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2026 North Dakota Livestock Research Report

NDSU NORTH DAKOTA STATE UNIVERSITY

(Photo by Rachel Gibbs, NDSU)

2026 North Dakota Livestock Research Report

Thanks for your interest in this year's North Dakota Livestock Research Report. This is my 15th year of coordinating and editing the report, and I continue to enjoy helping lead this effort. The report provides an opportunity to get our research findings to producers and industry personnel in the state and region. This report is also beneficial for our students, staff and faculty, helping them not only to get research information out to producers and others but also to gain experience in leading and collaborating, conducting research, analyzing data and writing research reports.

Our research ranges from discovery research, which could develop into new innovations or technologies that 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. 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. 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 authors of the individual reports. Thanks for your encouragement, interest and support of livestock research in North Dakota.

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Contents

Continued on page 4

Reproductive Physiology

Swine

Grazing Management

Sheep Cost of Production

Moderate prebreeding body condition improves reproductive efficiency and productivity in fall- and spring-lambing commercial Rambouillet ewes.

Samantha L. Ekstrom[1,2], Carlos D. Ruiz-Vázquez[1,2], Nikita So[2], Jetzairy Irizarry-Soto[2], Sherly García Rivera[2], Christopher S. Schauer[2] and Rachel L. Gibbs[2]

A moderate prebreeding BCS of approximately 3.0 maximized reproductive efficiency and lamb production in commercial Rambouillet ewes. While prebreeding condition influenced flock-level productivity through improved conception and prolificacy, it had limited effects on late-gestation metabolism, lamb growth, or survival. Strategic management of ewe body condition before breeding provides a practical approach to improving flock efficiency and year-round lamb supply.

Summary

Body condition before breeding is an important management tool for improving ewe reproductive success and flock productivity. This study evaluated 327 fall-lambing and 219 spring-lambing commercial Rambouillet ewes to determine how prebreeding body condition score (BCS) influences reproduction, ewe productivity, late-gestation health and lamb outcomes. Ewe BCS was evaluated prior to breeding and throughout gestation, and reproductive performance, lamb survival, growth and health outcomes were monitored through weaning. Prebreeding BCS influenced conception, prolificacy and total pounds of lamb weaned per ewe, with the greatest productivity among exposed ewes occurring at a moderate BCS of approximately 3.0, regardless of season. Greater prebreeding BCS further improved productivity among fall-lambing ewes that conceived but appeared to offer limited advantages for spring-lambing ewes. Prebreeding BCS had limited effects on late-gestation metabolism, lamb health, survival or growth in either season. These results indicate that maintaining ewes near a BCS of 3 before breeding can improve reproductive efficiency and flock productivity without negatively affecting ewe or lamb health and performance through weaning.

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Introduction

Increasing U.S. lamb demand and seasonal limitations in domestic production create opportunities to improve out-of-season production systems (USDA-ERS, 2025). Fall-lambing systems can increase production flexibility but require breeding outside the natural reproductive season, which may challenge ewe reproductive performance (Lomet et al., 2020). Body condition scoring is a practical tool for evaluating ewe nutritional status, which plays an important role in reproductive success by influencing energy availability, ovulation and pregnancy establishment (Muñoz et al., 2007). However, variation in prebreeding BCS is common in extensive production systems, and optimal BCS targets for maximizing productivity while maintaining downstream ewe and lamb outcomes remain unclear. Therefore, this study evaluated the relationship between prebreeding BCS thresholds and reproductive performance, ewe productivity, late-gestation metabolic status and lamb outcomes in commercial fall- and spring-lambing Rambouillet ewes.

Procedures

Data were collected from 327 fall-lambing and 219 spring-lambing multiparous commercial Rambouillet ewes (2-6 yr) managed at the NDSU Hettinger Research Extension Center under an approved NDSU Institutional Animal Care and Use Committee protocol. Ewes were managed under commercial flock conditions with uniform nutrition within each production season. Body condition was assessed before breeding, midgestation (~60-90 dGA), late-gestation (~135 dGA) and weaning, using a 1-5 scale in 0.5-point increments. A subset of ewes (fall: n = 78; spring: n = 36) was evaluated for metabolic status and lamb outcomes. Measurements included reproductive performance, lambing outcomes (birthing difficulty, lamb vigor, suckling assistance), lamb survival, adjusted weaning weights, ewe and lamb health, ewe metabolites, and lamb immune outcomes. Data were analyzed within each lambing season using SAS statistical software, with ewe age included in statistical models as a fixed effect.

Results and Discussion

Fall-lambing ewes entered the breeding season at a lower average BCS than spring-lambing ewes (2.74 vs. 3.23), while conception rates were similar between seasons (72.5% and 74.4%). Body condition increased throughout gestation in both systems, with fall-lambing ewes maintaining condition from mid- to late gestation, while spring-lambing ewes continued increasing condition through late gestation. Greater prebreeding BCS was associated with greater body condition throughout gestation. Prebreeding BCS influenced reproductive efficiency and flock productivity, with optimal conception and lamb production occurring near a BCS of 3.0. Greater prebreeding BCS increased the likelihood of multiple births and pounds of lamb weaned per productive ewe. However, prebreeding BCS had limited effects after pregnancy was established, with no major associations observed with lamb growth, mortality, lambing difficulty, ewe health, late-gestation metabolites or most lamb immune outcomes. Maintaining ewes at a moderate prebreeding BCS (~ 3.0) provides a practical strategy to improve reproductive performance and flock productivity without negatively affecting ewe or lamb health.

Table 1. Summary of experimental ewe cohorts and reproductive performance metrics.

	Fall (April 2025 – January 2026)	Spring (August 2025 – April 2026)
# Exposed ewes (n)	327	226
Average age	3.42 ± 0.06	3.25 ± 0.07
Average weight (lbs)	151.1 ± 1.19	155.1 ± 1.47
Average adjusted pre-breeding BCS	2.74 ± 0.03	3.23 ± 0.03
Conception rate (%)	72.5	74.4
# Productive ewes (n)	237	163

BCS = body condition score. Values are presented as mean ± standard error (SE) for continuous variables and percentages or counts for categorical variables. Exposed ewes represent all ewes participating in the breeding season, whereas productive ewes represent ewes that successfully conceived. Fall data was collected from April 2025 to January 2026, and spring data was collected from August 2025 to April 2026.

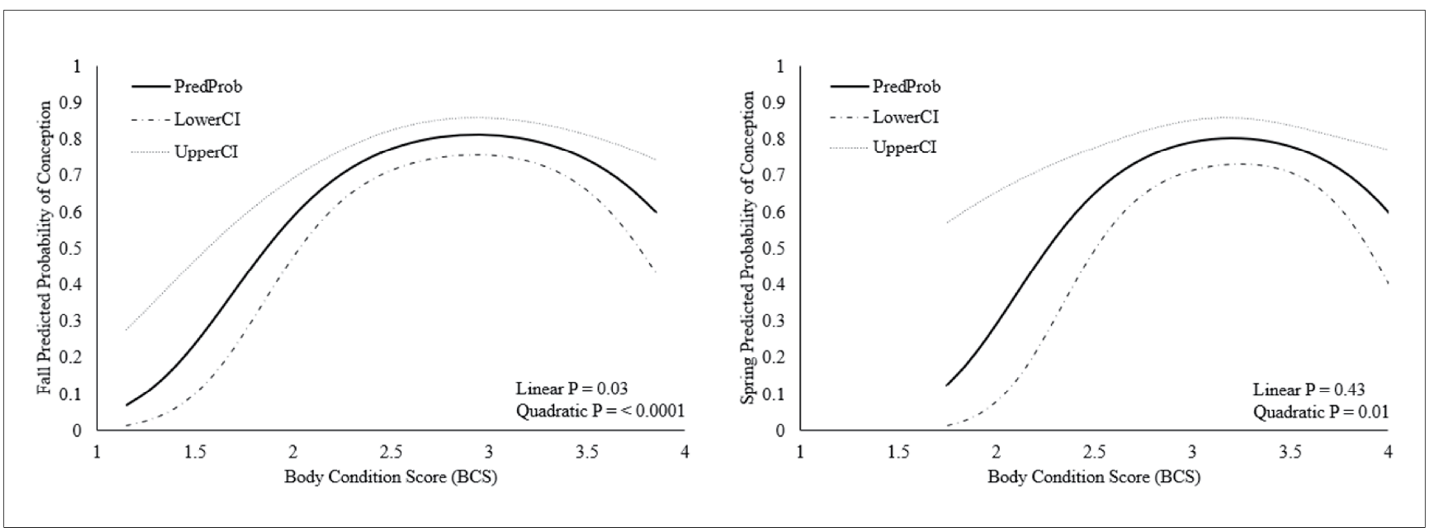

Figure 1. Predicted probability of conception as a function of ewe pre-breeding body condition score (BCS) in (a) fall- and (b) spring-lambing ewes. Lines represent predicted values (solid) ± 95% confidence intervals (dashed), restricted to the observed BCS ranges (fall: 1.15 - 3.85; spring: 1.64 - 4.05). Conception probability was quadratically associated with pre-breeding BCS in both fall- (P < 0.001) and spring-lambing ewes (P = 0.01), with a maximum at approximately BCS 2.9 and 3.2, respectively.

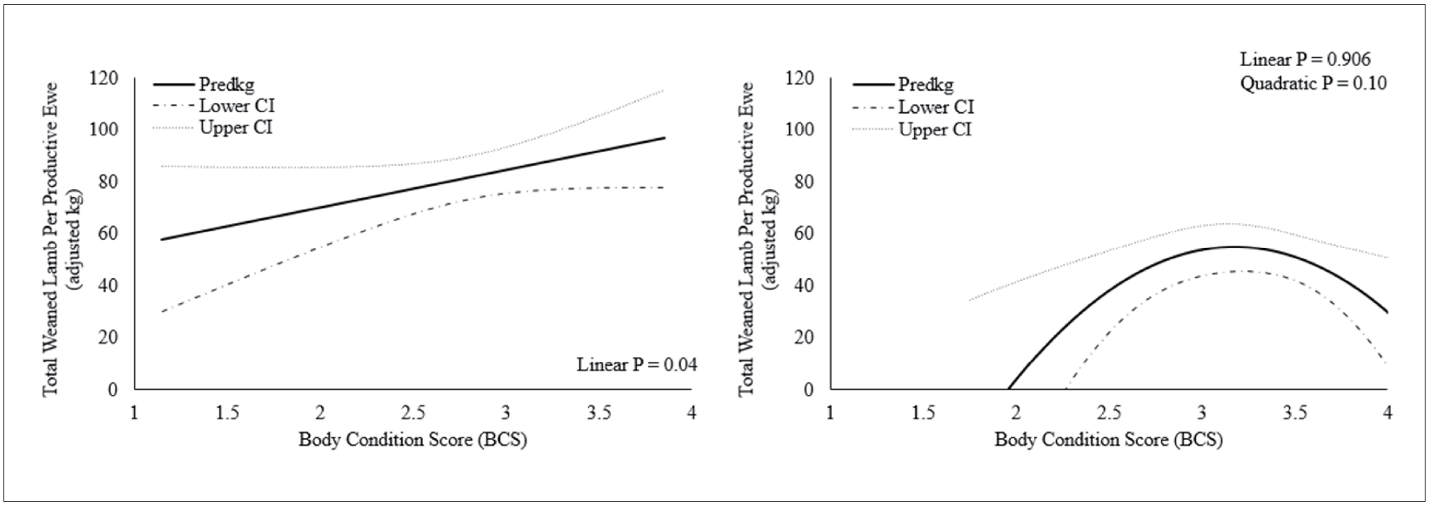

Figure 2. Total adjusted lamb weight weaned per productive ewe as a function of pre-breeding body condition score (BCS) in (a) fall- and (b) spring-lambing ewes. Lines represent predicted values (solid) ± 95% confidence interval (dashed), restricted to the observed BCS range (fall: 1.15 - 3.85; spring: 1.64 - 4.05). Total adjusted lamb weight weaned increased linearly with pre-breeding BCS in fall-lambing ewes ($P < 0.05$), whereas spring-lambing ewes exhibited a tendency for a quadratic relationship ($P = 0.10$), maximizing at approximately 3.2.

Acknowledgments

The authors thank the North Dakota State University Hettinger Research Extension Center staff for their contributions to animal care and research support. We also acknowledge the faculty, students, and technicians who assisted with data collection, laboratory analyses and project completion.

Literature Cited

Lomet, D., X. Druart, D. Hazlerigg, M. Beltramo, and H. Dardente. 2020. Circuit-level analysis identifies target genes of sex steroids in ewe seasonal breeding. Mol. Cell. Endocrinol. 512:110825.

Muñoz, C., A. F. Carson, M. A. McCoy, L. E. R. Dawson, N. E. O'Connell, and A. W. Gordon. 2007. Nutritional status of adult ewes during early and mid-pregnancy. 1. Effects of plane of nutrition on ewe reproduction and offspring performance to weaning. Animal. 2:52-63.

USDA Economic Research Service. 2025. Livestock and meat international trade data. U.S. Department of Agriculture. From: https://www.ers.usda.gov/data-products/livestock-and-meat-international-trade-data.

2025 Dakota Meat Goat Buck Performance Test

Casey Gambrel[1,2], Samantha Ekstrom[1,2], Carlos Ruiz[1,2], Christopher Schauer[2] and Rachel Gibbs[2]

The Dakota Meat Goat Test provides producers nationwide with an objective, centralized evaluation of growth performance, carcass merit and breed quality of meat-goat bucks under uniform management conditions. Bucks are ranked using a weighted performance index that incorporates key measures of growth and carcass value, allowing producers to identify sires with the greatest potential to improve terminal productivity within their herds. Eligible bucks may also earn breed ennoblement points through breed registration associations based on tested performance.

Summary

Seventy-four winter-born Kiko and Boer bucks from 21 consignors participated in the 2025 Summer Dakota Meat Goat Test, where they were evaluated over a 63-day centralized performance test for growth, carcass merit and breed standard. Growth performance was measured using average daily gain (ADG), while carcass traits, including ribeye area and backfat thickness, were evaluated by real-time ultrasound. Additional measurements included leg and scrotal circumference. Registered Boer bucks were also evaluated by a panel of three certified American Boer Goat Association (ABGA) judges for breed character, structural correctness and adherence to the ABGA breed standard. Sixty-eight bucks completed the performance test, with growth index scores ranging from 34.31 to 54.06 points and averaging 41.88 points. Across all breeds, bucks averaged 67.2 pounds at the start of the test, gained 0.48 pounds per day over the 63-day evaluation and finished at an average body weight of 93.1 pounds. Kiko bucks averaged 0.50 pounds per day of gain, while Boer bucks averaged 0.44 pounds per day. Ultrasound evaluation showed an average ribeye area of 1.91 in^2 and backfat thickness of 0.10 in across all bucks. Boer bucks exhibited larger average ribeye areas (2.33 in^2) than Kiko (1.75 in^2) bucks. These carcass measurements provide producers with additional information on muscling and maturity pattern to complement growth performance when selecting breeding stock.

Introduction

The Dakota Meat Goat Test was established through a collaborative effort with the North Dakota Meat Goat Association and American Boer Goat Association to provide producers with an objective, centralized performance testing program for meat goat bucks. By evaluating bucks under uniform management conditions, the test generates standardized data on growth and carcass merit to support more informed genetic selection decisions. The program also provides registered American Boer Goat Association (ABGA) bucks the opportunity to be evaluated against the breed standard and earn ABGA Ennoblement points.

Procedures

Seventy-four winter-born bucks from two meat goat breeds (Kiko and Boer), with birthdates ranging from Dec. 21, 2024, to Feb. 24, 2025, were consigned by 21 producers and received by the NDSU Hettinger Research Extension Center on June 17, 2025. To determine average daily gain (ADG), initial body weight was recorded when the testing period began on July 2, 2025, and at the end of the growth testing period on Sept. 4, 2025. At the beginning and the end of the growth testing period, real-time carcass ultrasound was performed to estimate ribeye area, ribeye depth and back fat cover between the 12th and 13th rib. Rear leg and scrotal circumferences were also measured at the end of the testing period. Registered Boer bucks were evaluated and scored by a panel of three ABGA-certified judges based on structure, breed character, any disqualifying faults and the breed association's established breed standard. Bucks were ranked using a Growth Index that combined average daily gain (30%), weight per day of age (30%), ribeye area adjusted to metabolic body weight (20%) and rear leg circumference adjusted to metabolic body weight (20%). Higher index scores indicate superior

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overall growth performance and muscling under the standardized test environment.

Results and Discussion

Sixty-nine bucks completed the 2025 Summer Dakota Meat Goat Test following the removal of six bucks by the Test Committee due to inability to adapt to the diet, chronic illness or other unforeseen circumstances. Individual buck data is presented in Tables 1 and 2 for Kiko and Boer bucks, respectively. Buck growth index scores ranged from 34.31 to 54.06, with an average of 41.88 points. The Kiko buck growth index scores ranged from 34.31 to 54.06 points, averaging 42.11, while the Boer bucks ranged from 34.42 to 49.44 points and averaged 42.29. The similarity in average index scores between breeds demonstrates that both Kiko and Boer genetics can perform competitively under a standardized management system, while the range of scores highlights substantial variation within breeds that producers can capitalize on through performance-based selection. Across the two breeds, bucks averaged 67.2 pounds at the start of the testing period and 93.1 pounds at the conclusion of the test, gaining an average of 0.48 pounds per day and 31.5 pounds over the testing period. Kiko bucks entered the test at an average weight of 53.4 pounds, gained 0.50 pounds per day and finished at 85.2 pounds. Boer bucks averaged 80.4 pounds at the start of the test, gained 0.44 pounds per day and concluded at an average weight of 112.0 pounds. Because the primary purpose of the Dakota Meat Goat Test is to compare bucks within a standardized environment rather than between breeds, growth differences among breeds should be interpreted with caution, particularly given the smaller number of Boer consignments. Carcass measurements provide producers with additional insight into muscling and maturity patterns. Bucks with larger ribeye

Table 1. Kiko buck performance summary

Test ID	70-Day ADG (lb)	REA (sq. in.)	Backfat (in.)	Index (pts)
204389	0.88	2.15	0.12	54.06
204391	0.73	1.95	0.12	50.11
204412	0.63	2.70	0.10	48.09
204413	0.68	1.92	0.10	47.76
204385	0.67	1.83	0.10	47.74
204397	0.59	2.03	0.10	47.18
204395	0.55	1.83	0.16	46.68
204414	0.60	1.63	0.10	46.46
204421	0.60	1.64	0.12	46.28
204428	0.60	1.58	0.08	45.91
204406	0.60	1.89	0.10	45.57
204386	0.55	1.66	0.08	45.08
204420	0.55	1.91	0.10	44.85
204431	0.52	1.94	0.06	44.70
204398	0.63	2.23	0.12	44.47
204426	0.61	1.50	0.06	44.47
204435	0.51	1.77	0.08	44.07
204399	0.56	1.77	0.08	44.02
204436	0.48	1.77	0.08	43.83
204396	0.45	1.97	0.13	43.19
204403	0.51	1.60	0.08	43.16
204388	0.55	2.19	0.08	43.08
204407	0.54	1.55	0.10	42.64
204434	0.41	1.75	0.08	42.44
204384	0.53	2.02	0.10	42.26
204383	0.47	1.74	0.10	42.16
204411	0.51	1.55	0.08	42.12
204424	0.49	1.16	0.06	41.47
204423	0.53	1.44	0.06	41.17
204427	0.50	1.89	0.10	41.10
204417	0.48	1.64	0.06	40.74
204409	0.48	1.88	0.10	40.26
204425	0.52	1.40	0.06	40.23
204430	0.40	1.78	0.08	40.03
204392	0.44	1.81	0.10	39.88
204410	0.39	1.64	0.08	39.59
204408	0.37	1.55	0.08	39.28
204433	0.41	1.60	0.06	39.12
204400	0.45	1.97	0.10	38.87
204419	0.40	1.66	0.06	38.76
204415	0.45	1.64	0.08	38.43
204429	0.41	1.66	0.06	38.16
204418	0.37	1.64	0.08	38.02
204387	0.46	1.86	0.08	37.85
204404	0.39	1.67	0.08	37.75
204432	0.29	1.64	0.10	36.96
204394	0.43	1.49	0.06	36.75
204405	0.35	1.55	0.06	35.60
204390	0.25	1.60	0.08	34.64
204401	0.37	1.39	0.10	34.58
204422	0.27	1.81	0.08	34.31
Breed Average	*0.5*	*1.75*	*0.08*	*42.08*
Overall Test Avg	**0.48**	**1.91**	**0.1**	**41.87**

ADG, average daily gain; REA, ribeye area areas generally exhibit greater muscling, while increased backfat thickness may indicate a faster maturity pattern. Across all bucks, average ribeye area measured 1.91 in², and average backfat thickness measured 0.10 in. Boer bucks exhibited the largest average ribeye area (2.33 in²) and greatest average backfat thickness (0.11 in), while Kiko bucks averaged 1.75 in² of ribeye area and 0.09 in of backfat. Evaluating carcass traits alongside growth performance allows producers to identify bucks that not only grow efficiently but also possess the muscling needed to improve the value of market offspring. Registered Boer bucks received ABGA breed standard scores averaging 77.7 points (range: 68.0-86.3), providing producers with an objective assessment of structural quality and breed character in addition to performance data.

Table 2. Boer buck performance summary

Test ID	70-Day ADG (lb)	REA (sq. in.)	Backfat (in.)	Index (pts)	ABGA Standard Score (pts)
204371	0.71	2.48	0.14	49.44	67.33
204363	0.52	2.45	0.08	47.14	77.00
204373	0.60	2.28	0.10	46.53	70.67
204375	0.50	2.73	0.12	46.38	80.33
204366	0.53	2.42	0.08	45.97	82.00
204382	0.54	1.94	0.08	45.12	.
204374	0.48	2.60	0.12	43.77	71.00
204381	0.45	1.89	0.06	42.57	.
204370	0.44	2.19	0.10	42.06	75.67
204361	0.41	2.28	0.14	41.91	86.33
204367	0.41	2.59	0.10	41.65	84.00
204368	0.40	2.25	0.10	40.74	70.00
204365	0.32	2.59	0.10	40.53	73.33
204378	0.40	2.25	0.10	39.78	74.33
204362	0.33	2.20	0.10	38.20	89.67
204377	0.31	2.29	0.15	37.54	80.67
204376	0.29	2.53	0.10	37.44	69.00
204369	0.29	2.08	0.08	34.42	78.33
Breed Average	*0.44*	*2.33*	*0.11*	*42.29*	*77.74*
Overall Test Average	**0.48**	**1.91**	**0.1**	**41.87**	**.**

ADG, average daily gain; REA, ribeye area

2025 Summer Dakota Ram Performance Test

Casey Gambrel[1,2], Samantha Ekstrom[1,2], Carlos Ruiz[1,2], Christopher Schauer[2] and Rachel Gibbs[2]

The Summer Dakota Ram Test is a multistate ram performance evaluation program designed to identify rams with superior genetic potential for economically important and heritable traits, including growth performance and carcass merit. Rams are evaluated under centralized management, and the test provides producers with objective performance data to support more informed genetic selection decisions. Rams are ranked using a weighted performance index that incorporates key measures of growth and carcass value, allowing producers to identify sires with the greatest potential to improve terminal productivity within their flocks.

Summary

Twenty-six Dorset, Hampshire and Suffolk/Hampshire cross ram lambs from six consignors participated in the 2025 Summer Dakota Ram Test at the NDSU Hettinger Research Extension Center (HREC) from June 24, 2025, to Sept. 4, 2025. Rams were evaluated over a 70-day centralized performance test for growth, feed efficiency and carcass merit. Growth performance was measured using average daily gain (ADG), feed efficiency (feed-to-gain) was evaluated during a 28-day SmartFeed Pro intake monitoring period, and carcass traits were assessed by ultrasound. Rams were ranked using a weighted performance index that emphasized growth (ADG), muscling (ribeye area) and lean composition (backfat). Across all breeds, rams averaged 0.75 lb/day ADG, gaining 52.8 lb to reach an average final weight of 156.3 lb. Hampshire rams exhibited the greatest average growth rate (0.78 lb/day), while Dorset and Suffolk/Hampshire cross rams averaged 0.75 and 0.72 lb/day, respectively. Twenty-two of the 26 rams successfully completed the feed efficiency evaluation, averaging 6.35 lb of feed per pound of gain, with individual feed-to-gain ratios ranging from 3.23 to 10.90. Average daily feed intake during the efficiency trial was 4.55 lb/day. Ultrasound evaluation showed an average ribeye area of 2.85 inches^2 and backfat thickness of 0.17 inch, with relatively small differences among breeds. Weighted performance index scores ranged from 62.3 to 135.3, demonstrating substantial variation in overall genetic merit for growth and carcass characteristics. Collectively, the results provide producers with objective data to identify superior ram lambs for improving flock growth performance, feed efficiency and carcass value.

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Introduction

Sheep producers throughout the northern Great Plains utilize performance testing to collect objective data to identify superior rams that have the greatest potential to improve flock productivity. Centralized performance testing standardizes environmental and management factors, allowing observed differences in performance to more accurately reflect the genetic potential of individual rams and to allow comparison across flock origins. The Summer Dakota Ram Test is a centralized performance test that measures several economically important and/or heritable traits that producers can evaluate when selecting rams or genetic lineages to retain within their flocks for terminal productivity.

Procedures

Twenty-six ram lambs of three different breeds (Dorset, Hampshire and Suffolk/Hampshire cross), with birthdates ranging from Jan. 21 to April 2 of 2025, were consigned by six producers and received by the Hettinger Research Extension Center on June 24, 2025. To determine average daily gain (ADG), initial body weight was recorded at the start of the testing period on June 25, 2025, every 28 days and at the end of the growth testing period on Sept. 4, 2025. To estimate feed efficiency, 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) to track individual ram feed intake. 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 to 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 28-day period to estimate feed-to-gain ratio or pounds of feed needed to gain one pound of body weight. At the beginning and the end of the growth testing period, a real-time carcass ultrasound was performed to estimate ribeye area, ribeye depth and back fat cover between the 12th and 13th rib. Ram lambs were ranked with a weighted performance index that combined growth rate, muscle development and fat thickness into a single score. Index scores were calculated by comparing each ram lamb's ADG, ribeye area and backfat thickness to the test average. Deviations from the test average were weighted according to their economic importance, with the greatest emphasis placed on growth (ADG weight = 75), additional credit assigned for greater ribeye area (weight = 20) and a penalty applied for excess backfat (weight = -90). An index score of 100 represents the test average, with scores above 100 indicating above-average combined growth and carcass merit.

Results and Discussion

Rams entered the 70-day performance test with an average body weight of 103.5 pounds, although expected breed differences were evident. Dorset rams averaged 84.4 pounds, Hampshire rams averaged 107.95 pounds and the Suffolk/Hampshire crossbred rams averaged 118.3 pounds at the start of the test. Across all three breeds, rams gained an average of 0.75 pounds per day (Table 1), resulting in a total average gain of 52.75 pounds and a final body weight of 156.25 pounds. Hampshire rams exhibited the greatest average growth rate (0.78 lb/day) and total weight gain (54.5 lb), finishing the test at 162.46 pounds. Dorset rams gained 0.75 pounds per day for a total gain of 52.19 pounds, reaching a final weight of 136.63 pounds, while Suffolk/Hampshire crossbred rams gained 0.72 pounds per day, averaging 50.64 pounds of total gain and a final body weight of 168.93 pounds.

Carcass and feed efficiency data (Table 1) provides producers with insight into ram efficiency and growth/maturity patterns. Carcass ultrasound evaluation at the conclusion of the test revealed an average ribeye area of 2.85 inches^2 and an average backfat thickness of 0.17 in across all rams. Dorset rams averaged 2.78 inches^2 of ribeye area and 0.18 inch of backfat, Hampshire rams averaged 2.83 inches^2 and 0.17 inch and Suffolk/Hampshire crossbred rams averaged the largest ribeye area at 2.97 inches^2 while also averaging 0.17 inch of backfat. Rams with larger ribeye areas indicate greater muscling and increased growth patterns, while rams with greater fat cover may indicate a faster maturity pattern. Twenty-two of the 26 rams successfully adapted to the SmartFeed Pro intake monitoring system and completed the 28-day feed efficiency evaluation. Average daily feed intake during the feed efficiency trial was 4.55 pounds per day, with individual intakes ranging from 3.11 to 6.59 pounds per day. Dorset rams consumed an average of 4.26 pounds per day (range 3.35-5.02), Hampshire rams averaged 4.97 pounds per day (range 3.11-6.59) and Suffolk/Hampshire crossbred rams averaged 4.08 pounds per day (range 3.24-5.18). Across all breeds, rams averaged a feed-to-gain ratio of 6.35, with individual values ranging from 3.23 to 10.90 pounds of feed per pound of gain. Dorset rams were the most feed efficient on average (5.73; range 3.23-9.15), followed by Hampshire rams (6.59; range 4.09-10.25) and Suffolk/Hampshire crossbred rams (7.00; range 4.27-10.90). Rams with lower feed-to-gain ratios indicate greater feed efficiency and more productive use of available feed resources, requiring fewer pounds of feed for each pound of body weight gained. Weighted performance index scores ranged from 62.31 to 135.28, demonstrating substantial variation in overall growth and carcass merit among the consigned rams.

Table 1. Ram performance summary

Test ID	70-Day ADG (lb)	28-Day Avg. DMI (lb)	28-Day Feed:Gain (lb)	REA (sq. in)	Backfat (in)	Index (pts)
Dorset						
204439	0.92	3.35	5.60	2.81	0.21	117.48
204441	0.84	3.95	3.23	2.82	0.14	108.24
204444	0.76	3.40	5.45	2.96	0.16	103.83
204438	0.74	4.98	4.48	3.05	0.16	93.51
204442	0.70	5.02	9.15	2.74	0.19	92.43
204440	0.67	4.36	6.96	2.82	0.21	90.69
204437	0.68	4.56	4.93	2.54	0.21	90.62
204443	0.66	4.42	6.02	2.46	0.15	83.74
Average	*0.75*	*4.26*	*5.73*	*2.78*	*0.18*	*97.57*
Hampshire						
204447	1.09	5.03	6.68	3.41	0.21	135.28
203654	0.94	6.27	8.14	3.95	0.19	134.69
204446	1.24	3.11	6.53	2.46	0.12	134.54
204451	0.94	3.65	4.91	2.48	0.19	112.40
25008	0.65	5.75	5.51	3.21	0.14	100.46
204448	0.74	4.49	6.83	2.73	0.16	98.30
204445	0.72	6.59	10.3	2.59	0.19	94.42
204449	0.64	4.96	5.72	3.02	0.23	84.27
204452	0.59	6.59	7.20	2.88	0.19	81.69
25058	0.52	3.3	4.09	2.06	0.16	74.17
25106	0.51	.	.	2.28	0.12	66.57
Average	*0.78*	*4.97*	*6.59*	*2.83*	*0.17*	*101.53*
Suffolk Hampshire Crossbred						
204458	0.78	3.24	7.71	3.04	0.10	117.31
204457	0.89	5.18	4.27	3.22	0.19	116.90
204456	1.00	4.12	5.10	3.39	0.12	113.71
173925	0.84	3.76	.	3.29	0.23	110.17
204459	0.61	.	10.9	2.28	0.12	98.98
173939	0.61	.	.	2.71	0.21	83.30
174061	0.34	.	.	2.85	0.23	62.31
Average	*0.72*	*4.07*	*7.00*	*2.97*	*0.17*	*100.38*
Overall Avg.	***0.75***	***4.55***	***6.35***	***2.85***	***0.17***	***100.00***

ADG, average daily gain; DMI, dry-matter intake; REA, ribeye area;

Columbia ram performance testing and certification: 2025-2026 Dakota Ram Test

Nikita So[2], Carlos Ruiz[1,2], Samantha Ekstrom[1,2], Christopher Schauer[2] and Rachel Gibbs[2]

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 can be used to help 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

Twelve registered Columbia ram lambs from six consignors participated in the 2025-2026 Dakota Ram Test, where they were evaluated over a 140-day centralized performance test for growth, feed efficiency, carcass merit and wool production. Growth performance was measured using average daily gain (ADG). Feed efficiency was assessed over a 28-day SmartFeed Pro intake monitoring period using residual feed intake (RFI). Carcass traits were evaluated by ultrasound, and wool characteristics were measured following shearing. Rams were also evaluated for breed-specific wool characteristics and structural traits to determine eligibility for Certified Columbia Ram designation through the Columbia Sheep Breeders Association (CSBA). Across the 140-day test, Columbia rams averaged 126 pounds at the start of the evaluation, gained 0.96 pounds per day and finished the test at an average body weight of 260 pounds. Carcass ultrasound measurements averaged 3.56 inches² of ribeye area and 0.28 inch of backfat, while adjusted ribeye area ranged from 1.09 to 1.69 inches² per 100 pounds of body weight. These measurements provide producers with additional information on muscling, maturity pattern and carcass value beyond traditional growth performance. Nine of the 12 rams successfully completed the feed efficiency evaluation. Average daily feed intake ranged from 4.61 to 7.98 pounds per day, averaging 6.23 pounds per day, while residual feed intake values ranged from -1.80 to 1.37, with lower values indicating greater feed efficiency. Wool evaluation showed an average 365-day adjusted clean fleece weight of 12.5 pounds, side fiber diameter of 26.39 microns, britch fiber diameter of 27.22 microns and 365-day adjusted staple length of 4.6 inches. Three rams met all requirements for CSBA Certified Columbia Ram designation, providing producers with valuable information for selection and future breeding decisions.

