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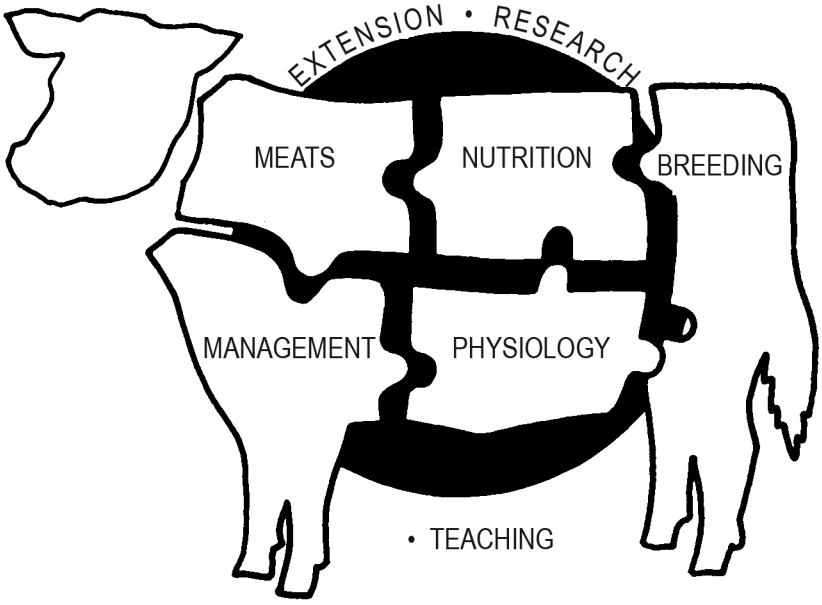


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# 2022 Beef Cattle Report

University of Nebraska Lincoln

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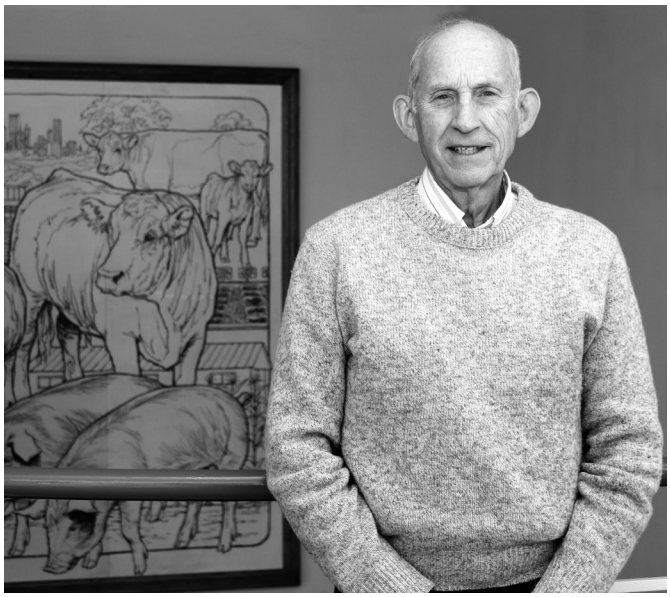
# The 2022 Nebraska Beef Cattle Report

## Dedicated in Memory of Dr. Terry Klopfenstein, Professor Emeritus of Animal Science



After completing his bachelor's, master's, and doctorate degrees from The Ohio State University, Terry joined the University of Nebraska–Lincoln as a ruminant nutritionist in 1965. Calling it his "dream job", Terry had only one position at UNL—ruminant researcher and teacher. Terry held the University of Nebraska Wagner Professorship from 1989–2007, the first endowed chair position in the Animal Science Department. As one of the premier research programs at UNL and nationwide, his findings have had a tremendous economic impact on cattle feeding in Nebraska and the nation. Terry was a pioneer in using corn byproducts from the ethanol and sweetener industries to supplement cattle feeding creating a win-win-win scenario for cattle feeders, grain farmers and the milling industries. Principles learned in the evaluation of protein sources, protein requirements and growing/finishing systems have been used by the feed and livestock industries. Research with grazing and treating crop residues have been adopted by cattle producers both within the US and internationally. Terry has authored over 300 refereed articles and over 1000 abstracts and technical articles. For many years, Terry was the leader of the ruminant nutrition program at Nebraska, both on campus and with the research and development centers across the state. Terry believed that research programs should be a Team Effort. He never talked about "his" research program. It was always "our" program or Nebraska's program. Terry mentored hundreds of graduate students in his 47-year career at UNL many of whom now hold important positions at universities, major agribusinesses, consulting firms, government agencies and as leaders in the livestock industry. Terry took a great deal of pride in working with students. His passion was instilled in him by his parents. Terry's mother was a teacher who began her career when she was 18 years old. Terry's father taught him the importance of higher education because he never had the chance to further his education during the Great Depression. Terry instilled the same motivation for knowledge in his students. He believed a faculty member's most important assignment was to teach students. Teaching included not only learning the fundamentals of science, but also helping students to mature and succeed. Terry valued work ethic and family values over grades and GRE scores. He provided students with the opportunity and support to succeed.

Because of the need for well-trained feedlot managers, the Feedlot Management Internship was initiated in 1988 and 179 students have completed the program. In 2003, an endowed fund was established in his honor at the University of Nebraska Foundation in recognition of his teaching accomplishments and contribution to the beef feedlot industry. Today, the funds provide support and recognition for students with an interest in beef production. In addition to his teaching and research activities, Terry has served as President of the Federation of Animal Science Societies and President of the American Society of Animal Science as well its Midwest section. Over the years, Terry has received numerous recognitions and awards from the scientific community and livestock industry. He was awarded the American Society of Animal Science highest honors: Morrison Award, Fellow Award, Teaching Award, and Nutrition Award. In 2017, the Terry Klopfenstein Midwest ASAS Symposium was initiated by student alumni in recognition of his focus on graduate student advising and outstanding research contributions. He was inducted into the Ohio State Animal Science and College of Ag Hall of Fame and received the Nebraska Hall of Agriculture Achievement Honoree. Throughout his career at UNL, Terry worked closely with the agriculture industries. He was recognized with the highest honors possible: Plains Nutrition Legends of Feedlot Nutrition, Cattle Feeders Hall of Fame Industry Leadership Award, and Nebraska Farm Bureau Silver Eagle Award. Perhaps Terry's favorite recognition, which he did not tell most people about, was receiving the Hilltop Distinguished Alumni Hall of Fame. Terry attended West Unity School in grades 1–11 and Hilltop his senior year, serving as class officer. Terry was the first graduate to receive the Alumni Hall of Fame honor.

To some, retirement means taking life easy and traveling across the country. To Terry, it meant continuing to go to the office, continuing to participate in research discussions and planning and continuing to invest in students, regardless of what his official university appointment was. Terry never fully retired but was a model of continuing to live each day with a purpose. Terry faithfully taught Sunday school every week. As a TeamMates mentor, he loyally met with his school aged mentees, taking time each week to invest in their life and helping them develop life skills. For many years, Nancy was involved in the Ag in the Classroom, a program sponsored by Farm Bureau. She convinced Terry to talk to the students about agriculture and the important role of ruminants. Because of his passion to educate young people, Terry continued to spend time with the students even as his health declined. Throughout his life, his greatest achievement was influencing the lives of his family, friends, students, and producers.

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# Impact of Cow Size on Economic Profitability in Cow-Calf and Feedlot Production Systems

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## Summary with Implications

*This study retrospectively evaluated the effect of cow size on profitability in the cow-calf segment and retained ownership of steer calves in the feedlot. Data were collected between 2005 to 2017 from the cowherd at Gudmundsen Sandhills Laboratory. From these data, two separate herds were assumed, one consisting of small-sized (1,000 lb) cows and another consisting of large-sized cows (1,220 lb) for the GSL cowherd. Larger cows weaned larger calves and produced heavier carcass weights of steers at slaughter. However, smaller cows generated more total pounds of output throughout the entire production system based on more calves retained in feedlots and more cull cows. Regardless of the pricing method used (i.e., live, carcass, grid), cow-calf producers in the Nebraska Sandhills maximized the highest amount of profit by selecting smaller cows.*

## Introduction

Cow-calf producers have placed heavy selection pressure on growth traits to increase weaning and yearling weights to increase revenue. The influence of cow size on calf weaning weights is known to vary depending on the production environment, management decisions, breed, and forage resources. Previous research has suggested smaller-framed cows that mature at an earlier age and lighter body weight may be more favorable in limited-resource environments. Increasing cow size increases forage intake requirements, which decreases the number of livestock that can be maintained on a fixed land base. This study hypothesized that increased cow size in a semi-arid environment could decrease the economic net returns of a cow-calf operation that sells non-replacement heifers at weaning and retains ownership of all steers through the finishing phase. Therefore, the objective of this research was to quantify the net return differences between a cow-calf operation that used either small or large mature weight cows.



## Procedure

A hypothetical partial budget was built to evaluate the producer net-return impacts of increasing cow size using data generated from the Gudmundsen Sandhills Laboratory between 2005 to 2017. Performance data were previously reported in the *2019 Nebraska Beef Cattle Report* (pp. 18–20). From these data, two separate herds were assumed, one consisting of small-sized (1,000 lb.) cows and the other consisting of large-sized cows (1,220 lb.) from the GSL cowherd. A hypothetical partial budget compared small and large cows on a 5,000-acre ranch in the Nebraska Sandhills providing 0.6 AUM/acre for annual grazing. Thus, a total of 156 and 136 cow-calf pairs could be maintained in the assumed ranch by small and large-sized cow herds, respectively. The total number of cows were derived to maximize the number of cows with a given land and resource. The sex of calf distribution of the calf crop was estimated at 50% for each sex. A 15% heifer replacement rate was assumed to maintain herd numbers.

A representative Nebraska Sandhills cow-calf producer was assumed to be trying to maximize profit by choosing dam size subject to fixed production costs and input and output price uncertainty. We assume that the cow-calf producer has two options: they can either 1) sell all calves at weaning or 2) sell all non-replacement heifers at weaning and retain steer calves into feedlots. Revenue for the cow-calf operation is generated by selling weaned calves and cull cows. Primary costs are pasture rent, other feed costs, and other cow costs. Calf prices were estimated using an average price for steers and heifers over a 10-yr period combined from auctions in Nebraska. Pasture lease rates were obtained from the University of Nebraska Farm Real Estate Market Survey for the North region of Nebraska on average quality pastures and averaged over 5 yr ($24.40/acre). A bull-to-cow ratio of 1:25 was assumed for both herds and bull purchase price was assumed at $3,000/bull. All assumptions used for the hypothetical operation are listed in Table 1.

The producer has the option to retain ownership of unsold weaned calves into the feedlot and sell fat cattle either live or on a grid. Retained calves in the feedlot are subject to daily per head yardage costs, feed costs, and other miscellaneous costs. Thus, operation net profit is the combination of both cow-calf and feedlot retention decisions and written as:

$$\underset{(\text{dam weight})}{\pi} = \sum_{p=1}^{P}\left(\sum_{k=1}^{K} \mathrm{TR}_{k}^{p} - \mathrm{TC}_{k}^{p} + \sum_{m=1}^{M} \mathrm{TR}_{m}^{p} - \mathrm{TC}_{m}^{p}\right)$$

where $p$ is the number of operational phases where $P$={cow-calf, feedlot}, $TR_k^p$ and $\mathrm{TR}_{\mathrm{m}}^{\mathrm{p}}$ is total revenue associated with output $k$ and output $m$ in production phase cow-calf and feedlot respectively, $TC_k^p$ and $\mathrm{TC}_{\mathrm{m}}^{\mathrm{p}}$ is the total cost associated with output $k$ and output $m$ in production phase cow-calf and feedlot respectively, $\mathrm{TR}_{\mathrm{k}}^{\mathrm{p}} - \mathrm{TC}_{\mathrm{k}}^{\mathrm{p}}$ is net profit from cow-calf production for $k$ outputs where $K$={heifers, cull cows}, and $\mathrm{TR}_{\mathrm{m}}^{\mathrm{p}} - \mathrm{TC}_{\mathrm{m}}^{\mathrm{p}}$ is the net profit from feedlot production for outputs $m$ where $M$={steers}. The analysis assumed all heifers not retained are sold in the cash market at weaning, 10% cow culling rate in herds with smaller cows, and 4% cow culling rate in herds with larger cows, which was calculated by pregnancy rates of those herds. All steer calves are assumed to be weaned and retained into feedlots and sold as fat cattle.

**Table 1. Total output (lb) estimated using small (1,000 lb) and large (1220 lb) cows using recommended stocking rates for a 5,000-acre ranch in the Nebraska Sandhills**

| Measurement | Small Cow | Large Cow | Source |
|---|---|---|---|
| **Cow-calf production** | | | |
| *Calf-crop* | | | |
| Cow-calf pairs, n | 156 | 136 | Stocking density is given at 5,000 acre |
| Cow pregnancy rate, % | 90 | 96 | *2019 Nebraska Beef Cattle Report*, pp. 18–20 |
| Total calves, n | 156 | 136 | Assumed from stocking density |
| Heifer retention rate, % | 15 | 15 | Average retention rate |
| Heifers sold at weaning | 55 | 58 | N heifers × retention rate |
| Heifer weaning weight, lb. | 449 | 480 | *2019 Nebraska Beef Cattle Report*, pp. 18–20 |
| Steers to retain into a feedlot, n | 78 | 68 | Half of the calf crop |
| Steer weaning weight, lb | 475 | 508 | *2019 Nebraska Beef Cattle Report*, pp. 18–20 |
| *Total heifer output, lb* | 24,684 | 27,817 | N heifers sold × heifer weaning weight |
| *Total steer output, lb* | 37,066 | 34,558 | N steers sold × steer weaning weight |
| *Cull cows* | | | |
| Cull cow rate, % | 10 | 4 | % open cows |
| Cull cows sold | 16 | 5 | Cow-calf pairs × cull cow rate |
| Cull cow weight, lb. | 1,000 | 1,220 | Assumed dam weight in each herd |
| *Total cull cow output, lb.* | 15,981 | 5,995 | Cull cows sold × cull weight |
| *Total cow-calf output, lb.* | 77,730 | 68,369 | steer output + heifer output + cull cow output |
| *Total cow-calf output sold[1], lb.* | 40,665 | 33,812 | heifer output + cull cow output |
| **Feedlot production** | | | |
| *Retaining ownership[1]* | | | |
| Steer HCW, lb. | 961 | 977 | *2019 Nebraska Beef Cattle Report*, pp. 18–20 |
| *Total feedlot output, lb* | 74,989 | 66,422 | HCW × N steers sold |

[1] Assumes all steers progeny are held for retained ownership into feedlots

## Results

All findings and calculations are displayed in Table 2. When considering the total offspring BW and cull cow BW, the total output at weaning was 9,361 lb greater in the small-sized cow herd compared with the large-sized cow herd. If steer calves were retained post-weaning through the finishing phase, the number of steers produced in the small-sized cow herd produced an additional 8,567 lb of steer HCW compared with the large-size cowherd. The increase in total pounds produced at weaning and after the feedlot phase is driven by increased carrying capacity in smaller-sized cows resulting in more weaned calves.

Herds with smaller cows produce more calves that are lighter resulting in lower gross revenue from heifer sales compared to herds with larger cows. In this data, herds with smaller cows cull a larger share of the herd each year resulting in $6,843 more cull cow gross revenue. Total costs to run a smaller cow were larger due to added fixed costs of running another cow-calf pair (i.e., veterinary costs, labor, interest etc.). If only heifers and cull cows were sold in the cash market, smaller cows were relatively more profitable than larger cows, on a per cow basis. Cow-calf operators would lose approximately $811 per small cow and $897 per large cow. If steers were also sold in the cash market at weaning, then cow-calf operators would lose approximately $393 per small cow and $468 per large cow. Total costs for only the cow-calf production segment were larger for herds with smaller cows, but those costs were spread across more cow-calf pairs.

Total feedlot costs were larger for herds with smaller cows due to more days on feed and more steers being finished. Grid pricing captures the relative carcass performance of each finished steer by assigning premiums and discounts to a set base (dressed wt.) price. If a cow-calf producer were to sell on the grid, the net profit would be approximately $1,196 per steer for steers from smaller cows and $1,229 from larger cows. More steers were finished from herds that have smaller cows. Overall, the net profit difference between herds with small and large cows was $9,720 under grid pricing. Finished cattle in Nebraska are generally sold either on a negotiated cash live weight basis or formula/grid dressed basis. If finished steers were sold on a live weight basis then the overall profit would be lower regardless of cow size. The overall net profit

**Table 2. Partial budget analysis used to evaluate net revenue generated from small (1,000 lb) and large (1,220 lb) cows using recommended stocking rates in the Nebraska Sandhills**

| Measurement | Small Cow | Large Cow | Source |
|---|---|---|---|
| **Cow-calf production** | | | |
| *Revenue* | | | |
| Total heifer output, lb | 24,684 | 27,817 | Table 1 |
| Heifer cash price1, $/lb | 1.68 | 1.61 | Average NE prices from 2005–2017, LMIC (2020) |
| *Total heifer revenue, $* | 41,556 | 44,879 | Heifer output× heifer price |
| Cull cow output, lb | 15,981 | 5,995 | Table 1 |
| Cull cow price, $/lb | 0.69 | 0.70 | Average cull cow prices from 2005–2017, LMIC (2020) |
| *Total cull cow revenue, $* | 11,027 | 4,184 | Cull cow output × cull cow price |
| *Total cow-calf revenue, $* | 52,584 | 49,063 | Heifer revenue + cow-calf revenue |
| | | | |
| *Costs* | | | |
| Number of bulls, n | 6 | 5 | ~25:1 cow:bull ratio |
| Price per bull, $ | 3,000 | 3,000 | The average price paid for bulls at GSL |
| *Total bull cost, $* | 18,000 | 15,000 | N bulls× price per bull |
| Pasture[3], $/acre | 24.40 | 24.40 | Nebraska Farm Real Estate Reports |
| Pasture, acre | 5,000 | 5,000 | Average ranch size in Nebraska |
| *Total grazing/feed cost, $* | 121,967 | 121,967 | Pasture land× rental rate |
| Misc. cow costs, $/cow | 251 | 251 | Total cow costs per year—feed & pasture costs, FINBIN (2020) |
| *Total misc. costs, $* | 39,156 | 34,136 | Cow-calf pairs × misc.cow costs |
| *Total cow-calf costs, $* | 179,123 | 171,103 | Bull cost + grazing cost + misc. cost |
| | | | |
| *Net profit cow-calf production* | | | |
| Profit, $ | -126,539 | -122,040 | Cow-calf revenue—cow-calf costs |
| Profit, $/cow | -811.15 | -897.35 | Profit/cow-calf pair |
| | | | |
| **Feedlot production** | | | |
| *Revenue* | | | |
| HCW, lb | 961 | 977 | Table 1 |
| YG, 1–5 | 2.800 | 2.800 | *2019 Nebraska Beef Cattle Report*, pp. 18–20 |
| Marbling | 500.230 | 500.350 | *2019 Nebraska Beef Cattle Report*, pp. 18–20 |
| QG | Choice | Choice | *2019 Nebraska Beef Cattle Report*, pp. 18–20 |
| Grid Premiums, $/lb | 0.022 | 0.022 | Average premiums from 2005–2017, LMIC (2020) |
| Grid Discounts, $/lb | 0.002 | 0.002 | Average discounts from 2005–2017, LMIC (2020) |
| Price dressed wt., $/lb | 1.769 | 1.769 | Average dressed wt. price from 2005–2017, LMIC (2020) |
| Price live wt., $/lb | 1.116 | 1.116 | Average live wt. price from 2005–2017, LMIC (2020) |
| *Total steer revenue (grid), $* | 134,114.28 | 118,793.00 | (Price dressed + Premiums-Discounts) × HCW × N Steers |
| *Total steer revenue (live wt.), $* | 114,234.37 | 101,184.19 | Price live × HCW × 1.37 × N steers |

difference between herds with small and large cows was $7,449.

*Total operational profit* is obtained by combining net profit from the cow-calf and feedlot operation, either live or grid. Regardless of the pricing method used, cow-calf producers maximize the highest amount of profit by selecting smaller cows. Overall net profit for a cow-calf producer using grid (live) pricing was -$340 for operations with smaller cows and -$412 for operations with larger cows.

## Conclusion

Cow size can have a large impact on cow-calf productivity and profitability from weaning throughout the finishing phase. The increase in total pounds produced at weaning and after the feedlot phase with the smaller-sized cowherd is driven by increased carrying capacity, which reflects forage intake differences. Along with decreased total pounds produced with larger cows, net returns declined in both the cow-calf and feedlot sectors of progeny from larger cows. While the cost and revenue

**Table 2. Continued**

| Measurement | Small Cow | Large Cow | Source |
|---|---|---|---|
| *Costs* | | | |
| Yardage costs, $/hd/d | 0.5 | 0.5 | The industry average in Nebraska |
| Days on feed, d | 240 | 237 | (HCW×1.37-Steer weaning weight) / average daily gain |
| *Total yardage costs, $* | 9360 | 8058 | N steers × DOF× yardage cost |
| Average daily gain, lb/d | 3.612 | 3.612 | *2019 Nebraska Beef Cattle Report*, pp. 18–20 |
| Feed conversion, lb of feed: lb of gain | 6.0 | 6.0 | Industry Average in Nebraska |
| Feed intake, lb/hd | 5,201.88 | 5,150.82 | Feed conversion× average daily gain× days on feed |
| Ration costs, $/lb | 0.08 | 0.08 | Industry Average in Nebraska |
| *Total feed costs, $* | 30,494.88 | 26,325.49 | Feed intake× ration cost× N steers |
| Misc. costs, $/hd/day | 0.05 | 0.05 | Accounts for vet costs, labor, interest, etc., (Expert opinion) |
| *Total misc. costs, $* | 936.00 | 805.80 | Misc.costs × N steers |
| *Total feedlot costs, $* | 40,790.88 | 35,189.29 | Yardage cost + feed cost + misc. cost |
| | | | |
| *Net profit feedlot production* | | | |
| Profit (live), $ | 73,443.49 | 65,994.90 | Total steer revenue (live)—total feedlot costs |
| Profit (live), $/hd. | 941.58 | 970.51 | Profit (live) / N steers |
| Profit (grid), $ | 93,323.40 | 83,603.71 | Total steer revenue (grid)—total feedlot costs |
| Profit (grid), $/hd. | 1,196.45 | 1,229.47 | Profit (grid) / N steers |
| | | | |
| **Operational Net Profit** | | | |
| Net profit (live), $ | -53,095.48 | -56,044.99 | Cow-calf net profit + feedlot net profit (live) |
| Net profit (live), $/cow | -340.36 | -412.10 | (Net profit (live)) / cow-calf pairs |
| Net profit (grid), $ | -33,215.58 | -38,436.17 | Cow-calf net profit + feedlot net profit (grid) |
| Net profit (grid), $/cow | -212.92 | -282.62 | (Net profit (grid)) / cow-calf pairs |
| Net profit (no feedlot), $ | -61,393.10 | -63,656.88 | Cow-calf net profit + (N steers × weaning weight × 3.86) |
| Net profit (no feedlot), $/cow | -393.55 | -468.07 | Net profit (no feedlot) / cow-calf pairs |

estimates are specific to the timeframe and location used in this study, producers can use the framework and operational-specific costs to determine the benefits or drawbacks of using smaller-framed cows. The tradeoff in production parameters between cow sizes should be evaluated in a wide variety of production segments and environments within beef production to optimize net returns to cow-calf operations.

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# Comparison of Partially Confined and Traditional Cow-Calf Systems

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## Summary with Implications

*Production of cow-calf pairs and grow/finish performance of calves from a partially-confined, fall-calving, intensive cow-calf system were compared to a traditional, spring-calving, extensive cow-calf system. Body condition was lower at breeding and weaning for the fall-calving alternative system compared to the traditional, spring-calving system. Conception, calving, and weaning rates were not different among treatments. Weaning weights were lower for the fall-calving alternative system than traditional, spring-calving system. Following weaning, calves were grown for 117 d and then subsequently finished to the same target fatness for both systems. In the grower phase, gain was greater and feed conversion improved for the fall-calving alternative system. In the finishing phase, gain was lower for fall-calving alternative system compared to traditional, spring-born calves. Intakes and carcass weight were not different among treatments during finishing, but calves from the fall-calving alternative system were fed 27 days more. The use of a fall-calving alternative cow-calf system had no impact on reproduction and weaning rates demonstrating potential value if pasture acres are limiting in areas with abundant crop acres, but calves will need to be grown longer to overcome lighter weaning weights.*

## Introduction

Traditional pasture has been converted to corn and soybean production in the northern plains region which has limited pasture availability for grazing. Limited grazing areas, and overall feed prices have steadily increased pasture rental rates. The reduction in perennial grasslands and increase in land values created a need for use of alternative forages and intensive cow-calf systems. Research has demonstrated that limit-feeding cows in a drylot setting is a comparable alternative to traditional pasture cow-calf systems. Additionally, winter grazing corn residue is an economical alternative to harvested forage or limit-feeding in confinement for non-lactating cows.

The use of double-crop annual forages (DCAF), commonly referred to as cover crops, has increased in popularity. Cover crops provide several advantages, including soil conservation, weed control, and an alternative forage source for livestock producers. Grazing late-summer planted cover crops provides economic incentives for livestock owners by adding weight to cattle, as well as economic incentives for crop producers with grazing rent and no impact on subsequent crop yields.

The objective of this study was to compare a traditional cow-calf system utilizing perennial pasture and corn residue grazing to an alternative cow-calf system utilizing drylot, fall forage oat and corn residue grazing on reproduction and calf growth performance, and subsequent post-weaning calf performance in a growing/finishing system.

## Procedure

Multiparous, cross-bred beef cows (n = 160; average age = 6.2 ± 2.8 years-old) were utilized in a general randomized block design with two treatments. In year 1, cows were blocked by cow age, stratified by age and origin source (two sources), and assigned randomly within strata to one of two production systems treatments with four replicates, each consisting of 20 cows. Once allocated, cows remained in assigned treatment for both years of the experiment. Treatments were (1) alternative fall-calving system utilizing confinement, summer-planted oats, and corn residue grazing (ALT) with calves born in the fall (August/September) or (2) traditional extensive spring calving (March/April) system utilizing perennial pasture and corn residue grazing (TRAD). To maintain herd size, cows culled between years were replaced with open, multiparous cows sourced from the same herd of the original cows. An additional replicate was maintained for each system so that replacement cows entered the experiment after being maintained in that system.

Each year, after the conclusion of weaning, calves were maintained in their respective dam's experimental unit to measure animal growth performance in a grower phase, finisher phase, and carcass characteristics. The post-weaning experiments utilized the same generalized randomized block design maintaining the same treatment and replication as the calf's dam.

### *Cow Breeding and Cow-Calf Health Processing*

Cows from both treatments were exposed to the same set of Simmental × Angus bulls that had passed an annual breeding soundness exam 30 days prior to breeding. The bull:cow ratio was 1:10 and the breeding season was 63 d (year 1) and 61 d (year 2). Two bulls were allocated to each replication of cows to prevent reproductive failure due to inadequate bull performance. All cows were given 5 ml of prostaglandin $F_{2\alpha}$ (5 mg/ml dinoprost tromethamine, Lutalyse, Zoetis Animal Health) following five days of bull exposure. Approximately one month before breeding, cows were vaccinated Bovi-Shield Gold FP 5 VL5 (Zoetis). Pregnancy was diagnosed via pregnancy detection blood test 31 d (TRAD; year 1), 29 d (ALT; year 1), 52 d (TRAD; year 2), and 50 d (ALT; year 2) after bulls were removed. Cows were treated annually with 1% doramectin (Dectomax, Zoetis) for control of internal and external parasites. Approximately one month before

calving, cows were vaccinated Scourguard 4KC (Zoetis).

Calves were vaccinated at birth with Inforce 3 (Zoetis), given a clostridial vaccine (Ultrabac 7; Zoetis), navels treated with iodine, and received a panel tag in the right ear with individual identification number, and birth weight recorded. If a cow gave birth to twins, one calf was selected randomly and removed from the experiment.

### Alternative Cow-Calf System Breeding

Each year of the experiment began at breeding, which occurred from October 11th to December 12th of 2017 (63 d; year 1) and October 18th to December 17th of 2018 (61 d; year 2). In year 1, cows were non-lactating at the time of breeding. Part of the ALT treatment design was to use fall forage oats to meet the nutrient requirements of the cows during lactation and breeding. Fall oat grazing began for the ALT treatment on October 11th and 23rd (years 1 and 2, respectively). Stocking rates for the fall oat fields were approximately 2.5 to 3.0 acres/pair. Each replicate of cow-calf pairs had full access to their assigned oat field.

On March 14th and 16th (years 1 and 2, respectively) cows in the ALT treatment were housed in open feedlot pens with approximately 30 in. of bunk space and 850 ft$^2$ of pen space per cow. Cows were limit-fed to meet requirements based on physiological stage during both gestation and lactation periods (NASEM, 2016; Table 1). Breeding body condition scores for the ALT treatment indicate that energy intakes were adequate for maintenance and lactation during the confinement period, which occurred directly prior to breeding. Cows were fed once daily between 0900 to 1200 h with ad libitum access to fresh water. The limit-fed diet, for year 1, consisted of 55.0% modified distillers grains plus solubles (MDGS), 40.0% wheat straw, and 5.0% supplement (DM basis). In year 2, the limit-fed diet consisted of 54.5% MDGS, 40.5% wheat straw, and 5.0% supplement (DM basis). In both years, the limit-fed diet was formulated to provide 200 mg/cow daily of monensin (Rumensin 90; Elanco Animal Health, Greenfield, IN). Diets were mixed and delivered using a truck-mounted feed mixer and delivery unit with scale measurements to the nearest 1.0 lb (Roto-Mix model 420, Roto-Mix, Dodge City, KS). All scales used for the study were calibrated twice annually. Cows in the ALT treatment were managed as a fall calving herd with calving occurring in feedlot pens from July 16th to September 12th of 2018 and July 20th to September 28th of 2019 (years 1 and 2, respectively). Cow-calf pairs remained in the feedlot until October 23rd (years 1 and 2) for a total of 222 and 224 d (years 1 and 2, respectively). At which time, cows would be moved to oat fields, as previously discussed.

**Table 1. Ingredient composition of limit-fed diet for an alternative cow-calf system[1]**

| Ingredient[2], % | Year 1 | | Year 2 | |
|---|---|---|---|---|
| MDGS[3] | 55.00 | | 54.45 | |
| Low Quality Forage[4] | 40.00 | | 40.55 | |
| Supplement[5] | 5.00 | | 5.00 | |
| | Gestation[6] | Lactation[7] | Gestation[8] | Lactation[9] |
| Fine ground corn | 2.47 | 2.44 | 2.49 | 2.45 |
| Beef trace mineral and salt premix[10] | — | — | 1.79 | 1.79 |
| Limestone | 1.98 | 1.98 | 0.57 | 0.57 |
| Salt | 0.30 | 0.30 | — | — |
| Tallow | 0.125 | 0.125 | 0.125 | 0.125 |
| Beef trace minerals[11] | 0.10 | 0.10 | — | — |
| Insect growth regulator[12] | — | 0.0275 | — | 0.0275 |
| Vitamin A-D-E[13] | 0.015 | 0.02 | 0.015 | 0.02 |
| Monensin[14] | 0.0138 | 0.0138 | 0.0158 | 0.0158 |
| Nutrient composition, % DM | | | | |
| Organic matter | 90.76 | | 90.79 | |
| Crude protein | 19.79 | | 20.93 | |
| Neutral detergent fiber | 53.81 | | 48.84 | |
| Acid detergent fiber | 35.07 | | 32.37 | |
| Ether extract | 5.22 | | 4.86 | |

[1]Treatment = alternative cow-calf system (ALT) calving in July/August and utilizing drylot, fall forage oat grazing, and corn residue grazing.

[2]All values represented on a DM basis.

[3]Modified wet distillers grains plus solubles.

[4]Low quality forage for year one was wheat straw, year two was wheat straw for 73 d, oat hay for 137 d, and ground corn residue for 14 d.

[5]Included at 4.79% (Year 1) and 3.58% (Year 2) total diet DM.

[6]Included in diet from March 16th, 2018 to July 18th, 2018.

[7]Included in diet from July 19th, 2018 to October 22rd, 2018.

[8]Included in diet from March 14th, 2019 to July 17th, 2019.

[9]Included in diet from July 18th, 2019 to October 22nd, 2019.

[10]Premix contained 21.5% salt, 30.5% Ca, 0.22% Zn, 0.22% Mn, 0.11% Cu, 0.0005% I, 0.0002% Co, 0.0001% Se.

[11]Premix contained 10% Mg, 6% Zn, 4.5% Fe, 2% Mn, 0.5% Cu, 0.3% I, and 0.05% Co.

[12]JustiFLY feedthrough, Champion Farmoquimico LTDA, Anapolis, Goias, Brazil. Formulated to provide 5g/kg.

[13]Premix contained 1,500 IU of vitamin A, 3,000 IU of vitamin D, and 3.7 IU of vitamin E per g.

[14]Rumensin 90, Elanco Animal Health, Indianapolis, IN. Formulated to provide 27.5 mg/kg

### Alternative Cow-Calf System Weaning

Cow-calf pairs grazed fall oats from October 23rd to January 13th of 2019 and October 23rd to approximately January 8th of 2020 (years 1 and 2, respectively). Grazing days were variable between years, with 82 d (year 1) and an average of 77 d (58 to 92 d; year 2). Cow-calf pairs were moved off oat fields when it was visually estimated that forage height was 5.1 cm. In the event this occurred prior to weaning, cows-calf pairs returned to the feedlot and were provided

the same limit-fed diet at the same intake amount they received prior to oat grazing. After weaning, cows were moved to corn residue fields on January 10th, 2019 of and 29th, 2020 (years 1 and 2, respectively). Stocking rates were approximately 3 acres/cow and grazing days were 64 and 52 d (year 1 and 2, respectively) for corn residue fields.

#### TRADITIONAL COW-CALF SYSTEM BREEDING

Cows were exposed to bulls from July 12th to September 12th of 2017 (63 d; year 1) and July 6th to September 4th of 2018 (61 d; year 2). In year one, TRAD cows were lactating and had the previous, non-experimental calf, with them.

#### TRADITIONAL COW-CALF SYSTEM CALVING

On approximately March 17th, 2018 and March 12th, 2019 (years 1 and 2, respectively), cows from the TRAD treatment were comingled prior to calving and fed ground grass hay provided at 30 lb for 31 d (year 1) and 20 lb for approximately 81 d (year 2) on dormant smooth bromegrass pastures. Calving began on April 10th to June 16th of 2018 and April 5th to June 6th of 2019 (year 1 and 2, respectively). On May 7th, 2018 and May 2nd, 2019 (year 1 and 2, respectively), cows in the TRAD treatment were moved to smooth bromegrass pastures. Stocking rate was 1.2 ha/cow (years 1 and 2) and grazing days were 186 and 197 d (years 1 and 2, respectively).

#### TRADITIONAL COW-CALF SYSTEM WEANING

Calves from the TRAD treatment were weaned on October 16th, 2018 and October 11th, 2019 (year 1 and 2, respectively). After weaning, on November 15th, 2018 and 8th, 2019 (years 1 and 2, respectively), cows in the TRAD treatment grazed corn residue fields. Corn residue fields were stocked at 1.69 and 1.43 ha/cow (years 1 and 2, respectively) and grazing days were 119 and 123 d (years 1 and 2, respectively).

#### GROWER PHASE

Calves were weaned using a fence-line weaning strategy. All calves from the four replicates within treatment were comingled in a pen. Calves were fence-line weaned for three d and limit-fed grass hay at 2.0 % of BW before transport to the feedlot at ENREC (2 miles). Calves, steers and heifers, were sorted into their previous cow group on d—6. Steers and heifers from each experimental unit were fed together in one pen. Weaning BW measurements were collected on two consecutive days and averaged following 5 d limit-fed period. The weaning BW measurement also served as the growing initial BW. Calves were implanted with 36 mg zeranol (Ralgro; Merck Animal Health, Madison, NJ) on d 1. Calves were vaccinated with Bovi-Shield Gold One Shot (Zoetis) and for Clostridial and *Histophilus somnus* (Ultrabac 7/Somubac; Zoetis). Calves received parasite control as well (Dectomax; Zoetis Animal Health). Calves were maintained in their original replicate for the grower and finisher phases. All calves received a common grower diet consisting of 35.0% grass hay, 30.0% modified distillers grains plus solubles (MDGS), 30.0% dry-rolled corn, and 5.0% supplement. The grower diet was formulated to provide 200 mg/calf daily of monensin (Rumensin 90; Elanco Animal Health). The ALT grower phase occurred from January 29th to May 22nd and February 5th to June 4th (years 1 and 2, respectively. The TRAD grower phase was from October 26th to February 16th and October 22nd to February 18th (years 1 and 2, respectively). The grower phase was 113 d and 120 d (years 1 and 2, respectively).

The ending BW for the grower phase was used to measure the initial BW for the finisher phase. The difference between the ending BW for the grower and initial BW for the finisher is the animal BW gain assumed for the limit-fed period (1 lb/d). Steers were implanted on d 1 with Revalor-IS and heifers implanted with Revalor-IH (Merck Animal Health). Cattle were re-implanted on d 84 with Revalor-200 (Merck Animal Health). The ALT finisher phase was from May 29th to October 29th (first shipping date; year 1) and December 10th (second shipping date; year 1) and June 10th to November 10th (first shipping date; year 2) and January 5th (second shipping date; year 2). The TRAD finisher phase was from February 22nd to July 16th (first shipping date; year 1) and August 13th (second shipping date; year 1) and February 25th to June 23rd (first shipping date; year 2) and July 28th (second shipping date; year 2). In year 1, the finishing diet consisted of 33.5% DRC, 33.5% HMC, 20.0% MDGS, 8.0% grass hay, and 5.0% supplement (DM basis). In year 2, due to feed seasonal limitations, the finishing diet consisted of 51.0% HMC, 30.0% Sweet Bran, 15.0% corn silage, and 4.0% supplement (DM basis). Shipping dates were calculated to target 0.6 in. of back fat between the 12th and 13th rib using ultrasound. Due to fat variation within pen, calves within pen were allotted to one of two shipping dates. In year 1, the ALT cattle were on feed for 154 and 196 d while the TRAD cattle were on feed for 145 and 173 d. In year 2, ALT cattle were on feed for 154 and 210 d and TRAD cattle were on feed for 120 and 155 d. Hot carcass weight (HCW) was collected on day of harvest. Following a 48 h chill, longissimus muscle (LM) area, 12th rib fat thickness, and USDA marbling score were collected. Carcass-adjusted final BW was calculated from HCW using a common dressing percent of 63% to calculate ADG and F:G.

### *Statistical Analysis*

Cow performance, pre-weaning calf growth, post-weaning growth, and finishing performance data were analyzed using the GLIMMIX procedures of SAS where original cow replicate was considered the experimental unit (n = eight replicates/treatment). Cows were blocked by cow age and stratified by original herd (two sources). The model included treatment and block as a fixed effect and year as a random effect. Proportion of heifers and twins were tested as covariates but were not significant ($P > 0.11$) and subsequently removed from the model.

Reproduction, body condition scoring, and morbidity data were analyzed using the GLIMMIX procedure of SAS with a binomial or multinomial models with replicate as the experimental unit and fixed effects of treatment and block. Year was included as a random effect.

## Results

### *Cow and Preweaning Performance*

There were no differences ($P \geq 0.27$) in conception rates, calving rates, and weaning rates for ALT vs. TRAD (Table 2). However,

**Table 2. Effects of cow-calf system on reproductive performance**

| | Treatment[1] | | | |
|---|---|---|---|---|
| | ALT | TRAD | SEM | *P*-Value |
| Groups, n | 8 | 8 | — | — |
| Age, year | 6.3 | 6.0 | 0.49 | 0.06 |
| Conception rate, % | 94.6 | 94.1 | 2.3 | 0.88 |
| Calving rate, % | 89.7 | 91.2 | 2.92 | 0.71 |
| Twin rate[2], % | 9.4 | 2.9 | 2.36 | 0.04 |
| Wean rate, % | 82.3 | 87.2 | 3.29 | 0.27 |
| Cow morbidity[3], % | 18.9 | 17.6 | 3.24 | 0.78 |
| Cow mortality, % | 0.62 | 0.62 | — | — |
| Replacement rate[4], % | 9.60 | 9.93 | 2.89 | 0.93 |

[1]Treatments = alternative cow-calf system (ALT) calving in July/August and utilizing drylot, fall forage oat grazing, and corn residue grazing; traditional cow-calf system (TRAD) calving in April/May and utilizing perennial pasture and corn residue grazing.

[2]One calf from each set of twins was selected randomly and removed from experiment.

[3]Number of cows treated for morbidity at least once.

[4]Percentage of cows removed from the herd due to failure to breed or maintain pregnancy.

**Table 3. Effects of cow-calf system on calf performance**

| | Treatment[1] | | | |
|---|---|---|---|---|
| | ALT | TRAD | SEM | *P*-Value |
| Groups, n | 8 | 8 | — | — |
| Birth BW, lb | 85.9 | 88.1 | 1.5 | 0.18 |
| Age at wean, d | 168 | 168 | 1.1 | 0.76 |
| Wean BW, lb | 405 | 504 | 12.1 | < 0.01 |
| lb weaned/cow exposed[2] | 330 | 438 | 15.9 | < 0.01 |
| Calf morbidity[2], % | 58.0 | 16.7 | 4.2 | < 0.01 |
| Calf mortality, % | 7.75 | 4.08 | — | — |

[1]Treatments = alternative cow-calf system (ALT) calving in July/August and utilizing drylot, fall forage oat grazing, and corn residue grazing; traditional cow-calf system (TRAD) calving in April/May and utilizing perennial pasture and corn residue grazing.

[2]lb of calf weaned divided by number of cows exposed to bull.

[3]Number of calves treated for morbidity at least once.

there was an increase ($P = 0.04$) in the rate of twin offspring (9.42 vs. 2.90 ± 3.29 %, respectively) for ALT vs. TRAD, respectively. This response was unexpected. In the current study, during the first five days of breeding, cows remained on the limit-fed diet, then placed on fall forage oats which may contribute to twinning. Cow morbidity and replacement rates did not differ ($P \geq 0.78$). Breeding BCS distributions did differ ($P < 0.01$) with a larger proportion of score 5.0 and fewer scores of 6.5 to 7.0 for ALT compared to TRAD cows (data not shown). Likewise, weaning BCS distributions were different ($P < 0.01$) with a larger proportion of scores 4.0 to 5.0 for ALT compared to TRAD cows (data not shown). In general, the ALT cows maintained a lower BCS closer to 5.0 throughout the production system. Differences in body condition among production systems are likely due to controlling energy intake of ALT cows during the confined, limit-feeding period compared to TRAD cows on pasture. Even though ALT cows had a shift towards lower BCS from breeding to weaning compared to TRAD cows, conception rates were not different ($P = 0.88$) among treatments.

As designed, calf age at weaning was not different ($P = 0.76$) at 168 d for both treatments (Table 3). Calf birthweight, not including the removed twin calf, did not differ ($P = 0.35$) among TRAD and ALT treatments. Calf wean BW was 99 lb lighter ($P < 0.01$) for ALT calves compared to TRAD calves. As a result of lower weaning weights, lb of calf weaned per cow exposed was 108 lb less ($P < 0.01$) for ALT cows compared to TRAD cows. In the current experiment, preweaning calf morbidity was greater ($P < 0.01$) for ALT calves compared to TRAD calves. Over half of the calves 58.04 %from the ALT treatment were treated at least once for morbidity compared to 16.70 % of TRAD calves. This difference may be attributed to wet pen conditions in the first year of the study.

### POST-WEANING PERFORMANCE

Due to differences in weaning BW in the cow-calf phase, initial BW for the grower phase was 96 lb lighter ($P <0.01$) for ALT calves compared to TRAD calves. Ending BW was 53 lb lighter ($P <0.01$) for ALT calves compared to TRAD calves, illustrating that ALT calves compensated with greater ADG ($P <0.01$) compared to TRAD calves. There was no difference ($P = 0.17$) for DMI among treatments. Thus, ALT calves had improved ($P < 0.01$) F:G compared to TRAD calves. Morbidity treatments (i.e. coccidiosis, diphtheria, ear infection, foot rot, lameness, pinkeye, prolapse, were greater ($P <0.01$) for TRAD compared to ALT calves.

Due to differences in ending BW in the grower phase, initial BW for the finisher phase was lower ($P <0.01$) for ALT calves compared to TRAD calves. Days on feed were 168 and 141 for ALT and TRAD treatments, respectively, in order to harvest cattle at a targeted 12$^{th}$ rib back fat thickness of 0.6 in. Carcass-adjusted final BW did not differ ($P = 0.15$) among treatments. Dry matter intake did not differ ($P = 0.33$) between production system, although ADG was lower ($P = 0.02$) for ALT calves compared to TRAD calves. Lower ADG and no difference in DMI lead to dramatically poorer ($P = 0.01$) F:G for ALT calves compared to TRAD calves.

Hot-carcass weight did not differ ($P =0.20$) between ALT and TRAD treatments. In the current experiment, cattle were harvested based on predicted 12$^{th}$ rib fat thickness, not age. *Longissimus* muscle area was greater ($P = 0.04$) for ALT compared to TRAD calves. The ALT treatment had less ($P = 0.05$) 12$^{th}$ rib back fat compared to the TRAD calves but were 0.59 vs. 0.65 in., respectively. Due to the large numerical improvement in growth performance for

**Table 4. Effects of cow-calf system on post-wean calf growth performance on a grower diet**

| | Treatments | | | |
|---|---|---|---|---|
| | ALT[1] | TRAD[2] | SEM | *P*-Value |
| Groups, n | 8 | 8 | — | — |
| Days on feed | 117 | 117 | — | — |
| Mortality, % | 1.52 | 0.00 | — | — |
| Removed[2], % | 0.76 | 0.00 | — | — |
| Morbidity[3], % | 5.3 | 37.7 | 11.0 | <0.01 |
| Initial BW, lb | 408 | 504 | 10.8 | <0.01 |
| Ending BW, lb | 764 | 817 | 6.4 | <0.01 |
| DMI, lb/d | 19.1 | 19.6 | 0.24 | 0.17 |
| ADG, lb | 3.06 | 2.69 | 0.044 | <0.01 |
| F:G | 6.37 | 7.30 | - | <0.01 |

[1]Treatments = alternative cow-calf system (ALT) calving in July/August and utilizing drylot, fall forage oat grazing, and corn residue grazing; traditional cow-calf system (TRAD) calving in April/May and utilizing perennial pasture and corn residue grazing.

[2]Percentage of calves removed due to health or injury.

