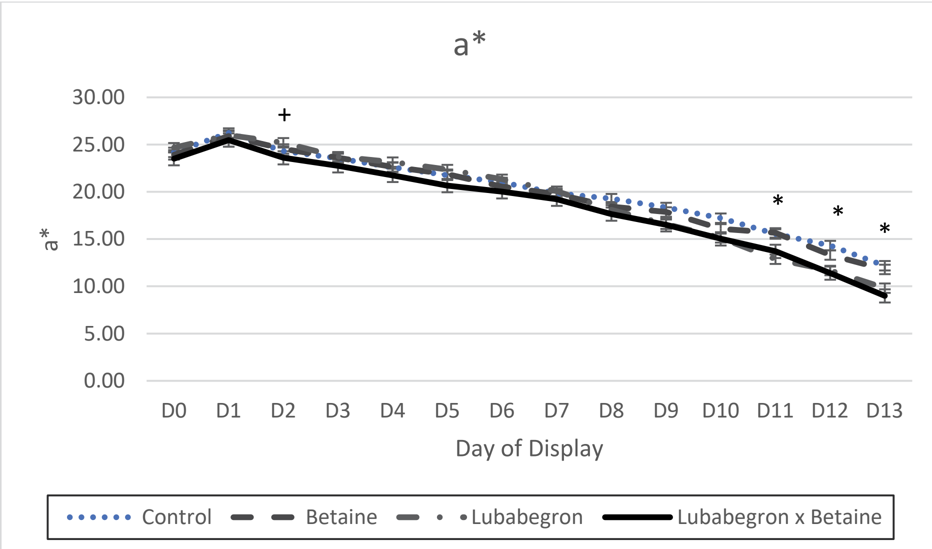
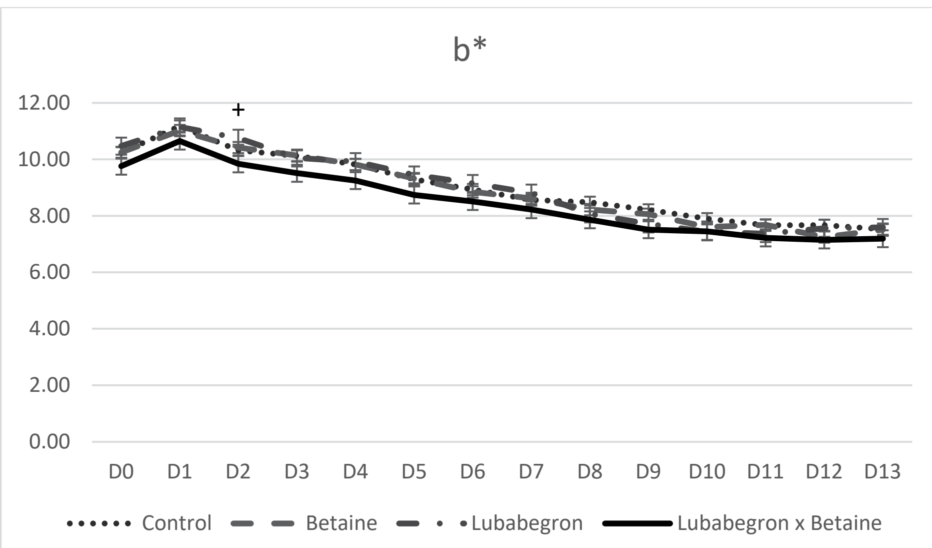


*The a** value indicates redness to greenness (+ = red; - = green)
* Lubabegron treatment decreased a* (redness; $P < 0.05$) on days 11-13 of retail display.
+ Interaction ($P < 0.05$) between betaine and lubabegron, where betaine decreased a* (redness) when lubabegron was also included.



The b* value indicates yellow to blue (+ = yellow; - = blue)
+ Interaction ($P < 0.05$) between betaine and lubabegron, where betaine decreased b* (yellowness) when lubabegron was also included.

Figure 1. Change in a* and b* values of beef strip loin steaks displayed in a retail cooler across a 14-day period

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Effects of leucine supplementation on growth and plasma metabolites in preweaned Holstein dairy calves

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Leucine supplementation during the preweaning phase altered plasma amino acid and glucose profiles, suggesting changes in nutrient utilization. These metabolic shifts may have implications for long-term productivity and warrant further investigation.

Summary

This study evaluated the effects of leucine and alanine supplementation in milk replacer on performance and blood metabolites of Holstein calves during the preweaning phase. No overall effects on body weight or weekly gain were observed. However, leucine altered plasma amino acid profiles and glucose dynamics, suggesting shifts in nutrient utilization. These findings indicate that while growth performance remained unchanged, leucine may influence metabolic pathways with potential implications for long-term development.

Introduction

Rapid growth during the preweaning phase programs lifetime productivity in dairy heifers. A meta-analysis showed that every additional 0.2 lb/d of average daily gain (ADG) before weaning yields ~190-240 lb more milk in the first lactation (Soberon & Van Amburgh, 2013). Because rumen function is minimal at this age, the nutrient profile of milk or milk replacer largely dictates anabolic potential.

Beyond supplying amino acids (AA) for protein accretion, certain AA act as metabolic signals. Leucine, in particular, activates the mTOR pathway, promoting translation initiation and muscle protein synthesis (Kimball & Jefferson, 2006). While leucine enhances lean tissue deposition in nonruminant neonates, data in young ruminants remain limited and inconclusive.

Reiners et al. (2022) supplemented Holstein bull calves with up to 0.8 g leucine/kg BW/day in milk replacer. Serum leucine concentration increased linearly, concentrations of several other amino acids linearly decreased, but ADG and nitrogen retention were unaffected by leucine supplementation. However, because added leucine increased nitrogen (and thus crude protein [CP]) intake, the study could not isolate leucine-specific effects from higher nitrogen supply. To our knowledge, no published research has evaluated isonitrogenous leucine supplementation that separates signaling effects from CP-related responses.

Therefore, the objective of this study was to evaluate the effects of supplementing milk replacer with leucine on growth performance and blood concentrations of AA, glucose and blood urea nitrogen in preweaned Holstein heifer calves.

Experimental Procedures

All animal procedures followed North Dakota State University animal care guidelines and were approved by the institutional committee. The study was conducted at the NDSU Dairy Unit in Fargo, North Dakota, between June 2023 and May 2024. Thirty-five newborn Holstein heifer calves were enrolled as they became available. At birth, each calf was separated from its dam, weighed and fed maternal colostrum within two hours to ensure good transfer of immunity; colostrum feeding continued for the first three days of life. Starting on day 4, all calves received a commercial milk replacer (Amplifier Max BOV MOS, Land O'Lakes).

Calves were randomly assigned, one out of every three births, to one of three treatments. Control (CON) calves received the milk replacer (20.4% CP) mixed as directed on the product label. Leucine (LEU) calves received the milk replacer with an inclusion of 5 % crystalline leucine (99.7 % purity) on a dry matter basis. Calves on the alanine (ALA) treatment received the milk replacer plus 3.47 % of crystalline L-alanine (99.7 % purity) to provide equal amounts of total nitrogen intake per day as the LEU calves. Milk replacer was offered twice daily at 5 a.m. and 2 p.m. During the first week, each feeding consisted of 0.69 lb of milk

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replacer powder blended into 2 qt of warm water; from the second week onward, 1.09 lb of powder was mixed into 3 qt of water per feeding. Calves also had ad libitum access to starter pellets and water from day 4 onward, with refusals weighed weekly to estimate starter intake.

Following NDSU Dairy Unit management procedures, calves were housed in a climate-controlled group pen during the first week. On day 8, they were moved to individual outdoor hutches bedded with straw, where they remained for the rest of the 56-day milk replacer-feeding phase, which ran from study day 4 through day 59. Body weight was recorded at the start (days 3-4), every seven days and at the end (day 59) of milk replacer-feeding. Blood samples were taken from the jugular vein three hours after feeding on days 28 and 56 of the milk replacer-feeding phase. Samples were allowed to clot for 30 minutes, kept on ice and spun in a refrigerated centrifuge, and the serum was stored at minus 20 degrees Celsius. Serum AA concentrations were measured by high-performance liquid chromatography, and glucose and urea nitrogen by ultraviolet/visible spectrophotometry.

All analyses were carried out with SAS 9.4 (SAS Institute Inc., Cary, NC). Growth variables (body weight and weekly gain) were fitted with a mixed-effects repeated-measures model that included fixed effects of dietary treatment (CTL, ALA, LEU), week (1 to 8) and their interaction. For the body weight response, the model was adjusted for initial weight at week 0, whereas this covariate was omitted when weekly gain (lb week^{-1}) was the dependent variable. Two a priori contrasts were tested: control versus the average of the two AA treatments (CTL vs. [ALA + LEU]) and ALA versus LEU. Statistical significance was declared at $P \leq 0.05$, and $0.05 < P \leq 0.10$ was interpreted as a tendency. Serum variables used the same model framework but replaced week with sampling day.

Results and Discussion

Dietary treatment did not affect BW or weekly gain during the eight-week milk replacer-feeding phase ($P > 0.10$; Figure 1). However, a treatment × week interaction was detected for weekly gain ($P = 0.042$; Figure 2) as LEU calves showed greater gain than CTL and ALA in week 3 ($P < 0.05$) with tendencies for reduced gain compared to CTL in week 6 and to ALA in week 7 ($P < 0.10$). These transient effects likely explain the lack of differences in final BW. Overall, leucine supplementation caused week-specific shifts in gain that were not consistent or cumulative, suggesting no performance advantage of ALA or LEU under these conditions.

Plasma urea nitrogen (BUN) concentration was not affected by treatment, day or their interaction ($P > 0.10$). For plasma glucose concentration, there was a treatment × day interaction ($P = 0.021$). Among calves fed the LEU diet, glucose concentration increased from day 28 to day 56 ($P = 0.042$), whereas no change over time occurred for CTL or ALA. Despite this, glucose concentrations were not different among treatments on both days, indicating a transient LEU effect on glucose metabolism.

For plasma essential amino acids (EAA), leucine ($P < 0.001$), threonine ($P = 0.010$) and valine ($P = 0.001$) were higher in supplemented groups (ALA + LEU) vs. CTL, with a tendency for lower phenylalanine ($P = 0.061$). Comparing the two supplemented groups, calves fed ALA had greater plasma concentrations of isoleucine ($P < 0.001$), lysine ($P = 0.013$) and methionine ($P = 0.003$), whereas calves fed LEU had markedly greater leucine concentrations ($P < 0.001$). Regarding nonessential amino acids (NEAA), supplementation had an

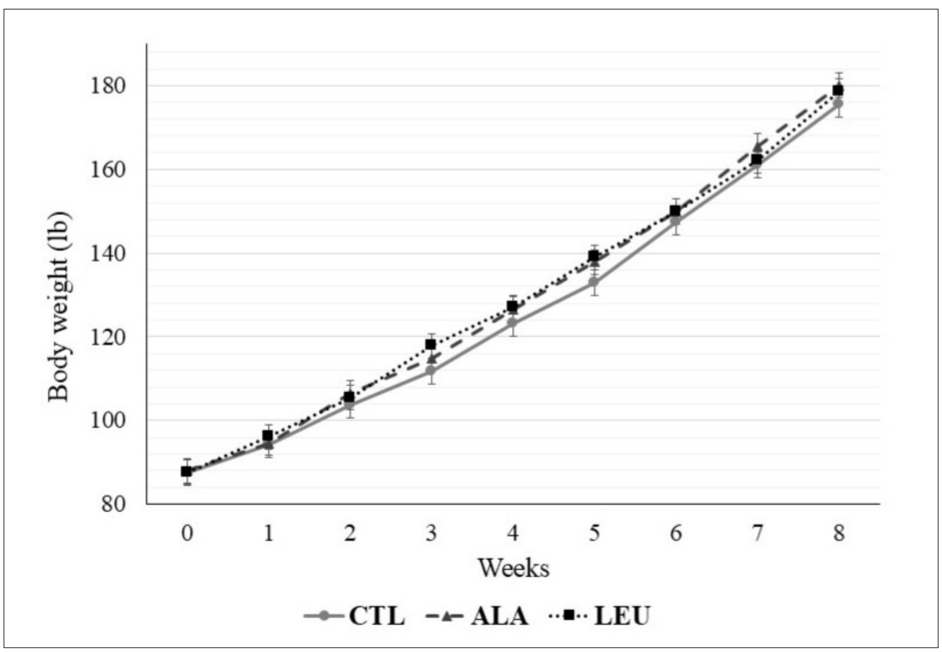

Figure 1. Average body weight (BW; mean ± SE) of Holstein heifer calves during the 8-week milk-replacer phase. Calves received CTL = unsupplemented milk replacer, ALA = milk replacer + alanine or LEU = milk replacer + leucine. *P*-values: Treatment = 0.664; Week < 0.001; Treatment × Week = 0.137. Planned contrasts: CTL vs (ALA + LEU) = 0.647; ALA vs LEU = 0.427.

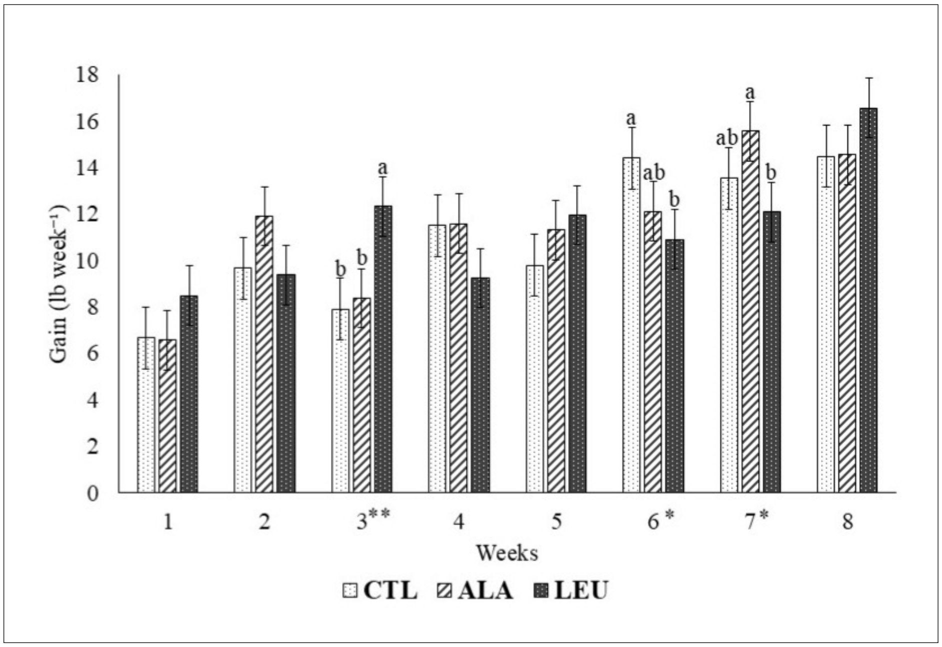

Figure 2. Weekly body-weight gain (lb week^{-1}) of Holstein heifer calves during the 8-week milk-replacer phase. Calves received CTL = unsupplemented milk replacer, ALA = milk replacer + alanine, or LEU = milk replacer + leucine. *P*-values: Treatment = 0.757; Week < 0.001; Treatment × Week = 0.043. Planned contrasts: CTL vs (ALA + LEU) P = 0.597; ALA vs LEU *P* = 0.593. Symbols below the x-axis mark overall treatment effects within each week: ** = significant ($P \leq 0.05$); * = tendency ($0.05 < P \leq 0.10$). Within a week, bars that do not share a common superscript letter differ ($P<0.10$).