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Introduction

Columbia sheep producers throughout the northern Great Plains utilize the Dakota Ram Test to generate important performance data for ram selection. Centralized performance tests measure several economically important and/or heritable traits that producers can evaluate when selecting rams or genetic lineages to retain within their flocks. The Dakota Ram Test is a 140-day ram performance test primarily established to evaluate differences in ram wool and postweaning growth performance under the same management conditions, nutritional plane and climate. The CSBA recognizes rams that excel in growth performance, carcass quality and wool quality with the merit of certification, a program initiated in 2017 to promote overall breed improvement.

Procedures

Twelve spring-born registered Columbia rams were consigned by six producers and received by the NDSU Hettinger Research Extension Center on or before Sept. 21, 2025. To determine average daily gain (ADG), initial body weight was recorded when the testing period began on Sept. 3, 2025, every 28 days and at the end of the growth testing period on Feb. 12, 2026. To estimate feed efficiency, 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) to track individual ram feed intake. 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 consistently. Feed efficiency was determined over 28 days as residual feed intake (RFI), which was calculated as the residual from a multiple linear regression model predicting individual dry matter intake (DMI) from average daily gain (ADG) and midtest metabolic body weight (BW^0.75), with negative RFI values indicating greater feed efficiency. At the end of the growth testing period, a real-time carcass ultrasound was performed to estimate ribeye area and fat cover between the 12th and 13th rib. 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. 13, 2026. 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

Columbia rams averaged 126 pounds at the start of the performance test, gained, on average, 0.96 pounds per day over 140 days and averaged 260 pounds at the end of the testing period (Table 2).

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 bodyweight
Face Wool Score	≤ 3
Belly Wool Score	1
Scrapie Resistance Genotype	RR or QR at Codon 171

Table 2. Ram carcass and feed efficiency summary

Ear tag	Reg. #	REA (sq. In)	Fat Depth (in.)	28-Day Avg. DMI (lb/day)	28-Day DMI Total (lb)	28-Day BW Gain (lb)	RFI (lb)
G1	Y22333	3.63	0.23	5.01	130.30	28.5	-0.15
G2	Y22422	3.33	0.27	6.61	178.58	30	1.37
G3	Y22465	3.02	0.25	.	.	.	.
G4	Y22466	2.99	0.29	.	.	.	.
G5	Y22502	2.98	0.21	.	.	.	.
G6	Y22503	3.04	0.39	5.61	151.55	30	0.23
G7	Y22487	3.32	0.37	4.69	126.59	32	-1.80
G8	Y22485	3.92	0.14	7.2	194.34	35	0.21
G9	Y22364	4.54	0.43	6.88	185.63	33	0.67
G10	Y22261	3.10	0.16	6.42	173.43	36	-0.44
G11	Y22260	4.94	0.33	7.98	215.45	25	1.02
G12	Y22259	3.92	0.33	7.26	195.99	16	0.68

REA, ribeye area; BW, body weight; DMI, dry matter intake; RFI, residual feed intake

Average ribeye area at the end of the testing period was 3.56 square inches, and the average back fat thickness over the 12th and 13th rib was 0.28 inches. Adjusted ribeye area ranged from 1.09 to 1.69 square inches per 100 pounds of body weight. Rams with larger ribeye areas and increased adjusted ribeye area ratio indicate greater muscling and increased growth patterns, while rams with greater fat cover may indicate a faster maturity pattern. Nine rams adapted to the smart-feed intake monitoring system and completed the 28-day feed efficiency trial. Average daily feed intake ranged from 4.61 to 7.98 pounds, with an average of 6.23 pounds. Ram residual feed intake ranged from -1.80 to 1.37. Rams with lower residual feed intakes indicate greater feed efficiency and a more productive use of available feed resources. Columbia ram fleeces averaged 12.5 pounds of 365-day adjusted clean wool, a 26.39-micron side fiber diameter, a 27.22-micron britch fiber diameter and a 4.6-inch 365-day staple length. Three rams met all the requirements to qualify for CSBA Certified Columbia Ram designation (Table 3). Of the twelve rams, three rams did not meet the adjusted ribeye area requirement, five rams did not meet the staple length requirement, two rams did not meet the micron requirement, and one ram did not meet the face score requirement to qualify for certification. Overall, the performance test demonstrated substantial variation among Columbia rams in growth, feed efficiency, carcass traits, and wool characteristics, providing producers with additional information to support selection decisions. Continued evaluation of these traits can help advance genetic progress while maintaining the production characteristics valued within the Columbia breed.

Acknowledgments

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

Table 3. Ram performance and certification summary

Ear Tag	Reg. #	Fiber Diameter (side micron)	Adj. STL (in)	140-d ADG (lb/d)	Adj. REA (in/100lb)	Belly Score (pt)	Face Score (pt)	Codon 171 Genotype	Certified?
G1	Y22333	27.1	4.9	0.92	1.43	1.00	1.00	QR	Y
G2	Y22422	26.8	3.9*	0.93	1.37	1.00	1.00	QR	N
G3	Y22465	25.7	4.8	0.91	1.33	1.00	1.00	QR	Y
G4	Y22466	23.2	4.6	1.11	1.23*	1.00	2.00	RR	N
G5	Y22502	27.4	5.1	0.90	1.44	1.00	1.25	RR	Y
G6	Y22503	25.3	5.2	0.95	1.17*	1.00	1.00	QR	N
G7	Y22487	23.2	4.2*	1.00	1.37	1.00	1.25	RR	N
G8	Y22485	26	4.7*	0.92	1.35	1.00	2.75	RR	N
G9	Y22364	25.2	4.4*	0.98	1.69	1.00	1.00	QR	N
G10	Y22261	30.4*	4.5	0.87	1.09*	1.00	4.00*	RR	N
G11	Y22260	29.1*	4.5	1.05	1.64	1.00	3.00	RR	N
G12	Y22259	27.3	4.7*	0.96	1.34	1.00	2.00	RR	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

Rambouillet ram performance testing and certification: 2025-2026 Dakota Ram Test

Nikita So[1], Samantha Ekstrom[1,2], Carlos Ruiz[1,2], Christopher Schauer[2] and Rachel Gibbs[1,2]

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 can be used to help 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 (ARBA) Register of Merit (ROM) program.

Summary

Fifty registered Rambouillet ram lambs from 11 consignors participated in the 2025-2026 Dakota Ram Test, where they were evaluated over a 140-day centralized performance test for growth, feed efficiency, carcass merit and wool production. Growth performance was measured using average daily gain (ADG). Feed efficiency was assessed over a 28-day SmartFeed Pro intake monitoring period using residual feed intake (RFI). Carcass traits were evaluated by ultrasound, and wool characteristics were measured following shearing. Rams were ranked using the American Rambouillet Sheep Breeders Association (ARSBA) Registry of Merit (ROM) performance index, which incorporates growth, adjusted staple length, adjusted clean fleece weight and fiber quality. The top 30% of rams were eligible for ARSBA Certified Ram status, provided they also met additional performance, wool, structural and scrapie-resistance requirements. Forty-seven rams completed the performance test, with index scores ranging from 84.88 to 153.58 and averaging 122.83. Fourteen of the top 15 index-eligible rams met all additional ARSBA certification requirements, while one ram was excluded due to exceeding the fiber diameter requirement. Across all rams, average daily gain was 0.93 pounds per day, increasing body weight from 144 pounds at the start of the test to 241 pounds at the conclusion of the 140-day evaluation. Thirty-two rams successfully completed the feed efficiency evaluation, with residual feed intake values ranging from -1.69 to 1.38 and averaging -0.09, where more negative values indicate greater feed efficiency. Ultrasound evaluation showed an average ribeye area of 3.45 inches^2 and backfat thickness of 0.25 inch, providing producers with additional information on muscling, maturity pattern and biological efficiency to complement the ARSBA performance index.

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Introduction

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. The 140-day ram performance test was established to evaluate differences in ram wool and post-weaning 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 spring-born registered Rambouillet rams were consigned by 11 producers and received by the NDSU Hettinger Research Extension Center on or before Sept. 21, 2025. To determine average daily gain (ADG), initial body weight was recorded when the testing period began on Sept. 3, 2025, every 28 days and at the end of the growth testing period on Feb. 12, 2026. To estimate feed efficiency, 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) to track individual ram feed intake.

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 consistently. Feed efficiency was determined over 28 days as residual feed intake (RFI), which was calculated as the residual from a multiple linear regression model predicting individual dry matter intake (DMI) from average daily gain (ADG) and midtest metabolic body weight ($BW^{0.75}$), with negative RFI values indicating greater feed efficiency. At the end of the growth testing period, a real-time carcass ultrasound was performed to estimate ribeye area and fat cover between the 12th and 13th rib. 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. 13, 2026. 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. 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 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-seven rams completed the 2025-2026 Dakota Ram Test. Ram index scores ranged from 84.88 to 153.58 points, averaging 122.83 points (Table 1). Index scores of rams within the top 30% ranged from 125.86 to 153.58 points. Of the rams scoring in the top 30%, 14 of 15 met the additional requirements for certification as a Certified Ram with the ARSBA (Table 2). One out of 15 index-eligible rams were deemed ineligible for certification due to not meeting the core micron requirement. Growth performance was consistent with rams consigned to previous performance tests at the Hettinger Research Extension Center. Rams averaged 144 pounds at the start of the performance test period, gained, on average, 0.93 pounds per day over 140 days and averaged 241 pounds at the end of the test period. 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 residual feed intake indicate greater feed efficiency and 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. Thirty-two rams adapted to the smart-feed intake monitoring system and completed the 28-day feed efficiency trial. Residual feed intake during the 28-day feed efficiency trial ranged from -1.69 to 1.38, with an average of -0.09. The average ribeye area was 3.45 square inches, and the average backfat thickness was 0.25 inches. The 2025-2026 Dakota Ram Test provides producers with an objective means of comparing Rambouillet rams across economically relevant production traits. Incorporating measures of growth, feed efficiency, carcass merit, and breed certification can help producers make more informed ram selection decisions and support continued genetic improvement within the breed.

Acknowledgments

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

Table 1. Ram performance index score summary

Ear Tag	Reg. #	140-d ADG (lb/d)	Adj-STL (in)	CL FL (lb)	Adjustments Dia. (pt)	Var. (pt)	Index Score (pt)	Index Ratio
Y-29	1001605	0.95	5.5	18.57	0.30	0.00	153.58	126%
Y-25	1001618	1.05	5.5	13.71	4.50	-1.00	143.54	118%
Y-18	1001532	1.08	5.1	14.42	2.70	-3.00	142.10	117%
Y-20	1001530	1.14	5.5	11.54	-0.30	-0.75	135.69	111%
Y-35	1001446	0.98	4.9	16.08	-6.00	-1.25	135.31	111%
Y-14	1001552	1.09	4.7	11.23	5.10	0.00	134.44	110%
Y-45	1001424	0.95	5.3	13.37	2.40	-2.50	131.84	108%
Y-33	1001588	1.12	4.5	10.84	5.40	-2.75	131.48	108%
Y-24	1001617	1.01	5.1	12.16	4.80	-5.25	129.60	106%
Y-30	1001602	0.81	5.5	13.40	7.20	-3.00	128.44	105%
Y-31	1001606	1.05	4.7	13.15	-6.00	0.00	128.24	105%
Y-13	1001563	1.03	4.8	12.26	1.50	-4.00	127.65	105%
Y-11	1001561	1.02	5.1	10.34	5.10	-0.50	127.48	105%
Y-5	1001560	0.85	5.5	12.84	3.00	-1.25	126.34	104%
Y-21	1001614	0.94	4.9	12.70	-0.30	-0.75	125.86	103%
Y-49	1001611	1.04	5.5	13.07	0.00	-3.00	133.86	110%
Y-23	1001616	0.88	5.5	12.87	7.80	-3.25	130.97	107%
Y-8	1001554	0.78	5.5	12.92	9.00	0.00	129.18	106%
Y-15	1001562	0.98	4.9	12.53	0.30	0.00	128.46	105%
Y-17	1001529	1.00	5.0	12.25	-3.30	0.00	125.81	103%
Y-12	1001559	1.00	5.1	10.36	4.80	-1.00	125.48	103%
Y-44	1001540	0.93	5.1	14.88	-6.00	-4.75	125.05	103%
Y-41	1001575	0.99	4.7	13.83	-0.60	-8.00	124.53	102%
Y-4	1001557	0.94	5.1	11.40	3.30	-2.00	124.04	102%
Y-3	1001553	0.98	4.7	10.99	2.10	0.00	123.84	102%
Y-16	1001565	0.87	4.8	12.29	3.00	-1.25	122.22	100%
Y-10	1001555	1.03	5.2	10.96	0.00	-5.25	121.21	99%
Y-46	1001534	0.89	5.5	10.28	6.00	-1.50	120.97	99%
Y-19	1001531	0.89	5.1	14.21	-6.00	-4.50	120.29	99%
Y-43	1001496	0.99	5.2	12.69	-6.00	-5.50	119.36	98%
Y-32	1001589	1.09	4.3	10.69	-6.00	0.00	119.25	98%
Y-27	1001603	0.80	5.4	11.67	3.60	-1.00	118.64	97%
Y-38	1001573	0.76	4.5	15.11	-5.70	0.00	118.53	97%
Y-22	1001615	0.83	5.4	10.47	8.10	-2.50	118.42	97%
Y-9	1001558	0.80	5.1	12.89	0.00	-1.75	118.26	97%
Y-28	1001604	0.79	5.4	11.01	4.50	0.00	117.67	97%
Y-42	1001577	0.94	5.5	10.19	-1.50	-1.00	116.40	95%
Y-39	1001574	0.75	5.0	14.57	-6.00	-1.25	115.91	95%
Y-40	1001576	0.85	5.3	11.52	-3.90	-2.25	112.40	92%
Y-7	1001564	0.90	4.3	10.94	-0.60	-2.00	112.26	92%
Y-1	1001549	0.86	5.1	10.25	1.80	-3.00	112.23	92%
Y-34	1001590	1.01	3.9	9.52	2.70	-5.25	111.37	91%
Y-2	1001550	0.50	4.9	10.66	-6.00	-1.50	84.88	70%

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

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-29	1001605	RR	153.58	0.95	5.50	18.57	1.00	1.00	1.00	21.90	Y
Y-25	1001618	RR	143.54	1.05	5.50	13.71	1.00	1.00	1.00	20.50	Y
Y-18	1001532	QR	142.10	1.08	5.10	14.42	1.00	2.00	1.00	21.10	Y
Y-20	1001530	RR	135.69	1.14	5.50	11.54	1.00	1.25	1.00	22.10	Y
Y-35	1001446	RR	135.31	0.98	4.90	16.08	1.00	1.00	1.00	24.20	Y
Y-14	1001552	RR	134.44	1.09	4.70	11.23	1.00	1.25	1.00	20.30	Y
Y-45	1001424	RR	131.84	0.95	5.30	13.37	1.00	1.00	1.25	21.20	Y
Y-33	1001588	RR	131.48	1.12	4.50	10.84	1.00	1.00	1.00	20.20	Y
Y-24	1001617	RR	129.60	1.01	5.10	12.16	1.00	1.00	1.25	20.40	Y
Y-30	1001602	RR	128.44	0.81	5.50	13.40	1.00	1.25	1.00	19.60	Y
Y-31	1001606	RR	128.24	1.05	4.70	13.15	1.00	2.25	1.50	25.00*	N
Y-13	1001563	RR	127.65	1.03	4.80	12.26	1.00	1.00	1.00	21.50	Y
Y-11	1001561	RR	127.48	1.02	5.10	10.34	1.00	1.00	1.00	20.30	Y
Y-5	1001560	RR	126.34	0.85	5.50	12.84	1.50	1.00	1.00	21.00	Y
Y-21	1001614	RR	125.86	0.94	4.90	12.70	1.00	1.00	1.00	22.10	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 summary

Ear Tag	Reg. #	REA (sq. in.)	Fat Depth (in.)	28-Day Avg. DMI (lb/day)	28-Day Total DMI (lb)	28-Day BW Gain (lb)	RFI
Y1	1001549	2.96	0.21	5.09	137.38	121	0.22
Y2	1001550	3.21	0.12	.	.	.	.
Y3	1001553	3.60	0.21	5.36	144.6	138	0.58
Y4	1001557	3.18	0.31	.	.	.	.
Y5	1001560	3.32	0.19	.	.	.	.
Y6	1001556	3.41	0.21	5.91	159.7	124	0.37
Y7	1001564	3.80	0.21	5.71	154.13	126	-0.07
Y8	1001554	2.62	0.23	5.43	146.48	109	0.36
Y9	1001558	3.19	0.31	.	.	.	.
Y10	1001555	3.47	0.25	6.9	186.42	144	1.38
Y11	1001561	2.90	0.29	6.34	171.12	143	0.17
Y12	1001559	4.06	0.27	6.9	186.34	140	0.19
Y13	1001563	3.83	0.33	6.49	175.19	145	0.99
Y14	1001552	3.39	0.29	.	.	.	.
Y15	1001562	3.08	0.21	.	.	.	.
Y16	1001565	3.49	0.29	.	.	.	.
Y17	1001529	3.16	0.23	4.13	111.44	141	-1.34
Y18	1001532	3.77	0.21	.	.	.	.
Y19	1001531	3.13	0.16	4.59	123.81	125	-1.06
Y20	1001530	4.05	0.25	5.47	147.63	160	-1.07
Y21	1001614	3.24	0.23	.	.	.	.
Y22	1001615	3.57	0.19	.	.	.	.
Y23	1001616	3.81	0.27	5.37	145.12	124	-0.32
Y24	1001617	3.88	0.27	4.47	169.8	142	-1.26
Y25	1001618	2.98	0.37	6.4	172.74	148	0.35
Y26	1001607	3.18	0.23	4.47	116.14	100	-1.33
Y27	1001603	2.70	0.25	2.86	77.29	112	-1.56
Y28	1001604	2.87	0.21	5.11	132.73	111	0.17
Y29	1001605	2.91	0.29	5.97	161.13	133	0.18
Y30	1001602	2.91	0.29	5.09	137.33	114	-0.82
Y31	1001606	3.91	0.25	6.13	165.56	147	0.12
Y32	1001589	3.80	0.23	6.45	174.16	153	0.49
Y33	1001588	3.78	0.19	6.29	169.96	157	0.18
Y34	1001590	4.26	0.19	7.01	189.24	141	1.28
Y35	1001446	3.60	0.25	.	.	.	.
Y38	1001573	3.19	0.31	.	.	.	.
Y1	1001549	2.96	0.21	5.09	137.38	121	0.22
Y2	1001550	3.21	0.12	.	.	.	.
Y3	1001553	3.60	0.21	5.36	144.6	138	0.58
Y4	1001557	3.18	0.31	.	.	.	.
Y5	1001560	3.32	0.19	.	.	.	.
Y6	1001556	3.41	0.21	5.91	159.7	124	0.37
Y7	1001564	3.80	0.21	5.71	154.13	126	-0.07

REA, ribeye area; BW, bodyweight; F:G, feed-to-gain; DMI, dry matter intake; RFI, residual feed intake

Discovering performance and value in North Dakota Calves: 2025-2026 Dakota Feeder Calf Show Feedout

Karl Hoppe[1] and Dakota Feeder Calf Show Livestock Committee[2]

The Dakota Feeder Calf Show is a feedout project in which North Dakota cattle producers identify cattle with superior growth and carcass characteristics. For the 2025-2026 feeding period, the average difference in profitability between consignments from the top five herds and the bottom five herds was $338.82 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 NDSU Carrington Research Extension Center Livestock Unit on Oct. 18, 2025. After a 263-day feeding period with 2.27% death loss, cattle averaged 1,450.2 pounds (shrunk harvest weight). Feed required per pound of gain was 8.6 (dry-matter basis). Overall pen average daily gain was 3.14 pounds. Feed cost per pound of gain was $0.782, and total cost per pound of gain was $1.080. Profit ranged from $333.94 per head for pen-of-three cattle with superior growth and carcass traits to $(283.33) per head. The variability among producers' herds remains substantial when considering the feeding and carcass value of spring-born calves.

Introduction

Although cattle prices are trending upward, cow-calf producers need to be competitive amid rising production costs and 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 exhibit exceptional feedlot performance and produce high-quality carcasses.

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. 18, 2025, at the Turtle Lake Weighing Station in Turtle Lake, North Dakota, 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 132,104 of which competed in the pen-of-three contest.

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

Calves were sorted and placed on a corn and distillers grains-based receiving diets. After an eight-week backgrounding period, the calves were transitioned to a 0.58 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-Choice on Jan. 27, 2026.

The cattle were harvested on July 9, 2026 (129 head). The cattle were sold to Tyson Fresh Meats in Dakota City, Nebraska, on a grid basis, with

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premiums and discounts based on carcass quality and yield. 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% of score), marbling score (25% of score) and profit (25% of score) and subtracting index value for calculated yield grade (25% 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 591.1 pounds upon delivery to the NDSU Carrington Research Extension Center Livestock Unit on Oct. 18, 2026. After a 263-day feeding period, cattle averaged 1,450.2 pounds (at plant, shrunk weight). Three steers died during the feeding period.

Average daily feed intake per head was 41.5 pounds on an as-fed basis and 27.0 pounds on a dry-matter basis. Pounds of feed required per pound of gain were 13.23 on an as-fed basis and 8.60 pounds on a dry-matter basis.

The overall feed cost per pound of gain was $0.782. The overall yardage cost per pound of gain was $0.126. Bedding cost was $0.050 per pound of gain. The combined cost per pound of gain, including feed, yardage, veterinary, trucking and other expenses except interest, was $1.080.

Calves were priced by weight upon delivery to the feedlot. The pricing equation ($ per 100 pounds = (-0.52529621* initial calf weight, pounds) + 790.4614008) was determined by regression analysis of local livestock auction prices reported for the week before delivery.

Overall, the carcasses contained U.S. Department of Agriculture Quality Grades at 5.4% Prime, 80.6% Choice (including 32.6% Certified Angus Beef), and 14.0% Select. The USDA Yield Grades for carcasses were 3.1% YG1, 18.6% YG2, 41.8% YG3, 26.4% YG4, and 10.1% 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 July 9, 2026, was $409.32 Choice YG3 base with premiums: Prime $15, CAB $6, YG1 $6.50 and YG2 $3; and discounts: Select minus $16, YG4 minus $16, YG5 minus $32 and carcasses heavier than 1,100 pounds minus $15 or lighter than 650 pounds minus $20.

Overall, the pen-of-three calves averaged 464.2 days of age and 1,483.3 pounds per head at slaughter (Table 1). The overall pen-of-three feedlot average daily gain was 3.33 pounds, while weight gain per day of age was 1.87 pounds. The overall pen-of-three marbling score was 512.4 (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 and average daily gain had higher correlations to profitability than average birth date, average weight per day of age, marbling score or yield grade.

The top-profit pen-of-three calves with superior genetics returned $333.94 per head, while the bottom pen-of-three calves returned a negative $283.33 per head. The profit of the five top-scoring pens of steers averaged $252.70 per head, while the profit of the bottom five scoring pens of steers averaged a negative $86.11 per head.

For the pen-of-three competition, average profit was $81.69 per head. The spread in profitability between the top and bottom five herds was $338.82 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. Higher profit per head was a result of superior feedlot weight gain and higher value carcass characteristics in 2026. Feedout projects continue to provide cattle producers with information on feedlot performance and individual animal differences, and discovering cattle value.

Table 1. Feeding performance — 2025-2026 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	2.744	23-Mar-25	1.93	1519.0	3.46	605.7	3.66	$303.52
2	2.704	12-Apr-25	1.88	1527.7	3.24	656.0	4.14	$333.94
3	2.471	20-Mar-25	1.94	1553.6	3.50	467.3	3.58	$284.48
4	2.383	4-May-25	2.21	1520.9	3.61	449.7	3.36	$193.24
5	2.292	18-Feb-25	1.83	1575.3	3.51	575.7	4.29	$148.34
Average Top 5 herds	**2.519**	**28-Mar-25**	**1.96**	**1539.3**	**3.46**	**550.9**	**3.81**	**$252.70**
6	2.251	27-Apr-25	1.97	1477.5	3.27	409.0	3.01	$169.58
7	2.233	18-Mar-25	2.00	1628.4	3.63	517.7	4.82	$244.75
8	2.213	31-Mar-25	1.91	1469.7	3.37	432.3	3.14	$118.51
9	2.194	13-Mar-25	1.86	1542.0	3.39	495.3	3.71	$117.27
10	2.183	23-Mar-25	1.68	1447.7	3.00	654.3	4.58	$122.62
11	2.116	8-Mar-25	1.97	1566.6	3.64	459.3	4.42	$178.59
12	2.113	23-Mar-25	1.79	1364.1	3.20	589.3	3.63	$(29.55)
13	2.088	8-Mar-25	1.81	1476.2	3.34	491.7	3.69	$58.07
14	2.057	5-Apr-25	2.00	1503.4	3.49	463.0	4.12	$116.77
15	2.053	14-Apr-25	1.95	1412.7	3.33	467.3	3.46	$32.66
16	2.043	6-Apr-25	1.31	1585.4	3.45	508.3	4.75	$161.09
17	2.015	16-Mar-25	2.01	1549.7	3.66	500.7	4.83	$124.04
18	2.005	20-Apr-25	1.79	1402.7	3.01	503.0	3.20	$(22.56)
19	1.968	2-May-25	1.94	1338.2	3.18	436.7	2.78	$(62.88)
20	1.949	3-Mar-25	1.77	1526.4	3.29	587.3	4.88	$52.45
21	1.940	n.a.(2)	n.a.[2]	1494.0	3.44	598.7	5.01	$25.94
22	1.930	29-Apr-25	1.91	1387.1	3.16	356.3	2.45	$(34.55)
23	1.927	5-Apr-25	1.78	1447.7	3.11	518.0	3.70	$(29.91)
24	1.916	n.a.(2)	n.a.[2]	1500.5	3.42	593.3	4.70	$(30.63)
25	1.842	14-Mar-25	1.73	1440.3	3.16	505.3	3.90	$(42.96)
26	1.752	26-Mar-25	1.82	1467.8	3.23	607.3	5.14	$(43.73)
27	1.284	16-May-25	1.88	1325.0	2.96	360.3	3.23	$(283.33)
Average bottom 5 herds	**1.744**	**7-Apr-25**	**1.80**	**1436**	**3.18**	**517**	**4.13**	**$(86.11)**
Overall average - pens of three	**2.112**	**31-Mar-25**	**1.87**	**1,483.32**	**3.33**	**511.44**	**3.932**	**$81.695**
Standard deviation		21.9	0.16	76.70	0.20	81.48	0.74	136.20
number		25	25	27	27	27	27	27

[1]Marbling score 300-399 = select, 400-499 = low choice, 500-599 = average choice, 600-699 = high choice, 700-799 = low prime
Spread: Top 5 to Bottom 5 Herds $338.82
[2]not available

Table 2. Correlations between profit and various production measures (pen of three) — 2025-2026 Dakota Feeder Calf Show Feedout

	Correlation coefficient
Profit and average birth date	-0.3567
Profit and average slaughter weight	0.7710
Profit and average daily gain	0.6270
Profit and weight per day of age	0.2250
Profit and marbling score	0.2887
Profit and yield grade	0.2001

Increasing grain in finishing diets improves feed efficiency in Rambouillet lambs

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

Feed accounts for the highest cost of finishing lambs, making feed efficiency critical to profitability. Increasing grain inclusion improved feed efficiency without changing growth performance or methane emitted per unit of feed consumed, supporting the use of higher-energy finishing diets to improve production efficiency.

Summary

Sheep are raised under diverse management systems, ranging from intensive confinement to more extensive pasture-based operations, which may influence how lambs utilize dietary energy for growth. To better understand the impact of dietary composition on performance, feed efficiency and methane intensity, three diets differing in grain-to-roughage ratio (GRR; high-grain, 50:50 and high-roughage) were evaluated. We found that grain-to-roughage ratio did not affect average daily gain or methane intensity but did improve feed efficiency.

Introduction

Feed is the largest expense in finishing lamb production, making feed efficiency a key factor influencing both profitability and production sustainability. Increasing the grain-to-roughage ratio is a common management practice used to increase dietary energy density and improve animal performance, but changes in dietary composition may also affect enteric methane production and overall energy utilization. Understanding these responses can help producers make informed feeding decisions that balance biological performance with feed costs and resource efficiency. The objective of this study was to evaluate the effects of three grain-to-roughage ratios on growth performance, feed efficiency and enteric methane emissions in finishing Rambouillet lambs. We hypothesized that increasing dietary grain inclusion would improve feed efficiency while reducing methane production by more efficient utilization of dietary energy.

Procedures

This study was approved by the Institutional Animal Care and Use Committee at North Dakota State University. Twenty-six finishing Rambouillet lambs were enrolled in this trial and assigned to one of three diets (Table 1): high-grain (HG; 80:20 GRR; n=7), half and half (MIX; 50:50 GRR; n=10) and high-roughage (HR; 20:80 GRR; n =9). Each diet differed in nutrient composition, most notably in fiber content (Table 2). All lambs were adapted to an automated feed intake monitoring system and used to evaluate the impact of dietary composition on finishing lamb growth performance and feed efficiency over a 35-day trial. Average daily gain was calculated using two-day body weights collected and averaged at the beginning of the growth testing period (days -1 and 0) and at the end of the growth test period (days 34 and 35). As an indicator of dietary energy utilization and resource efficiency, enteric CH_4 emissions were measured using an automated gas-capture system (GreenFeed; C-Lock Inc., Rapid City, South Dakota) over the five-week trial. Growth performance, feed efficiency and CH_4 intensity were

Table 1. Ingredient composition of experimental diets fed to Rambouillet lambs

	Treatment[2]		
Ingredient[1]	HG	MIX	HR
Corn, %	40	25	10
Oats, %	40	25	10
Market lamb supplement, %	20	20	20
Alfalfa, %	0	30	60

[1]Ingredient inclusion expressed as a percentage of dietary dry matter.
[2]HG – 80% grain, 20 % roughage; MIX – 50% grain, 50% roughage; HR = 20% grain, 80% roughage.

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analyzed using ANOVA (SAS 9.4; SAS Institute Inc.), with experimental diet, sex and their interaction included as fixed effects. Weekly CH_4 emissions were analyzed using a repeated measures mixed model, with animal as the subject and week, diet, sex and their interactions as fixed effects. Statistical significance was declared at $P \leq 0.05$, and tendencies toward significance were declared at $0.05 < P \leq 0.10$.