[3]Percentage of calves treated for morbidity at least once.

**Table 5. Effects of cow-calf system on post-wean calf growth performance on a finishing diet**

| | Treatment[1] | | | |
|---|---|---|---|---|
| | ALT | TRAD | SEM | *P*-Value |
| Groups, n | 8 | 8 | — | — |
| DOF[2] | 168 | 141 | — | — |
| Mortality, % | 1.55 | 0.72 | — | — |
| Removed[3], % | 0.96 | 0.91 | — | — |
| Morbidity, % | 20.88 | 40.36 | 12.210 | 0.23 |
| Initial BW, lb | 771 | 824 | 6.4 | < 0.01 |
| Final BW[4], lb | 1355 | 1333 | 13.7 | 0.15 |
| DMI, lb/d | 23.8 | 23.1 | 0.62 | 0.33 |
| ADG, kg | 3.35 | 3.99 | 0.48 | 0.02 |
| F:G | 7.09 | 5.85 | - | 0.01 |
| Carcass Characteristics | | | | |
| HCW, lb | 855 | 839 | 8.4 | 0.14 |
| lb HCW/cow exposed[6] | 667 | 707 | 28.0 | 0.33 |
| LMA, in$^2$ | 14.4 | 13.9 | 0.26 | 0.04 |
| Back fat, in | 0.59 | 0.65 | 0.017 | 0.05 |
| Marbling Score[7] | 532 | 539 | 14.3 | 0.73 |
| Calculated YG[8] | 3.1 | 3.4 | 0.07 | 0.03 |

[1]Treatments = alternative cow-calf system (ALT) calving in July/August and utilizing drylot, fall forage oat grazing, and corn residue grazing; traditional cow-calf system (TRAD) calving in April/May and utilizing perennial pasture and corn residue grazing.

[2]Treatments were fed to predict 1.52 cm of 12$^{th}$ rib fat thickness.

[3]Percent of calves removed due to health or injury.

[4]HCW divided by dressing percent (0.63).

[5]Adjusted final BW calculated as ((1.316 × HCW) +32) + [(28 − EBF) × 14.26])/0.891 from Guiroy et al., 2001.

[6]Pound of HCW divided by number of cows exposed to bull.

[7]Marbling score: 400=small$^{00}$, 500=Modest$^{00}$.

[8]Calculated as 2.5 + (6.35 x 12$^{th}$-rib fat thickness, cm)—(2.06 x LM area, cm$^2$) + (0.2 x 2.5 KPH fat, %) + (0.0017 x HCW, kg) where KPH fat was assumed to be 2.5 % (Boggs and Merkel, 1993).

[9]Calculated as 17.76207 + (4.68142 x 12th rib fat) + (0.01945 x HCW) + (0.81855 x QG)—(0.06754 x LM area) from Guiroy et al., 2001.

TRAD calves in year 2, predicted 12$^{th}$ rib back fat thickness was underestimated. Marbling score did not differ ($P$ = 0.73) among treatments. Performance differences shifted from growing to finishing, with ALT calves having greater ADG and better F:G than TRAD in the 117-d growing program, but lower ADG and poorer F:G in the finishing phase. It is worth noting that cattle were not fed at the same time of year, with weather stresses during finishing more challenging for ALT cattle.

## Conclusions

This experiment evaluated performance of a cow-calf production system utilizing confinement, cover crop, and corn residue compared to a traditional, pasture-based cow-calf production system. It provides evidence that reproduction is not impacted negatively in a partially-confined cow-calf system. However, the increased probability of twin offspring for the alternative cow-calf system is interesting. It is unclear what is causing the reduction in weaning weight for the partially-confined system but may be related to calving season.

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# Inflammatory Modulators Improve Daily Gain of Heat-Stressed Wethers

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## Summary with Implications

*Inflammation during heat stress may mediate poor growth in livestock. The effects of anti-inflammatory treatments on muscle growth during chronic heat stress were evaluated by using meat lambs as a smaller, cheaper model for feedlot steers. Wethers were maintained in normal (75°F) or heat stress (105°F for 12 hours/day, 85°F for 12 hours/day) environments for 30 days and received dexamethasone injections every 3 days, oral fish oil supplementation twice daily, or no intervention. Growth was tracked and muscles were weighed when harvested afterward. Dexamethasone and fish oil both increased average daily gain over the final 15 days of the study despite no difference in feed intakes. In general, heat stress reduced muscle weights. Dexamethasone recovered size deficits caused by heat stress for many but not all muscles. Fish oil supplementation also rescued size in some muscles but was less profound than dexamethasone. Nevertheless, these results show that targeting inflammation may be key to improving muscle growth in heat-stressed livestock.*

## Introduction

Chronic heat stress impairs muscle growth in livestock and costs producers in the beef industry an average of almost $400 million every year. Misters, shades, and other mechanical means to alleviate heat stress can be difficult and costly to implement. In addition to reducing daily feed intake, recent work by this lab shows heat stress causes systemic inflammation that contributes to deficits in growth. Polyunsaturated fatty acids (PUFA) are found in many food components and reduce inflammation. Dexamethasone is a synthetic version of the hormone cortisol that is widely used to reduce inflammation in sick or injured animals. It is hypothesized that treating with either may have the potential to improve growth outcomes in heat-stressed livestock, but these effects have not yet been characterized. The objective was to determine how dietary supplementation with PUFA-rich fish oil or treatment with injectable dexamethasone would impact daily feed intake, average daily gain, feed efficiency, and muscle growth in feedlot wethers during chronic heat stress.



**Table 1. Growth in heat-stressed feedlot wethers administered oral fish oil twice daily or injectable dexamethasone every 3 days for 30 days.**

| Metric | Experimental Group | | | |
|---|---|---|---|---|
| | Control | Heat Stress | Heat Stress + Dexamethasone | Heat Stress + Fish Oil |
| **Avg. Daily Gain (lb)** | | | | |
| Day 0–15 | 0.59 ± 0.13 | 0.55 ± 0.07 | 0.64 ± 0.13 | 0.37 ± 0.15 |
| Day 15–30 | 0.31 ± 0.11[a] | 0.29 ± 0.11[a] | 0.55 ± 0.11[b] | 0.66 ± 0.11[b] |
| Day 0–30 | 0.42 ± 0.09 | 0.40 ± 0.09 | 0.57 ± 0.07 | 0.53 ± 0.04 |
| **Feed Intake (lb/d)** | | | | |
| Day 015 | 3.35 ± 0.24 | 3.40 ± 0.24 | 3.35 ± 0.24 | 3.44 ± 0.24 |
| Day 15–30 | 3.31 ± 0.18 | 3.20 ± 0.18 | 3.40 ± 0.18 | 3.11 ± 0.18 |
| Day 0–30 | 3.33 ± 0.20 | 3.29 ± 0.20 | 3.37 ± 0.20 | 3.26 ± 0.20 |
| **Gain:Feed (lb/lb)** | | | | |
| Day 0–15 | 0.173 ± 0.031 | 0.161 ± 0.031 | 0.184 ± 0.031 | 0.107 ± 0.031 |
| Day 15–30 | 0.086 ± 0.037[x] | 0.076 ± 0.037[x] | 0.166 ± 0.037[y] | 0.218 ± 0.037[y] |
| Day 0–30 | 0.126 ± 0.025[x] | 0.114 ± 0.023[x] | 0.171 ± 0.008[y] | 0.162 ± 0.010[y] |

[a,b] Means with different superscripts differ ($P \leq 0.05$).

[x,y] Means with different superscripts tend to differ ($P < 0.10$).

NS, Not significant.

## Procedure

Wethers were stratified by bodyweight and randomly assigned to normal (i.e. controls; 75°C for 24 hours/day; n = 10) or heat stress (105°F for 12 hours/day, 85°F for 12 hours/day, 35% relative humidity) conditions for 30 days. Heat-stressed wethers received a) twice-daily oral fish oil capsules (0800 and 1600; 1200 mg, per previous studies in the literature; n = 8), intramuscular dexamethasone injections every three days (2 cc; n = 8), or no intervention (n = 8). Controls were pair-fed to the average intake of heat stressed wethers. Daily feed intake and weekly bodyweights were measured, and wethers were harvested upon completion of the 30-day period. Empty bodyweight was estimated postmortem by removing the digestive tract. Several muscles relevant to carcass composition were collected and weighed.

**Table 2. Skeletal muscle size in heat-stressed feedlot wethers administered oral fish oil twice daily or injectable dexamethasone every 3 days for 30 days.**

| Metric | Experimental Group | | | |
|---|---|---|---|---|
| | Control | Heat Stress | Heat Stress + Dexamethasone | Heat Stress + Fish Oil |
| **Muscle Weight (lbs)** | | | | |
| Biceps Femoris | $0.89 \pm 0.03^{x}$ | $0.81 \pm 0.03^{y}$ | $0.89 \pm 0.02^{x}$ | $0.88 \pm 0.02^{x}$ |
| Flexor digitorum superficialis | $0.09 \pm 0.002$ | $0.09 \pm 0.004$ | $0.10 \pm 0.004$ | $0.09 \pm 0.004$ |
| Gastrocnemius | $0.29 \pm 0.01^{x}$ | $0.28 \pm 0.02^{xy}$ | $0.30 \pm 0.004^{x}$ | $0.27 \pm 0.01^{y}$ |
| Longissimus dorsi | $1.5 \pm 0.1^{x}$ | $1.3 \pm 0.1^{y}$ | $1.4 \pm 0.1^{xy}$ | $1.3 \pm 0.04^{y}$ |
| Soleus | $0.006 \pm 0.001^{a}$ | $0.005 \pm 0.0002^{b}$ | $0.006 \pm 0.0002^{a}$ | $0.006 \pm 0.001^{a}$ |
| Semitendinosus | $0.32 \pm 0.01^{x}$ | $0.29 \pm 0.01^{y}$ | $0.30 \pm 0.01^{xy}$ | $0.29 \pm 0.01^{y}$ |
| **Mass/Empty BW (g/lbs)** | | | | |
| Biceps Femoris | $4.93 \pm 0.10^{a}$ | $4.59 \pm 0.10^{b}$ | $4.95 \pm 0.07^{a}$ | $4.86 \pm 0.11^{a}$ |
| Flexor digitorum superficialis | $0.53 \pm 0.01$ | $0.50 \pm 0.02$ | $0.56 \pm 0.01$ | $0.52 \pm 0.02$ |
| Gastrocnemius | $1.61 \pm 0.05^{a}$ | $1.58 \pm 0.04^{ab}$ | $1.64 \pm 0.03^{a}$ | $1.49 \pm 0.04^{b}$ |
| Longissimus dorsi | $8.1 \pm 0.3^{x}$ | $7.5 \pm 0.2^{y}$ | $7.6 \pm 0.2^{xy}$ | $7.0 \pm 0.1^{z}$ |
| Soleus | $0.037 \pm 0.004^{a}$ | $0.025 \pm 0.002^{b}$ | $0.030 \pm 0.001^{c}$ | $0.035 \pm 0.003^{ac}$ |
| Semitendinosus | $1.77 \pm 0.03^{x}$ | $1.68 \pm 0.05^{y}$ | $1.64 \pm 0.05^{z}$ | $1.64 \pm 0.04^{yz}$ |

$^{a,b}$ Means with different superscripts differ ($P \leq 0.05$).

$^{x,y}$ Means with different superscripts tend to differ ($P < 0.10$).

BW, bodyweight; NS, Not significant.

## Results

Initial and final bodyweights were not different among groups, but average daily gain was increased ($P < 0.05$) and feed efficiency tended to be increased ($P = 0.06$) over the last 15 days of the study for wethers treated with dexamethasone or fish oil (Table 1). Moreover, feed efficiency tended to be greater ($P = 0.10$) for wethers treated with dexamethasone or fish oil across the entire 30-d period. Heat stress decreased ($P < 0.05$) the size of the soleus muscle and tended to decrease ($P < 0.10$) the size of the biceps femoris, longissimus dorsi, and semitendinosus muscles (Table 2). Injection with dexamethasone every 3rd day improved the size deficits caused by heat stress for the biceps femoris (upper hindlimb), gastrocnemius (lower hindlimb), longissimus dorsi (loin), and soleus (lower hindlimb) muscles but did not recover size deficits in the semitendinosus (upper hindlimb) muscle. Twice-daily oral supplementation of fish oil improved ($P < 0.05$) size deficits caused by heat stress for biceps femoris and soleus muscles.

## Conclusions

From these findings, we conclude that although chronic heat stress in growing livestock diminished indicators of muscle growth, treating heat-stressed animals with anti-inflammatory agents improved many of these indicators. Indeed, the improved size of multiple muscles in heat-stressed lambs treated with dexamethasone or fish oil support the hypothesis that anti-inflammatory pharmaceuticals and nutritional compounds rescue muscle growth during heat stress. Continued investigation of the biological processes underlying these improvements will provide the basis for nutritional, supplemental, and pharmaceutical strategies to recover performance in heat-stressed livestock.

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# Zilpaterol Supplementation Improved Indicators of Well-Being, but not Growth in Heat-Stressed Red Angus Steers

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## Summary with Implications

*The effects of zilpaterol (β2 agonist) supplementation on respiration rate, body temperature, growth, and carcass traits were studied in chronically heat-stressed feedlot steers. Through a collaborative partnership with the University of Arizona, Red Angus steers were heat stressed (90–105°F) and fed zilpaterol-supplemented rations (Thermoneutral control steers were pair-fed to the average feed intake of heat-stressed steers) for 30 days. Hot and cold carcass weights for heat-stressed cattle were 3% less than for controls, despite equal feed intake. Zilpaterol did not affect growth but improved the heat stress-induced hyperventilation and elevated body temperatures. Lighter carcass weights in heat-stressed cattle show that factors other than nutrient intake hinder growth under heat stress. Contrary to previous anecdotal reports, this study found no evidence that zilpaterol supplementation worsened the effects of heat stress. In fact, respiration rates and body temperatures show that zilpaterol moderates some responses to chronic heat stress in cattle.*

## Introduction

Heat stress is a hindrance to livestock performance. Livestock experience heat stress when their total heat load exceeds their dissipation rate. Increasing the concentrate content of the diet may help to make up for the negative energy balance caused by decreased feed intake in heat-stressed livestock. However, recent findings in sheep indicate that the impact of heat stress is due to more than just reduced feed intake.

Cattle feeders implement a range of strategies to maximize performance. One such option is dietary supplementation of growth promoters like zilpaterol HCl (i.e. Zilmax). This β2 agonist has been shown to break down fat, increase muscle synthesis, and inhibit muscle breakdown, thus increasing size and leanness of carcasses and improving feed efficiency. Zilpaterol was commonly used in US feedlots until anecdotal reports of increased wellbeing issues in stressed cattle in 2013 caused it to be removed from the market by the manufacturer. Therefore, the objective of this study was to determine if supplementing zilpaterol to cattle under heat stress conditions has detrimental effects on growth and on respiration rates and body temperatures, which are indicators of wellbeing.



## Procedure

A cattle feeding study was performed with 24 Red Angus steers (572 ± 55 lbs) to evaluate the effects of feeding zilpaterol HCl during chronic heat stress on growth, respiration rates, rectal temperatures, and carcass traits. Steers were purchased from a commercial farm in Nebraska and transported to the University of Arizona Feedlot in Tucson, AZ. Upon arrival, steers were acclimated to diet and surroundings for several weeks, were halter-broken, and were trained to tie-stalls. Throughout the study, steers were fed an 88% concentrate diet composed primarily of ground-corn along with alfalfa hay (Table 1). These steers were randomly assigned to be housed indoors in adjacent stalls under heat stress (~105°F for 12 hours/day, 85°F for 12 hours/day; n = 12) or thermoneutral (~74°F constant; n = 12) conditions created by environmental chambers. In a 2 x 2 factorial, steers were also supplemented 0 or 3.81 mg/lb/day zilpaterol HCl (Intervet Merck) for 30 days. Steers were acclimated for 9 days in the environmental chambers before heat stress and supplementation began. Control steers were pair-fed to the average daily feed intake of heat-stressed steers. Respiration rates were estimated daily from single observations at 1500 by counting flank movements for 60 seconds. Body (rectal) temperatures were measured daily. Average daily feed intake, gain-to-feed ratios, and average daily gain were calculated for the 30-day period. Cattle were harvested in the abattoir of the University of Arizona Food Product and Safety Laboratory. Carcasses were weighed, chilled for 7 days, ribbed at the 12$^{th}$ rib, and carcass traits were measured. All growth and carcass data were analyzed for effects of environment, supplement, and their interaction by ANOVA using the mixed procedure of SAS. Respiration rates and body temperatures were analyzed by ANOVA, with day as a repeated measure. Because they were individually fed, steer was the experimental unit.

**Table 1. Diet fed to Red Angus steers supplemented with zilpaterol HCl and heat stressed for 21 days.**

| Dietary Component | % of Diet, DM |
|---|---|
| Alfalfa, chopped | 13.7 |
| Corn, cracked | 73.2 |
| Mineral mix[1] | 2.1 |
| Molasses | 6.3 |
| Soybean meal | 3.8 |
| Urea | 0.9 |

[1]Trace mineral-vitamin premix contained: Calcium Carbonate, Processed Grains, Sodium Chloride, Ammonium Sulfate, Potassium Chloride, Dicalcium Phosphate, Molasses, Magnesium Oxide, Zinc Sulfate, Ferrous Carbonate, Copper Sulfate, Magnesium Sulfate, Ferrous Sulfate, Sodium Selenite, Potassium Iodide, Cobalt, Carbonate, Vitamin A Acetate, and Vitamin E Supplement. (Manufactured by Maid Rite Feeds, Wilcox, AZ)

## Results

By design, there were no differences among groups for initial body weight or

**Table 2. Growth metrics and carcass traits in Red Angus steers supplemented with zilpaterol HCl and heat stressed for 21 days.**

| | Thermoneutral | | Heat Stress | | *P*-value | | |
|---|---|---|---|---|---|---|---|
| Metric | Control | Zilpaterol | Control | Zilpaterol | Envir. | Suppl. | E*S |
| *Growth* | | | | | | | |
| Initial Bodyweight, lbs | 561.4 ± 26 | 576.1 ± 17 | 578.3 ± 23 | 578.5 ± 14 | NS | NS | NS |
| Final Bodyweight, lbs | 663.0 ± 39 | 668.4 ± 22 | 689.3 ± 22 | 688.8 ±14 | NS | NS | NS |
| Average Daily Gain, lbs/day | 4.6 ± 0.3 | 3.8 ± 0.2 | 4.6 ± 0.2 | 4.6 ± 0.2 | NS | NS | NS |
| Feed Intake, lbs/day | 17.9 ± 0.3 | 17.9 ± 0.2 | 17.6 ± 0.3 | 18.5 ± 0.9 | NS | NS | NS |
| Gain:Feed | 0.48 ± 0.07 | 0.44 ± 0.02 | 0.53 ± 0.04 | 0.51 ± 0.04 | NS | NS | NS |
| *Carcass Traits* | | | | | | | |
| Hot Carcass Weight, lbs | 347.9 ± 4.0$^{x}$ | 357.6 ± 3.6$^{x}$ | 347.3 ± 3.5$^{y}$ | 340.4 ± 6.3$^{y}$ | - | - | 0.06 |
| Cold Carcass Weight, lbs | 339.2 ± 2.5$^{a}$ | 340.5 ± 4.2$^{a}$ | 333.7 ± 3.7$^{b}$ | 328.7 ± 5.6$^{b}$ | - | - | 0.05 |
| Ribeye area, in$^2$ | 23.3 ± 0.6 | 22.0 ± 0.5 | 23.0 ± 0.5 | 23.0 ± 0.2 | NS | NS | NS |
| Marbling[1] | 200 ± 20 | 250 ± 20 | 200 ± 20 | 230 ± 20 | NS | NS | NS |
| KPH fat, % | 1.2 ± 0.6 | 1.0 ± 0.04 | 1.0 ± 0.03 | 1.0 ± 0.03 | NS | NS | NS |
| Fat thickness, in | 0.04 ± 0.005 | 0.05 ± 0.006 | 0.04 ± 0.005 | 0.05 ± 0.005 | NS | NS | NS |
| Meat Color Score | 6.8 ± 0.2 | 6.7 ± 0.2 | 6.8 ± 0.2 | 7.1 ± 0.2 | NS | NS | NS |

[1]Marbling score 200=Slight, 300=Small.

$^{a,b}$ Means with different superscripts differ ($P < 0.05$). $^{x,y}$ Means with different superscripts tend to differ ($P < 0.10$).

NS, not significant.

**Table 3. Respiratory rates and body temperatures in Red Angus steers supplemented with zilpaterol HCl and heat stressed for 21 days.**

| | Thermoneutral | | Heat stress | | *P*-value | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | No Suppl. | Zilpaterol | No Suppl. | Zilpaterol | Env. | Suppl. | Day | E*S*D |
| Respiration, /min | | | | | NS | NS | NS | <0.01 |
| Day 8 | 59 ± 3$^{a}$ | 56 ± 3$^{a}$ | 106 ± 5$^{b}$ | 95 ± 4$^{c}$ | | | | |
| Day 11 | 44 ± 4$^{a}$ | 45 ± 3$^{a}$ | 111 ± 6$^{b}$ | 92 ± 13$^{b}$ | | | | |
| Day 15 | 41 ± 4$^{a}$ | 29 ± 5$^{c}$ | 103 ± 10$^{b}$ | 95 ± 8$^{b}$ | | | | |
| Day 19 | 53 ± 5$^{a}$ | 41 ± 3$^{c}$ | 108 ± 6$^{b}$ | 105 ± 4$^{b}$ | | | | |
| Rectal Temp, °F | | | | | NS | NS | NS | <0.01 |
| Day 8 | 101.3 ± 0.2$^{a}$ | 101.8 ± 0.2$^{c}$ | 102.7 ± 0.2$^{b}$ | 102.4 ± 0.4$^{b}$ | | | | |
| Day 11 | 101.7 ± 0.2$^{a}$ | 101.5 ± 0.4$^{a}$ | 103.3 ± 0.4$^{b}$ | 102 ± 0.4$^{a}$ | | | | |
| Day 15 | 101.7 ± 0.2$^{a}$ | 101.8 ± 0.2$^{a}$ | 103.3 ± 0.4$^{b}$ | 102.2 ± 0.4$^{a}$ | | | | |
| Day 19 | 101.7 ± 0.2$^{a}$ | 101.5 ± 0.4$^{a}$ | 103.5 ± 0.2$^{b}$ | 102.6 ± 0.4$^{c}$ | | | | |

$^{a-b}$ Means with different superscripts differ (P < 0.05) within day.

feed intake. There were also no differences among groups for final bodyweight, average daily gain, or feed efficiency or for the carcass traits ribeye area, marbling, color, fat thickness, and kidney pelvic and heart percentage (Table 2). Heat stress caused hot carcass weights to be 3% lighter ($P = 0.06$) and cold carcass weights to be 3% lighter ($P = 0.05$) than in controls, regardless of zilpaterol supplementation. Environment x supplement x day interactions were observed ($P < 0.05$) for body temperature and respiration rates (Table 3). In general, heat stress caused body temperatures to increase ($P < 0.05$) by 1 to 2°F. Zilpaterol supplementation reduced ($P < 0.05$) the elevation in body temperature in heat-stressed cattle in the last half of the 30-day period but not earlier in the period. Heat stress caused respiration rates to increase ($P < 0.05$) by up to 28%, but zilpaterol supplementation reduced ($P < 0.05$) hyperventilation by about half.

## Conclusions

Beef steers produced an average of almost 10 lbs less carcass when exposed to heat stress for three weeks, even when feed intake was made equivalent by pair-feeding. This demonstrates that factors independent of nutrient intake impair growth in heat-stressed cattle. Furthermore, zilpaterol supplementation helped reduce the hyperventilation and high body temperatures caused by heat stress. This provides evidence that zilpaterol alleviates some of the physiological effects of heat stress. Although the timeline for future market availability is unclear, this study indicates a potential role for controlling some negative outcomes of long-term heat stress in food animals.

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# Growth Performance in Livestock with Stress-Induced Low Birthweight is Recovered by Clenbuterol Administration

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## Summary with Implications

*Stress in pregnant livestock causes pathological low birthweight of the offspring and diminishes their muscle growth capacity. Using sheep as a model for beef cattle, this study determined that the limited growth capacity of offspring with stress-induced low birthweight could be recovered by postnatal treatments. Muscle in these animals has less growth-promoting β2 adrenergic activity and thus the injectable β2 adrenergic stimulant clenbuterol was used as a daily treatment. Lambs with stress-induced low birthweight continued to exhibit impaired muscle growth and feed efficiency well past the normal age for weaning. In addition, they began to put on excess fat around the age of weaning, making them destined to produce less meritorious carcasses even at equivalent liveweights. Daily clenbuterol injections improved growth rates, metabolic efficiency, and body composition in lambs with stress-induced low birthweight. By demonstrating that changes in β2 adrenergic activity are valid targets for recovering growth performance and body composition, these findings provide the basis for practical on-farm strategies to improve outcomes in low birthweight livestock such as oral supplementation of clenbuterol or other β2 agonists.*

## Introduction

Pathological low birthweight in livestock most commonly results from stress-induced intrauterine growth restriction of the fetus. Stressed fetuses become programmed to grow muscle at slower rates so that more of their energy can be devoted to coping with the stress. However, this "thrifty" growth persists after birth even when the stress does not, leading to slow, inefficient growth and less desirable body composition that diminishes carcass yield and merit. Stress-induced low birthweight occurs naturally in about 1 out of every 10 animals but can affect entire herds during times of drought, overgrazing, or other stressful conditions. Thus, effective postnatal treatment strategies to improve growth outcomes are warranted. This study examined the benefits of using the injectable β2 adrenergic stimulant clenbuterol to target reductions in growth-promoting β2 adrenergic activity that was previously observed in stress-induced low birthweight muscle. The objective was to specifically evaluate how these growth deficits manifested in inferior body composition and muscle mass at and around the weaning age, and whether daily clenbuterol treatment would at least partially recover growth and body symmetry. Because of the limitations associated with using cattle for such experiments, the study used a well-characterized proxy model of heat-stressed pregnant sheep to produce low birthweight offspring for this study.

## Procedure

These studies were approved by the Institutional Animal Care and Use Committee at the University of Nebraska–Lincoln, which is accredited by AAALAC International. To produce stress-induced low birthweight lambs, Polypay ewes were housed under heat stress (105°F, 35% humidity) during mid-gestation (40$^{th}$ to 95$^{th}$ day of gestation, birth is at 150 days), which stunted the placenta and in turn created fetal stress/growth restriction. Ewes birthed lambs naturally, and lambs were raised on milk replacer for the first 30 days followed by an *ad libitum* grain diet. Beginning at birth, one-half of the low birthweight lambs were randomly assigned to receive daily injections of 0.04 µg/lb clenbuterol. The other low birthweight lambs and all control lambs were injected with saline. Bodyweights (BW), head circumference, front cannon bone length, body girth, and body length were measured at birth, 30 days of age, and 60 days of age. Lambs were then euthanized and hindlimbs and flexor digitorum superficialis muscles were weighed. Lamb carcasses were chilled for 24 hours and loin-eye area was measured between the 12$^{th}$ and 13$^{th}$ ribs. To estimate body composition in the live animal, bioelectrical impedance analysis was performed in live lambs at 30 and 60 days of age. It was also performed on the loin muscle at necropsy. Proximate analysis was performed on loin muscle to determine fat and protein content. All data were analyzed as an ANOVA using the mixed procedure of SAS, with lamb as the experimental unit. Data are presented as mean ± standard error.

## Results

This study found that the poor growth and body composition previously observed in stressed fetuses and young low birthweight lambs persisted past weaning. Hindlimb weights and flexor digitorum superficialis muscle weights indicated that muscle growth capacity was reduced by stress-induced low birthweight. Likewise, bodyweight relative to head circumference, front cannon bone length, body girth, and body length indicate that muscle growth relative to skeletal growth was impaired by stress-induced low birthweight. At this older juvenile age, stress-induced low birthweight lambs also began to deposit more body fat, which was not observed at younger ages. However, daily treatment with injectable clenbuterol for the first 2 months after birth improved muscle growth and body composition in these lambs. Biometrics and lean tissue estimates at weaning age reflected asymmetrical growth patterns that were compounded by deficits in feed efficiency, bodyweight gain, and muscling. This manifested in reduced bodyweights

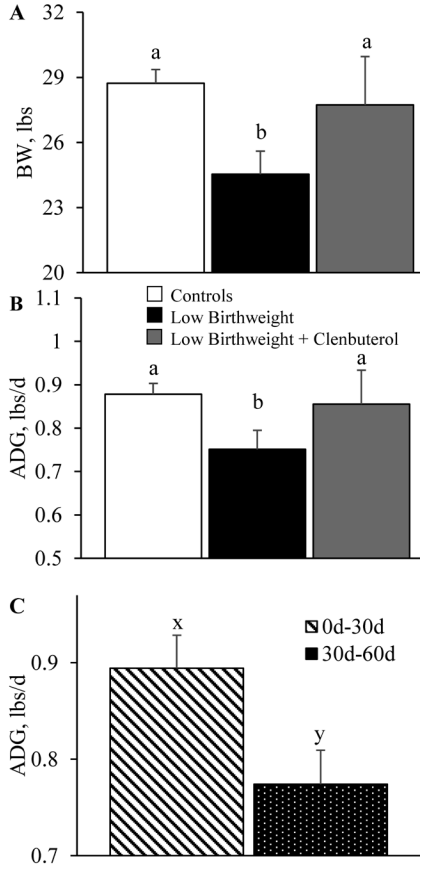


Figure 1. Bodyweight at 60 days of age and average daily gain in stress-induced low birthweight lambs treated daily with injectable clenbuterol. [a,b]Means with different superscripts differ ($P \leq 0.05$).

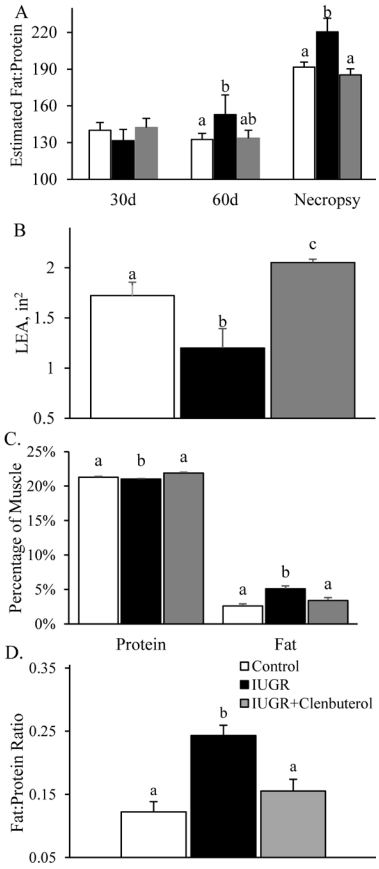


Figure 2. Muscle growth and composition at 60 days of age in stress-induced low birthweight lambs treated daily with injectable clenbuterol. [a,b,c]Means with different superscripts differ ($P \leq 0.05$).

at 60 days of age and reduced average daily gain from birth to 60 days, both of which were recovered by clenbuterol treatment (Figure 1). Additionally, weight gain was slower for all lambs in the 2nd month compared to the 1st month, which indicates that the opportunity for recovering growth may wane over time. The impact of stress-induced low birthweight on muscle growth was particularly evident in reduced loin-eye areas and in estimations of lean mass (Figure 2). Studies have previously shown that poor muscle growth following fetal stress/low birthweight is the result of faulty muscle stem cells and protein synthesis, and these problems were clearly not reconciled at the weaning age. Additionally, although stress-induced low birthweight lambs had less total fat mass at weaning, their percentage of fat was increased and protein-to-fat ratios were reduced, which further diminished body composition. Persistence of poor muscle growth and greater fat at this age helps to explain the reduced yield and carcass merit known to exist in low birthweight animals at harvest. Treatment with clenbuterol improved indicators of muscle growth body composition.

## Conclusion

The conclusion from this study is that the impact of stress-induced low birthweight on growth in general and on muscle growth in particular extends beyond early life and in fact continues through the weaning age. However, daily treatment with clenbuterol demonstrated a potential avenue to recover muscle growth and weight gain in these stress-induced low birthweight livestock. Although daily injections might not be a practical strategy for many livestock producers, this study lays the foundation for investigation of similar pharmaceutical products, including oral versions of clenbuterol or other β agonists.

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# Impact of Urea on Corn Silage Growing Cattle Diets

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**Summary with Implications**

*Two experiments were conducted to evaluate the effects of increasing urea in a corn silage growing cattle diet and ensiling time impact on rumen undegradable protein content of corn silage. Four treatments (urea inclusion at 0, 0.5, 1, and 1.5% of diet dry matter) were evaluated in diets containing 95% corn silage using 10 ruminally and duodenally cannulated heifers. Corn silage was sampled 5 times (every 32 days) to determine rumen undegradable protein content. Intake and total tract digestibility of dry matter, organic matter, and neutral detergent fiber all increased linearly with increasing inclusion of urea in the diet. Measured microbial crude protein synthesis was greatest for the 0.5 and 1% urea diets, averaging 15% of TDN. As ensiling time increased, rumen undegradable protein content of the corn silage decreased from 32% of crude protein on the day of corn silage harvest to 17% after 160 days. This was primarily driven by changes in the corn grain in the first 30 days of ensiling as the forage component of the corn silage had little change across time.*

## Introduction

Estimating the amount of microbial crude protein (MCP) synthesized in the rumen has large implications on diet formulation and estimated metabolizable protein (MP) requirements; especially for those animals that are growing and have a greater requirement for MP as a percentage of dietary dry matter (DM). In addition, growing cattle diets are often formulated to include ingredients such as corn silage, which contain intermediate amounts of fermentable energy and protein, and both forage and grain. This could lead to under- or over-feeding supplemental protein to growing cattle depending on which modeling technique is utilized.

Predicting the amount of rumen undegradable protein (RUP) supplied by corn silage is difficult and can have varying results. In situ techniques have been developed to estimate the RUP content of forages and concentrates; however, corn silage contains forage and grain components which could cause variation in analyses and sampling techniques. In addition, the amount of MCP contributing to MP is dependent on meeting rumen degradable protein requirements (through urea). Therefore, the objectives of this experiment were to estimate the microbial efficiency of diets consisting of 95% corn silage with additional urea and estimate the RUP content of the forage and grain components of corn silage separately to determine the RUP content of corn silage.

## Procedure

### *Experiment 1*

Ten ruminally and duodenally cannulated heifers were utilized in a replicated 4 × 4 Latin square digestion experiment with 4 periods and 4 dietary treatments. Four heifers were assigned in each square to one of four treatments for four consecutive 21-d periods. Two additional animals were assigned randomly to treatment in each period for a total of 10 observations per period or 40 observations total. The objective was to evaluate the effects of increasing dietary urea in corn silage-based diets. Four treatments were dietary urea included in the supplement at 0%, 0.5%, 1%, or 1.5% of total dietary DM in diets containing 95% corn silage and 5% supplement (Table 1).

Experimental periods were 21 d in length with the first 16 d of each period used for diet adaptation and d 17 to 21 used for sample collection. Titanium dioxide (5 g) was dosed through the rumen cannula at 0800 and 1700 h daily to determine fecal output in periods 1 and 2 (10 g per day). During periods 3 and 4, 8 g TiO2 was used to move the average sample concentration of marker closer to the center of the standard curve of known standards (16 g per day). On d 17 to 20, fecal grab samples (0.55 lb) and duodenal flow contents (250 mL) were collected four times daily at 0800, 1200, 1400, 1800 h. Whole rumen contents (4.5 lb) were collected at 1600 h (8 h post-feeding) on d 20 of each period to isolate bacterial pellets. Duodenal and bacterial composites were analyzed for purine concentration to determine duodenal flow of MCP.

### *Experiment 2*

The effects of ensiling time on the RUP content of forage and grain components of corn silage were measured utilizing 2 ruminally cannulated steers offered 50% silage, 32.5% Sweet Bran, 15% MDGS, and 2.5% supplement *ad libitum*. Whole corn silage samples (15.4 lbs) were collected at the time of corn silage harvest (d 0) and 32 d, 64 d, 96 d, and 160 d following ensiling after removing approximately 12 in from the face of the ag bag. Fresh corn silage samples were placed in water in order to separate the grain from the forage components of the silage with forage floating to the top and grain sinking to the bottom to be collected separately. After separation and freeze drying, forage samples were ground to pass through a 2-mm screen and the grain samples were left as-is.

Samples of forage and grain (5 g) were weighed into Dacron bags and sealed. Two steers were used for rumen incubation with 2 replications (bags) of each sample per steer. There were 10 experimental samples in total (5 forage and 5 grain samples representing each of the 5 different ensiling duration timepoints). At the time of removal from the rumen, all bags were rinsed in

**Table 1. Experimental diets fed to growing cattle in Exp. 1**

| | Dietary urea inclusion, % of DM | | | |
|---|---|---|---|---|
| Item | 0 | 0.5 | 1 | 1.5 |
| *Ingredient, % DM* | | | | |
| Corn silage | 95 | 95 | 95 | 95 |
| Supplement | 5 | 5 | 5 | 5 |
| Fine ground corn | 3.160 | 2.660 | 2.160 | 1.660 |
| Limestone | 1.350 | 1.350 | 1.350 | 1.350 |
| Urea | 0.000 | 0.500 | 1.000 | 1.500 |
| Salt | 0.300 | 0.300 | 0.300 | 0.300 |
| Tallow | 0.125 | 0.125 | 0.125 | 0.125 |
| Beef trace mineral[1] | 0.050 | 0.050 | 0.050 | 0.050 |
| Vitamin A-D-E[2] | 0.015 | 0.015 | 0.015 | 0.015 |
| *Nutrient Content, %DM* [3] | | | | |
| Organic matter | 94.46 | 94.55 | 94.60 | 94.57 |
| Neutral detergent fiber | 42.44 | 42.34 | 42.36 | 42.27 |
| Crude protein | 8.49 | 9.85 | 11.21 | 12.57 |

[1]Premix formulated to contain 6.0% Zn, 5.0% Fe, 4.0% Mn, 2.0% Cu, 0.29% Mg, 0.2% I, 0.05% Co

[2]Premix formulated to contain Vitamin A—30,000 IU, Vitamin D—6,000 IU, Vitamin E—7.5 IU / g

[3]Based on analyzed nutrients for each ingredient

water and then frozen until analysis. At the time of analysis, forage sample bags were refluxed for 75 min in neutral detergent solution to remove attached microbes. Dry bags were then opened, and the contents analyzed for N to determine RUP content of the samples. Because some of the protein would have been water soluble and therefore was removed from the grain prior to freeze drying, the CP content of the corn grain used in the calculation for RUP was adjusted to the CP of the originating whole corn. The CP content of the corn grain averaged 4.01% after ensiling and after separation in water from the stover components therefore we assume approximately 52% of the corn grain CP in corn silage was water soluble. Grain is assumed to make up 50% of corn silage CP content with the other 50% coming from forage.

### *Statistical Analysis*

Data from the metabolism experiment were analyzed using the MIXED procedure of SAS (SAS ver. 9.4; Inst IN., Cary, NC) with period and treatment as fixed effects and animal serving a random effect. Preplanned orthogonal contrasts for linearly spaced treatments were evaluated.

Rumen undegradable protein content from each of the corn silage components at each of the durations of ensiling were compared using the MIXED procedure of SAS. Corn silage components were modeled separately (forage and grain). Animal served as a random effect. Statistical comparisons were considered significant at $P \leq 0.05$.

## Results

### *Experiment 1*

Intake of DM, organic matter (OM), and neutral detergent fiber (NDF) linearly increased ($P < 0.01$) with increasing dietary urea while no differences in excretion were detected ($P \geq 0.18$; Table 2). Apparent total tract digestibility of the nutrients also increased linearly as dietary urea inclusion increased ($P < 0.01$). Diets with only corn silage appeared deficient in rumen degradable protein (RDP) based on the increases in intake and digestibility. True OM digestibility in the rumen increased quadratically ($P = 0.01$) with increasing amounts of urea. Maximum OM digestibility (71.5%) was determined at 0.92% urea inclusion.

A quadratic effect was detected for MCP flow ($P < 0.01$). Based on the first derivative of the quadratic equation, MCP would be maximized at 675 g/d when 0.88% of dietary DM was urea. Urea was included in the supplement of the total mixed ration and not top dressed or infused. This potentially stabilized ruminal ammonia concentrations compared to pulse dosing.

When dietary urea was increased to 0.5% of DM, MCP flow was 666 g MCP/d (measured) compared to 399 and 533 g/d estimated by well-known nutritional models, respectively (Table 3). With increasing urea supplementation, measured MCP flow decreased quadratically while the MCP flow predicted in both modeling techniques increased linearly ($P < 0.05$). When 1.5% urea was added to the diet, MCP flow predicted was not different than measured microbial flow. Estimated TDN intake linearly increased in the current study; however, no other dietary characteristics were changed other than urea. This is important, as these data highlight the need to meet RDP requirements before estimating MCP flow using currently available models.

Microbial efficiency was 15.8% of TDN intake when RDP requirements were met with 0.5 to 1.0% urea inclusion. As 1.5% urea was added to the all-corn silage diets in the study, microbial efficiency was 11.0%. The decreased microbial efficiency in corn silage-based diets may be in part caused by increased ammonia concentrations in the rumen or passage rate.

### *Experiment 2*

The estimated RUP content of whole corn silage decreased with increasing days ensiled (Table 4). The greatest decrease in RUP was between 0 and 32 d of storage, and the average RUP content was 16.1% of CP among samples collected between d 32 and d 160. The largest decrease was in the corn grain component, with less change in the forage component of the corn silage. This change in corn grain RUP is primarily driven by the increase in protein solubility in the corn component of corn silage

**Table 2. Effects of urea in corn silage-based diets on nutrient intake and apparent total tract digestibility in Exp. 1**

| | Dietary urea inclusion, % of DM[1] | | | | | Contrast[2] | | |
|---|---|---|---|---|---|---|---|---|
| Item | 0 | 0.5 | 1 | 1.5 | SEM | Linear | Quadratic | Cubic |
| *DM* | | | | | | | | |
| Intake, lb / d | 12.6 | 13.4 | 14.1 | 15.0 | 0.64 | <0.01 | 0.79 | 0.85 |
| Digestibility, % | 55.8 | 57.3 | 59.7 | 60.8 | 0.83 | <0.01 | 0.82 | 0.55 |
| *OM* | | | | | | | | |
| Intake, lb / d | 11.9 | 12.6 | 13.2 | 14.1 | 0.62 | <0.01 | 0.81 | 0.86 |
| Digestibility, % | 60.1 | 61.1 | 63.3 | 64.9 | 0.77 | <0.01 | 0.69 | 0.58 |
| *NDF* | | | | | | | | |
| Intake, lb / d | 5.3 | 5.7 | 6.0 | 6.2 | 0.26 | <0.01 | 0.92 | 0.98 |
| Digestibility, % | 40.4 | 43.0 | 45.4 | 47.8 | 1.50 | <0.01 | 0.94 | 0.99 |
| True OM rumen digestibility, % | 56.4 | 68.1 | 71.7 | 65.4 | 2.99 | 0.03 | 0.006 | 0.90 |
| Microbial Crude Protein flow, g/d | 268 | 666 | 606 | 511 | 71.6 | 0.04 | 0.001 | 0.18 |
| Microbial efficiency, % of TDN | 6.9 | 16.0 | 13.9 | 11.0 | 1.5 | 0.14 | 0.001 | 0.14 |

[1]Treatments were 0%, 0.5%, 1%, or 1.5% dietary urea included in the supplement of diets containing 95% corn silage and 5% supplement

[2]Orthogonal contrasts

**Table 3. Effects of urea inclusion in corn silage-based diets and modeling technique on predicted or measured microbial crude protein (MCP) synthesis in Exp. 1**

| | Dietary urea inclusion, % of DM[1] | | | | | Contrast[2] | | |
|---|---|---|---|---|---|---|---|---|
| Item | 0 | 0.5 | 1 | 1.5 | SEM | Linear | Quadratic | Cubic |
| *TDNI, g/d*[3] | 3,879 | 4,097 | 4,299 | 4,577 | 197 | <0.01 | 0.79 | 0.85 |
| *MCP synthesis, g/d* | | | | | | | | |
| Measured[4] | 268 | 666 | 606 | 511 | 71.6 | 0.040 | <0.01 | 0.19 |
| BCNRM[5] | 380 | 399 | 417 | 441 | 17.2 | <0.01 | 0.80 | 0.84 |
| NRC 1996[6] | 504 | 533 | 559 | 595 | 25.6 | <0.01 | 0.79 | 0.85 |

[1]Treatments were 0%, 0.5%, 1%, or 1.5% dietary urea included in diets containing 95% corn silage and 5% supplement

[2]Orthogonal contrasts

[3]Total digestible nutrient intake (TDNI); TDN for corn silage assumed as 67.7% of DM

[4]Measured in the current study

[5]Predicted using TDN intake from the current study and equation 6–1 pp. 95 of the 2016 NRC

[6]Predicted using TDN from the current and microbial efficiency of 13% of TDN (NRC, 1996)

associated with prolamin degradation. In many references, the RUP content of corn silage is listed as 25% of CP, which is likely overestimated and can affect diet formulation in high corn silage diets. In addition, previous research suggests only 50% of the RUP in corn silage is digestible. Combined, the digestible RUP content of silage is quite low, suggesting both RDP and RUP supplementation is necessary in corn silage-based diets.

## Conclusion

The RUP content of corn silage is reduced as time spent in storage increases. Analyzing the forage and grain components separately resulted in an estimate of 16% of CP as RUP, of which 50% is estimated to be digestible. Corn silage is low in CP and RDP relative to fermentable energy and supplementation of RDP in corn silage-based diets improves digestion.