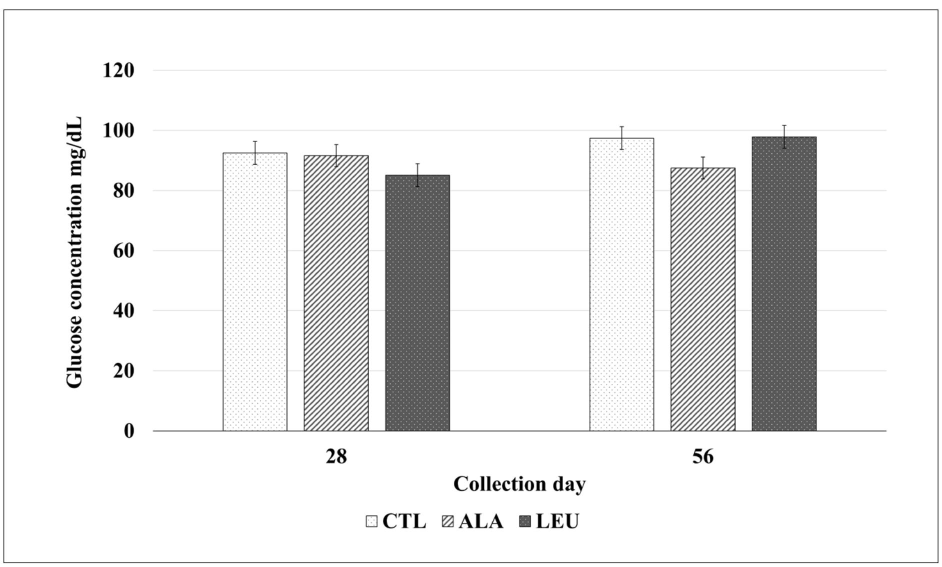

Figure 3. Plasma glucose concentrations (mean ± SE) of Holstein heifer calves on days 28 and 56 of the milk-replacer phase. Calves received CTL = unsupplemented milk replacer, ALA = milk replacer + alanine, or LEU = milk replacer + leucine. *P*-values: Treatment = 0.494; Day = 0.062; Treatment × Day = 0.022. The Treatment × Day interaction was driven by an increase in glucose from day 28 to 56 in the LEU group (*P* = 0.042).

effect on plasma alanine (*P* = 0.013), proline (*P* < 0.001) and tyrosine (*P* = 0.007) and a tendency for increased glutamic acid in the supplemented groups (*P* = 0.072). When comparing ALA and LEU groups, ALA calves had higher concentrations of asparagine (*P* = 0.040), cystine (*P* = 0.038) and proline (*P* < 0.001). No treatment × day interactions were observed for any NEAA.

Although no consistent improvements in performance were observed, the inclusion of leucine in the milk replacer led to distinct shifts in the plasma amino acid profile that cannot be attributed solely to increased nitrogen intake. Compared with alanine, which served as an isonitrogenous control, leucine supplementation altered concentrations of several essential and nonessential amino acids, suggesting changes in metabolic utilization and possibly enhanced protein synthesis. The transient increase in glucose concentration and the marked rise in circulating leucine itself further support the idea that leucine modulates nutrient partitioning during early development. From a practical standpoint, such metabolic adaptations could contribute to differences in muscle growth potential or efficiency in later productive stages, even if not immediately reflected in preweaning body weight.

In conclusion, supplementation of leucine in milk replacer during the preweaning phase did not improve short-term growth but elicited measurable metabolic responses that suggest altered amino acid utilization. These findings emphasize the need for further research to determine whether such early-life metabolic shifts influence long-term productivity in dairy heifers.

Table 1. Plasma amino-acid concentrations (μmol L^{-1}) of Holstein heifer calves fed a commercial milk replacer alone (CTL), or the same milk replacer supplemented with alanine (ALA) or leucine (LEU).

	Treatments				*P*-values		
Items	Control	Alanine	Leucine	SEM	CP level[1]	LEUvsALA[2]	Treatment x Day[3]
Essential amino-acids (EAA)							
Histidine	29.5	34.2	28.2	2.72	0.623	0.131	0.235
Isoleucine	108.8	116.9	87.1	4.89	0.272	<0.001	0.288
Leucine	152	164	526	27.1	<0.001	<0.001	0.078
Lysine	101.2	108.6	89.0	5.21	0.714	0.013	0.407
Methionine	177	183	141	9.0	0.192	0.003	0.244
Phenylalanine	41.4	35.0	37.8	2.06	0.061	0.345	0.306
Threonine	214	174	167	12.6	0.010	0.663	0.319
Tryptophan	49.4	52.8	51.7	2.40	0.350	0.749	0.411
Valine	80.1	65.2	61.2	3.81	0.001	0.472	0.125
Non-essential amino-acids (NEAA)							
Alanine	219	182	172	12.6	0.013	0.600	0.469
Arginine	154	165	157	9.3	0.518	0.535	0.578
Asparagine	34.8	39.8	29.3	3.48	0.954	0.040	0.215
Aspartic acid	214	237	213	13.5	0.538	0.217	0.709
Cystine	126	128	105	7.5	0.325	0.038	0.362
Glutamic acid	84.4	100.0	91.8	4.94	0.072	0.247	0.782
Glutamine	8.94	9.97	10.66	1.633	0.504	0.768	0.851
Glycine	293	306	318	16.7	0.359	0.593	0.541
Proline	352	642	286	23.8	<0.001	<0.001	0.493
Serine	155	146	130	8.0	0.108	0.170	0.910
Tyrosine	39.0	30.5	32.6	2.04	0.007	0.490	0.722

[1]Planned contrast comparing the CTL group with the mean of the two amino-acid–supplemented groups (ALA + LEU).
[2]Planned contrast comparing the Alanine group with the Leucine group. [3]P-value for the overall Treatment × Day interaction.
Differences were declared significant at $P \leq 0.05$ and considered a tendency when $0.05 < P \leq 0.10$.

Acknowledgments

This research was supported by the State Board of Agricultural Research and Education (SBARE) and the IDeA National Resource for Quantitative Proteomics Voucher Program. We also gratefully acknowledge the staff and students at the NDSU Dairy Barn and at the Animal Sciences Nutrition Laboratory for their valuable assistance and contributions to this study.

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Influence of feeding leucine-supplemented milk replacer on the muscle proteome and metabolic pathways in neonatal dairy calves

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This study evaluated the influence of leucine supplementation on the muscle proteome in neonatal dairy calves fed milk replacer. Our findings demonstrated that leucine supplementation altered the muscle proteome with changes in expression of proteins that promote protein synthesis and metabolic efficiency, which potentially improved growth and long-term productivity. These results highlight the potential of targeted neonatal nutritional interventions — such as leucine supplementation — to optimize muscle development and efficiency in dairy calves, contributing to more sustainable and productive livestock production systems.

Summary

Early postnatal nutrition is critical for muscle growth and metabolic programming in livestock. Leucine, a branched-chain amino acid, activates the mTOR signaling pathway to stimulate protein synthesis, yet its effects on the muscle proteome of neonatal dairy calves are not well understood. This study evaluated how leucine supplementation in milk replacer (MR) affects muscle proteomic profiles after 28 days of treatment. Thirty-five newborn Holstein heifer calves were randomly assigned to one of three groups: the control group (no added amino acids), Leucine-supplemented (5% in MR) or Alanine-supplemented (isonitrogenous to leucine). All calves were fed equal volumes of MR for 56 days. Muscle biopsies collected on day 28 were analyzed using data-independent acquisition (DIA) proteomics via Orbitrap Exploris 480, with protein quantification in Spectronaut. Protein-protein interaction (PPI) networks and Gene Ontology (GO) enrichment were analyzed using STRING v12.5. Leucine supplementation upregulated 25 proteins compared to the control group and 15 compared to the Alanine-supplemented group, with enrichment in pathways related to amino acid and nucleotide metabolism, protein synthesis and cell proliferation. Hormone-related proteins (dehydroepiandrosterone, estradiol, progesterone) and caseins were enriched in both comparisons, suggesting hormonal responses to supplemental amino acids. Proteins associated with catabolic processes were downregulated, indicating a shift toward an anabolic muscle environment. These findings demonstrate that leucine supplementation in milk replacer might promote favorable proteomic and metabolic changes in neonatal calves, which could enhance muscle development and efficiency of growth — key goals for improving productivity and sustainability in modern dairy production.

Introduction

Achieving optimal growth and productivity in dairy cattle is a central goal of the industry, with early-life nutrition playing a critical role in determining lifetime performance factors such as future milk production and overall herd health. Proper muscle development and efficient nutrient utilization during the neonatal stage are essential to establishing this foundation. However, many preweaning feeding strategies may not fully support these outcomes. In the first weeks of life, calves depend entirely on milk or milk replacer for nutrition because their rumen is not yet developed. As a result, digestion takes place mainly in the abomasum and intestines (Abe et al., 1979), allowing nutrients to be absorbed without substantial fermentation. Evidence suggests that providing a higher nutritional plane during the preweaning period can enhance milk yield later in life (Soberon et al., 2012), highlighting the importance of optimizing early-life

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feeding practices to support long-term productivity.

Leucine, an essential branched-chain amino acid, is known for its unique ability to stimulate skeletal muscle protein synthesis and regulate metabolism through activation of the mTORC1 signaling pathway (Drummond and Rasmussen, 2008). Although leucine is abundant in muscle tissue and recognized for its metabolic functions, its specific role in supporting muscle development in neonatal dairy calves remains relatively underexplored. Because skeletal muscle grows rapidly during the preweaning period, ensuring an adequate and balanced supply of amino acids during this stage could improve muscle growth, feed efficiency and, ultimately, productivity. This study aimed to address this knowledge gap by determining the effect of leucine supplementation in milk replacer on the muscle proteome of neonatal dairy calves at 28 days of age, providing insight into the mechanisms of early-life nutritional programming.

Experimental Procedures

All animal procedures were approved by the North Dakota State University Animal Care and Use Committee. The study was conducted at the NDSU Dairy Unit using 35 neonatal Holstein heifer calves. After a three-day colostrum-feeding period following birth, calves were assigned to individual calf hutches and began their respective dietary treatments. Calves were randomly assigned to one of three treatments: the control group (no added amino acids), Leucine (Leu) supplemented at 5% in the milk replacer or Alanine (Ala) supplemented isonitrogenously to match the nitrogen content of the Leu treatment. Milk replacer was provided twice daily, with 3 quarts per feeding, for a total of 56 days. At the end of the treatment period, calves were weaned and moved to group housing.

On day 28 of amino acid treatment, muscle biopsies were collected from the longissimus dorsi, snap-frozen in liquid nitrogen and stored at minus 80 degrees Celsius until analysis. Samples were submitted to the IDeA National Resource for Quantitative Proteomics for analysis. Proteomic profiling was performed using Data-Independent Acquisition (DIA) on an Orbitrap Exploris 480 mass spectrometer, and protein quantification was conducted using Spectronaut software. Protein-protein interaction (PPI) networks and Gene Ontology (GO) enrichment analyses were subsequently performed using STRING v12.5 to identify functional pathways and interactions associated with treatment effects.

Results and Discussion

Leucine supplementation resulted in distinct proteomic changes in the muscle tissue of neonatal dairy calves at 28 days of age. Compared to the control group, 59 proteins were differentially expressed in the leucine group (25 upregulated, 34 downregulated), while 24 proteins differed between the leucine and alanine groups (15 upregulated, nine downregulated; Table 1). In contrast, the alanine group showed a larger number of differentially expressed proteins relative to the control group (84 total; 19 upregulated, 65 downregulated) (Table 1), suggesting that leucine induces more targeted molecular effects than alanine.

Protein-protein interaction network analyses further highlighted the coordinated nature of these molecular changes. The upregulated proteins in leucine-supplemented calves (vs. control and alanine) formed highly connected networks (PPI enrichment P-values ≤ 4e-06 and 7.2e-07, respectively; Figure 1), indicating organized activation of anabolic and metabolic pathways. In contrast, downregulated proteins in leucine vs. alanine lacked significant network connectivity (PPI P-value = 1), reflecting a less coordinated suppression of pathways. Notably, the proteomic response to leucine supplementation was more focused than the broader, less targeted changes observed with alanine supplementation, which may be indicative of the role that leucine has as a regulator of muscle development at the molecular level. The CSN (casein) proteins were commonly found among the upregulated proteins in leucine-supplemented groups (Leu vs. Con and Leu vs. Ala), highlighting a potential link between leucine and casein-associated pathways in muscle growth and nutrient utilization. This suggests that leucine may not only enhance muscle protein synthesis through classical anabolic signaling but also modulate structural and regulatory proteins such as caseins that contribute to muscle fiber integrity and metabolic activity.

Interestingly, as shown in Figure 2A, the pathways associated with the upregulated proteins in leucine

Table 1: Differentially expressed proteins in muscle tissue of neonatal calves at 28 days of treatment across dietary groups ($P \leq 0.05$).