Results and Discussion

No diet × sex interactions were observed for growth performance or CH_4 emissions; therefore, results are presented across sexes. Lambs fed the high-grain (HG) diet were more feed efficient than lambs fed the high-roughage (HR) diet, while lambs fed the 50:50 (MIX) diet were intermediate (Table 3). Final body weight, total weight gain, average daily gain, and dry matter intake did not differ among dietary treatments. However, the relatively small sample size did produce numerical differences in feed intake among treatments, which may have influenced the gain-to-feed ratio. These findings indicate that increasing grain inclusion in finishing diets can improve feed efficiency without compromising lamb growth performance, providing producers with an opportunity to improve biological efficiency during the finishing phase. Lambs consuming the HG diet produced less CH_4 per day than lambs fed the HR diet, while CH_4 production was intermediate for lambs consuming the MIX diet (Table 4). However, CH_4 emissions expressed relative to feed intake were similar among treatments, indicating that the reduction in daily CH_4 production was primarily associated with lower feed consumption rather than a reduction in methane produced per unit of feed consumed. Collectively, these results suggest that increasing grain inclusion can improve feed utilization without increasing CH_4 intensity (emissions per pound of feed intake), although additional research is needed to determine whether dietary grain can consistently reduce enteric CH_4 emissions and to better understand its relationship to feed intake.

Table 2. Nutrient Composition of treatment diets fed to Rambouillet lambs

	Treatment[2]		
Nutrient[1]	HG	MIX	HR
CP, %	16.80	16.90	21.60
ADF, %	11.10	22.30	32.20
Ash, %	5.28	7.50	10.50
ME, Mcal/lb	0.69	0.64	0.58
NEm, Mcal/lb	0.41	0.37	0.33
NEg, Mcal/lb	0.27	0.25	0.21

[1] Values expressed on a dry matter basis.
[2] HG – 80% grain, 20 % roughage; MIX – 50% grain, 50% roughage; HR = 20% grain, 80% roughage.

Table 3. Effects of grain inclusion on lamb performance, dry matter intake and G:F

	Treatment[1]			
Item	HG	MIX	HR	*P*-value[2]
Final BW, lb	147.93 ± 4.10	140.06 ± 3.15	147.93 ± 3.57	0.20
BW gain, lb	18.54 ± 2.43	16.84 ± 1.87	16.38 ± 2.12	0.78
ADG, lb/d	0.53 ± 0.07	0.49 ± 0.04	0.46 ± 0.07	0.78
DMI, lb	147.7 ± 14.93	163.85 ± 11.51	183.23 ± 13.03	0.13
G:F	0.13 ± 0.01[a]	0.10 ± 0.01[ab]	0.09 ± 0.01[b]	0.04

[1]HG – 80% grain, 20 % roughage; MIX – 50% grain, 50% roughage; HR = 20% grain, 80% roughage.
[2]*P*-value for the overall F test of the treatments (n = 7, 10 and 9 for HG, MIX and HR respectively)
[a-b] Least squares means within a row with different superscripts differ ($P \leq 0.05$). Least square means were separated when *P*-values were < 0.05 for treatment.

Table 4. Effects of grain inclusion on CH4 emissions treatment in Rambouillet lambs

	Treatment[1]			
CH_4 Emissions	HG	MIX	HR	*P*-value[2]
CH_4, g/d	34.80 ± 4.83[a]	52.47 ± 3.55[ab]	50.29 ± 3.30[b]	0.02
CH_4, g/kg DMI	9.80 ± 2.04	12.74 ± 1.25	11.82 ± 1.36	0.48

[1]HG – 80% grain, 20 % roughage; MIX – 50% grain, 50% roughage; HR = 20% grain, 80% roughage.
[2]P-value for the overall F test of the treatments (n = 7, 10, and 9 for HG, MIX, and HR, respectively)
[a-b] Least squares means within a row with different superscripts differ ($P \leq 0.05$). Least square means were separated when *P*-values were < 0.05 for treatment.

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Whole soybeans and lubabegron in finishing diets: Effects on steer performance and carcass traits

Pauliane Pucetti[1], Madison Bierman[2], Timothy Schroeder[2] and Kendall C. Swanson[1]

Moderate whole-soybean inclusion was more practical than high inclusion. Steers fed 12.5% whole soybeans maintained overall gain closer to those fed 0% whole soybeans, whereas 25% whole soybeans reduced average daily gain and tended to reduce feed efficiency without reducing dry matter intake. Within the 25% whole-soybean diet, lubabegron supplementation tended to improve gain and increased carcass dressing percentage, but it should complement — not replace — careful diet formulation.

Summary

This study evaluated increasing whole-soybean inclusion and the response to lubabegron supplementation in finishing steers. Increasing whole soybeans reduced average daily gain without affecting dry matter intake, with a more pronounced reduction at 25% than at 12.5% inclusion. Within the 25% whole-soybean diet, lubabegron tended to improve gain and increased dressing percentage without increasing intake. These results support moderate whole-soybean inclusion in balanced finishing diets and indicate that lubabegron may improve selected performance and carcass outcomes when high levels of whole soybeans are fed.

Introduction

Feeding whole soybeans can provide dietary protein and lipids in cattle diets. For North Dakota cattle feeders, using whole soybeans directly in finishing diets may create an additional market for soybean growers while replacing part of the corn and supplemental protein source normally used in the ration. The energy value of the diet is expected to increase as soybean lipid replaces carbohydrate; however, more fat does not always result in more gain.

High concentrations of dietary lipid — particularly unsaturated fatty acids — can inhibit ruminal microorganisms, alter fiber digestion and change nutrient use. The response depends on the amount and source of lipid and on the remainder of the diet. Adequate effective fiber, a suitable balance of rumen-degradable and metabolizable protein, and appropriate grain and forage proportions remain important when whole soybeans are added (NASEM, 2016). In the present diets, predicted fat increased from 3.01% to 5.25% and 7.57% of dry matter as whole soybeans increased from 0% to 12.5% and 25%, respectively.

Lubabegron (Experior®; Elanco US Inc., Greenfield, Indiana) is a beta-adrenergic agonist/antagonist approved by the U.S. Food and Drug Administration for reducing ammonia gas emissions per pound of live weight and hot carcass weight when fed during the final 14 to 91 days on feed (FDA, 2018). Research also has reported improvements in average daily gain, feed efficiency and hot carcass weight when lubabegron was fed during the final 56 days (Kube et al., 2021). Whether similar performance responses occur when cattle receive a high level of whole soybeans is not well established. Therefore, the objectives were to determine the effects of increasing levels of whole-soybean inclusion on finishing steer diets and to evaluate the effects of lubabegron supplementation in the 25% whole-soybean diet on intake, growth, efficiency and carcass traits.

Experimental Procedures

A total of 130 crossbred beef steers, averaging approximately 952 lb at the start of the finishing period, were assigned to 16 pens in a completely randomized design at the NDSU Carrington Research Extension Center. Pens contained seven to nine steers each, and four pens were assigned to each treatment. The treatments were 0% whole soybeans (WSB), 12.5% WSB, 25% WSB and 25% WSB plus lubabegron. The first three treatments were used to evaluate the WSB dose response. The fourth treatment received the same 25% WSB basal diet and was used only for the direct lubabegron

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comparison. One steer was removed before final body weight and carcass data were collected, leaving 31, 33, 33 and 32 steers in the four treatments, respectively. The pen — not the individual animal — was the experimental unit.

The three basal diets were formulated to provide similar crude protein while WSB replaced soybean meal and portions of the energy ingredients (Table 1). The diets were fed for 162 days. Lubabegron was included in the designated 25% WSB treatment during the final 56 days, followed by a seven-day withdrawal interval before harvest. Feed delivery was recorded daily. Bunks were managed to remain practically clean and no measurable refusals were present; consequently, dry matter supplied was used as pen dry matter intake.

Steers were weighed on two consecutive days at the beginning of the experiment, at the start of lubabegron feeding and at the end of the experiment. These weights defined a 99-day prelubabegron period, a 63-day terminal period that included 56-day lubabegron supplementation and seven-day withdrawal, and the complete 162-day feeding period. Average daily gain was calculated from period-specific body weights, and gain-to-feed ratio was calculated as gain divided by dry matter intake. Hot carcass weight, dressing percentage, marbling score, ribeye area, backfat thickness and yield and quality grades were collected at harvest.

Continuous responses were analyzed using the MIXED procedure of SAS with treatment as a fixed effect and one observation per pen. Planned contrasts evaluated linear and quadratic responses among 0%, 12.5% and 25% WSB without lubabegron and the direct comparison between 25% WSB with and without lubabegron. Statistical significance was declared at $P \leq 0.05$ and tendencies at $0.05 < P \leq 0.10$.

WSB = whole soybeans; NDF = neutral detergent fiber. The 25% WSB + lubabegron treatment received the same basal diet as the 25% WSB treatment. Nutrient composition was predicted using the 2016 Beef Cattle Nutrient Requirements Model (NASEM, 2016).

Table 1. Ingredient and predicted nutrient composition of finishing diets containing increasing levels of whole soybeans (dry matter basis).

Item	0% WSB	12.5% WSB	25% WSB
Ingredient composition, % of diet DM			
Corn silage	30.00	30.00	30.00
Soybean hulls	11.80	13.70	10.00
Corn grain	37.50	32.00	32.00
Whole soybeans	0.00	12.50	25.00
Soybean meal	17.70	8.80	0.00
Limestone	1.50	1.50	1.50
Vitamin and mineral supplement	1.35	1.35	1.35
Salt	0.15	0.15	0.15
Predicted nutrient composition			
Net energy for maintenance, Mcal/lb	0.83	0.84	0.87
Net energy for gain, Mcal/lb	0.55	0.56	0.58
Crude protein, % DM	16.30	16.26	16.28
Fat, % DM	3.01	5.25	7.57
Physically effective NDF, % DM	12.41	14.16	16.00

Results and Discussion

Initial body weight and body weight at the start of lubabegron feeding did not differ among treatments ($P = 0.993$ and $P = 0.789$, respectively; Figure 1), indicating that pens were comparable at both reference points. During the 99-day period before lubabegron feeding, average daily gain decreased linearly from 3.66 to 3.46 and 3.18 lb/day as WSB increased from 0% to 12.5% and 25% of diet dry matter ($P = 0.001$). Gain-to-feed ratio also decreased linearly during this period (0.159, 0.146 and 0.143; $P = 0.005$), whereas dry matter intake did not change linearly ($P = 0.321$). Because these responses occurred before lubabegron was fed, they reflect the WSB diets rather than the feed additive.

Across the complete 162-day period, average daily gain was 3.50, 3.42 and 3.12 lb/day for 0%, 12.5% and 25% WSB, respectively, and decreased linearly as WSB inclusion increased ($P = 0.007$; Figure 1A). Overall dry matter intake averaged 24.93, 25.51 and 23.73 lb/day and was not affected by level of WSB inclusion ($P = 0.182$; Figure 1B). Gain-to-feed ratio tended to decrease linearly (0.141, 0.134 and 0.132; $P = 0.065$; Figure 1C) with increasing WSB inclusion. Thus, the lower gain at 25% WSB was not simply caused by cattle eating less feed. The 12.5% WSB treatment remained numerically close to the control, whereas performance declined more clearly at 25% WSB.

The diets were formulated to contain almost identical crude protein, and the predicted energy value increased as WSB inclusion increased. Nevertheless, the cattle did not convert the high-WSB diet into additional gain. The study did not directly measure ruminal fermentation or nutrient digestibility, so the mechanisms responsible for the decreased gain cannot be identified. However, the response is consistent with the practical concern that high unsaturated-lipid intake can alter rumen microbial activity and nutrient utilization. Whole soybeans should therefore be evaluated as part of the complete ration rather than only as a source of additional energy. Dietary lipid level, effective fiber, protein supply and the ingredients displaced by WSB all should be considered.

Within the direct 25% WSB comparison, lubabegron tended to increase average daily gain during the 63-day terminal period from 3.04 to 3.42 lb/day ($P = 0.088$), an increase of approximately 12%. Terminal dry matter intake was similar (26.12 vs. 26.55 lb/day; $P = 0.675$), and terminal gain-to-feed ratio increased numerically from 0.117 to 0.129 but was not statistically different ($P =$

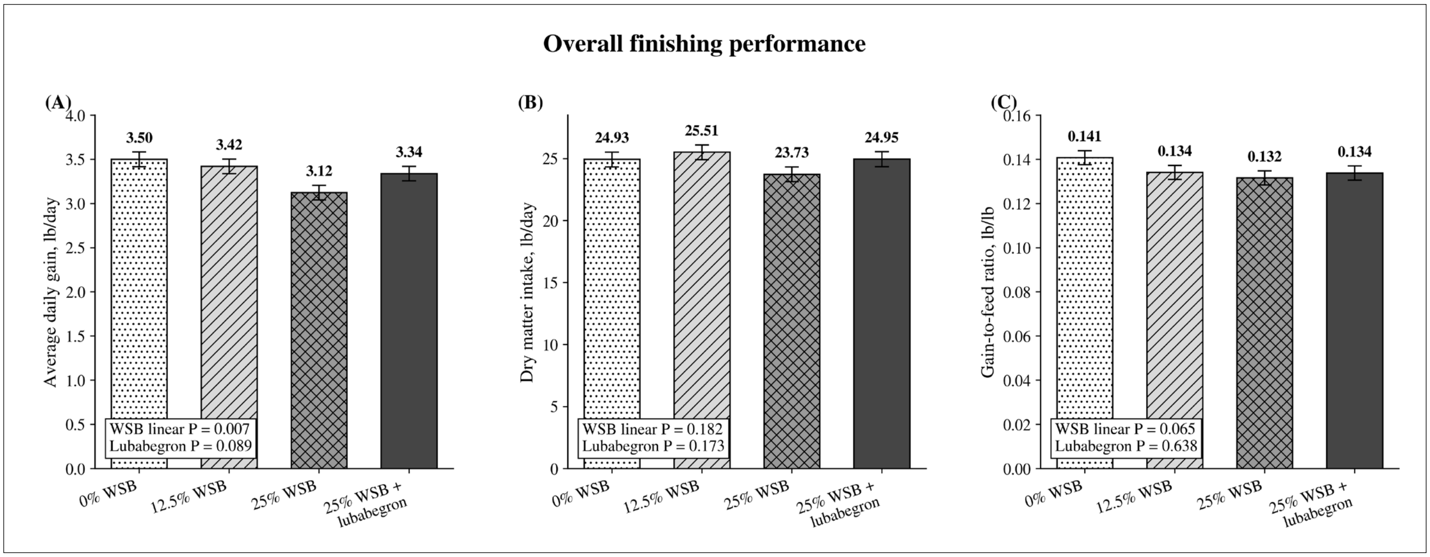

Figure 1. Overall (A) average daily gain, (B) dry matter intake, and (C) gain-to-feed ratio of steers fed diets containing 0%, 12.5%, or 25% whole soybeans (WSB), or 25% WSB plus lubabegron, for 162 days. Values are pen least-squares means ± SEM; n = 4 pens per treatment. For the linear contrast among 0%, 12.5%, and 25% WSB without lubabegron, *P*-values were 0.007, 0.182, and 0.065 for panels A, B, and C, respectively. For the comparison between the 25% WSB diets without and with lubabegron, P-values were 0.089, 0.173, and 0.638 for panels A, B, and C, respectively.

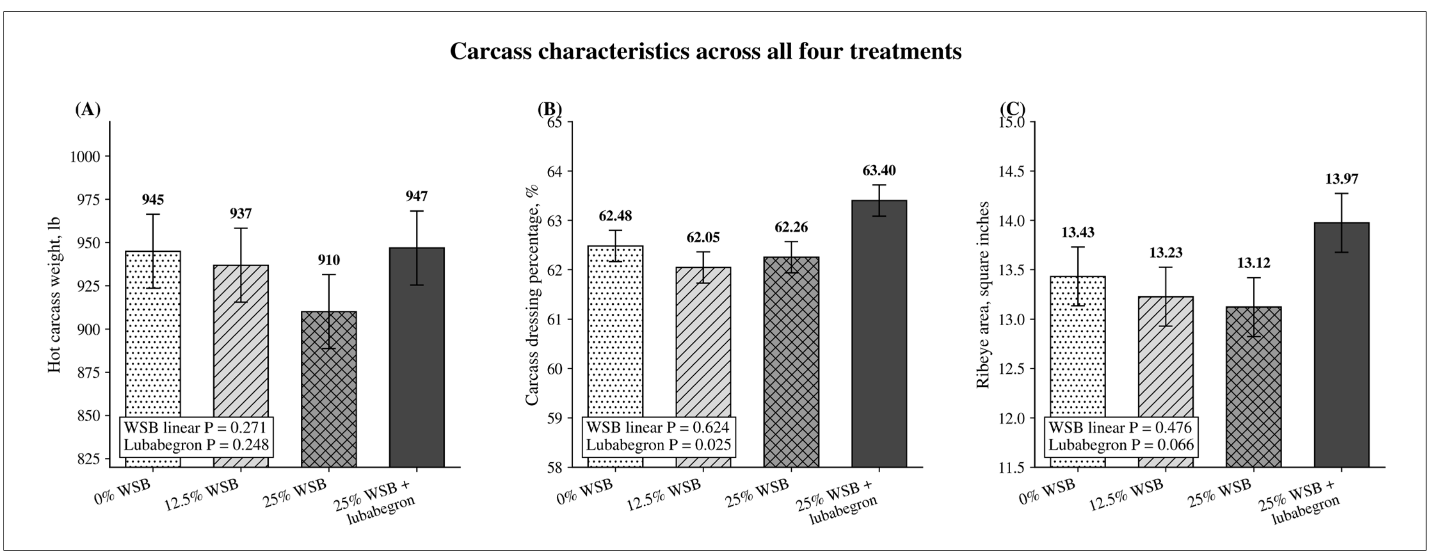

Figure 2. (A) Hot carcass weight, (B) carcass dressing percentage, and (C) ribeye area of steers fed diets containing 0%, 12.5%, or 25% whole soybeans (WSB), or 25% WSB plus lubabegron. Values are pen least-squares means ± SEM; n = 4 pens per treatment. For the linear contrast among 0%, 12.5%, and 25% WSB without lubabegron, *P*-values were 0.271, 0.624, and 0.476 for panels A, B, and C, respectively. For the comparison between the 25% WSB diets without and with lubabegron, P-values were 0.248, 0.025, and 0.066 for panels A, B, and C, respectively.

0.144). Overall average daily gain also tended to increase from 3.12 to 3.34 lb/day with lubabegron (*P* = 0.089; Figure 1A). These responses indicate that the possible gain benefit was not driven by greater feed intake.

Lubabegron increased dressing percentage from 62.26% to 63.40% within the 25% WSB diet (*P* = 0.025; Figure 2B). Ribeye area also tended to increase from 13.12 to 13.97 square inches (*P* = 0.066; Figure 2C). Hot carcass weight was 910 and 947 lb for 25% WSB without and with lubabegron, respectively, but the direct contrast was not significant (*P* = 0.248; Figure 2A). Marbling score, backfat thickness and calculated yield grade were not affected by lubabegron (*P* ≥ 0.386).

Lubabegron supplementation produced consistent positive responses within the 25% WSB diet. In addition to increasing dressing percentage, lubabegron tended to improve average daily gain and ribeye area and resulted in a numerical increase in hot carcass weight. Some of these responses did not reach statistical significance, which may be related to the limited number of experimental units available in this study. Future studies with more pens per treatment are warranted to confirm the magnitude and consistency of these responses when lubabegron is supplemented in diets containing high levels of whole soybeans.

In conclusion, whole soybeans can provide a locally available source of protein and energy for finishing cattle, but more was not necessarily better. Under the conditions of this study, 12.5% WSB provided the more balanced practical response, while 25% WSB reduced gain and tended to reduce feed efficiency without reducing intake. Lubabegron improved dressing percentage and tended to improve gain within the 25% WSB diet. It may improve the value recovered during the terminal feeding period, but it should be viewed as a management tool used with a well-balanced diet, not as a substitute for appropriate formulation.

Acknowledgments

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References

Food and Drug Administration (FDA). 2018. Freedom of Information Summary, Original New Animal Drug Application NADA 141-508, Experior (lubabegron Type A medicated article). U.S. Food and Drug Administration, Center for Veterinary Medicine. https://animaldrugsatfda.fda.gov/adafda/app/search/public/document/downloadFoi/5005

Kube, J. C., B. P. Holland, A. B. Word, J. B. Allen, M. Calvo-Lorenzo, D. McKenna and G. Vogel. 2021. Effects of various doses of lubabegron on calculated ammonia gas emissions, growth performance, and carcass characteristics of beef cattle during the last 56 days of the feeding period. Translational Animal Science 5:txab137.

National Academies of Sciences, Engineering, and Medicine (NASEM). 2016. Nutrient Requirements of Beef Cattle. 8th rev. ed. The National Academies Press, Washington, DC.

Corn grain processing and forage inclusion effects on finishing cattle growth performance and feeding behavior

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The objective of this experiment was to determine the effect of corn grain processing (dry-rolling vs. corn) and forage inclusion (5% vs. 15% of diet dry matter) on finishing cattle performance, feeding behavior and carcass characteristics. Our data indicate that feeding whole corn grain vs. dry-rolled corn and increasing forage inclusion in finishing diets increases dry matter intake without influencing average daily gain.

Summary

Seventy steers (776 ± 12.1 lb of body weight) were used to determine the effect of corn grain processing (dry-rolling vs. whole) and forage inclusion (5% vs. 15% inclusion, dry matter basis) on growth performance, feeding behavior and carcass characteristics. Steers were allotted by body weight to one of three pens. Within each pen, steers were assigned randomly to one of four dietary treatments: 1) dry-rolled corn + 5% forage [n = 19], 2) whole corn + 5% forage [n = 15], 3) dry-rolled corn + 15% forage [n = 18] and 4) whole corn + 15% forage [n = 18]. Intake and feeding behavior traits were calculated from data generated using the Insentec feeding system. Steers were slaughtered with an average body weight of 1382 ± 26.7 lb and were slaughtered in two groups at day 142 (n = 40) and day 203 (n = 30) of the finishing period. Final body weight and average daily gain were not influenced ($P \geq 0.12$) by dietary treatment. Dry matter intake was greater ($P \leq 0.004$) in steers fed whole corn grain and in steers fed 15% forage. Hot carcass weight, ribeye area, 12th rib fat and marbling score were not influenced ($P \geq 0.45$) by dietary treatment. Number of visits to the feeder per day was greater ($P = 0.01$) in steers fed 15% forage and number of meals per day was greater ($P = 0.004$) in steers fed dry-rolled corn. Time eating per day was greater ($P \leq 0.04$) in steers fed whole corn grain and in steers fed 15% forage. Time eating per meal was greater ($P = 0.002$) in steers fed whole corn grain. Dry matter intake per meal was greater ($P < 0.001$) in steers fed whole corn and tended to be greater ($P = 0.06$) in steers fed 15% forage. Our data indicate that feeding whole corn grain vs. dry-rolled corn and increasing forage inclusion in finishing diets increases dry matter intake without influencing average daily gain. Forage inclusion level does not seem to influence the effects of corn grain processing on growth performance. Efficiency of nutrient utilization seems to be improved when feeding dry-rolled corn vs. whole corn grain. Therefore, the decision to dry-roll corn for finishing diets is dependent on availability and cost of feed processing equipment for on-site rolling or costs of purchasing dry-rolled corn vs. whole corn grain.

Introduction

Feed costs represent the largest direct cost in beef production. Grain processing and forage inclusion level are two of the major factors influencing production efficiency in finishing operations. For smaller operations, such as farmer feeders or cow/calf producers finishing their own calves, equipment infrastructure for grain processing can dictate what is feasible, and dry-processing may be the best option in most cases.

There are many considerations when making the decision to dry-roll or not. The primary reason for grain processing is to increase the surface area of the grain to allow the microbes in the rumen to have better access to the inside of the kernel, containing starch, which is highly digestible and provides the majority of the energy for typical finishing cattle diets in North America. However, too much highly available starch can be detrimental and result in the microbes in the rumen producing excess acid, which can reduce growth performance because of influences on feed intake and ruminal and liver tissue health. Therefore, it is important to optimize grain processing to maximize digestion without the negative consequences of ruminal acidosis. Additionally, forage inclusion level influences ruminal fermentation and pH because consuming forage results

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in more chewing, rumination and salivation, which helps buffer the pH of the rumen.

Owens et al. (1997) summarized data from several studies that examined effects of grain source and processing method on growth performance of finishing cattle and reported that finishing cattle fed diets containing whole corn grain had improved gain-to-feed ratios compared with those fed dry-rolled corn. However, the results were summarized and calculated across several studies, and typically, the diets containing whole corn grain contained a lower inclusion of forage, which could have increased energy supply since corn has more dietary energy than forage. Therefore, our objective was to determine the effects of corn grain processing (dry-rolled vs. whole) and forage inclusion level (5% vs. 15% of DM) on growth performance and feeding behavior. We hypothesized that corn grain processing would influence growth performance differently depending on forage inclusion level.

Procedures

All procedures with animals were approved by the North Dakota State University (NDSU) Animal Care and Use Committee. Seventy steers (776 ± 12.1 lb of body weight), predominantly of Angus and Simmental breeding, were used in a 2 × 2 factorial arrangement of treatments to determine the effect of corn grain processing (dry-rolling vs. whole) and forage inclusion (5% vs 15% inclusion, dry matter basis) on growth performance, feeding behavior and carcass characteristics. Steers were allotted into three pens (light, medium and heavy pens) and housed at the NDSU Beef Cattle Research Complex. Within each pen, steers were assigned randomly to one of four dietary treatments: 1) dry-rolled corn + 5% forage [n = 19], 2) whole corn + 5% forage [n = 15], 3) dry-rolled corn + 15% forage [n = 18] and 4) whole corn + 15% forage [n = 18]. Diets were offered for ad libitum intake. Steers were adapted to experimental diets by transitioning to the final diet over a 21-day period. Intake and feeding behavior traits were calculated from data generated via the Insentec feeding system. Steers were slaughtered with an average body weight of 1382 ± 26.7 lb and were slaughtered in two groups at day 142 (n = 40) and day 203 (n = 30) of the finishing period. Data were analyzed as a completely randomized block (days to slaughter) design using the mixed procedure of SAS with a 2 × 2 factorial arrangement of treatments. Data were considered significant when $P \leq 0.05$, and a tendency was considered when $0.05 < P \leq 0.10$.

Results and Discussion

Final body weight and average daily gain were not influenced ($P \geq 0.12$) by dietary treatment (Table 3). Dry matter intake was greater ($P \leq 0.004$) in steers fed whole corn grain and in steers fed 15% forage. Hot carcass weight, ribeye area,

Table 1. Diet composition.

	Treatment			
	5% forage		15% forage	
Dietary Component, % of DM	Dry-rolled	Whole	Dry-rolled	Whole
Corn, dry-rolled	77.5	-	62.5	-
Corn, whole	-	77.5	-	62.5
DDGS	10	10	10	10
Corn silage	5	5	15	15
Grass hay	2.5	2.5	7.5	7.5
Fine-ground corn	1.61	1.61	1.61	1.61
Limestone	1.5	1.5	1.5	1.5
Urea	1.0	1.0	1.0	1.0
Salt	0.1	0.1	0.1	0.1
Vitamin premix[1]	0.01	0.01	0.01	0.01
Mineral premix[2]	0.05	0.05	0.05	0.05
Rumensin[3]	0.02	0.02	0.02	0.02

[1]Contained 48,510 kIU/kg vitamin A and 4,630.5 kIU/kg vitamin D.
[2]Contained 3.62% Ca, 2.56% Cu,16% Zn, 6.5% Fe, 4.0% Mn, 1.050 mg/kg I, and 250 mg/kg Co.
[3]Contained 176.4 g monensin/kg premix.

Table 2. Analyzed nutrient concentrations of diets (DM basis).

	Treatment			
	5% forage		15% forage	
Dietary Component, % of DM	Dry-rolled	Whole	Dry-rolled	Whole
Organic matter	95.9	95.9	93.9	93.8
Crude protein	14.5	14.6	14.7	14.9
Neutral detergent fiber	20.0	20.4	27.5	26.5
Acid detergent fiber	4.63	4.70	6.11	7.22
Starch	56.7	58.2	47.0	37.9
Ether extract	3.36	3.36	2.95	2.97
Calcium	0.54	0.52	0.82	0.78
Phosphorus	0.34	0.34	0.33	0.32

12th rib fat and marbling score were not influenced ($P \geq 0.45$) by dietary treatment. Number of visits to the feeder per day was greater (P = 0.01) in steers fed 15% forage, and number of meals per day was greater (P = 0.004) in steers fed dry-rolled corn (Table 4). Time eating per day was greater ($P \leq 0.04$) in steers fed whole corn grain and in steers fed 15% forage. Time eating per meal was greater (P = 0.002) in steers fed whole corn grain. Dry matter intake per meal was greater ($P < 0.001$) in steers fed whole corn and tended to be greater (P = 0.06) in steers fed 15% forage.

Research results are inconsistent across studies when examining the effects of including dry-rolled corn vs. whole corn in finishing cattle diets on growth performance. When data were summarized using data from several studies, Owens et al. (1997) reported that cattle fed diets containing whole corn grain had decreased dry matter intake and improved gain-to-feed ratios compared with those fed dry-rolled corn. However, the results were summarized and calculated from several studies, and typically, the diets containing whole corn grain contained a lower inclusion of forage, which could have increased energy supply since corn has more dietary energy than forage. This is in contrast to the observed increase in dry matter intake in steers fed diets containing whole corn grain in the current experiment. Reasons for this discrepancy are not clear, but because digestibility (and thus

Table 3. Effects of grain processing and forage inclusion on growth performance and carcass characteristics in finishing cattle.

	Treatment							
	5% forage		15% forage					
Item	Dry-rolled	Whole	Dry-rolled	Whole	SEM[a]	Processing	Forage	Processing × forage
Initial weight, lb	764	797	767	779	26.2	0.40	0.32	0.52
Final weight, lb	1351	1387	1396	1396	57.7	0.39	0.32	0.52
Average daily gain, lb/d	3.22	3.18	3.37	3.40	0.126	0.95	0.12	0.79
Dry matter intake, lb	24.5	25.7	26.9	28.5	0.51	0.004	<0.001	0.79
Gain:feed	0.131	0.126	0.125	0.119	0.004	0.071	0.13	0.80
Hot carcass weight, lb	864	862	877	869	16.1	0.68	0.47	0.84
Ribeye area, in^2	12.9	13.1	13.1	13.4	0.34	0.54	0.45	0.88
12th rib fat, in	0.685	0.530	0.705	0.646	0.0445	0.54	0.45	0.88
Marbling score[b]	544	522	549	537	25.1	0.47	0.69	0.83

[a]Standard error of the mean (n = 15).
[b]400 to 499 = small, 500 to 599 = modest.

Table 4. Effects of grain processing and forage inclusion on feeding behavior in finishing cattle.

	Treatment							
	5% forage		15% forage			*P*-value		
Item	Dry-rolled	Whole	Dry-rolled	Whole	SEM[a]	Processing	Forage	Processing × forage
Events, per d								
Visits	34.3	36.6	40.8	43.2	2.66	0.35	0.01	0.98
Meals	8.77	7.93	8.93	8.33	0.277	0.007	0.29	0.64
Time eating, min								
Per visit	2.69	2.91	2.76	2.77	0.244	0.63	0.87	0.65
Per meal	10.2	12.6	11.5	13.5	0.708	0.002	0.11	0.77
Per day	89.4	98.9	101.1	111.4	5.14	0.04	0.01	0.93
Eating rate, lb								
Per visit	0.744	0.765	0.727	0.705	0.051	0.99	0.42	0.65
Per meal	2.82	3.29	3.06	3.46	0.118	<0.001	0.06	0.79
Per min	0.294	0.271	0.272	0.260	0.014	0.19	0.22	0.68

[a]Standard error of the mean (n = 15).

dietary) net energy concentration of diets containing whole corn grain is likely decreased, it would be expected that dry matter intake would be greater in cattle fed diets containing whole corn grain because dry matter intake typically increases when less energy-dense finishing diets are fed (Krehbiel et al., 2006). Similarly, we also observed an increase dry matter intake in steers fed diets containing 15% forage, likely because of the effects that forage inclusion has on digestibility and energy density of the diet. The lack of an interaction between corn processing and forage inclusion suggests that the effects of corn processing on growth performance measures are not influenced by forage inclusion level. Overall, the observed decrease in feed intake and gain-to-feed ratio suggests that dry-roll processing improves the efficiency of nutrient utilization in finishing cattle, at least with forage inclusion levels between 5% and 15% of the diet dry matter.