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**Table 4. Main effect of ensiling time on rumen undegradable protein (RUP) content of forage and corn components of corn silage in Exp. 2**

| | Ensiling time, d | | | | | | Contrast[1] | | |
|---|---|---|---|---|---|---|---|---|---|
| Item | 0 | 32 | 75 | 96 | 160 | SEM | Linear | Quad | Cubic |
| *Whole Silage* | | | | | | | | | |
| DM | 39.04 | 39.82 | 39.10 | 39.30 | 36.20 | - | - | - | - |
| CP, %DM | 8.57 | 9.20 | 8.72 | 8.96 | 9.35 | - | - | - | - |
| RUP, %CP[2] | 31.97 | 16.80 | 19.91 | 15.73 | 17.11 | - | - | - | - |
| *Forage*[3] | | | | | | | | | |
| CP, %DM | 7.92 | 8.79 | 8.67 | 7.06 | 8.33 | - | - | - | - |
| RUP, %CP | 20.28 | 17.81 | 19.00 | 21.49 | 18.06 | 2.19 | 0.44 | 0.28 | <0.01 |
| *Corn*[4] | | | | | | | | | |
| CP, %DM[5] | 8.57 | 9.20 | 8.72 | 8.96 | 9.35 | - | - | - | - |
| RUP, %CP | 43.65 | 15.79 | 10.82 | 9.96 | 16.15 | 2.55 | <0.01 | <0.01 | <0.01 |

[1]Orthogonal contrasts calculated for unevenly spaced treatments

[2]Estimated as the average of RUP content for the forage and grain components assuming whole silage is 50% corn grain and 50% forage from stover with similar amounts of CP

[3]Forage component of corn silage after being separated from grain in water

[4]Corn grain component of corn silage after being separated from forage in water

[5]Corrected to match the CP of the whole corn silage. Measured CP of corn after washing in water averaged 4.01% of DM due to soluble protein loss in water.

# Interaction of Urea with Frequency and Amount of Distillers Grains Supplementation for Growing Steers

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## Summary with Implications

*A study was conducted to determine the interaction of urea with the frequency and amount of distillers grain supplementation for growing steers consuming forage. Steers were individually fed for 84 d and received ad libitum grass hay and 1 of 8 treatments. Treatment design was a 2 × 2 × 2 factorial. Supplement was fed either every day or 3x/week, amount of supplement fed was 13.99 lb/week or 28.00 lb/week, and contained either no urea or 1.3% urea. Supplementation frequency and the inclusion of urea did not impact steer average daily gain. The amount of supplement did impacted steer average daily gain and hay intake as those receiving more supplement had greater gains but consumed less hay. Urea had no significant effect on hay intake. These results suggest that a dried distillers grain supplement can be fed infrequently to growing steers on a high forage diet without reducing animal performance.*

## Introduction

Reducing frequency of supplementation can reduce labor costs in backgrounding cattle operations. Dried distillers grains (DDG) is a popular supplement choice for growing cattle on forage-based diets due to its cost, availability, and nutrient content. However, previous work done at the University of Nebraska observed that infrequent supplementation of DDG reduced steer ADG by 10% (*2003 Nebraska Beef Cattle Report*, pp 8–10). The protein content of DDG is high in rumen undegradable protein but low in rumen degradable protein (RDP). In the case of low-quality forage-based diets, RDP is often limiting. However, because of the ability of the ruminant to recycle nitrogen from excess metabolizable protein to the rumen, the addition of an RDP source to a DDG supplement does not improve performance in daily supplemented cattle (*2004 Nebraska Beef Cattle Report*, pp 20–21). In the case of infrequent supplementation, the N recycling mechanism could lag between the supply of N and the demand for N in the rumen required to optimize rumen fermentation. This would reduce fiber utilization and subsequent animal performance. Therefore, it was hypothesized that the addition of urea to a DDGS supplement would immediately contribute to rumen available nitrogen if the animals' nitrogen recycling system could not match microbial demands due to an infrequent supplementation pattern. By supplying urea at the time of supplementation, this could overcome the potential RDP deficiency limiting forage digestibility and subsequent animal performance. The objective of the study was to determine the interaction of the inclusion of urea with a dried distillers grains supplement fed at either a low or high amount, and either daily or 3 times per week.

## Procedure

One hundred and twenty crossbred steers (543 lb; SD = 44) were fed one of eight treatments for 84 days. There were two turns, or replications, of 60 steers through the same barn, turn one was conducted November through February, and turn two was March through June. There was a total of 15 animals per treatment. To try and balance the treatments across the whole experiment, if there were 7 animals assigned to treatment in turn one, then 8 animals were assigned to that treatment in turn two, and vice versa. Animals were blocked by turn then stratified by body weight within turn and assigned randomly to treatment. Treatment design was a 2 × 2 × 2 factorial. Factors included frequency of supplementation, amount of supplementation, and inclusion of urea. Supplement was fed either every day (D) or 3x/week (ALT), amount of supplement fed was 13.99 lb/week (LO) or 28.00 lb/week (HI) and contained either no urea (-U) or 1.3% urea (+U). Steers on the D LO and D HI treatments received 2.00 lb/d and 4.00 lb/d, respectively. Steers on the ALT LO and ALT HI received 4.66 lb and 9.33 lb, respectively, on each Monday, Wednesday, and Friday. Steers were fed individually in a Calan gate system and received ad libitum grass hay (6.8% CP). Body weights were measured for three consecutive days following a five-day limit feeding period at the start and end of the trial. Cattle were implanted prior to the start of trial with zeranol. Amount of hay offered was recorded daily and refusals were collected weekly. To ensure total consumption of supplement and ad libitum hay intake, hay was not fed until 5 hours post-supplement feeding. Weekly orts were dried with forced air at 60°C for 48 h to measure dry matter. Data were analyzed using the MIXED Procedure of SAS (SAS Inst. Inc., Cary, NC). Four animals were removed from the analysis, 2 due to death, 1 due to chronic illness, and the other was a bull. Animal served as the experimental unit. The model was first analyzed with an interaction of turn and treatment. However, this interaction was not significant and was removed from the model. The model included amount of supplementation, frequency of supplementation, inclusion of urea, and all factorial interactions. There were no significant ($P > 0.05$) factorial interactions so only the main effects are reported.

## Results

Ending body weight did not differ between D and ALT treatments, nor +U and -U ($P \geq 0.56$; Table 1). However, ending BW was greater for HI compared to LO steers, 702 lb and 645 lb, respectively ($P < 0.01$) Average daily gain was 0.66 lb/d greater for steers receiving a HI amount of supplement than LO, ($P < 0.01$). Frequency and urea

**Table 1. Performance of steers fed steers fed distillers grains supplement either daily (D) or alternate days (ALT), at a high (HI) or low (LO) amount, and with (+U) or without (-U) the inclusion of urea**

| | Treatment | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Freq[1] | | Amt[2] | | Urea[3] | | | *P*-value | | |
| | D | ALT | LO | HI | -U | +U | SEM | Freq | Amt | Urea |
| Initial BW, lb | 543 | 543 | 543 | 543 | 543 | 543 | 1.80 | 0.86 | 0.72 | 0.87 |
| Final BW, lb | 675 | 671 | 645 | 702 | 673 | 673 | 2.30 | 0.56 | <0.01 | 0.99 |
| ADG, lb/d | 1.58 | 1.52 | 1.21 | 1.87 | 1.54 | 1.54 | 0.01 | 0.20 | <0.01 | 0.82 |
| Hay DMI, lb/d | 13.33 | 12.14 | 13.18 | 12.32 | 12.96 | 12.54 | 0.12 | <0.01 | <0.01 | 0.25 |

[1] D = daily, ALT = every other day

[2] LO = 0.4% of body weight, HI = 0.8% of body weight

[3] +U = inclusion of urea at 1.3% of supplement DM, -U = no inclusion of urea

inclusion did not affect steer ADG ($P \geq 0.20$). Hay dry matter intake was reduced by 0.86 lb/d for steers on the HI treatment compared to the LO ($P < 0.01$). Additionally, frequency of supplementation reduced hay dry matter intake. Steers receiving ALT supplementation consumed 12.14 lb/d of hay while D steers consumed 13.33 lb/d ($P < 0.01$). Urea inclusion had no effect on hay DMI ($P = 0.25$)

## Conclusion

Animal performance was not impacted by the addition of urea, suggesting that N recycling was adequate for rumen function. However, in contrast to previous work, reducing supplementation frequency of DDG did not reduce steer gains. The results of these studies suggest that a DDGS supplement with a lower fat content can be fed infrequently to growing steers on a high forage diet with no reduction in performance and urea is not required when supplementing DDGS at 0.4% of body weight.

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# Interaction of Urea with Frequency and Amount of Distillers Grains Supplementation on Growing Steer Rumen Digestion Parameters

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## Summary with Implications

*Ruminally cannulated steers were used in 8 × 6 row-column design with 8 animals and 6 periods. Treatment design was a 2 × 2 × 2 factorial, with factors including amount of supplementation, frequency of supplementation, and inclusion of urea. Hay dry matter intake was reduced by increased amount of supplementation and by decreased frequency of supplementation. Total VFA concentration did not differ among treatments. Rumen ammonia-N concentration was impacted by an interaction of amount of supplementation and inclusion of urea but there was no effect of supplementation frequency. In situ NDF disappearance did not differ between daily and alternate day supplemented animals. These results suggest there is no difference in rumen digestion parameters between daily and alternate day supplementation, and the inclusion of urea to a DDG supplement does not improve digestion parameters of a forage based diet.*

## Introduction

Reducing the frequency of supplementation has been one method utilized by cattle producers to reduce labor and costs on a backgrounding operation. However, infrequent supplementation of certain supplements, such as dried distillers grains, has been observed to cause a decrease in animal performance (*2003 Nebraska Beef Cattle Report*, pp 8–10). One hypothesis for this response is that there is a lag in the N recycling mechanism when dried distillers grains (DDG) is fed infrequently. In low-quality forage-based diets, rumen degradable protein (RDP) is often the limiting nutrient. Due to the ability of the ruminant to recycle excess nitrogen, even in the case of DDG supplementation RDP is often sufficient for rumen digestion, as the inclusion of RDP has not improved performance in daily DDG supplemented cattle (*2004 Nebraska Beef Cattle Report*, pp 20–21). Yet, this mechanism could be impacted by infrequent supplementation, resulting in a lag between the supply of N to the rumen and the demand of N required to optimize rumen fermentation. It was hypothesized the inclusion of urea, an RDP source, to a DDGS supplement would immediately contribute to rumen available nitrogen if the animals' nitrogen recycling system could not match rumen microbial demands due to infrequent supplementation. The objective of the study was to determine the interaction of the inclusion of urea with a dried distillers grains supplement fed at either a low or high amount, and supplemented either daily or on alternative days, on growing steer rumen digestion parameters.



## Procedure

Eight ruminally cannulated crossbred steers (682 lb, SD = 55) were used in an 8 × 6 row-column design with 8 steers and 6 periods to determine effects of inclusion of urea with the frequency and amount of distillers grain supplementation on rumen digestion parameters. Treatment design was a 2 × 2 × 2 factorial, with factors including amount of supplementation, frequency of supplementation, and inclusion of urea. Steers received supplement at 2.8% **(LO)** or 5.6% **(HI)** of BW per week (0.4 and 0.8% of BW per day, respectively). Supplement amount was split into feedings, either every day **(D)** or every other day **(ALT)**. Urea was included at 0% **(-U)** or 1.3% **(+U)** of the supplement's dry matter. Supplement was fed at 0700 h immediately followed by hay. Brome grass hay (11.5% CP) was fed to attain ad libitum intake. To ensure hay intake was not limited, hay orts were removed and weighed daily. Adjustments to the amount of hay offered were made depending on refusal amount. Periods were 14 d, with 7 d for adaptation and 7 d for collections. Steers on the ALT treatment received supplement for a total of 7 d during the period (d 2, 4, 6, 8, 10, 12, 14). Hay orts during the collection period were subsampled and dried in a forced air oven at 60°C for 48 h to measure dry matter intake **(DMI)**. All animals consumed all supplement offered within 6 h so no supplement orts were collected. The same hay that was fed during the trial was also utilized for in situ incubations. Three in situ bags per time point were placed in a mesh laundry bag with a weight. Bags were inserted in the rumen through cannula at 0700 h then incubated for 4, 8, 12, 24 and 96 h. To determine if there were potential differences in rumen fermentation between days steers received supplement and days they did not, animals on the ALT treatment had two sets of in situ incubations; one on the day of feeding (d 10, 11), and a second on the subsequent non-supplemented day (d 11, 12). However, only one 96 h in situ incubation was conducted, removed on d 14. Animals on the D treatment had one set of in situ incubations, the same day the ALT animals had their supplemented day collections (d 10, 11). Rumen fluid was collected at 2, 4, 8, 12, 16, and 24 h post-feeding to analyze rumen ammonia-N and VFA concentration. Similar to in situ incubations, animals on the ALT treatment had two sets of collections, one on supplemented day (d 12) and not supplemented (d 13). Daily supplemented animals had rumen fluid collected on d 12. To best understand the impacts of frequency, two different data sets were analyzed. One set compared D to ALT, in which values for each measurement for ALT treatments were averaged across all collection days. The other set compared alternate fed **(ALT-F)** to alternate not fed **(ALT-NF)**, in which only the ALT treatments were analyzed but values were averaged for the collection days steers received

**Table 1. Hay intake of steers fed distillers grains supplement either daily (D) or alternate days (ALT), at a high (HI) or low (LO) amount, and with (+U) or without (-U) the inclusion of urea during digestion trial**

| | Treatment | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Freq[1] | | Amt[2] | | Urea[3] | | | *P*-value | | |
| | D | ALT | LO | HI | -U | +U | SEM | Freq | Amt | Urea |
| Hay DMI, lb/d | 13.95 | 12.91 | 14.52 | 12.34 | 13.17 | 13.68 | 1.28 | <0.01 | <0.01 | 0.21 |

[1] D = daily, ALT = every other day

[2] LO = 0.4% of body weight, HI = 0.8% of body weight

[3] +U = inclusion of urea at 1.3% of supplement DM, -U = no inclusion of urea

**Table 2. In Situ NDF Disappearance for steers fed distillers grains supplement either daily (D) or alternate days (ALT), and at a high (HI) or low (LO) amount**

| | Treatment | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | D | | Alt | | | *P*-Value | | |
| | Hi | LO | Hi | Lo | SEM | Freq[1] | Amt[2] | Interaction |
| Washout Fraction | 0.25 | -0.05 | -0.08 | 0.12 | 0.12 | 0.82 | 0.90 | 0.51 |
| Potentially Digestible Fraction, % | 49.6 | 51.5 | 49.1 | 50.2 | 0.90 | 0.12 | 0.36 | 0.66 |
| Rate, %/h | 4.19[b] | 5.22[a] | 4.19[b] | 4.23[b] | 0.24 | 0.06 | 0.03 | 0.05 |

[a,b] Within a row, common superscripts indicate no significant difference between means, $P > 0.05$

[1] D = daily, ALT = every other day

[2] LO = 0.4% of body weight, HI = 0.8% of body weight

**Table 3. In Situ NDF Disappearance for steers fed distillers grains supplement on alternative days comparing day fed (ALT-F) to day not fed (ALT-NF), and at a high (HI) or low amount (LO)**

| | Treatment | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | ALT-F | | ALT-NF | | | P-Value | | |
| | Hi | Lo | Hi | Lo | SEM | Day Fed[1] | Amt[2] | Interaction |
| Washout Fraction | -0.5 | -0.2 | 0.4 | 0.5 | 0.7 | 0.44 | 0.63 | 0.91 |
| Potentially Digestible Fraction, % | 51.2 | 49.4 | 51.8 | 51.0 | 1.2 | 0.31 | 0.34 | 0.62 |
| Rate of NDF Digestibility, %/h | 3.76[b] | 4.72[a] | 4.63[b] | 3.75[b] | 0.43 | 0.89 | 0.92 | <0.01 |

[a,b] Within a row, common superscripts indicate no significant difference between means, P > 0.05

[1] ALT-F = fed, ALT-NF = not fed

[2] LO = 0.4% of body weight, HI = 0.8% of body weight

supplement, and the collection days they did not. The model for the D vs ALT data set included amount of supplementation, frequency of supplementation, inclusion of urea, and all factorial interactions. The ALT-F vs ALT-NF model included amount of supplementation, feeding of supplementation, inclusion of urea, and all factorial interactions. Time post feeding was also included in both models for those variables analyzed as repeated measures. Interactions that were not significant ($P < 0.05$) were removed from the models. Rumen ammonia-N and VFA data were analyzed using repeated measures over time. For DMI, rumination, and in situ NDF disappearance rate, data were analyzed using the MIXED Procedure of SAS (SAS Inst. Inc., Cary, NC). To determine the in situ degradation ratio, the NCIN Procedure of SAS with the Marquardt degradation model was used.

## Results

Hay intake was impacted by both amount and frequency of supplementation ($P < 0.01$; Table 1). High amount of supplement reduced hay DMI by 2.19 lb/d compared to LO, and ALT reduced hay DMI by 1.03 lb/d compared to D. Urea inclusion had no significant effect on hay DMI ($P = 0.21$).

For in situ NDF disappearance, there were no significant three-way interactions for D vs ALT treatments or ALT-F vs ALT-NF treatments ($P > 0.05$). There were also no significant differences in the washout fraction, or the potentially digestible fraction in either data set (Table 2). For the D vs ALT comparison, there was an interaction of frequency × amount ($P = 0.05$) for rate of NDF disappearance. Treatment D LO had a faster rate of NDF disappearance than D HI, ALT HI, and ALT LO (Table 2). For the ALT-F vs ALT-NF comparison, there was an interaction of feeding amount ($P < 0.01$; Table 3). Rate of NDF disappearance was greater for ALT-F LO and ALT-NF HIGH than ALT-F HI and ALT-NF LO ($P < 0.01$). If RDP was limiting for forage digestion, one would expect an improvement in NDF digestibility for treatments with urea. However, that was not observed in this data.

In the D vs ALT data set for rumen ammonia-N concentration, there was a significant interaction of amount × urea ($P < 0.01$; Table 4). Treatment HI +U had the greatest

**Table 4. Ruminal Ammonia-N concentration for steers fed distillers grains supplement either daily (D) or alternate days (ALT), at a high (HI) or low (LO) amount, and with (+U) or without (-U) the inclusion of urea**

| | Treatment | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Hi | | Lo | | | *P*-Value | | |
| | +U | -U | +U | -U | SEM | Amt[1] | Urea[2] | Interaction |
| Ammonia-N, mg/dL | 8.05[a] | 5.00[b] | 5.01[b] | 3.60[c] | 0.325 | <0.01 | <0.01 | <0.01 |

[a,b] Within a row, common superscripts indicate no significant difference between means, $P > 0.05$

Time interaction ($P < 0.01$), data not shown

[1] LO = 0.4% of body weight, HI = 0.8% of body weight

[2]+U = inclusion of urea at 1.3% of supplement DM, -U = no inclusion of urea

**Table 5. Ruminal Ammonia-N concentration for steers fed distillers grains supplement on alternative days comparing day fed (ALT-F) to day not fed (ALT-NF), at a high (HI) or low amount (LO), and with (+U) or without (-U) the inclusion of urea**

| | Treatment | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ALT-F | | | | ALT-NF | | | | | | | | |
| | Hi | | Lo | | Hi | | Lo | | | P-Value | | | |
| | +U | -U | +U | -U | +U | -U | +U | -U | SEM | Day Fed | Amt | Urea | Day Fed × Urea |
| Ammonia-N, mg/dL | 10.56[a] | 4.89[c] | 5.63[b] | 3.58[c] | 5.13[b,c] | 4.49[b,c] | 4.17[c] | 3.78[c] | 0.489 | <0.01 | <0.01 | <0.01 | <0.01 |

[a,b] Within a row, common superscripts indicate no significant difference between means, P > 0.05

[1] ALT-F = fed, ALT-NF = not fed

[2] LO = 0.4% of body weight, HI = 0.8% of body weight

[3] +U = inclusion of urea at 1.3% of supplement DM, -U = no inclusion of urea

**Table 6. Ruminal VFA concentration for steers fed distillers grains supplement either daily (D) or alternate days (ALT), at a high (HI) or low (LO) amount, and with (+U) or without (-U) the inclusion of urea**

| | Treatment | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D | | | | Alt | | | | | P-Value | | | |
| | Hi | | Lo | | Hi | | Lo | | | | | | 3-way |
| | +U | -U | +U | -U | +U | -U | +U | -U | SEM | Freq[1] | Amt[2] | Urea[3] | Interaction |
| Acetate, % | 64.2 | 64.7 | 65.7 | 66.9 | 67.5 | 65.3 | 69.2 | 68.1 | 0.09 | <0.01 | <0.01 | 0.52 | 0.89 |
| Butyrate, % | 11.1 | 11.0 | 9.73 | 10.0 | 8.98 | 9.87 | 8.80 | 9.34 | 0.04 | <0.01 | 0.02 | 0.46 | 0.94 |
| Propionate, % | 22.4 | 21.2 | 21.2 | 20.1 | 21.4 | 21.8 | 20.2 | 20.1 | 0.05 | 0.28 | <0.01 | 0.22 | 0.58 |
| A:P ratio[1] | 2.94 | 3.12 | 3.19 | 3.37 | 3.24 | 3.07 | 3.51 | 3.47 | 0.10 | 0.02 | <0.01 | 0.64 | 0.65 |

Freq × Urea interaction ($P < 0.05$). Urea did not affect A:P for D, but tended to reduce A:P for ALT $P < 0.08$

[1] D = daily, ALT = every other day

[2] LO = 0.4% of body weight, HI = 0.8% of body weight

[3] +U = inclusion of urea at 1.3% of supplement DM, -U = no inclusion of urea

average ruminal ammonia concentration. There was also a significant amount × urea × time interaction ($P < 0.01$). For all treatments, ruminal ammonia-N concentration was greatest 2 h post-feeding and decreased from 4 h post-feeding to 16 h post-feeding. Ammonia-N concentrations reached their lowest at 16 h post feeding for all treatments. None of these treatments reached a ruminal ammonia-N concentration below 2 mg/dL. Concentrations were then increased at 24 h post-feeding for all treatments. In the ALT-F vs ALT-NF data set, there was a significant interaction of feeding × amount × urea ($P < 0.01$; Table 5). Steers on the HIGH +U treatment on the day they were fed, had the greatest ruminal ammonia-N concentration. A ruminal ammonia-N concentration below 2 mg/dL is the value stated at which fibrolytic bacteria growth is inhibited. Thus, none of the treatments reaching a concentration below this would suggest that ruminal available nitrogen pool was not limiting for fiber digestion.

Ruminal VFA concentrations for the D vs ALT comparison, had no significant three-way interactions ($P \geq 0.58$; Table 6). For both acetate and butyrate, the main effects of frequency and amount were significant ($P \leq 0.02$). However, only the main effect of amount was significant for propionate ($P < 0.01$). Alternate day supplementation animals had greater concentration of acetate compared to D, but lesser concentrations of butyrate. Steers supplemented a HI amount of supplement had increased concentrations of propionate and butyrate but decreased concentration of acetate compared with the LO supplemented steers. This resulted in HI steers having a lower A:P ratio than LO steers ($P < 0.01$). This result would be expected as HI steers con-

**Table 7. Ruminal VFA concentration for steers fed distillers grains supplement on alternative days comparing day fed (ALT-F) to day not fed (ALT-NF), at a high (HI) or low amount (LO), and with (+U) or without (-U) the inclusion of urea**

| | Treatment | | | | | | | | | P-Value | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ALT-F | | | | ALT-NF | | | | | | | | 3-way |
| | Hi | | Lo | | Hi | | Lo | | | | | | |
| | +U | -U | +U | -U | +U | -U | +U | -U | SEM | Freq[1] | Amt[2] | Urea[3] | Interaction |
| Acetate, % | 65.1 | 62.4 | 67.1 | 65.1 | 70.0 | 68.1 | 71.0 | 71.0 | 0.08 | <0.01 | <0.01 | 0.02 | 0.59 |
| Butyrate[4], % | 10.3 | 11.7 | 9.91 | 10.6 | 7.62 | 7.91 | 8.21 | 7.71 | 0.03 | <0.01 | 0.26 | <0.01 | 0.07 |
| Propionate, % | 23.2 | 23.1 | 21.4 | 22.1 | 19.5 | 20.0 | 19.0 | 18.4 | 0.05 | <0.01 | <0.01 | 0.68 | 0.03 |
| A:P ratio | 2.88 | 2.73 | 3.18 | 3.08 | 3.60 | 3.46 | 3.84 | 3.90 | 0.10 | <0.01 | <0.01 | 0.32 | 0.41 |

[1] ALT-F = fed, ALT-NF = not fed

[2] LO = 0.4% of body weight, HI = 0.8% of body weight

[3] +U = inclusion of urea at 1.3% of supplement DM, -U = no inclusion of urea

[4]Freq × Amt interaction ($P$ <0.01). Butyrate concentrations were not affected by amount of supplement on days when supplement was not fed ($P$ > 0.47), but HI supplement resulted in greater butyrate concentration than LO on days when supplement was fed ($P$ < 0.01).

Freq × Urea interaction ($P$ <0.05). Butyrate concentrations were not affected by urea on days when supplement was not fed ($P$ > 0.14), but urea decreased butyrate concentration on the day supplement was fed ($P$ < 0.01).

sumed less forage than LO. In the ALT-F vs ALT-NF data set, a feeding × amount interaction ($P$ < 0.01) and feeding × urea interaction ($P$ < 0.05) were observed (Table 7). Acetate and propionate concentrations were affected by both feeding and amount. On the day not supplemented, steers had increased concentration of acetate, but decreased concentration of propionate and butyrate ($P$ < 0.01). However, on the day steers were supplemented, concentrations of propionate and butyrate increased, but acetate concentration decreased ($P$ < 0.01). HI steers also had greater concentration of propionate compared to the LO steers, but lesser concentration of acetate ($P$ < 0.01). Again, these results would be expected given the hay intake data.

## Conclusion

Overall, rumen digestion parameters were not impacted by the inclusion of urea, suggesting that RDP was sufficient for rumen digestion, and there was not a lag in N recycling when supplementing DDG infrequently. The results of these studies suggest that a DDGS supplement can be fed every other day to growing steers on a high forage diet without impacting forage digestion.

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# Effect of Rapeseed Inclusion in Late-Summer Planted Oat Pasture on Growing Performance of Beef Steers

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### Summary with Implications

*An oat monoculture was planted in late summer at 100 lb/ac and compared to oats planted at 50 lb/ac with rapeseed included at 3 lb/ac. Seed cost of the oat monoculture ($20/ac) was greater than the mix ($15/ac). Initial forage yield was not affected by the inclusion of rapeseed with fall oat. Calf gain was significantly greater and cost of gain was significantly decreased when rapeseed was included due to the combination of greater gains and lesser seed cost. Including rapeseed in late summer planted oats may be beneficial for producers who want to graze growing calves in the fall.*

### Introduction

Cover crops planted after corn silage harvest, spring wheat, or hybrid seed corn harvest provide an opportunity for grazing calves or cows in late fall and into winter. Winter-sensitive annuals such as oats with or without brassicas such as turnips or rapeseed are commonly used in Nebraska. These species are highly digestible and thus considered high energy with only slight decreases in digestibility throughout the winter (*2018 Nebraska Beef Cattle Report*, pp. 60–62). Crude protein (CP) content of late-summer planted oats and brassicas remains relatively constant throughout the winter grazing period. Fall grazing an oat monoculture planted after corn silage harvest resulted in average daily gain (ADG) of 2.35 lb/d (*2020 Nebraska Beef Cattle Report*, pp. 35–37). In a different study, fall grazing of an oat-brassica mix resulted in ADG of 2.25 lb/d (*2016 Nebraska Beef Cattle Report*, pp. 55–57). However, direct comparisons of oat monocultures to oat-brassica mixes have not been conducted. The extremely high digestibility of brassicas (87 % IVOMD) likens them to a concentrate and would be expected to increase the energy content of the diet. Brassicas also contain elevated protein (22% CP) content (*2018 Nebraska Beef Cattle Report*, pp. 60–62). Therefore, inclusion of rapeseed into a late fall and winter grazing system may improve calf gain compared to grazing oats, while also decreasing cost of gain due to lower cost per acre for seeding rapeseed. The objective of this study was to evaluate the inclusion of a brassica (rapeseed) with late summer planted oats and the effect on forage yield, forage quality, and calf gain. It was hypothesized that forage yield of the oats-rapeseed mix would be similar to the oats monoculture and that growing calf performance and cost of gain would be improved by inclusion of rapeseed.



### Procedure

This 3-year study was conducted at the US Meat Animal Research Center near Clay Center, Nebraska. An initial report of the first 2 years of this study was previously published (*2019 Nebraska Beef Cattle Report*, pp. 40–41). Following corn silage harvest or alfalfa termination, 5 irrigated pivots were divided into four quarters and planted. Pivots were identified as 33A in year one, 23C and 24D in year two, and 32B and 34A in year three. Of the pivots previously described, 33A and 24D followed alfalfa termination while the other 3 pivots followed corn silage harvest. Two quarters from each pivot were planted with 100 lb/ac oat seed (*Avena sativa*; OAT) while the other two quarters were planted with 50 lb/ac oat seed and 3 lb/ac rapeseed (*Brassica napus*; MIX). Nitrogen (N) was applied via pivot to 23C and 24D in year 2 (15.6 and 31.4 lbs of N/ac, respectively) and to 34A in year 3 (26.3 lbs of N/ac). Nitrogen was not applied to pivots that followed alfalfa termination.

Spring born cross-bred steers (n = 120, 240 and 240 in years 1, 2 and 3, respectively) were assigned to treatments based on weights taken prior to d 0. Steers were then weighed, sorted, and began grazing on d 1(initial BW 583 ± 4.9, 637 ± 11.7, and 516 ± 9.5 lbs in years 1, 2 and 3, respectively) Steers were turned out to graze on November 1 in year 1, November 13 in year 2, and November 9 in year 3. Grazing continued until forage appeared to be limiting in one quarter, with approximately 3 inches of growth remaining, upon which grazing ceased for all steers. Steers grazed until February 7 in year 1 (99 days), January 23 (71 days) in year 2 and January 19 (71 days) in year 3. Steers were removed from pivots and weighed on the same day and placed into the feedlot.

Forage quality and biomass samples were taken prior to grazing, monthly throughout the grazing period, and post grazing. Oat and rapeseed were clipped to ground level and immediately put on ice and froze for at least 24 hours before drying in a 60˚C oven. Samples were ground to a 1 mm particle size through a Wiley mill. Nutrient analysis was conducted to evaluate organic matter (OM, % of DM) and in-vitro organic matter digestibility (IVOMD, % of OM). Digestible organic matter (DOM) was used to express the actual amount of digestible energy of each treatment and to serve as a similar comparison to total digestible nutrients (TDN). Calculation for DOM was made by multiplying the OM% of the forage by the IVOMD.

A partial budget analysis was conducted to evaluate the establishment costs of each forage treatment. Average seed costs for OAT across years was $20.33/ac while cost of seed for MIX was $14.83. Average seeding and fencing costs for all pivots across years were $13.88/ac and $5/ac, respectively. Fertilizer amounts were different among pivots and were charged using N cost of $0.42 /lb N in year 2 and $0.40/lb

**Table 1. Forage yield, initial forage quality and for disappearance of a oat monoculture or a oat-rapeseed mix planted in late-summer and grazed from early November into January**

| Item | OAT | MIX | SEM | *P*-value |
|---|---|---|---|---|
| Yield, lbs DM/ac | | | | |
| Pre-grazing | 3119 | 3144 | 284 | 0.86 |
| Post grazing | 1415 | 1379 | 126 | 0.78 |
| Disappearance, lb/hd/d | 28.2 | 28.4 | 5.70 | 0.92 |
| Nutrient content, % of DM | | | | |
| OM | 86.4 | 86.0 | 0.55 | 0.16 |
| DOM[1] | 65.5[a] | 68.9[b] | 0.83 | <0.01 |

[1]DOM = digestible organic matter a proxy for total digestible nutrients. Calculated by multiplying IVOMD by the OM content of the forage

[a,b]Means with different superscripts differ ($P \leq 0.05$)

**Table 2. Steer performance during the grazing period**

| Item | OAT | MIX | SEM | *P*-value |
|---|---|---|---|---|
| IBW, lbs | 580 | 577 | 3.6 | 0.60 |
| EBW, lbs | 737 | 748 | 4.05 | 0.075 |
| ADG, lb/d | 1.93[a] | 2.10[b] | 0.053 | <0.01 |
| Cost of gain, $/lb | 0.54[a] | 0.46[b] | 0.039 | <0.01 |

[1]Abbreviations: IBW = initial body weight, EBW = ending body weight, ADG = average daily gain

[a,b]Means with different superscripts differ ($P \leq 0.05$)

[2]Cost of gain includes seed costs at $20.33 /ac for oats or $14.83/ac for mix, plus seeding costs at $13.88/ac, fertilizer $6.80/ac, irrigation $33.40/ac and fencing at $5/ac.

N in year 3. Irrigation costs and amounts were also different among pivots and were charged $8.92/acre-inch in years 1 and 2 and $9.39/acre-inch in year 3. Amount of water applied was 3.8, 2.6, and 4.6 inches/acre in years 1, 2, and 3, respectively. Total costs per acre were estimated to be $76.16/ac for OAT and $70.66/ac for MIX.

Performance and forage quality data were analyzed using the MIXED procedure of SAS (SAS Institute Inc., Cary, N.C.) as a completely randomized design with pivot quarter as the experimental unit. Year and treatment were included in the model as fixed effects and pivot as a random effect. Treatment differences were significant at $\alpha \leq 0.05$ and tendencies were discussed when $0.05 \leq \alpha \leq 0.10$. There were 2 replicates per treatment in year 1 and 4 replicates per treatment in years 2 and 3.

## Results

With the exception of post-grazing biomass, no interactions between treatment and year were observed. Initial yield prior to the start of grazing did not differ ($P = 0.86$; Table 1) among the OAT and MIX, nor was an effect of year observed ($P = 0.17$). In the MIX, rapeseed represented 25.4% of initial biomass on a dry matter (DM) basis. No significant differences were observed for post grazing yield ($P = 0.78$) although a significant difference was observed for effect of year ($P < 0.01$). A tendency for an interaction between treatment and year was observed ($P = 0.07$) for post grazing which is due to there being no differences among treatment in year 1 and 2, but a tendency ($P = 0.06$) for MIX to be greater than OAT in year 3, with yields of 1518 and 1123 lbs/ac, respectively.

No differences ($P = 0.83$) were observed between MIX and OAT for forage disappearance, at approximately 28 lbs of DM/hd/d. This disappearance rate would equate to 4.8% of BW, suggesting that significant trampling losses occurred as it is unlikely that cattle consumed more than 50 to 60% of what disappeared. There were no differences in disappearance among years ($P = 0.14$).

There were no differences ($P = 0.16$) in initial OM content of the forage, however a greater ($P < 0.01$) initial DOM was observed for MIX, suggesting that the mix could offer the potential for greater energy intake.

Average daily gain (ADG) was greater ($P < 0.01$) for MIX than OAT, with MIX steers gaining 0.17 lb/d greater than OAT, although both would be considered moderate to high gains (Table 2). A year effect ($P < 0.01$) was observed for ADG, with the low being 1.86 lb/d and the high being 2.2 lb/d. Cost of gain decreased significantly ($P < 0.01$) for MIX steers, being $0.08 lower per pound of gain. Again, this is due to not only a greater gain for MIX, but also to a lower seed cost.

## Conclusion

Inclusion of rapeseed at 3 lb/ac with 50 lb/ac of oat seed in late summer produced yield in November that was similar to an oat monoculture planted at 100 lb/ac. The higher digestibility of rapeseed yields a more energy-dense cover crop when planted with oats in late summer. Greater ADG and a decreased cost of gain were observed for steers grazing MIX, suggesting that inclusion of rapeseed into late-summer planted oats is a viable option for producers wanting to economically achieve calf gain during the fall and winter grazing period.

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# Economics of Grazing Calves on Oats Planted After Corn Silage in Eastern Nebraska

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## Summary and Implications

*A five-year study (2015–2019) evaluated profitability of planting and grazing an oats cover crop after early harvested corn silage in eastern Nebraska. Oats were typically planted in the first week of September. Stocking rate ranged from 1.7 to 0.6 steers per acre and was based on oats biomass. Calves were turned out in early November each year and allowed to graze until oats biomass or weather limited intake. Grazing period ranged from 30 to 69 days. Average daily gain of calves ranged from 3.35 to 1.29 pounds with an average of 1.97 pounds. Shortened grazing seasons in some years were due to ice or excessive trampling losses which resulted in higher forage expenses per day and calves being sold prior to the usual market uptick in January which reduced profitability. However, the system was profitable four out of five years.*

## Introduction

Early corn silage harvest leaves behind bare ground in addition to unused growing degree days in the season. Growing degree days are heat units that are used in determining plant growth and maturity. A cover crop planted after corn silage harvest provides ground cover, weed suppression, and decreased soil erosion, while utilizing GDD. While cover crops offer potential soil benefits, producers may choose not to use them due to the expense of establishment. Additionally, fear of decreased subsequent crop yields may also cause producers to be wary. However, forage resources can be increased, and grazing season extended by the cover crop. The additional forage and potential calf weight gain provided by fall grazing may provide economic incentive to plant cover crops after early harvested corn silage. Late summer planted oats can provide a high-quality forage that do not over winter and thus do not require spring management. They also produce more fall biomass than winter-hardy species such as rye. Producers weaning calves in the fall or feedlots looking to purchase calves at a low cost in the fall can potentially utilize late summer planted oats for fall/winter grazing. The objective of this study was to evaluate the economics of planting oats after early corn silage harvest and grazing weaned calves.



## Procedure

A five-year study was conducted on a 104-acre irrigated, no-till, field enrolled in a corn and soybean rotation at the Eastern Nebraska Research and Extension Center (ENREC) near Mead, Nebraska. Half the field was planted to corn and the other half in soybeans. Within the half planted to corn, one half was harvested as high moisture corn and the other half as corn silage. The effects of planting oats and effects of grazing the oats after high moisture corn harvest or corn silage during the first 4 years of the trial has previously been reported (2020 *Nebraska Beef Cattle Report*, pp. 35–37). Planting and grazing oats after high moisture corn or corn silage did not impact subsequent yields. The amount of oat forage produced after high moisture corn was minimal, resulting in less desirable cattle gains than corn silage. This current report summarizes the variation in oat yield, animal performance, and economics of planting and grazing oats after corn silage harvest.

Corn silage harvest occurred each year around September 1st with the planting of an oat-monoculture following soon afterwards. Planting dates were September 1st, September 6th, September 7th, August 29th, and September 5th, for 2015, 2016, 2017, and 2019, respectively. In 2018, oats experienced limited emergence and were therefore replanted in mid-September. Horsepower oats were planted using a no-till drill at 96 lb/ac with 7.5-inch row spacing. Oats also received urea fertilizer to deliver 40 lb/ac of nitrogen before or during oats planting.

The area to be grazed was divided into 2 paddocks (~11.5 acres each) and oats forage were hand-harvested from 5 locations (36 x 22.5 in) in each paddock in late October at ground level and dried at 60°C to determine dry matter (DM) yield/ac and determine stocking rate. With the exception of 2015, post-grazing oats biomass samples were collected in the same manner after the grazing period ended. Oats disappearance was then determined for 2016, 2017, 2018, and 2019 using pre-graze minus post-grazing oats biomass divided by the number of steers divided by number of grazing days.

Oat quality samples were also collected in late-October. Forage samples were cut at ground level from random locations (~20) within each paddock. These samples were freeze dried and analyzed for organic matter (OM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), in-vitro organic matter digestibility (IVOMD), and digestible organic matter (DOM).

Growing steers (485 ± 18 lb) were stocked according to available initial forage biomass in paddocks and targeting a 70-day grazing period. Forage allotments in the initial years (2015 and 2016) were approximately 25.5 lb DM/hd/day. Later years (2017, 2018, and 2019) forage allotments were increased to 39 lb DM/hd/day of oats biomass to increase chances of a 70-day grazing period. Stocking rates were 1.7, 1.3, 0.9, 0.7, and 0.6 hd/ac for 2015, 2016, 2017, 2018, and 2019, respectively. Random-

**Table 1. Biomass of oats planted after corn silage harvest and sampled in late October before grazing (pre-graze) and again after grazing (post-graze) with growing steers.**

| | Year | | | | | | |
|---|---|---|---|---|---|---|---|
| Item | 2015 | 2016 | 2017 | 2018 | 2019 | SEM | *P-value* |
| Oat pre-graze biomass, (lb DM/ac) | 2857[a] | 2273[b] | 2401[b] | 1952[c] | 1535[d] | 76.0 | <0.01 |
| Oat post graze biomass, (lb DM/ac) | ND[2] | 1909[a] | 312[b] | 321[b] | 254[b] | 129 | <0.01 |
| Oat disappearance[1], (lb DM/steer/d) | ND[2] | 29.5[c] | 49.5[b] | 80.5[a] | 29.5[c] | 3.50 | <0.01 |

[1]Total amount of oats disappearance would include consumption, trampling losses, and weathering losses.

[2]Post graze biomass was not measured in 2015.

**Table 2. Weather conditions and number of grazing days of each year's grazing season.**

| | Year | | | | |
|---|---|---|---|---|---|
| Item | 2015 | 2016 | 2017 | 2018 | 2019 |
| Number of grazing days | 62 | 42 | 48 | 30 | 69 |
| Percentage of grazing days at or below 32° F | 39 | 31 | 19 | 60 | 45 |
| Percentage of grazing days with precipitation[1], % | 31 | 14 | 8 | 20 | 23 |
| Precipitation total for grazing period[2], inches | 6.4 | 1.2 | 0.5 | 1.9 | 4.3 |

[1]Percentage of total grazing days at or below freezing.

[2]Percentage of total grazing days in which precipitation was received

ly selected steers in each paddock were designated as testers and used to evaluate animal performance. Ten steers in 2015 and 2016, 5 steers in 2017 and 2018, and 6 steers in 2019 per paddock were designated as testers.

Before being turned out to graze, steers were limit fed a common diet of 50% Sweet Bran (Cargill Wet Milling; Blair, NE) and alfalfa hay for 5 days before being weighed for 3 successive days to establish initial body weight. Steers were implanted with 36 mg Zeranol (Ralgro, Merck Animal Health, Madison, NJ), stratified by body weight and assigned to paddock. Steers were turned out on their assigned grazing pastures in early November and allowed to graze until oat biomass or weather limited intake. After the grazing season, steers were pulled from pastures and returned to the feedlot. They were limit fed the same diet for 8 days and weighed during the last 3 days to determine final body weight.

A partial budget was constructed each year to determine system profitability. Costs of $23.50 per acre for oats seed, $17.00 per acre for custom drilling, $7.00 per acre custom fertilizer application and $4.40 per acre in fencing costs were charged in all five years. A 45% urea fertilizer was applied at 89 lb (40 lb of N) each year with the average cost of $0.11 per pound, resulting in a cost of $9.52 per acre. Expenses per acre were divided across the number of grazing steers that oats forage allowed each year causing expenses to vary with year. Additionally, $2.64 per steer was charged for transportation. Cattle interest was charged per steer at a 5% annual interest on the initial steer price. The number of days cattle were retained was considered when calculating total interest. In order to determine value of gain, animals were valued prior to and after grazing utilizing the Nebraska price reported by the USDA. Cattle gains and market values post-grazing were then compared back to the cost of CC establishment and the expenses associated with grazing cattle.

The MIXED procedure in SAS (SAS Institute, Inc., Cary, N.C.) was used to analyze the data with year as a fixed effect. There were two replicates (paddocks) per year that served as the experimental unit. The pdiff statement was used to separate means when the F-test was significant. Data was considered significant with $P \leq 0.05$.

## Results

Oats pre-graze biomass, oats post-graze biomass, and oats disappearance differed ($P < 0.01$) among years (Table 1). Average pre-graze yield was 2,448 lb DM/ac and there was almost a ton of DM per acre difference between the highest and lowest yielding years. Average post-graze biomass was 699 lb DM/ac. The post-graze biomass in 2016 was greater ($P < 0.01$) than all other years. This was caused by an ice storm forcing cattle to be removed from the oats early. Years 2017, 2018, and 2019 did not differ ($P > 0.71$) with an average of 296 lb DM/ac. Oats disappearance was greatest ($P < 0.01$) in 2018, intermediate in 2017 and lowest ($P < 0.03$) in 2016 and 2019 which did not differ ($P = 1.00$). A set of heavy precipitation events early in the 2018 grazing season caused muddy and wet conditions and likely increased cattle trampling. Weather conditions during grazing can be found in Table 2. The amount of pre-graze oats biomass did not appear to directly impact the number of grazing days achieved. Instead, weather (i.e., ice storm, precipitation that resulted in mud) appeared to be the greatest determining factor of grazing period length.

The oats quality including OM, NDF, ADF, IVOMD, and DOM varied among years ($P \leq 0.05$), while CP ($P = 0.35$) did not (Table 3). Overall, differences in nutritive content where minor among years, both digestibility (65% DOM) and protein content (17.8% CP) being excellent for forage.

Steer body weights, average daily gain (ADG), gain per acre, and animal grazing days per acre differed ($P \leq 0.02$) among years (Table 4). Overall, rate of gains

**Table 3. Forage nutritive value in late October of oats planted after corn silage harvest**

| | Year | | | | | | |
|---|---|---|---|---|---|---|---|
| Item[1] | 2015 | 2016 | 2017 | 2018 | 2019 | SEM | *P-value* |
| OM, % DM | 83.8$^{c}$ | 89.1$^{a}$ | 85.0$^{b}$ | 88.9$^{a}$ | 89.2$^{a}$ | 0.279 | <0.01 |
| NDF, % DM | 43.7$^{a}$ | 40.8$^{b}$ | 36.6$^{c}$ | 32.3$^{d}$ | 36.7$^{c}$ | 0.462 | <0.01 |
| ADF, % DM | 25.6$^{a}$ | 25.7$^{a}$ | 25.4$^{a}$ | 19.5$^{b}$ | 20.7$^{b}$ | 0.489 | 0.05 |
| CP, % DM | 18.1 | 19.2 | 17.1 | 18.6 | 15.8 | 1.51 | 0.35 |
| IVOMD, % DM | 78.4$^{c}$ | 80.4$^{b}$ | 78.5$^{c}$ | 89.4$^{a}$ | 88.1$^{a}$ | 0.503 | <0.01 |
| DOM, % DM | 59.8$^{c}$ | 63.3$^{b}$ | 60.6$^{bc}$ | 71.7$^{a}$ | 71.3$^{a}$ | 0.964 | <0.01 |

[1]ADF, acid detergent fiber, CP, crude protein, DOM, digestible organic matter, IVOMD, in-vitro dry matter digestibility, NDF, neutral detergent fiber, OM, organic matter.