Sl no.	Treatment groups	Total genes	Upregulated	Downregulated
1	Alanine vs. Control	84	19	65
2	Leucine vs. Control	59	25	34
3	Leucine vs. Alanine	24	15	9

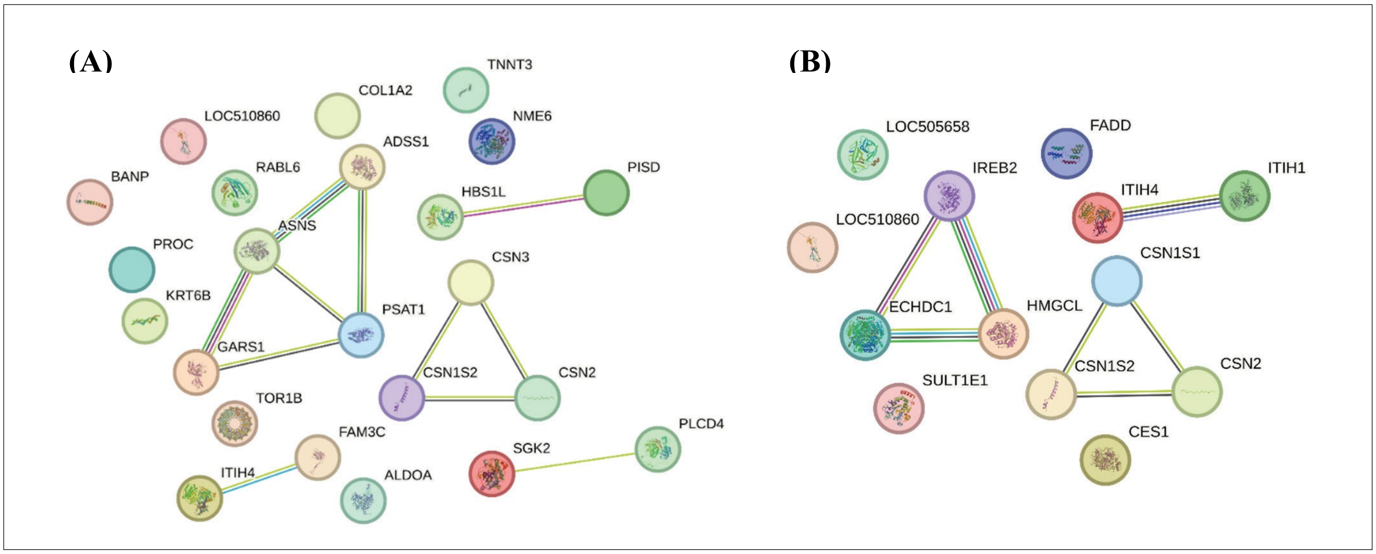

Figure 1: Protein-protein interaction networks of significantly upregulated proteins in neonatal calf muscle following leucine supplementation. (A) Network of proteins significantly upregulated (FDR ≤ 0.05) in the Leucine vs. Control comparison. (B) Network of proteins significantly upregulated (FDR ≤ 0.05) in the Leucine vs. Alanine comparison.

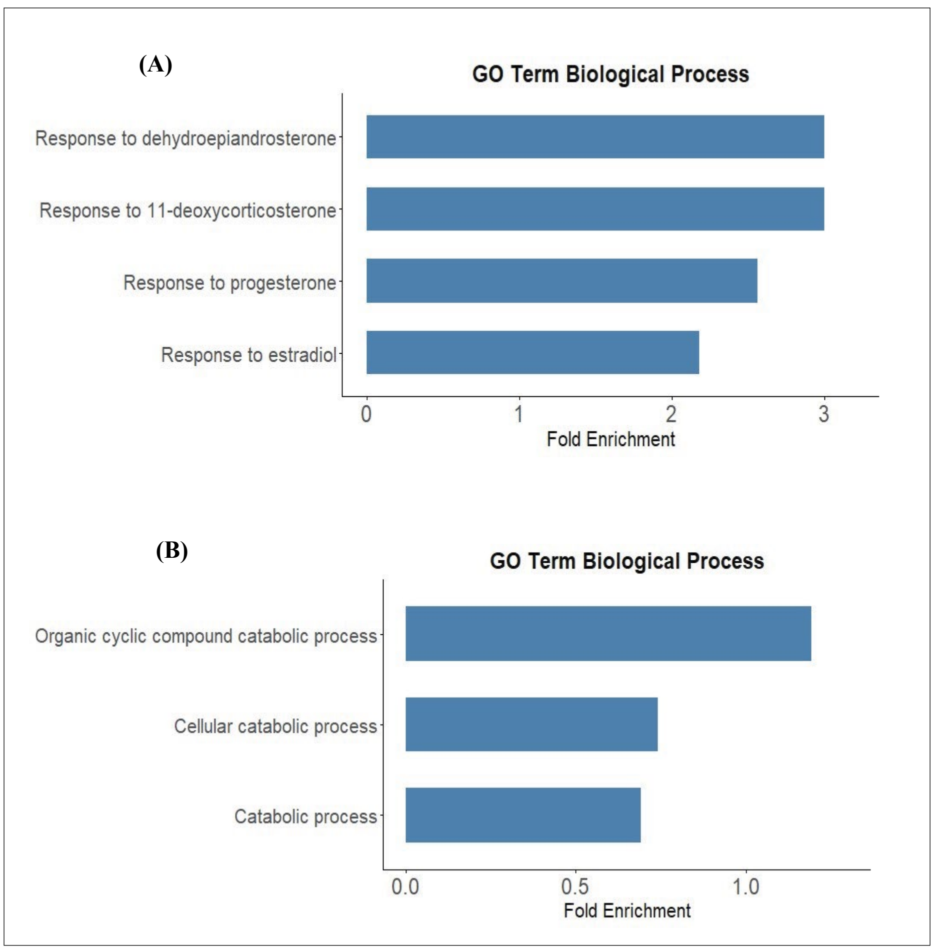

Figure 2: Gene Ontology (GO) biological processes enriched among differentially expressed proteins in neonatal calf muscle following leucine supplementation. (A) GO biological processes associated with proteins significantly upregulated (FDR ≤ 0.05) in Leucine vs. Control and Leucine vs. Alanine comparisons. (B) GO biological processes associated with proteins significantly downregulated (FDR ≤ 0.05) in Leucine vs. Control comparison.

supplementation groups were involved with steroid hormone responses, including pathways involving dehydroepiandrosterone, estradiol and progesterone. These findings suggest that leucine may influence hormonal pathways that contribute to muscle growth and nutrient metabolism during the neonatal stage. The downregulated proteins in leucine-supplemented calves were largely associated with catabolic processes, further supporting a metabolic shift toward an anabolic state (Figure 2B).

These findings demonstrate that targeted leucine supplementation to calves fed milk replacer influences the expression of proteins that enhance anabolic processes and reduce catabolic pathways, with potential implications for improving feed efficiency and long-term productivity in dairy cattle. Optimizing early-life amino acid nutrition through milk replacer formulations represents a promising strategy for developmental programming in modern dairy production systems.

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This research was supported by the State Board of Agricultural Research and Education (SBARE) and the IDeA National Resource for Quantitative Proteomics Voucher Program. We also gratefully acknowledge the staff and students at the NDSU Dairy Barn and at the Animal Sciences Nutrition Laboratory for their valuable assistance and contributions to this study.

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Rambouillet ram performance testing and certification: 2024-2025 Dakota Ram Test

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The Dakota Ram Test is a multistate ram performance testing program that evaluates ram wool and growth performance under centralized management. Data generated from this test is a valuable selection tool that helps producers identify rams with superior wool and/or growth performance. Rams are ranked by a productive index, and the top 30% are eligible for designation as Certified Rams as part of the American Rambouillet Sheep Breeders Association (ARSBA) Register of Merit (ROM) program.

Summary

Sheep producers throughout the northern Great Plains utilize the Dakota Ram Test to generate performance data on Rambouillet rams. This centralized performance test measures several economically important and/or heritable traits that producers can evaluate when selecting rams or genetic lineages to retain within their flocks. Fifty-one Rambouillet rams completed the performance test at the Hettinger Research Extension Center (HREC) from Sept. 26, 2024, to Feb. 13, 2025. Sixteen rams had index scores within the top 30% of the performance test, and 13 met the additional requirements for merit of certification through the American Rambouillet Sheep Breeder’s Association (ARSBA).

Introduction

The Dakota Ram Test is a 140-day ram performance test that was primarily established to evaluate differences in ram wool and postweaning growth performance under the same management conditions, nutritional plane, and climate. The ARSBA recognizes high-performing Rambouillet rams participating in the Dakota Ram Test with the merit of certification, which can serve as a value-added marketing strategy.

Procedures

Fifty-one spring-born registered Rambouillet rams were consigned by 13 producers and received by the HREC on or before Sept. 22, 2024. To determine average daily gain (ADG), initial body weight was recorded when the testing period began (Sept. 26, 2024), every 28 days and at the end of the growth testing period (Feb. 13, 2025). To monitor feed intake, rams were equipped with radio frequency identification (RFID) tags and adapted to a smart-feed intake monitoring system (SmartFeedPro, C-Lock Inc., Rapid City, South Dakota). Rams were adapted to the smart-feed intake monitoring system for seven days and removed from the feed efficiency trial if they failed to acclimate and/or utilize the smart-system feed bunk. Feed efficiency was determined using total individual ram feed intake and ram body weight gain over a 21-day period to estimate feed-to-gain ratio or pounds of feed needed to gain one pound of body weight. At the end of the growth testing period, a real-time carcass ultrasound was performed to estimate ram ribeye area and fat cover between the 12th and 13th ribs. Rams were also evaluated for adherence to breed standards by the Dakota Ram Test Committee, and scores for face wool, belly wool and wrinkle/skin fold (postshearing) were collected. Scores were assigned on a four-unit basis (1-4), with higher scores representing a greater degree of wool covering or skin folding. Rams were then shorn, staple length was measured and wool samples were collected on Feb. 14, 2025. Staple length was determined by averaging the length of wool at the shoulder, side and britch, and then was adjusted to estimate 365-day staple length (Adj. STL). Wool samples were sent to Texas A&M University for clean fleece weight and fiber diameter (micron) analysis. Clean fleece weight was determined from laboratory-scoured clean yield estimates and adjusted to estimate

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365-day clean fleece weight (Adj. CL FL) production. Ram performance was estimated utilizing the approved index formula for the ARSBA's ROM program. This index includes adjustments for fiber diameter and fiber diameter variability, with positive scores indicating fleeces with a finer fiber diameter and reduced fiber diameter variability. Rams were ranked by index score, and the top 30% were eligible for certification. Additional requirements for certification include the following: ADG ≥ 0.55lb/d, Adj. CL FL ≥ 9lb, Adj. STL ≥ 4", side fiber diameter ≤ 24.9 microns, britch fiber diameter ≤ 27.84 microns, face wool score ≤ 2.7pt, wrinkle/skin fold score ≤ 2.5pt, and QR or RR Codon 171 genotype for scrapie resistance.

Index Score: 60*(ADG) + 4*(Adj. STL up to 5.5") + 4*(Adj. CL FL) +/- Fiber Diameter

Results and Discussion

Forty-five rams completed the 2024-2025 Dakota Ram Test following the removal of six rams by the Dakota Ram Test Committee due to skeletal abnormalities inconsistent with breed standards. Ram index scores ranged from 88.24 to 137.95 points, averaging 110.77 points (Table 1). Index scores of rams within the top 30% ranged from 115.46 to 137.95 points. Of the rams scoring in the top 30%, 13 of 16 met the additional requirements to be ARSBA Certified Rams (Table 2). Three of the 16 index-eligible rams were deemed ineligible for certification due to the clean fleece requirement (1 ram) and core micron requirement (2 rams). Growth performance was consistent with rams consigned to previous performance tests at the HREC. Rams averaged 103 pounds at the start of the performance test period and gained, on average, 0.91 pounds per day over 140 days, averaging 232 pounds at the end of the test period.

Table 1. Ram performance index score summary

Ear Tag	Reg. #	140-d ADG (lb/d)	Adj-STL (in)	CL FL (lb)	Adjustments Dia. (pt)	Adjustments Var. (pt)	Index Score (pt)	Index Ratio
Y-25	1001263	1.07	4.9	14.56	-1.80	-2.50	137.95	125%
Y-21	1001235	1.09	5.1	12.59	-3.60	-1.50	130.93	118%
Y-24	1001260	1.03	5.2	12.08	0.30	-4.25	126.92	115%
Y-22	1001231	0.94	4.9	12.89	0.30	-1.00	126.82	114%
Y-12	1001279	1.07	5.4	11.45	-1.50	-5.00	125.23	113%
Y-28	1001265	1.05	4.9	11.42	1.80	-4.75	125.15	113%
Y-47	1001212	1.10	4.7	9.43	2.70	-0.50	124.67	113%
Y-23	1001234	0.99	5.0	10.79	0.30	1.00	123.63	112%
Y-27	1001259	0.96	5.2	12.90	-6.00	-2.25	122.03	110%
Y-9	1001273	0.94	4.7	9.36	9.00	-1.25	120.53	109%
Y-51	1001185	1.11	4.6	11.54	-6.00	-5.00	120.48	109%
Y-44	1001299	0.94	4.8	12.75	-6.00	-0.75	119.46	108%
Y-11	1001275	0.91	4.5	10.25	4.80	-0.50	117.96	106%
Y-30	1001281	1.07	4.4	8.81	-3.00	2.00	116.17	105%
Y-6	1001244	1.00	4.4	9.82	-1.50	0.50	115.78	105%
Y-46	1001301	0.71	4.8	14.06	2.70	-5.00	115.46	104%
Y-1	1001256	0.86	4.9	9.34	7.80	-1.50	114.93	104%
Y-10	1001274	1.05	3.2	8.79	2.40	0.75	114.19	103%
Y-3	1001245	0.98	5.1	9.20	3.00	-4.75	114.12	103%
Y-18	1001236	0.95	5.0	11.05	-4.50	-3.50	113.39	102%
Y-33	1001283	1.08	4.0	9.39	-0.60	-5.00	112.72	102%
Y-50	1001184	0.99	4.8	10.94	-4.80	-5.00	112.20	101%
Y-16	1001272	0.86	5.8	8.46	9.00	-4.75	111.94	101%
Y-48	1001216	0.91	4.6	10.59	-2.40	-1.75	111.37	101%
Y-34	1001284	0.99	4.7	10.48	-6.00	-3.00	110.97	100%
Y-32	1001282	0.76	4.8	12.49	-4.50	-0.50	110.06	99%
Y-36	1001194	0.96	4.3	7.06	7.50	-1.00	109.61	99%
Y-41	1001199	0.84	5.4	10.60	-2.40	-2.75	109.45	99%
Y-4	1001250	0.74	5.3	11.20	0.60	-3.50	107.78	97%
Y-37	1001192	0.96	4.7	9.49	-2.10	-5.00	107.50	97%
Y-38	1001193	1.04	4.5	8.90	-6.00	-4.25	105.89	96%
Y-35	1001191	0.96	4.4	9.51	-3.90	-3.75	105.76	95%
Y-43	1001197	0.89	6.0	10.36	-6.00	-5.00	105.59	95%
Y-53	1001297	1.02	4.3	7.04	2.40	-3.75	105.11	95%
Y-26	1001144	0.87	4.5	10.75	-6.00	-3.50	103.61	94%
Y-29	1001190	0.69	4.8	9.61	9.00	-5.00	103.27	93%
Y-49	1001218	0.92	4.0	9.38	-4.80	-1.75	102.31	92%
Y-17	1001278	0.87	4.6	8.70	0.30	-4.25	101.41	92%
Y-13	1001276	0.86	5.2	8.90	-6.00	-4.00	97.69	88%
Y-19	1001232	0.71	5.4	10.14	-6.00	-3.25	95.62	86%
Y-45	1001300	0.79	3.9	10.01	-6.00	-3.00	94.35	85%
Y-40	1001198	0.72	4.9	10.44	-6.00	-5.00	93.44	84%
Y-7	1001248	0.84	4.3	7.84	-3.60	-4.50	90.85	82%
Y-42	1001196	0.81	4.4	8.60	-6.00	-5.00	89.91	81%
Y-39	1001195	0.72	4.1	7.98	-3.60	0.25	88.24	80%

Double Line = Top 30% Cut Off
ADG, average daily gain; Adj. STL, adjusted staple length, Adj. CL FL, adjusted clean fleece

Carcass and feed efficiency data presented in Table 3 are not included as part of the productive index but provide producers with insight into ram efficiency, growth and maturity patterns. Rams with lower feed-to-gain ratios indicate better feed efficiency and a more productive use of available feed resources. Rams with larger ribeye areas indicate greater muscling and increased growth patterns, while rams with greater fat cover may indicate a faster maturity pattern. Forty-two of 51 rams adapted to the smart-feed intake monitoring system and completed the 21-day feed efficiency trial. Ram feed-to-gain ratios averaged 5.33 pounds of feed per pound of body weight gain, with individual feed-to-gain ratios ranging from 1.89 to 8.10 pounds of feed per pound of body weight gain. The average daily feed intake during the 21-day feed efficiency trial ranged from 2.17 to 7.29 pounds per day, with an average of 4.92 pounds per day. The average ribeye area size was 3.34 square inches, and the average back-fat thickness was 0.30 inches.