The observed increases in time spent eating per day in steers fed whole corn grain and in steers fed 15% is consistent with past research that has shown that feeding diets that are less digestible results in increased time eating per day (Carvalho et al., 2020; Carvalho and Felix, 2021). Consistent with these findings, we also observed that steers fed whole corn grain spent more time eating per meal and consumed more feed per meal than steers fed dry-rolled corn. This could be because whole corn grain requires greater mechanical breakdown of the corn for efficient utilization, resulting in slower consumption and more chewing and rumination.

In conclusion, forage inclusion level did not influence the effects of corn grain processing on growth performance. Efficiency of nutrient utilization tended to be improved when feeding dry-rolled corn vs. whole corn grain. The decision to dry-roll corn for finishing diets is dependent on availability and cost of feed processing equipment for on-site rolling or costs of purchasing dry-rolled corn vs. whole corn grain.

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References

Carvalho, P. H. V., and T. L. Felix. 2021. Effects of feeding dry-rolled corn or whole shelled corn on feedlot performance, carcass characteristics, and eating behavior of finishing Holstein steers. Appl. Anim. Sci. 37:132–139.

Carvalho, P. H. V., A. C. J. Pinto, D. D. Millen, and T. L. Felix. 2020. Effect of cattle breed and basal diet on digestibility, rumen bacterial communities, and eating and rumination activity. J. Anim. Sci. 98:skaa114.

Krehbiel, C. R., J. J. Cranston, and M. P. McCurdy. 2006. An upper limit for caloric density of finishing diets. J. Anim. Sci. 84 E. Suppl.:E34–E49.

Owens, F. N., D. S. Secrist, W. J. Hill, and D. R. Gill. 1997. The effect of grain source and grain processing on performance of feedlot cattle: a review. J.Anim.Sci. 75:868–879.

High forage versus high concentrate heifer diets during gestation on progeny carcass traits

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Maternal diets during gestation may influence progeny carcass characteristics, as steers from the high-forage dams have displayed heavier cold carcass weights and primal chuck weights, while no significant differences were observed in marbling, ribeye area and 12th rib backfat.

Summary

Limited research has examined the effects of maternal nutrition throughout the whole of gestation in heifers on progeny carcass characteristics and meat quality. This study evaluated the impact of high-forage (HF, 75% forage, 25% concentrate, n = 11) or high-concentrate (HC, 75% concentrate, 25% forage, n = 11) diets fed to crossbred Angus heifers from 15 days prebreeding through calving on offspring carcass traits and meat quality. Progeny were all fed a typical finishing diet and harvested at approximately 14 months of age over a one-month period. The carcasses were evaluated for ribeye area, yield grade, marbling score and 12th rib backfat. Blade, ribeye, sirloin and round steaks were collected upon carcass fabrication for drip loss, shelf-life, thaw loss, cook loss and Warner-Bratzler shear force (14- and 21-day-aged). Cold carcass weights and primal chuck weights were heavier ($P < 0.002$), and hot carcass weights tended ($P < 0.075$) to be heavier for HF compared to HC progeny. Live weight, dressing percentage, yield grade, ribeye area, 12th rib backfat and round weights did not differ between treatments. Kidney, pelvic and heart fat percentage tended to be lower ($P < 0.09$) in HF carcasses. Shear force values did not differ at 14 days of aging; however, at 21 days, HC shear force values were lower ($P < 0.019$). The HF blade steaks had less water loss ($P < 0.008$) during thawing. During shelf-life evaluation, HF blade steaks were less ($P < 0.05$) red (a^*) on days 5-7, and there was a tendency ($P < 0.06$) for lower lightness (L^*) in HF round steaks on day 7. Results suggest maternal heifer diets may influence progeny carcass weight as well as affect meat tenderness, thaw loss and color stability in carcass forequarter. The novelty of our findings regarding the chuck indicates a need for all aspects of the carcass parts to be evaluated.

Introduction

High forage-based diets for pregnant heifers may not always be feasible, particularly during times of drought or seasonal changes in the quality of available forages-grasses where nutritional requirements may not be met. Therefore, alternative diets should be considered, as the nutritional needs of heifers are greater than in cows and change throughout the entire length of gestation. There is limited research on the effects of feeding different sources of dietary energy during the whole of gestation on heifers and on progeny outcomes, particularly the quality and yield of the meat they produce. Previous research has evaluated maternal diets and the effects on progeny carcass characteristics, but the focus has been on mature cows and targets specific times of gestation, usually mid- to late-gestation. Radunz et al. (2012) found that progeny that were harvested from cows fed a low-starch diet during late gestation had higher marbling scores, but USDA Low Choice, Upper ⅔ and Prime did not differ between treatments (low-starch [grass hay and dried corn distillers grains with solubles] vs. high-starch [corn]). Ewes fed a diet containing high inclusion of dried corn distillers grains with solubles during mid- to late-gestation had lower dressing percentages and boneless, closely trimmed retail cuts of the DDGS diet (Radunz et al. 2011). Given the limited research conducted in this area, it is important to understand which carcass traits can be affected by the diet fed to cows and heifers during gestation. Therefore, the objective was to evaluate the effect of feeding high-forage or high-concentrate diets from 15 days prebreeding through calving on progeny carcass characteristics and meat quality traits.

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Procedures

Forty-six crossbred Angus heifers from 15 days prebreeding through calving were fed two different diets to achieve similar average daily gains consisting of either 75% forage and 25% concentrate (n = 24; HF) or 75% concentrate and 25% forage (n = 22; HC). The heifers conceived and calved at the NDSU Beef Cattle Research Complex. For this study, a subset (n = 11; HF, n = 11; HC) of progeny steers were managed similarly throughout growing and finishing. During finishing, all steers were fed the same high-concentrate diet (90% concentrate, DM basis). Steers were fed out at the NDSU Animal Nutrition and Physiology Center and were harvested at approximately 14 months of age over one month, with treatment stratified across harvest days. The steers were harvested at the NDSU Meat Lab under USDA inspection. Carcasses were weighed, and kidney fat was removed and weighed prior to entrance into the carcass cooler. Carcass measurements were recorded, including weight, marbling, ribeye area and 12th rib fat depth. Carcasses were stored in the cooler for 14 days prior to fabrication. Upon fabrication, primal weights and circumference were recorded for round (IMPS 158) and chuck (IMPS 113). Steaks (1 in) from the round (top), sirloin (top), ribeye and blade were cut during carcass fabrication for shelf-life and Warner-Bratzler shear force (WBSF). Smaller samples (1.7 oz) from each cut were used to evaluate drip loss for 48 hours. Steaks for shelf-life were placed on polystyrene trays, overwrapped with PVC film and stored in an upright refrigerator at 34 degrees Fahrenheit for seven days, with L^* (black to white), a^* (red to green) and b^* (yellow to blue) values recorded every 24 hours using a HunterLab spectrophotometer for the evaluation of fresh meat color. Steaks for WBSF were weighed, vacuum packaged and either frozen at minus 3 degrees Fahrenheit (aged 14 days) or stored at 34 degrees Fahrenheit for an additional seven days (aged 21 days) then frozen until evaluation. Steaks were thawed at 34 degrees Fahrenheit and weighed to measure thaw water loss. Steaks were cooked on a clam-shell grill to 152-154 degrees Fahrenheit, removed and rested on a metal tray until a peak temperature of 165-170 degrees Fahrenheit was reached and recorded. Cooked steaks were weighed to determine cook loss percentage. Steaks were stored at 34 degrees Fahrenheit overnight. For WBSF, a minimum of three cores were removed parallel with muscle fiber, and shear force was determined by measuring the amount of force needed in kilograms to shear through each core using a Warner-Bratzler shear force machine.

Results and Discussion

Steers from the heifers given the HF diet during gestation had a tendency ($P < 0.08$) for higher hot carcass weights (766.1 lb vs. 741.6 lbs.; SE = 9.3 lb). The left side cold carcass weight was heavier for the high forage than the high concentrate diet (364.9 lb vs. 342.4 lb, respectively; SE = 4.4 lb; $P < 0.002$). Additionally, the primal chuck weight for the HF diet was heavier (129.9 lb vs. 121.7 lb; SE= 1.5 lb; $P < 0.002$). There weren't any differences ($P > 0.1$) of maternal diets on steer progeny final live weights,

Table 1. Least square means for carcass measurements from steers whose dams were fed either a high concentrate (HC) or high forage (HF) diet throughout gestation.

	Treatment			
Variable	Concentrate (HC)	Forage (HF)	SEM	*P*-value
Live Weight (lb.)	1,262.40	1,282.40	16.8	0.40
Hot Carcass Weight (lb.)	741.6	766.1	9.3	0.08
Dressing Percentage (%)	58.8	59.7	0.4	0.14
12th Rib Backfat (in.)	0.63	0.69	0.06	0.53
Kidney, Pelvic, and Heart Fat (%)	2.32	2.14	0.07	0.10
Ribeye Area (in.^{2})	12	12.17	0.9	0.67
Marbling Score	421	449	13	0.13
Total Kidney Fat (lb.)	7.44	6.85	1.07	0.70
Final Yield Grade	2.1	2.2	0.2	0.73

Marbeling Score = 400-499 = small; 500-599 = modest

Table 2. Least square means for cold carcass weight and primal chuck and round measurements from steers whose dams were fed either a high concentrate (HC) or high forage (HF) diet throughout gestation.

	Treatment			
Variable	Concentrate (HC)	Forage (HF)	SEM	*P*-value
Cold Carcass Weight - one side (lb.)	342.6	364.9	4.4	0.002
Primal Round Weight (lb.)	75.4	79.4	1.8	0.12
Primal Round Circumference (in.)	44.2	45	0.6	0.28
Primal Chuck Weight (lb.)	121.7	129.9	1.5	0.002
Primal Chuck Circumference (in.)	59.3	60.9	0.7	0.13

dressing percentages, 12th rib backfat and ribeye area, marbling score, total kidney fat and final yield. Water loss during thawing was greater for the HC diet in the blade steak (6.77% vs. 5.12% $P < 0.008$). Additionally, the blade steak also tended ($P < 0.05$) to have higher a* values (more red) for days 5, 6 and 7 of simulated retail display in the HC diet. There was also a tendency ($P < 0.06$) for lower L* values (lightness) in HF round steaks on day 7 of display. While no differences were observed in the 14-day aged steaks between the treatment diets, WBSF for the HC diet was lower compared to the high forage (2.37 kg vs. 2.58 kg; $P < 0.019$) in 21-day aged steaks, which is most likely driven by a large difference between blade steaks where the HC diet showed lower (more tender) WBSF values compared to the HF diet (2.5 kg vs. 2.94 kg; $P < 0.04$). Based on our observations, the primal chuck of offspring carcasses was influenced the most by heifer gestational diet. The HF steers had heavier primal chuck while the HC steers had a more red, lighter blade steaks that were more tender after 21 days of aging. However, the HC had greater thaw loss. Evaluation of the beef chuck has not often been evaluated in previous evaluations of maternal diet on progeny meat yield and quality. Based on the results of this study, evaluation of the primal chuck should be investigated further.

Acknowledgments

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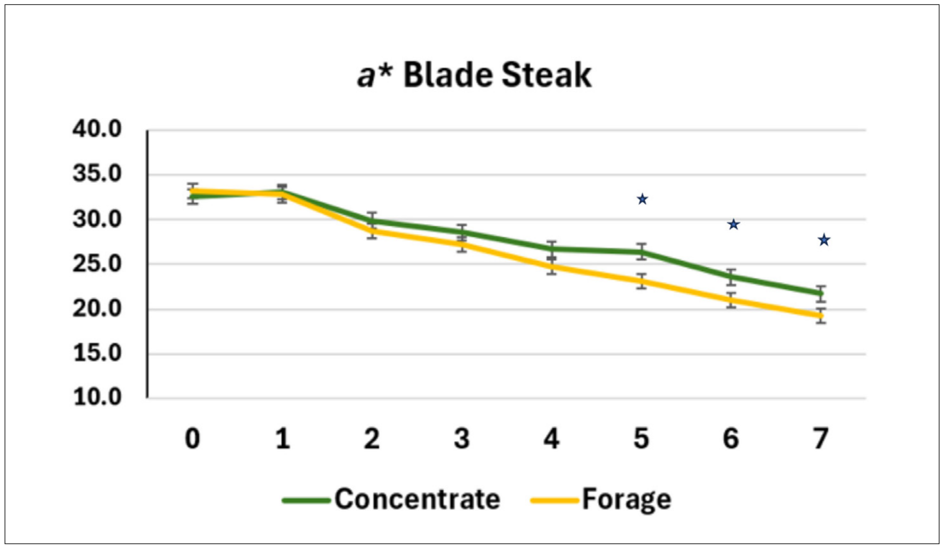

Figure 1. Instrumental *a values of concentrate and forage in the blade steaks**

* = Indicates days where HC diet was significant $P < .05$

Literature Cited

Finck, C. A., P. Pucetti, G. Aryee, K. Helmuth, C. R. Dahlen, K. K. Sedivec, S. Amat, and K. C. Swanson. 2025. Evaluating the impact of maternal diet during gestation on offspring energetic efficiency in finishing steers. North Dakota Livestock Research Report, pg. 9–11.

Kuzel, B. M., J. L. Hurlbert, K. R. M. Slavick, M. S. P. Carlis, C. R. Dahlen, S. Amat, K. K. Sedivec, K. C. Swanson, J. S. Caton, S. R. Underdahl, and G. D. Ramirez-Zamudio. 2025. 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. North Dakota Livestock Research Report, pg. 12–16.

Radunz, A. E., F. L. Fluharty, A. E. Relling, T. L. Felix, L. M. Shoup, H. N. Zerby, and S. C. Loerch. 2012. Prepartum dietary energy source fed to beef cows: II. effects on progeny postnatal growth, glucose tolerance, and carcass composition. J. Anim. Sci. 90:4962–4974.

Radunz, A. E., F. L. Fluharty, I. Susin, T. L. Felix, H. N. Zerby, and S. C. Loerch. 2011. Winter-feeding systems for gestating sheep II. effects on feedlot performance, glucose tolerance, and carcass composition of Lamb progeny. J. Anim. Sci. 89:478–488.

Protein and energy supplementation during midgestation in beef heifers and the impacts on maternal performance, metabolic status, calving characteristics and offspring outcomes through weaning

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This study evaluated whether protein and energy supplementation during midgestation could improve heifer nutritional status, calving characteristics and calf growth through weaning. Strategic protein and energy supplementation during midgestation improved heifer body weight and condition and reduced reliance on body reserves for protein and energy metabolism. Calves born to supplemented heifers were heavier at birth and tended to be heavier through weaning, with the greatest weight advantage observed at pasture turn out.

Summary

Forage quality for beef cattle often declines in late summer, fall and winter, potentially limiting the protein and dietary energy available to pregnant cows and heifers. Strategic supplementation during midgestation may help meet increasing nutrient demands while supporting dam condition and calf growth. This study evaluated whether protein and energy supplementation of pregnant beef heifers from day 90 to 186 of gestation could improve dam nutritional status and calf growth through weaning. Heifers received either a forage-based diet (CON; n = 22) or a forage-based diet plus a protein and energy supplement (SUPP; n = 22) before being managed similarly after the supplementation period. Supplemented heifers gained more weight, had greater body condition scores and had lower circulating nonesterified fatty acids, indicating less reliance on body fat reserves. Calves from supplemented heifers were 5.2 lb heavier at birth and tended to be heavier through weaning, with the greatest weight advantage of 17.5 lb observed at pasture turnout. Overall, strategic protein and energy supplementation during midgestation improved maternal nutritional status and supported greater early life calf growth, although further evaluation is needed to determine whether these benefits persist beyond weaning. Further evaluation of postweaning performance and subsequent breeding season success in the cow herd will help determine the long-term production value of this management strategy.

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Introduction

Nutritive value of grazed forages for beef cattle often declines in the late summer/fall and winter months, with crude protein levels dropping below 6% in some regions (Schauer et al., 2005). During this period, pregnant heifers in the northern Great Plains, often in their second trimester of gestation for spring-calving cow herds, may struggle to meet the protein and energy demands of gestation with grazed forages alone. Strategic supplementation during midgestation therefore has the potential not only improve forage utilization and digestibility in the dam but also elicit positive outcomes on calf growth before birth and subsequently throughout postnatal life (Llewellyn et al., 2006; Cappellozza et al., 2014).

The objectives were to evaluate the impacts of providing a protein and energy supplement to beef heifers during midgestation on dam performance, calving outcomes, circulating blood metabolites in the dam and calf, and growth performance of the male offspring through weaning. We hypothesized that protein/energy supplementation would increase dam and calf body weights, enhance circulating blood metabolites, and positively influence placental and colostrum characteristics at calving and postnatal growth in the calf.

Procedures

Angus-based beef heifers (n = 143) were bred via artificial insemination (AI) using male sexed semen at the NDSU Central Grasslands Research Extension Center (CGREC). Pregnancies were confirmed on day 35 after breeding, and fetal sex was determined at day 65 after breeding. Shortly after, all heifers pregnant to AI with male fetuses (n = 44; initial body weight [BW] = = 940.9 ± 68 lb) were transported to the NDSU Beef Cattle Research Complex (BCRC) in Fargo, North Dakota, stratified by body weight and randomly assigned to receive a protein and energy supplement with a basal forage diet (SUPP; n = 22) or a basal forage diet with no supplementation (CON; n = 22) from day 90 to day 186 of gestation. The diet for SUPP heifers consisted of 30% corn silage, 45% grass hay and 25% Accuration (Land O' Lakes Purina) on a dry-matter basis, while the diet for CON heifers consisted of 40% corn silage and 60% grass hay on a dry-matter basis. All heifers received a pelleted mineral product at the company-directed rate of 1 lb per day.

Daily feed intakes were managed strategically with the Insentec feeding system to target daily gains of 0.62 lb/day for heifers assigned to CON and 1.74 lb/day for heifers assigned to SUPP. Body weights were collected on the pregnant heifers every two weeks and body condition scores on a nine-point scale were recorded at the start (day 90), midpoint (day 138) and end (day 186) of the second trimester feeding trial. Following the treatment period, all heifers were transported back to the CGREC and managed on a common forage-based diet through parturition and pasture turnout. Heifers were also weighed shortly before calving (d 257), at calving (average d 279) and at pasture turnout (average 68 day postpartum). Blood samples were collected from the dams at these six major time points throughout the experiment and from their calves at birth, pasture turnout and at weaning. Blood serum samples were analyzed for concentrations of glucose, nonesterified fatty acids (NEFA) and blood urea nitrogen (BUN).

At calving and prior to suckling, BW of the dam and neonatal calf (*n* = 21 CON; *n* = 21 SUPP) were recorded, and calving date was recorded to calculate gestation length. Dams were assigned a calving ease score from 1 to 5 (1 = unassisted birth to 5 = cesarean). Additionally, a single quarter of the udder was completely milked to estimate colostrum volume and mass. The placenta was collected upon expulsion and rinsed and weighed, and total number of cotyledons were counted. In the period shortly after birth, calves were assigned a vigor score of 1 to 5 (1 = nursed independently to 5 = stillborn). At 24 hours after colostrum consumption, calf BW was recorded, and morphometric characteristics were evaluated, including chest and abdominal circumference, crown-rump length, shoulder-to-hip length, hip width and hip height. Calves continued to be weighed at pasture turnout and at weaning.

As mentioned previously, the male calves born in this experiment were weighed, and blood was collected at birth, pasture turnout and weaning to determine if maternal supplementation influenced long-term growth and metabolism.

Statistical Methods

Data were analyzed as a completely randomized design, and individual animal was considered the experimental unit for all analysis. All variables were analyzed using the MIXED procedure of SAS with repeated measures applied where appropriate. Variables were analyzed for the effect of F0 treatment, day of gestation/age and the respective interaction. Significance was considered at $P \leq 0.05$, and tendencies considered at $0.05 < P \leq 0.10$.

Results and Discussion

The actual gains recorded during the midgestation supplementation period were 0.55 lb/day and 1.66 lb/day for CON and SUPP heifers, respectively. Furthermore, SUPP heifers were heavier than CON at the end of the supplementation period and at calving ($P = 0.02$; Figure 1).

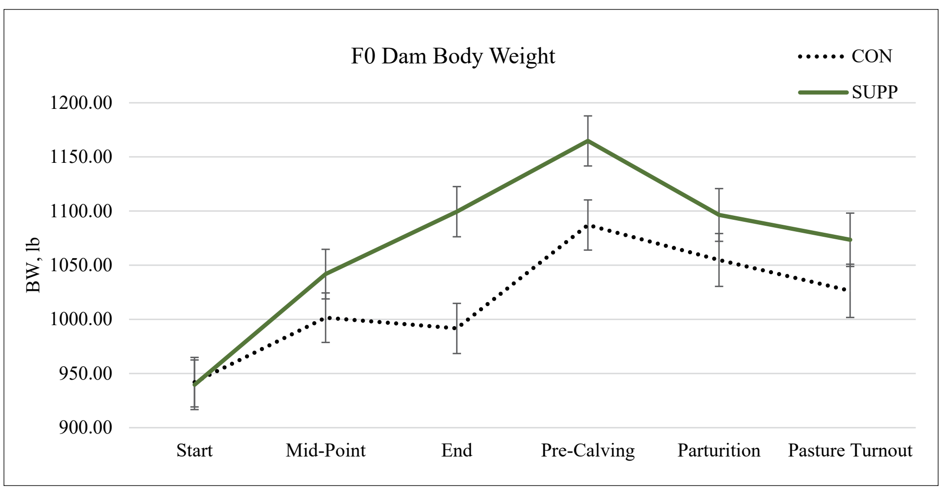

Figure 1. Body weights of pregnant (F0) beef heifers from the start of the second trimester of gestation (treatment start) to the conclusion of the second trimester (treatment end) and into late gestation and early lactation. Treatments were: F0 dams were provided with either a basal forage diet (CON) or a basal forage diet plus a protein and energy supplement (SUPP) from day 90 to 186 of gestation. * indicates significance (*P* ≤ 0.05)

While heifers were similar in BW at the start of the trial (day 90 in pregnancy) by design, at day 186, we observed a 108-lb difference in BW between treatments ($P < 0.05$). Interestingly, this weight difference was sustained through late pregnancy (77-lb difference; $P < 0.05$) and pasture turnout (42-lb difference; $P < 0.10$). The body condition scores recorded during this period complement the weight differences we observed, with SUPP heifers having greater body condition scores at the end of the supplementation period than CON heifers (5.8 vs. 4.7 BCS; $P = 0.01$).

At calving, we observed no differences in gestation length ($P = 0.13$) between CON and SUPP (280 vs. 278 days, respectively), calving ease ($P = 0.32$) or calf vigor scores ($P = 0.68$). Colostrum production and mass were also not different ($P \geq 0.16$) between CON and SUPP, and placental characteristics (weight, number of cotyledons and weight of cotyledons) were not different ($P \geq 0.50$) between treatments. However, the F1 bull calves born to SUPP heifers were 5.2 lb heavier ($P = 0.04$) than calves born to CON heifers prior to suckling (Figure 2). Also at birth, SUPP calves had greater chest circumference ($P = 0.05$) and tended to have greater abdominal circumference and greater hip height measurements ($P < 0.10$) compared with CON. Despite a difference in birth weights of SUPP and CON calves, the long-term growth performance of the F1 bull calves was not impacted by the interaction of treatment and day ($P = 0.36$; Figure 2). However, postnatal bull calf growth performance tended ($P = 0.10$) to be greater in SUPP calves compared with CON, which was driven by a 17.5-lb weight advantage in SUPP calves at pasture turnout but only a 1-lb advantage in SUPP calves at weaning. Calf body weight was also impacted by the effect of day ($P < 0.01$), which is expected as calf weights increased from birth to weaning.

We observed no impact ($P \geq 0.18$) of the interaction of treatment and day on circulating blood metabolites in the dam for glucose or BUN. However, we observed a tendency ($P = 0.08$) for concentrations of NEFA in the F0 dam to be influenced by the interaction of treatment and day. We also observed that both NEFA and BUN were impacted ($P \leq 0.05$) by protein/energy supplementation during midgestation (Table 1), in which concentrations of NEFA were lower ($P = 0.02$) for SUPP heifers compared with CON and concentrations of BUN were greater ($P = 0.05$) in SUPP compared with CON heifers. We observed no impact ($P = 0.34$) of treatment during midgestation on circulating concentrations of glucose in the dam. The effect of day was also observed ($P \leq 0.01$) for glucose, NEFA and BUN in SUPP and CON dams (Table 1).

In the F1 bull calves born to CON and SUPP dams, we observed an interaction of treatment and day ($P = 0.04$) for concentrations of NEFA in the calf, indicating greater concentration of NEFA in SUPP calves at birth and pasture turn out ($P \leq 0.05$) compared with CON calves. We also observed an effect of day for concentrations of glucose and BUN in the F1 calf ($P \leq 0.01$). However, concentrations of glucose and BUN in the F1 calf were not influenced by the main effect of F0 maternal treatment ($P \geq 0.11$; Table 2).

Most fetal growth and increases in nutrient demand for the pregnant cow occur between mid- and late gestation. Because of this, the level of protein and energy provided to cows during midgestation can influence both cow condition and early calf performance. In the current study, protein and energy supplementation increased cow body weight, body condition score, and improved metabolic indicators of energy and protein status during pregnancy. Supplemented cows had lower circulating NEFA, indicating less reliance on body fat mobilization, and slightly greater BUN, reflecting improved protein intake and nitrogen availability (Silva et al., 2019). These results suggest that strategic supplementation helped cows meet pregnancy demands using dietary nutrients rather than body reserves.

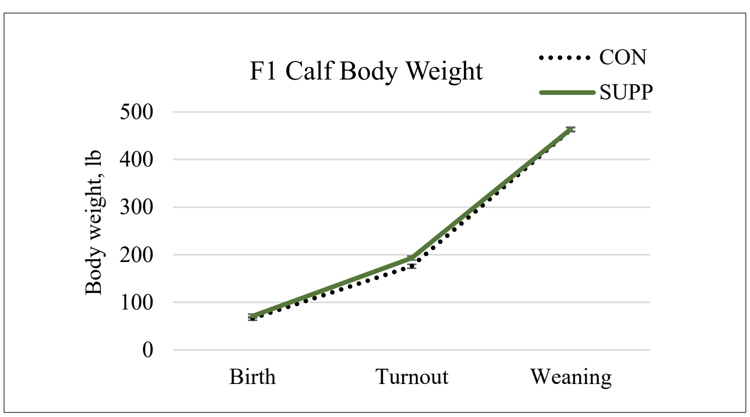

Figure 2. Body weights for the F1 bull calves from birth to weaning. Treatments of the F0 dams during midgestation were the following: F0 dams were provided with either a basal forage diet (CON) or a basal forage diet plus a protein and energy supplement (SUPP) from day 90 to 186 of gestation. Dams were managed as a single group from the end of the second trimester through weaning the next fall. Sampling timepoints were birth (average 279-day gestation length); pasture turnout (average 68 days of age), and weaning (average 174 days of age).

Table 1. Blood metabolites in F0 beef heifers during the supplementation period (day 90 to 186) through calving and pasture turnout.

Item[3]	Treatment[1]			*P*-Values		
	CON	SUPP	SEM[2]	TRT	Day	TRT×Day
Glucose, mg/dL				0.34	<0.01	0.79
Start	66.0	69.3	3.10			
Midpoint	60.0	64.0	3.07			
End	63.7	63.1	3.10			
Precalving	68.5	71.2	3.18			
Parturition	96.1	95.8	4.73			
Pasture Turnout	59.9	58.7	3.31			
NEFA, µmol/L				0.02	<0.01	0.08
Start	268.8	211.1	39.51			
Midpoint	264.7	270.9	38.97			
End	606.3	428.8	40.18			
Precalving	977.9	716.5	45.70			
Parturition	662.8	600.2	40.94			
Pasture Turnout	334.5	404.6	41.51			
BUN, mg/dL				0.05	<0.01	0.77
Start	7.6	7.7	0.56			
Midpoint	10.8	11.5	0.56			
End	11.1	11.8	0.57			
Precalving	9.6	9.4	0.57			
Parturition	6.7	7.5	0.59			
Pasture Turnout	8.9	9.7	0.61			

[1]Heifers were assigned to receive a basal forage diet with target body weight gains of 0.28 kg/hd/d (CON, n = 22) or a basal forage diet plus a protein and energy supplement with target body weight gains of 0.79 kg/hd/d (SUPP, n = 22).
[2]Standard error of the mean.
[3]Metabolites evaluated included glucose, nonesterified fatty acids (NEFA) and blood urea nitrogen (BUN).

Table 2. Blood metabolites in F1 male offspring born to dams provided with a basal diet (CON) or to dams provided with a basal diet plus a protein/energy supplement (SUPP).

Item[3]	Treatment[1]			*P*-Values		
	CON	SUPP	SEM[2]	TRT	Day	TRT×Day
Glucose, mg/dL				0.11	<0.01	0.61
Birth	70.4	63.3	4.01			
Turnout	97.8	89.8	4.23			
Weaning	81.5	80.8	4.12			
NEFA, µmol/L				0.01	0.03	0.14
Birth	172.2	252.6	27.51			
Turnout	92.5	194.2	29.29			
Weaning	209.4	208.8	26.74			
BUN, mg/dL				0.56	<0.01	0.19
Birth	9.1	10.3	0.48			
Turnout	8.9	8.9	0.52			
Weaning	16.4	15.9	0.50			

[1]F0 Heifers were assigned to receive a basal forage diet with target body weight gains of 0.28 kg/hd/d (CON, n = 22) or a basal forage diet plus a protein and energy supplement with target body weight gains of 0.79 kg/hd/d (SUPP, n = 22). The F1 offspring were managed on a common diet from birth through weaning.
[2]Standard error of the mean.
[3]Metabolites evaluated included glucose, nonesterified fatty acids (NEFA) and blood urea nitrogen (BUN).

Calves born to supplemented cows were 5.2 lb heavier at birth and 17.5 lb heavier at pasture turnout (approximately 70 days of age), demonstrating a short-term growth advantage. However, body weight differences did not persist through weaning, likely due to similar postnatal grazing conditions across treatment groups and catch-up growth exhibited by CON calves. Although long-term weight differences were not observed, calves from supplemented cows showed greater circulating NEFA early in life, suggesting differences in energy use or fat metabolism during the preweaning period. Because midgestation coincides with critical periods of muscle and fat tissue development, improved maternal nutrition during this window may influence early tissue growth and metabolic function in the calf.

Similar responses have been observed in related work from our laboratory, where protein and energy supplementation during early gestation in beef heifers resulted in sustained improvements in cow body weight and modest, short-term increases in calf birth weight, observed as a 2-lb birth weight advantage in calves born to supplemented dams (Baumgaertner et al., 2024). In that study, body weight differences in female offspring were negligible at weaning, but re-emerged after puberty, suggesting that gestational nutrition may have longer-term impacts on animal performance that are not immediately evident at weaning.

Overall, these findings indicate that strategic protein and energy supplementation during midgestation can improve cow condition, reduce reliance on body reserves and enhance early calf growth. While postweaning management may minimize visible weight differences, improved maternal nutrition during pregnancy may still provide long-term benefits for offspring performance and productivity. Additional evaluation of postweaning growth and carcass traits will help determine the full production value of midgestation supplementation programs for offspring developed for terminal or breeding markets.

Conclusions

These data show that providing supplemental protein and energy and greater rates of gain during the second trimester of pregnancy supported increased birth weight and body measurements in the neonatal calf, but did not impact maternal BW at calving, colostrum production or placental characteristics. Further evaluation of growth performance and metabolic phenotype in the F1 male offspring at later postnatal time points will help determine whether maternal nutritional management during gestation induces long-term programming outcomes that could enhance offspring productivity and contribute to global food security.

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Literature Cited

Baumgaertner, F., A. C. B. Menezes, W. J. S. Diniz, J. L. Hurlbert, K. A. Bochantin, S. R. Underdahl, J. D. Kirsch, S. T. Dorsam, K. L. McCarthy, G. D. Ramirez-Zamudio, K. K. Sedivec, J. S. Caton, and C. R. Dahlen. 2024. Effects of rate of body weight gain during the first trimester of gestation on beef heifer and offspring performance, concentrations of hormones and metabolites, and response to vaccination. *J. Anim. Sci*. 102:skae193.