**Table 4. Performance of growing steers grazing oats planted after corn silage**

| | Year | | | | | | |
|---|---|---|---|---|---|---|---|
| Item | 2015 | 2016 | 2017 | 2018 | 2019 | SEM | *P-value* |
| Initial body weight, lb | 467$^{c}$ | 502$^{a}$ | 462$^{c}$ | 506$^{a}$ | 487$^{b}$ | 2.09 | 0.02 |
| Ending body weight, lb | 547$^{b}$ | 694$^{a}$ | 626$^{a}$ | 545$^{b}$ | 592$^{a}$ | 8.03 | <0.01 |
| Average daily gain, lb/d | 1.29$^{c}$ | 2.41$^{b}$ | 3.35$^{a}$ | 1.29$^{c}$ | 1.53$^{c}$ | 0.180 | <0.01 |
| Animal grazing days[1], steer·d/acre | 92$^{a}$ | 47$^{b}$ | 38$^{c}$ | 18$^{d}$ | 35$^{c}$ | 1.35 | <0.01 |
| Gains per acre, lb/ac | 134$^{a}$ | 128$^{a}$ | 143$^{a}$ | 25$^{b}$ | 61$^{b}$ | 13.2 | 0.01 |

[1]Number of days of grazing x number of steers per acre.

**Table 5. Economic analysis of grazing growing steers in the fall on oats planted after corn silage harvest**

| | Year | | | | | | |
|---|---|---|---|---|---|---|---|
| Item | 2015 | 2016 | 2017 | 2018 | 2019 | SEM | *P-value* |
| Total cost per steer, $/steer | 41.42$^{e}$ | 50.70$^{d}$ | 72.76$^{c}$ | 95.74$^{b}$ | 112.44$^{a}$ | 2.31 | <0.01 |
| Cost of gain, $/lb | 0.52$^{b}$ | 0.50$^{b}$ | 0.46$^{b}$ | 2.56$^{a}$ | 1.05$^{b}$ | 0.245 | 0.01 |
| Value of gain, $/lb | 2.54$^{a}$ | 1.04$^{b}$ | 1.72$^{ab}$ | 2.25$^{a}$ | 2.45$^{a}$ | 0.285 | 0.06 |
| Return per steer, $/steer | 151.67$^{b}$ | 50.57$^{c}$ | 193.77$^{a}$ | -16.85$^{d}$ | 147.81$^{b}$ | 6.53 | <0.01 |

averaged 1.97 lb/d. In 2017, steers had the greatest ADG ($P \leq 0.02$). Daily gain in 2016 was greater ($P \leq 0.03$) than 2015, 2018, and 2019 which did not differ from one another. Weather seemed to be a major factor in rate of gain, as both 2016 and 2017 had relatively few grazing days with subfreezing temperatures and precipitation. The longer grazing period coupled with a higher stocking rate used, resulted in 2015 having the greatest ($P < 0.01$) number of animal grazing days per acre with almost double that of the next best year. Animal grazing days in 2016, 2017 and 2019 did not differ and were greater ($P < 0.01$) than 2018. However, gains per acre were greater in 2016 and 2017 than 2015. Gain per acre in 2016 and 2017 did not differ from one another ($P < 0.01$) while being greater ($P \leq 0.02$) than 2018 and 2019, which did not differ from one another.

Total cost, cost of gain, value of gain and total profit differed ($P \leq 0.01$) among years, while value of gain did not differ ($P = 0.06$) among years (Table 5). Total cost per steer was largely impacted by stocking rates, and the number of steers to which the forage production costs were distributed. All years differed from each other with 2019 being the greatest, followed closely by 2018, then 2017, followed by 2016 and 2015 having the least total cost per steer. However, the short grazing season coupled with low rate of gain resulted in cost of gain to be greatest in 2018 ($P < 0.01$) with all other years not differing ($P \geq 0.16$). Value of gain describes how market value changed over the grazing period, and the five-year average for value of gain was $2 per lb gained. Shortened grazing seasons resulted in cattle being sold in less desirable market conditions than when grazing was extended into January. Profit per steer was the greatest ($P \leq 0.01$) in 2017, followed by 2015 and 2019 which did not differ, but were greater than 2016, and profit per steer was lowest ($P < 0.01$) in 2018 which resulted in a loss. However, across the 5 years, average profit was $136/steer.

## Conclusion

In this study, the oats fall-grazing system proved to be profitable four out of five years with the average profit being approximately $136 per steer. Weather proved to have the strongest influence on system profitability as it impacted many other factors within the system (oats biomass, oats disappearance, animal performance, grazing period, and cattle market). Therefore, producers weaning calves in the fall or feedlots looking to purchase calves at a low cost in the fall can potentially utilize late summer planted oats for fall/winter grazing.

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# Evaluation of Models to Predict Dry Matter Intake of Forage Based Diets

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## Summary with Implications

*Dry matter intake (DMI) data from growing cattle experiments at the Eastern Nebraska Research and Extension Center were summarized in order to evaluate the accuracy of model predicted DMI. Cattle were fed individually (n = 78) or in pens (n = 15) and predicted DMI using the Beef Cattle Nutrient Requirements Model (BCNRM, 2016) was compared to observed DMI. The model over predicted DMI when total digestible nutrients (TDN) was less than 64%, under predicted DMI when dietary TDN was greater than 64%, and had a low accuracy, explaining less than 22% of the variation in DMI. An equation to predict DMI was developed using dietary neutral detergent fiber (NDF), energy (NEm), and calf shrunk body weight. The inclusion of dietary NDF concentration improved the prediction precision of DMI for growing cattle consuming low-energy, forage-based diets. Intake may be limited due to rumen fill as well as decreased passage rate from the high NDF concentration of the diets. Including the additional variable of dietary NDF could allow for more precise predictions of DMI and animal performance resulting in more accurate dietary formulations.*

## Introduction

The concept of modeling is to use previous data to create a tool that can predict dry matter intake (DMI), protein and energy requirements, along with performance of growing cattle. The current Beef Cattle Nutrient Requirements Model (BCNRM, 2016) equation for predicting DMI focuses on the use of dietary NEm concentration. The hypothesis was that the data used to build the current BCNRM was based primarily on studies consisting of medium- to high-energy growing or finishing diets, and these data were extrapolated to fit low-energy, high-forage diets. Thus, the objective was to evaluate the BCNRM's ability to predict DMI in low-energy, high-forage diets and to develop a more robust prediction equation for growing calves fed these diets in the western corn belt. These data are an update to the *2021 Nebraska Beef Cattle Report* (pp. 36–37).



## Procedure

All experiments were conducted at the Eastern Nebraska Research and Extension Center, near Mead, NE, utilizing similar protocols. In each experiment, cattle were individually fed or pen-fed. Individually fed calves used the Calan gate system with 6 to 24 replications per treatment. Pen-fed cattle had 8 to 12 head per pen with 4 to 8 replications per treatment. Overall, there were 93 treatment means with 78 of those being individually fed calves and 15 of those being pen-fed calves.

Treatment means were sorted into categories dependent on the type of forage that was fed. Originally there were 9 categories which were separated based on forage type and whether distillers grains (DG) or other corn byproducts were included in the diet. These categories included: (1) grass hay or sorghum silage-based diets without DG (controls), (2) controls + DG, (3) ensiled corn residue-based, (4) corn silage-based, (5) corn silage + DG, (6) dry corn residue, (7) reconstituted corn residue, (8) corn residue + DG, and (9) ensiled residue + DG. After evaluation of the data, cattle fed corn residue had considerably lower intakes and it appears the mechanism controlling DMI on residue-based diets was different than other forage types (*2021 Nebraska Beef Cattle Report,* pp. 33–35); therefore, these treatments were excluded from evaluation of the model. The remaining treatment means in the data set included control (n = 24), control + DG (n = 31), corn silage (n = 28) and corn silage + DG (n = 10).

Actual shrunk BW and dietary NEm (determined through digestion experiments) for each treatment mean was entered into the BCNRM (2016) equation to predict intake of the cattle during the experimental period. Implant status was included in the model, however the effect of ionophore was not included. The predicted intake was compared with the observed intake of the cattle to determine the accuracy of the prediction model.

### *Statistical Analysis*

All statistical analysis was conducted using the GLM and REG procedures of SAS (SAS Inst. Inc., Cary, NC). Equations were developed to predict DMI as a % of BW. Variables were considered that were previously included in the NRC (1996) and BCNRM (2016) equations such as metabolic BW, average BW, and dietary NEm concentration. Other considerations included dietary concentration measures that could contribute to varied DMI such as dietary NDF concentration, dietary TDN, and fecal excretion (FE) as calculated from the current database. Variables were then selected using a backwards step-wise regression technique.

Validation of developed equations was done by regressing observed DMI on predicted DMI for each equation. The strength of the relationship between observed and predicted DMI was obtained through the coefficient of determination ($r^2$).

## Results

### *Evaluation of the BCNRM*

Observed and predicted intake as a % of BW were plotted across calculated TDN values to evaluate their relationship (Figure 1). As TDN increased, the observed DMI increased linearly, while the predicted DMI slope slightly decreased linearly. The difference in the slope of the lines suggests

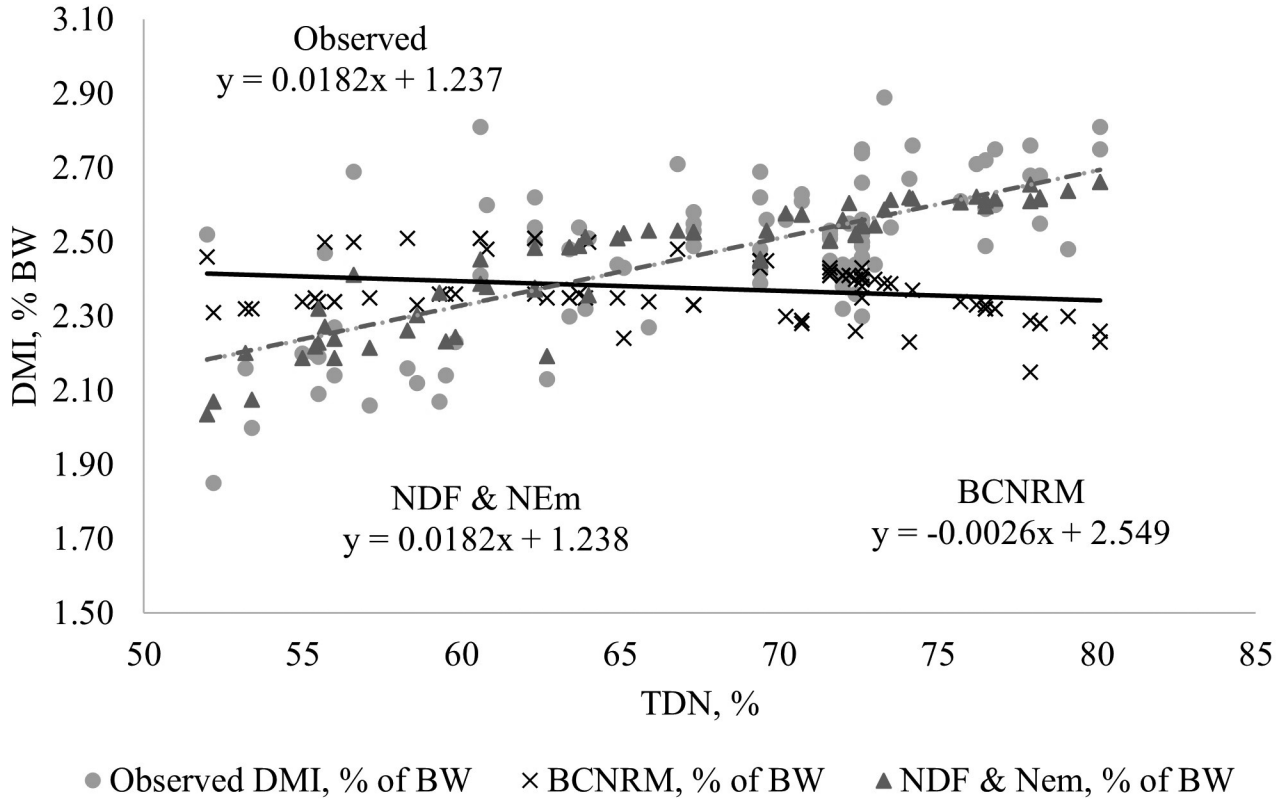


Figure 1. Observed, BCNRM, and new NDF & NEm equation predicting dry matter intake (DMI) as a % of body weight (BW). Plot of (93 treatment means) for forage-based diets (hay or corn silage-based with and without distillers grains) with TDN of 52 to 82%. Observed = light gray short dashed line and circles; BCNRM predicted = Solid black line and x's; NDF & NEm predicted = dark gray long dashed line and triangles.

the BCNRM may not correctly account for differences in diet type or there are other factors controlling intake than what is used in the BCNRM (2016) equation. When TDN was low (< 64%) in the dataset, the predicted intake was greater than that of the observed. As TDN increased, observed DMI increased at a greater rate than the predicted DMI. The intersection of when predicted intake over or under predicted DMI was approximately 64% TDN. Diets consisting of 64 to 82% TDN would be considered as medium to high energy diets. Because the BCNRM (2016) only uses NEm to predict DMI, it was assumed that energy is considered the limiting factor of DMI at any energy level. However, the observed data would conflict with this assumption because DMI increased with increasing TDN for the current data set. At 52 and 82% dietary TDN, the BCNRM (2016) predicted calves would consume 2.41 and 2.33% of BW, respectively. The observed DMI's were 2.18 and 2.73% of BW for calves fed 52 and 82% TDN diets, respectively. Because the BCNRM (2016) had a negative slope for predicted intake and the observed intake slope was positive, there must be another factor controlling DMI in low-energy, forage-based diets.

### *Equation Development*

An effort was made to predict DMI as a % of BW in order to reduce the impact of animal body weight. The equations developed included both dietary NDF and NEm concentration together and then evaluated both variables separately to predict DMI as a % of BW. Figure 1 shows the relationship of observed DMI and predicted DMI using the BCNRM and the newly developed model on a % BW basis. The newly developed model has similar slope and intercept as the observed DMI, suggesting it is more precisely predicting DMI. This was expected as the same dataset was used to develop the equations.

While the use of a single variable may not be able to predict intake accurately and precisely, the use of multiple variables to predict DMI can greatly improve the use of the model. Due to the current data set being forage-based diets with low-energy content (average NEm = 0.71 Mcal/lb DMI), the use of NDF content of the diet greatly improved the precision of the prediction models. Improved precision may be due to the greater NDF content creating a partial limit in DMI due to gut fill and a decreased passage rate, which would limit intake compared with strictly using an NEm based equation. The observed DMI from the current data set increased as a % of BW with increasing energy concentration, at least up to 82% dietary TDN.

The difference between observed DMI and BCNRM (2016) predicted DMI, as a % of BW, were plotted relative to TDN concentration of the diet (Figure 2). As TDN increased from 52 to 82%, the difference between observed and predicted intake

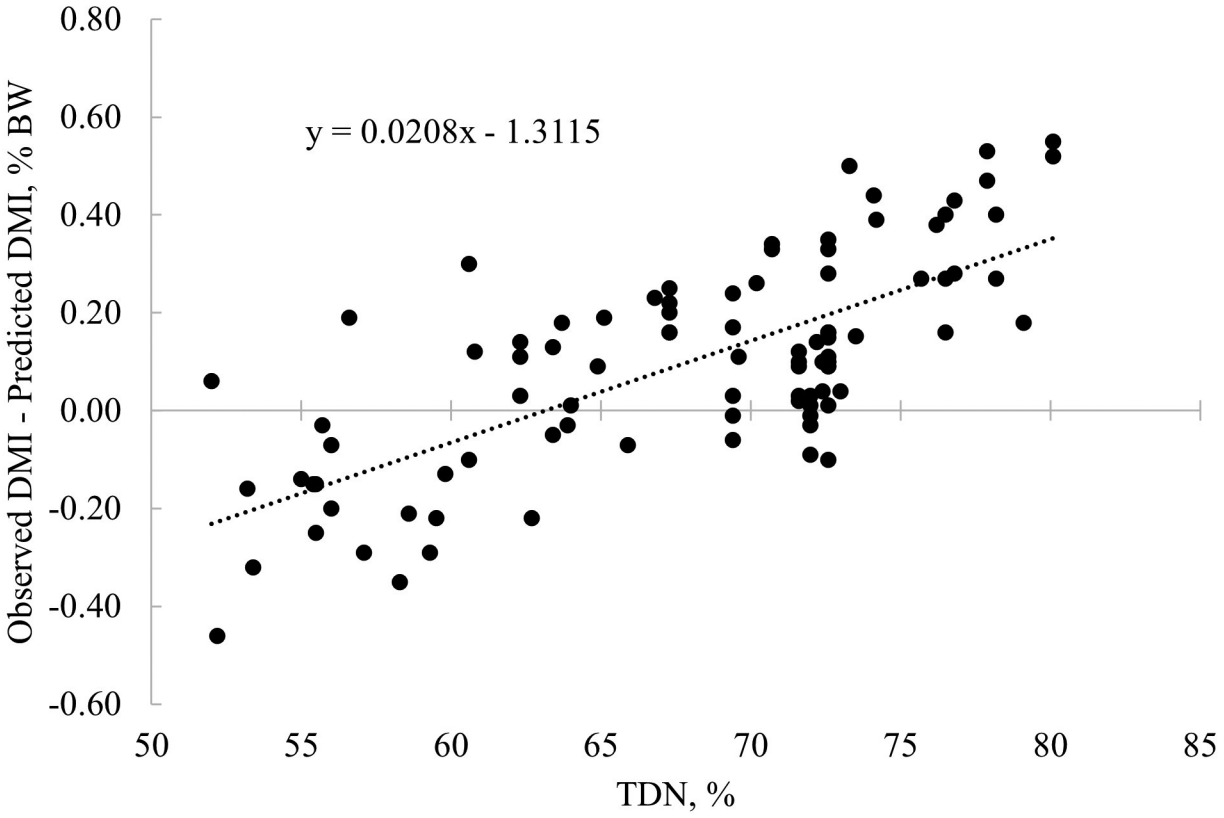


Figure 2. Plot of observed (93 treatments means) dry matter intake (DMI) minus BCNRM (2016) predicted DMI for forage-based diets (hay or corn silage-based with or without distillers grains) with TDN of 52 to 82%

**Table 1. Observed versus predicted DMI as a % of BW of different diet types[1]**

| | Observed | Predicted | *P*-Value | $r^2$ |
|---|---|---|---|---|
| Overall Means[2] | 2.47 | 2.37 | 0.02 | 0.0802 |
| Control[3] | 2.30 | 2.35 | 0.08 | 0.2185 |
| Control DG[4] | 2.52 | 2.37 | 0.15 | 0.1267 |
| Corn Silage[5] | 2.54 | 2.39 | 0.05 | 0.1577 |

[1]Comparison of observed versus predicted dry matter intake (DMI) using the BCNRM (2016) model on a % body weight (BW) basis

[2]All treatment means developed, n = 93

[3]Traditional forage-based diets with no distillers grains n = 24

[4]Traditional forage-based diets with distillers grains, n = 31

[5]Corn silage-based diets with and without distillers grains, n =38

increased linearly ($P < 0.01$) at 0.021% of BW with each 1% unit increase in TDN. At approximately 64% TDN, Observed DMI—Predicted DMI = 0; therefore, the model over predicted DMI for TDN < 64% and under predicted DMI in diets greater than 64% TDN.

In Table 1, the strength of the BCNRM model and the correlation between predicted and actual intake, as a % of BW, are shown for the overall treatment means and the different categories of diets. While the BCNRM model was considered significant, it was not precise in predicting intake of the overall means ($r^2 = 0.0802$; $P = 0.02$). The explanation of variation became greater ($r^2$ values improved) with individual diet types, but the significance of the model (*P*-values) did not improve. The BCNRM (2016) explained 0.2185 of the variation in DMI with a *P*-value of 0.08 for the control diets. Control diets that included DG had a lower $r^2$ value of 0.1267 and a *P*-value of 0.15. Corn silage diets with or without DG had the strongest significance at *P*-value = 0.05 but the explanation of variation was very poor ($r^2 = 0.1577$). The BCNRM model had relatively low $r^2$ values for all categories, suggesting it was not precise in predicting DMI as a % of BW of growing calves on these forage-based diets.

The lack of precision could be due to a lack of data points using low-energy, forage-based diets to develop the model. The current data set had an average dietary NEm concentration of 0.71 Mcal/lb, compared to 0.92 Mcal/lb in the BCNRM dataset. Extrapolation from more energy dense diets did not provide the same accuracy due to differences in the mechanisms that control rumen fill and satiation.

### *Comparison of BCNRM with Developed Prediction Equations*

The range in observed and predicted DMI as % of BW is presented in Table 2. Using the BCNRM resulted in a tighter

**Table 2. Mean and range of observed and predicted DMI as a % of BW[1]**

| Measure | Observed | BCNRM | NDF and NEm |
|---|---|---|---|
| Mean | 2.47 | 2.37 | 2.47 |
| Minimum | 1.85 | 2.15 | 2.04 |
| Maximum | 2.89 | 2.51 | 2.66 |

[1]Values shown are observed and predicted dry matter intake (DMI) as a % of body weight (BW) using the Beef Cattle Nutrient Requirements model (BCNRM) or a newly developed equation based on dietary fiber (NDF) and energy (NEm).

range of predicted DMI as a % of BW (2.15 to 2.51%) compared to the observed (1.85 to 2.89%). The range in predicted DMI as a % of BW when using the equation including both dietary NDF and NEm as predictors was 2.04 to 2.66% of BW. The range in predicted DMI for any equation was not as large as the range in observed DMI.

The inability of the equations to predict the extreme data points in the current data set demonstrates the challenge in predicting the outliers. Individual calves are affected differently by forage type and energy content of the diet and therefore outliers were kept in the dataset.

Prediction of DMI as a % of BW was improved on the current data set by including dietary NDF as a means of estimating rumen fill. While this is encouraging for accurately predicting DMI in low-energy, forage-based diets of growing calves, the new equations must be validated on additional data sets with similar performance goals to be considered valuable to the industry.

## Conclusion

The current model that included dietary fiber (NDF) as a proxy for rumen fill, along with dietary energy (NEm) concentration increased the explanation of variation by approximately 50% when predicting DMI as a % of BW. This model improved DMI predictions for cattle fed Eastern Nebraska forage-based diets but needs to be further evaluated using additional validation datasets to determine robustness with additional forage and cattle types.

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# Interaction of Sweet Bran Inclusion and Corn Processing Method in Beef Finishing Diets

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## Summary with Implications

*The effects of corn processing method and Sweet Bran concentration on finishing cattle performance and carcass characteristics were evaluated in steam-flaked corn or a blend of high-moisture and dry-rolled corn-based diets. Sweet Bran was included at 0, 20, or 40% of diet dry matter. When cattle were fed 0% Sweet Bran, feeding steam-flaked corn resulted in a 11.7% improvement in feed conversion and heavier hot-carcass weight compared to feeding high-moisture/dry-rolled corn. As Sweet Bran increased in the diet, there was a linear improvement in feed conversion for high-moisture/dry-rolled corn-fed steers and no change in feed conversion for steam-flaked corn-fed cattle. Accordingly, in diets with 40% Sweet Bran, the improvement in feed conversion due to feeding steam-flaked corn narrowed to 3.7%. These data suggest concentrations up to 40% Sweet Bran (dry-matter basis) can be fed with steam-flaked corn diets without affecting performance and the optimal level of Sweet Bran for high-moisture/dry-rolled corn-based finishing diets is 40%.*

## Introduction

Feeding Sweet Bran replaces starch with highly digestible fiber in finishing diets, which improves intake (DMI) and average daily gain (ADG). Depending on the corn processing method employed, feeding Sweet Bran may maintain or improve feed efficiency while simultaneously reducing the occurrence and severity of acidosis. Previous research suggests concentrations up to 35% Sweet Bran can be fed with steam-flaked corn (SFC) based diets (*2003 Nebraska Beef Cattle Report*, pp.24–25). Final weights, ADG, and feed conversion were similar across treatments (0, 10, 20, 25, 30, and 35% Sweet Bran). Previous research evaluated high-moisture corn/dry-rolled corn (HMC/DRC) based finishing diets comparing 0% Sweet Bran to only one other Sweet Bran concentration (*2001 Nebraska Beef Cattle Report*, pp. 59–63; *2005 Nebraska Beef Cattle Report*, pp. 37–38). In the current experiment, increasing concentrations of Sweet Bran were fed and the interaction between Sweet Bran concentration and corn processing method were evaluated. Therefore, the objective of this research was to determine the optimal level of Sweet Bran in SFC and HMC/DRC based finishing diets.

## Procedure

A feedlot performance study conducted at the University of Nebraska–Lincoln Eastern Nebraska Research and Extension Center near Mead, NE utilized 480 crossbred yearling steers [initial body weight (BW) = 799 ± 33.3 lb.] Steers were sorted into 3 BW blocks, stratified by BW within block, and assigned randomly to one of 48 pens (10 steers/pen). The light block included 4 replicates, while the medium block included 3 replicates, and the heavy block included 1 replicate. All steers were weighed for two consecutive days after limit feeding a common diet of 50% alfalfa and 50% Sweet Bran at 2% of BW for 5 days to minimize gut fill.

Treatments were arranged as a 2 × 3 factorial, that consisted of two corn processing methods (SFC or a 2/3 HMC 1/3 DRC blend) and three inclusions of Sweet Bran (0, 20, or 40% of diet DM). Steam-flaked corn was processed to a flake density of 28.6 lb/bushel at a commercial feedlot (Raikes Feedyard, Memphis, NE) and delivered to the research feedlot on a weekly basis. High-moisture corn was harvested at approximately 73% moisture , processed through a roller mill, and stored in a concrete bunker for approximately 250 d. Treatment diets are provided in Table 1. All steers were fed monensin (Rumensin, Elanco Animal Health, Greenfield, IN) at 30 g/ton and tylosin (Tylan, Elanco Animal Health) was included at 8.8 g/ton (DM basis). Ractopamine (Optaflexx, Elanco Animal Health) was fed the last 28 (heavy and middle blocks) or 42 (light block) days on feed to target 300 mg/steer daily followed by a one-day withdrawal prior to slaughter. Feed was delivered once daily between 7 and 10 am.

Steers were implanted with 80 mg of trenbolone acetate and 16 mg estradiol (Revalor-IS, Merck Animal Health, De Soto, KS) on d -2 and then reimplanted with 200 mg trenbolone acetate and 20 mg of estradiol (Revalor-200, Merck Animal Health) on d 75 for the light block and d 76 for the medium and heavy blocks. The medium and heavy blocks were on feed for 154 days. The light block was shipped 2 weeks later and on feed for 168 days to achieve a similar 12$^{th}$ rib fat thickness as the medium and heavy blocks.

Cattle were harvested at a commercial abattoir (Greater Omaha; Omaha, NE). On the day of harvest, hot carcass weight (HCW) was recorded, and carcass-adjusted final BW was calculated using a 63% dressing percentage. Carcass-adjusted final BW was used to determine average daily gain (ADG) and feed conversion (Feed:Gain). On the day of harvest, liver abscess scores were recorded immediately after evisceration. Following a 48 h-chill, marbling score, 12th rib fatness, and longissimus muscle (LM) area were measured.

Data were analyzed using the MIXED procedure of SAS as a generalized randomized block design with pen as the experimental unit and block as a fixed effect. The experiment was analyzed as a 2 × 3 factorial with two corn processing methods (steam-flaked corn or high-moisture/dry rolled

**Table 1. Dietary treatment composition (DM basis) for finishing steers fed high-moisture and dry-rolled corn or steam-flaked corn with 0, 20, or 40% Sweet Bran**

| | Treatment[1] | | | | | |
|---|---|---|---|---|---|---|
| | SFC | SFC | SFC | HMC/DRC | HMC/DRC | HMC/DRC |
| Ingredient | 0 | 20 | 40 | 0 | 20 | 40 |
| Steam-flaked corn | 80 | 60 | 40 | - | - | - |
| High-moisture corn | - | - | - | 53.33 | 40 | 26.67 |
| Dry-rolled corn | - | - | - | 26.67 | 20 | 13.33 |
| Sweet Bran | 0 | 20 | 40 | 0 | 20 | 40 |
| Corn Silage | 15 | 15 | 15 | 15 | 15 | 15 |
| Supplement[2] | | | | | | |
| Fine Ground Corn | 1.32 | 2.39 | 2.96 | 1.32 | 2.39 | 2.96 |
| Limestone | 1.66 | 1.59 | 1.52 | 1.66 | 1.59 | 1.52 |
| Tallow | 0.125 | 0.125 | 0.125 | 0.125 | 0.125 | 0.125 |
| Urea | 1.5 | 0.5 | 0 | 1.5 | 0.5 | 0 |
| Salt | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Vitamin A-D-E Premix | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 |
| Beef Trace Premix | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| Rumensin Premix[3] | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 |
| Tylan Premix[4] | 0.009 | 0.009 | 0.009 | 0.009 | 0.009 | 0.009 |
| Analyzed Nutrient Composition, % of DM | | | | | | |
| Organic Matter | 96.19 | 94.91 | 93.70 | 95.57 | 94.44 | 93.26 |
| Neutral Detergent Fiber | 11.86 | 17.19 | 22.47 | 13.52 | 18.43 | 23.39 |
| Acid Detergent Fiber | 5.76 | 7.21 | 8.65 | 6.05 | 7.43 | 8.80 |
| Crude Protein | 12.15 | 12.49 | 14.55 | 12.63 | 12.95 | 14.79 |
| Calcium | 0.796 | 0.793 | 0.791 | 0.772 | 0.775 | 0.779 |
| Phosphorus | 0.194 | 0.395 | 0.535 | 0.292 | 0.439 | 0.584 |

[1]Treatments included SFC 0: steam-flaked corn with 0% Sweet Bran, SFC 20: steam-flaked corn with 20% Sweet Bran, SFC 40: steam-flaked corn with 40% Sweet Bran, HMC/DRC 0: high-moisture corn/dry-rolled corn with 0% Sweet Bran, HMC/DRC 20: high-moisture corn/dry-rolled corn with 20% Sweet Bran, and HMC/DRC 40: high-moisture corn/dry-rolled corn with 40% Sweet Bran.

[2]Supplement fed at 5% of dietary DM for all treatments.

[3]Formulated to supply Rumensin-90 (Elanco Animal Health) at 30 g/ton DM.

[4]Formulated to supply Tylan-40 (Elanco Animal Health) at 90 mg per steer daily.

corn) and three inclusions of Sweet Bran (0, 20, or 40%). Linear and quadratic interactions between treatment factors were tested using covariate regression. If no interaction was observed, then main effects of corn processing and Sweet Bran inclusion were evaluated. If an interaction was observed, then simple effects of Sweet Bran inclusion were evaluated within each corn processing method. Liver abscesses were analyzed using the MIXED procedure of SAS as a binomial evaluating the presence or absence of liver abscesses. Arithmetic means are presented due to unbalanced blocking.

## Results

### *Interaction of Sweet Bran and Corn Processing*

There were no quadratic interactions or quadratic effects of Sweet Bran ($P > 0.22$). There was a linear interaction of corn pro-

**Table 2. Carcass adjusted performance of cattle fed a combination of high-moisture and dry rolled corn or steam-flaked corn with 0, 20, or 40% Sweet Bran[1]**

| | Treatment | | | | | | | *P*-value[2] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Item | SFC 0 | SFC 20 | SFC 40 | HMC/DRC 0 | HMC/DRC 20 | HMC/DRC 40 | SEM | Corn × SB Linear | Corn | SB Linear |
| Days on feed, n | 161 | 161 | 161 | 161 | 161 | 161 | - | - | - | - |
| *Performance* | | | | | | | | | | |
| Initial BW, lb | 799 | 799 | 799 | 799 | 799 | 799 | 11.6 | 0.77 | 0.81 | 0.34 |
| Final BW[3], lb | 1562 | 1578 | 1593 | 1473 | 1522 | 1570 | 10.9 | < 0.01 | < 0.01 | < 0.01 |
| DMI, lb/d | 26.7 | 27.5 | 28.3 | 26.4 | 27.5 | 28.6 | 0.30 | 0.41 | 0.89 | < 0.01 |
| ADG, lb | 4.81 | 4.91 | 5.01 | 4.25 | 4.56 | 4.87 | 0.07 | <0.01 | < 0.01 | < 0.01 |
| Feed:Gain[4] | 5.56 | 5.61 | 5.67 | 6.21 | 6.04 | 5.88 | - | < 0.01 | < 0.01 | 0.24 |
| *Carcass Characteristics*[c] | | | | | | | | | | |
| HCW, lb | 984 | 994 | 1004 | 928 | 959 | 989 | 6.8 | < 0.01 | < 0.01 | < 0.01 |
| LM area, in[2] | 15.0 | 15.1 | 15.2 | 14.5 | 14.7 | 14.9 | 0.16 | 0.60 | <0.01 | 0.07 |
| 12th rib fat, in | 0.61 | 0.63 | 0.66 | 0.58 | 0.61 | 0.63 | 0.02 | 0.92 | 0.10 | 0.02 |
| Marbling[5] | 512 | 520 | 528 | 486 | 488 | 490 | 11.3 | 0.60 | < 0.01 | 0.42 |
| Calculated Yield Grade[6] | 3.45 | 3.51 | 3.57 | 3.31 | 3.43 | 3.54 | 0.08 | 0.57 | 0.27 | 0.05 |
| Liver abscesses, %[7] | 41.56 | 29.11 | 43.59 | 58.75 | 55.0 | 48.75 | 0.056 | 0.17 | < 0.02 | 0.33 |

[1]Arithemtic means are reported

[2]Corn×SB= P-value for linear interaction between corn processing method (a combination of high-moisture corn and dry rolled corn or steam-flaked corn) and Sweet Bran inclusion (0, 20, or 40%); corn=*P*-value for main effect of corn processing method; SB= *P*-value for linear main effect of SB inclusion

[3]Calculated on a carcass-adjusted basis using a common dressing percentage (63%).

[4]Statistics based on Gain:Feed

[5]Marbling score 300=slight, 400=small, 500=modest, etc.

[6]Calculated as 2.5 + (2.5 x 12th rib fat, in) + (0.02 x 2.0 [KPH, %]) + (0.0038 x HCW, lb)—(0.32 x LM area, in[2]).

[7]Calculated as a percent of total steers; dead steers removed

cessing method and Sweet Bran inclusion for ADG ($P < 0.01$; Table 2; Figure 1). In both SFC and HMC/DRC diets, ADG increased linearly from 0 to 40% Sweet Bran inclusion ($P < 0.05$). The SFC diet had greater ADG than HMC/DRC diet at 0% Sweet Bran, but as Sweet Bran increased in the diet, the ADG for HMC/DRC increased at a greater rate compared to SFC resulting in similar ADG at 40% Sweet Bran. There was also a linear interaction for F:G ($P < 0.01$). As Sweet Bran increased in the diet, there was no improvement in F:G for SFC diets ($P = 0.19$) but a linear improvement in F:G in HMC/DRC diets ($P < 0.01$). At 0% Sweet Bran, there was a 11.7% improvement in F:G when feeding SFC compared to HMC/DRC, which is consistent with previous research. While the F:G for SFC remained better than HMC/DRC when 40% Sweet Bran was fed ($P = 0.04$), the improvement in F:G was only 3.7% when 40% Sweet Bran was fed compared to 11.7% when no Sweet Bran was fed. Additionally, there was an interaction for HCW and carcass-adjusted final BW ($P < 0.01$). At 0% Sweet Bran, the SFC diet had greater HCW and carcass-adjusted final BW than the HMC/DRC diet. As Sweet Bran inclusion increased, there was a tendency for an increase in HCW and carcass-adjusted final BW for SFC diets ($P = 0.06$) and a significant increase for HMC/DRC diets ($P < 0.01$) resulting in similar HCW and carcass-adjusted final BW between the two corn processing methods fed with 40% SB.

There were no interactions for DMI, LM area, 12th rib fat, marbling, calculated yield grade, or liver abscesses ($P > 0.92$), so main effects of corn processing method or Sweet Bran inclusion will be discussed.

### *Corn Processing*

There was a tendency for steers fed SFC to have greater fat depth than steers fed HMC/DRC ($P = 0.10$). Accordingly, steers fed SFC had a greater degree of marbling compared to steers fed HMC/DRC ($P < 0.01$). Steers fed SFC had a larger LM area than steers fed HMC/DRC ($P <$

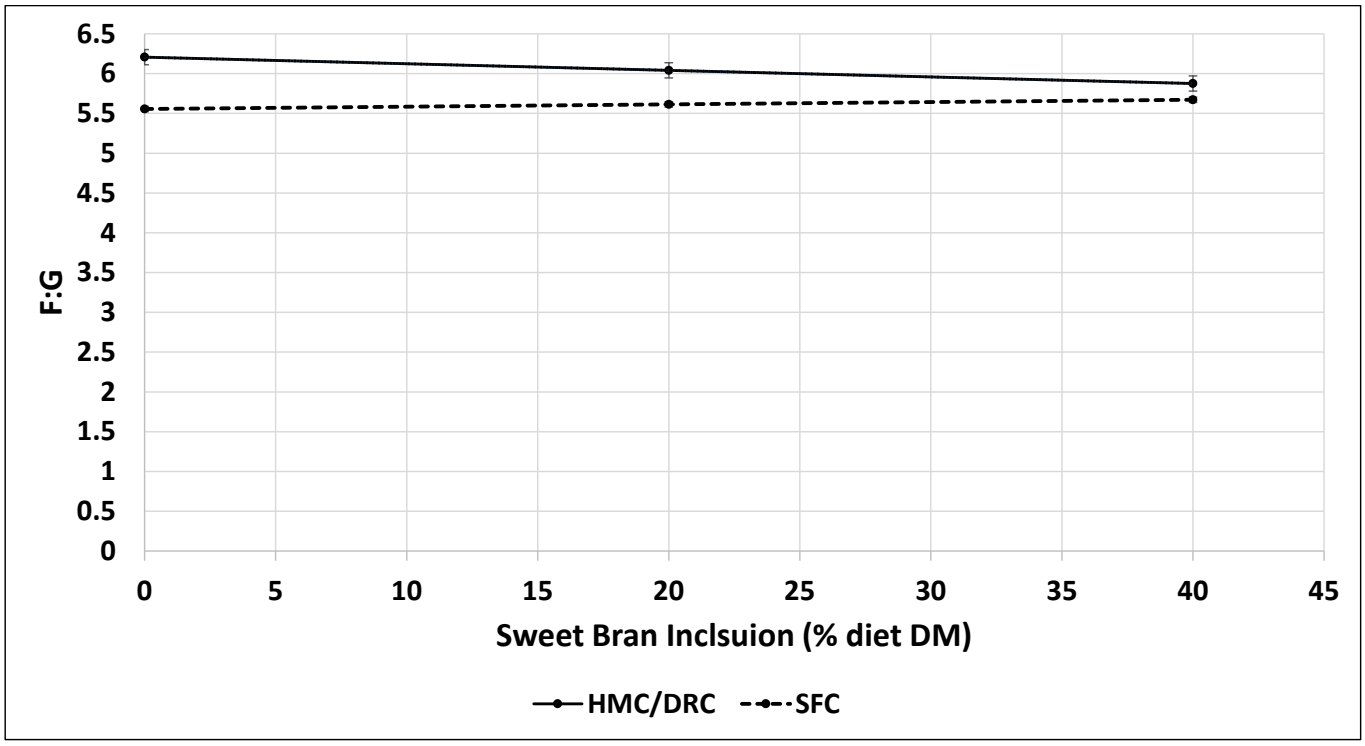


Figure 1. Effect of corn processing method and Sweet Bran inclusion on feed to gain ratio. Corn processing methods include steam-flaking (SFC) or a blend of 2/3 high-moisture corn and 1/3 dry-rolled corn (HMC/DRC). The linear interaction of corn processing and Sweet Bran was analyzed as Gain:Feed and was significant ($P < 0.01$).

0.01). Impacts on carcass traits likely reflect changes in performance as cattle fed SFC generally gained better. Lastly, there was an effect of corn processing on liver abscesses with steers fed HMC/DRC having a greater prevalence of liver abscesses compared to steers fed SFC ($P < 0.02$). It is unclear why abscess rates were abnormally high as all steers were fed tylosin in this study.

### *Sweet Bran*

There was a linear increase in DMI as Sweet Bran increased in the diet regardless of corn processing method ($P < 0.01$). There was also an increase of 12th rib fat with fat increasing as Sweet Bran increased in the diet ($P = 0.02$), which lead to a linear increase in calculated yield grade as Sweet Bran increased in the diet ($P = 0.05$). As Sweet Bran increased in the diet, LM area also tended to increase ($P = 0.07$).

## Conclusions

These data suggest that up to 40% Sweet Bran can be fed with SFC without affecting feed conversion and the optimal level of Sweet Bran for HMC/DRC based finishing diets is 40%. Therefore, feeding Sweet Bran in HMC/DRC based finishing diets makes HMC/DRC diets more competitive with SFC-based finishing diets allowing producers without steam-flaking capabilities to achieve similar gains and conversions.

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# Interaction of Sweet Bran Inclusion and Corn Processing Method in Beef Finishing Diets on Digestibility

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## Summary with Implications

*Six ruminally and duodenally fistulated steers were utilized in a 6 × 6 Latin square design to evaluate the interaction of corn processing method and Sweet Bran inclusion in finishing diets on total tract digestibility and rumen fermentation characteristics. Treatments were designed as a 2 × 3 factorial, with one factor as corn processing method (steam-flaked corn or a blend of high-moisture and dry-rolled corn) and the second factor as Sweet Bran inclusion at 0, 20, or 40% of diet dry matter. Cattle fed steam-flaked corn diets had greater starch digestibility while cattle fed high-moisture/dry-rolled corn diets had greater neutral detergent fiber digestibility. As Sweet Bran concentration increased in the diet, cattle fed both steam-flaked corn and high-moisture/dry-rolled corn diets had greater dry matter intakes and as a result, greater intakes of digestible energy. Increased energy intake may contribute to improvements in gain and efficiency when feeding Sweet Bran observed in a corresponding finishing trial.*

## Introduction

A recent finishing study (*2022 Nebraska Beef Cattle Report*, pp. 42–45) evaluated 0, 20, and 40% of Sweet Bran (SB) in steam-flaked corn (SFC) and high-moisture corn (HMC)/ dry-rolled corn (DRC) based finishing diets. When cattle were fed 0% SB, feeding SFC resulted in a 11.7% improvement in F:G compared to feeding HMC/DRC. As SB increased in the diet, there was a linear improvement in F:G for HMC/DRC fed steers and no change in F:G for SFC fed cattle. Accordingly, in diets with 40% SB, the improvement in F:G due to feeding SFC narrowed to 3.7%. Therefore, feeding up to 40% SB in SFC based finishing diets did not affect animal performance. Additionally, the optimal inclusion for high-moisture/dry-rolled corn-based finishing diets was 40%. The hypothesis of this experiment was that the improvement in animal performance results from a reduction in the occurrence and severity of acidosis or increased energy intake due to greater DMI. Therefore, the objective of this digestion study was to evaluate the interaction of corn processing method and SB inclusion on total tract digestibility and rumen fermentation characteristics to understand the performance response observed in the finishing study.

## Procedure

Six ruminally and duodenally fistulated crossbred steers were used in a 6 × 6 Latin square design with 21-d periods consisting of an 18-d adaptation followed by a 3-d collection period. The study was conducted over 126 days. Dietary treatments were designed in a 2 × 3 factorial arrangement with factors consisting of 1) corn processing method ((2/3 HMC 1/3 DRC blend, or 100% SFC) and 2) Sweet Bran inclusion (0, 20, or 40% of diet DM). Steam-flaked corn was processed to a flake density of 28.6 lb/bushel at a commercial feedlot (Raikes Feedyard, Ashland, NE) and delivered to the research feedlot on a weekly basis. High-moisture corn was harvested at approximately 73% moisture , processed through a roller mill, and stored in a concrete bunker for approximately 250 d. All supplements were formulated to include 30 g/ton of monensin (Rumensin, Elanco Animal Health, Greenfield, IN) and 8.8 g/ton of tylosin (Tylan, Elanco Animal Health). Diet and supplement composition are shown in Table 1.

Steers were fed twice daily at 0700 h and 1300 h and had ad libitum access to feed and water. Cattle were housed in individual, rubber slatted pens in a temperature-controlled room. Ingredient samples were taken during the collection period at the time of mixing, composited by period, freeze dried and ground through a Wiley Mill using a 1-mm screen. Feed refusals were collected on d 18 and 19 prior to feeding, dried in a forced air oven, ground through a Wiley Mill using a 1-mm screen, and composited by steer within collection period. Beginning on d 7 of each period, titanium dioxide was dosed intraruminally at 0700 and 1700 h to provide a total of 16 g/d. Fecal samples were collected at 6 times/d at 0700, 1100, 1500, 1900, 2300, and 0300 h on d 19 and 20. Fecal samples were composited by day, freeze dried, ground as previously described, and composited by animal within period. Fecal samples were analyzed for titanium dioxide to determine fecal output and nutrient digestibility. Feed ingredients, feed refusals, and fecal samples were analyzed for dry matter (DM), organic matter (OM), neutral detergent fiber (NDF), total starch, and crude protein (CP).

Ruminal pH was measured continuously throughout the trial with SmaXtec wireless pH probes. Measurements for pH included average ruminal pH, minimum and maximum pH, magnitude of change, and variance. The number of minutes spent ruminating and eating per day was also continuously measured using CowManager Sensor ear-tags.

Data were analyzed using the MIXED procedure of SAS as a 6 × 6 latin square experimental design with period and steer as a fixed effect. The treatment design was a 2 × 3 factorial with two corn processing methods (steam-flaked corn or high-moisture/dry rolled corn) and three inclusions of Sweet Bran (0, 20, or 40%). Data were tested for linear and quadratic interactions between treatment factors using covariate regression. If no interaction was observed, then main effects of corn processing and Sweet Bran inclusion were

**Table 1. Dietary treatment composition (DM basis) for finishing steers fed high-moisture and dry-rolled corn or steam-flaked corn with 0, 20, or 40% Sweet Bran**

| | Treatment[1] | | | | | |
|---|---|---|---|---|---|---|
| | SFC | SFC | SFC | HMC/DRC | HMC/DRC | HMC/DRC |
| Ingredient | 0 | 20 | 40 | 0 | 20 | 40 |
| Steam-flaked corn | 80 | 60 | 40 | - | - | - |
| High-moisture corn | - | - | - | 53.33 | 40 | 26.67 |
| Dry-rolled corn | - | - | - | 26.67 | 20 | 13.33 |
| Sweet Bran | 0 | 20 | 40 | 0 | 20 | 40 |
| Corn Silage | 15 | 15 | 15 | 15 | 15 | 15 |
| Supplement[2] | | | | | | |
| Fine Ground Corn | 1.32 | 2.39 | 2.96 | 1.32 | 2.39 | 2.96 |
| Limestone | 1.66 | 1.59 | 1.52 | 1.66 | 1.59 | 1.52 |
| Tallow | 0.125 | 0.125 | 0.125 | 0.125 | 0.125 | 0.125 |
| Urea | 1.5 | 0.5 | 0 | 1.5 | 0.5 | 0 |
| Salt | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Vitamin A-D-E Premix | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 |
| Beef Trace Premix | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| Rumensin Premix[3] | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 |
| Tylan Premix[4] | 0.009 | 0.009 | 0.009 | 0.009 | 0.009 | 0.009 |
| Analyzed Nutrient Composition, % of DM | | | | | | |
| Organic Matter | 96.13 | 94.98 | 93.73 | 95.57 | 94.49 | 93.45 |
| Neutral Detergent Fiber | 13.04 | 20.10 | 26.97 | 11.90 | 19.18 | 26.40 |
| Crude Protein | 13.22 | 14.10 | 16.39 | 13.66 | 14.50 | 16.61 |
| Starch | 61.58 | 49.25 | 37.40 | 56.14 | 45.46 | 34.68 |
| Gross Energy, cal/g | 4248 | 4256 | 4324 | 4274 | 4309 | 4338 |

[1]Treatments included SFC 0: steam-flaked corn with 0% Sweet Bran, SFC 20: steam-flaked corn with 20% Sweet Bran, SFC 40: steam-flaked corn with 40% Sweet Bran, HMC/DRC 0: high-moisture corn/dry-rolled corn with 0% Sweet Bran, HMC/DRC 20: high-moisture corn/dry-rolled corn with 20% Sweet Bran, and HMC/DRC 40: high-moisture corn/dry-rolled corn with 40% Sweet Bran.