Table 2. Eligibility for certified ram designation

Ear Tag	Reg. #	Codon 171 Genotype	Index Score (pt)	140-d ADG (lb/d)	Adj. STL (in)	Adj. CL-FL (lb)	Belly Score (pt)	Face Score (pt)	Skin Score (pt)	Side Micron	Certified?
Y-25	1001263	RR	137.95	1.07	4.9	14.56	1.00	1.50	1.00	22.60	Y
Y-21	1001235	RR	130.93	1.09	5.1	12.59	1.00	2.50	1.25	23.20	Y
Y-24	1001260	RR	126.92	1.03	5.2	12.08	1.00	1.50	1.00	21.90	Y
Y-22	1001231	RR	126.82	0.94	4.9	12.89	1.00	2.50	1.00	21.90	Y
Y-12	1001279	RR	125.23	1.07	5.4	11.45	1.00	1.00	1.00	22.50	Y
Y-28	1001265	RR	125.15	1.05	4.9	11.42	1.00	1.00	1.00	21.40	Y
Y-47	1001212	RR	124.67	1.10	4.7	9.43	1.25	2.50	1.75	21.10	Y
Y-23	1001234	RR	123.63	0.99	5.0	10.79	1.00	1.50	1.00	21.90	Y
Y-27	1001259	RR	122.03	0.96	5.2	12.90	1.00	1.00	1.50	24.10	Y
Y-9	1001273	RR	120.53	0.94	4.7	9.36	1.00	1.00	1.00	18.50	Y
Y-51	1001185	RR	120.48	1.11	4.6	11.54	1.00	2.00	1.00	25.40*	N
Y-44	1001299	RR	119.46	0.94	4.8	12.75	1.00	2.00	1.00	27.80*	N
Y-11	1001275	RR	117.96	0.91	4.5	10.25	2.00	1.00	1.00	20.40	Y
Y-30	1001281	RR	116.17	1.07	4.4	8.81*	1.00	1.75	1.50	23.00	N
Y-6	1001244	RR	115.78	1.00	4.4	9.82	1.00	1.25	1.00	22.50	Y
Y-46	1001301	RR	115.46	0.71	4.8	14.06	1.00	1.25	1.00	21.10	Y

* = Does not meet certification requirement
ADG, average daily gain; Adj. STL, adjusted staple length, Adj. CL FL, adjusted clean fleece

Table 3. Ram carcass and feed efficiency

Ear Tag	Reg. #	REA (sq. in.)	Fat Depth (in.)	21-Day Avg. DMI (lb/day)	21-Day DMI Total (lb)	21-Day BW Gain (lb)	21-Day F:G (lbs feed/lb gain)
Y-1	1001256	3.47	0.29	5.43	103.13	22	4.69
Y-3	1001245	3.10	0.25	5.38	107.60	19	5.66
Y-4	1001250	2.82	0.27	5.32	110.13	15	7.34
Y-6	1001244	2.95	0.33	5.99	114.12	23	4.96
Y-7	1001248	3.02	0.23	4.40	90.20	21	4.30
Y-9	1001273	3.12	0.35	5.64	113.39	19	5.97
Y-10	1001274	3.61	0.21	5.42	110.93	24	4.62
Y-11	1001275	3.44	0.35	4.38	88.52	14	6.32
Y-12	1001279	3.91	0.33	5.30	109.49	18	6.08
Y-13	1001276	4.53	0.27	5.05	101.06	13	7.77
Y-16	1001272	3.27	0.27	.	.	.	.
Y-17	1001278	3.55	0.31	4.67	93.38	24	3.89
Y-18	1001236	3.36	0.29	5.59	111.75	24	4.66
Y-19	1001232	2.91	0.25	5.12	105.15	18	5.84
Y-21	1001235	3.07	0.31	3.81	76.35	22	3.47
Y-22	1001231	3.24	0.27	.	.	.	.
Y-23	1001234	3.29	0.27	.	.	.	.
Y-24	1001260	3.13	0.37	.	.	.	.
Y-25	1001263	3.16	0.27	7.29	145.83	18	8.10
Y-26	1001144	3.57	0.37	3.64	74.29	19	3.91
Y-27	1001259	2.88	0.28	5.08	100.84	17	5.93
Y-28	1001265	3.63	0.27	5.45	114.13	21	5.43
Y-29	1001190	4.25	0.33	3.92	79.73	17	4.69
Y-30	1001281	3.32	0.31	4.18	79.48	20	3.97
Y-32	1001282	3.29	0.31	4.27	88.00	14	6.29
Y-33	1001283	3.77	0.31	5.35	110.33	22	5.02
Y-34	1001284	2.87	0.25	5.70	116.11	21	5.53
Y-35	1001191	3.36	0.33	6.59	135.41	28	4.84
Y-36	1001194	2.67	0.27	3.48	70.17	14	5.01
Y-37	1001192	2.82	0.31	2.17	43.58	23	1.89
Y-38	1001193	2.73	0.33	5.21	104.95	23	4.56
Y-39	1001195	3.38	0.31	4.16	82.22	12	6.85
Y-40	1001198	3.08	0.31	5.01	100.55	17	5.91
Y-41	1001199	3.35	0.31	5.67	114.08	21	5.43
Y-42	1001196	3.50	0.33	.	.	.	.
Y-43	1001197	3.52	0.37	5.85	120.18	18	6.68
Y-44	1001299	3.29	0.39	5.47	113.01	18	6.28
Y-45	1001300	3.58	0.29	.	.	.	.
Y-46	1001301	3.33	0.33	.	.	.	.
Y-47	1001212	3.21	0.37	2.58	59.47	12	4.96
Y-48	1001216	3.69	0.37	4.12	84.77	18	4.71
Y-49	1001218	4.34	0.33	.	.	.	.
Y-50	1001184	2.62	0.29	4.20	87.28	20	4.36
Y-51	1001185	3.02	0.35	6.77	135.75	27	5.03
Y-53	1001297	3.13	0.27	.	.	.	.

REA, ribeye area; BW, body weight; F:G, feed-to-gain; DMI, dry matter intake

Columbia ram performance testing and certification: 2024-2025 Dakota Ram Test

Carlos Ruiz[1], Samantha Ekstrom[1], Rachel Gibbs[1], Christopher Schauer[1] and Jaelyn Whaley[2]

The Dakota Ram Test is a multistate ram performance testing program established to evaluate ram wool and growth performance under centralized management. Data generated from this test is a valuable selection tool that helps producers identify rams with superior wool and/or growth performance. Columbia rams that meet the criteria outlined by the Columbia Sheep Breeders Association (CSBA) are eligible for designation as Certified Columbia Rams.

Summary

Columbia sheep producers throughout the northern Great Plains are utilizing the Dakota Ram Test as a means to generate important performance data for ram selection. This centralized performance test quantifies several economically important and/or heritable traits that producers can evaluate when selecting rams or genetic lineages to retain within their flocks. Sixteen Columbia rams were consigned to the 2024-2025 Dakota ram test. Of these, 19% met the CSBA criteria for Certified Columbia Ram designation.

Introduction

The Dakota Ram Test is a 140-day ram performance test that was primarily established to evaluate differences in ram wool and postweaning growth performance under the same management conditions, nutritional plane, and climate. The CSBA certifies rams that excel in growth performance, carcass quality, and wool quality through a program initiated in 2017 to promote overall breed improvement.

Procedures

Sixteen spring-born registered Columbia rams were consigned by eight producers and received by the HREC on or before September 22, 2024. To determine average daily gain (ADG), initial body weight was recorded when the testing period began (Sept. 26, 2024), every 28 days and at the end of the growth testing period (Feb. 13, 2025). To monitor feed intake, rams were equipped with radio frequency identification (RFID) tags and adapted to a smart-feed intake monitoring system (SmartFeedPro, C-Lock Inc., Rapid City, South Dakota). Rams were adapted to the smart-feed intake monitoring system for seven days and removed from the feed efficiency trial if they failed to acclimate and/or utilize the smart-system feed bunk. Feed efficiency was determined using total individual ram feed intake and ram body weight gain over a 21-day period to estimate feed-to-gain ratio or pounds of feed needed to gain one pound of body weight. At the end of the growth testing period, a real-time carcass ultrasound was performed to estimate carcass metrics, including ribeye area and fat cover between the 12th and 13th ribs. Ribeye area was adjusted to account for differences in ram body weight; thus, it is reported as inches per 100 pounds. The Dakota Ram Test Committee also evaluated rams at the end of the testing period, and scores for face wool covering and belly wool expansion were collected before shearing. Scores were assigned on a four-unit basis (1-4), with higher scores representing a greater degree of wool covering/expansion. Rams were then shorn, staple length was measured and wool samples were collected on Feb. 14, 2025. Staple length was determined by averaging the length of wool at the shoulder, side and britch, then adjusted to estimate 365-day staple length (Adj. STL). Wool samples were sent to Texas A&M University for clean fleece weight and fiber diameter (micron) analysis. Clean fleece weight was determined from laboratory-scoured clean yield estimates and adjusted to estimate 365-day clean fleece weight (Adj. CL FL) production. The criteria and requirements for CSBA certification as Certified Columbia Rams can be found in Table 1.

Results and Discussion

Sixteen Columbia rams completed the 2024-2025 Dakota Ram Test. Rams averaged 0.91 pounds of gain per day over the 140-day test period and gained an average of 128

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pounds. Columbia ram carcass and feed efficiency data are presented in Table 3. Fifteen of the 16 rams adapted to the smart-feed intake monitoring system and completed the 21-day feed efficiency trial. Ram feed-to-gain ratios averaged 5.39 pounds of feed per pound of body weight gain, with individual feed efficiency reports ranging from 2.54 to 8.04 pounds of feed per pound of body weight gain. Average daily feed intake during the 21-day feed efficiency trial ranged from 2.24 to 5.46 pounds per day, with an average of 5.39 pounds per day. Average ribeye area was 3.13 square inches, and the average back fat thickness over the 12th and 13th ribs was 0.35 inches. Rams with lower feed-to-gain ratios indicate better feed efficiency and a more productive use of available feed resources. Rams with larger ribeye areas indicate greater muscling and increased growth patterns, while rams with greater fat cover may indicate a faster maturity pattern. Columbia ram fleeces averaged 9.20 pounds of 365-day adjusted clean wool, a 25.44-micron fiber diameter and a 4.6-inch 365-day adjusted staple length. Three rams met all of the requirements to qualify for CSBA Certified Columbia Ram designation (Table 2). Of the remaining 13 rams, three rams did not meet the fiber diameter requirement, five rams did not meet the ADG requirement, six rams did not meet the adjusted ribeye area requirement, seven rams did not meet the staple length requirement and three rams did not meet the belly wool score requirement. Despite a moderate reduction in the certification rate (down 2% from 2023-2024), the growth performance, wool quality and carcass quality

Table 1. CBSA criteria for certified ram designation

Criteria	Requirement
Fiber Diameter	Within 22.05 & 27.84 microns
Adj. Staple Length	≥ 4.3 inches if fiber diameter is within 22.05 & 24.94 microns ≥ 4.8 inches if fiber diameter is within 24.95 & 27.84 microns
Average Daily Gain	≥ 0.80 pounds per day
Adj. Ribeye Area	≥ 1.3 inches per 100 pounds of body weight
Face Wool Score	≤ 3
Belly Wool Score	1
Scrapie Resistance Genotype	RR or QR at Codon 171

Table 2. Ram performance and certification summary

Ear Tag	Reg. #	Fiber Diameter (micron)	Adj. STL (in)	140-d ADG (lb/d)	Adj. REA (in/100lb)	Belly Score (pt)	Face Score (pt)	Codon 171 Genotype	Certified?
W-1	Y21576	24.70	4.4	0.99	1.19*	1.00	2.00	QR	N
W-2	Y21575	26.20	4.1*	0.83	1.23*	1.00	1.50	RR	N
W-3	Y21574	23.60	4.1*	1.19	1.58	1.00	1.25	RR	N
W-4	Y21548	22.20	4.6	1.03	1.40	1.00	2.75	RR	Y
W-5	Y21544	24.00	4.5	0.94	1.70	1.00	1.25	RR	Y
W-6	Y21546	26.20	4.8	1.08	1.56	1.00	1.00	RR	Y
W-7	Y21547	23.20	4.8	0.97	1.38	3.00*	1.75	RR	N
W-8	Y20954	30.00*	4.4*	0.71*	1.47	1.00	1.00	RR	N
W-9	Y20947	26.30	4.6*	0.68*	1.14*	2.00*	3.00	RR	N
W-10	Y21487	23.10	4.7	0.98	1.27*	1.00	1.00	QR	N
W-12	Y21541	28.30*	4.5*	0.89	1.35	1.00	1.00	RR	N
W-13	Y21540	25.40	4.4*	0.74*	1.49	3.00*	1.00	QR	N
W-14	Y21550	25.40	4.9	0.79*	1.67	1.00	1.00	QR	N
W-15	Y21551	23.60	5.0	0.79*	1.39	1.00	1.75	QR	N
W-16	Y21589	29.80*	4.7*	1.04	1.20*	1.00	1.25	RR	N
W-17	Y21590	25.10	5.3	0.97	1.21*	1.00	1.75	QR	N

* = Does not meet the certification requirement
ADG, average daily gain; Adj. STL, adjusted staple length, Adj. REA, adjusted ribeye area, F:G, feed-to-gain

of Columbia rams produced in the northern Great Plains have steadily improved since breed improvement standards for ram certification were outlined by the CSBA in 2017. The addition of feed efficiency testing in the 2024-2025 Dakota Ram Test expands potential selection criteria for producers interested in optimizing growth efficiency in their production systems.