Cappellozza, B. I., R. F. Cooke, M. M. Reis, P. Moriel, D. H. Keisler, and D. W. Bohnert. 2014. Supplementation based on protein or energy ingredients to beef cattle consuming low-quality cool-season forages: II. Performance, reproductive, and metabolic responses of replacement heifers. *J. Anim. Sci.* 92:2725–2734.

Llewellyn, D. A., R. C. Cochran, T. T. Marston, D. M. Grieger, C. G. Farmer, and T. A. Wickersham. 2006. Influence of limited fall protein supplementation on performance and forage utilization by beef cattle grazing low-quality native grass pastures. *Anim. Feed Sci. Technol*. 127:234–250.

Schauer, C. S., D. W. Bohnert, D. C. Ganskopp, C. J. Richards, and S. J. Falck. 2005. Influence of protein supplementation frequency on cows consuming low-quality forage: Performance, grazing behavior, and variation in supplement intake. *J. Anim. Sci.* 83:1715–1725.

Silva, L. F. P., R. M. Dixon, and D. F. A. Costa. 2019. Nitrogen recycling and feed efficiency of cattle fed protein-restricted diets. *Anim. Prod. Sci.* 59:2093–2107.

Utilizing a precision supplement delivery system to provide protein and energy supplementation to beef heifers grazing fall native range pasture during midgestation

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The objectives of this study were to evaluate the effects of providing a protein and energy supplement using precision feeding technology to beef heifers during midgestation grazing fall native range pasture on body weight, supplement intake, metabolic status and diet digestibility. We observed that heifers assigned to receive supplementation on fall pasture tended to be heavier than nonsupplemented controls and had altered blood concentrations of blood urea nitrogen (BUN) and nonesterified fatty acids (NEFA), suggesting an influence of supplementation on energy balance and nitrogen metabolism in supplemented heifers. However, impacts on body weights of the calves exposed to different maternal nutritional environments during the second trimester of gestation were limited.

Summary

Our objectives were to utilize precision feed delivery systems to deliver a protein and energy supplement to beef heifers grazing fall native range pastures and to evaluate the effects of supplementation during midgestation on body weight, supplement intake and metabolic status. The potential impacts on birth and pasture turnout weights of the calves born to females exposed to protein and energy supplementation or the control diet (pasture grazing only) were also evaluated. We observed that heifers receiving supplementation tended to be heavier than nonsupplemented heifers, but we did not observe an impact on calf birth or pasture turnout body weights. Metabolic status appeared to be improved in supplemented heifers, as circulating concentrations of blood urea nitrogen and nonesterified fatty acids reflected a more positive energy balance and nitrogen recycling state compared with control-fed heifers. Measures of digestibility also improved with supplement delivery as forage nutritive value fell in the late fall.

Introduction

Nearly one-third of the heifer calves in North Dakota are retained each year as replacement females, making their development critical to the future productivity and genetic progress of the state's beef industry. Because first-calf heifers must simultaneously support fetal growth, lactation and their own continued growth, their nutrient requirements exceed those of mature cows. In North Dakota spring-calving herds, however, midgestation coincides with the fall grazing season, when native range forage quality declines substantially, creating nutritional challenges for both the pregnant heifers and their developing calves (Schauer et al., 2005; Llewellyn et al., 2006). Therefore, the objectives of this project were to determine whether strategic corn-based protein and energy supplementation via a precision delivery system during midgestation could improve nutrient digestibility, maternal metabolic status and subsequent performance of the dam and her offspring. We hypothesized that beef heifers receiving supplemental protein/energy while grazing low-quality fall pasture during midgestation would have differing hormone/metabolite profiles and have enhanced measures of digestibility on pasture compared with nonsupplemented cohorts. We further hypothesized that calves born to protein/energy-supplemented dams would exhibit altered postnatal growth compared with calves born to nonsupplemented dams.

Procedures

To accomplish these objectives, Angus-based heifers (n = 30; initial body weight [BW] = 960 ± 79.3 lb) were bred by live cover bulls, then stratified by BW and randomly assigned to one of two treatments at approximately day 90 of pregnancy

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(start of second trimester). Heifers were assigned to either graze native range pasture (**CON**; n = 15) or the same native range pasture plus have access to a protein and energy supplement (**SUPP**; n = 15) delivered at a rate of 0.6% of BW on a dry-matter basis using SmartFeed Pro units from C-Lock, Inc. in two enclosed trailers on the pasture (Figure 1). The protein and energy supplement was a corn and dried distillers grains-based supplement with 18% crude protein. Treatments were applied for 59 days beginning in late September and concluding in late November. Following the end point collection at the end of the 59-day period, heifers were managed on a common diet in a single pen until pasture turnout in the spring.

Supplement intake was controlled for all animals in the pasture with the use of a radio frequency identification (RFID) tag. The RFID tag associated with each animal either allowed access to the supplement via a gate that opened at a maximum intake level assigned daily (SUPP) or did not allow access to the feeders (CON). This system allowed individualized management and feed intake records of each animal on a daily basis.

Consecutive-day body weights, blood serum and pasture clippings were collected at the beginning (September), midpoint (October) and end (December) of the 59-day supplementation period. Consecutive-day body weights were used to assign the heifers to their individual supplement allotments (SUPP heifers only) at 0.6% of body weight on a dry-matter basis. Weights were also collected from the dam prior to calving (late January) and at pasture turnout (May) and from the calves born in the spring at birth (April) and again at pasture turnout to evaluate the potential long-term outcomes on maternal supplementation during the second trimester of gestation.

Blood samples were analyzed for concentrations of glucose, nonesterified fatty acids (NEFA) and blood urea nitrogen (BUN) to assess metabolic status of the dams throughout the supplementation period. A chemical analysis was performed on pasture clippings collected throughout the supplementation period to assess the expected decline in forage quality as the grazing season advanced.

Digestibility trials were conducted immediately before supplementation in the fall (period 1) and again near the end of the 59-day grazing period (period 2) via oral administration of chromium oxide boluses for 10 consecutive days at the start and end of the feeding trial, with five consecutive days (day 5 through 10 of bolus administration) of spot-collected fecal samples. The concentration of chromium in the fecal samples was utilized to predict daily fecal output, and subsequent calculations of nutritive composition of the feed available (supplement and forage) and in the feces were used to estimate digestibility.

Statistical Methods

Individual animal was considered the experimental unit as intake of the supplement was monitored on an individual basis. All variables were analyzed using the MIXED

Figure 1. Images show one of the SmartFeed Pro units (C-Lock, Inc.) in use on a single native range pasture. Both SUPP and CON heifers were placed together in a single pasture, and RFID tags fitted to each animal either allowed or denied access to the feeding units (Right). Supplement allowances were programmed on the C-Lock online interface and were reset automatically on a daily basis. Once a heifer reached her daily feed allowance, she was no longer able to access the supplement for the remainder of the day.

procedure of SAS with repeated measures applied where appropriate. Results are presented as LSMEANS with the standard error of the mean. Variables were analyzed for the effect of F0 treatment, day of gestation/age and the respective interaction. Significance was considered at $P \leq 0.05$, and tendencies considered at $0.05 < P \leq 0.10$.

Results and Discussion

As expected, crude protein levels in the native range pasture decreased from 8.6% in September to 5.8% in November. Neutral detergent (NDF) and acid detergent fiber (ADF) increased, however, from mid-September to late November, with NDF increasing from 61.1% to 67.6% and ADF increasing from 34.1% to 38.1% from September to November. Supplement intake recorded from the SmartFeed Pro system (Figure 2) indicated that, despite average daily feed allowances set for SUPP heifers across the 59-day supplement access period at 6.05 lb dry-matter per day (0.6% of BW), the actual dry-matter consumption of supplement was only 4.90 lb per day (0.47% of BW).

Digestibility trials were conducted at the beginning (day -13 to day -4 prior to supplement access (period 1)) and near the end of the supplementation period (day 50 to day 59 (period 2)). During period 1, CON and SUPP heifers had similar forage intake, fecal output and apparent diet digestibility ($P \geq 0.10$; Table 1), suggesting that the groups entered the study with comparable intake and nutrient utilization. Consistent with the decline in forage nutritive value described above, fecal output increased (DM, OM, NDF, ADF) in both treatments ($P \leq 0.01$) and apparent dry matter (DM) and crude protein (CP) digestibility decreased in CON heifers ($P \leq 0.03$) throughout the grazing season. During period 2, CON heifers consumed more forage than SUPP heifers (26.94 vs. 22.55 lb DM/d), whereas SUPP heifers consumed 5.84 lb supplement DM/d during period 2 (10 d average), resulting in only a modest increase in total DMI (28.37 vs. 26.94 lb/d). This represented a substitution rate of approximately 0.75 lb forage DM per kilogram of supplement DM consumed. Despite lower forage intake, SUPP heifers had greater ($P = 0.01$) DM digestibility than CON heifers during trial 2 (46.5 vs. 41.5%) and markedly greater ($P < 0.01$) CP digestibility (41.2 vs. 11.9%). This particularly large improvement in CP digestibility suggests that, at least in part, the greater CP supply provided by the supplement and the replacement of low-quality mature forage with a feed ingredietn containing more readily digestible protein.

Circulating blood metabolites for heifers during the fall grazing period also indicated differences in nitrogen and energy metabolism between treatments as the supplementation period progressed. Concentrations of BUN were greater in SUPP heifers compared with CON at the midpoint and end of the fall feeding period but similar at the start of the trial, as identified with an interaction of treatment and day ($P = 0.02$; Table 2). Similarly, concentrations of NEFA were also greater in SUPP heifers compared with CON at the end-point blood collection but were similar at the beginning and midpoint of the feeding trial, as observed as an interaction between treatment and day ($P = 0.01$). No differences were observed between SUPP and CON for concentrations of blood glucose throughout the feeding period ($P \geq 0.11$); however, a day effect was observed ($P = 0.03$) in which glucose concentrations increased throughout the feeding period for both CON and SUPP heifers.

The blood metabolite responses support the differences in nutrient

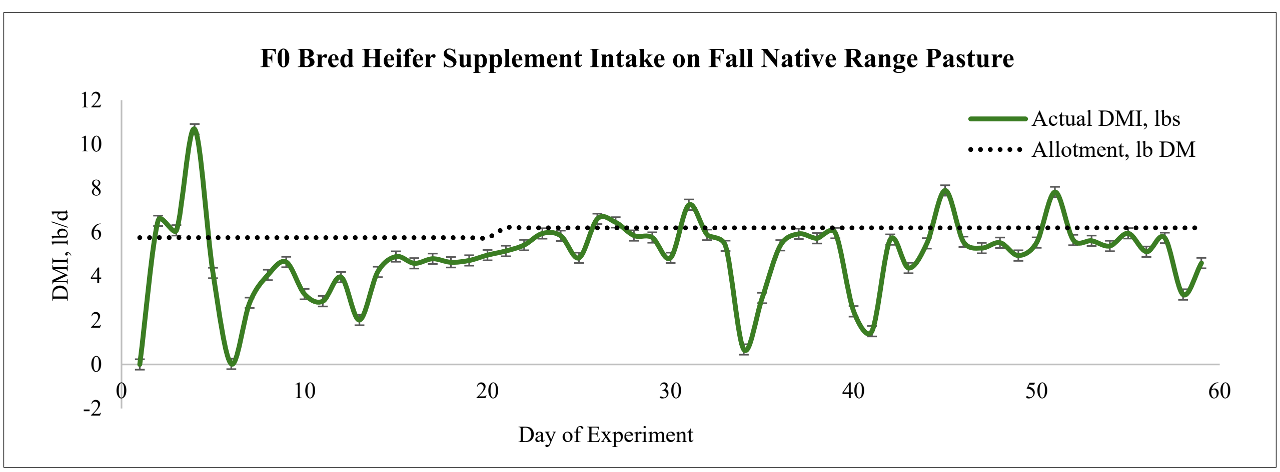

Figure 2. Daily average supplement intakes (solid line; lb DMI) throughout the 59-day feeding period during midgestation. The average daily allotment for all heifers assigned to receive the SUPP diet is represented by the dotted line. Error bars on the solid line represent the standard error of the mean.

utilization observed during period 2. As forage CP declined through the grazing season, greater apparent CP digestibility in SUPP heifers was accompanied by greater circulating BUN, supporting increased nitrogen availability and metabolism in response to protein and energy supplementation. Conversely, lower BUN concentrations in CON heifers were consistent with reduced dietary nitrogen availability as forage quality declined. Greater NEFA concentrations in CON heifers at the end of supplementation further suggest increased mobilization of body fat reserves as nutrient availability from pasture became increasingly limited. Collectively, the digestibility and circulating metabolite responses indicate that

Table 1. Diet digestibility in bred heifers during the second trimester of pregnancy while grazing native range pastures with (n = 15) or without (n = 15) protein and energy supplementation delivered at a rate of 0.6% of BW on a DMB.

	Period 1[1] Treatment		*Period 2* Treatment			*P*-values[4]		
Item[2]	CON	SUPP	CON	SUPP	SEM[3]	TRT	Day	TRT×Day
DM								
Forage intake, kg/d	9.49[a]	9.98[a]	12.22[b]	10.22[a]	0.428	0.13	<0.01	0.01
Supplement intake, kg/d	0 a	0[a]	0[a]	2.65[b]	0.065	<0.01	<0.01	<0.01
Total intake, kg/d	9.49	9.98	12.22	12.87	0.449	0.24	<0.01	0.82
Fecal output, kg/d	5.15	5.22	7.15	6.87	0.221	0.71	0.01	0.17
Digestibility, %	46.51[a]	47.34[a]	41.51[b]	46.52[a]	1.000	0.01	0.01	0.03
OM								
Forage intake, kg/d	8.41[a]	8.85[a]	10.76[b]	9.00[a]	0.378	0.13	<0.01	0.01
Supplement intake, kg/d	0[a]	0[a]	0[a]	2.54[b]	0.063	<0.01	<0.01	<0.01
Total intake, kg/d	8.41	8.85	10.76	11.55	0.399	0.16	<0.01	0.56
Fecal output, kg/d	4.02	4.07	5.62	5.49	0.181	0.85	<0.01	0.39
Digestibility, %	52.69	53.56	47.83	52.35	1.054	0.01	0.01	0.07
NDF								
Forage intake, kg/d	5.83[a]	6.11[a]	8.26[b]	6.91[c]	0.280	0.10	<0.01	0.01
Supplement intake, kg/d	0[a]	0[a]	0[a]	0.74[b]	0.018	<0.01	<0.01	<0.01
Total intake, kg/d	5.83[a]	6.11[a]	8.26[b]	7.65[c]	0.286	0.61	<0.01	0.03
Fecal output, kg/d	2.75	2.78	4.08	3.96	0.148	0.80	<0.01	0.41
Digestibility, %	53.27	54.32	50.65	48.18	1.110	0.51	0.01	0.06
ADF								
Forage intake, kg/d	3.26[a]	3.41[a]	4.66[b]	3.90[c]	0.158	0.09	<0.01	0.01
Supplement intake, kg/d	0[a]	0[a]	0[a]	0.22[b]	0.005	<0.01	<0.01	<0.01
Total intake, kg/d	3.26[a]	3.41[a]	4.66[b]	4.12[c]	0.159	0.28	<0.01	0.01
Fecal output, kg/d	1.67	1.66	2.39	2.21	0.088	0.40	<0.01	0.12
Digestibility, %	49.05[ab]	51.01[a]	48.81[ab]	46.27[b]	1.241	0.80	0.02	0.03
CP								
Forage intake, kg/d	0.80[a]	0.85[a]	0.71[b]	0.59[b]	0.030	0.35	<0.01	0.01
Supplement intake, kg/d	0[a]	0[a]	0	0.48[b]	0.012	<0.01	<0.01	<0.01
Total intake, kg/d	0.80[a]	0.85[a]	0.71[a]	1.07[b]	0.034	<0.01	0.01	<0.01
Fecal output, kg/d	0.61	0.62	0.62	0.63	0.026	0.74	0.64	0.74
Digestibility, %	24.36[a]	24.53[a]	11.94[b]	41.21[c]	2.638	<0.01	0.36	<0.01

[1]Trial 1 was conducted for 10 d from 09/11/2024 to 9/20/2024 prior to the initiation of treatments (CON, n = 15; SUPP, n = 15). Trial 2 was conducted for 10 d from 11/12/2024 to 11/21/2024 while treatments were applied. Both trials took place on a single, native range pasture and supplement delivery was controlled and limited to SUPP heifers via an electronic feeder.

[2]Variables evaluated included: DM, dry matter; OM, organic matter; NDF, neutral detergent fiber; ADF, acid detergent fiber; CP, crude protein; EE, ether extract.

[3]Standard error of the mean.

[4]Means within a row lacking a common superscript differ ($P \leq 0.05$).

supplementation helped mitigate the nutritional challenges associated with declining fall forage quality.

These physiological responses were accompanied by differences in subsequent maternal performance. Although a treatment by day interaction was not detected (P = 0.44), SUPP heifers tended (P = 0.08) to be heavier than CON from the end of the feeding period through pasture turn out (Figure 3). At the end of the feeding period (day ~150 of gestation), SUPP heifers were approximately 19.5 lb heavier than CON and 71.2 lb heavier than CON prior to calving. During the grazing period in midgestation, SUPP heifers tended (P = 0.07) to have a greater average daily gain (2.4 lb/d) compared with CON heifers (2.1 lb/d). Interestingly, despite body weight differences in the SUPP and CON heifers at precalving and pasture turnout, we did not observe body weight differences at birth and at pasture turnout in calves born to these dams ($P \geq 0.69$). Average birth weights for calves were 72.7 and 79.1 lb for CON and SUPP, respectively, and average pasture turnout weights for calves were 154.8 and 155.2 lb, respectively.

The tendency for SUPP heifers to remain heavier after supplementation concluded suggests that the benefits associated with improved nutrient utilization and metabolic status during the fall grazing period may have persisted into late gestation and early lactation. Although subsequent

Table 2. Blood metabolites in F0 pregnant beef heifers on fall pasture with grazing access (CON) or grazing access plus a protein and energy supplement (SUPP).

	Treatment[1]			P-Values[4]		
Item[3]	CON	SUPP	SEM[2]	TRT	Day	TRT×Day
Glucose, mg/dL				0.15	0.03	0.11
Start	48.9	47.6	2.26			
Mid-Point	47.8	49.3	2.26			
End	49.4	55.0	2.30			
NEFA, µmol/L				<0.01	<0.01	<0.01
Start	215.6[b]	198.8[bc]	19.81			
Mid-Point	129.0[d]	143.4[cd]	19.46			
End	292.6[a]	196.9[bc]	22.07			
BUN, mg/dL				<0.01	<0.01	0.02
Start	15.5[a]	16.4[a]	0.84			
Mid-Point	6.8[d]	10.8[c]	0.84			
End	10.2[c]	13.7[b]	0.84			

[1]F0 bred heifers were assigned to graze native range pasture (**CON**; n = 15) or graze the same native range pasture plus have access to a protein and energy supplement (**SUPP**; n = 15) delivered at a rate of 0.6% of BW on a dry-matter basis. Treatments were applied to the F0 dams in late September (start) through late November (end).
[2]Standard error of the mean.
[3]Metabolites evaluated included glucose, nonesterified fatty acids (NEFA) and blood urea nitrogen (BUN).
[4]Means lacking a common superscript differ ($P \leq 0.05$).

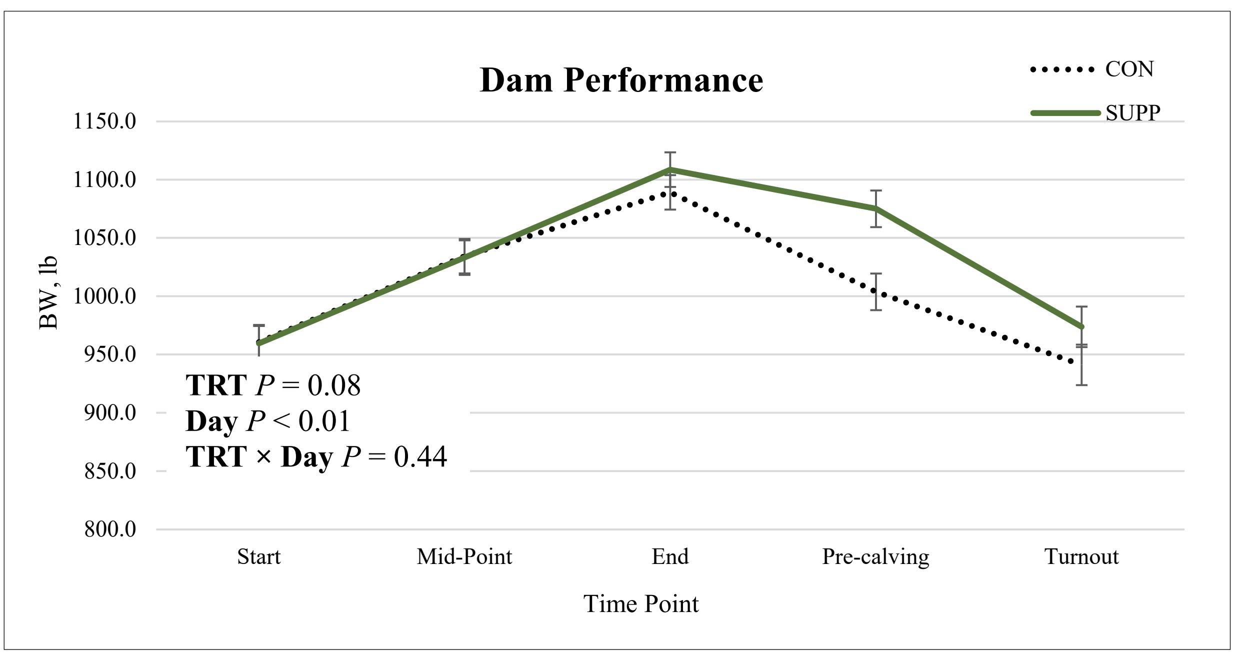

Figure 3. Body weights of F0 pregnant heifers during the 59-day feeding trial (start to end) followed by precalving and pasture turnout time points.

reproductive performance of the dams in this study was not evaluated, entering the second breeding season at a greater BW and potentially improved nutritional status may better position young females to support the concurrent demands of lactation, continued maternal growth, and reproduction. Whether this carryover advantage ultimately translates into improved pregnancy success and long-term productivity in the herd warrants further investigation.

Conclusions

From a production standpoint, strategic protein and energy supplementation during midgestation buffered the nutritional challenges associated with declining fall forage quality and resulted in performance advantages that persisted beyond the supplementation period. Improved nutritional status and dam performance observed here may better position females for the demands of late gestation, lactation and the subsequent breeding season. Although reproductive performance was not evaluated, it is unclear whether these carryover benefits translate into improved breed-back success; however, we suspect that an improved nutritional state and body condition after calving may be associated with reproductive advantages in the next breeding season.

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Literature Cited

Llewellyn, D. A., R. C. Cochran, T. T. Marston, D. M. Grieger, C. G. Farmer, and T. A. Wickersham. 2006. Influence of limited fall protein supplementation on performance and forage utilization by beef cattle grazing low-quality native grass pastures. *Anim. Feed Sci. Tech.* 127:234-250.

NASEM, 2016. Nutrient requirements of beef cattle. 8th revised ed. Washington, DC: National Academics Press.

Schauer, C., D. W. Bohnert, D. C. Ganskopp, C. J. Richards, and S. J. Falck. 2005. Influence of protein supplementation frequency on cows consuming low-quality forage: Performance, grazing behavior, and variation in supplement intake. *J. Anim. Sci.* 83:1715-1725.

Influence of protein and energy supplementation during mid-gestion on beef heifers and their offspring while grazing pasture

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The objective of this study was to evaluate the effects of feeding a protein and energy supplement during mid-gestation on body weight, growth performance, body composition traits, blood metabolites, and offspring growth responses of grazing beef heifers. Heifers receiving a supplement had greater body weight gain, ribeye area, and fat measurements after the supplement period, and their offspring tended to be heavier through pasture turnout. In addition, their blood metabolite responses were consistent with improved nutrient status, indicating that strategic supplementation can help maintain heifer performance when forage quality is declining.

Summary

Maternal nutrition during gestation plays a central role in regulating dam performance, placental function, fetal development, and offspring productivity (Funston et al., 2010). The objective of this study was to evaluate the effects of protein and energy supplementation during mid-gestation on dam and offspring performance, including body weight (BW), blood metabolites, and body composition. The study was conducted at North Dakota State University's Central Grassland Research Extension Center (CGREC) in Streeter, North Dakota. Pregnant crossbred Angus-based heifers (n = 46) each carrying a male fetus from a single artificial insemination sire were used for the study. Heifers were randomly assigned to either a control treatment (CON; n = 22) or a supplemented treatment (SUPP; n = 24). Supplemented heifers received supplement, at 0.6% of body weight (as-fed basis; dry matter adjusted), delivered individually through SmartFeed Pro trailers (C-Lock Inc., Rapid City, South Dakota), during a 90-day grazing period. Body weight and blood samples were evaluated at four intervals throughout the trial, and body composition, including rump fat, rib fat, ribeye area (REA) and intramuscular fat (IMF), was determined via ultrasound at the beginning and end of the trial. Supplemented heifers had greater final body weight than control heifers (493.8 ± 8.35 vs. 440.0 ± 7.76 kg; $P < 0.0001$). At the end of the trial, supplemented heifers also had more ($P < 0.0001$) rump fat and rib fat and greater REA than control heifers, whereas IMF did not differ. Blood results supported these performance responses, as supplemented heifers had greater ($P < 0.0001$) glucose and blood urea nitrogen (BUN) at selected sampling times, while control heifers had greater nonesterified fatty acids (NEFA) on day 56 of the trial and tended to remain greater on day 90. Overall, these findings indicate that protein and energy supplementation during mid-gestation can potentially improve growth, body condition and metabolic status of grazing beef heifers. Calves from supplemented dams tended to be heavier at birth, at turnout and at breeding than calves from control dams, indicating potential developmental programming effects that could persist postnatally.

Introduction

In forage-based beef production systems, maternal nutrition during gestation can influence fetal development and subsequent offspring performance (Shokrollahi et al., 2025). This issue is especially relevant at the CGREC in the Missouri Coteau region of central North Dakota, where grazing cattle rely on native mixed-grass prairie and forage quality declines as the season advances. Previous work

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from this region has shown that advancing season is associated with increased forage fiber and reduced nitrogen and digestibility, indicating a progressive decline in nutritive value of grazed forage (Chilcoat et al., 2016). Similarly, McCarthy et al. (2023) characterized this seasonal trajectory at CGREC by tracking forage crude protein, fiber and mineral composition across a late-summer to early-fall grazing period on native mixed prairie and relating those changes to heifer performance and supplementation responses. As the grazing season progresses, forage crude protein declines and fiber increases, which may reduce forage nutritive value enough to increase the need for supplementation in grazing cattle (McCarthy et al., 2023; Chilcoat et al., 2016). For spring calving cows in North Dakota, the late-summer to early-fall pasture quality decline overlaps with mid-gestation. Inadequate maternal nutrition at this stage is broadly understood to alter fetal development and to carry over to the calf at birth and through the early postnatal period (Shokrollahi et al., 2025).

Therefore, the objective of this study was to evaluate the effects of maternal protein and energy supplementation during midgestation on body weight, growth performance, body composition, blood metabolites and offspring outcomes of grazing beef heifers over a 90-day feeding period. We hypothesized that supplemented heifers would have greater weight gain, heavier final BW, improved body composition and blood metabolite responses consistent with improved nutrient status compared with nonsupplemented control heifers. Along with this, we also hypothesized that calves from supplemented heifers would have improved birth weight, vigor, and early postnatal growth compared to calves from nonsupplemented control heifers.

Procedures

Pregnant crossbred Angus-based heifers located at CGREC were used to evaluate a mid-gestation supplementation program. Prior to treatment assignment, all heifers were managed together under the same conditions through breeding and early gestation. A total of 150 heifers were artificially inseminated with male-sexed semen from a single sire. After pregnancy confirmation and a two-week acclimation period to SmartFeed Pro trailers, 46 heifers carrying male fetuses were assigned to either a control treatment (CON; n = 22) or a supplemented treatment (SUPP; n = 24) and grazed pasture for 90 days (d). Supplemented heifers received a pelleted protein and energy supplement at 0.6% of their BW, delivered through SmartFeed Pro trailers. The supplement was composed primarily of wheat middlings, cracked corn, DDGS ethanol and ground fine corn. Guaranteed analysis from the manufacturer indicated a minimum of 16.0% crude protein (CP) and 7.5% crude fat, with a maximum of 5.6% crude fiber, calcium ranging from 0.01 to 0.51%, and phosphorus ranging from 0.65 to 0.74%. Nutrient analysis conducted by the NDSU Nutrition Laboratory was similar, reporting 16.12% CP, 8.29% crude fat, 5.50% crude fiber, 0.07% calcium, and 0.65% phosphorus.

During the 90-day supplementation period, heifers remained at CGREC but were managed in a separate pasture from the remainder of the herd. Body weights and blood samples were collected on days 0, 27, 56 and 90 using a two-day consecutive weighing procedure, and body weight gain and average daily gain (ADG) were calculated. Forage samples were collected at three sampling intervals during the grazing period at days 0, 27 and 56 of the trial. At each interval, forage was clipped from 16 plots within the pasture to a height of 3.75 cm above ground (Undi et al., 2008), and each sample was weighed and oven dried in a forced-air oven at 60 degrees Celsius for at least 48 hours. Dried samples were ground through a 2-mm screen using a Wiley mill (Arthur H. Thomas, Philadelphia, PA). Following grinding, 5.0-gram subsamples from each of the 16 samples were combined to form one composite sample for laboratory analysis at each collection interval. Ultrasound measurements were taken at the beginning and end of the feeding period to evaluate rump fat, rib fat, ribeye area (REA) and intramuscular fat (IMF). Blood serum samples were analyzed for glucose, blood urea nitrogen (BUN) and nonesterified fatty acids (NEFA).

Following the 90-day supplementation period, all heifers were recombined with original herd and managed together through calving. Additional body weights and blood samples were collected from dams on day 263 of gestation. Calf body weights were recorded at calving (n = 41) and again at pasture turnout (approximately 2 months of age) and at dam breeding (approximately 3 months of age) to assess early offspring performance associated with dam treatment. After calving, all cow-calf pairs were managed together as a single group until pasture turnout at day 59 postpartum (PP), body weights and blood samples were collected from dams, and body weights were collected from calves.

Statistical Analysis

Data were analyzed using SAS 9.4 (SAS Inst. Inc., Cary, NC). For heifer variables, the individual heifer served as the experimental unit. Blood metabolite data were analyzed using the MIXED procedure of SAS with treatment, collection day, and the treatment × day interaction included as fixed effects. Day was treated as a repeated measure, with heifer ID as the subject and an autoregressive covariance structure [AR(1)] applied. For calf BW data, the individual calf served as the experimental unit. Calf BW was analyzed using the MIXED procedure with dam treatment, day, and the dam treatment × day interaction as fixed effects, and day treated as a repeated measure with calf ID as the subject. Denominator degrees of freedom were adjusted using the Kenward-Roger method. Results are presented as least squares means (LSMEANS) with standard error (SE). Significance was declared at $P \leq 0.05$ and tendencies at $0.05 \leq P \leq 0.10$.

Results and Discussion

Forage composition of composite pasture samples indicated changes in nutritional value across the grazing period (Table 1). Total digestible nutrients (TDN) remained relatively stable, ranging from 60.5 to 62.0%. However, crude protein (CP) declined from 9.02% in September to 7.1% in October and 6.8% in November. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were lowest in October (59.1% and 34.1% respectively), suggesting greater intake potential and digestibility in October than in September or November. In contrast, the lower CP concentration observed in November indicates that forage quality declined later in the grazing season.