[2]Supplement fed at 5% of dietary DM for all treatments.

[3]Formulated to supply Rumensin-90 (Elanco Animal Health) at 30 g/ton DM.

[4]Formulated to supply Tylan-40 (Elanco Animal Health) at 90 mg per steer daily.

evaluated. If an interaction was observed, simple effects of Sweet Bran inclusion were evaluated within each corn processing method.

## Results

### *Intake*

There were no significant linear or quadratic interactions for corn processing method and SB inclusion ($P \geq 0.19$, Table 2). Increasing the concentration of SB in the diet resulted in a linear increase in DM and OM intake, regardless of corn processing method ($P < 0.01$). There was a tendency for a quadratic interaction for corn processing and SB inclusion for starch intake ($P = 0.09$; not shown). At 0% SB, starch intake was similar (11.16 and 11.17 lb/d) for cattle fed SFC and HMC/DRC. Even though starch content of the diet was lesser at 20% SB, cattle fed SFC had greater intakes resulting in a greater starch intake for SFC-fed steers (12.13 vs 9.28 lbs/d). In comparison, cattle fed HMC/DRC had lower DMI resulting in lower starch intakes at 20% SB. As SB increased to 40%, starch intake continued to decrease for cattle fed HMC/DRC (8.56 lbs/d) and significantly decreased for cattle fed SFC (9.66 lbs/d). Steers fed SFC had greater starch intakes compared to steers fed HMC/DRC ($P <$

**Table 2. Nutrient intake and digestibility of cattle fed a combination of high-moisture and dry-rolled corn or steam-flaked corn with 0, 20, or 40% Sweet Bran[1]**

| | Treatment | | | | | | | *P*-value[2] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Item | SFC 0 | SFC 20 | SFC 40 | HMC/DRC 0 | HMC/DRC 20 | HMC/DRC 40 | SEM | Corn × SB Linear | Corn | SB Linear |
| DM | | | | | | | | | | |
| Intake, lb/d | 18.6 | 24.6 | 26.2 | 20.0 | 22.0 | 24.7 | 1.01 | 0.19 | 0.29 | < 0.01 |
| Digestibility, % | 74.96 | 76.30 | 74.75 | 77.37 | 77.62 | 74.60 | 1.32 | 0.30 | 0.26 | 0.24 |
| OM | | | | | | | | | | |
| Intake, lb/d | 18.2 | 23.3 | 24.1 | 19.5 | 19.7 | 23.3 | 1.23 | 0.42 | 0.31 | < 0.01 |
| Digestibility, % | 78.25 | 78.61 | 76.41 | 79.62 | 78.11 | 77.15 | 1.35 | 0.76 | 0.60 | 0.10 |
| NDF | | | | | | | | | | |
| Intake, lb/d | 2.5 | 4.9 | 7.1 | 2.4 | 4.1 | 6.7 | 0.33 | 0.64 | 0.11 | < 0.01 |
| Digestibility, % | 36.26 | 49.03 | 51.72 | 39.99 | 51.12 | 59.83 | 4.78 | 0.66 | 0.08 | < 0.01 |
| Starch | | | | | | | | | | |
| Intake, lb/d | 11.61 | 12.13 | 9.66 | 11.17 | 9.28 | 8.56 | 0.61 | 0.57 | < 0.01 | < 0.01 |
| Digestibility, % | 99.03 | 99.39 | 99.18 | 95.07 | 96.11 | 96.58 | 0.75 | 0.31 | < 0.01 | 0.24 |
| DE | | | | | | | | | | |
| Apparent Energy Digestibility, % | 73.76 | 74.36 | 73.87 | 74.88 | 75.72 | 73.66 | 1.19 | 0.62 | 0.41 | 0.70 |
| DE, Mcal/d | 26.52 | 35.34 | 37.90 | 28.94 | 32.39 | 36.08 | 1.74 | 0.25 | 0.58 | < 0.01 |
| DE, Mcal/lb | 6.91 | 6.97 | 7.05 | 7.05 | 7.20 | 7.05 | 0.12 | 0.59 | 0.25 | 0.59 |

[1]Arithmetic means are reported

[2]CornxSB= *P*-value for linear interaction between corn processing method (a combination of high-moisture corn and dry rolled corn or steam-flaked corn) and Sweet Bran inclusion (0, 20, or 40%); corn=*P*-value for main effect of corn processing method; SB= *P*-value for linear main effect of SB inclusion

0.01). There was a linear increase in NDF, and digestible energy intake as SB concentration increased in the diet, regardless of corn processing method ($P < 0.01$).

### *Digestion*

Steers fed HMC/DRC tended to have greater NDF digestibility than cattle fed SFC ($P = 0.08$). Steers fed SFC had greater starch digestibility compared to steers fed HMC/DRC ($P > 0.01$). There were no differences for the main effect of corn processing method for DM, OM, or apparent energy digestibility ($P \geq 0.58$). As SB concentration increased in the diet, OM digestibility tended to decrease ($P = 0.10$). In addition, NDF digestibility increased as Sweet Bran increased in the diet because the NDF in Sweet Bran being is more digestible than NDF from silage ($P < 0.01$). Digestible energy intake per day also increased as SB concentration increased ($P < 0.01$).

### *Ruminal pH*

There were no interactions ($P \geq 0.16$, Table 3), no effect of corn processing method ($P \geq 0.64$) and no effect of Sweet Bran ($P \geq 0.29$) observed for minimum, maximum, average, magnitude of change or variation.

### *Rumination*

There were no interactions ($P \geq 0.73$, Table 4), effect of corn processing method ($P \geq 0.20$), or effect of Sweet Bran ($P \geq 0.35$) observed for number of minutes spent ruminating or eating per day.

These data suggest cattle fed increasing concentrations of Sweet Bran have greater DM, OM, NDF, and starch intake. OM digestibility tended to decrease as Sweet Bran increased in the diet while ADG and feed conversion in the finishing trial improved from 0 to 40% Sweet Bran. The decrease in OM digestibility is consistent with increasing NDF intake. While gross energy was similar among diets, DMI increased from 0 to 40% Sweet Bran resulting in greater digestible energy intakes per day. As a result, cattle have a greater intake of energy for gain over maintenance energy requirements, which may have contributed to the greater gains and conversions as observed in the finishing trial.

**Table 3. Ruminal pH characteristics of cattle fed a combination of high-moisture and dry-rolled corn or steam-flaked corn with 0, 20, or 40% Sweet Bran[1]**

| | Treatment | | | | | | | *P*-value[2] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Item | SFC 0 | SFC 20 | SFC 40 | HMC/DRC 0 | HMC/DRC 20 | HMC/DRC 40 | SEM | Corn × SB Linear | Corn | SB Linear |
| Minimum pH | 5.88 | 5.77 | 5.76 | 5.78 | 5.83 | 5.72 | 0.078 | 0.67 | 0.80 | 0.29 |
| Maximum pH | 6.58 | 6.68 | 6.63 | 6.71 | 6.66 | 6.58 | 0.067 | 0.23 | 0.75 | 0.71 |
| Average pH | 6.24 | 6.20 | 6.15 | 6.19 | 6.21 | 6.15 | 0.087 | 0.66 | 0.81 | 0.33 |
| pH magnitude | 0.69 | 0.91 | 0.87 | 0.92 | 0.79 | 0.86 | 0.087 | 0.20 | 0.64 | 0.48 |
| pH variance[3] | 0.17 | 0.21 | 0.23 | 0.34 | 0.18 | 0.22 | 0.027 | 0.16 | 0.68 | 0.46 |

[1]Arithmetic means are reported

[2]CornxSB= P-value for linear interaction between corn processing method (a combination of high-moisture corn and dry rolled corn or steam-flaked corn) and Sweet Bran inclusion (0, 20, or 40%); corn=*P*-value for main effect of corn processing method; SB= *P*-value for linear main effect of SB inclusion

[3]Standard deviation of daily ruminal pH

**Table 4. Rumination characteristics of cattle fed a combination of high-moisture and dry-rolled corn or steam-flaked corn with 0, 20, or 40% Sweet Bran[1]**

| | Treatment | | | | | | | *P*-value[2] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Item | SFC 0 | SFC 20 | SFC 40 | HMC/DRC 0 | HMC/DRC 20 | HMC/DRC 40 | SEM | Corn × SB Linear | Corn | SB Linear |
| Rumination, min/d | 212 | 282 | 325 | 228 | 207 | 249 | 59 | 0.81 | 0.20 | 0.35 |
| Eating, min/d | 59 | 46 | 89 | 72 | 75 | 57 | 20 | 0.73 | 0.80 | 0.67 |

[1]Arithmetic means are reported

[2]CornxSB= P-value for linear interaction between corn processing method (a combination of high-moisture corn and dry rolled corn or steam-flaked corn) and Sweet Bran inclusion (0, 20, or 40%); corn=*P*-value for main effect of corn processing method; SB= *P*-value for linear main effect of SB inclusion

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# Characterizing Digestion Traits of Novel Corn Bran Products

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## Summary with Implications

*A digestion study was conducted to evaluate novel corn bran products from Cargill Corn Milling on nutrient digestibility in beef steers. Three bran products (Bran A/B/C) were included at 70% of diet dry matter of TRT A, B and C, with an internal control (SFC control) diet which consisted of 70% SFC. The SFC control exhibited the greatest dry matter (DM), organic matter (OM) and starch digestibility, and the least neutral detergent fiber (NDF) digestibility. Among TRT A, B and C when bran products were included at 70%, there was no difference in DM or OM intake and digestibility. NDF digestibility was greatest for TRT A fed steers, least for TRT C with TRT B intermediate. Starch intake was greatest for TRT C fed steers, least for TRT A with TRT B intermediate; while starch digestibility was greatest for TRT A fed steers, least for TRT C with TRT B intermediate. Bran products had minimal effect on energy digestibility, ruminal pH, rumination activity and blood parameters. Digestion trait differences existed among different corn bran products, of which Bran A was better digested, and corn bran products could replace SFC up to 70% dietary inclusion without compromising digestible energy of diet.*

## Introduction

Sweet Bran® is a well-known feed from Cargill wet milling of corn. As the wet milling process continues evolving over time, novel bran products emerge, which may be used as cattle feed. The evaluation of new bran products is necessary for continued improve of use by the cattle industry. The objective of this study was to evaluate three novel corn bran products from Cargill Wet Milling on rumen fermentation, digestion and blood profiles in cattle.



**Table 1. Diet composition (DM basis) fed to fistulated steers to evaluate nutrient digestion of steers fed different corn bran products**

| | Treatments[1] | | | |
|---|---|---|---|---|
| Ingredient, % DM | TRT A | TRT B | TRT C | SFC Control |
| Bran A | 70 | - | - | - |
| Bran B | - | 70 | - | - |
| Bran C | - | - | 70 | - |
| Sweet Bran™ | - | - | - | 25 |
| Steam Flaked Corn (SFC) | 25 | 25 | 25 | 70 |
| Wheat Straw | 5 | 5 | 5 | 5 |
| **Nutrient composition[2], %DM** | | | | |
| Organic Matter (OM) | 93.9 | 95.4 | 95.8 | 95.4 |
| Crude Protein | 17.9 | 14.2 | 13.7 | 14.3 |
| Starch | 28.8 | 42.8 | 48.6 | 58.5 |
| Neutral Detergent Fiber (NDF) | 33.5 | 26.6 | 24.3 | 20.1 |

[1] Treatment include: TRT A, 70% Bran A, 25% SFC, 5% wheat straw on dry matter basis; TRT B, 70% Bran B, 25% SFC, 5% wheat straw on dry matter basis; TRT C, 70% Bran C, 25% SFC, 5% wheat straw on dry matter basis; SFC Control, 25% Sweet Bran™, 70% SFC, 5% wheat straw on dry matter basis

[2] Based on analyzed nutrients for each ingredient

## Procedure

All corn bran products (Bran A/B/C) and Sweet Bran® were provided by Cargill Wet Milling (Blair, NE). Eight ruminally cannulated beef steers were utilized in a 4×4 replicated Latin Square design with four treatment periods. Steers were housed individually in concrete slatted pens with *ad libitum* access to feed and water. Within Square, four steers were assigned randomly to four treatment diets over four periods. Composition of treatment diets (Table 1, dry matter basis) were 70% Bran A, Bran B or Bran C in TRT A, B and C, respectively, in addition to 25% steam flaked corn (SFC) and 5% wheat straw. The SFC Control diet served as an internal control which consisted of 25% Sweet Bran®, 70% SFC and 5% wheat straw. Minerals and vitamins were blended in the bran products and Sweet Bran® to meet or exceed the animals' requirements. Each period was 21 d in length with 14 d of adaptation followed by 7 d of collection. Diets were mixed twice weekly and stored in a cooler to ensure freshness. Steers were fed twice daily at 0700 h and 1300 h, and feed refusals were removed and weighed daily before morning feeding. Refusals were collected for day 16 to 19, and dried in 140 °F forced-air oven for 48 hours to correct DMI. Refusals were ground through a 1-mm screen using a

**Table 2. Total tract digestibility for steers fed different corn bran products**

| | Treatments[1] | | | | | |
|---|---|---|---|---|---|---|
| Item[2] | TRT A | TRT B | TRT C | SFC Control | SEM | *P*-Value |
| **DM** | | | | | | |
| Intake, lb | 26.6 | 26.4 | 27.1 | 27.2 | 1.36 | *0.97* |
| Fecal output, lb | 7.8 | 7.5 | 7.9 | 7.2 | 0.43 | *0.68* |
| Digestibility, % | 71.37[b] | 71.92[b] | 71.05[b] | 73.63[a] | 0.65 | *0.05* |
| **OM** | | | | | | |
| Intake, lb | 25.0 | 25.2 | 26.0 | 26.0 | 1.28 | *0.93* |
| Fecal output, lb | 6.6 | 6.5 | 7.0 | 6.3 | 0.38 | *0.63* |
| Digestibility, % | 74.26[b] | 74.58[ab] | 73.20[b] | 75.82[a] | 0.63 | *0.06* |
| **NDF** | | | | | | |
| Intake, lb | 9.0[a] | 7.1[b] | 6.6[b] | 5.5[c] | 0.38 | *<.01* |
| Fecal output, lb | 3.8 | 3.7 | 4.0 | 3.6 | 0.23 | *0.67* |
| Digestibility, % | 59.04[a] | 48.31[b] | 39.97[c] | 34.95[d] | 2.00 | *<.01* |
| **Starch** | | | | | | |
| Intake, lb | 7.8[d] | 11.6[c] | 13.4[b] | 16.2[a] | 0.60 | *<.01* |
| Fecal output, lb | 0.1[c] | 0.3[b] | 0.5[a] | 0.1[c] | 0.04 | *<.01* |
| Digestibility, % | 99.20[a] | 97.60[b] | 96.58[c] | 99.29[a] | 0.23 | *<.01* |
| **Energy** | | | | | | |
| Apparent Energy Digestibility, % | 70.69 | 70.83 | 68.68 | 71.25 | 0.93 | *0.24* |
| DE, Mcal/day | 36.80 | 36.31 | 36.19 | 36.62 | 1.84 | *0.99* |
| DE Mcal/lb | 1.40 | 1.39 | 1.34 | 1.35 | 0.02 | *0.21* |

[a-d] Means in a row with different superscripts are different ($P < 0.10$)

[1] Treatment include: TRT A, 70% Bran A, 25% SFC, 5% wheat straw on dry matter basis; TRT B, 70% Bran B, 25% SFC, 5% wheat straw on dry matter basis; TRT C, 70% Bran C, 25% SFC, 5% wheat straw on dry matter basis; SFC Control, 25% Sweet Bran™, 70% SFC, 5% wheat straw on dry matter basis

[2] DM: Dry matter; OM: Organic matter; NDF: Neutral detergent fiber; DE: Digestible energy

Wiley mill, composited by steer within each period and analyzed to correct nutrient intake. Samples of individual ingredients were taken before diet mixing during collection week, composited by period, lyophilized, and ground through a 1-mm screen. Steers were dosed twice daily through the rumen cannula with titanium dioxide (5g/dose or 10 g/day) at 0700 and 1700 h from day 7 to day 20 of each period. Fecal grab samples were taken at 0700, 1100, 1500, 1900, 2300 and 0300 h and composited on wet basis (30 g each) daily on day 19 and 20. The lyophilized and ground (1 mm) daily fecal composites were then composited on a dry weight basis by steer within each collection period. Fecal samples (ground through 0.5 mm screen) were analyzed for titanium dioxide concentration and used to determine total fecal output.

Feed, refusals and fecal samples (ground through 1 mm screen) were analyzed for gross energy content (calories/g) using a bomb calorimeter. Digestible energy (DE) was calculated by subtracting the fecal energy from the total gross energy intake. Nutrients such as dry matter (DM), organic matter (OM), neutral detergent fiber (NDF), and starch content of feed, refusals and fecal samples were also analyzed and used for calculation of total tract nutrient digestibility. Behavior measuring tags (CowManager) and pH probes (Smaxtec) were used during the entire period to measure rumination activity and ruminal pH, respectively. Catheters were put in jugular vein to collect blood at 0700, 1100, 1500, 1900, 2300 and 0300 h on day 19 and 20 for blood gas (ABL90 FLEX blood gas analyzer) measurements.

Nutrient digestibility, rumination and ruminal pH (by day average, minimum, maximum, etc) data were analyzed using the PROC MIXED procedure of SAS 9.4 (SAS Institute, Inc., Cary, NC, USA), with period, treatment and steer within square as fixed effect. The ruminal pH and blood gas measurements were analyzed using the PROC MIXED procedure with treatment, period, hour, treatment by hour interaction included in the model and hour being considered a repeated measure. *P*-values ≤ 0.10 were considered significant.

## Results

There was no dietary treatment effect on DM and OM intake or fecal output (Table 2; $P \geq 0.63$). Dry matter and OM digestibility was greatest ($P \leq 0.06$) for SFC control, with no difference among TRT A, B and C in which each of the bran products were included at 70%. Neutral detergent fiber intake was greatest ($P < 0.01$) for TRT A, least for SFC control, with TRT B and C being intermediate. The NDF intake difference was due to different dietary NDF content (Table 1) of each diet, in which the TRT A diet had the greatest NDF content, SFC control had the least NDF content provided mainly by wheat straw. There was no difference for NDF fecal output ($P = 0.67$) among treatments. The digestibility of NDF ($P < 0.01$) was least for SFC control when compared to other treatments. Among TRT A, B and C where each bran product included at 70%, the NDF digestibility was greatest for TRT A, least for TRT C, with TRT B being intermediate. Starch intake was greatest ($P < 0.01$) for steers fed SFC control diet as it contained the greatest starch content (58.5% of diet DM; Table 1). Starch intake

**Table 3. Ruminal pH characteristics for steers fed different corn bran products**

| | Treatments[1] | | | | | |
|---|---|---|---|---|---|---|
| Item[2] | TRT A | TRT B | TRT C | SFC Control | SEM | *P*-Value |
| Minimum | 5.96 | 5.97 | 5.86 | 5.90 | 0.05 | *0.38* |
| Maximum | 6.56 | 6.61 | 6.67 | 6.70 | 0.05 | *0.24* |
| Average | 6.25 | 6.29 | 6.29 | 6.32 | 0.04 | *0.69* |
| Magnitude | 0.59[b] | 0.64[b] | 0.81[a] | 0.80[a] | 0.06 | 0.05 |
| Variation | 0.138[b] | 0.145[b] | 0.181[a] | 0.190[a] | 0.013 | *0.02* |

[a-b] Means in a row with different superscripts are different ($P < 0.10$)

[1] Treatment include: TRT A, 70% Bran A, 25% SFC, 5% wheat straw on dry matter basis; TRT B, 70% Bran B, 25% SFC, 5% wheat straw on dry matter basis; TRT C, 70% Bran C, 25% SFC, 5% wheat straw on dry matter basis; SFC Control, 25% Sweet Bran™, 70% SFC, 5% wheat straw on dry matter basis

[2]Averages of pH over 4 days during the collection week

**Table 4. Rumination characteristics for steers fed different corn bran products**

| | Treatments[1] | | | | | |
|---|---|---|---|---|---|---|
| Item | TRT A | TRT B | TRT C | SFC Control | SEM | *P*-Value |
| Ruminating, min/day | 298 | 319 | 339 | 356 | 19.1 | *0.20* |
| Ruminating, min/ lb DMI | 10.8 | 11.5 | 12.5 | 12.9 | 0.66 | *0.13* |
| Eating, min/day | 33.9 | 48.7 | 44.6 | 47.5 | 6.58 | *0.39* |

[a-b] Means in a row with different superscripts are different ($P < 0.10$)

[1] Treatment include: TRT A, 70% Bran A, 25% SFC, 5% wheat straw on dry matter basis; TRT B, 70% Bran B, 25% SFC, 5% wheat straw on dry matter basis; TRT C, 70% Bran C, 25% SFC, 5% wheat straw on dry matter basis; SFC Control, 25% Sweet Bran™, 70% SFC, 5% wheat straw on dry matter basis

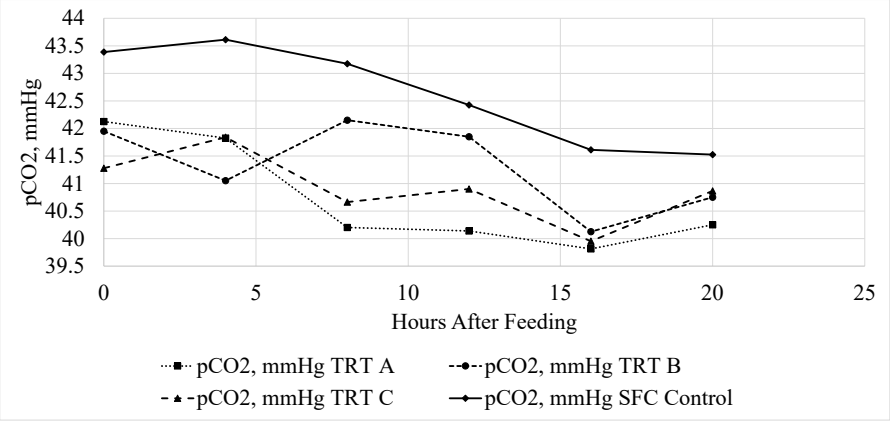


Figure 1. Jugular Vein Blood $pCO_2$ for Stees fed Different Corn Bran Products

was least for TRT A, with TRT B having less starch intake than TRT C. Fecal starch output ($P < 0.01$) was greatest for TRT C, least for TRT A and SFC control, with TRT B being intermediate. There was no difference ($P = 0.78$) for starch digestibility between TRT A and SFC control; with TRT C having the least starch digestibility and TRT B being intermediate. Even though apparent energy digestibility of the SFC control treatment was numerically higher, there was no dietary treatment effect ($P \geq 0.20$) on energy digestibility, digestible energy intake per day or digestible energy per lb of the DMI among treatments.

There was no dietary treatment effect ($P \geq 0.24$; Table 3) on average, minimum, and maximum rumen pH parameters. Ruminal pH values below 5.6 were not observed in this study, mainly due to the higher inclusion of corn bran products in the diets; even the SFC control diet had a NDF level greater than 20%. There were significant differences ($P \leq 0.05$) in the magnitude and variation of ruminal pH. Steers fed SFC control and TRT C diet exhibited greater ruminal pH change magnitude ($P \leq 0.05$) and variation ($P \leq 0.02$) when compared to steers fed TRT A or B. There was no treatment effect ($P \geq 0.13$) on ruminating (expressed as minutes per day or per lb DMI) and eating (expressed as minutes per day) activity of steers fed different corn bran products (Table 4). Among the jugular vein blood parameters measured in this study, no treatment effect ($P \geq 0.20$) was observed for blood Glucose, Lactate, pH and partial pressure of $O_2$ (data not shown). A Treatment × Hour effect ($P = 0.04$) on blood partial pressure of $CO_2$ ($pCO_2$) was observed where the SFC control-fed steers exhibited greater $pCO_2$ (Figure 1). The increased $pCO_2$ may indicate an increased production and absorption of VFA from the rumen to the blood.

## Conclusion

There was no difference in DM/OM digestibility among the three corn bran products when included at 70% of the diet DM; while the NDF and starch digestibility were greatest for TRT A, least for TRT C with TRT B being intermediate. Results indicated that digestion trait differences existed among different corn bran products from corn wet milling processing and Bran A resulted in better digestion in terms of NDF and starch. The SFC Control exhibited the highest DM, OM and starch digestibility, and the least NDF digestibility, while the digestible energy was not different among treatments, which suggested that either corn bran products could replace SFC in the diet up to 70% inclusion without impacting digestible energy intake.

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# Effect of Finishing Cattle with Blends of High Moisture and Steam-Flaked Corn with and without Distillers Grains

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**Summary with Implications**

*The objective of this study was to determine the impacts of feeding different ratios of high-moisture corn and steam-flaked corn in diets with or without distillers grains and test for an associative effect between grain processing methods. Steers (n=120; BW=775 ± 15.6 lb) were assigned randomly to one of 8 diets. Diets tested included 100:0, 75:25, 50:50, 25:75, and 0:100 of high-moisture corn:steam-flaked corn in diets with 20% modified distillers grains or 100:0, 50:50, and 0:100 in diets without distillers grains. There was an interaction observed for average daily gain as gain improved in 50:50 blends of HMC:SFC in diets without distillers grains and was not different as grain type changed when distillers grains was in the diet. Feeding modified distillers grains plus solubles increased carcass weight, average daily gain, intake, and fat thickness compared to control diets. Also feeding greater inclusions of steam-flaked corn resulted in an improvement in feed conversion. In conclusion, a possible positive associative effect was observed for a 50:50 blend of high-moisture corn and steam-flaked corn when no byproduct was included in the diet. Including modified distillers grains plus solubles in these finishing diets improved gain when compared to diets without byproducts. Additionally, feeding steam-flaked corn improved conversion compared to high-moisture corn.*



## Introduction

Steam-flaking is a corn processing method widely used by feedlots located in the southern United States. Higher priced corn can make steam-flaking more economical due to improved feed conversion (F:G) by maximizing starch digestibility. Likewise, access to distillers grains (DGS) and benefits from harvesting and storing corn early in the fall has led to Midwestern feedlots basing their rations around high-moisture corn (HMC) and distillers grains, which also improves F:G compared to dry-rolled corn based diets. Use of steam-flaked corn (SFC) in Midwest finishing rations is increasing. Some producers recognize the benefits of having corn inventory and price secured in the fall and continue to store and feed HMC in their operations. While both SFC and HMC are rapidly fermented in the rumen, it is possible that rates of fermentation differ so that a positive associative effect may be observed when fed in combination.

Distillers grains, a byproduct of the ethanol industry, continues to be an economical source of both protein and energy in Midwestern finishing rations. Steam-flaked corn has improved F:G compared to HMC when fed without distillers (*2007 Nebraska Beef Cattle Report*, pp. 33–35). Similarly, SFC has improved F:G compared to DRC when fed without byproducts, but when both corn types are fed with 35% wet DGS, performance is similar (*2012 Nebraska Beef Cattle Report*, pp. 70–72). When distillers grains is included in HMC diets and SFC diets, F:G has been variable depending on the study (*2007 Nebraska Beef Cattle Report*, pp. 33–35; *2021 Nebraska Beef Cattle Report*, pp. 44–45). Therefore, the objective of this experiment was to determine the implications of feeding different inclusions of HMC and SFC with and without 20% modified DGS (MDGS) in the diet on a DM basis. Additionally, this study was designed to determine if positive associative effects are observed when HMC and SFC are fed together in diets with or without MDGS.

## Procedure

The relationship between HMC and SFC in diets with and without MDGS was explored at the Eastern Nebraska Research and Extension Center (ENREC) to compare finishing cattle performance. This study utilized 120 crossbred yearling steers (775 ± 15.6 lbs) individually fed from the end of June to mid-November using the Calan gate system. Treatments included (Table 1) 100% HMC, 50:50 blend HMC:SFC, or 100% SFC fed with and without distillers. Additionally, a 25:75 blend and a 75:25 blend of HMC:SFC was fed with MDGS only for a total of 8 treatments (DM basis; corn grain was included at 60% of the diet when MDGS was included and 80% of the diet when MDGS was not included). All cattle were stepped up to their respective diet over 22 d with corn replacing silage and wheat straw. Initial diets included 40% corn silage and 20% or 25% wheat straw for the control diets and MDGS diets, respectively. Control diets included 30% corn in step one and increased by an average of 12.5 units over 4 steps to reach a finishing diet containing 80% corn. Similarly, MDGS diets contained 15% corn in step one and increased by an average of 11.3 units over 4 steps to reach a finishing diet containing 60% corn. Distillers inclusion remained constant across all steps at 20% DM. Steam-flaked corn averaged 29.9 lb/bu and was delivered three times per week from Raikes Feedlot near Memphis, Nebraska. High moisture corn (70% DM) was harvested, rolled in a roller mill, and stored in bunkers before initiation of this trial. All diets contained 15% corn silage and 5% supplement, which was formulated with 1% urea and 0.5% Empyreal (Cargill corn milling, Blair NE) in diets without MDGS and 0.5% urea in diets with MDGS to ensure metabolizable protein requirements were met. All supplements were formulated to provide 30 g/ton of DM Rumensin (Elanco Animal Health) and to provide 90 mg/steer daily Tylan (Elanco Animal Health).

Cattle were implanted on day 1 with

**Table 1. Composition of steam-flaked corn and high-moisture corn based finishing diets with or without modified distillers gains plus solubles**

| | Control | | | 20% MDGS | | | | |
|---|---|---|---|---|---|---|---|---|
| | HMC | 50:50 HMC:SFC[5] | SFC | HMC | 75:25 HMC:SFC | 50:50 HMC:SFC | 25:75 HMC:SFC | SFC |
| SFC[1] | - | 40.0 | 80.0 | - | 15.0 | 30.0 | 45.0 | 60.0 |
| HMC[2] | 80.0 | 40.0 | - | 60.0 | 45.0 | 30.0 | 15.0 | - |
| MDGS[3] | - | - | - | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 |
| Corn Silage | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |
| Supplement[4] | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| Urea | 1.0 | 1.0 | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Empyreal | 0.5 | 0.5 | 0.5 | - | - | - | - | - |

[1]SFC—Steam-flaked corn average (29.9 lb/bu.)

[2]HMC—High-moisture corn (70% DM rolled and stored in bunker).

[3]MDGS—modified distillers grains plus solubles. (51.2% DM)

[4]Supplement—formulated to contain 30 g/ton monensin (Rumensin, Elanco Animal Health) diet DM, and provide 90 mg/hd/d tylosin (Tylan, Elanco Animal Health). Suppment contained limestone, vitamins ADE, and trace mineral package to meet all mineral and vitamin requirements.

[5]HMC:SFC—ratio of high-moisture corn to steam-flaked corn in each diet

Revalor IS (Merck Animal Health) and re-implanted on day 51 with Revalor 200 (Merck Animal Health). Cattle were on feed 140 days. Initial body weight (BW) was determined based on an average 3-day BW following 5 days of limit feeding to equalize gut fill. Before slaughter, a 1-day final BW was collected and animals were slaughtered at a commercial abattoir. During harvest, hot carcass weight (HCW) was recorded and carcass adjusted final BW was calculated based on a common 63% dressing percentage. Carcass characteristics including marbling, 12$^{th}$ rib fat thickness, and *Longissimus* muscle (LM) area were collected following a 48-hour chill.

Data were analyzed using the PROC MIXED procedure of SAS (SAS Institute Inc., Cary, N.C.) as a completely randomized design with cattle stratified by initial BW and animal was the experimental unit. This resulted in 15 replications per diet. The model included the proportion of SFC and HMC, distillers inclusion, and interaction for those 3 ratios balanced across both distillers inclusions. Linear and quadratic contrasts were developed to evaluate corn ratio in diets with 20% MDGS. For the 3 ratios balanced with 0 or 20% MDGS, corn processing ratio within distillers inclusion was tested for linear and quadratic responses. Main effects of distillers inclusion and corn ratio (100:0, 50:50, and 0:100) are presented if an interaction was not detected. A *P*-value of less than 0.10 was considered significant.

## Results

A tendency for an interaction ($P = 0.11$; Table 2) was observed for ADG between distillers inclusion and ratio of HMC:SFC. Cattle fed diets with no distillers grains exhibited a quadratic response (P = 0.07) with ADG increasing when diets changed from 100% HMC to 50:50 blend, which was similar to cattle fed 100% SFC. Based on ADG, a positive associative effect was observed for the 50:50 blend of HMC:SFC in diets without MDGS, but ADG was not positively impacted for the 50:50 treatment compared to either 100% SFC or 100% HMC in diets with 20% MDGS. Gain was not impacted ($P > 0.59$) as SFC replaced HMC in diets with 20% MDGS.

Additionally, a tendency for an interaction was detected for backfat ($P = 0.13$). Diets without MDGS had a tendency for a linear increase ($P = 0.13$) from 0.42 inches to 0.49 inches as diets increased in SFC inclusion from 0 to 100%. Diets containing MDGS had no difference in backfat ($P = 0.66$; Table 2) and averaged 0.54 inches.

There were no interactions for any other parameters measured so main effects of corn blends and distillers inclusion will be discussed. There was a tendency for live final BW, carcass adjusted final BW, and HCW to linearly increase ($P \leq 0.15$) as SFC inclusion increased in the diet. Also F:G improved significantly ($P = 0.03$) as SFC increased in the diet due to DMI remaining constant ($P = 0.67$). Marbling also linearly increased ($P = 0.08$) as SFC inclusion increased in the diet. Modified distillers grains inclusion resulted in improved ($P \leq 0.04$) carcass adjusted final BW, HCW, DMI, and fat thickness compared to diets without MDGS. No differences ($P \geq 0.19$) in F:G, *longissimus* muscle area, or marbling were detected for diets with or without MDGS.

For the different ratios of HMC:SFC within diets containing 20% MDGS, there was little impact on final BW, HCW, DMI, or ADG ($P > 0.26$; Table 3). Based on changes in DMI and ADG, although not significant, there was an impact on F:G due to ratio of HMC:SFC. As SFC replaced HMC in diets containing 20% MDGS, F:G improved linearly ($P = 0.09$). Carcass characteristics were not impacted ($P > 0.44$) as ratio of HMC:SFC changed in diets with 20% MDGS.

## Conclusion

These data demonstrate a positive associative effect at a 50:50 HMC:SFC blend when fed without MDGS, shown by similar ADG and F:G for the 50:50 blend and 0:100 blend of HMC:SFC which were both improved compared to 100:0 blend. These

**Table 2. Effect of steam-flaked corn and high-moisture corn inclusion in finishing diets with or without modified distillers grains**

| | HMC | 50:50 HMC:SFC[5] | SFC | SEM | C x D Lin[6] | C x D Quad | Lin | Quad | DGS[7] |
|---|---|---|---|---|---|---|---|---|---|
| Initial BW, lb | | | | 15.6 | 0.80 | 0.74 | 0.66 | 0.67 | 0.86 |
| 0% MDGS[8] | 773 | 776 | 776 | - | - | - | 0.89 | 0.94 | - |
| 20% MDGS[9] | 768 | 784 | 779 | - | - | - | 0.43 | 0.8 | - |
| Live FBW, lb | | | | 25.4 | 0.87 | 0.71 | 0.15 | 0.68 | 0.32 |
| 0% MDGS | 1318 | 1356 | 1359 | - | - | - | 0.25 | 0.58 | - |
| 20% MDGS | 1349 | 1366 | 1381 | - | - | - | 0.28 | 0.71 | - |
| Adj. FBW[1], lb | | | | 28.0 | 0.59 | 0.27 | 0.11 | 0.38 | 0.04 |
| 0% MDGS | 1280 | 1357 | 1339 | - | - | - | 0.13 | 0.16 | - |
| 20% MDGS | 1360 | 1369 | 1389 | - | - | - | 0.26 | 0.99 | - |
| ADG, lb | | | | 0.149 | 0.23 | 0.11 | 0.14 | 0.32 | 0.02 |
| 0% MDGS | 3.63 | 4.15 | 4.02 | - | - | - | 0.06 | 0.07 | - |
| 20% MDGS | 4.23 | 4.18 | 4.27 | - | - | - | 0.59 | 0.91 | - |
| DMI, lb | | | | 0.73 | 0.27 | 0.21 | 0.67 | 0.86 | <0.01 |
| 0% MDGS | 22.1 | 23.2 | 22.6 | - | - | - | 0.63 | 0.32 | - |
| 20% MDGS | 25.3 | 24.1 | 24.2 | - | - | - | 0.31 | 0.99 | - |
| F:G[2] | | | | - | 0.78 | 0.46 | 0.03 | 0.42 | 0.92 |
| 0% MDGS | 6.22 | 5.68 | 5.67 | - | - | - | 0.09 | 0.28 | - |
| 20% MDGS | 6.02 | 5.79 | 5.70 | - | - | - | 0.09 | 0.93 | - |
| HCW[3], lb | | | | 17.6 | 0.59 | 0.27 | 0.11 | 0.38 | 0.04 |
| 0% MDGS | 807 | 855 | 844 | - | - | - | 0.13 | 0.16 | - |
| 20% MDGS | 857 | 863 | 875 | - | - | - | 0.26 | 0.99 | - |
| LM Area, in$^2$ | | | | 0.38 | 0.81 | 0.26 | 0.20 | 0.72 | 0.19 |
| 0% MDGS | 13.9 | 14.6 | 14.5 | - | - | - | 0.28 | 0.29 | - |
| 20% MDGS | 14.6 | 14.6 | 15 | - | - | - | 0.66 | 0.76 | - |
| Fat, in | | | | 0.036 | 0.13 | 0.80 | 0.55 | 0.92 | <0.01 |
| 0% MDGS | 0.42 | 0.45 | 0.49 | - | - | - | 0.13 | 0.92 | - |
| 20% MDGS | 0.55 | 0.54 | 0.51 | - | - | - | 0.66 | 0.73 | - |
| Marbling[4] | | | | 26.8 | 0.77 | 0.28 | 0.08 | 0.72 | 0.58 |
| 0% MDGS | 439 | 482 | 492 | - | - | - | 0.15 | 0.61 | - |
| 20% MDGS | 451 | 438 | 489 | - | - | - | 0.44 | 0.68 | - |

[1]Adjusted final body weight—calculated based on HCW/common 63% dress

[2]F:G—feed conversion calculated based on DMI/ADG

[3]HCW—hot carcass weight

[4]Marbling—400 = small 00, 500 = modest 00, 600 = moderate 00

[5]HMC:SFC—ratio of high-moisture corn to steam-flaked corn in each diet

[6]C x D Lin—p-value testing for linear interactions between corn type and distillers inclusion

[7]DGS—main effect of modified distillers grains

[8]0% MDGS—p-values represent the simple effects in 0% distillers diets

[9]20% MDGS—p-values represent the simple effects in 20% distillers diets

**Table 3. Effect of steam-flaked corn and high-moisture corn inclusion in finishing diets fed with 20% MDGS on performance characteristics**

| | HMC | 75:25 HMC:SFC[5] | 50:50 HMC:SFC | 25:75 HMC:SFC | SFC | SEM | Lin[6] | Quad |
|---|---|---|---|---|---|---|---|---|
| Initial BW, lb | 768 | 762 | 784 | 779 | 779 | 15.6 | 0.43 | 0.80 |
| Live FBW, lb | 1349 | 1369 | 1366 | 1394 | 1381 | 25.4 | 0.28 | 0.71 |
| Adj. FBW[1], lb | 1360 | 1359 | 1369 | 1401 | 1389 | 28.0 | 0.26 | 0.99 |
| ADG, lb | 4.23 | 4.27 | 4.18 | 4.44 | 4.27 | 0.149 | 0.59 | 0.91 |
| DMI, lb/d | 25.3 | 25.5 | 24.1 | 25.3 | 24.2 | 0.73 | 0.31 | 0.99 |
| F:G[2] | 6.02 | 6.09 | 5.79 | 5.72 | 5.70 | — | 0.09 | 0.93 |
| HCW[3], lb | 857 | 856 | 863 | 882 | 875 | 17.6 | 0.26 | 0.99 |
| LM Area, in$^2$ | 14.6 | 15.0 | 14.6 | 14.7 | 15.0 | 0.38 | 0.66 | 0.76 |
| 12$^{th}$ rib Fat, in | 0.55 | 0.53 | 0.54 | 0.55 | 0.51 | 0.036 | 0.66 | 0.73 |
| Marbling[4] | 451 | 489 | 438 | 476 | 489 | 26.8 | 0.44 | 0.68 |

[1]Adjusted final body weight—calculated based on HCW/common 63% dress

[2]F:G—feed conversion calculated based on DMI/ADG

[3]HCW—hot carcass weight

[4]Marbling—400 = small 00, 500 = modest 00

[5]HMC:SFC—ratio of high-moisture corn to steam-flaked corn in each diet

[6] Lin—p-value testing linear differences between inclusion of grain in diets containing 20% MDGS

data suggest that feeding higher inclusions of SFC in diets that contain MDGS will improve feed conversion. Finally, these data support the idea that replacing HMC, SFC, or a blend of the two grains with MDGS results in increased final BW, HCW, ADG, and DMI, but does not change feed efficiency. In conclusion, replacing HMC with SFC will result in improved feed efficiency and replacing these grains with MDGS will increase final weight and ADG, but feed efficiency will be similar.

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# Evaluating Performance of Cattle Fed Steam-Flaked Corn Based Finishing Diets fed Increasing Inclusions of Wet or Modified Distillers Grains

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## Summary with Implications

*A finishing trial using 560 calf-fed steers was conducted to evaluate the effect of distillers type and inclusion on finishing cattle performance and carcass characteristics in steam-flaked corn based diets. Treatments were applied in a 2 × 3 + 1 factorial arrangement, with the first factor being distillers type (modified distillers grains plus solubles or wet distillers grains plus solubles) and the second factor being distillers grains inclusion of 10%, 20%, or 30%, as well as a control diet containing no distillers. There was an interaction between inclusion and type of distillers for feed conversion. A linear improvement in feed conversion was observed as wet distillers inclusion increased but no change in feed conversion was observed with increasing modified distillers inclusion. Cattle fed distillers grains had greater intake, gain, and carcass weights. Cattle fed modified distillers had greater intake but poorer feed conversion compared to cattle fed wet distillers. Feeding wet distillers in steam-flaked corn-based finishing diets improved gain and feed conversion while feeding modified distillers increased gain but not feed efficiency.*

## Introduction

Steam-flaked corn (SFC) has been widely used in feedlots in the southern United States to improve feed conversion (F:G) by increasing total tract starch digestibility. Research has shown that feeding SFC results in a 12% improvement in F:G compared to feeding dry-rolled corn based diets when no byproducts are fed. Distillers grains has become a common ingredient in feedlot diets in the Midwest. Adding distillers to feedlot diets is largely due to availability and a competitive price relative to the performance benefits associated with feeding distillers in dry-rolled corn or high-moisture corn based finishing diets. The relationship between SFC and distillers grains is not well understood. Research has shown no change in feed efficiency when wet distillers grains plus solubles (WDGS) were fed in SFC based diets (*2007 Nebraska Beef Cattle Report*, pp. 33–35; *2012 Nebraska Beef Cattle Report*, pp. 70–72) and similar feed efficiency was observed when modified distillers grains plus solubles (MDGS) were fed with SFC (*2022 Nebraska Beef Cattle Report*, pp. 53–56). Steam flaking in the Midwest is increasing in prevalence, so understanding response to distillers in SFC diets is important. The objective of this study was to compare the effect of feeding MDGS or WDGS at increasing inclusions in SFC-based finishing diets on feedlot performance and carcass characteristics.

## Procedure

A feedlot study was conducted at the University of Nebraska-Lincoln Eastern Nebraska Research and Extension Center (ENREC) near Mead, Nebraska. Crossbred calf-fed steers (n=560; initial BW = 658 ± 3.8 lb) were used in a 2 × 3 + 1 factorial design with factors consisting of two distillers types (MDGS or WDGS) fed at 10%, 20%, or 30% of diet dry matter (DM) replacing SFC. A 0% distillers treatment was used for a control diet and was considered the 0% inclusion for both distillers types when determining type by level interactions. Corn silage was used as the roughage source in all diets (Table 1). Supplements were formulated to meet metabolizable protein and rumen degradable protein requirements for each diet. A branded corn gluten meal (Empyreal, Cargill, Blair, NE) was added at 2.0% and 1.0% DM-basis for the control diet and the 10% distillers diets, respectively. Urea was added at 1.2, 0.8, and 0.4% DM-basis for the control diet, 10% distillers diets, and 20% distillers diets, respectively. No additional protein was added to the diets containing 30% distillers. All supplements were formulated to supply 30 g/ton Rumensin (Elanco Animal Health) on a DM basis and to provide 90 mg/steer daily of Tylan (Elanco Animal health). All cattle were stepped up to their respective diet over 25 d with SFC replacing grass hay and corn silage. Initially grass hay and corn silage were included in all diets at 26% and 30%, respectively. Steam-flaked corn averaged 29.6 lb/bu and was delivered three times per week from Raikes Feedlot near Memphis, Nebraska. Initial body weight (BW) was determined based on an average of 2-day BW following 5 days of limit feeding a 50% alfalfa 50% sweetbran diet at 2.0% of BW to equalize gut fill. Three blocks were used with 4 replications on the light block, 3 replications on the mid block, and 1 replication on the heavy block for a total of 56 pens and 8 replications per treatment (10 steers/pen).