Acknowledgments

The authors would like to express their appreciation for Dave Pearson, Hettinger Research Extension Center shepherd and Dakota Ram Test manager, for his hard work and dedication to the Dakota Ram Test program.

Table 3. Ram carcass and feed efficiency

Ear Tag	Reg. #	REA (sq. in.)	Fat Depth (in.)	REA (sq. in./ 100 lb BW)	21-Day Avg. DMI (lb/day)	21-Day DMI Total (lb)	21-Day BW Gain (lb)	21-Day F:G (lbs feed/lb gain)
W1	Y21576	2.64	0.35	1.19	4.52	92.04	13	7.08
W2	Y21575	2.76	0.31	1.23	3.34	66.92	15	4.46
W3	Y21574	3.95	0.35	1.58	6.15	125.84	29	4.34
W4	Y21548	2.98	0.41	1.40	5.44	111.07	23	4.83
W5	Y21544	2.81	0.27	1.70	.	.	.	.
W6	Y21546	3.24	0.31	1.56	4.06	83.36	20	4.17
W7	Y21547	2.84	0.31	1.38	4.68	92.27	25	3.69
W8	Y20954	4.03	0.45	1.47	5.26	103.78	17	6.10
W9	Y20947	3.30	0.43	1.14	5.46	112.61	14	8.04
W10	Y21487	3.08	0.39	1.27	3.76	78.77	15	5.25
W12	Y21541	2.81	0.31	1.35	2.24	48.27	19	2.54
W13	Y21540	3.18	0.33	1.49	5.36	106.4	17	6.26
W14	Y21550	3.44	0.39	1.67	5.46	111.63	17	6.57
W15	Y21551	2.71	0.31	1.39	4.77	97.42	15	6.49
W16	Y21589	3.43	0.37	1.20	4.77	97.46	22	4.43
W17	Y21590	2.98	0.35	1.21	4.58	91.68	14	6.55

REA, ribeye area; BW, body weight; F:G, feed-to-gain; DMI, dry matter intake

Profitability of postweaning lamb feeding in North Dakota

Isaac D. Brunkow[1], Jon T. Biermacher[2], Steven E. Anderson[1] and Travis W. Hoffman[1]

This study evaluated animal performance and analyzed the profitability of feeding lambs postweaning at North Dakota State University. Over the three-year average, it was more profitable to sell feeder lambs than finished lambs with the given scenario in 2020-2022. The net return for our lamb feeding study was a loss of $18.91/head compared to marketing as feeder lambs.

Summary

Sheep producers face many issues, with a prevalent problem being how to maintain profitability. Many different strategies have arisen to address this issue. One such strategy is to retain lambs at weaning, as opposed to selling them as feeder lambs. The postweaning feeding of lambs and economics will change based on a variety of inputs, including feeder lamb value, feed cost and market lamb price. Our analysis did not support the strategy to feed lambs profitably under our NDSU scenario.

Introduction

As with any livestock species, profitability can make or break an operation. This is especially true with sheep producers, as profit margins are often very thin, if they exist at all. Many marketing strategies exist in livestock production outside of the standard production practice of selling lambs at, or shortly following, weaning. Individuals may retain lambs at weaning and feed to a finished market weight. Thus, it is possible to sell them via an auction barn or direct-market them to processors or consumers. This analysis explored the profitability of selling the retained lambs through a local auction barn.

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Procedures

An exploratory exercise was conducted utilizing previously collected data to determine the economic feasibility of retaining lambs to a postweaning finished weight before marketing via a sale barn auction. The objectives of this study were to determine the economic feasibility of retaining feeder lambs at weaning, feeding to a finished weight and selling at local sale barns as a profitable marketing strategy. Data from three years (2020-2022) of spring-born Hampshire lambs (n = 125) was obtained from the North Dakota State University Sheep Unit in Fargo, North Dakota.

These lambs were retained, and postweaning and growth data were collected. Performance measurements included birth weight (BW) and date, weaning weight (WW) and date, average daily gain (ADG) from birth to weaning, age at weaning, finishing weight (FW) and date, total gain (TG) from weaning to finishing, ADG over the feeding period, days on feed (DOF), ADG from birth to finishing and TG from birth to finishing (Table 1). Growth data was then paired with the cost of inputs, opportunity cost of retaining the feeder lamb and price of finished lamb to determine net return to land management and farm overhead (Table 2). Sensitivity analysis was also conducted to determine the required percent change of production factors (feeder/fed lamb price and ration cost) necessary to reach operation profitability.

Results and Discussion

The lamb crops for all three years (2020, 2021 and 2022) were 49 head, 37 head and 39 head, respectively. The average WW over the three years were 79.7, 70.0 and 67.5 lb, respectively, with the WW decreasing progressively due to a decrease in weaning age [75.3 days (2020), 65.9 days (2021) and 62.2 days (2022)]. Average DOF during the finishing period was 70, 79 and 80 days for 2020, 2021 and 2022, respectively. Days on feed typically have a great impact on finishing weight. Feeder lamb ADG over the finishing period for 2020, 2021 and 2022 was 0.43, 0.59 and 0.87 lb/head, respectively, and TG was 29.92, 46.70 and 70.03 lb/head, respectively. The short feeding period for the year 2020 may also be why the initial group had the poorest growth performance over the feeding period (0.66 lb/head) and average total gain (94.99 lb/head). The 2020 group (n = 49) also had the highest average weaning weight, due to also

Table 1. Descriptive statistics for measures of animal performance for feeder lambs

Variable	N	Mean	Std Dev	Min.	Max.
Birth weight (lb/head)	125	13.87	2.23	9.20	20.00
Weaning weight (lb/head)	125	73.03	12.43	40.00	99.00
Average daily gain from birth to weaning (lb/head)	125	0.87	0.14	0.50	1.15
Age at weaning (days)	125	68.39	8.92	50.00	86.00
Finishing weight (lb/head)	125	120.43	22.17	74.00	198.00
Gain from weaning to finishing (lb/head)	125	59.16	11.32	29.00	83.20
Average daily gain over feeding period (lb/head)	125	0.61	0.23	0.17	1.24
Total gain over feeding period (lb/head)	125	47.40	20.44	12.00	110.00
Days on feed	125	75.93	8.09	50.00	96.00
Average daily gain from birth to finishing (lb/head)	125	0.74	0.14	0.41	1.11
Total gain (lb/head)	125	106.56	21.73	61.00	180.60

Table 2. Measures of animal performance and expected costs, revenue, and Net return to land management and farm overhead ($/head) to land, management and farm overhead for feeding lambs

Variable	N	Mean	Std Dev	Minimum	Maximum
Feeder lamb cost	125	150.59	11.29	139.21	164.36
Feeder lamb interest	125	2.65	0.21	1.62	3.11
Feed and hay cost	125	45.06	14.83	29.59	65.01
Labor cost	125	13.64	2.74	9.52	18.29
Vet/healthcare	125	1.00	0.00	1.00	1.00
Fuel/equipment maintenance cost	125	1.00	0.00	1.00	1.00
Marketing cost	125	2.00	0.00	2.00	2.00
Total variable cost	125	217.16	7.37	212.07	231.50
Total fixed cost	125	3.50	0.00	3.50	3.50
Total cost	125	220.66	7.37	215.57	235.00
Gross revenue	125	201.75	37.13	123.96	331.69
Net return to land management and farm overhead	125	-18.91	33.22	-91.61	96.69

having the highest average age at weaning (79.71 days). The 2021 lamb group was the smallest in size (n = 37) with an average total ADG (0.71 lb/hd) observed group over a 79-day period for all lambs — an average total gain of 103.05 lb/hd. The final reported year of 2022 had an increase in retained lambs from the previous year (n = 39) and the lowest average weaning weight of 67.51 lb/head. Reported values for average DOF, average finishing weight, average total ADG and average total gain were all the highest from the data analyzed. The increase in DOF paired with increasingly improved ADG resulted in an increase in finishing weight and total gain in feeder lambs from 2020 to 2022.

Preweaning data is very consistent over the collected years. Birth weight averages stay similar over the three years: 14.6 lb for 2020, 13.7 lb for 2021 and 13.1 lb for 2022, with an average standard deviation of 2.2 lb for the total three-year period. Additionally, ADG from birth to weaning is relatively consistent across the three years, with the largest variation occurring from 2021 to 2022 — ADG increasing from 0.85 lb in 2021 to 0.88 lb in 2022. This may offer an explanation for the variances in weaning weight, with weaning weights consistently decreasing over the three years. Average daily gain over this period was similar, but age at weaning was different than the 2020 season — the year with highest weaning weight (79.71 lb/hd) and an average age at weaning of 75 days — compared to the 2022 season — the year with the lowest average weaning weight (67.51 lb/hd) and an average age of 62 days of age.

Performance measures following weaning, however, have more variability. For instance, while ADG for the preweaning period saw little variance from year to year, postweaning ADG increased from 0.43 in 2020 to 0.86 lb in 2022. Finishing weight also saw an increase of 27.91 lb from 2020 (109.63 lb/hd) to 2022 (137.54 lb/hd). These increases through progressive years can be attributed to not only an increasing ADG but also an increase in DOF; 2020 (70 days), 2021 (79 days) and 2022 (80 days). Total ADG from birth to weaning also increased progressively through the three years, with a measurement of 0.66 lb/head for the 2020 lamb crop and a 0.87 lb/head for the 2022 lamb crop.

Calculated financial data, such as average cost of production, gross revenue and net return to land, management and farm overhead, averaged for all three years, is displayed in Table 2. Overall total cost of production was tabulated for each year as follows: $215.57/head (2020), $216.16/head (2021) and $231.32/head (2022). The highest calculated costs were the opportunity cost of retaining a feeder lamb and the ration cost to feed the lamb to finishing weight. Cost of feeder lambs began to decrease over the observed time period, with the highest value being $164.36/head in 2020 and the lowest being $139.21/head in 2022. Ration cost increased from $29.59/head (2020) to $65.01/head (2022), primarily due to days on feed. The calculated average total cost per head was valued at $220.66/head.

Gross revenue increased from 2020 to 2022, with gross revenue being $183.66/hd for 2020, $195.50/hd for 2021 and $230.40/hd for 2022. These increases are partially due to an increase in finishing weight from 2020 to 2022. The overall average gross revenue for all three years was calculated as $201.75/hd. The calculated gross revenue shows profit potential if production costs are kept low.

With both total production cost increasing and gross revenue increasing from 2020 to 2022, there was a reduction in the perceived deficit to net return to land management and farm overhead from -$31.92/hd to -$0.91/hd. The nearest to profitability was 2022, with an average loss of less than a dollar per head. The average net return to land management and farm overhead over the three-year period was tabulated as -$18.91/hd, meaning that the proposed system was not successful in making producers profitable.

Result of a sensitivity analysis was conducted to show the effects of changes to fed lamb prices, feeder lamb prices and ration cost on net return to land management and farm overhead. The sensitivity analysis determined that the price of fed lambs had the greatest influence on profitability in this system, with an increase of 10% in the price of fed lambs from the base, resulting in the system becoming profitable. A decrease in fed lamb price of 10% also drastically increases losses in comparison to the base. A 15% decrease in the base price of feeder lamb prices was required to increase the net return to $4.07/hd. The cost of feed was the least sensitive. A substantial 50% decrease in pelleted ration cost, with all other inputs the same, resulted in the net return to profit of $3.18/hd.

The results indicate that with current input prices, it was not profitable to feed lambs postweaning in North Dakota in the years 2020, 2021 and 2022. More work is needed to evaluate and determine improved efficiency of growth and animal performance and/or production cost savings for profitability of finishing lambs in North Dakota farm flock operations. In addition, more production systems should explore the potential of direct marketing of lambs, either with marketing contracts to processors or directly to consumers.

Assessment of cold storage effects on meat quality attributes in U.S. retail ready sirloin lamb chops

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This study evaluated how different cold storage methods (fresh, frozen, and Suspended Fresh®) impacted the quality of U.S. retail-ready sirloin lamb chops. Results showed that Suspended Fresh® storage for 75 or 90 days improved tenderness and reduced moisture loss, while maintaining color and limiting fat breakdown similar to frozen storage. These findings suggest that Suspended Fresh® may be a practical tool to help the lamb industry extend product availability and maintain quality without relying solely on freezing.

Summary

Due to challenges caused by seasonal lambing patterns, the U.S. lamb industry's ability to meet year-round consumer demand for fresh product, especially during high-demand periods, has been strenuous. While freezing helps extend supply, it can negatively affect product quality and consumer acceptance. This study evaluated the impact of different cold storage methods (fresh, frozen, and Suspended Fresh® for 60, 75, and 90 days) on lamb sirloin chop quality. Key findings showed that Suspended Fresh® for 75 and 90 days reduced moisture loss and improved tenderness compared to fresh and frozen chops. While frozen chops retained visual redness better during retail display, Suspended Fresh® maintained lighter color and similar oxidative stability, helping preserve a fresh appearance. Additionally, lipid oxidation (a marker for shelf-life and fat degradation) was highest in fresh chops but controlled in both frozen and Suspended Fresh® chops. Overall, these results suggest that Suspended Fresh® technology offers a promising alternative to freezing, allowing processors to extend product availability while maintaining quality traits that mater to consumers.

Introduction

The U.S. lamb industry continues to struggle with keeping a steady supply of fresh lamb available throughout the year. This is mainly due to the seasonal nature of lambing, with most lambs born in the early months of the year (Redden et al., 2018). As a result, supply does not always match up with demand, especially during peak buying times like Easter and Passover (USDA-ERS, 2012).

To help bridge this supply gap, processors often freeze lamb to stretch availability. While this helps with inventory, many consumers still prefer fresh meat and are hesitant to buy frozen lamb. The consumers' concerns usually center around changes in meat quality, such as color and eating experience. Even when frozen, lamb can still develop off-flavors and lose its fresh appearance over time due to oxidation.