Heifer body weight was impacted by a treatment × day interaction (Figure 1). Though similar at the initiation of treatments, (416.7 ± 73 vs. 426.7 ± 7.84 kg for CON and SUPP, respectively) the SUPP heifers became heavier by the end of the feeding period compared with CON heifers (493.8 ± 8.35 vs. 440.0 ± 7.76 kg; $P < 0.0001$). Average daily gain over the feeding period was greater for SUPP than CON heifers (0.73 ± 0.03 vs. 0.24 ± 0.03 kg/day; adjusted $P < 0.0001$). Daily gain over each of the individual periods showed a similar pattern: gains did not differ from day 0 to 27 (1.14 vs 1.02 kg/d; $P = 0.2041$), but SUPP heifers gained more during each of the weight intervals through the end of the experiment. Interestingly, during the period from day 57 to 90, CON heifers lost weight whereas SUPP heifers maintained a slight gain (0.09 vs. -0.64 kg/d; $P < 0.0001$). These results suggest supplementation became more important as the trial progressed

Table 1. Forage analysis of representative sample composites of pasture grazed by beef heifers during the grazing period.[1, 4]

	Grazing period[2]		
Item	September	October	November
TDN[3]	54.39	51.96	53.50
CP, %	8.80	6.90	8.11
Ash	10.57	10.72	11.00
NDF, %	67.16	74.25	72.54
ADF, %	43.68	46.76	44.81
Ca, %	0.51	0.43	0.48
P, %	0.10	0.08	0.10
S, %	0.33	0.29	0.31
N, %	1.41	1.10	1.30

[1]Clipped forage samples from 16 different locations reported herein are composite over all locations within the representative sampling dates.
[2]Values presented are mean values of the representative sampling dates within the given month: September ($n = 1$), October ($n = 1$), and November ($n = 1$).
[3]TDN = 88.9 – (0.79 × ADF%); Holland and Kezar, 1995
[4]SUPP = heifers grazing pasture receiving protein and energy supplementation; CON = heifers grazing pasture without supplementation.

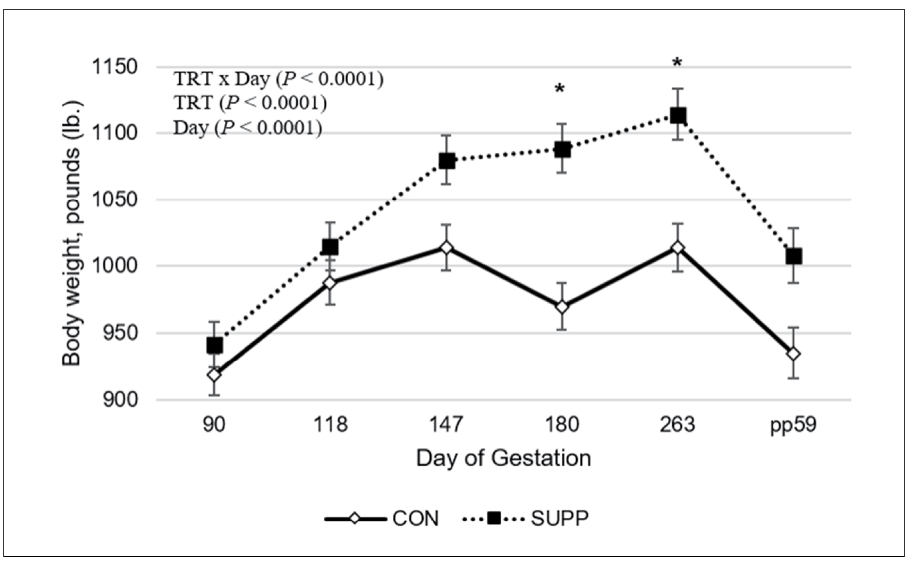

Figure 1. Body weight (lb) of the control (CON) and supplemented (SUPP) heifers measured on day 0 = 90, 27 = 118, 56 = 147, 90 = 180 of the trial through day 59 postpartum (pp). Error bars represent variability among animals.

and pasture conditions became less favorable.

Ultrasound measurements also indicated that body composition changed through the feeding period (Table 2). At the end of the trial, SUPP heifers had greater rump fat (1.93 ± 0.14 vs. 1.16 ± 0.11 cm; $P < 0.001$), rib fat (1.22 ± 0.07 vs. 0.81 ± 0.05 cm; $P < 0.0001$), and REA (67.35 ± 1.81 vs. 55.10 ± 1.42 cm^2; $P < 0.001$) than CON heifers, whereas IMF did not differ (5.18 ± 0.24 vs. 5.64 ± 0.16 %; $P = 0.113$). Changes over the feeding period followed the same pattern. Together, these results suggest that supplementation results in greater deposition of muscle and external fat during the study period, while IMF was not affected.

Blood metabolite responses were affected by treatment × day interactions for glucose, BUN, and NEFA (Figure 2). Glucose concentrations were greater in SUPP than CON heifers on day 27 (64.0 vs. 58.9 mg/dL; $P = 0.025$) and day 56 (65.5 vs 55.2 mg/dL; $P < 0.0001$) but did not differ on day 0 or 90 of the trial nor day 263 of gestation. Likewise, BUN concentrations were greater in SUPP than CON heifers on day 27 (11.4 vs. 7.2 mg/dL; $P < 0.0001$), day 56 (17.6 vs. 12.8 mg/dL; $P < 0.0001$), and day 90 (15.7 vs. 10.3 mg/dL; $P < 0.0001$), with no differences on day 0 of trial or day 263 of gestation. In contrast, NEFA concentrations were greater in CON than SUPP heifers on day 56 (408.4 vs. 189.9 mEq/L; $P < 0.0001$) and day 90 (622.4 vs. 529.0 mEq/L; $P = 0.13$) but did not differ on day 0 or 27 of trial nor 263 of gestation. These blood metabolite results suggest supplemented heifers were in a more favorable nutritional state during the trial, which is consistent with their improved BW gain and body composition.

Calf BW was not affected by dam treatment × day interaction ($P = 0.35$). Calf BW tended to be greater for calves born to SUPP dams than calves born to CON dams ($P = 0.06$). Across all calves, average BW was 34.7 kg at birth, 85.3 kg at turnout and 130.3 kg at breeding. Numerically, calves from supplemented dams were heavier at each time point, averaging 35.5 kg to 34.06 kg at birth, 87.99 kg to 82.70 kg at pasture turnout and 134.62 kg to 126.02 kg at mid-summer for SUPP and CON dams. These results suggest that maternal protein and energy supplementation during mid-gestation may have slightly improved early calf growth, but further post-natal evaluations are needed to confirm whether body weight changes persist toward sexual maturity.

Table 2. Ultrasound body composition characteristics at the beginning and end of the 90-day feeding period.

	Treatment[1]			
Item	CON	SUPP	SEM	*P*-value
Rump fat, in				
Beginning	0.19	0.20	0.02	0.5398
End	0.18	0.31	0.02	0.0001
Change[2]	-0.002	0.109	0.01	<0.0001
Rib fat, in				
Beginning	0.14	0.14	0.01	0.9988
End	0.13	0.19	0.01	<0.0001
Change	-0.018	0.049	0.009	<0.0001
REA, in^2				
Beginning	9.46	9.33	1.71	0.726
End	8.45	10.41	1.80	<0.0001
Change	-1.018	1.074	1.07	<0.0001
IMF, %				
Beginning	4.89	4.81	0.19	0.7655
End	5.58	5.23	0.209	0.2568
Change	0.686	0.426	0.148	0.2221

[1]Treatment
[2]Change = measurement at end of experiment – measurement at beginning of experiment

Conclusion

Overall, these results suggest that protein and energy supplementation during mid-gestation helps grazing beef heifers maintain growth, body condition, and muscle area when pasture quality is declining. Supplemented heifers finished the trial heavier, had greater ADG, and showed greater rump fat, rib fat, and REA than CON heifers, while IMF did not differ between treatments. Blood metabolite responses supported this interpretation, indicating that SUPP heifers were in a more favorable nutritional state during the trial. In addition, calves born to SUPP dams tended to be heavier through pasture turnout and mid-summer than calves born to CON dams. Together, these findings suggest that strategic supplementation during mid-gestation may be a useful management practice for producers when forage alone does not meet nutrient requirements and that impacts may extend into the postnatal period for calves gestated in this paradigm.

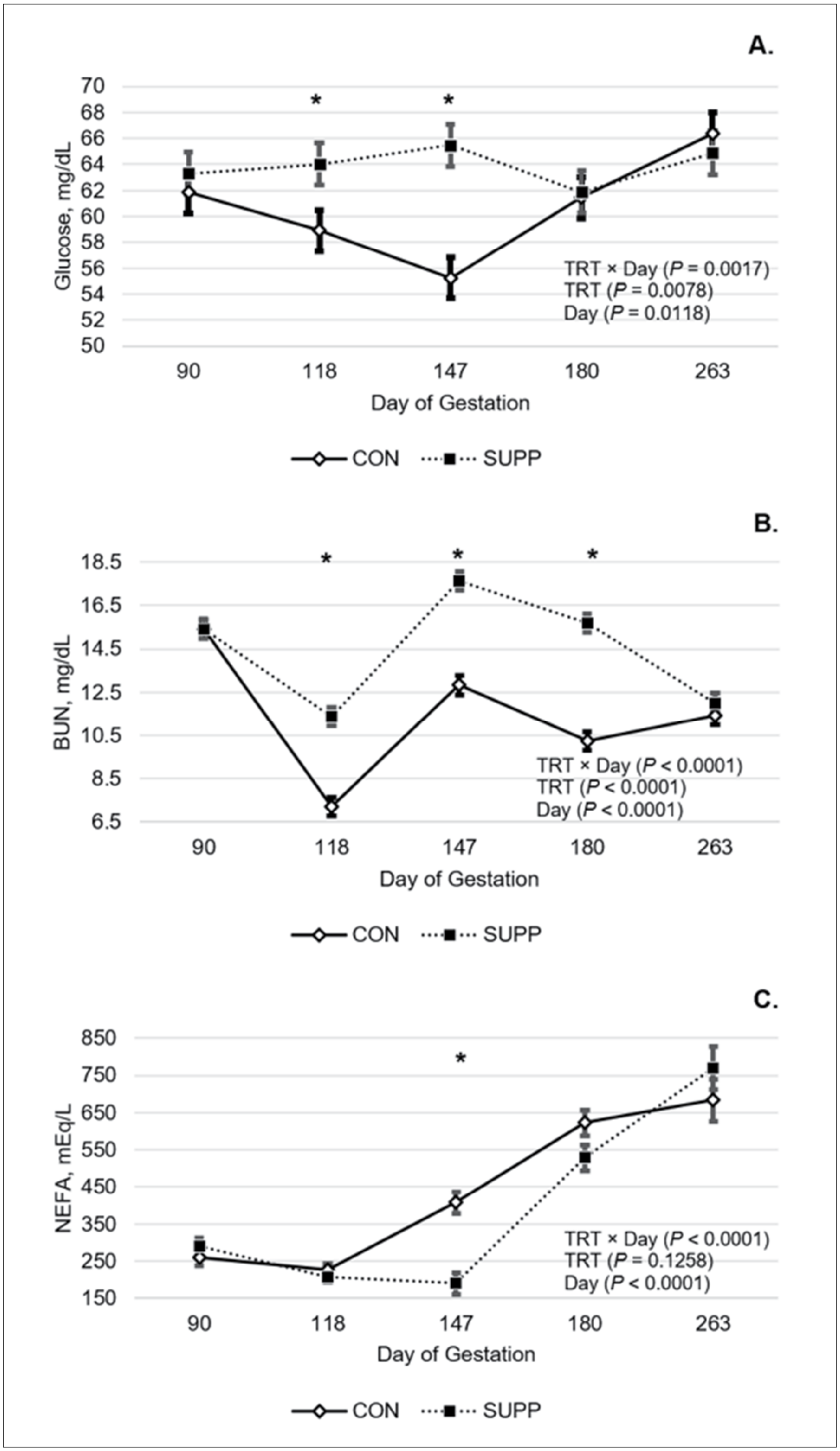

Figure 2. Concentrations of glucose (A), blood urea nitrogen (BUN; B), and nonesterified fatty acids (NEFA; C) during gestation in control (CON) heifers maintained on pasture only and supplemented (SUPP) heifers receiving protein and energy supplementation at 0.6% of BW on pasture. Values are least squares means ± SE. Significance was declared at $P \leq 0.05$ and tendency at $0.05 < P < 0.10$. Trial days correspond to gestation days as follows: d 0 = 90, d 27 = 118, d 56 = 147, and d 90 = 180 of gestation.

References

Chilcoat, K. E., M. S. Crouse, B. W. Neville, and J. S. Caton. 2016. effects of grazing intensity and advancing season on dietary chemical composition and in vitro organic matter digestibility in steers grazing mixed-grass prairie. J. Anim. Sci. 87:375–383.

Funston, R.N., Martin, J.L., Adams, D.C., & Larson, D.M. (2010). Winter grazing system and supplementation of beef cows during late gestation: Effects on progeny performance. J. Anim. Sci. 88:4094–4101.

McCarthy, K. L., S. R. Underdahl, M. Undi, and C. R. Dahlen. 2023. Using precision tools to manage and evaluate the effects of mineral and protein/energy supplements fed to grazing beef heifers. Transl. Anim. Sci. 7:txad013.

Shokrollahi, B., M. Park, G. S. Jang, S. Jin, S. J. Moon, K. H. Um, S. S. Jang, and Y. C. Baek. 2025. Maternal overnutrition in beef cattle: effects on fetal programming, metabolic health, and postnatal outcomes. Biology (Basel). 14:14060645.

Undi, M., C. Wilson, K. H. Ominski, K. M. Wittenberg, and K. Wittenberg. 2008. Comparison of techniques for estimation of forage dry matter intake by grazing beef cattle. Can. J. Anim. Sci. 88:693-701.

Influence of feed intake on nutrient and energy balance in heifers

Kendall C. Swanson[1], Pauliane Pucetti[1] and Christy A. Finck[1]

The objective of this experiment was to examine the effect of feed intake of a forage-based diet on nutrient and energy metabolism in heifers. Our data indicate that increasing dry matter intake decreases digestive efficiency and increases energy intake and losses. However, the increase in energy intake is greater than the losses associated with decreased digestibility, resulting in increased average daily gain as dietary energy intake increases.

Summary

Eight Angus heifers (approximately 10 months of age; 763 ± 4.0 lb of body weight) were used in a replicated 4 × 4 Latin square design to examine the effect of feed intake of a forage-based diet on nutrient and energy metabolism in heifers. Dietary treatments consisted of feeding a total mixed ration consisting (dry matter basis) containing 48.5% alfalfa hay, 48.5% corn silage and 3% vitamin/mineral supplement offered at 1.0%, 1.4%, 1.8% or 2.2% (dry matter basis) of body weight. Sample collection periods were 15 days, with the first 10 days for adaptation to the feeding level, followed by five days of sample collection. Dry matter, neutral detergent fiber, starch, and crude protein intake, fecal excretion, and lb digested per day increased linearly ($P \leq 0.02$) with increasing intake. Dry matter, neutral detergent fiber, starch, and crude protein digestibility (% of intake) linearly decreased ($P \leq 0.04$) with increasing intake. Gross energy intake, fecal energy, digestible energy, urinary energy, gaseous energy, metabolizable energy, heat production and retained energy increased linearly ($P < 0.001$) with increasing intake. However, the increase in energy intake was greater than the energy losses associated with the decrease in digestibility, resulting in an increase in average daily gain. Retained energy for heifers fed 1.0% and 1.4% of body weight was negative, suggesting these heifers were in negative energy balance. Further analyses will be conducted to calculate estimated maintenance energy requirements and efficiency of energy use and compared to past research. This could provide insights into potential differences between cattle with current genetics as compared to cattle from research conducted 30-plus years ago.

Introduction

There has been considerable recent interest in how cow size influences efficiency of weaned calf production. The size of cows, as well as carcass weight of finished cattle, has increased dramatically over the past 30-plus years. This has been driven by the selection for greater growth rate in calves and the demand for heavier finished carcasses by the packers. Dietary energy requirement models (NASEM, 2016) for beef cattle utilize the net energy system for predicting requirements, which accounts for all inputs (intake) and losses (fecal, urinary, gaseous and heat). However, there has been limited research quantifying all inputs and losses over the last 30-plus years, especially for replacement heifers and cows that are typically fed forage-based diets. Therefore, this study was conducted to examine the effects of dry matter intake on diet digestibility and energy balance in nonpregnant replacement Angus heifers.

Procedures

All procedures with animals were approved by the North Dakota State University (NDSU) Animal Care and Use Committee. Eight Angus heifers (approximately 10 months of age; 763 ± 4.0 lb of body weight) were used in a replicated 4 × 4 Latin square design to examine the effect of feed intake of a forage-based diet on nutrient and energy metabolism in heifers. Dietary treatments consisted of feeding a total mixed ration (Table 1) consisting (dry matter basis) of 48.5% alfalfa hay, 48.5% corn silage and 3% vitamin/mineral supplement offered at 1.0%, 1.4%, 1.8% or 2.2% of body weight. Periods were 15 days in length, with the first 10 days for adaptation to the feeding level, followed by five days of sample collection. Offered feed (hay and supplements) and refusals (if present) were weighed and sampled

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Table 1. Nutrient composition of total mixed ration fed to heifers.

Nutrient	% of DM
Organic matter	89.7
Crude protein	13.5
Neutral detergent fiber	49.6
Acid detergent fiber	31.2
Starch	15.1
Ether extract	1.34
Gross energy, kcal/g	4,261

daily during the collection phase. Total feces and urine were collected over four consecutive days (days 11 to 14). 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 concentration. Urine was collected via urinary catheters, preserved in HCl and subsampled daily. Total mass was recorded, and aliquots were frozen for nitrogen and energy analysis.

Heat production and methane production were measured using headbox respiration chambers over 24 hours on day 15 of each period. Steers were tethered and had access to the total mixed ration 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 concentrations. Total air flow was recorded and corrected for temperature and humidity. Methane energy loss was calculated by multiplying methane 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 square, steer within square, period within square and treatment. Linear and quadratic effects were determined using contrast statements. Significance was declared at $P < 0.05$.

Results and Discussion

Dry matter, neutral detergent fiber, starch, and crude protein intake, fecal excretion, and lb digested increased linearly ($P \leq 0.02$) with increasing intake (Table 2). There were also trends for quadratic effects, which occurred because some of the heifers fed the higher intakes did not consume all of the feed offered. Dry matter, neutral detergent fiber, starch and crude protein digestibility (% of intake) linearly decreased ($P \leq 0.04$) with increasing intake, which is consistent with past research (Tyrrell and Moe, 1975; Van Soest and Fox, 1992). Gross energy intake, fecal energy, digestible energy, urinary energy, gaseous energy, metabolizable energy, heat production and retained energy increased linearly ($P <$ 0.001) with increasing intake (Table

Table 2. Influence of dry matter intake of a forage-based diet on nutrient digestibility in Angus heifers.

	DM offered, kg					*P*-value	
Item	1%	1.4%	1.8%	2.2%	SEM	Linear	Quadratic
Dry matter							
Intake, lb/d	7.47	10.43	12.10	12.94	0.542	<0.001	0.06
Feces, lb/d	3.15	4.45	5.11	6.08	0.158	<0.001	0.30
Digested, lb/d	4.32	5.95	6.99	6.86	0.461	<0.001	0.07
Digested, % of intake	57.9	57.1	57.6	51.0	2.08	0.04	0.18
Neutral detergent fiber							
Intake, lb/d	3.86	5.38	6.26	6.66	0.284	<0.001	0.06
Feces, lb/d	1.65	2.34	2.73	3.28	0.086	<0.001	0.42
Digested, lb/d	2.23	3.04	3.53	3.37	0.251	0.002	0.06
Digested, % of intake	57.6	56.6	56.0	48.2	2.45	0.02	0.51
Starch							
Intake, lb/d	1.19	1.65	1.91	2.03	0.091	<0.001	0.08
Feces, lb/d	0.073	0.108	0.123	0.152	0.0055	<0.001	0.47
Digested, lb/d	1.11	1.55	1.78	1.88	0.0880	<0.001	0.07
Digested, % of intake	93.6	93.5	93.4	92.3	0.28	0.005	0.08
Crude protein							
Intake, lb/d	1.05	1.46	1.70	1.82	0.067	<0.001	0.04
Feces, lb/d	0.525	0.734	0.850	1.011	0.021	<0.001	0.25
Digested, lb/d	0.524	0.728	0.850	0.805	0.057	0.002	0.04
Digested, % of intake	50.1	49.7	49.8	41.6	2.15	0.02	0.09

3), which is expected because of increased dry matter intake and thus increased energy intake and losses. However, the increase in energy intake was greater than the energy losses associated with the decrease in digestibility, which resulted in increased average daily gain. Further research is needed to examine if the digestive efficiency losses associated with increased energy intake have changed over time and if the currently used equations to predict net energy supply (NASEM, 2016) are appropriate for cattle with current genetics. Retained energy for heifers fed 1.0% and 1.4% of body weight were negative, suggesting these heifers were in negative energy balance. Further analyses will be conducted to calculate estimated maintenance energy requirements and efficiency of energy use and compared to past research. This could provide insights into potential differences between cattle with current genetics and those from research conducted 30-plus years ago.

Acknowledgments

The authors would like to thank the staff and student employees at the NDSU Beef Unit and Animal Nutrition and Physiology Center for assistance with care and feeding of cattle, and the staff of the NDSU Animal Sciences Nutrition Laboratory for assistance with feed analysis. Funding for the project was partially supported by the North Dakota State Board of Agricultural Research and Education.

References

NASEM. 2016. Nutrient Requirements of Beef Cattle. The National Academies Press, Washington, DC.

Tyrrell, H. F., and P. W. Moe. 1975. Effect of intake on digestive efficiency. J. Dairy Sci. 58:1151–1163.

Van Soest, P. J., and D. G. Fox. 1992. Discounts for net energy and protein - fifth edition, Proc. Cornell Nutr. Conf., Ithaca, NY. p. 40–68.

Table 3. Influence of dry matter intake of a forage-based diet on energy balance in Angus heifers.

	DM offered, kg					*P*-value	
Item, Mcal/d	**1%**	**1.4%**	**1.8%**	**2.2%**	**SEM**	**Linear**	**Quadratic**
Gross energy intake	14.8	20.7	24.8	28.6	0.40	<0.001	0.02
Fecal energy	6.2	8.8	10.1	12.0	0.36	<0.001	0.32
Digestible energy	8.7	11.9	14.7	16.6	0.37	<0.001	0.09
Urinary energy	0.87	0.97	1.02	1.11	0.040	<0.001	0.99
Gaseous (methane) energy	1.11	1.38	1.52	1.67	0.048	<0.001	0.26
Metabolizable energy, Mcal	6.7	9.6	12.2	13.8	0.341	<0.001	0.09
Heat production	9.7	11.4	12.0	13.4	0.28	<0.001	0.58
Retained energy	-3.03	-1.86	0.17	0.41	0.315	<0.001	0.15

Placental vascular development, cellular proliferation and angiogenic factor expression in beef heifers throughout gestation

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The objective of this study was to characterize placental vascular development, cellular proliferation and angiogenic factor expression throughout gestation in beef heifers. Distinct expression patterns of VEGFR1 and VEGFR2 suggest complementary roles in maternal and fetal placental vascular development. These findings provide a baseline for future studies evaluating the effects of maternal nutrition and management on placental function and fetal growth.

Summary

Placental vascular development is essential for fetal growth, but the temporal regulation of angiogenic signaling throughout gestation in beef cattle is not well understood. Therefore, the objective of this study was to characterize placental vascular development, cellular proliferation and angiogenic factor expression throughout gestation in beef heifers. Placentomes were collected from 80 primiparous crossbred Angus beef heifers at 10 gestational stages (days 34, 50, 63, 83, 161, 181, 250, 260, 272 and parturition). Immunofluorescence was used to evaluate vascular development (CD31 and CD34), cellular proliferation (Ki67), and angiogenic and vasoactive factors (VEGF, VEGFR1, VEGFR2, endothelial nitric oxide synthase (eNOS) and soluble guanylyl cyclase [sGC]). Capillary area density (CAD), capillary number density (CND) and protein expression were quantified in the maternal caruncle (CAR) and fetal cotyledon (COT). Placental vascularity increased throughout gestation, with CAD increasing from 1.00 ± 0.77% to 12.47 ± 0.61% in the COT and from 3.76 ± 0.77% to 8.62 ± 0.61% in the CAR ($P < 0.01$). Cellular proliferation also increased during gestation and remained greater in the CAR than the COT during late pregnancy. Expression of eNOS increased during early to midgestation before declining during late gestation, whereas sGC expression was highest during early gestation and increased again near term. Distinct regional differences were observed in VEGF receptor expression, with VEGFR1 predominating in the maternal CAR and VEGFR2 in the fetal COT. Strong VEGF immunostaining was also observed in binucleate giant cells (BNGCs), suggesting a potential role in placental angiogenesis and maternal-fetal communication. Overall, placental vascular development, endothelial proliferation and angiogenic signaling changed dynamically throughout gestation, providing baseline information for future studies evaluating placental function, maternal nutrition and fetal growth in beef cattle. Observed in VEGF receptor expression. VEGFR1 was greater in the maternal CAR, particularly at days 63 and 181 ($P < 0.01$), whereas VEGFR2 was greater in the fetal COT, peaking at day 83 and remaining elevated during late gestation. In conclusion, placental vascular development, endothelial proliferation and angiogenic signaling changed dynamically throughout gestation. VEGFR1 predominated in maternal placental tissue, whereas VEGFR2 predominated in fetal placental tissue, and strong VEGF expression in binucleate giant cells (BNGCs) suggests these specialized trophoblasts cells may contribute to placental angiogenesis and maternal-fetal communication.

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Introduction

The placenta is a transient but highly specialized organ that supports fetal growth by facilitating the exchange of oxygen, nutrients and metabolic waste between the maternal and fetal circulations (Reynolds and Redmer, 2001). As gestation progresses, placental vascular development must increase to meet the growing metabolic demands of the fetus. In ruminants, the placentome, composed of the maternal caruncle (CAR) and fetal cotyledon (COT), is the primary site of maternal-fetal exchange; therefore, proper vascular development is essential for placental function, fetal growth and pregnancy success (Borowicz et al., 2007). Placental vascular development is regulated through coordinated processes of angiogenesis and cellular proliferation. Endothelial cell markers CD31 and CD34 are widely used to identify placental capillaries and quantify vascular development, whereas Ki67 is a reliable marker of cellular proliferation (Scholzen and Gerdes, 2000). Angiogenesis is primarily regulated by vascular endothelial growth factor (VEGF) and its receptors, VEGFR1 and VEGFR2, while placental vascular function is further controlled by the nitric oxide pathway through endothelial nitric oxide synthase (eNOS) and soluble guanylyl cyclase (sGC), which regulate placental blood flow (Reynolds and Redmer, 2001). Although placental vascular development has been extensively studied in sheep, relatively little information is available regarding placental vascularity, cellular proliferation and angiogenic factor expression throughout gestation in beef cattle. Therefore, the objective of this study was to characterize placental vascular development, cellular proliferation and the expression of key angiogenic and vasoactive factors throughout gestation in beef heifers, providing a baseline for future studies of placental function, fetal growth and maternal nutrition.

Procedures

The study included 80 pregnant crossbred Angus beef heifers managed at the North Dakota State University Beef Cattle Research Complex. Placental tissues were collected throughout gestation (approximately 280 days) on days 34 (n = 5), 50 (n = 5), 63 (n = 8), 83 (n = 8), 161 (n = 7), 181 (n = 10), 250 (n = 7), 260 (n = 9), 272 (n = 8) and at parturition (n = 13). At tissue collection, fetal and placental weights were recorded, and placentomes were dissected for histological evaluation. Placentomes were fixed in 10% neutral-buffered formalin, embedded in paraffin, sectioned at 5 μm and mounted on microscope slides. Tissue sections were stained using immunofluorescence to evaluate placental vascular development, cellular proliferation and angiogenic factor expression. Endothelial cells were identified using CD31 and CD34. Cellular proliferation was assessed using the nuclear proliferation marker Ki67. Angiogenic and vasoactive proteins evaluated included VEGF red1, VEGFR1, VEGFR2, eNOS and sGC. Images were captured using a Mica Microhub fluorescence microscope (Leica Microsystems Inc., Buffalo Grove, Illinois), and quantitative image analysis was performed using Image-Pro Premier software (Version 9.0.1; Media Cybernetics, Inc., Silver Spring, MD). Capillary area density (CAD) and capillary number density (CND) were measured separately in the fetal cotyledon (COT) and maternal caruncle (CAR) of each placentome. Protein expression and Ki67 labeling index were quantified as the percentage of positively stained areas within each region. Data was analyzed using the PROC GLM and PROC REG procedures of SAS (Version 9.4; SAS Institute Inc., Cary, NC). Differences among days of gestational and placental regions were considered statistically significant at $P \leq 0.05$, with $P \leq 0.01$ indicating stronger statistical evidence,and regression analyses were performed to characterize changes in placental vascularity and angiogenic factor expression throughout gestation.

Results and Discussion

Placental and fetal weights increased throughout gestation, following a sigmoidal (S-shaped) growth pattern characterized by slow early growth, rapid mid-gestation growth, and leveling off near term, with excellent model fit (placental weight, $R^2 = 0.9388$; fetal weight, $R^2 = 0.9827$; Figure 1). Placental growth occurred earlier and increased gradually, whereas fetal growth accelerated after approximately day 160. This pattern indicates that placental development precedes rapid fetal growth, increasing the capacity for nutrient and oxygen exchange. Similar growth patterns have been reported in sheep and other ruminants (Reynolds and Redmer, 2001; Reynolds et al., 2005).

During early gestation (days 34-83), CAD was greater in the CAR than in the COT ($P < 0.05$), whereas by late gestation (days 250-272), both CAD and CND were greater in the COT ($P < 0.01$; Table 1). Capillary area density increased approximately 12-fold in the COT compared with 2.3-fold in the CAR, while CND increased more than 11-fold in the COT and 4-fold in the CAR. Cellular proliferation (Ki67) also increased throughout gestation and was greater in the CAR from days 63 to 272 ($P < 0.05$), indicating continued maternal placental remodeling. Together, these findings demonstrate a developmental shift from the maternal placenta during early gestation to rapid fetal placental vascular expansion during late gestation, supporting the increasing nutrient demands of fetal growth (Reynolds et al., 2023).

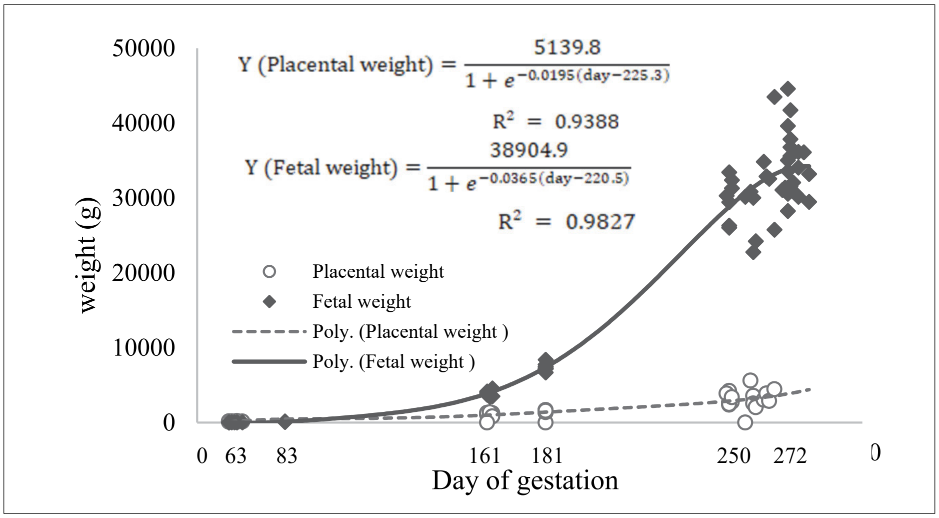

Figure 1. Relationship between placental weight and fetal weight in beef cattle.

Table 1. Changes in placental vascularity and cellular proliferation throughout gestation.