Cattle were implanted on day 1 with a Revalor IS (Merck Animal Health). Steers on the mid/heavy blocks were reimplanted on day 70 and steers on the light block were reimplanted on day 75. Cattle were on feed for 174 and 188 d for the mid/heavy and light blocks, respectively. Cattle were slaughtered at a commercial abattoir (Greater Omaha Packing, Omaha, NE). One day final BW were collected on the day that cattle shipped to the plant. Hot carcass weight (HCW) and liver scores were collected on the day of slaughter and LM area, USDA marbling score, and 12$^{th}$ rib fat thickness were collected following a 48-hour chill. Final live BW was calculated using the pen average final live BW shrunk 4% to adjust for fill. Carcass adjusted final BW was calculated by dividing HCW by a common dressing percentage of 63%.

Data were analyzed using GLIMMIX procedure of SAS as a 2 × 3 + 1 factorial design with main effects of distillers grains type and distillers grains inclusion, and the appropriate interactions. Orthogonal

**Table 1. Composition of steam-flaked corn based finishing diets with increasing inclusions of wet distillers grains plus solubles or modified distillers grains plus solubles.**

| | Treatments | | | | | | |
|---|---|---|---|---|---|---|---|
| Ingredient | Control | 10% MDGS | 20% MDGS | 30% MDGS | 10% WDGS | 20% WDGS | 30% WDGS |
| SFC[1] | 79.0% | 69.0% | 59.0% | 49.0% | 69.0% | 59.0% | 49.0% |
| MDGS[2] | - | 10.0% | 20.0% | 30.0% | - | - | - |
| WDGS[3] | - | - | - | - | 10.0% | 20.0% | 30.0% |
| Corn Silage | 15.0% | 15.0% | 15.0% | 15.0% | 15.0% | 15.0% | 15.0% |
| Supplement[4] | 6.0% | 6.0% | 6.0% | 6.0% | 6.0% | 6.0% | 6.0% |
| FGC[5] | 0.45% | 1.89% | 3.43% | 3.83% | 1.89% | 3.43% | 3.83% |
| Limestone | 1.66% | 1.63% | 1.63% | 1.63% | 1.63% | 1.63% | 1.63% |
| Tallow | 0.30% | 0.30% | 0.30% | 0.30% | 0.30% | 0.30% | 0.30% |
| Urea | 1.20% | 0.80% | 0.40% | - | 0.80% | 0.40% | - |
| Empyreal | 2.00% | 1.00% | - | - | 1.00% | - | - |
| Salt | 0.30% | 0.30% | 0.30% | 0.30% | 0.30% | 0.30% | 0.30% |
| Trace Mineral | 0.05% | 0.05% | 0.05% | 0.05% | 0.05% | 0.05% | 0.05% |
| Vit ADE | 0.015% | 0.015% | 0.015% | 0.015% | 0.015% | 0.015% | 0.015% |
| Rumensin | 0.017% | 0.017% | 0.017% | 0.017% | 0.017% | 0.017% | 0.017% |
| Tylan | 0.01% | 0.01% | 0.01% | 0.01% | 0.01% | 0.01% | 0.01% |

[1]SFC—steam-flaked corn (29.6 lb/bu)

[2]MDGS—modified distillers grains plus solubles (45.6% DM)

[3]WDGS—wet distillers grains plus solubles (29.6% DM)

[4]Supplment—formulated to target 30 g/ton Rumensin and 90 mg/steer Tylan

[5]FGC—fine ground corn

**Table 2. Effect of modified distillers grains plus solubles or wet distillers grains plus solubles inclusion in steam-flaked corn based finishing diets on performance characteristics.**

| | Control | 10% MDGS | 20% MDGS | 30% MDGS | 10% WDGS | 20% WDGS | 30% WDGS | SEM | Level X Type | Type | MDGS Linear | MDGS Quad | WDGS Linear | WDGS Quad |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Initial BW, lb | 659 | 657 | 657 | 658 | 656 | 658 | 659 | 33.3 | 0.23 | 0.68 | 0.53 | 0.16 | 0.53 | 0.06 |
| Live Final BW, lb | 1350 | 1382 | 1375 | 1394 | 1376 | 1407 | 1402 | 42.4 | 0.33 | 0.28 | 0.03 | 0.60 | <0.01 | 0.21 |
| Final BW[1], lb | 1338 | 1382 | 1395 | 1400 | 1375 | 1408 | 1409 | 38.7 | 0.44 | 0.66 | <0.01 | 0.13 | <0.01 | 0.17 |
| DMI, lb/d | 20.5 | 21.3 | 21.7 | 21.9 | 21.0 | 21.5 | 21.1 | 0.76 | 0.06 | 0.04 | <0.01 | 0.24 | 0.04 | 0.08 |
| ADG, lb | 3.80 | 4.06 | 4.13 | 4.15 | 4.02 | 4.20 | 4.19 | 0.12 | 0.52 | 0.69 | <0.01 | 0.10 | <.001 | 0.11 |
| F:G | 5.39 | 5.25 | 5.25 | 5.28 | 5.22 | 5.12 | 5.04 | - | 0.02 | 0.03 | 0.26 | 0.24 | <0.01 | 0.58 |
| HCW, lb | 843 | 871 | 879 | 882 | 866 | 887 | 888 | 24.4 | 0.42 | 0.63 | <0.01 | 0.13 | <0.01 | 0.17 |
| LM Area, in$^2$ | 14.0 | 14.4 | 14.4 | 14.4 | 14.2 | 14.1 | 14.1 | 0.36 | 0.20 | 0.05 | 0.08 | 0.15 | 0.69 | 0.33 |
| Fat, in | 0.54 | 0.54 | 0.57 | 0.61 | 0.56 | 0.57 | 0.63 | 0.02 | 0.86 | 0.46 | <0.01 | 0.31 | <0.01 | 0.37 |
| Marbling[1] | 450 | 447 | 458 | 437 | 446 | 459 | 436 | 11.1 | 0.99 | 0.99 | 0.51 | 0.36 | 0.51 | 0.35 |
| Dressing, % | 62.6 | 63.1 | 64.1 | 63.2 | 62.9 | 63.1 | 63.6 | 0.4 | 0.21 | 0.39 | 0.07 | 0.06 | 0.05 | 0.86 |

[1]Final BW—calculated as HCW/a common 63% dress

[2]400 = small, 500 = modest, 600 = moderate

contrasts were used to analyze linear and quadratic effects. The control diet was analyzed as a common 0% distillers inclusion. This control diet was considered the 0% inclusion in both WDGS and MDGS diets. Significance was declared at a $P \leq 0.05$ and tendencies at $P \leq 0.10$.

## Results

There were no interactions between DGS inclusion and DGS type (Table 2) for initial BW, final live BW, carcass adjusted final BW, ADG, HCW, *logissiums* muscle (LM) area, fat, marbling, or dressing percentage ($P > 0.20$). However, an interaction was observed for dry matter intake (DMI; $P = 0.06$) and feed conversion (F:G; $P = 0.02$). Dry matter intake linearly increased as inclusion of DGS increased; however, DMI for steers consuming MDGS increased more dramatically than those consuming WDGS. Dry matter intake of steers fed increasing inclusion of WDGS tended to increase quadratically ($P = 0.08$) with the greatest intake observed at 20% inclusion. Steers fed MDGS had similar F:G as the cattle fed 0% distillers grains on the SFC control diet ($P > 0.24$), whereas F:G improved linearly as WDGS increased in the diet ($P < 0.01$).

Final live BW, adjusted final BW, HCW, and backfat increased linearly ($P \leq 0.03$) as inclusion of distillers grains plus solubles (DGS) increased, regardless of type. Additionally, a tendency for a quadratic increase in ADG ($P \leq 0.11$) from 0% DGS to 30% DGS was observed. The control diet had an ADG of 3.80 lb/d which improved to 4.15 lb/d and 4.19 lb/d at the 30% inclusion of MDGS and WDGS, respectively. Feeding MDGS resulted in an increase in LM area by 0.3 $in^2$ compared to WDGS ($P = 0.05$).

## Conclusion

Overall, feeding distillers grains in SFC based finishing diets resulted in improved HCW, ADG and F:G, but DMI also increased compared to diets without distillers. Interactions between level and type of distillers were observed for F:G and a tendency for an interaction for DMI. Feed efficiency was similar for MDGS compared to the control diet, but linearly improved as WDGS inclusion increased, which was a result of a larger increase in DMI for the cattle fed MDGS and a more subtle increase in DMI when WDGS were used. Wet distillers grains out performed MDGS by maintaining ADG and consuming less feed, resulting in improved F:G, which has been observed in other finishing diets when comparing WDGS and MDGS. Increasing distillers grains, regardless of type, resulted in increased fat depth and tended to increase HCW and FBW. These data suggest that feeding distillers in SFC-based finishing diets will improve cattle ADG, regardless of type. Additionally, feeding WDGS improves F:G when replacing SFC.

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# Impact of Steam-Flaked Rye Fed in Combination with Steam-Flaked Corn on Performance and Carcass Characteristics of Yearling Steers

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### Summary with Implications

*A finishing study evaluated the effect of feeding steam-flaked rye on performance and carcass characteristics of yearling steers. Treatments consisted of different ratios of steam-flaked rye to steam-flaked corn. The ratios were 0:100, 25:75, 50:50, and 100:0 rye:corn. Increasing inclusions of rye linearly decreased final body weight, dry matter intake, average daily gain, and hot carcass weight. As a result, feed conversion was poorer as rye replaced corn. Carcass characteristics reflected lower gain with linear decreases in marbling score, ribeye area, and backfat thickness. There was no difference in yield grade among treatments. Based on dietary energy calculated from performance, steam-flaked rye has approximately 92% the energy value of steam-flaked corn.*

### Introduction

Finishing diets in cattle are always changing in reference to availability of ingredients and grain prices. Traditionally, rye grain has not been a common ingredient in finishing diets due to concerns about ergot toxicity, along with high market prices due to low supply. A new hybrid variety of rye has been released with several benefits such as reduced ergot risk and higher yields. With farmers beginning to utilize this new hybrid, and selling the grain into the market, supply may increase causing prices to become competitive relative to corn in the future.

Previous research has suggested a decrease in average daily gain, dry matter intake and poorer feed conversion when dry rolled rye replaced dry rolled corn in the diet. However, there are no data on feeding steam-flaked rye to feedlot cattle. With the possible increase in rye on the market, research is needed to determine the energy content of feeding steam-flaked rye and impact on performance with increasing inclusion of hybrid rye in cattle diets.

The objective of this study was to determine the effects of feeding different inclusions of steam-flaked hybrid rye (SFR) replacing steam-flaked corn (SFC), on the performance and carcass characteristics of yearling steers.

### Procedure

All procedures involving animal care and management were approved by the University of Nebraska–Lincoln's Institutional Animal Care and Use Committee.

A 140-day finishing study was conducted in October of 2020 using 400 crossbred yearling steers at the Eastern Nebraska Research and Extension Center (ENREC) near Mead, NE. Half of the steers were purchased in September 2020, received at ENREC and fed in the feedlot until trial initiation (Source 1). The other half of the steers used in the trial were purchased in October 2019 and received at ENREC. These steers were grown on cornstalks, grass, and in the feedlot over the winter, spring, and summer (Source 2).

Steers were limit-fed a diet consisting of 50% Sweet Bran (Cargill Wet Milling; Blair, NE) and 50% alfalfa hay at approximately 2% of body weight for five consecutive days before collecting initial weights in order to minimize variation due to gastrointestinal fill. Steers were weighed on two consecutive days to establish initial weights (856 lb ± 48 for source 1; 903 lb ± 57 for source 2). Cattle were assigned to pens based on the first day's weight and sorted into one of three weight blocks: light (1 replication), medium (3 replications), and heavy (1 replication) within each source. Steers were then stratified by weight and assigned to pens to ensure equal initial pen weights by block. Pens were then assigned randomly to treatment within block with 5 pens per treatment within source. A 21-day adaptation period was used whereby Sweet Bran decreased from 77% to 20% while the grain was increased from 5% to 62%, all other ingredients remained constant. All rye to corn ratios remained constant during the adaption period. The first adaptation diet was fed for 4 days and consisted of 77% Sweet Bran and 5% grain. The second diet was fed for 5 days and consisted of 62% Sweet Bran and 20% grain. The third diet was fed for 6 days and consisted of 47% Sweet Bran and 35% grain. The fourth adaption diet was fed for 6 days and consisted of 32% Sweet Bran and 50% grain. The final finishing diet is presented in Table 1 and consisted of 20% Sweet Bran and 60% grain.

Four treatments were evaluated as a generalized randomized block design. The cattle were bought from two different sources and were blocked within source with three different weight blocks: light (4 pens per source; 8 total pens), medium (12 pens per source; 24 total pens), and heavy (4 pens per source; 8 total pens) for a total of 40 pens with 10 steers per pen. Cattle from source 1 were weighed, implanted, and sorted on day -4 of the trial. Source 2 was weighed, implanted, and sorted on day 0 of the trial. Both groups were started on treatment diets on day 1 of the trial to allow all 10 replications to be stepped together by treatment. Treatments consisted of 0:100, 25:75, 50:50, and 100:0 (SFR:SFC). All diets contained 60% grain, and each treatment differed only in the ratio of SFR to SFC. Treatment diets are provided in Table 1.

Rye grain was cleaned prior to flaking using a two-screen grain shaker with air in order to decrease total ergots. Rye was sampled upon delivery and evaluated for ergot contamination based on sample date. All grain was processed at the same feedyard (Raikes Feedyard, Ashland, NE). Grain was delivered approximately weekly. At time of delivery, SFR was sampled as some

**Table 1. Dietary treatment compositions (DM basis) for finishing steers fed increasing inclusions of steam-flaked rye replacing steam-flaked corn.**

| Treatments (% Rye) | 0% | 25% | 50% | 100% |
|---|---|---|---|---|
| Steam-Flaked Corn | 60.0 | 44.6 | 29.2 | - |
| Steam-Flaked Rye[1] | - | 15.4 | 30.8 | 60.0 |
| Sweet Bran | 20.0 | 20.0 | 20.0 | 20.0 |
| Forage Corn Silage | 10.0 | 10.0 | 10.0 | 10.0 |
| Corn Stalks | 2.0 | 2.0 | 2.0 | 2.0 |
| Corn Oil | 3.0 | 3.0 | 3.0 | 3.0 |
| Supplement | 5.0 | 5.0 | 5.0 | 5.0 |
| Fine Ground Corn | 2.086 | 2.536 | 2.986 | 2.986 |
| Limestone | 1.60 | 1.60 | 1.50 | 1.5 |
| Tallow | 0.125 | 0.125 | 0.125 | 0.125 |
| Urea | 0.80 | 0.40 | 0 | 0 |
| Salt | 0.30 | 0.30 | 0.30 | 0.30 |
| Trace Mineral premix | 0.05 | 0.05 | 0.05 | 0.05 |
| Vitamin ADE premix | 0.015 | 0.015 | 0.015 | 0.015 |
| Rumensin-90 premix[2] | 0.0165 | 0.0165 | 0.0165 | 0.0165 |
| Tylan-40 premix[3] | 0.0075 | 0.0075 | 0.0075 | 0.0075 |
| Nutrient composition[4] | | | | |
| CP,% | 13.1 | 12.7 | 12.3 | 13.6 |
| NDF,% | 19.8 | 22.9 | 25.9 | 31.7 |
| ADF,% | 8.5 | 8.8 | 9.1 | 9.6 |
| EE,% | 6.2 | 5.9 | 5.7 | 5.2 |

[1]Rye inclusion was adjusted based on corn contamination on day 22

[2]Supplement formulated to provide 30 g/ton of Rumensin® (Elanco Animal Health, DM Basis)

[3]Supplement formulated to provide 8.8 g/ton Tylan® (Elanco Animal Health, DM Basis)

[4]Based on analyzed nutrients for each ingredient

visual contamination of SFC was observed in the SFR which was corn left in the steam chest at the end of the day before rye was processed. Using sieves, corn was separated in a sample, and quantified as a percentage (Table 2). Early on, SFR contained approximately 8% SFC contamination. After a few weeks, limited corn contamination was observed, averaging less than 2% SFC present. As a result, the proportion of SFR was adjusted on day 22 for the 25:75 and 50:50 proportions in an attempt to account for any SFC contamination, albeit small. After the decrease in SFC contamination was observed, the 25:75 and 50:50 diets were then readjusted on day 69. Due to acidosis concerns based on intake and loose stools, corn stalks were added to all diets at an inclusion of 2% and grain decreased to 60% on day 37 of the trial. Optaflexx was added to the diets on day 110 to target 300 mg/steer daily (Elanco Animal Health) and fed for 28 days then removed 2 days before slaughter.

All steers were implanted with Revalor-IS (Merck Animal Health) as an initial implant. Steers were implanted on day -4 for source 1 and day 0 for source 2 and all cattle started on treatment diets on day 1. Revalor-200 (Merck Animal Health) was administered as the terminal implant on day 54 for source 1 and day 55 for source 2.

Steers were fed trial diets for 140 days. On the day of harvest, kill order, liver abscess scores, and hot carcass weight (HCW) were recorded. Carcass-adjusted final body weight was calculated using a 63% dressing percentage. Marbling score, longissimus muscle area (LM area), and fat

**Table 2. Percentage of steam-flaked corn detected in steam-flaked rye samples at delivery.**

| Sample Date | Corn Contamination (%) |
|---|---|
| 10/12/2020 | 6.64 |
| 10/28/2020 | 12.97 |
| 11/9/2020 | 4.19 |
| 11/19/2020 | 4.11 |
| 11/25/2020 | 1.15 |
| 12/3/2020 | 2.20 |
| 12/11/2020 | 2.56 |
| 12/28/2020 | 1.68 |
| 1/5/2021 | 0.64 |
| 1/12/2021 | 1.98 |
| 1/20/2021 | 0.14 |
| 1/29/2021 | 1.02 |
| 2/10/2021 | 1.52 |
| 2/23/2021 | 0.84 |
| Average | 2.97 |

depth were collected after a 48-hour chill. Carcass adjusted final body weight was used to calculate ADG and F:G. USDA yield grade was calculated using an assumed 2% KPH (kidney, pelvic, heart fat). Individual carcass data were averaged by pen, then analyzed with pen as the experimental unit. Performance-adjusted net energy values were calculated using average initial weights, carcass-adjusted ADG, DMI, and mean shrunk final body weight.

Data were analyzed using the MIXED procedure of SAS as a generalized randomized block design, with pen as the experimental unit and source and weight block as fixed effects. Effect of increasing the SFR:SFC ratio on performance and carcass characteristics were analyzed using linear and quadratic contrasts. Orthogonal contrast coefficients were calculated with Proc IML to account for unequal spacing.

## Results

As the level of rye increased in the diet HCW, carcass-adjusted final body weight, ADG, and DMI decreased linearly ($P < 0.01$; Table 3). Intakes were 27.9 to 30.7 lb/d for these large yearling steers but feeding SFR decreased dry matter intake by 2.7 lb/d as the SFR:SFC ratio increased from 0:100 to 100:0. Gains also decreased 14.5% when grain changed from SFC to SFR. Lower DMI and ADG with increasing SFR may be due to faster ruminal starch digestion and acidosis risk which has been shown to decrease DMI and ADG. A linear increase ($P < 0.01$) in feed conversion (F:G) was observed as ratio of SFR:SFC increased. Calculated NEm and NEg also linearly decreased ($P < 0.01$) with increasing inclusion of SFR. These data suggest no associative effect of blending SFR with SFC as all performance responses were linear. Carcass characteristics were also affected by treatment. With increasing levels of rye, LM area ($P < 0.01$), 12$^{th}$ rib fat ($P = 0.03$), and marbling score ($P < 0.01$) decreased linearly. USDA yield grade did not differ among treatments ($P = 0.16$). The observed impacts on carcass characteristics reflect the decrease in ADG over the 140-day study.

The SFR was composited over the feeding period and analyzed for various nutrients. The rye grain was found to contain approximately 28.4% neutral detergent fiber, 4.3% acid detergent fiber, 12.7% crude protein, 1.8% fat, and 54.7% starch on a dry matter basis. Ergot levels were evaluated by delivery time and averaged 1878 ppb on average (Table 4). Sampled ergot concentrations ranged from 1183 to 2740 ppb. Although ergot toxicity symptoms are often difficult to distinguish from other health concerns, we observed some evidence that foot health may have been compromised in cattle fed rye. Treatments for lameness was 3% for the 0% rye and 11% for the 100% rye treatment, while the 25 and 50% rye cattle had pull rates of 8% and 6%, respectively. Ergot toxicity levels are not well established, but some indications for concern with the ergot contamination in this study/source may be influencing results. More data are needed to establish toxicity thresholds and the effects of ergot on animal health and performance.

## Conclusion

Feeding finishing cattle increasing ratios of steam-flaked rye to steam-flaked corn linearly decreased overall gains, intakes, and resulted in poorer feed conversion. Increasing inclusion of steam-flaked rye in the diet also decreased marbling scores, backfat thickness, and LM area due to impacts on performance. Based on dietary energy calculated from performance, steam-flaked rye has approximately 92% the energy value of steam-flaked corn.

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**Table 3. Performance and carcass characteristics of finishing yearlings fed increasing inclusions of steam-flaked rye replacing steam-flaked corn.**

| | % Steam-Flaked Rye | | | | | P-value | |
|---|---|---|---|---|---|---|---|
| Item | 0% | 25% | 50% | 100% | SEM | Linear | Quadratic |
| *Performance* | | | | | | | |
| Initial BW, lb | 882 | 880 | 881 | 882 | 1.8 | 0.66 | 0.50 |
| Final BW, lb[1] | 1528 | 1493 | 1478 | 1434 | 7.5 | <0.01 | 0.44 |
| DMI, lb/d | 30.6 | 29.7 | 28.9 | 27.9 | 0.24 | <0.01 | 0.22 |
| ADG, lb[1] | 4.62 | 4.39 | 4.27 | 3.95 | 0.051 | <0.01 | 0.55 |
| F:G | 6.63 | 6.76 | 6.77 | 7.07 | - | <0.01 | 0.67 |
| NEm, Mcal/lb | 0.821 | 0.809 | 0.801 | 0.790 | 0.0072 | <0.01 | 0.90 |
| NEg, Mcal/lb | 0.533 | 0.523 | 0.526 | 0.507 | 0.0066 | <0.01 | 0.67 |
| *Carcass Characteristics* | | | | | | | |
| HCW, lb | 963 | 941 | 931 | 903 | 4.7 | <0.01 | 0.46 |
| Marbling Score[2] | 594 | 566 | 563 | 534 | 12.4 | <0.01 | 0.68 |
| LM Area, in$^2$ | 14.1 | 14.0 | 13.9 | 13.5 | 0.14 | <0.01 | 0.63 |
| Fat Thickness, in | 0.66 | 0.66 | 0.65 | 0.62 | 0.013 | 0.03 | 0.57 |
| Calc. USDA YG[3] | 3.69 | 3.66 | 3.63 | 3.57 | 0.067 | 0.16 | 0.98 |
| Liver Abscesses, %[4] | 9.09 | 9.00 | 8.16 | 6.19 | - | - | - |

[1]Calculated from hot carcass weight, adjusted to a 63% dressing percentage

[2]Marbling Score 400=Small00, 500=Modest00

[3]Calculated yield grade = [2.5 + (2.5 × fat thickness, in) + (0.2 × 2% KPH) + (0.0038 × HCW, lb)—(0.32 × LM area, in$^2$)]

[4]Liver scores were evaluated in SAS as a binomial distribution, and was not significant ($P$ = 0.44)

**Table 4. Average hybrid rye ergot alkaloid concentration (DM basis)[1,2]**

| Ergot Alkaloid | Concentration, ppb |
|---|---|
| Ergosine | 95 |
| Ergotamine | 109 |
| Ergocornine | 95 |
| Ergocryptine | 224 |
| Ergocristine | 215 |
| Ergosinine | 82 |
| Ergotaminine | 117 |
| Ergocorinine | 187 |
| Ergocryptinine | 412 |
| Ergocristinine | 342 |
| Total | 1878 |

[1] North Dakota State University Diagnostic Laboratory

[2] Detection limit = 20 ppb

# Evaluation of Processing Technique for High-Moisture and Dry Corn on Nutrient Digestion when fed to Finishing Cattle

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## Summary with Implications

*A digestion trial was conducted to determine the effect of corn milling method when processing dry or high-moisture corn on nutrient digestion. Treatments were evaluated as a 2 × 2 factorial with the first factor as corn type [dry corn or high-moisture corn] and second factor as mill type [roller mill or hammer mill]. Feeding high-moisture corn decreased the amount of excreted dry matter and organic matter regardless of processing method, but there tended to be an interaction between corn type and milling method for digestibility. There was no difference between milling treatments fed as high-moisture corn, but hammer milled dry corn was more digestible than dry rolled corn. Cattle fed high-moisture corn based diet had greater starch digestibility compared to dry corn, but milling method had no impact. There was no difference in average pH, but feeding high-moisture corn diets resulted in greater variance and greater area under pH 5.6 compared to dry corn diets. Overall, feeding cattle high-moisture compared to dry corn increased nutrient digestibility, but milling method had limited impact.*

## Introduction

Corn processing is utilized in feedlot finishing diets to increase starch digestion and improve feed conversion. For dry and high-moisture corn fed to cattle, a hammer mill or roller mill are the most common methods for processing corn in Nebraska. Although each method is sufficient at processing grains, each method has unique advantages and disadvantages. Hammer mills are generally more cost effective and require less dollars to maintain; but are energetically inefficient. Roller mills are more expensive to buy and maintain; however, they tend to be more energy efficient to operate.

A performance study previously evaluated the effect of feeding dry corn (DC), high-moisture corn (HMC), or a blend of DC:HMC to cattle processed using either a roller mill (ROLL; Automatic Ag, Pender) or hammer mill (HAMMER) and concluded that cattle fed ROLL HMC were approximately 5% more efficient than steers fed HAMMER HMC (*2021 Nebraska Beef Cattle Report*, pp 46–49). Thus, the objective of this experiment was to evaluate the effect of feeding dry or high-moisture corn processed with a hammer mill or roller mill in diets containing 20% modified distillers grains plus solubles (MDGS) on nutrient digestion and rumen characteristics.

Table 1. Composition (DM basis) and chemical analysis of diet comparing dry corn (DC) to high-moisture corn (HMC) using either a roller (ROLL) or hammer mill (HAMMER).

| | ROLL | | HAMMER | |
|---|---|---|---|---|
| | DC | HMC | DC | HMC |
| Dry corn | 70 | - | 70 | - |
| High-moisture corn | - | 70 | - | 70 |
| Modified Distillers plus Solubles | 20 | 20 | 20 | 20 |
| Corn stalks, ground | 5 | 5 | 5 | 5 |
| Supplement [1] | | | | |
| Urea | 0.5 | 0.5 | 0.5 | 0.5 |
| *Chemical Composition* | | | | |
| CP, % | 14.6 | 14.7 | 14.6 | 14.6 |
| Ca, % | 0.65 | 0.65 | 0.65 | 0.66 |
| P, % | 0.41 | 0.39 | 0.41 | 0.37 |
| NDF, % | 17.1 | 16.4 | 18.0 | 16.6 |
| ADF, % | 7.40 | 7.72 | 7.28 | 7.61 |
| Starch, % | 53.0 | 52.0 | 52.3 | 52.0 |

[1] Supplement formulated to contain 30 g/ton monensin (Rumensin, Elanco Animal Health) diet DM, and provide 90 mg/steer daily of tylosin (Tylan, Elanco Animal Health). Supplement contained limestone, vitamins ADE, and trace mineral package to meet all mineral and vitamin requirements.

## Materials and Methods

Seven ruminally fistulated steers were used in a 4 × 7 incomplete, replicated Latin square, with each steer assigned randomly to each dietary treatment once for 4 consecutive, 21-d periods. Periods allowed for 14 d of adaptation, followed by 7 d of collections. Treatment design was a 2 × 2 factorial design, with DC or HMC processed with a roller mill (ROLL) or hammer mill (HAMMER). Diets were mixed twice weekly and stored in a cooler (4° C) to ensure freshness. Experimental diet included (Table 1): 70% corn, 20% modified distillers grains plus solubles, 5% corn stalks, and 5% supplement. Supplement was formulated

**Table 2. Diet intake, total tract digestibility, and ruminal pH parameters for steers fed dry corn (DC) to high-moisture corn (HMC) using either a roller (ROLL) or hammer mill (HAMMER).**

| | ROLL[1] | | HAMMER | | | *P*-Value[2] | | |
|---|---|---|---|---|---|---|---|---|
| Item | DC | HMC | DC | HMC | SEM | Grain | Mill | Int. |
| *Dry Matter* | | | | | | | | |
| Intake, lb/d | 19.5 | 17.3 | 19.3 | 18.0 | 1.42 | 0.20 | 0.85 | 0.74 |
| Digestibility, % | 76.4[b] | 83.3[a] | 80.0[a] | 82.9[a] | 2.54 | <0.01 | 0.22 | 0.13 |
| *Organic Matter* | | | | | | | | |
| Intake, lb/d | 18.8 | 16.7 | 18.7 | 17.3 | 1.37 | 0.20 | 0.85 | 0.77 |
| Digestibility, % | 77.7[c] | 85.3[a] | 81.5[b] | 84.5[ab] | 2.39 | <0.01 | 0.26 | 0.10 |
| *Starch* | | | | | | | | |
| Intake, lb/d | 9.76 | 8.52 | 9.23 | 9.38 | 0.703 | 0.43 | 0.81 | 0.30 |
| Digestibility, % | 91.5 | 99.0 | 93.7 | 98.4 | 1.21 | <0.01 | 0.56 | 0.29 |
| *Energy* | | | | | | | | |
| DE Intake, Mcal/lb | 1.49[b] | 1.68[a] | 1.56[b] | 1.67[a] | 0.049 | <0.01 | 0.29 | 0.13 |
| DE, % of GE | 76.3[c] | 83.9[a] | 80.0[bc] | 83.6[ab] | 2.53 | <0.01 | 0.22 | 0.15 |
| *Ruminal pH* | | | | | | | | |
| Minimum pH | 5.27[a] | 5.03[b] | 5.08[ab] | 5.15[ab] | 0.106 | 0.34 | 0.39 | 0.07 |
| Maximum pH | 6.46 | 6.55 | 6.39 | 6.45 | 0.159 | 0.58 | 0.51 | 0.93 |
| Average pH | 5.73 | 5.54 | 5.54 | 5.60 | 0.149 | 0.56 | 0.61 | 0.27 |
| pH Variance | 0.082 | 0.141 | 0.096 | 0.110 | 0.0205 | 0.04 | 0.61 | 0.18 |
| Time < 5.6, min/d | 747 | 900 | 853 | 972 | 145.2 | 0.27 | 0.47 | 0.89 |
| Area < 5.6 | 156 | 324 | 245 | 390 | 79.6 | 0.05 | 0.33 | 0.88 |

[a, b, c] Values within a row without common superscripts differ ($P \leq 0.10$)

[1]Treatments were corn processed with a roller mill (ROLL) or hammer mill (HAMMER) and fed as dry corn (DC) or high-moisture corn (HMC).

[2] Grain = *P*-value associated with the main effect of grain type, Mill = *P*-value associated with main effect of milling method, Int = *P*-value associated with grain × mill

to provide 30 g/ton monensin (Rumensin, Elanco Animal Health), 90 mg/steer daily of tylosin (Tylan, Elanco Animal Health), 0.5% urea, calcium, salt, trace mineral, and vitamins to meet or exceed steer requirements. Cattle were adapated to new diets between periods by blending the diet from the previous period with the diet for the new period over the course of 5 d. Ingredients were sampled twice during each 21-d period and analyzed for DM using a 60°C forced-air oven to ensure proper formulation of treatment diets. Feed refusals were collected from d 16 to 21, subsampled, DM determined, and intakes were corrected.

Titanium dioxide was ruminally dosed at a rate of 5.0 g/steer twice daily at 0700 and 1700 for 7 d before and for the duration of the collection period. Fecal grab samples were collected three times daily on d 17–21 and composited into 1-d samples. Fecal samples were freeze-dried, ground through a 1-mm screen, and composited by animal within period for analysis of neutral detergent fiber (NDF), acid detergent fiber (ADF), DM, OM, $TiO_2$ for total fecal DM output, and starch. Diet ingredient samples were also composited into period samples and analyzed for NDF, ADF, DM, OM, and starch concentration. Ruminal pH probes were inserted in the rumen on d 14 and recorded pH every minute until removal on d 21. Rumen pH data were analyzed for d 16–20. Data were analyzed using the MIXED procedure of SAS with fixed effect of treatment and period, and steer treated as a random effect. Ruminal pH data were also analyzed using MIXED procedure of SAS and day was included as a repeated measure. Treatment differences were considered significant when $\alpha \leq 0.05$ and a tendency was considered when $0.05 < \alpha \leq 0.15$.

## Results

There were no interactions ($P \geq 0.18$; Table 2) between corn type and milling method for total tract DM intake, OM intake, NDF intake or NDF digestibility. There tended to be an interaction ($P = 0.13$) between corn type and milling method for total tract DM digestibility, resulting from a larger increase in DM digestibility for HMC compared to DC when rolled (6.9 percentage units) compared with hammer mill (2.9 percentage units). Organic matter digestibility followed the same trend ($P = 0.10$) with a more dramatic increase in OM digestion for ROLL HMC than ROLL DC (7.6 percentage units) compared to corns processed with HAMMER (3.0 percentage units). Feeding HMC processed either way was similar in total tract OM digestibility and averaged 85%. Digestibility of OM was lower for dry corns, but HAMMER was greater than ROLL.

There were no interactions ($P \geq 0.27$) for starch intake or digestibility. Feeding HMC increased total tract starch digestion compared to DC ($P < 0.01$). High-moisture corn diets had the greatest digestible energy intake (Mcal/lb DM) regardless of processing method; however, processing HMC compared with DC with ROLL increased digestible energy intake at a greater magnitude compared with HAMMER, resulting in a tendency ($P = 0.13$) for an interaction. There was a tendency ($P = 0.07$) for an interaction for minimum pH; ROLL HMC had a lower pH than ROLL DC but HAMMER HMC had a greater than ROLL DC. There was no effect ($P \geq 0.27$) due to milling method or corn type for average or maximum pH. Feeding HMC resulted in greater pH variance and area below a pH of 5.6 ($P < 0.05$) compared to DC.

## Conclusion

Results suggest that feeding HMC increases DM, OM, and starch digestibility, but mill type has limited effect on nutrient digestibility. Processing corn with ROLL resulted in a greater magnitude of change when fed as high-moisture corn compared to dry corn, resulting in a tendency for an interaction between grain type and mill type for DM and OM digestibility and digestible energy intake. Furthermore, there was limited effect on ruminal pH for corn type or milling method. Overall, feeding HMC increases nutrient digestibility compared to DC, but milling method had limited effect.

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# Evaluation of Green Grass on Nutrient Digestibility and Fatty Acid Flow in Cattle Finishing Diets

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## Summary with Implications

*Six ruminally and duodenally cannulated steers were utilized in a 3 × 3 replicated Latin square experiment to test 0, 15, and 30% dietary inclusion of Green Grass (Sunseo Omega 3; Chungcheong Duk-Do, South Korea), a feed comprised of sesame meal, giant kelp, cassava, and sorghum (not currently approved to be fed in the US). Dry matter and fiber intake increased linearly with increased Green Grass inclusion. Dry matter and organic matter digestibility were not affected by Green Grass inclusion. Concentration of saturated fatty acids at the duodenum were similar for Green Grass 0 and Green Grass 15 with a decrease for Green Grass 30; however, amount of saturated fatty acids increased with increasing Green Grass in the diet. The concentration and flow of unsaturated, mono-unsaturated, poly-unsaturated, and trans fatty acids responded quadratically with the largest increase for Green Grass 30. Omega-3 fatty acid concentration and flow increased linearly from 0 to 30% Green Grass inclusion (1.1 and 11.8 g/d, respectively). Feeding Green Grass increases unsaturated and omega-3 fatty acids flowing to the duodenum, which would be expected to impact fatty acid composition of the beef and may have human nutrition implications.*

## Introduction

There has been recent interest in the amount of omega-3 fatty acids in food products due to perceived health benefits (cardiovascular health, cognitive function, reduced cancer risk) in the human diet. The effects of supplementing cattle with dietary ingredients that contain large amounts of omega-3 fatty acids have been evaluated using fish oil, linseed oil, and flaxseed. Increasing the inclusion of the omega-3 fatty acids that are consumed by the animal can increase omega-3 fatty acids flowing to the duodenum. There is also evidence that increasing the amount of omega-3 fatty acids in the diet increases the amount of

**Table 1. Dietary composition (DM basis) of feeding Green Grass in finishing cattle diets**

| | Green Grass Inclusion, % | | |
|---|---|---|---|
| *Ingredient, %* | 0 | 15 | 30 |
| Dry rolled corn | 60 | 45 | 30 |
| Modified distillers grains plus solubles | 15 | 15 | 15 |
| Green Grass[1] | - | 15 | 30 |
| Corn silage | 20 | 20 | 20 |
| Supplement | 5 | 5 | 5 |
| Fine ground corn | 2.38 | 2.88 | 2.88 |
| Limestone | 1.61 | 1.61 | 1.61 |
| Tallow | 0.12 | 0.12 | 0.12 |
| Urea | 0.5 | - | - |
| Salt | 0.3 | 0.3 | 0.3 |
| Trace minerals[2] | 0.05 | 0.05 | 0.05 |
| Vitamin A-D-E[3] | 0.02 | 0.02 | 0.02 |
| Monensin[4] | 0.02 | 0.02 | 0.02 |
| *Nutrient Composition, %*[5] | | | |
| Organic matter | 94.9 | 93.4 | 92.2 |
| Crude protein | 12.4 | 14.6 | 18.1 |
| Neutral detergent fiber | 21.6 | 26.5 | 31.4 |
| Acid detergent fiber | 11.1 | 13.5 | 15.9 |
| Ether Extract | 4.80 | 5.28 | 5.68 |

[1]Green Grass (Sunseo Omega 3; Chungcheong Duk-Do, South Korea) is a mixture of sesame meal, giant kelp, cassava and sorghum.

[2]Premix contained 10% Mg, 6% Zn, 4.5% Mn, 0.5% Cu, 0.3% I, and 0.05% Co.

[3]Premix contained 1,500 IU of vitamin A, 3,000 IU of vitamin D, and 3.7 IU of vitamin E per g.

[4]Supplements contained 30 g/ton monensin (Rumensin-90; Elanco Animal Health, Indianapolis, IN).

[5]Diet nutrient compositions calculated using analyzed individual ingredient nutrient profile

**Table 2. Analyzed nutrient composition (% DM basis) of Green Grass[1]**

| Nutrient | Green Grass |
|---|---|
| Dry matter | 90.8 |
| Organic matter | 90.7 |
| Crude protein | 30.9 |
| Neutral detergent fiber | 46.7 |
| Ether extract | 7.03 |

[1]Green Grass (Sunseo Omega 3; Chungcheong Duk-Do, South Korea) is a mixture of sesame meal, giant kelp, cassava and sorghum.

omega-3 fatty acids found in the meat and adipose tissue.

The objective of this study was to evaluate the effect of a new product, Green Grass (GG; Sunseo Omega 3; Chungcheong Duk-Do, South Korea) on nutrient digestibility in cattle finishing diets and determine fatty acid flow to the duodenum. A companion experiment feeding GG to cattle and evaluating fatty acid profile of the beef has also been completed (*2020 Nebraska Beef Cattle Report*, pp. 78–82). Cattle fed GG at 10, 20, or 30% of diet DM had poorer feed conversion than cattle not fed GG. The hypothesis for this experiment was that increasing the inclusion of GG would result in increased unsaturated fatty acid (UFA) flow and omega-3 fatty acid flow, but would decrease dry matter and organic matter digestibility.

## Procedure

Six ruminally and duodenally cannulated beef steers were utilized in a 3 × 3 replicated Latin square design. Steers were assigned randomly to each dietary treatment for six, 21 d periods allowing for 16 d of adaptation and 5 d of collection. Diets consisted of increasing inclusion of Green Grass from 0 to 30% inclusion [dry matter (DM) basis] and are presented in Table 1. Nutrient composition of GG is presented in Table 2. Green Grass is not currently FDA approved to be fed to cattle entering the U.S. food chain and cattle were composted at completion of the experiment.

Cattle were fed once daily at 0700 h. Feed refusals were collected on d 16 to 20, subsampled and analyzed to determine nutrient refusals. From d 7 to 20, 5 grams of titanium dioxide were dosed twice daily (10 g/d) at 0700 and 1600 h via the rumen cannula to determine fecal output. Fecal and duodenal samples were collected at 0700, 1100, 1500, and 1900 h on d 17 to 20 of each period. Determination of fat content and fatty acid concentration was conducted on all ingredient and duodenal samples using gas chromatography. Orts were collected daily and dried for 48 h in a 60° C forced-air oven to determine DM intake (DMI). Ruminal pH was determined utilizing wireless pH probes inserted on d 15 to 21 and rumen pH was recorded every minute. Gross energy (GE) of the diets was measured using a bomb calorimeter and used to calculate digestible energy (DE) and total digestible nutrients (TDN).

Nutrient digestibility and intake data were analyzed using the MIXED procedure of SAS (SAS Inst., Inc., Cary, NC). The model included treatment and period as fixed effects with animal as a random effect. Ruminal pH data were analyzed as a repeated measure, with day repeated, using the MIXED procedure of SAS. Orthogonal contrasts were utilized to determine the effect of GG inclusion and to compare the slopes of the linear and quadratic lines for nutrient digestibility and intake data. Significance was declared at $P \leq 0.10$.

## Results

Dry matter intake increased as GG inclusion increased from 0 to 30 % of diet DM (Table 3). There was no effect ($P \geq 0.31$) on DM or OM digestibility with increasing inclusion of GG. Intake, excretion, and digestibility of neutral detergent fiber (NDF) linearly ($P \leq 0.03$) increased with increasing inclusion of GG.

Gross energy and DE intake (Mcal/d) increased linearly ($P \leq 0.02$) with increased GG inclusion. Digestible energy expressed as Mcal/lb or calculated TDN value were not different ($P \geq 0.49$) between treatments and there were no linear or quadratic ($P \geq 0.24$) trends observed with increased GG inclusion. There were no differences ($P \geq 0.51$) reported for DE as a % of gross energy. This is not in alignment with the companion cattle performance experiment where cattle increased feed intake with similar daily gain as GG inclusion increased in the diet.

There was not a difference in minimum ruminal pH. A quadratic ($P < 0.02$) response for maximum rumen pH was observed with maximum pH decreasing from GG0 to GG15 then increasing from GG15 to GG30. A similar quadratic ($P < 0.03$) response was observed for average rumen pH. Time and area under either pH of 5.6 or 5.3 increased from GG0 to GG15 and then decreased from GG15 to GG30.

Fatty acid concentration and fatty acid duodenal flow data are represented in Table 4. Fat flow increased linearly ($P < 0.01$) as inclusion of GG increased from 0 to 30% of diet DM. A quadratic trend ($P \leq 0.02$) was observed for saturated fatty acid (SFA) concentration and the ratio of SFA concentration to unsaturated fatty acid (UFA) concentration with a slight decrease from GG0 to GG15 and a more dramatic decrease from GG15 to GG30. Unsaturated fatty acid, monounsaturated fatty acid (MUFA), polyunsaturated fatty acid (PUFA) and trans fatty acid concentrations responded quadratically ($P \leq 0.01$), with little difference between GG0 and GG15 and a large increase from GG15 to GG30. Omega-6 fatty acid (ω6) concentration decreased linearly ($P < 0.01$) with increased GG inclusion while the opposite was true of omega-3 fatty acid concentration (ω3). Omega-3 FA concentrations increased quadratically ($P < 0.04$) with ω3 concentration being almost 3.5 times and 8 times greater than the concentration of GG0 for GG15 and GG30, respectively.

While concentration of SFA decreased with increasing inclusion of GG, the duodenal flow of SFA on a g/d basis increased quadratically ($P < 0.07$) with a large increase from GG0 to GG15 and an increase at a decreased rate from GG15 to GG30. This is due to the increased fat flow through the duodenum in the GG diets compared to the control. Fatty acid flow on g/d basis increased quadratically ($P \leq 0.05$) for UFA, MUFA, PUFA, and trans FA, with increases from GG0 to GG15 and increasing at a greater rate from GG15 to GG30. Omega-6 FA flow was not altered by increased inclusion of GG resulting in no linear or quadratic ($P \geq 0.19$) trends between treatments. Omega-3 concentrations increased quadratically ($P < 0.03$), increasing from GG0 to GG15 and increasing at an increasing rate from GG15 to GG30.

**Table 3. Effect of Green Grass inclusion on apparent total tract nutrient digestibility and rumen pH in finishing diets**

| | GG inclusion, %[1] | | | | *P*-Value[2] | |
|---|---|---|---|---|---|---|
| Measure | 0 | 15 | 30 | SEM | Lin. | Quad |
| Dry matter | | | | | | |
| Intake, lb/d | 21.1 | 22.7 | 23.1 | 0.59 | 0.04 | 0.40 |
| Digestibility, % | 74.1 | 74.4 | 72.8 | 0.90 | 0.31 | 0.39 |
| Organic matter | | | | | | |
| Intake, lb/d | 20.2 | 21.1 | 21.3 | 0.55 | 0.16 | 0.46 |
| Digestibility, % | 76.0 | 76.1 | 74.9 | 0.91 | 0.39 | 0.53 |
| Neutral detergent fiber | | | | | | |
| Intake, lb/d | 4.4 | 5.9 | 7.0 | 0.24 | < 0.01 | 0.28 |
| Digestibility, % | 50.9 | 55.9 | 56.6 | 2.84 | 0.03 | 0.31 |
| Energy | | | | | | |
| Digestible energy, Mcal/lb | 1.35 | 1.39 | 1.43 | 0.045 | 0.24 | 0.93 |
| Digestible energy, % of Gross Energy | 73.1 | 72.1 | 73.0 | 1.21 | 0.97 | 0.51 |
| TDN[3] | 67.3 | 69.6 | 71.3 | 2.30 | 0.34 | 0.93 |
| *Rumen pH* | | | | | | |
| Minimum pH | 5.25 | 5.14 | 5.15 | 0.050 | 0.16 | 0.31 |
| Maximum pH | 6.60 | 6.53 | 6.72 | 0.072 | 0.04 | 0.02 |
| Average pH | 5.89 | 5.74 | 5.85 | 0.069 | 0.55 | 0.03 |
| Time < 5.6, min/d | 369 | 595 | 489 | 85 | 0.19 | 0.03 |
| Area < 5.6 | 69 | 156 | 109 | 28 | 0.27 | 0.03 |
| Time < 5.3, min/d | 86 | 256 | 156 | 50 | 0.31 | 0.03 |
| Area < 5.3 | 8 | 45 | 18 | 12 | 0.55 | 0.04 |

[abc] Means within a row with different superscripts differ ($P < 0.10$).