To address these concerns, the industry has been exploring better preservation methods and one of the promising technologies under investigation is Suspended Fresh®, a patented, proprietary, trademarked process that stores product just above the meat freezing point (around 28 degrees Fahrenheit) to keep the classification of fresh, without actually freezing it. This method has been shown to help reduce moisture loss, maintain color stability, and improve eating quality (Small et al., 2012; Kiermeier, 2013; Choe et al., 2016). However, how well this technology works for lamb sirloin chops has not been thoroughly studied, especially under conditions typical of U.S. lamb production and retail markets. Therefore, the objectives of this study were to compare how different cold storage methods affect key meat quality traits in lamb sirloin chops.

Procedures

Retail ready paired sirloin lamb chops (n = 100) were sourced from a U.S. lamb processing facility and equally divided into five categories: fresh (F), frozen (FZ), and Suspended Fresh® (SF) for 60, 75, and 90 days. Frozen chops were immediately

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frozen and held at minus 4 degrees Fahrenheit until the completion of all SF storage periods. Frozen chops were given 24 hours to thaw before evaluation.

One sirloin chop from each pair was assigned to a 6 day retail display study and lipid oxidation. Approximately 50 g sample was collected from the chop and frozen until further analysis. The other sirloin chop was used to evaluate for moisture (drip and cook loss) and tenderness (Warner-Bratzler shear force [WBSF]).

Drip loss was evaluated by weighing an ~25 g sample and suspending the sample with a large paperclip in a wire closure bag that was stored for 24 hours at 39 degrees Fahrenheit. After 24 hours, samples were reweighed for final weight and drip loss percentage was calculated. Chops assigned to WBSF were weighed and cooked on an electric grill preheated to 350 degrees Fahrenheit and the internal temperature of the chops were monitored with a thermapen, placed in the center of each chop. Once the internal temperature of 160 degrees Fahrenheit was reached, chops were removed from the electric grill and allowed to cool to room temperature. Cooked chops were reweighed to calculate for the percentage of cook loss. Three cores were taken from each cooked chop and the core samples were used with a shear force machine to imitate the force used during the first bite, to analysis tenderness. The average of the three cores from each cooked chop were averaged and used for statistical analysis.

Chops assigned to retail display were placed on polystyrene trays and overwrapped with oxygen permeable polyvinylchloride film, and then placed into a retail refrigerated display case at 39 degrees Fahrenheit under continuous fluorescent lighting. Color measurements (L^*, a^*, and b^*) were recorded every 24 hours for six days.

The frozen ~50 g sample was partially thawed and ~1.0 g samples were taken from the 50 g samples allocated to lipid oxidation. Minced samples were mixed with a buffer to breakdown products from the fat. Utilizing a TBARS (thiobarbituric acid reactive substances) assay kit, the amount of fat indicating rancidity was measured. Results were reported in mg of malondialdehyde (MDA) per kg of meat. The higher the MDA levels were used to indicate increased fat breakdown had occurred.

Data were analyzed using PROC GLIMMIX procedure of SAS (SAS 9.4, SAS Institute Inc., Cary, NC). Treatment was established as the fixed effect. Means were separated using the PDIFF option and were considered significant when $P \leq 0.05$.

Results and Discussion

Differences were observed in drip loss ($P = 0.002$), cook loss ($P = 0.05$), tenderness ($P < 0.0001$), and in lipid oxidation (MDA levels; $P < 0.0001$) as shown in Table 1. Sirloin chops stored using SF method for 75 and 90 days had less drip loss compared to F, FZ, and SF 60-day chops. Cook loss in SF 90-day chops was similar to F chops and lower than SF 75-day chops, indicating better moisture retention. All SF treated chops were more tender, based on WBSF results, than either F or FZ chops. However, tenderness was similar across all SF storage durations. Fresh chops had the highest levels of lipid oxidation, suggesting a shorter shelf-life. In contrast, there were no differences in oxidation levels between FZ and SF chops, indicating that both methods are effective at limiting fat breakdown.

There were differences ($P < 0.0001$) in how the color changed over time in the display case (Figures 1 and 2). Across the first four days of the simulated retail display, all SF chops appeared visually lighter (higher L^* values) than F or FZ chops. The FZ chops demonstrated stability in redness (a^* values) throughout the retail display, while SF 60-day chops showed the lowest redness throughout the display period.

In regard to meat quality, the results from this study indicate that Suspended Fresh® cold storage technologies offer a viable alternative to traditionally frozen storage for retail-ready sirloin lamb chops.

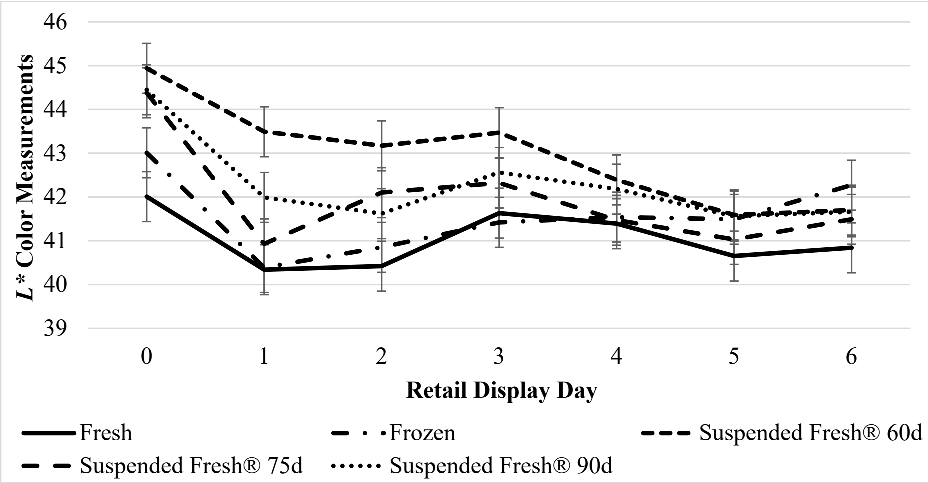
Table 1. Least-square means of lamb sirloin chops for moisture loss (drip and cook loss) and Warner-Bratzler shear force (tenderness)

	Variables[1]			
Treatment	Drip loss, %	Cook loss, %	WBSF, kg	MDA levels
Fresh	0.44[a]	18.52[a]	2.31[a]	14.22[a]
Frozen	0.42[a]	19.07[ab]	2.33[a]	9.95[b]
Suspended Fresh® 60d	0.38[a]	19.25[ab]	2.07[b]	7.82[b]
Suspended Fresh® 75d	0.34[b]	20.51[b]	2.04[b]	8.28[b]
Suspended Fresh® 90d	0.29[b]	18.26[a]	1.92[b]	7.65[b]
SEM[2]	0.28	0.55	0.07	0.89
P Value	0.0015	0.05	< 0.0001	< 0.0001

[1]Variables: Drip loss = [(initial weight – final weight) / initial weight] x 100; Cooking loss = [(raw weight – cooked weight) / raw weight] x 100; MDA Levels = mg of malondialdehyde/kg of meat

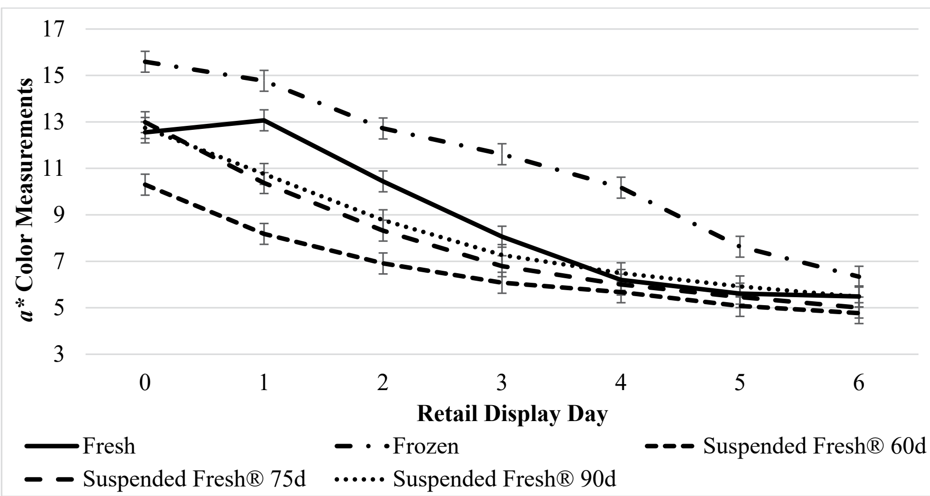
[2]SEM (largest) of the least-square means.

[a-c]Least-square means within the same column without common superscript differ ($P < 0.05$).



*L**: 0 = black; 100 = white

Figure 1. Instrumental *L (lightness) values of lamb sirloin chops assigned fresh, frozen or Suspended Fresh® treatment**



*a**: -60 = green; 60 = red

Figure 2. Instrumental *a (redness) values of lamb sirloin chops assigned fresh, frozen or Suspended Fresh® treatment**

Acknowledgments

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Assessment of cold storage effects on meat quality attributes in U.S. retail ready loin lamb chops

Kiersten M. Gundersen[1], Taylor M. Dieball[2], Greta E. Huber[2], Wanda L. Keller[1], Mara R. Hirchert[1], Virginia Montgomery[1], Erin S. Beyer[2], Kasey R. Maddock-Carlin[1] and Travis W. Hoffman[1]

This study evaluated how different cold storage methods (fresh, frozen, and Suspended Fresh®) impacted the quality of U.S. retail-ready loin lamb chops. The results from this study highlighted that Suspended Fresh® was able to preserve moisture retention without sacrificing palatability.

Summary

The seasonal nature of lamb production in the U.S. has made it difficult for the industry to consistently supply fresh lamb throughout the year, particularly during peak demand times. Although freezing is commonly used to stabilize supply, this preservation method may compromise product quality and reduce consumer appeal. This study evaluated the impact of different cold storage methods (frozen and Suspended Fresh® for 76 days) on lamb loin chop consumer preference and quality. Initial findings showed that Suspended Fresh® trended toward higher consumer acceptance and noticeable improvement in drip loss. These results demonstrate that Suspended Fresh® can preserve moisture retention without compromising consumer acceptance.

Introduction

Maintaining a consistent supply of fresh lamb year-round remains a persistent challenge for the U.S. lamb industry, largely due to the seasonal timing of lambing, which primarily occurs in the early part of the year (Redden et al., 2018). This seasonal production pattern often leads to mismatches between supply and consumer demand, particularly during major holidays such as Easter and Passover (USDA-ERS, 2012). To manage these supply gaps, processors frequently resort to freezing lamb to extend product availability. However, despite its logistical benefits, frozen lamb is often less preferred by consumers, who associate it with diminished quality attributes like discoloration and reduced palatability. Over time, frozen meat can also develop undesirable flavors and lose its fresh appearance due to oxidative changes.

In response to these quality concerns, the industry has begun to investigate alternative preservation strategies. One such innovation is Suspended Fresh®, a patented and proprietary technology that preserves meat just above freezing temperatures (around 28 degrees Fahrenheit), allowing the product to remain classified as fresh without undergoing the detrimental effects of freezing. Previous research suggests that this method may help with moisture retention and enhance sensory characteristics (Small et al., 2012; Choe et al., 2016). Nonetheless, limited research has evaluated the effectiveness of Suspended Fresh® for lamb loin chops under conditions reflective of U.S. production and retail systems. Therefore, the present study aimed to assess how various cold storage techniques influence critical quality attributes in lamb loin chops.

Procedures

Full lamb loins (*N* = 30) were sourced from a Northeast processing facility and split longitudinally (IMPS #232A, NAMP, 2010) and randomly assigned a treatment: frozen (FZ) or Suspended Fresh® (SF). Frozen loins were immediately frozen and held at minus 4 degrees Fahrenheit until the completion of the SF storage period (76 days). All split loins were fabricated into ~1.0 in. chops (IMPS #1232A lamb loin chops, NAMP, 2010). Chops from each loin were assigned to sensory evaluation, moisture loss, tenderness evaluation, or lipid oxidation evaluation.

Seventy-four untrained panelists were served six, 0.50 in cubed and cooked samples, and asked to evaluate each sample for juiciness-like, tenderness-like, flavor-like, and overall-like, on a 0 to 100 hedonic scale, with 0 being extremely dislike and 100 being like extremely.

Purge loss was evaluated by weighing each split loin still encased

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[2]Animal Sciences, Kansas State University, Manhattan, KS

in vacuum packaging, then removing the packaging and weighing the loin, before calculating purge loss percentage. Drip loss was evaluated by weighing an ~25 g sample and suspending the sample with a large paperclip in a wire closure bag that was stored for 24 hours at 39 degrees Fahrenheit. After 24 hours, samples were reweighed for final weight and drip loss percentage was calculated. Chops assigned to Warner-Bratzler shear force (WBSF) were weighed and cooked on an electric grill preheated to 350 degrees Fahrenheit and the internal temperature of the chops were monitored with a thermapen, placed in the center of each chop. Once the internal temperature of 160 degrees Fahrenheit was reached, chops were removed from the electric grill and allowed to cool to room temperature. Cooked chops were reweighed to calculate for the percentage of cook loss. Three cores were taken from each cooked chop and the core samples were used with a shear force machine to imitate the force used during the first bite, to analysis tenderness. The average of the three cores from each cooked chop were averaged and used for statistical analysis.

Approximately 1.0 g samples were taken from each chop allocated to lipid oxidation. Minced samples were mixed with a buffer to breakdown products from the fat. Utilizing a TBARS (thiobarbituric acid reactive substances) assay kit, the amount of fat indicating rancidity was measured. Results were reported in mg of malondialdehyde (MDA) per kg of meat. The higher the MDA levels were used to indicate increased fat breakdown had occurred.

Data were analyzed using PROC GLIMMIX procedure of SAS (SAS 9.4, SAS Institute Inc., Cary, NC). Treatment was established as the fixed effect. Means were separated using the PDIFF option and were considered significant when $P \leq 0.05$

Results and Discussion

No differences ($P > 0.05$) were observed for any palatability trait as shown in Table 1. However, numerical trends showcased that panelists tended to rate SF chops more favorably in juiciness, tenderness, and overall liking.

Differences were seen in drip loss ($P < 0.0001$; Table 2) with SF chops having noticeably lower drip loss percentage (0.63% ± 0.30) compared to FZ chops (3.61% ± 0.30). No differences were observed for purge loss ($P = 0.66$), cook loss ($P = 0.34$), WBSF ($P = 0.99$) and MDA levels ($P = 0.98$) between FZ and SF chops.