Measurement	Days of gestation	Region[1] COT	CAR	*P*-value[2] of region
(CD31&CD34) Capillary Area Density, %	34	1.003 ± 0.768	3.757 ± 0.768	**0.0007**
	50	2.223 ± 0.768	5.244 ± 0.768	**0.0002**
	63	3.505 ± 0.701	6.438 ± 0.701	**<0.0001**
	83	5.546 ± 0.701	7.079 ± 0.701	**0.0352**
	161	7.955 ± 0.649	7.349 ± 0.649	0.3639
	181	8.521 ± 0.543	7.518 ± 0.543	0.0741
	250	11.528 ± 0.649	8.373 ± 0.649	**<0.0001**
	260	12.021 ± 0.551	8.541 ± 0.574	**<0.0001**
	272	12.466 ± 0.607	8.623 ± 0.607	**<0.0001**
	Parturition	18.275 ± 0.716	N/A	
(CD31&CD34) Capillary Number Density, %	34	0.055 ± 0.034	0.081 ± 0.034	0.4870
	50	0.068 ± 0.031	0.184 ± 0.031	**0.0022**
	63	0.097 ± 0.031	0.211 ± 0.031	**0.0010**
	83	0.123 ± 0.029	0.231 ± 0.029	**0.0017**
	161	0.231 ± 0.024	0.265 ± 0.024	0.2782
	181	0.260 ± 0.029	0.276 ± 0.029	0.5349
	250	0.512 ± 0.027	0.323 ± 0.027	**<0.0001**
	260	0.598 ± 0.049	0.328 ± 0.032	**<0.0001**
	272	0.618 ± 0.021	0.319 ± 0.021	**<0.0001**
	Parturition	0.419 ± 0.02	N/A	
Ki-67 (%Li)	34	3.302 ± 3.751	6.391 ± 3.751	0.5618
	50	14.999 ± 3.751	18.991 ± 3.751	0.4536
	63	16.434 ± 3.424	34.649 ± 3.424	**0.0003**
	83	21.646 ± 3.424	41.611 ± 3.424	**<0.0001**
	161	27.527 ± 3.424	50.220 ± 3.424	**<0.0001**
	181	29.222 ± 2.652	54.482 ± 2.652	**<0.0001**
	250	38.352 ± 3.170	59.265 ± 3.170	**<0.0001**
	260	32.487 ± 2.145	41.528 ± 2.458	**<0.0001**
	272	27.958 ± 2.965	36.847 ± 2.965	**0.0368**

[1]CAR = caruncle; COT = cotyledon;
[2]*P*-values in bold indicate significant differences between COT and CAR.

In the COT, eNOS expression increased from 14.08 ± 4.02% on day 34 to 22.31 ± 3.68% on day 181 before declining during late gestation ($P \leq 0.01$; Figure 2). In contrast, sGC expression was highest during early gestation (35.09 ± 10.34% on day 34), decreased during midgestational and increased again near term (15.60 ± 4.27% on day 272), indicating dynamic regulation of nitric oxide signaling. VEGF was expressed throughout gestation in both placental regions, with particularly strong immunostaining in binucleate giant cells (BNGCs). Because BNGCs are specialized trophoblast cells involved in placental development and maternal-fetal communication (Klisch and Leiser, 2003), their strong VEGF expression suggests a role in placental angiogenesis and vascular remodeling, consistent with the established roles of VEGF and nitric oxide signaling in placental vascular function (Reynolds and Redmer, 2001).

As shown in Figure 3, VEGFR1 and VEGFR2 exhibited distinct regional expression patterns. VEGFR1 expression was greater in the maternal CAR than in the fetal COT, particularly at days 63 and 181 ($P < 0.01$). In contrast, VEGFR2 predominated in the fetal COT, peaking at day 83 (35.50 ± 8.17%) and remaining elevated during late gestation ($P < 0.01$). Because VEGFR2 is the primary receptor mediating VEGF-induced angiogenesis, whereas VEGFR1 regulates VEGF signaling and vascular organization, these expression patterns suggest active angiogenesis in the fetal placenta and vascular stabilization in the maternal placenta, consistent with previous reports in ruminants (Reynolds and Redmer, 2001).

Overall, placental vascular development, endothelial proliferation and angiogenic signaling changed dynamically throughout gestation. A developmental shift from the maternal caruncle during early gestation to the fetal cotyledon during mid- and late gestation was accompanied by

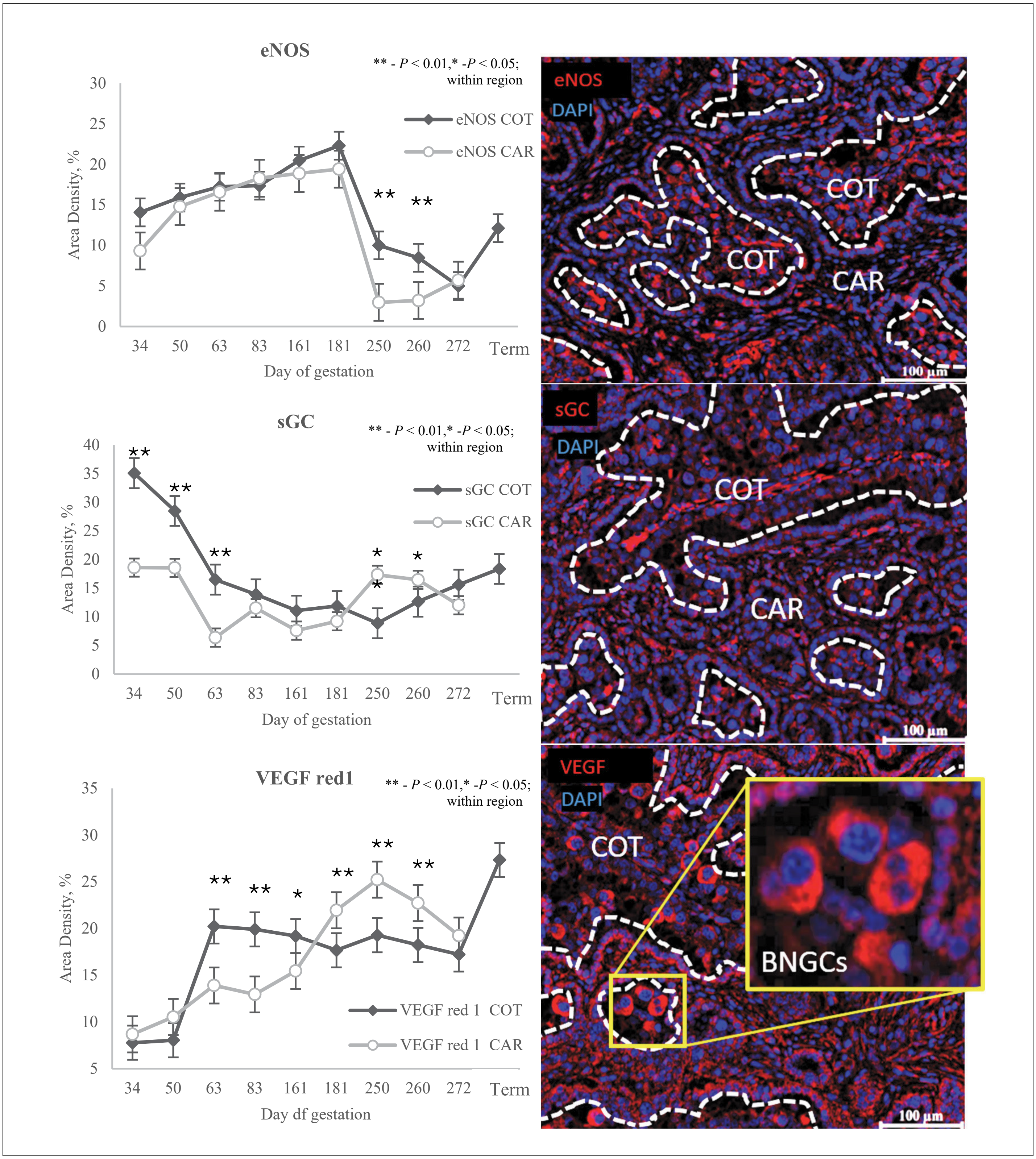

Figure 2. Gestational regulation of eNOS, sGC, and VEGF expression in COT and CAR of beef heifer placentomes.

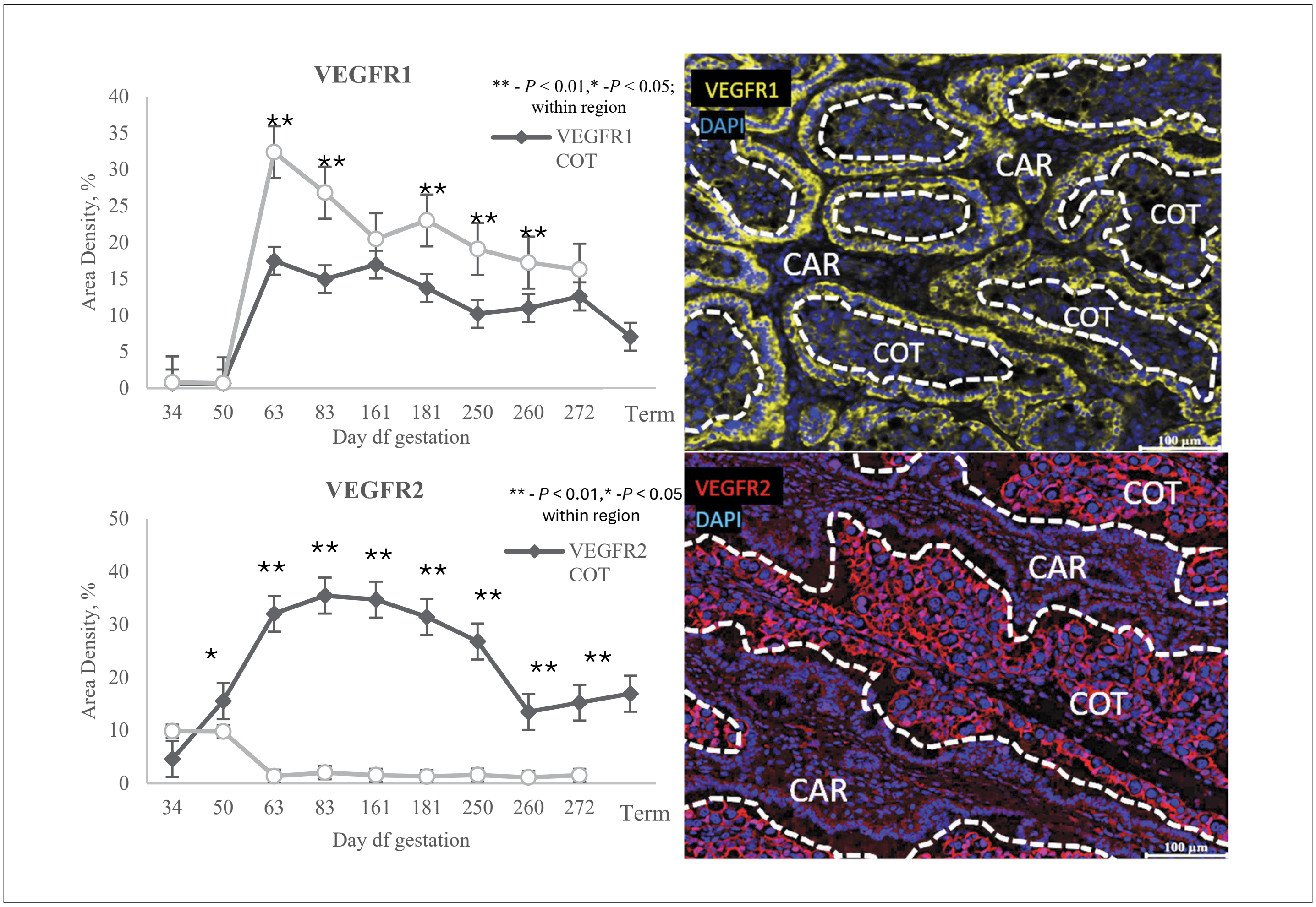

Figure 3. Gestational expression of VEGFR1 and VEGFR2 in CAR and COT of beef heifer placentomes.

predominant VEGFR1 expression in the maternal placenta and VEGFR2 expression in the fetal placenta. Strong VEGF expression in binucleate giant cells further suggests that these specialized trophoblast cells may contribute to placental angiogenesis and maternal-fetal communication.

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Literature Cited

Borowicz, P. P., D. R. Arnold, M. L. Johnson, A. T. Grazul-Bilska, D. A. Redmer, and L. P. Reynolds. 2007. Placental growth throughout the last two-thirds of pregnancy in sheep: Vascular development and angiogenic factor expression. Biol. Reprod. 76:259–267.

Klisch, K., and R. Leiser. 2003. In bovine binucleate trophoblast giant cells, pregnancy-associated glycoproteins and placental prolactin-related protein-I are conjugated to asparagine-linked N-acetylgalactosaminyl glycans. Histochem. Cell Biol. 119:211–217.

Reynolds, L. P., P. P. Borowicz, D. R. Dahlen, A. K. Ward, M. S. Crouse, B. J. Dávila-Ruiz, C. Kanjanaruch, K. J. McLean, K. L. McCarthy, A. C. B. Menezes, W. J. S. Diniz, R. A. Cushman, and J. S. Caton. 2023. Role of the placenta in developmental programming: Observations from models using large animals. Anim. Reprod. Sci. 257:107322.

Reynolds, L. P., and D. A. Redmer. 2001. Angiogenesis in the placenta. Biol. Reprod. 64:1033–1040.

Scholzen, T., and J. Gerdes. 2000. The Ki-67 protein: From the known and the unknown. J. Cell. Physiol. 182:311–322.

The effects of oxidizing air purification on swine barn air quality and pig health, performance, and behavior during the farrowing phase of production

Keara J. Leong-Machielse[1], Jennifer M. Young[1], Xiaoyu Feng[2], Samat Amat[1] and Christopher J. Byrd[1]

Oxidizing air purification (OAP) technology did not affect air quality parameters in a commercial-like sow nursing environment. However, OAP did differentially affect piglet performance and behavior. More work is needed to determine whether OAP has meaningful beneficial effects on pig health, performance, and welfare.

Summary

This study investigated the effects of a novel oxidizing air purification (OAP) technology on swine barn air quality and piglet performance and behavior during the farrowing (i.e., nursing) phase of production. Shortly before farrowing, sows were randomly assigned to a room that contained two OAP mobile units or a room that did not. Concentrations of particulate matter size 10 microns or smaller (PM_{10}), ammonia (NH_3) and hydrogen sulfide (H_2S) were measured weekly. Piglets were weighed every six days during the farrowing phase to determine body weights and average daily gain (ADG). Piglet behavior was evaluated from video recorded throughout the experimental period. Particulate matter, NH_3 and H_2S were not significantly different between the OAP and control rooms. Despite air quality parameters not being different, piglets exposed to OAP spent more time nursing on days 1 and 10 of age. Control piglets tended to be heavier at weaning than OAP piglets. These results suggest that OAP may affect pig welfare, as indicated by some differences in behavior and performance, but the mechanism is not clear. Further work is needed to fully elucidate the effect of OAP on piglet health, performance and behavior.

Introduction

Particulate matter (i.e., dust), ammonia (NH_3) and hydrogen sulfide (H_2S) present in air at high concentrations have the potential to negatively affect pig health, performance and welfare. Therefore, mitigation of these contaminants is important to the swine industry. The most common method of managing air quality in swine facilities is ventilation; however, none of the widely used ventilation systems provide full control over the environmental air quality of the barn. Several supplemental strategies for improving indoor air quality have been developed and tested, but their use is not widespread, and concerns about particulate matter and gas emission exposures within swine facilities remain. Therefore, there is a need to identify novel strategies to mitigate indoor air quality challenges.

One potential alternative method is oxidizing air purification (OAP) technology, which uses ozone to oxidize and reduce common air-quality emissions of concern. Early studies have shown ozone to be effective at reducing indoor gas emissions (Priem, 1977; Elenbaas-Thomas et al., 2005; Banhazi, 2011); however, humans and animals cannot be directly exposed to ozone without risk to their health. The OAP technology used in this study (CerroZone Mobile Units; now owned and marketed by Micron Pure, LLC.; St. Louis, MO) mitigates this issue by utilizing a closed purification environment to perform the following: 1) intake room air, 2) convert the oxygen contained within room air to ozone, 3) allow ozone to oxidize and remove pathogens and volatile compounds of concern from the air, and 4) exhaust the purified air back into the barn. The objective of this study was to evaluate the use of OAP on swine barn air quality and swine welfare, as indicated by performance and behavior traits.

Procedures

Animals were housed in the farrowing rooms at the NDSU Swine Research and Teaching Center. This study took place during two repeated

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trials (i.e., one winter trial and one summer trial). In trial one (winter), sows were randomly assigned to the OAP treatment farrowing room (n = 4 sows) or the control treatment farrowing room (n = 5 sows). In trial two (summer), three sows were randomly assigned to each treatment room. Oxidizing air purification mobile units were powered on in the OAP treatment rooms when sows entered the rooms. Environmental air samples were collected on days 0 (when sows entered the farrowing rooms), 7, 14, 21, and 28 to analyze for NH_3 and H_2S. Particulate matter (PM_{10}) was collected on the same days. During lactation, piglets were weighed every six days to calculate average daily gain (ADG). Video cameras positioned above each gestation stall recorded piglet behavior. Six hours of behavioral data (0800-1000, 1100-1300, 1400-1600 h) when piglets were one, two, three, seven, 10, and 14 days of age were analyzed for nursing duration and frequency and postural traits of lying, standing and sitting. Piglets were weaned at 23.7 ± 4.8 days of age.

Table 1. Least squares means for air quality parameters by treatment (oxidizing air purification [OAP] and control) and day of study (day 0 is when sows were moved into farrowing).

Trait	Day	OAP	Control	SED[1]	*P*-value[2]
Ammonia (NH_3), ppm					
	0	5.70	2.80	1.79	0.14
	7	5.87	5.50	1.79	0.84
	14	8.47	4.43	1.79	0.05
	21	4.74	4.72	1.79	0.99
	28	5.87	5.73	1.79	0.94
Hydrogen sulfide (H_2S), ppm					
	0	0.128	0.090	0.046	0.44
	7	0.146	0.092	0.046	0.27
	14	0.063	0.038	0.046	0.59
	21	0.112	0.108	0.046	0.92
	28	0.087	0.080	0.046	0.88
Particulate matter size 10 microns or smaller (PM_{10}), µg/m^3					
	0	59.1	11.4	234.9	0.84
	7	175.6	579.9	241.6	0.11
	14	496.8	47.7	242.3	0.07
	21	17.0	151.5	242.3	0.58
	28	43.6	30.4	242.3	0.96

[1] Standard error of the difference between the two treatments on a day is reported.
[2] *P*-value is for the difference between treatments on the same day.

Results and Discussion

Environmental air quality parameters were not significantly different between treatments on any day; however, NH_3 and PM_{10} tended to be higher on day 14 in the OAP rooms compared to the control rooms (Table 1). The lack of differences between rooms may be due to the low concentrations of each parameter already present in the farrowing rooms compared with those typically observed in large commercial facilities. A repeated trial effect was observed for NH_3 and H_2S, with NH_3 concentration being lower during the summer trial compared to the winter trial (0.70 ± 0.80 ppm vs. 10.07 ± 0.80 ppm; $P < 0.0001$) and H_2S concentration being lower during the summer trial compared to the winter trial (0.04 ± 0.02 ppm vs. 0.15 ± 0.02 ppm; $P = 0.0005$). These repeated-trial effects were expected, given the likelihood of increased NH_3 and H_2S concentrations during winter months when ventilation within the barn is minimized to maintain acceptable room temperature.

Although no meaningful differences in air quality between treatment rooms were observed, we did identify differences in piglet behavior and performance between treatments. Piglets exposed to OAP spent more time nursing on days 1 and 10 of age (Figure 1; $P = 0.01$ and 0.01, respectively) and tended to spend more time nursing on days 2, 7, and 14 of age ($P = 0.06$, 0.09, and 0.07, respectively). This resulted in OAP piglets spending more time nursing compared to control piglets overall (126.1 ± 13.1 min vs. 77.6 ± 11.7 min; $P = 0.007$). For nursing frequency, OAP piglets nursed more frequently than control piglets (8.48 ± 1.00 vs. 5.56 ± 0.98; $P = 0.04$), which was largely driven by OAP piglets performing more nursing bouts at one day of age compared to control piglets (11.6 ± 1.8 vs. 5.4 ± 1.7 bouts; $P = 0.01$).

Effective nursing during the first 24-48 hours postfarrowing is required for ensuring adequate piglet colostrum intake. The nursing results presented here provide some evidence that OAP improved piglets' ability to nurse during this critical period, which may have future immunity and health benefits. However, regardless of increased OAP piglet nursing duration and frequency during this period, control piglets tended to be heavier than OAP treatment piglets at weaning (Figure 2; $P = 0.07$) and tended to have greater overall ADG compared to OAP piglets (0.72 ± 0.03 vs. 0.63 ± 0.04 lb/d; $P = 0.097$).

Postural data is presented in Table 2. No main treatment effects

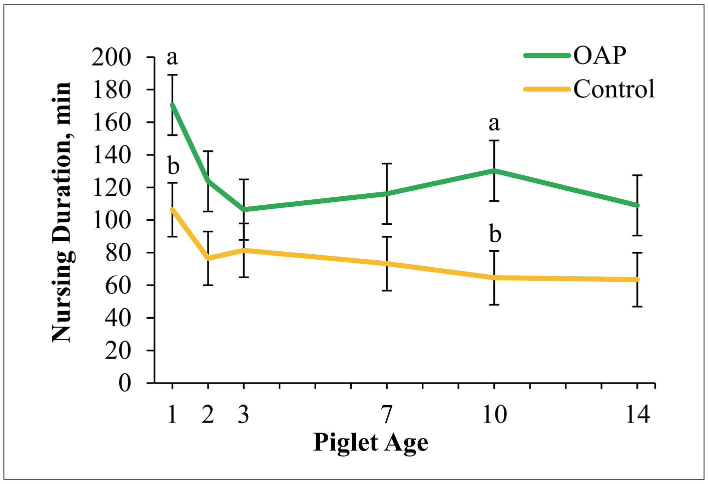

Figure 1. Effect of oxidizing air purification (OAP) on nursing duration of piglets.

[a,b] Time points with differing superscripts differ between treatments at $P < 0.05$.

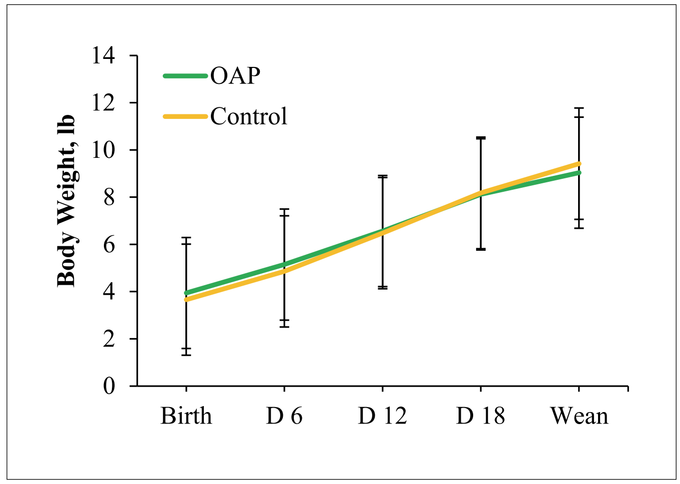

Figure 2. Effect of oxidizing air purification (OAP) on piglet weight throughout the farrowing phase of production.

were observed for lying ($P = 0.58$) or standing ($P = 0.68$). However, there was a tendency for increased lying exhibited by control pigs compared to OAP pigs at 10 days of age ($P = 0.09$).

No treatment differences for standing were observed at any time point ($P > 0.10$). There was a main effect of treatment on the percentage of piglets sitting per day ($P = 0.0003$), with OAP piglets exhibiting a greater percentage of sitting per day compared to CON-f piglets (3.20 ± 0.27 vs. 1.79 ± 0.29). This result was largely driven by OAP piglets exhibiting greater sitting percentages at one and three days of age ($P = 0.0006$ and 0.04, respectively) and tending to exhibit a greater sitting percentage at 14 days of age ($P = 0.053$) compared to control piglets. The increased sitting behavior performed by OAP piglets on days 1 and 3 may be related to common postural changes associated with nursing duration and frequency, which were also increased in the OAP treatment. However, more work is needed to confirm this potential interpretation.

Table 2. Least squares means for piglet postural data by treatment (oxidizing air purification [OAP] and control) and day of age.

Trait	Day	OAP	Control	SED[1]	*P*-value[2]
Percentage of pigs lying per day					
	1	68.1	63.3	5.1	0.36
	2	67.4	66.5	5.3	0.87
	3	70.2	72.2	5.3	0.71
	7	76.2	76.7	6.5	0.93
	10	66.6	77.0	5.8	0.09
	14	64.5	70.1	7.8	0.48
Percentage of pigs standing per day					
	1	19.3	27.3	4.7	0.10
	2	21.6	28.3	4.9	0.18
	3	19.1	23.0	4.9	0.43
	7	19.2	18.9	5.6	0.96
	10	27.4	20.5	5.2	0.20
	14	29.0	27.2	6.6	0.78
Percentage of pigs sitting per day					
	1	4.90	2.52	0.59	0.0006
	2	3.00	2.29	0.63	0.27
	3	2.81	1.44	0.63	0.04
	7	2.87	1.58	0.76	0.11
	10	3.06	2.33	0.69	0.31
	14	2.56	0.59	0.96	0.05

[1] Standard error of the difference between the two treatments on a day is reported.
[2] *P*-value is for the difference between treatments on the same day.

Conclusion

In conclusion, oxidizing air purification (OAP) did not affect air quality parameters in a commercial-like sow nursing environment. However, OAP did differentially affect piglet performance and behavior. Continuing work in this area will evaluate the effect of OAP on pig health, as well as the environmental and pig microbiomes.

Acknowledgments

Funding for this project was provided by the North Dakota Agricultural Experiment Station and the North Dakota State Board of Agricultural Research and Education. We thank Micron Pure LLC, Univox LLC, and CerroZone LLC for their technical assistance and for lending the oxidizing air purification mobile units. We also thank Megan Kavanagh, staff, and students at the NDSU Swine Research and Teaching Center for their assistance during this project.

Literature Cited

Banhazi, T. 2011. Treatment of airborne pollutants in livestock buildings with ozone as potential abatement option. Aust. J. Multi-Discip. Eng. 8:147–156.

Elenbaas-Thomas, A. M., L. Y. Zhao, Y. Hyun, X. Wang, B. Anderson, G. L. Riskowski, M. Ellis, and A. J. Heber. 2005. Effects of room ozonation on air quality and pig performance. Trans. ASAE. 48:1167–1173.

Priem, R. 1977. Deodorization by means of ozone. Agric. Environ. 3:229–237.

Winter cereal cover crops as an alternative forage source for extended season grazing

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

Winter cereal cover crops are a high-quality forage source for extended season grazing. Rye has superior winter hardiness and produces greater early-spring biomass when planted late in the fall compared to triticale and wheat.

Summary

Winter cereal cover crops are increasingly used for their ecological benefits and are a potential forage source for livestock. This study evaluated winter rye, triticale and wheat cover crops as alternative forage sources for extended season grazing of beef heifers. Triticale provided the highest quality forage but insufficient biomass to support grazing. Rye had superior winter hardiness and biomass production compared to triticale and wheat. Grazing was heavily dependent on planting date, temperature and precipitation.

Introduction

Cover crops have gained popularity as a practice implemented across the United States. Producers are incorporating cover crops to improve soil health, increase crop yields, reduce soil erosion, manage water and increase forage options for livestock (CTIC 2025). Cereal rye, also called winter rye, is the most frequently grown cover crop, with the winter cereals of wheat and triticale also being common. Winter cereals are typically planted in the fall following a cash crop. They will initiate growth in the fall, undergo vernalization in the winter and transition to reproductive growth in the spring. Winter cereal cover crops provide ecological benefits such as protecting organic matter, enhancing soil pore development, reducing erosion and lowering nitrate concentrations in runoff. Economic returns from these ecological benefits are slow and difficult to track. Incorporating livestock may provide additional economic benefits while adding additional soil benefits (Kumar et al., 2019). In recent years, producers have expressed increased interest in livestock integration. The 2024-25 National Cover Crop Survey revealed 32.2% of crop advisors surveyed anticipate they will start to see more cover crops being grazed (CTIC, SARE and ASTA, 2025).

Dual-purpose CC practices often use winter cereals, such as rye or triticale, planted in the fall and then used for spring grazing (Drewnoski et al., 2018). Winter rye is commonly selected due to its winter hardiness, high biomass production and low cost. However, triticale and select winter wheat varieties produce higher-quality forage (Sedivec et al., 2021). 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. In other regions, these species are dual-harvested (fall and spring) with grazing in addition to a cash crop. Currently, there is limited research evaluating the potential to dual graze a winter cereal for livestock forage in the northern Great Plains and assessing the economic and ecological benefits of integrated crop-livestock systems.

The objective of this study was to determine the impacts of long-term livestock integration and cover crop management on crop production, soil health and system profitability. This project compared management of winter rye, triticale and wheat cover crops and livestock integration through dual season (fall and spring) grazing, spring grazing, no grazing or no cover crop. The study evaluated cover crop production by biomass and nutritional value, as well as livestock performance in terms of grazing days.

Procedures (materials and methods)

A 40-acre site at the NDSU Central Grasslands Research Extension Center was selected. The site was divided into nine paddocks and randomly assigned one of three grazing treatments: dual season (fall

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and spring) grazing (DG), spring grazing (SG) or no grazing (NG). The NG plots included a split-plot no-cover-crop (NCC) treatment. Treatments were established in fall 2022, and the site was converted to no-till management (Wianecki, 2025). In 2024 and 2025, cover crop treatments were subdivided into winter rye (*Secale cereale* L.), triticale (*x Triticosecale* Wittmack) and winter wheat (*Triticum aestivum* L.).

Prior to and following every grazing period, cover crop biomass samples were collected to determine production, set stocking rates and evaluate utilization; cattle's two-day weights were also recorded. Four 0.82 ft^2 frames were clipped to ground level per winter cereal per plot. Forage samples were dried at 122 degrees Fahrenheit for 48 hours and weighed to determine biomass production. Samples were ground to 2 mm and submitted to the North Dakota State University Nutrition Laboratory (Fargo, North Dakota) for analysis of crude protein (CP), total minerals (Ash), neutral detergent fiber (NDF), acid detergent fiber (ADF), in vitro organic matter digestibility (IVOMD) and in vitro dry matter digestibility (IVDMD). Forage biomass samples were not collected in fall 2025 due to limited growth. Nutritional analyses were not conducted in spring 2026 due to inadequate sample size.

Winter cereals were grazed spring of 2025 at 0.13 AUM ac^{-1} and in the fall at 1.06 AUM ac^{-1}. In fall 2025, cows were additionally provided liquid protein supplement due to low nutritional value of corn stalk residue and lack of winter cereal biomass. In spring 2026, there was no grazing period due to insufficient forage production.

All statistical differences were determined by analysis of variance (ANOVA) within R v4.6.0 using the aov() function. Fixed effects included grazing period, treatment, cereal type and all associated interactions. Comparison of means was performed using Tukey's HSD through the emmeans() package (Lenth, 2024). Significance was determined at $P \leq 0.05$.

Results and Discussion

In spring of 2025, cover crop biomass production varied by treatment and cereal type (Figure 1). Pre grazing, SG rye produced greater biomass than triticale and wheat. The NG rye produced greater biomass than grazed rye, grazed and NG triticale, and wheat. There were no post grazing differences between DG and SG, as treatments were grazed at the same stocking rates to achieve the same level of utilization. In 2026, rye produced greater biomass than triticale and wheat (Figure 2). Triticale and wheat did not start growing as early or quickly as rye.