[1]GG = Green Grass; Treatments were 0, 15, and 30% inclusion of Green Grass in the diet.

[2]F-test = *P*-value for treatment differences. Lin and Quad = *P*-Value for orthogonal contrasts determining linear or quadratic trends.

[3]Total digestible nutrients (TDN) values calculated from digestible energy (DE) of the diet; TDN, % = DE intake, Mcal/kg ÷ 4.4.

## Conclusion

Feeding GG up to 30% of diet DM resulted in increased intakes with no change in digestibility. The amount of fat reaching the duodenum was increased with increased GG inclusion along with the amount of SFA, UFA, MUFA, PUFA, Trans FA, and ω3. Increased duodenal flow of desirable fatty acids suggests GG could be a viable feed option in finishing diets. Due to the correlation between FA absorption and FA abundance in the meat profile, increasing GG inclusion in the diet is expected to result in greater ω3 concentrations in beef.

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**Table 4. Fatty acid concentration and abundance in cattle finishing diets with increasing inclusion of Green Grass**

| | Green Grass inclusion, %[1] | | | | *P*—Values[2] | |
|---|---|---|---|---|---|---|
| Measure | 0 | 15 | 30 | SEM | Lin. | Quad |
| Duodenal Fat Flow, g/d[3] | 443 | 563 | 629 | 24.8 | < 0.01 | 0.31 |
| *Fatty Acid (FA) Concentration, % of total fat* | | | | | | |
| Saturated FA | 79.03 | 78.18 | 70.23 | 0.94 | < 0.01 | < 0.01 |
| Unsaturated FA | 20.55 | 21.32 | 29.14 | 0.96 | < 0.01 | < 0.01 |
| SFA:UFA | 4.00 | 3.76 | 2.47 | 0.18 | < 0.01 | 0.02 |
| Monounsaturated FA | 12.52 | 13.68 | 18.93 | 0.65 | < 0.01 | 0.01 |
| Polyunsaturated FA | 8.03 | 7.62 | 10.15 | 0.52 | < 0.01 | 0.01 |
| Trans FA | 4.85 | 5.08 | 8.99 | 0.52 | < 0.01 | < 0.01 |
| Omega-6 | 1.10 | 0.91 | 0.71 | 0.09 | < 0.01 | 0.96 |
| Omega-3 | 0.24 | 0.86 | 1.89 | 0.09 | < 0.01 | 0.04 |
| *Fatty Acid Flow, g/d*[4] | | | | | | |
| Saturated FA | 351 | 440 | 442 | 20.9 | < 0.01 | 0.07 |
| Unsaturated FA | 91 | 120 | 184 | 7.1 | < 0.01 | 0.03 |
| Monounsaturated FA | 55 | 77 | 120 | 4.5 | < 0.01 | 0.05 |
| Polyunsaturated FA | 36 | 43 | 64 | 3.7 | < 0.01 | 0.05 |
| Trans FA | 21 | 30 | 57 | 3.5 | < 0.01 | 0.04 |
| Omega-6 | 5.0 | 5.0 | 4.3 | 0.54 | 0.19 | 0.38 |
| Omega-3 | 1.1 | 5.0 | 11.8 | 0.71 | < 0.01 | 0.03 |

[abc] Means within a row with different superscripts differ ($P < 0.10$)

[1]GG = Green Grass; Treatments were 0, 15, and 30% inclusion of Green Grass in the diet.

[2]F-test = *P*-value for treatment differences. Lin and Quad = *P*-Value for orthogonal contrasts determining linear or quadratic trends

[3]Duodeanl fat flow measured as ether extract g/d

[4]Fatty acid flow = duodenal fat flow, g/d × fatty acid concentration, %

# Effect of Feeding CARS on Digestibility and Fatty Acid Flow in Finishing Cattle Diets

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## Summary with Implications

*An experiment was conducted to evaluate the impact of a liquid feed, Condensed Algal Residue Solubles (CARS) on diet digestibility and fatty acid flow to the small intestine. Three treatments included CARS at 0, 2.5, and 5% of the diet dry matter, replacing steam-flaked corn. The base diet included 73, 70.5, or 68% steam flaked corn, 15% dried distillers grains plus solubles, 8% alfalfa haylage, and 4% supplement. Inclusion of CARS in the diet did not affect dry matter or organic matter intake or digestibility of dry matter, organic matter or neutral detergent fiber. Amount of fatty acid flowing to the duodenum was not affected by treatment; however, the fatty acid profile changed, with a lesser portion of saturated fatty acids and a greater portion of unsaturated and poly-unsaturated fatty acids available for post rumen absorption as CARS increased in the diet. Concentration of both omega-3 and omega-6 fatty acids at the duodenum increased linearly. The CARS product can be included up to 5% of finishing diets without affecting diet digestibility which complements the performance data from a companion experiment. It also increased unsaturated fatty acid flow to the small intestine, which might alter concentration of these fatty acids in the beef.*

## Introduction

With improved methods of cultivating and harvesting algae for omega-3 supplementation in aquaculture and pet diets, the residue known as Condensed Algal Residue Solubles (CARS; Veramaris, The Netherlands; Table 1) has also become available as a byproduct feed for cattle (Blair, NE). The CARS product contains de-oiled algae cells plus biomass residual fermentation substrates and has expert-affirmed generally recognized as safe (GRAS) status. The CARS feed has relatively high levels of protein as well as omega-3 fatty acids. Docosahexaenoic acid (DHA) is an omega-3 fatty acid important in human nutrition and is commonly supplemented in human diets with fish or algae products. Feeding CARS to cattle may increase the omega-3 fatty acid content of beef. Previous research has shown a 4.3% improvement in feed:gain with 2.5% CARS inclusion in finishing cattle diets (*2021 Nebraska Beef Cattle Report*, pp. 56–58). Thus, the objective of this study was to evaluate diet digestibility and fatty acid flow at the duodenum of cattle fed increasing amounts of CARS.

**Table 1. Nutrient composition of Condensed Algal Residue Solubles (CARS) as an ingredient in cattle finishing diets[1]**

| *Dry Matter (DM), %* | 22.7 |
|---|---|
| | *Dry Basis* |
| Organic Matter | 63.0 |
| Crude Protein | 21.7 |
| Neutral Detergent Fiber | 1.59 |
| Fat[2] | 6.10 |
| Calcium | 0.44 |
| Phosphorus | 0.53 |
| Potassium | 0.80 |
| Sulfur | 3.05 |
| Sodium | 9.96 |

[1]Nutrient composition of CARS analyzed by Ward Laboratories, Inc. (Kearney, NE) with DM, OM, CP, and NDF analyzed at the University of Nebraska–Lincoln (Lincoln, NE).

[2]Total fat was analyzed using an acid hydrolysis method.

## Procedure

This study utilized 6 ruminally and duodenally cannulated steers in a 3 × 3 replicated Latin Square design. Treatments differed by increasing inclusion of CARS at 0, 2.5, and 5% of diet DM (0%, 2.5%, 5%), replacing steam flaked corn. All diets contained 15% dry distillers grains, 8% alfalfa haylage, and 4% supplement. Supplement contained Rumensin-90 (fed to target 30 g/ton of diet DM), Tylan-40 (fed to target 90 mg/hd/d), along with trace minerals, vitamins A-D-E, tallow, limestone, salt (not included in the 5% CARS diet) and urea to meet rumen degradable protein requirements with fine ground corn as a carrier.

The steers were fed *ad libitum*, with feed delivered once each day in the morning. Periods lasted 21 d, with 16 d for adaption and 5 d of collections. Rumen pH probes were placed directly into the rumen on d 14. Orts were collected on days 16 to 21 and feed ingredient samples were collected on day 18. Steers were dosed twice daily with 5 g of titanium dioxide ($TiO_2$) for a total of 10 g/d on days 7 to 20. Duodenal and fecal grab samples were collected four times/d on days 17 to 20 and composited into 4 samples (1 per day) per period. Whole rumen samples were collected on day 21 to correct for microbial contamination in the duodenal samples, and pH probes were removed. Feed, fecal, orts and duodenal samples were freeze dried, ground through a 1-mm screen, composited and analyzed for dry matter (DM), organic matter (OM), and neutral detergent fiber (NDF). Fecal and duodenal samples were also ground again through a ½ mm screen to measure $TiO_2$ concentration to determine both fecal output and diet digestibility. Total fat and fatty acid profile analysis was conducted on both the feed ingredient and duodenal samples. The data were analyzed using the MIXED procedure in SAS (SAS Inst., Cary,

**Table 2. Fatty acid profile of diets including Condensed Algal Residue Solubles (CARS)**

| | Treatment Diets[1] | | |
|---|---|---|---|
| | 0% | 2.5% | 5% |
| Total Fat, % of diet DM | 3.38 | 3.46 | 3.54 |
| Fatty Acid, % of Fat | | | |
| Saturated FA | 18.7 | 19.0 | 19.4 |
| Unsaturated FA | 81.0 | 80.6 | 80.1 |
| Mono-unsaturated FA | 26.3 | 25.6 | 24.9 |
| Poly-unsaturated FA | 54.7 | 54.9 | 55.2 |
| Omega-3 | 4.15 | 5.73 | 7.30 |
| Omega-6 | 0.003 | 0.007 | 0.011 |
| C16:0 | 0.358 | 0.361 | 0.354 |
| C18:0 | 0.240 | 0.241 | 0.232 |
| C18:1T | 24.7 | 24.1 | 23.4 |
| C18:1 Oleic | 0.488 | 0.473 | 0.467 |
| C18:1 Vaccenic | 50.3 | 48.9 | 47.5 |
| C18:2 Linoleic | 3.96 | 3.93 | 3.89 |
| C18:3ω3 α-Linolenic | 0.427 | 0.427 | 0.427 |
| C20:5ω3 (EPA) | 0.153 | 1.38 | 2.59 |
| C22:6ω3 (DHA) | 14.8 | 15.0 | 15.3 |

[1]Treatments varied in CARS inclusion, 0%, 2.5%, and 5% of the diet DM replacing steam flaked corn.

NC) with CARS inclusion and period as fixed effects and animal as a random effect. Orthogonal contrasts were used to test linear and quadratic effects of CARS inclusion.

## Results

Total fatty acid content of the diets numerically increased with the addition of CARS (Table 2), with omega-3 fatty acids increasing from 0.13 to 0.33% of diet DM for 0% and 5% diets, respectively. Intake of both DM and OM were not affected by CARS inclusion ($P \geq 0.17$; Table 3), though there was a linear decrease ($P = 0.07$) in NDF intake as CARS was included in the diet. Inclusion of CARS had no effect on total tract DM, OM, or NDF digestibility ($P \geq 0.52$). Gross energy (GE), DM intake, and digestible energy (DE) intake were not different ($P \geq 0.32$). Apparent ruminal DM, OM and NDF digestibility were not affected by treatment ($P \geq 0.20$). True ruminal DM and OM digestibility were not affected by treatment ($P \geq 0.38$).

Total fatty acid flow at the duodenum was unaffected ($P = 0.18$; Table 4) as CARS increased in the diet, though the fatty acid profile was impacted, with a linear decrease ($P = 0.06$) in saturated fatty acids (SFA), correlated with a linear increase ($P \leq 0.07$) in unsaturated (UFA), mono-unsaturated (MUFA), and poly-unsaturated fatty acids (PUFA) as CARS increased in the diet. There was a linear increase ($P < 0.01$) of C16:0, C18:0, C18:1T, and C18:1 Vaccenic acid in the fatty acid flow to the small intestine. There was also a quadratic response for C18:3ω3 α-Linolenic acid concentrations ($P = 0.01$) with CARS included at 2.5% having the greatest g/d flow of α-Linolenic acid, increasing from 1.54 g/d with 0% CARS to 2.07 g/d with 2.5% CARS, and decreasing to 1.87 g/d flow to the small intestine for the 5% CARS treatment.

Both omega-3 and omega-6 fatty acid content of total flow to the small intestine increased linearly ($P \leq 0.02$) as CARS increased in the diet, with 5% having the greatest omega-3 and omega-6 content and 0% having the least omega-3 and omega-6 fatty acids. The DHA content of fat available for post rumen absorption was significantly different ($P < 0.01$) with 5% CARS treatment having the greatest DHA content at 7.75 g/d flow to the small intestine compared to 2.5% CARS having 5.12 g/d and 0% CARS having the least at 4.57 g/d. Concentrations of these fatty acids deposited in the beef were not measured but are expected to be similar to flow at the duodenum.

Average ruminal pH linearly increased from 5.76 to 6.06 ($P < 0.01$) as CARS was included in the diet. There was a linear decrease ($P \leq 0.01$) in both time (661 to 324 min/d) and area under pH 5.6 (156 to 68.9) as CARS was included.

## Conclusion

Replacing up to 5% steam-flaked corn with CARS did not impact DM and OM intake, or DM, OM, and NDF total tract digestibility. With a small numerical increase in fatty acid content of the diet and small numerical decrease in DMI, there was no effect on total fatty acid flow to the small intestine. However, concentration of PUFA, including omega-3 in the duodenal flow, increased with CARS inclusion in the diet. Both metabolism and performance data demonstrate that CARS can be effectively included in feedlot finishing diets up to 5% of the diet DM and inclusion will be primarily dictated by availability and price of CARS.

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**Table 3. Effect of CARS inclusion on diet digestibility**

| | Treatment[1] | | | | *P*-Value[2] | |
|---|---|---|---|---|---|---|
| Item | 0% | 2.5% | 5% | SEM | Linear | Quadratic |
| ***DM*** | | | | | | |
| Intake, lb/d | 17.4 | 17.2 | 16.3 | 0.69 | 0.27 | 0.67 |
| Apparent Rumen digestibility, % | 26.2 | 22.2 | 25.6 | 2.18 | 0.86 | 0.20 |
| True Rumen digestibility, % | 53.6 | 51.8 | 55.1 | 2.405 | 0.66 | 0.38 |
| Total Tract digestibility, % | 81.2 | 81.3 | 82.2 | 1.45 | 0.58 | 0.80 |
| ***OM*** | | | | | | |
| Intake, lb/d | 16.6 | 16.3 | 15.3 | 0.65 | 0.17 | 0.67 |
| Apparent Rumen digestibility, % | 34.3 | 31.4 | 33.3 | 2.318 | 0.77 | 0.42 |
| True Rumen digestibility, % | 62.3 | 61.2 | 64.1 | 2.51 | 0.62 | 0.53 |
| Total Tract digestibility, % | 83.6 | 83.7 | 84.3 | 1.349 | 0.68 | 0.87 |
| ***NDF*** | | | | | | |
| Intake, lb/d | 2.80 | 2.69 | 2.49 | 0.108 | 0.07 | 0.75 |
| Apparent Rumen digestibility, % | 14.2 | 14.7 | 13.3 | 4.98 | 0.87 | 0.85 |
| Total Tract digestibility, % | 53.4 | 51.1 | 54.4 | 4.885 | 0.83 | 0.52 |
| ***Energy*** | | | | | | |
| Gross Energy Intake, Mcal/d | 31.1 | 30.9 | 29.4 | 1.25 | 0.32 | 0.66 |
| Digestible Energy Intake, Mcal/d | 24.9 | 25.0 | 24.3 | 1.34 | 0.71 | 0.78 |
| Digestible Energy, Mcal/lb of DM | 1.42 | 1.50 | 1.49 | 0.029 | 0.15 | 0.94 |

[1]Treatments varied in CARS inclusion, 0%, 2.5%, and 5% of the diet DM replacing steam flaked corn; CARS = condensed algae residue solubles.

[2] Linear and quadratic orthogonal contrasts are shown for CARS inclusion.

[abc] Means in a row with different superscripts differ ($P < 0.05$).

**Table 4 Effect of CARS inclusion on fatty acid profile of duodenal flow**

| | Treatment[1] | | | | *P*-Value[2] | |
|---|---|---|---|---|---|---|
| Fatty Acid, g/d[3] | 0% | 2.5% | 5% | SEM | Linear | Quadratic |
| **Total Duodenal Fat Flow** | 438.4 | 493.2 | 458.2 | 25.817 | 0.60 | 0.18 |
| Saturated FA | 315 [ab] | 332 [a] | 238 [b] | 25.449 | 0.06 | 0.10 |
| Unsaturated FA | 123 [b] | 158 [b] | 212 [a] | 11.469 | < 0.01 | 0.52 |
| Mono-unsaturated FA | 73.6 [c] | 107.0 [b] | 154.2 [a] | 10.375 | < 0.01 | 0.60 |
| Poly-unsaturated FA | 49.2 [b] | 51.2 [ab] | 58.0 [a] | 3.095 | 0.07 | 0.54 |
| Omega-3 | 11.0 [b] | 12.1[b] | 15.4[a] | 4.22 | < 0.01 | 0.09 |
| Omega-6 | 3.92 [b] | 4.02 [b] | 4.59 [a] | 1.32 | 0.02 | 0.28 |
| C16:0 | 63.6[c] | 93.7[b] | 111.2[a] | 5.49 | < 0.01 | 0.36 |
| C18:0 | 236.9[a] | 218.5[a] | 108.1[b] | 23.16 | < 0.01 | 0.13 |
| C18:1T | 31.5[c] | 59.5[b] | 108.5[a] | 9.66 | < 0.01 | 0.39 |
| C18:1 Oleic | 34.8 | 37.0 | 33.1 | 2.05 | 0.59 | 0.24 |
| C18:1 Vaccenic | 4.26[b] | 5.92[a] | 7.36[a] | 0.60 | < 0.01 | 0.88 |
| C18:2 Linoleic | 40.5 | 40.3 | 39.3 | 2.72 | 0.77 | 0.90 |
| C18:3ω3 α-Linolenic | 1.54[b] | 2.07[a] | 1.87[a] | 0.101 | 0.04 | 0.01 |
| C22:6ω3 (DHA) | 4.57[a] | 5.12[a] | 7.75[b] | 3.99 | < 0.01 | 0.19 |

[1]Treatments varied in CARS inclusion, 0%, 2.5%, and 5% of the diet DM replacing steam flaked corn; CARS = condensed algae residue solubles.

[2] Linear and quadratic orthogonal contrasts are shown for CARS inclusion.

[3] Fatty acids reported as g/d of fat flowing to the duodenum.

[abc] Means in a row with different superscripts differ ($P < 0.05$).

# Impact of a Natural Feed Additive using Direct Fed Microbes on Finishing Beef Cattle Performance and Liver Abscess Rate

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## Summary with Implications

*A feedlot study with individually fed steers (n=60) was conducted comparing a natural feed additive (Direct Fed Microbial) to no feed additive (control) on performance and liver abscess rate of finishing beef cattle. There were no significant differences between treatments on intake, gain, feed conversion, or hot carcass weight and carcass traits. Liver abscess occurrence and severity were similar for both treatments with 4/29 steers having abscessed livers in the control group and 3/29 steers in the group that received direct fed microbials. The direct fed microbial feed additive fed in this exploratory study did not significantly affect performance, liver abscess rate, or the severity of liver abscesses of finishing beef cattle.*

## Introduction

The most common and effective method to control liver abscesses today is feeding tylosin, but it requires a veterinary feed directive. An effective alternative for liver abscess prevention that does not require veterinary approval or require feeding an antibiotic is of great interest. The direct fed microbial (DFM) feed additive used in this study was specifically developed to target and reduce the population of the liver abscess causing *Fusobacterium necrophorum* and the major lactic acid producing bacteria *Streptococcus bovis* in the rumen. The DFM has been validated in laboratory cultures and is naturally occurring in the rumen and was isolated from cattle. The objective of this study was to determine the effect of this specific DFM on finishing beef cattle performance, liver abscess occurrence, and severity of liver abscesses derived from ruminal acidosis.



**Table 1. Diet composition of feed delivered to steers during the finishing period (% of diet DM).**

| Ingredient | % Diet DM[1] |
|---|---|
| High-moisture corn | 36.5 |
| Dry-rolled corn | 24.5 |
| Modified distillers grains plus solubles | 20.0 |
| Corn Silage | 15.0 |
| Supplement2 | |
| Limestone | 1.64 |
| Fine Ground Corn | 1.40 |
| Urea | 0.50 |
| Salt | 0.30 |
| Tallow | 0.10 |
| Beef Trace Minerals Premix | 0.05 |
| Vitamin A-D-E Premix | 0.015 |

[1] Diet DM: 65.81%

[2] Supplement fed at 4% of dietary DM for all treatments

## Procedure

A finishing study conducted at the Eastern Nebraska Research and Extension Center utilized 60 head of crossbred steers (initial shrunk BW 604 lb SD = 26.2 lb). Steers were individually fed in 2 pens (barn of 30 steers) using Calan gates. To avoid DFM contamination from social housing systems, barn was assigned randomly to DFM treatment. Based on past performance studies, barn was found to not impact performance. The two treatments consisted of a control diet (CON) without DFM and a diet with DFM (DFM). The CON treatment is designed to represent the effect from the diet when no means of liver abscess prevention are used. The GRAS approved DFM strain used for this study was top dressed in the feed targeting 1 billion bacterial cells/steer daily. Bacterial cells were cultured and confirmed to be the correct strain using 16S rRNA sequencing and cell counts were estimated using cell cytometry.

Cattle received a diet consisting of high moisture corn, dry rolled corn, modified distillers grains plus solubles, 15% corn silage, and supplement once a day (Table 1). High moisture corn was processed through a roller mill before ensiling. Ensiled HMC averaged 69% dry matter to maximize starch availability and digestion rate to increase the potential for lactic acidosis in this study. Cattle were fed this diet for the duration of the trial, 189 days. On day 0, cattle received 80 mg trenbolone acetate and 16 mg estradiol via implant (Revalor-IS). On day 100, cattle were re-implanted with 200 mg trenbolone acetate and 20 mg estradiol (Revalor-200). Weights were collected on days: -2,-1,0, 57, 100, 148, and 189. The finishing diet was fed on Day 1 of the study at 1.8% of BW of feed DM delivered. Steers were adapted to ad libitum intakes by increasing DM offered by 0.5 lb DM from day 2 of the study until ad libitum intake by individual was attained (approximately 20 days).

Steers were shipped to Greater Omaha for harvest, where carcass data were recorded. On day of harvest, HCW and liver abscess scores were collected. Following a 48—hour chill, USDA marbling score,

**Table 2. Performance and carcass characteristics of beef steers fed a finishing diet with a novel Direct Fed Microbial.**

| | Treatments[1] | | | |
|---|---|---|---|---|
| Item | CON | DFM | SEM | *P*-value |
| *Carcass-Adjusted Performance* | | | | |
| Initial BW, lb | 604 | 603 | 4.9 | 0.93 |
| Final BW, lb[2] | 1297 | 1289 | 16.5 | 0.76 |
| DMI, lb/d | 21.3 | 21.0 | 0.36 | 0.51 |
| ADG, lb | 3.67 | 3.63 | 0.08 | 0.77 |
| F:G | 5.81 | 5.76 | - | 0.75 |
| *Carcass Characteristics* | | | | |
| HCW, lb | 817 | 812 | 10.41 | 0.76 |
| Marbling[3] | 465 | 448 | 20.35 | 0.57 |
| LM area, in[2] | 13.8 | 13.0 | 0.42 | 0.21 |
| 12th rib fat, in | 0.57 | 0.53 | 0.29 | 0.28 |
| Liver Abscesses, %[4] | 13.79 | 10.34 | - | - |

[1] Treatments included control and DFM (top dressed)

[2] Calculated from HCW divided by a common dressing percentage (63%).

[3] Marbling score 400 = small, 500 = modest, etc.

[4] Calculated as a percentage of total animals for that treatment; lame and dead animals removed.

LM area, and 12th rib fat thickness were recorded. Carcass-adjusted performance was calculated using final BW based on HCW divided by a common dressing percentage.

Data were analyzed using the PROC Mixed procedure of SAS evaluating the individual animal as the experimental unit. Steers were stratified by weight, as such no block was used. Liver abscesses were analyzed as binomial since all liver abscesses received the same score and cattle either had an abscessed liver or they did not. One steer was removed from the study due to lameness issues and one steer was removed due to mortality derived from abomasum hemorrhage. Final calculations do not include the dead or removed steers. Treatment differences were declared significant for all statistical analysis at $P \leq 0.05$.

## Results

Throughout the feeding period, no significant differences ($P > 0.51$) in final BW, DMI, ADG, or F:G (Table 2) were detected. Similarly, no significant differences between treatments ($P > 0.21$) in HCW, marbling, LM area, 12th rib fat, or liver abscesses were observed. Liver abscess incidences were low, with only 4 out of 29 observed for control and 3 out of 29 steers fed the DFM. Abscess rates were low overall despite not feeding any additives and a diet with high-moisture corn.

## Conclusion

Feeding this specific DFM at 1 billion bacterial cells/steer daily to finishing beef cattle did not significantly affect performance, carcass characteristics, liver abscess rate, or the severity of liver abscesses.

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# Impact of Biochar Supplementation in Finishing Diets on Greenhouse Gas Emissions

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## Summary with Implications

*A study was conducted to evaluate the impact of feeding biochar in a finishing diet on cattle performance, methane and carbon dioxide emissions, and carcass characteristics. Two treatments were evaluated, a high-concentrate control diet without biochar and a diet with biochar included at 1.0% of the diet dry matter, replacing high moisture corn in the diet. Pens of cattle were rotated through a two-sided emissions barn (2 pens evaluated simultaneously) to capture $CH_4$ and $CO_2$ production. There were no statistical differences in gas emissions for biochar supplemented steers compared to control. There was a 2.4% decrease in dry matter intake and 5.9% decrease in average daily gain for steers supplemented biochar, resulting in lighter and leaner carcasses for biochar fed steers.*

## Introduction

Methane ($CH_4$) emissions have been an environmental concern over the last few decades, and the beef industry has been challenged to lower/mitigate $CH_4$ emissions. One proposed method to reduce $CH_4$ production in cattle is by feeding biochar. Biochar is produced by burning organic matter at high temperatures in the absence of oxygen, resulting in a carbonized charcoal product. In cattle, $CH_4$ production is critical in ruminal fermentation, but does represent an energetic loss for the animal, estimated between 2 to 12% of total energy intake. There are several theories on mode of action when biochar is included in cattle diets. Biochar may adsorb $CH_4$, act as a hydrogen sink, or impact rumen microbial community, resulting in reduced $CH_4$ produced during rumination and eructation. A study conducted at UNL evaluated biochar supplemented to cattle at 0.8 and 3.0% of the diet and measured emissions utilizing headbox technology. This study reported a decrease in $CH_4$ emissions for cattle that were supplemented biochar at these concentrations in the diet (*2019 Nebraska Beef Cattle Report*, pp. 56–59). Biochar used in this experiment had a C content of 85%, bulk density of 5.5 lb/ft$^3$ and surface area of 323 m$^2$/g.

The objective of this study was to quantify the impact of biochar supplementation on cattle performance, $CH_4$ and $CO_2$ production, and carcass characteristics of finishing steers.

**Table 1. Diet composition for steers fed a finishing diet with or without biochar inclusion (DM basis)**

| Ingredient, % | Control | Biochar |
|---|---|---|
| Wheat Straw | 5 | 5 |
| Sweet Bran[1] | 35 | 35 |
| High Moisture Corn | 55 | 54 |
| Supplement[2] | 5 | 5 |
| Biochar[3] | 0 | 1 |

[1]Cargill Corn Milling, Blair, NE

[2]Formulated to provide 0.3% salt, 1.63% limestone, 0.10% tallow, beef trace mineral, vitamin A-D-E, Rumensin (Elanco Animal Health) targeted 30 g/ton, Optaflexx (Elanco Animal Health) targeted 300 mg/hd/d for last 28d, Tylan (Elanco Animal Health) targeted 90 mg/hd/d as % of diet DM, with fine ground corn as the carrier

[3]Biochar was added as an ingredient to the feed truck and replaced high moisture corn inclusion in the diet

## Procedure

A 111-day feedlot finishing study was conducted at the University of Nebraska–Lincoln Eastern Nebraska Research and Extension Center (ENREC) near Mead, NE. Yearling steers (n=128; initial BW=1058 lb) were assigned to two treatments (Table 1); a control finishing diet (no biochar inclusion) and finishing diet with 1.0% biochar inclusion which replaced 1% high moisture corn (HMC) in the ration. Diets were identical other than biochar inclusion, and contained wheat straw, HMC, and Sweet Bran (Cargill, Blair, NE).

Pens were assigned randomly to treatment (8 pens/treatment) and steers were stratified into 2 BW blocks (6 light reps and 2 heavy reps) and assigned randomly to pen (8 hd/pen). Before trial initiation, steers were limit-fed a common diet of 50% alfalfa hay and 50% Sweet Bran offered at 2% of BW for 5 days. Steers were weighed in the morning of day 0 and 1 of trial and weights were averaged to establish initial BW. Steers were implanted with Revalor-200 (200 mg trenbolone acetate + 20 mg estradiol; Merck Animal Health, Summit, NJ) on day 1 of study.

Biochar was provided by High Plains Biochar (Laramie, WY), and was sourced from ponderosa pine wood waste. Dry matter of the biochar fluctuated with moisture in the air from 57% to 76% DM with an average of 70%. On a DM basis, carbon (C) content of the biochar was 82.8%, with a surface area of 426 m$^2$/g, bulk density of 6.73 lb/ft$^3$, and pH of 9.49. Biochar particle size ranged from < 0.5-mm to 8-mm, with approximately 66% of biochar sampled sizing <2-mm and 1% of biochar sampled >4-mm.

The UNL ENREC emission barn, equipped with a negative pressure system to monitor and record $CH_4$ and $CO_2$ production, was utilized for 8 consecutive weeks to monitor emissions from finishing steers. The emission barn has 2 isolated pens (no

emission cross-over) and operates using two air sensors, the LI-COR 7500 and LI-COR 7700 (LI-COR, Lincoln, NE) to monitor $CO_2$ and $CH_4$, respectively. Eight pens of cattle, 4 control and 4 biochar, were selected randomly and rotated through the barn for two 5-d periods, with each treatment represented in the barn concurrently. Each week, steers entered the barn Wednesday morning, were removed Monday morning and returned back to their feedlot pen. Manure $CO_2$ and $CH_4$ emissions were calculated from the remainder of Monday. The barns were scraped clean each Tuesday to develop a baseline emission level post manure removal. An average $CO_2$ value of 17.45 g per steer and $CH_4$ value of 0.07 g per steer were subtracted from the daily emission total for $CO_2$ and $CH_4$ as contributions from manure.

Steers were harvested at a commercial abattoir (Greater Omaha, Omaha, NE) at study completion. Hot carcass weights were recorded on day of slaughter and USDA marbling scores, yield grade, and LM area were recorded after a 48-hr chill. Biochar is not currently approved by the FDA to be fed to cattle intended for human consumption. Prior to trial initiation, a food use authorization from the FDA was obtained for cattle utilized in this study to be harvested for human food use.

Data were analyzed using the MIXED procedure of SAS (SAS Institute, Inc., Cary, NC) with pen as the experimental unit. Performance data included BW block as a fixed effect and emissions data included barn as a fixed effect. Due to complications with the $CO_2$ analyzer, $CO_2$ emissions were averaged from one replication per treatment for each turn. In addition, one replication (week two of barn rotations) had unusable data for all emissions.

**Table 2. Effect of biochar addition at 1.0% diet DM on performance and carcass characteristics of finishing steers**

| | Treatments | | | |
|---|---|---|---|---|
| | Control | Biochar | SEM | *P*-value |
| *Performance* | | | | |
| Initial BW, lb | 1057 | 1061 | 4.58 | 0.55 |
| Final BW, lb | 1471 | 1450 | 8.83 | 0.10 |
| DMI, lb/d | 29.5 | 28.8 | 0.14 | <0.01 |
| ADG, lb | 3.73 | 3.51 | 0.069 | 0.02 |
| Feed:Gain[1] | 7.91 | 8.19 | — | 0.22 |
| *Carcass characteristics* | | | | |
| HCW, lb | 927 | 914 | 5.6 | 0.10 |
| LM area, $in^2$ | 14.8 | 14.7 | 0.14 | 0.93 |
| Marbling | 455 | 455 | 10.2 | 0.97 |
| $12^{th}$ rib fat[2], in | 0.61 | 0.57 | 0.018 | 0.12 |
| Calculated yield grade | 3.23 | 3.18 | 0.041 | 0.02 |

[1]Analyzed as Gain:Feed, the reciprocal of Feed:Gain

[2]$12^{th}$ rib fat, in: calculated by back calculating from the USDA YG equation

**Table 3. Effect of biochar addition at 1.0% diet DM on daily $CO_2$ and $CH_4$ emissions of finishing steers**

| | Treatments | | | |
|---|---|---|---|---|
| | Control | Biochar | SEM | *P*-value |
| DMI, lb/steer[1] | 26.0 | 26.4 | 0.55 | 0.59 |
| $CH_4$, g/steer | 168.7 | 165.7 | 5.6 | 0.71 |
| $CH_4$, g/lb of DMI | 6.8 | 6.5 | 0.43 | 0.60 |
| $CO_2$, g/steer | 6282 | 6173 | 375 | 0.87 |
| $CO_2$, g/lb of DMI | 267 | 238 | 65 | 0.80 |

[1]Dry matter intake (DMI) used to determine emission quantities was averaged from the weekly intakes of each treatment during rotation through the emission barn

## Results

Biochar supplemented steers had lower dry matter intake (DMI; $P < 0.01$; Table 2) and average daily gain (ADG; $P = 0.02$) and tended to have a lighter carcass adjusted final BW ($P = 0.10$) compared to the control. Feed conversion did not differ between the two treatments ($P = 0.22$; Table 2). Biochar supplemented steers tended to be lighter in hot carcass weight (HCW; $P = 0.10$) and USDA calculated yield grade was significantly lower ($P = 0.02$) for biochar fed steers compared to control due to lower ADG. Results from this study showed no difference in other USDA quality ($P = 0.97$) or yield grade parameters ($P \geq 0.12$) including LM area ($in^2$) and $12^{th}$ rib fat (in). Emissions of $CO_2$ and $CH_4$ were not different between steers fed biochar and control treatments ($P \geq 0.60$; Table 3).

## Conclusion

Pine-sourced biochar included at 1.0% of diet DM in finishing steers did not have a significant impact on $CO_2$ or $CH_4$ emissions. There was a numerical decrease in DMI and ADG for biochar fed steers, resulting in a lighter and leaner carcass. Type of diet, physical properties of the biochar, and inclusion percentage of biochar in the diet are all potentially influencing emission and performance differences across studies.

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# Evaluation of Methane and $CO_2$ Production in Growing and Finishing Cattle Raised in Conventional or Partial Confinement-based Herds

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## Summary with Implications

*Methane emissions from growing and finishing calves compared either a spring calving, conventional cow system or a summer calving, partially-confined cow system. Calves weaned from the confinement-based production system were smaller at weaning and compensated with greater gain during the growing phase. More days on feed in the finishing phase were needed for the calves from the confinement system to reach same backfat thickness. Over the entire growing and finishing phases, calves from the confinement-based system produced more total $CH_4$ and $CH_4$ per lb. HCW. Production of methane and CO2 per lb. of gain was lower in calves from the confinement system in the growing phase. During the finishing period, calves from the conventional system had greater daily gain and lower methane per lb. of gain. Cattle consuming finishing diets had less $CH_4$ per lb. feed intake and feeding growing diets resulted in less $CO_2$ per animal per day and per lb. feed intake. Differences in GHG emissions were a function of size, feed intake, growth rate and diet composition.*

## Introduction

The production of beef is scrutinized due to production of greenhouse gases (GHG), particularly enteric methane. Previous work has shown that cattle naturally produce methane ($CH_4$). There is a positive correlation between $CH_4$ production and dry matter intake (DMI) and forage intake, and a negative correlation with concentrate inclusion. Diets containing high levels (>40%) of forage result in greater $CH_4$ production per lb. of intake, per calorie of energy intake, and lb. of gain or production, but not necessarily per animal per day. Carbon dioxide ($CO_2$) is also a GHG produced by cattle due to respiration. While not as potent as $CH_4$, a greater understanding of $CO_2$ production is important when quantifying total GHG production of beef systems. But many times, $CO_2$ production is ignored in GHG budgeting. Although GHG production by cattle consuming diets of various quality has been measured, there are no known comparisons of GHG from cattle of similar genetics originating from different cow/calf production systems.

The objective of this study was to measure post-weaning GHG production from calves raised in different beef systems when consuming a high forage growing diet or a high concentrate finishing diet. Comparisons were made between the diets, and the systems for total GHG production and various measures of animal production and performance.

## Procedure

The GHG emissions from progeny from two cow/calf confinement systems were evaluated. At the onset of the trial, 160 cows were assigned randomly to one of 2 production systems, Conventional (CONV) and Alternative (ALT). Cow age was equally represented in both systems. In each system, 4 groups of cows (n=20) were raised under set conditions for 2 consecutive years, and post-weaning practices remained the same for all calves (steers and heifers). The CONV system was a pasture-based system. Cow/calf pairs grazed bromegrass pastures from April 25 to October 15, calved between April 15 and June 15 and weaned October 15 when calves were approximately 168 days of age. After weaning, cows grazed corn residue until March 15, then returned to grass pastures and were fed grass hay until forage growth was adequate for grazing. The ALT system was an intensive, feedlot-based system during the summer and grazing during the fall and winter. Cows entered the feedlot on March 15 and were limit-fed from March 15 until calving which occurred July 15 to September 15. Cow feed intakes were adjusted to meet gestation and lactation needs according to a well-established beef cattle model. After calving, cow/calf pairs grazed secondary annual forage from October 15 to January 15, when calves were weaned. Calves from both systems were fence-line weaned for 5 days and limit-fed at 2% of bodyweight (BW) a diet of 50% alfalfa hay and 50% Sweet Bran (DM-basis). Cattle were weighed 2 consecutive days before starting a growing period (113 d year 1, 120 d year 2) and fed 35% grass hay, 30% modified distillers grains plus solubles, 30% dry-rolled corn, and 5% supplement (DM basis) for *ad-libitum* intake (Table 1). When the growing period ended, cattle were limit-fed at 2% BW a diet of 50% alfalfa and 50% Sweet Bran for 5 consecutive days and weighed 2 consecutive days to determine initial body weight for the finishing phase. Following weighing, cattle were adapted to a high grain finishing diet using 4 step up diets over 24 days and finished to a target of 0.5 inches of backfat projected using 2 ultrasound measurements over the feeding period. The finishing diet in year 1 was 34% dry-rolled corn, 34% high-moisture corn, 20% modified distillers grains plus solubles, 7% grass hay, and 5% supplement (DM basis), and in year 2, 40% HMC, 40% Sweet Bran, 15% corn silage, and 5% supplement (DM basis). Two years of calf crops from both CONV and ALT were monitored during growing and finishing phases.

During both growing and finishing, each pen of calves was put into a double-sided pen-scale GHG measurement barn chamber for 5 consecutive days. Methane and $CO_2$ were monitored through a negative pressure system. The barn contains 2 methane chambers that are completely enclosed and separated from each other. Each chamber contains two fans to pull

**Table 1. Composition of diets (DM basis) fed to cattle during growing and finishing phases.**

| | Growing | Finishing | |
|---|---|---|---|
| Ingredient, % DM | Years 1 and 2 | Year 1 | Year 2 |
| Dry rolled corn | 30 | 34 | |
| High moisture corn | | 34 | 40 |
| Sweet Bran | | | 40 |
| Modified distillers grains | 30 | 20 | |
| Corn silage | | | 15 |
| Grass hay | 35 | 7 | |
| Supplement | 5 | 5 | 5 |
| Fine ground corn | 2.52 | 2.29 | 1.88 |
| Limestone | 1.98 | 1.69 | 1.63 |
| Tallow | 0.13 | 0.13 | 0.1 |
| Urea | 0 | 0.5 | 0 |
| Salt | 0.30 | 0.30 | 0.30 |
| Beef trace mineral | 0.05 | 0.05 | 0.05 |
| Vitamine ADE premix | 0.015 | 0.015 | 0.015 |
| Rumensin 90 premix | 0.012 | 0.017 | 0.017 |
| Tylan 40 premix | 0 | 0.011 | 0.010 |

air through at a rate of 2,789 feet$^3$/minute. Sampling ports are located near the fans, with pumps that pull air into a sampling line. The air is analyzed using two open path lasers, the LI-COR 7500 for $CO_2$ and the LI-COR 7700 for $CH_4$. The air sampling system cycles between 3 sampling lines; one line in each chamber (east and west) and one line on the south side for ambient air supply. Each cycle lasts 20 minutes during which each side of the barn and ambient air are sampled.

Calves from one pen were split evenly between both chambers of the barn after sorting to equalize heifers and steers in each chamber. After 5 days, calves were removed, and the manure that accumulated over the previous 5 days was monitored for GHG emissions for 24 hours. On the 7$^{th}$ day, manure was removed from the barn using a skid loader and then a final 24 hours measurement of the empty barn with no manure or cattle was performed for baseline measurements. The GHG production from manure was calculated by the difference from baseline. It was assumed that the GHG contributions from manure were equal to one-half of what was measured during the 24 hours, since, on average, half of the accumulated manure was present in the barn at any one time during the 5-day measurement period. The GHG contribution from manure was subtracted from the total GHG emissions to determine GHG emissions from the cattle. This correction was small, averaging 1.32 grams of $CH_4$ and 130 grams of $CO_2$ per animal per day. When the 7-day cycle was complete, the cycle was repeated for the other 3 reps in the production system. Calves from both CONV and ALT systems were in the barn for the same days on feed within year, on average, for both growing and finishing, but were at different times of the year between systems due to differing calving dates.

Total GHG production (grams/animal daily) was analyzed as an ANOVA using PROC MIXED, with day in barn as the repeated measure. There were 5 days of measurements each time cattle were in the barn. The means of the 5 days for of $CO_2$ and $CH_4$ production from each chamber were used to calculate GHG production from each replicate within groups. These were used to calculate $CO_2$ and $CH_4$ emissions expressed per lb. of intake. The $CO_2$ and $CH_4$ values per lb. of DMI were used to calculate grams of $CO_2$ and $CH_4$ per lb. of gain, per animal daily, and the total over the entire feeding period. Cattle in CONV and ALT were slaughtered at equal backfat thicknesses, but groups had different numbers of days on feed and different feed intakes. Differences in $CH_4$ and $CO_2$ production were analyzed using the MIXED procedure of SAS (SAS Institute, Inc., Cary, NC) with pen as the experimental unit and year as a random variable.

## Results

### *Production Systems*

Cattle consuming the growing diet did not differ in DMI between CONV and ALT (Table 2). Calves from the ALT system had greater ADG and lower F:G ($P < 0.01$) during the growing period compared to CONV. Greater $CH_4$ and $CO_2$ production per lb. of ADG ($P < 0.01$) and a tendency for greater $CO_2$ production over the entire growing period ($P = 0.07$) were observed in CONV calves. During the finishing phase there were no differences in DMI ($P = 0.25$); however, CONV calves had greater ADG and reduced F:G ($P < 0.01$). Due to the difference in ADG, CONV calves had lower $CH_4$ emissions per lb. of ADG ($P = 0.01$) during finishing. CONV calves had less total $CO_2$ per animal ($P = 0.02$) during finishing. Over the entire growing and finishing period CONV calves had less $CH_4$ per lb. HCW ($P = 0.04$) and less total $CH_4$ ($P = 0.02$). There were no differences in carcass adjusted final BW, HCW, ADG, DMI, or F:G over the combined growing and finishing period ($P = 0.15$). Cattle in ALT system were approximately 100 lb. lighter at the start of growing but were fed, on average, 35 days longer during finishing. This explains the differences in ADG but lack of differences in final BW and HCW.

**Table 2. Performance and greenhouse gas production by cattle raised in conventional (CONV) or alternate (ALT) partial confinement production systems.**

| | CONV | ALT | SEM | *P value* |
|---|---|---|---|---|
| Growing Phase | | | | |
| DMI, lb./day | 19.6 | 19.1 | 0.25 | 0.15 |
| ADG, lb. | 2.67 | 3.05 | 0.04 | <0.01 |
| F:G | 7.35 | 6.25 | - | <0.01 |
| Days, n | 116 | 116 | | |
| $CH_4$ Production | | | | |
| Per animal per day, g | 122.9 | 121.9 | 3.42 | 0.79 |
| Per lb. DMI, g | 7.31 | 7.14 | 0.24 | 0.62 |
| Per lb. ADG, g | 53.7 | 44.8 | 2.53 | <0.01 |
| Total per animal, lb. | 632.3 | 558.2 | 36.4 | 0.06 |
| $CO_2$ Production | | | | |
| Per animal per day, g | 4713 | 4948 | 193 | 0.25 |
| Per lb. DMI, g | 297.8 | 271.9 | 12.9 | 0.18 |
| Per lb. ADG, g | 2188 | 1702 | 135 | <0.01 |
| Total per animal, lb. | 25779 | 21233 | 1812 | 0.03 |
| Finishing Phase | | | | |
| DMI, lb./day | 23.31 | 23.83 | 0.43 | 0.25 |
| ADG, lb. | 3.99 | 3.34 | 0.07 | <0.01 |
| F:G | 5.88 | 7.13 | - | <0.01 |
| Days, n | 148 | 183 | | |
| $CH_4$ Production | | | | |
| Per animal per day, g | 125.1 | 145.1 | 11.3 | 0.10 |
| Per lb. DMI, g | 5.34 | 6.07 | 0.46 | 0.14 |
| Per lb. ADG, g | 31.7 | 43.2 | 4.45 | 0.02 |
| Total per animal, lb. | 687.8 | 910.5 | 114.4 | 0.07 |
| $CO_2$ Production | | | | |
| Per animal per day, g | 7576 | 7101 | 345 | 0.19 |
| Per lb. DMI, g | 326.2 | 299.7 | 15.2 | 0.11 |
| Per lb. ADG, g | 2009 | 2138 | 79 | 0.13 |
| Total per animal, lb. | 42384 | 44359 | 3045 | 0.53 |

*Diets*

Shown in Table 3, there was greater DMI the finishing period ($P < 0.01$), and there was a production system by diet interaction for F:G and ADG ($P < 0.01$). The interaction is explained by greater ADG in the growing period by calves in the ALT system and greater ADG in the finishing period by calves in the CONV system. With no differences in DMI this resulted in an interaction in F:G. At weaning calves from ALT system were 100 lbs. lighter than calves in the CONV system and compensatory growth occurred in the growing phase. Subsequently, calves from CONV system had greater ADG in the finishing phase ($P < 0.01$). There was a system by diet interaction for both $CH_4$ and $CO_2$ per lb. of ADG ($P < 0.01$). There was greater DMI when calves consumed a finishing diet, however, there were more $CH_4$ emissions during growing per lb. DMI ($P < 0.01$). One explanation is the greater forage content of the growing diet that led to greater $CH_4$ per lb. of DMI (7.23 vs 5.71 grams per lb. DMI). The opposite is true for $CO_2$. When consuming the finishing diet, cattle produced more $CO_2$ per animal per day ($P < 0.01$) and a tendency for more $CO_2$ per lb. DMI ($P = 0.06$). This was likely due to more $CO_2$ generated from metabolism in finishing cattle that were, on average, heavier than cattle consuming a growing diet.