Drip loss is a key indicator of the moisture retention of lamb retail cuts, which can affect saleable weight. Excessive drip loss can lead to unattractive packaging and reduced yield, eroding consumer confidence and lowering retail profitability (Hybu Cig Cymru, 2021). Adoption of Suspended Fresh® cold storage technologies could potential help processors and retailers maneuver around challenges of supply seasonality without sacrificing consumer satisfaction.

Table 1. LSMEANS of lamb palatability ratings[1] for lamb loin chops from consumer sensory panels

	Palatability Traits			
Treatment	**Juiciness**	**Tenderness**	**Flavor**	**Overall liking**
Frozen	66.24	67.86	65.99	66.03
Suspended Fresh®	70.65	72.57	64.51	68.08
SEM[2]	2.13	1.99	1.66	1.73
P Value	0.15	0.09	0.53	0.41

[1]Sensory scores: 0 = extremely dry/tough/dislike; 50 = neither dry nor juicy, neither tough nor tender, neither like nor dislike; 100 = extremely juicy/tender/like extremely.

[2]SEM (largest) of the least-square means

Table 2. LSMEANS of lamb loin chops for moisture loss, tenderness, and lipid oxidation

	Variables[1]				
Treatment	**Purge loss, %**	**Drip loss, %**	**Cook loss, %**	**WBSF, kg**	**MDA levels**
Frozen	1.64	3.61^a	13.44	2.15	13.13
Suspended Fresh®	1.70	0.63^b	14.18	2.15	13.11
SEM[2]	0.09	0.30	0.55	0.08	0.91
P Value	0.66	< 0.0001	0.34	0.99	0.98

[1]Variables: Purge loss = [(initial weight – final weight) / initial weight] x 100; Drip loss = [(initial weight – final weight) / initial weight] x 100; Cook loss = [(initial weight – final weight) / initial weight] x 100; WBSF = Warner-Bratzler shear force; MDA Levels = mg of malondialdehyde/kg of meat

[2]SEM (largest) of the least-square means.

[a-b]Least-square means within the same column without common superscript differ ($P < 0.05$).

Acknowledgements

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Assessment of cold storage effects on meat quality attributes in American ground lamb

Kiersten M. Gundersen[1], Amy L. Volk[1], Wanda L. Keller[1], Mara R. Hirchert[1], Virginia Montgomery[1], Erin S. Beyer[2], Kasey R. Maddock-Carlin[1] and Travis W. Hoffman[1]

This study evaluated how different cold storage methods (fresh, frozen, and Suspended Fresh®) impacted the quality of American ground lamb. Results indicated that Suspended Fresh® had comparable or improved moisture retention, lipid oxidation, and color stability compared to Fresh and Frozen storage. These findings provide compelling support for Suspended Fresh® as a strategy to extend shelf-life without diminishing quality.

Summary

The seasonal nature of lambing in America presents ongoing difficulties in maintaining a consistent, year-round supply of fresh lamb, particularly during peak demand periods. Although freezing extends product availability, it may compromise meat quality and shelf-life stability. This study evaluated the impact of different cold storage methods (fresh, frozen, and Suspended Fresh® for 36 days) on ground lamb quality. Initial findings showed that Suspended Fresh® reduced cook loss, lowered lipid oxidation levels, and increased color stability over a five-day retail display compared to fresh and frozen ground lamb. Therefore, the results support the feasibility of Suspended Fresh® technology as a practical alternative solution to address supply chain limitations in the sheep industry.

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Introduction

Ensuring a steady, year-round availability of fresh lamb remains a significant hurdle for the American lamb industry due to the concentration of lambing in the early months of the year (Redden et al., 2018). This seasonal production often results in an imbalance between supply and demand, especially during high-consumption periods like Easter and Passover (USDA-ERS, 2012). To compensate for these shortfalls, processors commonly freeze lamb products to prolong shelf-life and availability. Despite this practical solution, many consumers view frozen lamb less favorably, citing concerns over quality degradation such as discoloration, off-flavors, and inferior texture due to oxidative damage over time.

To address these quality-related issues, the industry is exploring new preservation methods. One such approach is Suspended Fresh®, a proprietary technology that stores meat slightly above its freezing point (approximately 28 degree Fahrenheit), preserving its "fresh" classification while avoiding the quality losses typically associated with freezing. Studies have shown that this method may minimize moisture loss and support better color stability (Small et al., 2012; Kiermeier, 2013; Choe et al., 2016). However, little is known about how this technology performs when applied to ground lamb under typical U.S. production and retail conditions. As such, this study was designed to evaluate the impact of different cold storage methods on key meat quality traits in ground lamb patties.

Procedures

Vacuum-packaged ground lamb (1.0 lbs.; $n = 60$) were sourced from a U.S. lamb processing facility and equally divided into three categories: fresh (F), frozen (FZ), and Suspended Fresh® (SF). Frozen ground lamb was immediately frozen and held at minus 4 degrees Fahrenheit until the completion of SF storage period. Frozen chops were given 24 hours to thaw before evaluation. Half-pound patties were made from each package using a commercially available patty maker. One patty from each package was assigned to pH, another patty for cook loss, a third patty was assigned to color stability analysis and lipid oxidation analysis. For lipid oxidation, an approximately 50 g sample was collected and frozen at minus 112 degrees Fahrenheit until analysis.

The pH of the patties was determined by weighing ~10 g of finely chopped sample into a blender.

Next, 100 mL of de-ionized water was added to the blender and blended for 30 seconds (well mixed, but not emulsified). The mixture was then filtered through cheese cloth before pH readings were recorded.

Patties assigned to cook loss were weighed and cooked on an electric grill preheated to 350 degrees Fahrenheit and the internal temperature of the patties were monitored with a thermapen, placed in the center of each patty. Once the internal temperature of 160 degrees Fahrenheit was reached, patties were removed from the electric grill and allowed to cool to room temperature. Cooked patties were reweighed to calculate for the percentage of cook loss.

Patties assigned to retail display were placed on polystyrene trays and overwrapped with oxygen permeable polyvinylchloride film, and then placed into a retail refrigerated display case at 39 degrees Fahrenheit under continuous fluorescent lighting. Color measurements (L^*, a^*, and b^*) were recorded every 24 hours for five days.

The frozen ~50 g sample was partially thawed and ~1.0 g samples were taken from the 50 g samples allocated to lipid oxidation. Minced samples were mixed with a buffer to breakdown products from the fat. Utilizing a TBARS (thiobarbituric acid reactive substances) assay kit, the amount of fat indicating rancidity was measured. Results were reported in mg of malondialdehyde (MDA) per kg of meat. The higher the MDA levels were used to indicate increased fat breakdown had occurred.

Data were analyzed using PROC GLIMMIX procedure of SAS (SAS 9.4, SAS Institute Inc., Cary, NC). Treatment was established as the fixed effect. Means were separated using the PDIFF option and were considered significant when $P \leq 0.05$.

Results and Discussion

Differences were observed in pH ($P < 0.0001$), purge loss ($P = 0.04$), and MDA levels ($P < 0.0001$) as shown in Table 1. Suspended Fresh® patties maintained an intermediate pH value compared to F and FZ patties. Suspended Fresh® patties were comparable to purge loss with F patties, but had a higher purge loss percentage than FZ patties. Frozen and Suspended Fresh® patties were similar in MDA levels (lipid oxidation identifier), but SF patties had noticeably lower MDA levels compared to F patties.

The L^* (lightness) values showed distinct differences over time between storage methods (Figure 1). Fresh patties exhibited higher L^* values throughout the 5 day retail display, indicating a lighter surface appearance. The lowest L^* values were constantly observed in FZ patties, while SF patties maintained intermediate lightness values.

The a^* (redness) values showed a steady decline from day 0 to day 5 of the retail display (Figure 2). However, the rate of the decline is what differed between storage methods. Fresh patties demonstrated the quickest decline in surface redness appearance, while FZ declined more gradually. Suspended Fresh® patties followed a similar trend as F and FZ patties, but maintained a slightly more stable trajectory.

Collectively, this study supports the implementation of Suspended Fresh® technology as a practical solution to maintain and(or) improve meat quality without sacrificing consumer confidence.

Acknowledgments

This project was supported by a coordinated agreement between North Dakota State University and the American Lamb Board. A special thank you to iQFoods and the Suspended Fresh® team for collaboration on this research.

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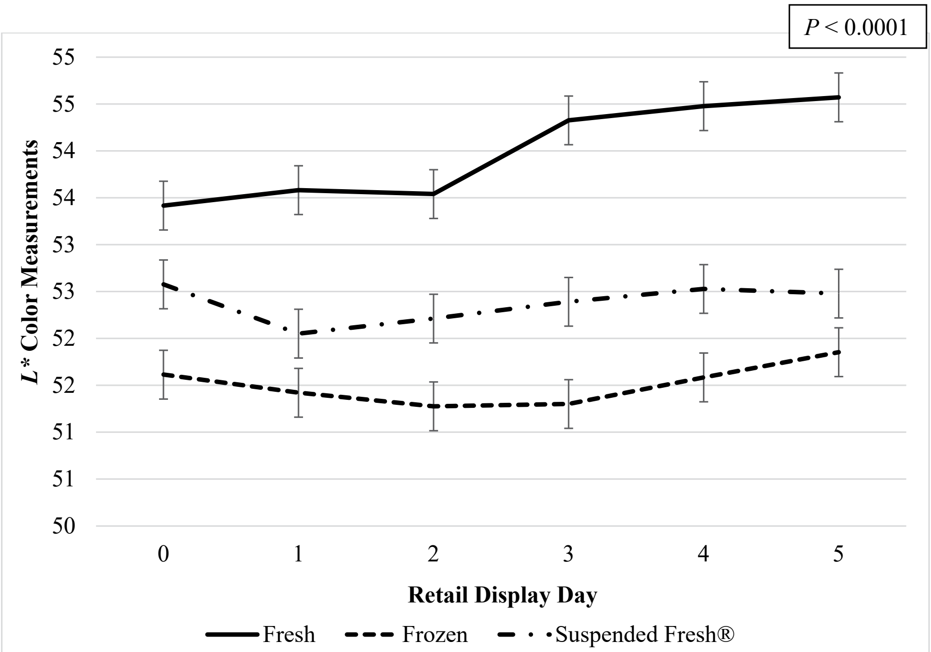
Table 1. LSMEANS of ground lamb for pH, moisture loss (purge and cook loss), and lipid oxidation

	Variables[1]			
Treatment	pH	Purge loss, %	Cook loss, %	MDA levels
Fresh	5.13[c]	2.46[ab]	30.05	13.34[a]
Frozen	5.40[a]	2.38[b]	30.45	11.05[b]
Suspended Fresh®	5.27[b]	2.70[a]	28.57	10.70[b]
SEM[2]	0.20	0.09	0.61	0.24
P Value	< 0.0001	0.04	0.08	< 0.0001

[1]Variables: Purge loss = [(initial weight – final weight) / initial weight] x 100; Cooking loss = [(raw weight – cooked weight) / raw weight] x 100; MDA Levels = mg of malondialdehyde/kg of meat

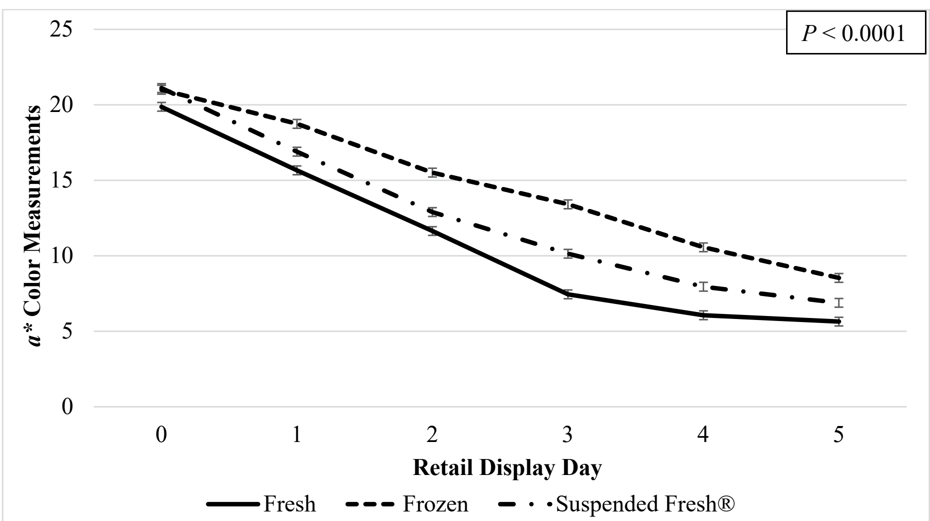
[2]SEM (largest) of the least-square means.

[a-c]Least-square means within the same column without common superscript differ ($P < 0.05$).



*L**: 0 = black; 100 = white

Figure 1. Instrumental *L (lightness) values of ground lamb assigned fresh, frozen or Suspended Fresh® treatment**



*a**: -60 = green; 60 = red

Figure 2. Instrumental *a (redness) values of ground lamb assigned fresh, frozen or Suspended Fresh® treatment**

USDA-ERS. 2012. Lamb/mutton production expected to show strength leading up to the Spring religious holidays. From: https://www.ers.usda.gov/data-products/charts-of-note/chart-detail?chartId=75628. United States Department of Agriculture-Economic Research Service.

NDSU Extension and Partners Enhance North Dakota's Foreign Animal Disease Response Capacity

Mary A. Keena[1] and Miranda A. Meehan[2]

When the Highly Pathogenic Avian Influenza (HPAI) outbreak occurred in 2022, many responders in North Dakota lacked knowledge and technical skills to respond to foreign animal diseases and the associated mass livestock mortalities. North Dakota State University Extension led the development of curriculum and training to enhance the abilities of local communities and the state of North Dakota to respond to foreign animal disease outbreaks and mortalities. Following training, 100% of participants had increased ability to respond, and 92% indicated that their community was better prepared for a foreign animal disease.

Summary

The 2022 HPAI outbreak impacted North Dakota. Many responders had no previous experience responding to a foreign animal disease, including 62% of NDSU Extension agents. Through a USDA Animal and Plant Health Inspection Service (APHIS) National Animal Disease Preparedness and Response Program grant, NDSU Extension trained 65 professionals on how to safely respond to an animal disease outbreak or mass livestock mortality. Participant evaluations revealed that 100% of respondents indicated that the training increased their confidence and improved their ability to respond to an animal disease or mass livestock mortality. Additionally, 93% reported that the training improved their ability to provide support to individuals in high-stress situations. Six-month follow-up evaluation data indicated that 92% of respondents (25) considered their community to be better prepared for and able to respond to an animal disease or mass livestock mortality. The training successfully built relationships between responders in the state; 48% reported collaborating with individuals they connected with at the training to better prepare their communities.