Nutritional analysis of winter cereals was completed in spring 2025 (Table 1). Triticale had lower NDF and ADF than wheat and rye. Rye had lower CP than triticale. Wheat had lower IVDMD and IVOMD than rye and triticale. This indicates that triticale had the highest forage quality, while winter wheat had the lowest. Rye was intermediate quality but produced the greatest biomass. This is consistent with the findings of Sedivec (2021). Winter kill was observed in the wheat and

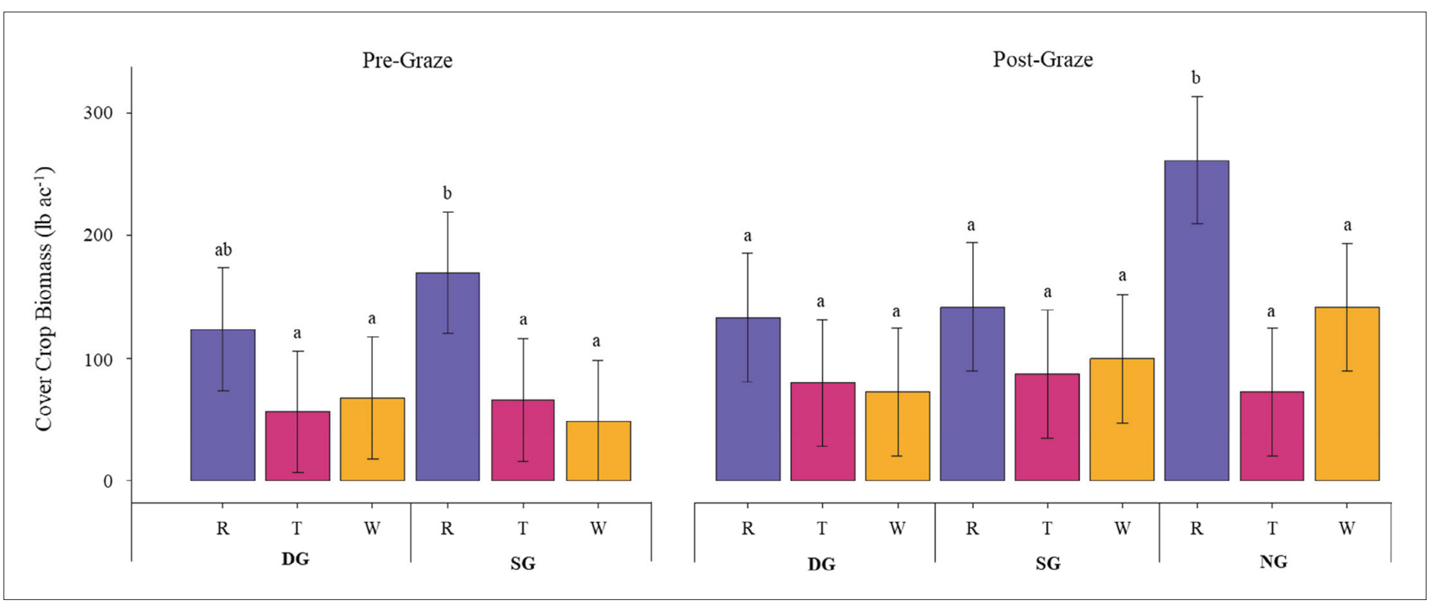

Figure 1. Spring 2025 winter cereal biomass production.

[abc] Means not connected by the same letters are significantly different within grazing period ($P \leq 0.05$).

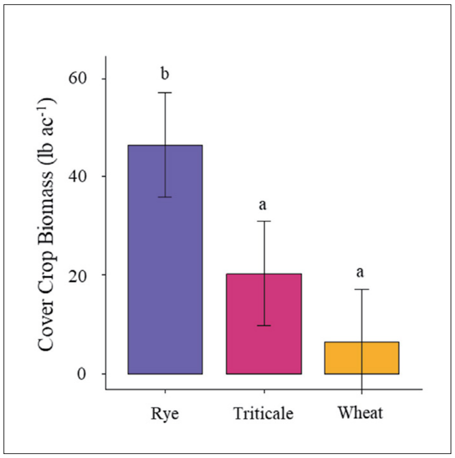

Figure 2. Spring 2026 winter cereal biomass production.

[abc] Means not connected by the same letters are significantly different within grazing period (*P* ≤0.05).

triticale, along with a delay in spring emergence compared to rye, resulting in differences in growth at sampling. Post graze forage was lower in IVDMD than pre graze forage. This is expected, as forage continues to grow and mature; digestibility typically decreases.

Average daily gain (ADG) for 2025 spring graze was -2.55lbs day^{-1}, and fall graze was -3.58lbs day^{-1}. Although the nutritional value of forage was high, these short grazing periods resulted in a loss of gain. This can be attributed to the grazing periods of less than two weeks, which do not allow adequate time for livestock to adjust to the new diet. Drewnoski (2018) reported fall-weaned calves that grazed a fall cover crop for a 48–64-day period had an ADG of 1.32 to 2.43 lbs.

Grazing cover crops is heavily dependent on planting date, temperature and precipitation but can provide a high-quality forage source. Of the three winter cereals evaluated, triticale produced the highest quality forage but insufficient biomass to support grazing. If planting a cover crop late in the fall, we recommend using winter rye, as it produces the greatest spring biomass to support a short grazing period.

Acknowledgments

Thank you to North Dakota Soybean Council and North Dakota Corn Council for project funding,

Table 1. 2025 winter cereal nutirional analysis results pre- and post-grazing

Period	Trt	Cereal	Ash%	NDF%	ADF%	CP%	IVDMD%	IVOMD %
Pre-Graze	DG	Rye	13.307	46.084	23.171	18.024	80.447	80.800
		Triticale	14.056	43.321	21.994	18.909	81.567	81.927
		Wheat	17.657	49.680	29.364	16.932	64.986	66.873
	SG	Rye	13.329	50.394	26.798	13.302	77.329	77.818
		Triticale	10.706	46.801	22.406	16.162	84.012	83.212
		Wheat	14.771	49.376	28.064	17.738	72.957	73.032
Post-Graze	DG	Rye	28.000	58.074	35.151	15.068	66.990	75.321
		Triticale	18.186	47.014	25.813	23.873	75.613	79.303
		Wheat	23.328	50.450	29.740	21.564	60.669	68.540
	NG	Rye	10.435	51.047	25.810	17.975	78.529	78.970
		Triticale	14.032	NaN	NaN	30.630	83.512	85.005
		Wheat	28.164	50.931	31.839	22.535	65.310	74.261
	SG	Rye	27.914	54.460	32.561	15.505	66.781	75.182
		Triticale	19.468	46.562	23.642	25.325	75.341	78.726
		Wheat	25.121	57.315	33.886	19.272	59.949	72.485
	***P*-value**	**Period**	**≤ 0.001***	**0.002***	**0.010***	**0.053**	**0.003***	**0.187**
		Trt	**0.244**	**0.375**	**0.207**	**0.153**	**0.012**	**0.066**
		Cereal	**0.210**	**0.015***	**0.024***	**0.005***	**0.001***	**≤ 0.001***
		Period*Trt	**0.717**	**0.183**	**0.386**	**0.277**	**0.899**	**0.733**
		Period*Cereal	**0.353**	**0.1 62**	**0.372**	**0.083**	**0.777**	**0.342**
		Trt*Cereal	**0.205**	**0.915**	**0.402**	**0.921**	**0.705**	**0.407**
		Period*Trt*Cereal	**0.891**	**0.105**	**0.361**	**0.554**	**0.554**	**0.653**

and the staff and technicians at the NDSU Central Grasslands Research Extension Center for their assistance.

Literature Cited

CTIC, SARE, and ASTA, 2025. National Cover Crop Survey Report 2024-2025. Joint publication of the Conservation Technology Information Center, Sustainable Agriculture Research & Education, and American Seed Trade Association.

Drewnoski, M., J. Parsons, H. Blanco, D. Redfearn, K. Hales, and J. MacDonald. 2018. Forages and pastures symposium: cover crops in livestock production: whole-system approach. Can cover crops pull double duty: conservation and profitable forage production in the Midwestern United States?. *J. Anim. Sci.. 96*:3503-3512.

Kumar, S., H. Sieverding, L. Lai, N. Thandiwe, B. Wienhold, D. Redfearn, D. Archer, D. Ussiri, D. Faust, D. Landblom, E. Grings, J. J. Stone, J. Jacquet, K. Pokharel, M. Liebig, M. Schmer, P. Sexton, R. Mitchell, S. Smalley, S. Osborne, S. Ali, S. Şentürklü, S. Sehgal, V. Owens, and V. Jin. 2019. Facilitating crop–livestock reintegration in the northern great plains. Agron. J. 111:2141-2156.

Sedivec, K., S. Alm, M. Undi, and J. Leier. 2021. Forage production and quality, livestock performance and cost comparison for winter cereal forages. *NDSU Central Grasslands Research Extension Center 2020 Annual Report*.

Wianecki, J.V. 2025, Enhancing Winter Cover Crop Practices Through Integrated Crop Livestock Systems, M.S. Thesis, North Dakota State University.

Calf grazing patterns and performance under virtual fence management

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When utilizing virtual fence to manage cow-calf pairs, we found no difference in containment within the virtual fence boundary between collared cows and their uncollared calves. However, the distance that calves grazed from their dams increased as the grazing season progressed. Additionally, calves in the virtual fence patch graze treatment group had increased average daily gains than calves in a continuous grazing system.

Summary

Virtual fence systems are a growing option for livestock grazing management, but there is little information on how efficient they are at managing cows with calves and the distance calves will creep graze without physical fences restricting their movement. A subset of cow-calf pairs in a virtual fence-managed patch grazing trial was tagged with 701x ear tags to track cow and calf movement throughout the grazing season. There was no difference between containment with the virtual fence boundary between the dam and calf overall, but there was a significant difference between cow-calf pair containment and period within the grazing season, indicating an uptick in creep grazing. Calves did graze significantly farther from their dams as the grazing season progressed. Calves in the virtual fence treatment group also gained approximately 0.57 lbs. more per day compared to continuous-graze calves. While more research is needed to better understand how the cow/calf relationship interacts with virtual fence management, our data indicate improved calf performance in a virtual fence patch-grazing system compared to a continuous-grazing system.

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Introduction

Virtual fencing systems utilize digital fence boundaries and global positioning system (GPS) that enable collars or ear tags to manage the movement of grazing animals. Auditory and electrical stimuli are used to keep individual animals within the boundaries designated by virtual fences. Most virtual fence technologies are not recommended for calves because they would require constant monitoring and adjustment to account for their growth, and the electrical stimuli is designed for animals over 500 lbs. Therefore, virtual fence technologies are commonly evaluated to determine their effects on livestock production outcomes on stocker or dairy cattle.

There is minimal information on the behavior of calves grazing with their dams managed by virtual fence. Preliminary research from Utsumi et al (2023) found that cows managed by virtual fence received more virtual fence cues preweaning and were more responsive to virtual fence cues postweaning (Utsumi et al. 2023). The purpose of this study is to understand calf creep-grazing behavior when managing cows with virtual fence and to document the performance of calves during creep grazing by utilizing virtual fence collars on cows and GPS ear tags on calves.

Procedures

One hundred and ten cow/calf pairs were turned out in three replications of patch grazing with virtual fence from June 11 to Oct. 6 (116 days) during the 2025 grazing season at Schnell Recreation Area. Cows were trained on the virtual fence system for four days prior to turnout using a standardized system training protocol. Three pastures were divided into quadrants using virtual fence, and cows were permitted to graze ¼ of the pasture for the first 50 days, ½ the next 50 days and ¾ of the pasture for the remainder of the grazing season, resting ¼ of the pasture (Figure 1). This pattern created a gradient of disturbance by varying grazing intensity over space and time, impacting vegetation structure. Pastures ranged from 440 to 532 acres, and within the pastures, the patches ranged from 110 to 133 acres. Forty-six cow/calf pairs were

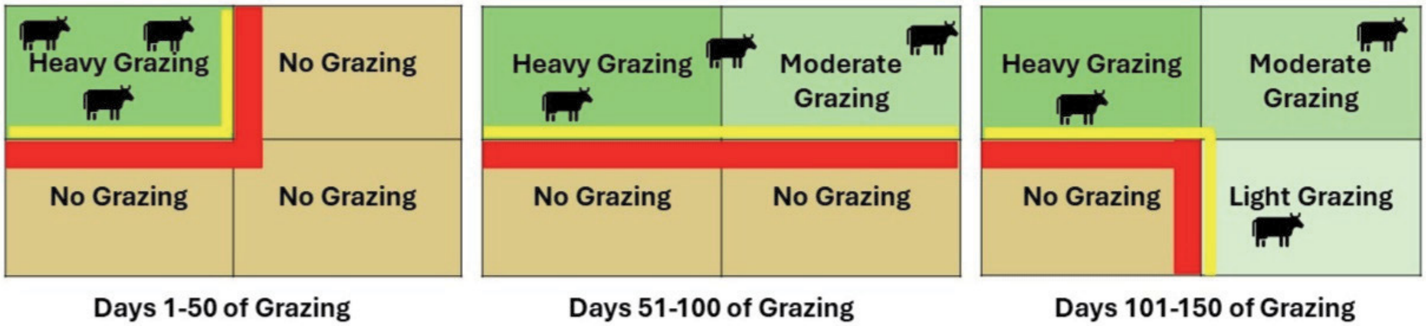

Figure 1. Patch grazing with virtual fence. Yellow and red lines indicate the virtual fence for the period, with yellow lines indicating the sound stimulus barrier, and red lines indicate the shock stimulus barrier.

continuously grazed as a control treatment.

According to protocol, only the cows were collared, as collars are not recommended for calves because of growth and weight restrictions. Of the 110 cows, a subset of 38 cows received 701xPro ear tags and their calves received 701xLite ear tags. Of the cow/calf pairs tagged, GPS data for the entire grazing season was recorded and recovered for 12 sets of tags.

All data cleaning and analysis was conducted in R Studio. Containment within the virtual fence boundary was determined by the time spent inside and outside the boundary, based on GPS points and timestamps. The daily containment averages were used in a t-test after testing for assumptions to identify differences in cow and calf containment within the virtual fence boundary.

To determine the degree to which calves engaged in creep grazing, GPS points were used to determine the average distance of a calf from its dam over time. The first GPS point for each hour was used to determine the distance between each dam and her calf to overcome inconsistencies in datapoint timestamps. These data were used in a linear model to capture any change in that occurred outside of the virtual fence boundary as the grazing season progressed. An ANOVA and Tukey test determined variance between months.

Two-day weights were collected pre- and postgrazing for all calves in the virtual fence patch graze treatment group (n = 104) as well as for calves continuously grazed at the same site (n = 46). The impact of virtual fence patch grazing on calf performance was determined by comparing average daily gain between the two groups using an ANOVA.

Results and Discussion

The difference in containment time between cow and calf containment was used to determine how much cow-calf pairs spent inside and outside of the virtual fence boundary. Positive differences indicate that the calf spent less time within the virtual fence boundary and, therefore, presumably creep grazing, and negative values indicate the time the calf spent within the virtual fence boundary while the dam was not contained. Values closer to zero indicate similar grazing behavior in cow and calf. Cow-calf containment between pairs did not differ across the grazing season. The majority of variance in cow containment is driven by individual cow behavior ($P < 0.001$) and timepoint during the grazing season ($P = 0.003$) (Figure 2). Variance in cow containment was not related to

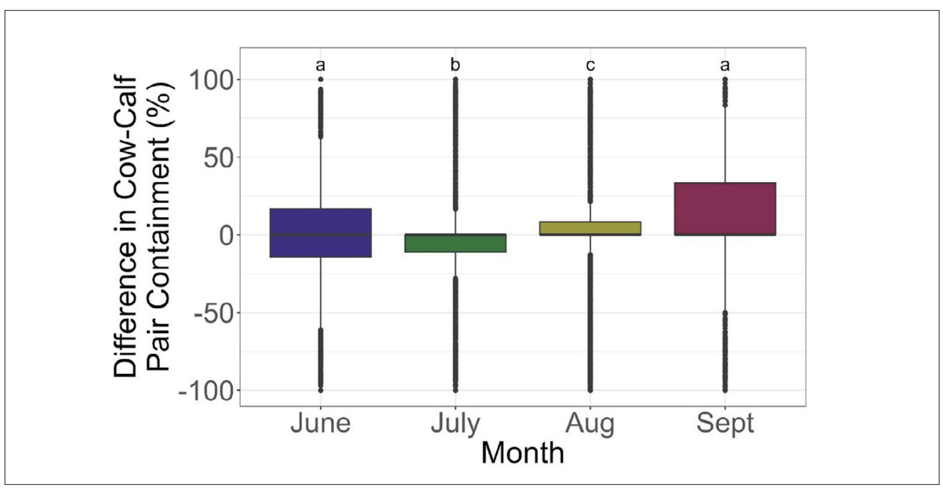

Figure 2. Difference in cow-calf pair containment with virtual fence boundaries over time on the Schnell Recreation Area near Richardton, North Dakota, in 2025. Letters denote significant differences ($P < 0.05$) between months. Positive values indicate greater incidence of creep grazing.

calf containment ($P = 0.34$). Calves spent more time outside of the virtual fence boundary than their dams every month, with the highest incidence of creep grazing occurring in August.

The distance between calves and their dams increased as the grazing season progressed ($P < 0.001$). On average, calves grazed 289.9 feet from their dam in June, 413.3 feet in July, 434.0 feet in August and 380.5 feet in September (Figure 3). Calves continued to graze farther from their dams over time.

Calves in the virtual fence patch graze treatment performed better than those in the continuous grazing group ($P < 0.001$) (Figure 4). Virtual fence treatment calves gained approximately 0.57 lbs/day more than calves in the continuous grazing group.

In this study, we found no difference ($P > 0.05$) in containment within the virtual fence boundary between cows and calves. Calves did creep graze more and farther from their dams as the grazing season progressed, even as cows were granted a larger virtual fence boundary over time. This complements preliminary findings from Utsumi et al (2023) that calves of cows managed by virtual fence graze further away from their dams as the grazing season progresses.

Our results indicate that patch grazing with virtual fence can improve calf performance outcomes. Additionally, our results align with previously published literature that reported creep feeding, including creep grazing, is correlated with improved calf weight gain (Lardy et al. 2007). While virtual fence patch grazing has been shown to improve calf performance, further research is needed to better understand the cow and calf drivers to cross a virtual fence boundary, to better inform virtual fence management decision-making and to further improve production outcomes.

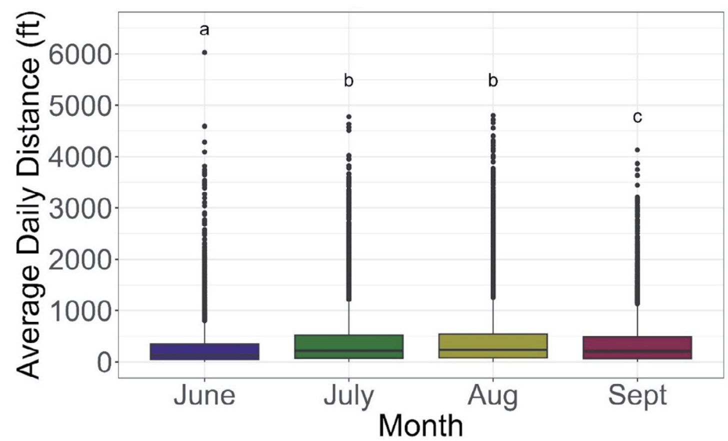

Figure 3. Calf grazing distance from dam by month on the Schnell Recreation Area near Richardton, North Dakota, in 2025. Letters indicate significant differences ($P < 0.05$) between months.

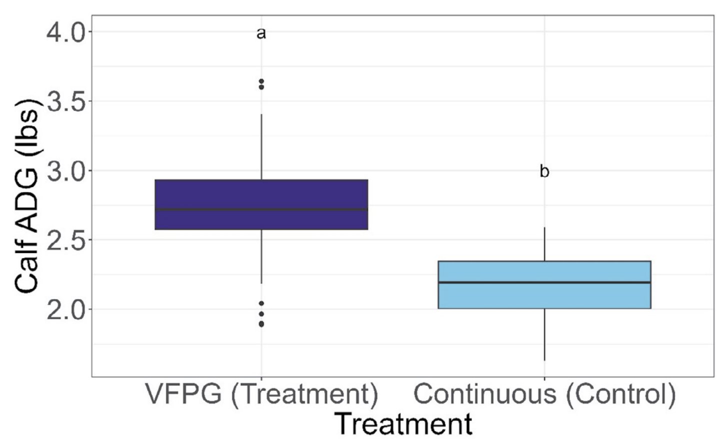

Figure 4. Calf average daily gain by treatment on the Schnell Recreation Area near Richardton, North Dakota, in 2025. Comparison between calves in the virtual fence patch graze group (VFPG) and the continuous graze group (Control). Letters denote significant differences ($P < 0.05$) between treatments.

Acknowledgments

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Literature Cited

Lardy, G. P., and T. D. Maddock. 2007. Creep feeding nursing beef calves. Vet.Clin. N. Amer.: Food Anim. Pract. 23:21-28.

Utsumi, S., S. Nyamuryekung'e, M. Spetter, A. Cox, L. Macon, R. Estell, and G. C. Duff, 2023. Virtual fencing of rangeland cows during late lactation and following weaning. J. Anim. Sci. 101(suppl.3):478-479.

Projected economics for a range-based commercial sheep operation in North Dakota

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The objective was to determine expected sources of revenues, production costs, and net return to management and overhead for a representative 250-ewe commercial range-based sheep operation common to North Dakota. The results suggest that for the 2025/2026 production year, producers can expect to earn a net return to management and overhead of $31.28/ewe ($7,824/operation).

Summary

The objective was to determine expected sources of revenues, production costs, and net return to management and overhead for a representative 250-ewe commercial range-based sheep operation common to North Dakota. Enterprise budgeting techniques were used to calculate projections for revenues, production costs, and net returns to management and overhead. Data for projected prices and quantities used in the analysis were obtained from local markets, supply dealers, industry and academic reports and publications, and academic experts and experienced sheep producers. Results suggest that producers can expect to earn a net return of $31.28/ewe ($7,824/operation) over the 2025/2026 production year, and this is net of the cost of land and owner's labor. The individual breakeven prices of feeder lambs, pasture rent, hay and grain-based feed are $2.66/lb, $45/acre, $140/t and $274/t, respectively.

Introduction

Sheep production is an important economic activity in North Dakota. According to the Census of Agriculture, in 2022, there were 62,000 sheep on North Dakota farms across 482 operations that generated a combined total gross income of $7.46 million (USDA-NASS, 2026). A significant portion of sheep in North Dakota is produced on range-based forages located west of the Missouri River. Current, reliable estimates of revenue sources and individual production costs for commercial range-based sheep operations in North Dakota are not currently available to help sheep producers base upcoming production and marketing decisions for their operations. The specific objectives were to determine projections of revenue sources, individual production costs, and net return to management and farm overhead for a representative 250-ewe range-based sheep operation for the 2025/2026 production year, as well as to determine breakeven prices for feeder lambs, pasture rent, hay and grain-based feed.

Materials and Methods

Enterprise budgeting techniques were used to calculate sources of revenue, individual production costs, and net returns to management and overhead for the representative North Dakota sheep operation (AAEA, 2000). Data on prices and quantities used in the analysis were obtained from local markets, supply dealers, industry and academic reports and publications, and industry and academic experts and experienced sheep producers. Essential projections for price and quantity parameters are reported in Table 1. Assumptions used in our calculations for revenues and individual production costs are reported in the following paragraphs.

We assumed that sheep operators will produce feeder lambs with an average weight of 75 pounds with a lambing rate equal to 1.25 lambs/ewe, with culling rates of 10% for ewes and 15% for rams. NDSU projections for feeder lamb prices for October 2026 were assumed to be in the neighborhood of $3.00/lb. We used a mature ewe death loss rate of 6.5% of the flock, a coverage rate of 31 ewes per ram (8 rams/flock) and a 4% transportation shrink in the revenue calculations. Although the current price of wool is $0.90/lb, the cost to transport wool to the closest buyer in Belle Fourche, South Dakota, is expected to be much greater than the value of the wool, so we assumed

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Table 1. NDSU projections for essential price and quantity parameters

Price/assumptions	$/unit
Feeder lambs ($/lb)	3.00
Wool, market ($/lb)	0.00
Pasture rental rate ($/acre)	30.00
Price of hay ($/ton)	80.00
Price of grain-based feed ($/ton)	150.00
Distance to market (miles)	50
Price for shearing ($/ewe)	8
Price for shearing ($/ram)	12
Round-trip distance to shear site (miles)	300
Wage rate for hired labor ($/hour)	25.00
Wage rate for owners/family labor ($/hour)	25.00
Interest rate for operating capital (% APR)	6.50%

the price of wool is equal $0.0/lb. However, loan deficiency payments for unshorn pelts ($2.59/lamb) and ungraded wool ($0.38/lb) for lambs, ewes and rams were included as sources of revenue.

To calculate the costs for pasture and feed, we assumed that it would require two acres of pasture at a rate of $30/acre to support one ewe, and pasture would be grazed for 180 days per year, implying that ewes and rams would be provided feed in a drylot for 185 days during the winter months. We assumed that sheep would require a daily ration of hay at a quantity equal to 3% of their body weight at a price of $80/t, and require a daily ration of grain-based feed equal to 1.5% of their body weight at a price of $150/t. We also included the cost of feed for guard dogs.

NDSU Extension's recommended vaccination and healthcare regimens for lambs, ewes, rams and guard dogs were budgeted using current market prices obtained from local farm supply retailers. The annual cost of breeding rams was amortized over five years, assuming a purchase price of $500/ram, a life expectancy of five years and an interest rate for investment capital of 7.5%. In addition, a breeding soundness exam was included at a cost of $75/ram.

We calculated marketing costs using average market rates for auction/commission fees ($2.25/lamb), inspection ($0.15/lamb), yardage ($0.35/lamb), feed ($0.25/lamb) and mandatory checkoff costs for live sheep ($0.007/lb), feeder lambs ($0.53/lamb), cull ewes ($0.05/ewe) and cull rams ($1.58/ram).

The costs for shearing included the 2026 federal mileage rate of $0.72/mile for a round-trip distance of 300 miles, plus shearing rates of $8/ewe and $12/ram, and lunch and beverages for breaks for the shearer (and helper) at a cost of $60.

Feeder lambs, cull ewes and rams were assumed to be transported using a commercial truck and a 48-by-53-feet livestock trailer with an animal capacity of 1,284 square feet. Required spacing for lambs, ewes and rams was assumed to be 2.75, 4.50 and 5.50 square feet, respectively. A 50-mile distance-to-market and round-trip price of $6.5/mile was assumed for transportation cost calculations.

Costs for hired and family labor were included in the budget, assuming1.5 hours of labor per day per flock on pasture and three hours per day per flock in drylot during the winter. It was assumed that the share of hired labor was 10% of total labor hours needed during the production year; that is, the family provides 90% of all labor. A wage rate of $25/hour was used to calculate the cost of hired labor and family labor.

In addition to having dogs for herding and protecting sheep on pasture, costs for nonlethal predator control were included at $750/year. We assumed that producers would take advantage of the $150 federal cost share for nonlethal options for predator control products, so the total cost was $600/year. The type of nonlethal control was not assumed, but examples of devices qualifying for cost share include fencing and barriers, light and sound devices, and sheep bells.

Annual fixed costs ($/ewe) were calculated for alternative pieces of machinery and equipment deemed necessary for a commercial range-based sheep operation in North Dakota. They include the use of a 90-horsepower 4x4 tractor ($60,000), an all-terrain vehicle ($15,000), a half-ton work truck ($50,000), eight six-panel hay ring feeders ($300/feeder) and three feeders for feeding grain rations ($1000/feeder). We assume all machinery and equipment are purchased new with a seven-year life expectancy and a 30% salvage value for the tractor, truck and ATV. It was also assumed that only 25% of the tractor, truck and ATV would be used for the sheep enterprise. All other buildings, equipment and machinery used for sheep production are considered part of farm overhead.

Variable costs for fuel, lubrication and repairs were calculated as 7% of each piece of machinery's initial purchase price, multiplied by the 25% rate that machinery was assumed to be used for the sheep operation. In addition, utilities were assumed to be $150/month, taxes were assumed to be 1% of the assessed value of the land on a dollar-per-ewe basis, and farm liability insurance was assumed to be $1,000/year, or $4/ewe.

Results and Discussion

Results suggest that producers can expect to earn a net return of $31.28/ewe ($7,824/operation) over the 2025/2026 production year (Table 2). Total gross revenue was projected to be $295/ewe, with 92% expected to come from the sale of feeder lambs. Total cost (variable and fixed) is projected to be $264/ewe, with variable costs accounting for 89.4% of the total. Costs associated with pasture (rent), hay and feed combined account for 56% of total costs. Fuel, lube, repairs and utilities are expected to be roughly 6% of total costs, and labor (family and hired labor combined) accounts for about 10%. Fixed costs account for 10.57% of total costs, with annual fixed costs for machinery and equipment accounting for about 80% of total fixed costs. When multiplied over the 250-ewe operation, the net return of $264/ewe translates into a total projected profit of $7,824 for the 2026 production year.

The projected net return is most sensitive to feeder lamb prices, pasture rent rates, and hay and feed prices; breakeven prices for those variables are reported in Table 3. The breakeven price for feeder lambs is $2.66/lb (i.e., the price where net return = $0.00/ewe), which is only 11% less than the projected 2026 price of $3.00/lb. Holding all other prices constant, the most a producer can afford to pay to rent pasture is $45/acre, which is 50% more than the assumed rate in the model. The projected net return is also sensitive to the prices of hay and feed but to a lesser degree than feeder lamb prices. Holding all other prices constant, the most a producer can afford to pay for hay is $140/ton, 78% more than the assumed price, and the breakeven price of grain-based feed is $274/ton, which is 83% more than the assumed price. It is important to note that the projected net return of $31.28/ewe is net of the cost of pastureland and labor (hired and family). Excluding pasture rent and owner's labor cost, the net return would be $112/ewe.

Table 2. Projected sources of revenue, production costs and net return for a representative 250-head range-based sheep operation in North Dakota

Gross revenues:	$/ewe	$/flock	%/revenue
Lambs	270.00	67,500	91.56%
Cull ewes	13.87	3,468	4.70%
Cull rams	0.88	220	0.30%
Wool, including loan deficiency payments	10.14	2,536	3.44%
Total gross revenue	**294.90**	**73,724**	**100.00%**
Variable costs:	**$/ewe**	**$/flock**	**%/total cost**
Pasture	60.00	15,000	22.76%
Hay	39.34	9,835	14.92%
PRF rainfall insurance	5.50	1,375	2.09%
Feed grain	36.88	9,220	13.99%
Salt and mineral	6.03	1,507	2.29%
Veterinarian and health	4.60	1,150	1.75%
Breeding (ram cost per ewe)	6.35	1,589	2.41%
Marketing and hauling	5.13	1,283	1.95%
Fuel, lube, repairs and utilities	16.58	4,144	6.29%
Shearing ewes	9.36	2,340	3.55%
Predator control (nonlethal)	2.40	600	0.91%
Dog food for three sheep dogs	7.88	1,971	2.99%
ALB checkoff	0.75	189	0.29%
Operator/family labor	24.30	6,075	9.22%
Hired labor	2.70	675	1.02%
Interest on operating capital	7.95	1,986	3.02%
Total variable costs	**235.76**	**58,937**	**89.43%**
Fixed costs:	**$/ewe**	**$/flock**	**%/total cost**
Machinery, equipment and vehicles	21.88	5,470	8.30%
Interest on retained livestock	0.47	118	0.18%
Taxes and insurance	5.50	1,375	2.09%
Total fixed costs	**27.85**	**6,963**	**10.57%**
Total costs	**263.61**	**65,900**	**100.00%**
Net return to management and overhead	**31.28**	**7,824**	**-**

Conclusions

The net return of $31.28/ewe for a representative 250-ewe operation is expected to be quite a bit higher than previous years, reflecting a significant increase in feeder lamb prices driven by strong consumer demand for lamb, as well as relatively steady feed and hay prices. Note that this projection is based solely on NDSU projections for prices for the

Table 3. Breakeven prices of feeder lambs, pasture rent, hay and grain-based feed.

Price variable	Breakeven price ($/unit)
Feeder lamb price ($/lb)	2.66
Pasture rental rate ($/acre)	45
Hay price ($/ton)	140
Feed price ($/ton)	274

2025/2026 production year. However, because every range-based sheep operation differs in size and scope, we extended our effort with this project to develop an Excel-based decision support tool that allows producers to enter their own operation-specific projections for price and quantity parameters, allowing them the option to make a direct comparison between the economics of their own individualized economic projections and NDSU projections. The interactive decision tool can be found at https://www.ndsu.edu/agriculture/ag-hub/ag-topics/livestock/tools.

Literature Cited

AAEA (American Agricultural Economics Association). 2000. Commodity Costs and Returns Estimation Handbook. A report of the AAEA task force on commodity costs and returns. Found at: https://ideas.repec.org/p/isu/genres/1315.html.

USDA-NASS (National Agricultural Statistics Service). 2026. Quick Stats database. Found at: https://quickstats.nass.usda.gov.

Notes

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