Introduction

The 2022 HPAI outbreak impacted North Dakota. Responders to the outbreak included the North Dakota Department of Agriculture, North Dakota Department of Environmental Quality, APHIS, NDSU Veterinary Diagnostic Laboratory (VDL), NDSU Extension, county emergency managers and veterinarians. Many responders were new employees and were not involved in response efforts during the 2015 HPAI outbreak, including 62% of NDSU Extension agents. The lack of experience and knowledge resulted in a significant amount of time and effort spent determining the appropriate agencies to contact, defining agency roles, developing educational resources and creating an awareness of biosecurity and procedures used in active cases. Additionally, limited attention was given to stress management, mental health and well-being for personnel involved in the response.

To address these gaps, NDSU Extension developed curriculum and training to increase the knowledge and technical skills of local responders in responding to a foreign animal disease and mass livestock mortalities. The objectives of this training were the following: 1) enhance the abilities of local communities and the state of North Dakota to respond to foreign animal disease outbreaks and mass livestock mortalities by developing resources and providing hands-on training related to biosecurity, depopulation, disposal and decontamination, 2) develop and deliver mental health, stress and conflict management training resources for responding personnel and 3) build relationships and enhance communication between individuals and agencies responding to foreign animal disease outbreaks and mass livestock mortalities.

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[2]Animal Sciences Department, NDSU

Procedures

NDSU Extension collaborated with the North Dakota Department of Agriculture, North Dakota Department of Environmental Quality, APHIS and the NDSU VDL to identify training topics and develop curriculum. Training topics included an overview of animal diseases; continuity of business planning; personal protective equipment and decontamination; incident command systems, local response roles and impact assessment; humane endings; carcass disposal site selection and methods; stress management and responding to stressed people; effective communication in high-stress situations; and response simulation exercises. The curriculum was developed over a five-month period and included nine presentations, two response simulations (HPAI and anthrax), 22 Extension publications (14 of which were translated to Spanish), 130 kits with personal protective equipment (PPE) and a resource hub.

The curriculum was previewed by 25 attendees during the North Dakota Veterinary Medical Association's Annual Winter Conference in January 2024. Eleven attendees responded to a survey, all agreeing that the training increased their confidence in responding to a foreign animal disease (FAD), while 91% indicated that the materials presented were appropriate for those responding to an animal disease outbreak at the local level. All topic areas were rated as either moderately useful or very useful. Suggested improvements to the curriculum were made over the next four months leading up to the first full training.

The one-and-a-half-day training events were held in person at the NDSU Carrington Research Extension Center in June and September 2024. The training format included lectures, group work, demonstrations and hands-on activities (Figure 1). Each participant received a kit that contained personal protective equipment (Figure 2). A tabletop exercise at the end of the training integrated all topics presented and provided time for groups to share experiences with response efforts.

Figure 1. Participants of the Emergency Response Preparedness for Foreign Animal Diseases and Mass Livestock Mortalities in North Dakota training viewed a nondisease mortality compost site. NDSU photo.

Figure 2. Emergency Response Preparedness for Foreign Animal Diseases and Mass Livestock Mortalities in North Dakota training participants practiced donning PPE during the hands-on portion of the training. NDSU photo.

Results and Discussion

In post-event evaluations of training participants, all respondents (57) indicated that the training increased their confidence and ability in responding to an animal disease or mass livestock mortality event. Additionally, 96% of respondents indicated they planned to make changes to be better prepared and better able to respond to animal diseases or mass livestock mortalities because of their participation in the training. Responses also indicated 93% improved their ability to provide support to individuals in high-stress situations.

Post-training evaluation respondent comments included the following:

- *"One of the best trainings I've ever attended. Please make sure new ANR [agriculture and natural resources] agents attend this in the future.*
- *"This was a great training and I appreciate all the work put into it! It was good to understand the chain of command and know that many other offices would be working with a producer in a situation involving a FAD."*
- *"I appreciated the number of different professions represented at this meeting and their unique perspectives for this type of emergency response."*
- *"It was a great learning experience. The information was very useful and will be put to use if an event occurs. We EMs [emergency managers] don't normally deal directly with the emotional responses, but we are resources for finding avenues for emotional support, which is great to know that there are people to reach out to in the animal industry. Overall, it was great to network with others, and I have more tools in the toolbox for when the situation occurs. GREAT JOB to everyone involved!!"*

Six-month follow-up evaluation data indicated that 92% of respondents (25) felt their community is better prepared for, and able to respond to, an animal disease or mass livestock mortality. Of these respondents, 60% took action to be more prepared for an animal disease or mass livestock mortality. Additionally, the training successfully built relationships between responders in the state, with 48% collaborating with individuals they connected with at the training to better prepare their communities to respond to an animal disease or mass livestock mortality. Since the training, 12% of participants have responded to an animal mortality, 100% of whom felt they were better equipped to respond due to the training.

As part of the six-month evaluation, respondents were asked if they had taken actions to prepare for an animal disease or mass livestock mortality. Comments included the following:

- *"Put together a list of resources, working on a response plan, informed stakeholders on the process and procedures involved."*
- *"Monitoring of animal diseases in state and working with local producers and Extension county agent."*
- *"I have been more diligent about collecting names of producers or contacts needed if any outbreak would occur."*

Acknowledgments

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A five-year review of usefulness, change and benefit gained from NDSU Extension horse management webinars

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Data from the 2017 National Agricultural Statistics Service publication showed 10 North Dakota counties were home to 45% of the 29,423 head that made up the North Dakota equine inventory. At the request of North Dakota State University Extension stakeholders, 23 webinars were hosted over five years, covering 18 topic areas. A five-year program review revealed management changes in all 18 topic areas. Changing management practices leads to more efficient land use, which saves money, reduces pollution potential and improves water quality.

Summary

Data from the 2017 National Agricultural Statistics Service (the latest data gathered on equids) showed that 10 North Dakota counties were home to 45% of the 29,423 head that comprised the North Dakota equine inventory. North Dakota State University Extension stakeholders requested in-person meetings for horse owners and stable managers in two counties before the COVID-19 work-from-home order was issued in 2020. An online platform was used, allowing the horse community in all parts of North Dakota to join live during noontime sessions or watch later. Twenty-three webinars were hosted over five years, with 972 participants attending live and 4,472 views of the recordings on the NDSU Extension YouTube channel.

Live webinar participants responded to the same poll question from 2021 to 2024. Of the 320 respondents, 82% rated the webinars as very or extremely useful. A five-year review of the program was conducted in December 2024 and received 96 responses. Horse owners comprised 66% of the respondents, and stable owners/managers comprised another 12%. Participants expressed making changes to their practices in all 18 topic areas, with 44% making one to five changes. All educational objectives were met or exceeded for this program.

Introduction

Data from the 2017 National Agricultural Statistics Service publication (the latest data gathered on equids) showed 10 North Dakota counties (Burleigh, Dunn, McKenzie, Morton, Emmons, Stark, Mountrail, McHenry, Williams and Ward) were home to 45% of the 29,423 head that made up the North Dakota equine inventory.

Our initial goal, at the request of NDSU Extension stakeholders, was to host an educational meeting in two of the 10 counties. When the COVID-19 pandemic halted the planned programming, we pivoted to an online platform. Our objectives became the following:

- Host four webinars per year for at least five years and reassess participation and feedback at that time
- Create a contact list of North Dakota equine enthusiasts for educational communication
- Include at least one webinar per year focusing on manure management to reduce nonpoint source pollution potential to our surface and groundwater

Procedures

When the pandemic halted the planned programming, we pivoted to an online platform that allowed the horse community in all parts of North Dakota to join live during noontime sessions or watch at a later date. A total of 23 webinars were hosted over five years, covering 18 topic areas: arena and facility footing, bedding management, biosecurity practices, drought management, communicable disease management, emergency field aid, equine conditioning, facility management, fencing, genetic disease management, geriatric horse or foal care, grazing management, haying management, manure management, mortality management, parasite management, weed management and winter horse management.

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Webinars were marketed via state press releases, Extension county listservs and, starting in 2023, a social media campaign (Facebook and Twitter/X). The press releases also led to local radio interviews across North Dakota. The social media campaign consisted of marketing the entire webinar series, specific webinars as the dates approached and the recorded video links after each webinar was held.

We used the "meeting" version of Zoom instead of the "webinar" version, as it allowed for more participant interaction. Webinars were one hour long (five-minute introduction and housekeeping session, 45-minute teaching session and 10-minute question and answer session). The intended audience works during regular business hours and uses the evening hours for animal interaction, so webinars were hosted live at noon sessions and recorded for rewatching later.

Recordings of each webinar were edited and posted on the NDSU Extension YouTube channel. Email addresses of participants were gathered during online registration, and a link was sent to participants when the videos were ready to view.

Webinars were hosted in March, April and May, which tend to be the time for limited outdoor activities in North Dakota due to poor weather and ground conditions (cold and muddy). Webinar topic ideas for the following year were gathered via Zoom poll participation during current-year live sessions and social media inquiries. A variety of speakers have participated in the programming efforts, including Extension and researchers from both NDSU and the University of Minnesota, as well as an industry partner. Speakers were chosen based on appropriateness for the topic and ability to convey information clearly.

Results and Discussion

Live webinar participants responded to the same poll question from 2021 to 2024, rating the overall usefulness of the webinar they were attending. Of the 320 respondents, 42% rated the webinars as extremely useful, 40% as very useful and 18% as useful.

A five-year survey was sent to the participant listserv in December 2024 and received 96 responses. Horse owners comprised 66% of the respondents, and stable owners/managers comprised 12%. North Dakota was represented by 39% of the survey respondents, while 23% were from Minnesota.

Survey respondents were asked what specific changes they made due to the information obtained from the NDSU Extension horse management webinar series. Survey respondents were also asked what the benefit has been to them, their animal(s), their finances and/or the environment.

Participants expressed making changes to their practices in all 18 topic areas, with 44% making one to five changes. The following are the top six areas where respondents expressed changes to their practices:

- 40% in grazing management
- 34% in manure management
- 31% in haying management
- 30% in winter horse management
- 25% in emergency first aid
- 25% in weed management

The following are examples of changes made by respondents after viewing the webinars:

- *"I have changed my grazing rotation and used electric fencing to make the horses graze a smaller area for a short period of time. I have also been more aware of the length of grass I allow the horses to graze the pasture down to."*
- *"Moving, piling, and composting manure."*
- *"Working on better manure management plan (it's a work in progress)."*
- *"Your webinar on weed management has helped us identify and mitigate weeds that we had in our pasture."*
- *"I have been more selective about the quality of hay that I have been purchasing."*
- *"We went from generic feed for everyone to individual needs-based feed."*

The following are examples of benefits resulting from management changes:

- *"The benefit has been to our horses by providing better pasture grass to them."*
- *"Pasture is healthier due to delayed spring grazing and early removal in the fall. Additional changes to manure management will yield fewer flies, more changes to be made."*
- *"It's more money saved with more pasture producing forage and manure fertilizing it."*
- *"The weedy areas of my pasture are going away and my pasture has more even forage coverage."*
- *"Hay is lasting longer as it is fed more wisely in the winter which saves money."*
- *"Animal [individual] based feed has helped keep weight on my old guys."*

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(Photo by Karl Hoppe, NDSU)

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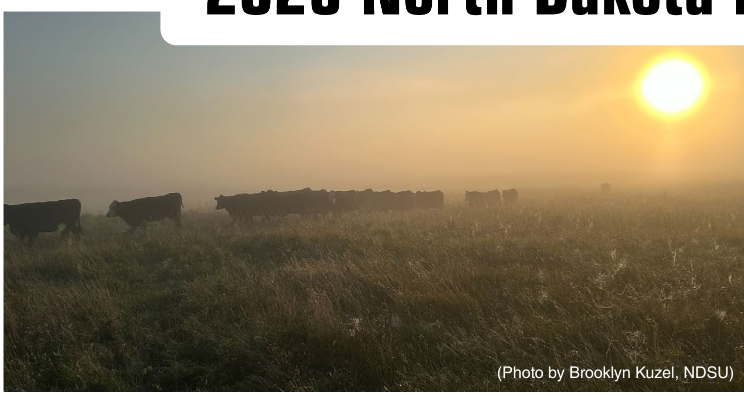
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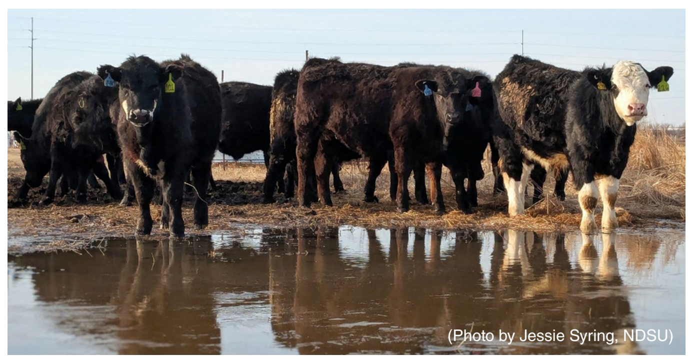
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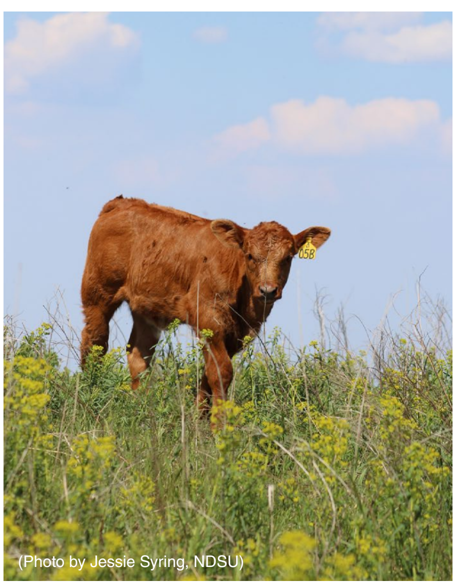
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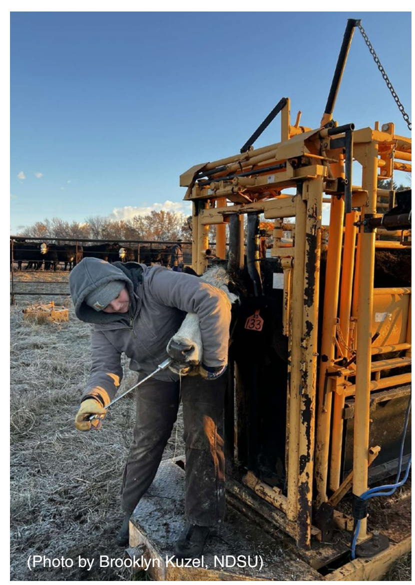
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