## Conclusion

Cattle raised in a partial-confinement cow/calf production system and born in the summer produced 17% less total $CH_4$ and 22% less total $CO_2$ per lb. of ADG when consuming a growing diet compared to calves raised in a conventional, grass-based system. The data from the study suggests that this was due to differences in BW, DMI and ADG. Cattle consuming a forage-based growing diet produced 21% more $CH_4$ and 9.8% less $CO_2$ per lb. of dietary intake compared to a grain-based diet. However, cattle consuming a grain-based diet produced 24% less $CH_4$ and 6.5% more $CO_2$ per lb. of ADG. During the finishing phase, cattle raised in the confinement-based system produced 14% more total $CO_2$ and 46% more total $CH_4$ because of more days on feed. Over the entire growing and finishing

**Table 2. Continued**

| | CONV | ALT | SEM | *P value* |
|---|---|---|---|---|
| Growing and Finishing Phases | | | | |
| Initial BW, lb. | 508 | 409 | 8.7 | <0.01 |
| Carcass adjusted Final BW, lb. | 1333 | 1356 | 17 | 0.19 |
| HCW, lb. | 840 | 855 | 11 | 0.18 |
| DMI, lb./day | 21.7 | 21.9 | 0.3 | 0.45 |
| ADG, lb. | 3.38 | 3.22 | 0.1 | 0.15 |
| F:G | 6.49 | 6.80 | - | 0.16 |
| $CH_4$ Production | | | | |
| Per lb. DMI, g | 6.13 | 6.44 | 0.27 | 0.27 |
| Per animal per day, g | 132.8 | 141.5 | 6.24 | 0.18 |
| Total per animal, lb. | 77.3 | 94.5 | 6.5 | 0.02 |
| Per lb. HCW, g | 41.8 | 50.2 | 3.76 | 0.04 |
| $CO_2$ Production | | | | |
| Per lb. DM, g | 315.2 | 290.0 | 13 | 0.07 |
| Per animal per day, g | 6816 | 6341 | 252 | 0.08 |
| Total per animal, lb. | 3984 | 4180 | 158 | 0.23 |
| Per lb. HCW, g | 2153 | 2226 | 99 | 0.47 |

**Table 3. Performance and greenhouse gas production of cattle consuming growing or finishing diets.**

| | | | | *P* value | | |
|---|---|---|---|---|---|---|
| | Growing | Finishing | SEM | Diet | System | Diet x System |
| DMI, lb. | 19.3 | 23.5 | 0.3 | <0.01 | 0.95 | 0.10 |
| ADG, lb. | 2.86 | 3.66 | 0.14 | <0.01 | 0.36 | <0.01 |
| F:G | 6.76 | 6.44 | 1.4 | 0.19 | 0.59 | <0.01 |
| $CH_4$ Production | | | | | | |
| Per animal per day, g | 139.7 | 135.1 | 8.23 | 0.59 | 0.43 | 0.11 |
| Per lb. DM | 7.23 | 5.71 | 0.34 | <0.01 | 0.42 | 0.19 |
| Per lb. ADG | 49.2 | 37.50 | 2.6 | <0.01 | 0.63 | <0.01 |
| $CO_2$ Production | | | | | | |
| Per animal per day, g | 5506 | 7339 | 277 | <0.01 | 0.05 | 0.76 |
| Per lb. DM | 284.9 | 313.0 | 28.1 | 0.06 | 0.08 | 0.99 |
| Per lb. ADG | 1945 | 2073 | 118 | 0.29 | 0.14 | 0.01 |

period calves raised in a confinement-based system produced 22% more $CH_4$ and 20% more CH4 per lb. HCW. Differences in diet composition, rates of gain, and days on feed impact GHG emissions, which impacts total GHG emission prior to harvest.

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# Impact of Spring Corn Residue Grazing on Soil Physical Properties and Crop Yield

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## Summary with Implications

*The effects of stocking density for spring corn residue grazing on soil physical properties and soybean yield were evaluated in an experiment with three treatments: no grazing, normal density, and high density. Normal density was stocked at 3 calves/acre and grazed 45 days starting in mid-February. High-density was stocked at 9 calves/acre and grazed 15 days starting in mid-March. Increased stocking density decreased residue cover and increased surface roughness. Bulk density and penetration resistance were increased for normal density compared to no graze, with no difference between grazed treatments, illustrating that grazing may cause minor compaction, regardless of stocking density. However, these values were below the threshold that would be expected to cause issues with plant growth. Soybean emergence did not differ among treatments and soybean yield was increased by grazing. Spring grazing may cause minor compaction, and increase surface roughness, but improves subsequent soybean yields in an irrigated, no till, high yielding field.*

## Introduction

The University of Nebraska–Lincoln has conducted extensive research in the area of corn residue grazing, as it is an effective way to integrate crop and livestock production. Unfortunately, it is still an under-utilized forage resource in much of the Midwest. It is well known that corn residue can be a low-cost feed resource for cattle producers. Despite this, not all farmers are comfortable with grazing corn residue due to concerns about compaction. In a survey of Nebraska farmers, of those who chose not to graze or allow grazing of corn residue, 47% thought soil compaction was a major issue (*2017 Nebraska Beef Cattle Report*, pp. 112–115). Studies have shown this to not be the case, with there being little impact on soil physical properties under normal grazing conditions during the winter months (*2015 Nebraska Beef Cattle Report*, pp. 53–55; *2017 Nebraska Beef Cattle Report*, pp. 50–52). However, minimal research has evaluated spring residue grazing, especially when applying heavier stocking densities; thus, this study investigated these factors and the effects on soil physical properties and subsequent soybean yield.



## Procedure

A corn residue grazing experiment was conducted during the spring of 2019 and 2020 at the Eastern Nebraska Research and Extension Center of the University of Nebraska–Lincoln located near Mead, Nebraska to evaluate the effect of high stocking density on soil physical properties and its influence on soybean emergence and yield. The 160-ac field was irrigated, under no-till management and in a corn-soybean rotation. Approximately, one-half of the field was in corn each year. The soil is mainly Tomek silt loam and Yutan silty clay loam. The treatments were: (i) no grazing (NG) (negative control), (ii) normal stocking density (NSD) (positive control), and (iii) high stocking density (HSD). The study utilized 128 calves each year (609 ± 9.6 lb) assigned to either a NSD treatment (3 calves/ acre) with a target grazing period of 45 days or HSD treatment (9 calves/ acre) with a target grazing period of 15 days. This resulted in an equal number of head days for the two grazing treatments (135 head days/acre). There were 4 groups of calves (replicates) for each grazing treatment each year with eight calves per group in NSD and 24 calves per group in HSD. The corn yield in this field was 233 bu/ac and the target grazing rate was based on the estimate of 16 lb of leaf and husk produced per bushel of corn grain, 50% of leaf and husk available for grazing, and an intake of 10 lb (dry matter basis) per calf per day which is 15% of the total residue (cornstalks, cobs, leaves, and husks) in the field. Calves were provided a dry distillers grain supplement daily at 5.4 lb DM/hd/d. Calves in NSD began grazing in mid-February with the HSD calves beginning to graze in early March. The objective of the high intensity group was to create a worst-case scenario to evaluate the effects on the soil; thus, the HSD groups were put on their plots after a rain event occurred. Until then, the HSD cattle grazed corn residue in an adjoining field at normal stocking rate. Calves were taken off treatments by March 27, 2019, and March 31, 2020, with soil measurements taken 21- and 49-days post removal of calves. Three measurements were taken on the soil: bulk density, soil penetration resistance, and surface roughness. Residue cover was measured only in the second year of the study, 21 days post-removal of calves. Soybean planting occurred on May 2, 2019, and April 29, 2020, and crop emergence was evaluated 30 days post-planting. For all measures, 4 rows were sampled in each plot with 3 sample sites per row, resulting in 12 sample sites per plot. Data were analyzed using Proc Mixed of SAS with treatment considered significant at $P \leq 0.05$. Experimental unit was treatment plot.

## Results

### *Soil cover and compaction parameters*

The amount of residue cover at the end of grazing differed ($P < 0.01$) among treatments, with NG having greater ($P < 0.01$) cover than NSD and NSD having greater ($P < 0.01$) residue cover than HSD (Table 1). Indeed, the high stocking treatment visually had more bare ground than the other treatments. The decreased residue cover in the high stocking density treatment is thought to be primarily due to increased trampling losses as the intake between NSD and HSD

**Table 1. Percentage of residue cover and surface roughness present after corn residue was not grazed (NG), grazed in the spring at a normal stocking density (NSD) or spring grazed using a high stocking density (HSD).**

| | NG | NSD | HSD | SEM | NG vs NSD | NSD vs HSD |
|---|---|---|---|---|---|---|
| **Residue cover[1], %** | 87.9 | 37.7 | 17.7 | 2.8 | <0.01 | <0.01 |
| **Surface roughness[2], %** | 1.6 | 9.5 | 14.9 | 0.78 | <0.01 | <0.01 |

[1] Residue cover measured in year 2, 21-days post removal of calves.

[2] Surface roughness was measured using a 20-foot-long chain which decreased in length with increased surface roughness. It is expressed as the percent change in chain length.

**Table 2. Soil parameters measured[1] after corn residue was either not grazed (NG), grazed in early spring at a normal stocking density (NSD) with 3 steers/acre for 45 days or at a high stocking density (HSD) with 9 calves/acre for 15 days.**

| | | | | | *P*-value | |
|---|---|---|---|---|---|---|
| Item | NG | NSD | HSD | SEM | NG vs NSD | NSD vs HSD |
| **Bulk density, g/cm³** | | | | | | |
| 21 days | | | | | | |
| 0–2 in | 0.85 | 1.02 | 0.99 | 0.041 | <0.01 | 0.45 |
| 2–4 in | 1.16 | 1.25 | 1.25 | 0.028 | <0.01 | 0.92 |
| 49 days | | | | | | |
| 0–2 in | 0.88 | 1.01 | 1.02 | 0.036 | <0.01 | 0.80 |
| 2–4 in | 1.18 | 1.27 | 1.27 | 0.016 | <0.01 | 0.86 |
| **Penetration resistance, MPa** | | | | | | |
| 21 days | | | | | | |
| 0–2 in | 0.50 | 1.53 | 1.64 | 0.12 | <0.01 | 0.29 |
| 2–4 in | 0.71 | 1.36 | 1.58 | 0.07 | <0.01 | 0.02 |
| 49 days | | | | | | |
| 0–2 in | 0.52 | 1.67 | 1.76 | 0.11 | <0.01 | 0.37 |
| 2–4 in | 0.73 | 1.45 | 1.64 | 0.12 | <0.01 | 0.08 |
| **Moisture content, %** | | | | | | |
| 21 days | | | | | | |
| 0–2 in | 23.8 | 19.7 | 17.1 | 0.89 | <0.01 | <0.01 |
| 2–4 in | 23.0 | 22.2 | 22.0 | 0.59 | 0.35 | 0.81 |
| 49 days | | | | | | |
| 0–2 in | 25.2 | 19.5 | 18.0 | 0.86 | <0.01 | 0.20 |
| 2–4 in | 24.1 | 22.0 | 21.9 | 0.37 | <0.01 | 0.78 |

[1] Cattle were pulled off treatments at the end of March. Soil samples were taken 21- and 49-days post removal of calves and were taken in rows in which no equipment had travelled.

cattle would be expected to be similar. Similarly, across both years, surface roughness at the end of grazing (Table 1) differed ($P < 0.01$) among treatments with NG having less ($P < 0.01$) roughness than NSD and NSD having less ($P < 0.01$) roughness than HSD. Again, these data suggest increased trampling in HSD.

Bulk density and penetration resistance (Table 2) were measurements taken to determine compaction at two depths and two timepoints after grazing. At the end of grazing, both bulk density and penetration resistance differed ($P < 0.01$) among treatments. At both timepoints and depths, NG had less ($P < 0.01$) bulk density compared to NSD. No difference ($P \geq 0.45$) between the grazed treatments (NSD and HSD) were observed for bulk density. These data indicate that grazing resulted in minor compaction but stocking density did not affect compaction. Penetration resistance at the shallow depth followed the same pattern as bulk density. Not grazing had less ($P < 0.01$) penetration resistance than NSD at both timepoints, but there was no difference ($P = 0.29$) among the grazed treatments. Penetration resistance at the deeper depth shows a little different result. At both timepoints, NG had less ($P < 0.01$) penetration resistance than NSD. At 21 days post-removal of calves, NSD had less ($P = 0.02$) penetration resistance than HSD. At the second timepoint, 49 days, there tended to be a difference ($P < 0.08$) between the grazed treatments. While bulk density and penetration resistance were increased by grazing, it is important to understand that these changes were very minor and likely of little biological significance. A penetration resistance value greater than 2 MPa could result in restricted root growth. A bulk density value of 1.65 g/cm³ or more could also restrict root growth. Thus, it is unlikely that the increase in penetration resistance and bulk density would be considered detrimental as penetration resistance values were ≤ 1.76 MPa and bulk density values were ≤ 1.27 g/cm³ across all treatments at both depths and timepoints.

Moisture content (Table 2) differed ($P < 0.01$) among treatments at both timepoints within the shallow depth with NG being greater ($P < 0.01$) than NSD. Moisture content was also greater for NSD ($P < 0.01$) than HSD at 21 days post removal, but there was no difference ($P = 0.20$) between grazed treatments at 49 days. The only significant difference for moisture content at the deeper depth was at the 49-day timepoint, with NG being greater ($P < 0.01$) than NSD. Penetration resistance was not adjusted for moisture content and the wetter the soil, the easier it is to penetrate. With less residue cover, there appeared to be more evaporative loss, resulting in dryer soil, especially within the first two inches of the HSD treatment. Differences in moisture content may explain why more change is observed with penetration resistance com-

**Table 3. Soybean emergence and yield when planted after corn residue was either not grazed (NG), grazed in early spring prior to soybean planting[1] at a normal stocking density (NSD) with 3 steers/acre for 45 days or at a high stocking density (HSD) with 9 calves/acre for 15 days.**

| Item | NG | NSD | HSD | SEM | NG vs NSD | NSD vs HSD |
|---|---|---|---|---|---|---|
| **Emergence[2], plants/ac** | 102,311 | 107,340 | 109,267 | 3,754 | 0.34 | 0.70 |
| **Soybean yield, bu/ac** | 72.9 | 75.7 | 77.4 | 0.61 | <0.01 | 0.06 |

[1] Cattle were pulled off treatments at the end of March and soybeans were planted approximately 30 days later.

[2]Emergence counts were taken 30 days post-planting.

pared to bulk density and why bulk density is usually considered a better estimate of compaction.

### *Soybean emergence and yield*

There were no differences ($P \geq 0.34$) in emergence, but yield differed among treatments (Table 3). Soybean yield was less ($P < 0.01$) for NG (72.9 bu/ac) than NSD (75.7 bu/ac) and NSD tended to be less ($P = 0.06$) than HSD (77.4 bu/ac). The greater yields in the grazing treatments may be due to warmer soil temperatures, because of less residue cover, or potentially increased microbial activity in the soil which may speed up nutrient cycling (*2017 Nebraska Beef Cattle Report*, pp. 50–52).

## Conclusion

When stocking at the recommended rate, stocking density does not have major impacts on soil physical properties and subsequent crop yield. The results indicate that, regardless of stocking density, grazing corn residue in the spring may cause minor compaction; however, it is below the threshold to reduce the subsequent soybean yield. This study was conducted to create a worst-case scenario (grazing in muddy conditions) and yet there was still soybean yield improvement with grazing. Thus, producers should not be concerned about grazing cattle on residue in the spring causing compaction. However, winter grazing would still be considered ideal as there is less surface roughness to contend with at planting and less trampling loss of residue.

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# Effect of Biochar as a Feedlot Pen Surface Amendment on Manure Nutrient Capture

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## Summary with Implications

*Two mass balance experiments were conducted during winter and summer seasons to evaluate the effect of spreading biochar on the feedlot pen surface on manure nutrient retention. The winter experiment (Dec to June) evaluated three treatments including biochar spread to pen surface (approximately 54 lb of biochar per steer), hydrated lime spread to pen surface (cooperation with UNL Environmental Engineering; approximately 68 lb per steer) and negative control (no treatment applied). The summer experiment (June to Nov) evaluated biochar treatment (approximately 68 lb of biochar per steer) against negative control. Biochar utilized in winter and summer was unprocessed and sourced from Eastern red cedar. Biochar addition to the feedlot pen surface increased N concentration in manure but did not translate into increased lb of N or P removed from feedlot pens (mass balance) for both experiments. There was a significant improvement in steer average daily gain for biochar addition in the summer, with no impact on steer performance or carcass characteristics for winter.*

## Introduction

Improving manure nutrient capture of nitrogen (N) and phosphorus (P) is beneficial for the environment, with less nitrogen lost to the atmosphere via volatilization, and has the potential to improve the economic value of manure as a fertilizer. One proposed method of improving manure nutrient capture of N and P is applying biochar to the feedlot pen surface. Biochar can be produced from forest industry by-products (wood trimmings, etc.) and has been used as a soil amendment and manure treatment. The utilization of biochar as a soil amendment has shown improved plant and soil health, reduced nutrient losses via leaching and volatilization, improved soil structure (by reducing erosion), and sequestration of carbon.

The objective of this study was to evaluate the effects of applying biochar to the feedlot pen surface during two seasonal feeding periods on manure N, P, and organic matter (OM). The application of hydrated lime (calcium hydroxide) to the feedlot pen surface was in cooperation with UNL Environmental Engineering to determine the impact of lime on microbial activity on the pen surface. The alkaline stabilization properties of lime are hypothesized to reduce antimicrobial resistant bacteria in cattle manure (*2022 Nebraska Beef Cattle Report*, pp. 91–94).

## Procedure

### *Cattle Performance*

The WINTER (Dec to June) and SUMMER (June to Nov) mass balance experiments were conducted at the University of Nebraska–Lincoln Eastern Nebraska Research, Extension and Education Center (ENREEC) near Mead, NE.

**Table 1. Diet composition[1] for steers in WINTER mass balance**

| Ingredient | Diet Inclusion, % DM |
|---|---|
| High moisture corn | 51 |
| Sweet Bran[2] | 20 |
| Corn Silage | 15 |
| Modified distillers grains | 10 |
| Supplement[3] | 4 |

[1]Mean dietary crude protein 13.7% and dietary P 0.45%

[2]Cargill Corn Milling, Blair, NE

[3]Formulated to provide 0.3% salt, 1.63% limestone, 0.10% tallow, beef trace mineral, vitamin A-D-E, Rumensin (Elanco Animal Health) targeted 30 g/ton, Optaflexx (Elanco Animal Health) targeted 300 mg/hd/d for last 28 d, Tylan (Elanco Animal Health) targeted 90 mg/hd/d as % of diet DM, with fine ground corn as the carrier

In WINTER, crossbred calves (n = 150; initial BW = 604 lb) were assigned to three treatments; negative control, biochar application to pen surface, and lime application to pen surface. Unprocessed biochar made from Eastern red cedar trees was applied to the pen surface in equal volumes (approximately 270 lb dry matter; DM; per pen) at trial initiation in December and again in February. Lime treatment was applied to pen surface (approximately 680 lb DM per pen) one day prior to shipping cattle for harvest Pens were assigned randomly to treatment (5 pens/treatment) and steers were assigned randomly to pen (10 hd/pen). Steers were on feed for 186 d and the finishing diet contained high moisture corn (HMC), Sweet Bran (Cargill Corn Milling, Blair, NE), corn silage, and modified distillers grains (Table 1).

In SUMMER, crossbred yearlings (n = 80; initial BW = 747 lb) were assigned to two treatments; negative control and biochar application to pen surface. Unprocessed biochar was applied to the pen surface in equal volumes (approximately 270 lb DM per pen) at trial initiation in June and again in August. Pens were assigned to the same treatment (5 pens/treatment) as the WINTER phase and steers were assigned randomly to pen (8 hd/pen). Steers were on feed for 153 d and the finishing diet contained HMC, Sweet Bran, and cornstalks (Table 2).

**Table 2. Diet composition[1] for steers in SUMMER mass balance**

| Ingredient | Diet Inclusion, % DM |
|---|---|
| High moisture corn | 51 |
| Sweet Bran[2] | 40 |
| Cornstalks | 5 |
| Supplement[3] | 4 |

[1]Mean dietary crude protein 14.5% and dietary P 0.53%

[2]Cargill Corn Milling, Blair, NE

[3]Formulated to provide 0.3% salt, 1.63% limestone, 0.10% tallow, beef trace mineral, vitamin A-D-E, Rumensin (Elanco Animal Health) targeted 30 g/ton, Optaflexx (Elanco Animal Health) targeted 300 mg/hd/d for last 28 d, Tylan (Elanco Animal Health) targeted 90 mg/hd/d as % of diet DM, with fine ground corn as the carrier

**Table 3. Performance and carcass characteristics for steers fed the same diet with different pen amendments in WINTER phase**

| | Treatments[1] | | | | |
|---|---|---|---|---|---|
| | Control | Biochar | Lime | SEM | *P*-value |
| *Performance* | | | | | |
| Initial BW, lb | 604 | 604 | 604 | 2.8 | 0.95 |
| Final BW, lb | 1363 | 1372 | 1384 | 12.4 | 0.50 |
| DMI, lb/d | 22.1 | 22.2 | 22.6 | 0.08 | 0.10 |
| ADG, lb | 4.09 | 4.13 | 4.19 | 0.064 | 0.50 |
| Feed:Gain[2] | 5.41 | 5.39 | 5.39 | — | 0.98 |
| *Carcass characteristics* | | | | | |
| HCW, lb | 859 | 864 | 871 | 7.8 | 0.50 |
| LM area, in$^2$ | 13.4 | 13.6 | 13.6 | 0.20 | 0.76 |
| Marbling | 472 | 463 | 476 | 13.71 | 0.79 |
| 12$^{th}$ rib fat[3], in | 0.57 | 0.55 | 0.56 | 0.020 | 0.79 |
| Calculated yield grade | 3.43 | 3.38 | 3.40 | 0.050 | 0.78 |

[1]Control = no treatment applied; Biochar = red cedar biochar applied in Dec and Feb at 270 lb per pen for each application; Lime = applied 1 d prior to cattle harvest approximately 680 lb per pen

[2]Analyzed as Gain:Feed, the reciprocal of Feed:Gain

[3]12$^{th}$ rib fat calculated from the USDA YG equation

Biochar was provided by Sawle Mill (Springview, NE), and was sourced from Eastern red cedar trees. Dry matter of the biochar fluctuated with moisture in the air from 85% to 95% DM with an average of 90%. On a DM basis, carbon (C) content of the biochar was 80.3%, with a surface area of 233 m$^2$/g, bulk density of 9.7 lb/ft$^3$, and pH of 6.3. Biochar particle size ranged from 0.5-mm to 50-mm, with approximately 70% of biochar sampled sizing >8-mm.

Prior to WINTER and SUMMER initiation, steers were limit-fed a common diet of 50% alfalfa hay and 50% Sweet Bran offered at 2% of BW for 5 days. Steers were weighed in the morning of day 0 and 1 of trial and weights were averaged to establish initial BW. Steers were implanted with Revalor-IS (80 mg trenbolone acetate + 16 mg estradiol; Merck Animal Health, Summit, NJ) on d 1 of study and reimplanted with Revalor-200 (200 mg trenbolone acetate + 20 mg estradiol; Merck Animal Health, Summit, NJ) on d 76 and d 68 for WINTER and SUMMER, respectively.

Steers were harvested at a commercial abattoir (Greater Omaha, Omaha, NE) at WINTER and SUMMER completion. Hot carcass weights (HCW) were recorded on day of slaughter and USDA marbling scores, yield grade, and LM area were recorded after a 48- and 72-hr chill for WINTER and SUMMER, respectively. Performance traits including final body weight (BW), average daily gain (ADG), and feed:gain (F:G) were calculated based on HCW adjusted to a common dressing percentage of 63.

### *Nutrient Mass Balance*

Nutrient mass balance experiments were conducted using open dirt feedlot pens. Prior to cattle entering pens, 12 soil core samples (6-inch depth) were taken from each pen for both experiments. After cattle were removed from pens on day 186 (WINTER) and 153 (SUMMER), pen surface was cleaned with a box scraper, and a skid steer scraped the cement apron and piled manure. The manure pile was sampled (n = 30) for moisture and nutrient analysis as manure was loaded out from the pen. Manure trucks were weighed to determine weight of manure removed from each individual pen. Manure samples (n = 10 per pen; analyzed in duplicate) were oven dried over 48-hr to determine DM removal from each pen. Nutrient analysis was completed by Ward Laboratories (Kearney, NE) on manure samples (n = 20 per pen) after freeze drying. Following manure removal from pen, an additional 12 soil cores per pen were sampled to determine pen cleaning equivalence.

Nutrient intake was determined by monthly feed ingredient composites and feed refusals on a pen basis. The N and P retained by the animal were calculated utilizing energy, protein, and P retention equations. Nutrient excretion was then calculated by subtracting nutrient retention from nutrient intake. Runoff was not measured in this experiment, and generally accounts for 3–5% of total nutrient lost from an open dirt lot. Total nutrient loss (lb/steer) was calculated by subtracting manure nutrients (corrected for soil cores) from excreted nutrients. Cattle performance and nutrient mass balance data were analyzed using the MIXED procedure of SAS (SAS Institute, Inc., Cary, NC) with pen as the experimental unit.

**Table 4. Performance and carcass characteristics for steers fed the same diet in SUMMER phase**

| | Treatments[1] | | | |
|---|---|---|---|---|
| | Control | Biochar | SEM | *P*-value |
| *Performance* | | | | |
| Initial BW, lb | 747 | 747 | 2.39 | 0.92 |
| Final BW, lb | 1466 | 1503 | 13.20 | 0.05 |
| DMI, lb/d | 26.7 | 26.8 | 0.099 | 0.48 |
| ADG, lb | 4.70 | 4.94 | 0.086 | 0.05 |
| Feed:Gain[2] | 5.69 | 5.43 | — | 0.08 |
| *Carcass characteristics* | | | | |
| HCW, lb | 924 | 947 | 8.3 | 0.05 |
| LM area, in$^2$ | 14.4 | 14.4 | 0.18 | 0.89 |
| Marbling | 492 | 499 | 15.1 | 0.76 |
| 12$^{th}$ rib fat[3], in | 0.59 | 0.59 | 0.026 | 0.98 |
| Calculated yield grade | 3.48 | 3.48 | 0.065 | 0.98 |

[1]Control = no treatment applied; Biochar = red cedar biochar applied in June and August at 270 lb per pen for each application

[2]Analyzed as Gain:Feed, the reciprocal of Feed:Gain

[3]12$^{th}$ rib fat calculated from the USDA YG equation

## Results

### *Cattle Performance*

There were no significant differences in dry matter intake (DMI; $P = 0.10$), ADG or F:G ($P \geq 0.50$) due to pen treatment in WINTER (Table 3). Carcass characteristics were not impacted by pen treatments for cattle in WINTER ($P \geq 0.50$). There was a significant increase in carcass-adjusted final BW ($P = 0.05$) and ADG ($P = 0.05$) for steers on biochar amended treatment in SUMMER (Table 4) compared to control, and no difference between treatments for DMI ($P = 0.48$). This improvement in gain tended to improve feed conversion ($P = 0.08$) for steers in biochar treated pens compared to control and resulted in significantly heavier HCW ($P = 0.05$) for biochar treatment. Results from SUMMER showed no difference in other USDA quality or yield grade parameters ($P \geq 0.76$).

The significant increase in ADG and final BW for SUMMER steers on biochar treatment may have been influenced by the moisture content of the pen surface (*2021 Nebraska Beef Cattle Report*, pp. 95–104). The biological and chemical properties of wood-sourced biochar may absorb water and reduce moisture content on the pen surface reducing the impacts of mud; however, pen surface moisture across time was not measured in this experiment. More biochar per animal was added to the pen surface for SUMMER experiment and the SUMMER feeding period had greater precipitation compared to WINTER.

### *Nutrient Mass Balance*

In the WINTER experiment (Table 5), N intake, retention, and excretion were similar between treatments ($P \geq 0.42$). Manure concentration of N tended to differ between treatments ($P = 0.07$), with biochar treatment having the greatest manure N as a percent of manure DM. In WINTER, P intake, retention, and excretion were all similar between treatments ($P \geq 0.38$) and there was no difference between treatments in concentration of manure P ($P = 0.23$) as a percent of manure DM. Manure nutrient amounts (with correction for soil) were numerically greatest in lime treatment and lowest in biochar treatment for N ($P = 0.15$) and P ($P = 0.75$). Manure nutrient losses were similar for all treatments and averaged 54% loss of N ($P = 0.68$) and 0.43% loss of P ($P = 0.87$). The DM removed from the pen surface in WINTER was numerically lowest for biochar treatment ($P = 0.17$). Oven dried manure samples averaged 89, 88, and 90% DM content for control, biochar, and lime, respectively.

In the SUMMER experiment (Table 6), N intake and excretion were similar between treatments ($P \geq 0.35$) and steers on biochar treatment had significantly greater N retention compared to the control ($P = 0.04$). The intake and excretion of P was similar between treatments ($P \geq 0.35$), and P retention was significantly greater for biochar treatment compared to control ($P = 0.03$). Steers fed in biochar-treated pens had significantly higher ADG ($P = 0.05$), and final BW ($P = 0.05$) compared to control, resulting in greater N and P retention. The manure DM removed from the pen surface in SUMMER tended to be greater for control treatment ($P = 0.08$). Manure N as a percent of manure DM tended to be greatest for biochar treatment ($P = 0.07$) with no difference in manure P as a percent of manure DM ($P = 0.23$). Manure nutrient losses were similar for biochar and control with 71% of N (58 lb/steer; $P \geq 0.78$) and 10% of P (10 lb/steer; $P \geq 0.88$) lost during the SUMMER experiment. Oven dried manure samples averaged 55 and 56% DM content for control and biochar, respectively.

## Conclusion

These data suggest that the addition of unprocessed red cedar biochar to the feedlot pen surface (54 to 68 lb per steer) did not improve manure nutrients and did not decrease N losses. Biochar addition to the feedlot pen surface did improve growth performance of steers in the SUMMER phase, although no differences were found in growth performance for the WINTER phase.

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**Table 5. Effect of biochar and lime pen amendments on nitrogen (N), phosphorus (P) and organic matter (OM) during WINTER[1]**

| | Treatments[2] | | | | |
|---|---|---|---|---|---|
| | Control | Biochar | Lime | SEM | *P*-value |
| N Intake | 91.3 | 92.1 | 93.5 | 1.2 | 0.46 |
| N Retention[3] | 16.1 | 16.3 | 16.4 | 0.3 | 0.60 |
| N Excretion[4] | 75.2 | 75.8 | 77.0 | 1.0 | 0.42 |
| Manure N, % of DM[5] | 1.57[ab] | 1.71[a] | 1.51[b] | 0.06 | 0.07 |
| Manure N[6] | 34.0 | 33.6 | 37.1 | 1.3 | 0.15 |
| N Lost | 41.3 | 42.3 | 39.9 | 1.9 | 0.68 |
| N Lost, %[7] | 54.9 | 55.7 | 51.7 | 2.0 | 0.37 |
| P Intake | 18.7 | 18.9 | 19.2 | 0.3 | 0.43 |
| P Retention[8] | 3.9 | 4.0 | 4.0 | 0.1 | 0.60 |
| P Excretion[9] | 14.8 | 14.9 | 15.2 | 0.2 | 0.38 |
| Manure P, % of DM[10] | 0.69 | 0.76 | 0.69 | 0.031 | 0.23 |
| Manure P[11] | 14.8 | 14.5 | 15.4 | 0.8 | 0.75 |
| P Lost | 0.01 | 0.40 | -0.19 | 0.80 | 0.87 |
| P Lost, %[12] | -0.1 | 2.7 | -1.3 | 5.3 | 0.87 |
| DM Removed | 985 | 794 | 994 | 78.5 | 0.17 |
| OM Removed | 348 | 319 | 372 | 30.3 | 0.48 |

[1]Values expressed as lb/steer over entire feeding period (186 days on feed)

[2]Control = no treatment applied; Biochar = red cedar biochar applied in Dec and Feb at 270 lb per pen for each application; Lime = applied 1 d prior to cattle harvest

[3]Calculated using the NRC net energy and net protein equations

[4]Calculated as N intake—N retention

[5]Total N in manure as % of manure DM

[6]Manure N with correction for soil N

[7]Calculated as N lost divided by N excretion

[8]Calculated using the NRC phosphorus retention equation

[9]Calculated as P intake—P retention

[10]Total P in manure as % of manure DM

[11]Manure P with correction for soil P

[12]Calculated as P lost divided by P excretion

[ab]Means within a row with different superscripts differ

**Table 6. Effect of biochar as a pen amendment on nitrogen (N), phosphorus (P) and organic matter (OM) during SUMMER[1]**

| | Treatments[2] | | | |
|---|---|---|---|---|
| | Control | Biochar | SEM | *P*-value |
| N Intake | 95.7 | 96.9 | 1.3 | 0.35 |
| N Retention[3] | 14.4 | 15.1 | 0.3 | 0.04 |
| N Excretion[4] | 81.3 | 81.8 | 1.1 | 0.67 |
| Manure N, % of DM[5] | 2.01 | 2.20 | 0.06 | 0.07 |
| Manure N[6] | 23.1 | 24.8 | 4.0 | 0.78 |
| N Lost | 58.2 | 57.0 | 4.3 | 0.85 |
| N Lost, %[7] | 71.6 | 69.6 | 5.0 | 0.79 |
| P Intake | 21.6 | 21.9 | 0.2 | 0.35 |
| P Retention[8] | 3.5 | 3.7 | 0.1 | 0.03 |
| P Excretion[9] | 18.1 | 18.2 | 0.2 | 0.69 |
| Manure P, % of DM[10] | 1.06 | 1.13 | 0.06 | 0.36 |
| Manure P[11] | 16.5 | 16.1 | 2.3 | 0.90 |
| P Lost | 1.6 | 2.1 | 2.4 | 0.88 |
| P Lost, %[12] | 8.5 | 11.4 | 13.1 | 0.88 |
| DM Removed | 589 | 515 | 36.6 | 0.08 |
| OM Removed | 258 | 256 | 11.4 | 0.87 |

[1]Values expressed as lb/steer over entire feeding period (153 days on feed)

[2]Control = no treatment applied; Biochar = red cedar biochar applied in June and Aug at 270 lb per pen for each application

[3]Calculated using the NRC net energy and net protein equations

[4]Calculated as N intake—N retention

[5]Total N in manure as % of manure DM

[6]Manure N with correction for soil N

[7]Calculated as N lost divided by N excretion

[8]Calculated using the NRC phosphorus retention equation

[9]Calculated as P intake—P retention

[10]Total P in manure as % of manure DM

[11]Manure P with correction for soil P

[12]Calculated as P lost divided by P excretion

# Effects of Lime Amendment on Antibiotic Resistance in Beef Cattle Manure of Open Feedlots

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## Summary with Implications

*The objective of this study was to evaluate the effectiveness of lime amendment on the reduction of antimicrobial resistant bacteria and antimicrobial resistance genes in beef cattle manure in open feedlots. Hydrated lime was uniformly applied to the surface of feedlot pen floor 1 day prior to cattle harvest at a rate of 0.36 lb/ft$^2$ and samples were collected over time. Collected samples were analyzed for change in pH and levels of antimicrobial resistant bacteria and antimicrobial resistance genes. Lime amendment elevated the pH of pen floor surface materials to pH > 12 for 4 hours and then pH > 11 for another 24 hours. Lime amendment reduced the concentration of generic and resistant Escherichia coli by 1–2 log for up to 4 hours. The abundance of antimicrobial resistance genes, such as tet(X) and tet(O), decreased by 1–2 order of magnitude with lime amendment. Results indicate that lime addition reduced the concentrations of antimicrobial resistant bacteria and antimicrobial resistance genes in pen surface materials from open beef feedlot pens.*

## Introduction

The proliferation of antimicrobial resistance is an emerging global health concern. In livestock agriculture, antimicrobials are used to control and treat infections in animals. Livestock manure application has been identified as a potential pathway for environmental exposure of antimicrobial resistance, as manure contains antimicrobial resistant bacteria (ARB) and antimicrobial resistance genes (ARGs). ARGs are the genetic determinants that make bacteria resistant to antimicrobials. Hence, mitigating antimicrobial resistance in manure at feedlots is important in preventing the potential spread of antimicrobial resistance into the environment and into meat packing plants.

Alkaline stabilization is a process recommended by the US Environmental Protection Agency to treat biosolids from municipal wastewater treatment plants. During alkaline stabilization, pathogens in biosolids are significantly reduced due to elevated pH and treated biosolids can then be safely land applied. To meet the requirements of Class A biosolids, a pH of 12 or above needs to be maintained for 72 hours and a temperature of 125°F or above be maintained for at least 12 hours. To meet the requirements for Class B biosolids, a pH of 12 or above needs to be maintained for 2 hours. Alkaline stabilization has not been previously used to mitigate antimicrobial resistance in manure from feedlot pen surfaces. Hence, the objective of this study was to evaluate the effectiveness of alkaline stabilization on the reduction of ARB and ARGs in beef feedlot pen surface manure.

## Procedure

The study was conducted at the Eastern Nebraska Research and Extension Center (ENREC) near Mead, NE in June 2020. Ten pens, each containing ten finishing beef cattle, were included in this study. Five pens were designated randomly for lime amendment and five pens as control which did not receive lime application. In the lime amendment pens, lime was applied uniformly using a skid loader at a rate of 0.36 lb/ft$^2$ on a 30 ft × 63 ft pen surface area the day before cattle were shipped for harvest.

Pen floor material samples were collected from the amendment and control pens. Within each pen, samples were collected from 3 different sections of the pen and three locations within each section using sterile spoons. On the first sampling day, samples were collected immediately after lime application (0.5 hours), and then at 2 hours, 4 hours, and 6 hours. Additional samples were collected on subsequent days at 24 hours, 48 hours, and 72 hours. Collected samples were stored on ice in coolers, transported back to the laboratory, and processed within a day.

Manure pH was determined by adding appropriate weight of manure sample to water in a 1:2 w:v ratio [manure sample (w): deionized water (v)] and measured using the Orion 3-star pH meter (Thermo Scientific, Waltham, MA, USA). Moisture content of manure samples was determined gravimetrically by oven-drying at 105°C for 24 h.

For ARB analysis, samples were enumerated to determine the abundance of total culturable *Escherichia coli* and *Enterococci*, as well as their resistant subpopulations. Manure samples were diluted 1:10 (*w*/*v*) in phosphate buffered tryptic soy broth (Becton Dickson, Sparks, MD; TSB-$PO_4$). The suspension was plated for bacterial enumeration using an Eddy Jet 2 spiral plater with spiral counting grids (IUL, S.A., Barcelona, Spain). *E. coli* was enumerated on CHROMagar plates amended with no antibiotic, 20 mg L$^{-1}$ azithromycin or 32 mg L$^{-1}$ tetracycline. Similarly, *Enterococci* was enumerated on Slanetz-Bartley agar containing no antibiotic, 32 mg L$^{-1}$ tylosin, or with 32 mg L$^{-1}$ tetracycline. The CHROMagar plates were incubated at 37°C for 24 hours while the Slanetz-Bartley plates were incubated at 37°C for 4 hours followed by 48 h at 44°C. Blue colonies on CHROMagar plates were enumerated as *E. coli* colonies, while brown and maroon colonies on Slanetz-Bartley plates as *Enterococci* colonies. The colonies counted were converted to colony forming units (CFU) per g sample on a dry weight basis.

DNA was extracted from the manure samples for ARG measurement. To avoid the negative impacts of high pH on the DNA extraction efficiency, the pH of samples collected from lime amended pens

**Table 1. Effects of lime amendment and sampling time on bacteria concentration in beef cattle feedlot pen floor surface materials**

| | | [a]Time (hour) | | | | | | | *P*-value | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0.5 | 2 | 4 | 6 | 24 | 48 | 72 | Lime × time | Lime | Time |
| Tetracycline[R] *Enterococci* | Lime | 1.53 | 2.18 | 2.03 | 2.09 | 1.79 | 1.67 | 1.71 | 0.35 | 0.10 | <0.01 |
| | Control | 1.47 | 2.69 | 2.47 | 2.54 | 2.01 | 1.50 | 1.81 | | | |
| Tylosin[R] *Enterococci* | Lime | 1.27 | 2.11 | 2.27 | 2.67 | 2.06 | 1.54 | 1.88 | 0.05 | <0.01 | <0.01 |
| | Control | 2.29 | 2.80 | 2.73 | 2.92 | 2.17 | 1.67 | 2.16 | | | |
| Total *Enterococci* | Lime | 1.57 | 2.46 | 2.46 | 2.83 | 2.46 | 1.90 | 2.39 | <0.01 | <0.01 | <0.01 |
| | Control | 2.91 | 3.40 | 3.23 | 3.41 | 2.50 | 2.10 | 2.91 | | | |
| Tetracycline[R] *E. coli* | Lime | 1.87 | 1.70 | 1.97 | 2.04 | 1.51 | 2.06 | 1.74 | <0.01 | <0.01 | <0.01 |
| | Control | 2.68 | 3.00 | 2.71 | 3.12 | 2.44 | 2.40 | 2.07 | | | |
| Azithromycin[R] *E. coli* | Lime | 2.03 | 2.08 | 2.33 | 3.05 | 2.82 | 3.16 | 3.08 | <0.01 | 0.01 | <0.01 |
| | Control | 3.76 | 3.59 | 3.64 | 3.73 | 3.42 | 3.47 | 3.39 | | | |
| Total *E. coli* | Lime | 2.17 | 2.14 | 2.22 | 2.99 | 3.01 | 3.19 | 2.19 | <0.01 | 0.01 | <0.01 |
| | Control | 3.85 | 3.71 | 3.82 | 4.01 | 3.41 | 3.44 | 2.14 | | | |

[a] Mean ARB concentration (Log CFU $g^{-1}$ manure dry weight)

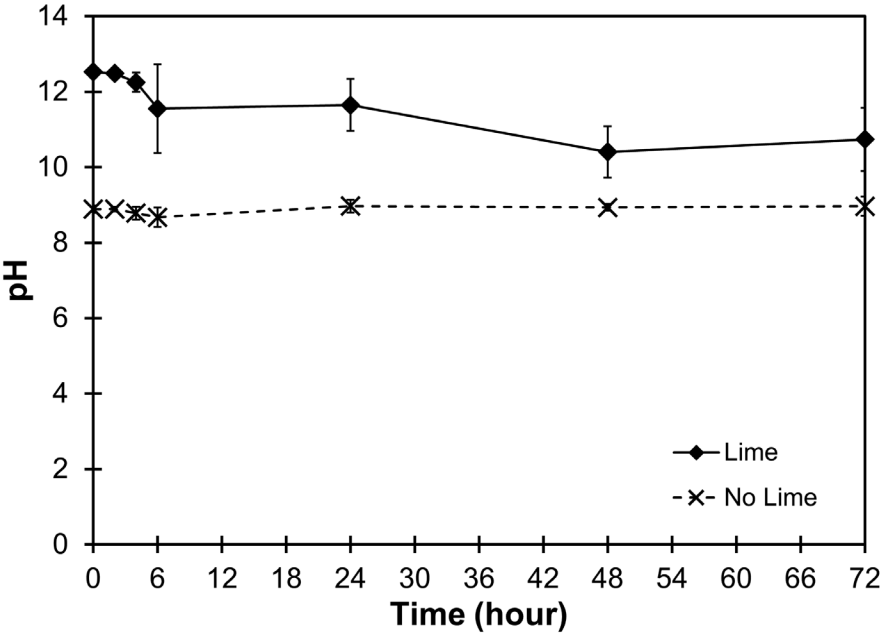


Figure 1. Effect of lime amendment on the pH of feedlot pen floor surface materials.

was adjusted to neutral pH prior to DNA extraction using 5× concentrated phosphate buffer saline. DNA was extracted using the Powersoil Powerlyzer DNA extraction kit (Qiagen, Germantown, MD). Extracted DNA was used for ARG analysis of macrolide resistance genes [*erm*(B), *erm*(C), and *erm*(F)], tetracycline resistance genes [*tet*(D), *tet*(O), and *tet*(X)], beta-lactam resistance gene [*bla*TEM], as well as the 16S rRNA gene and the Class 1 integron integrase gene *intI1*. Results from ARG concentrations was quantified in duplicate, the average concentration was used for statistical analysis and is reported as log copy number (CN) per gram of manure.

Data were analyzed using the GLIMMIX procedure SAS (SAS Institute, Cary NC). Repeated measures analysis of variance (rANOVA) was conducted to evaluate the impacts of lime amendment on the concentration of ARB and ARGs in beef cattle manure across time. Least significant difference (LSD) tests were used to determine significance of the differences among treatment conditions if treatment method was found to be significant according to rANOVA. Cattle performance and mass balance data for these pens are reported in the *2022 Nebraska Beef Cattle Report*, pp. 86–90.

## Results

The pH of the pen floor surface materials reached 12.5 after lime application and pH was maintained at 12 and higher for 4 hours. After that, the pH decreased slightly and was maintained at 11.5 until 24 hours after lime application. Thereafter, pH was maintained above 10.0 until 72 hours after lime amendment (Figure 1). The pH from the control pens averaged at 8.9 throughout the sampling period.

Significantly lower concentrations of bacteria were recovered from the lime amended plots than from the control plots ($P < 0.05$, Table 1), with the exception of tetracycline resistant *Enterococci*. For both total and resistant bacteria, the log concentration was lower in manure from pens that were amended with lime (Figure 2). Lime amendment reduced ARB especially when the pH was above 11. Lime amendment reduced the concentration of total and tylosin resistant *Enterococci* by 1–2 orders of magnitude for up to 6 hours. After 6 hours, the distinction became smaller. The abundance of resistant and total *E. coli* was significantly reduced by lime amendment

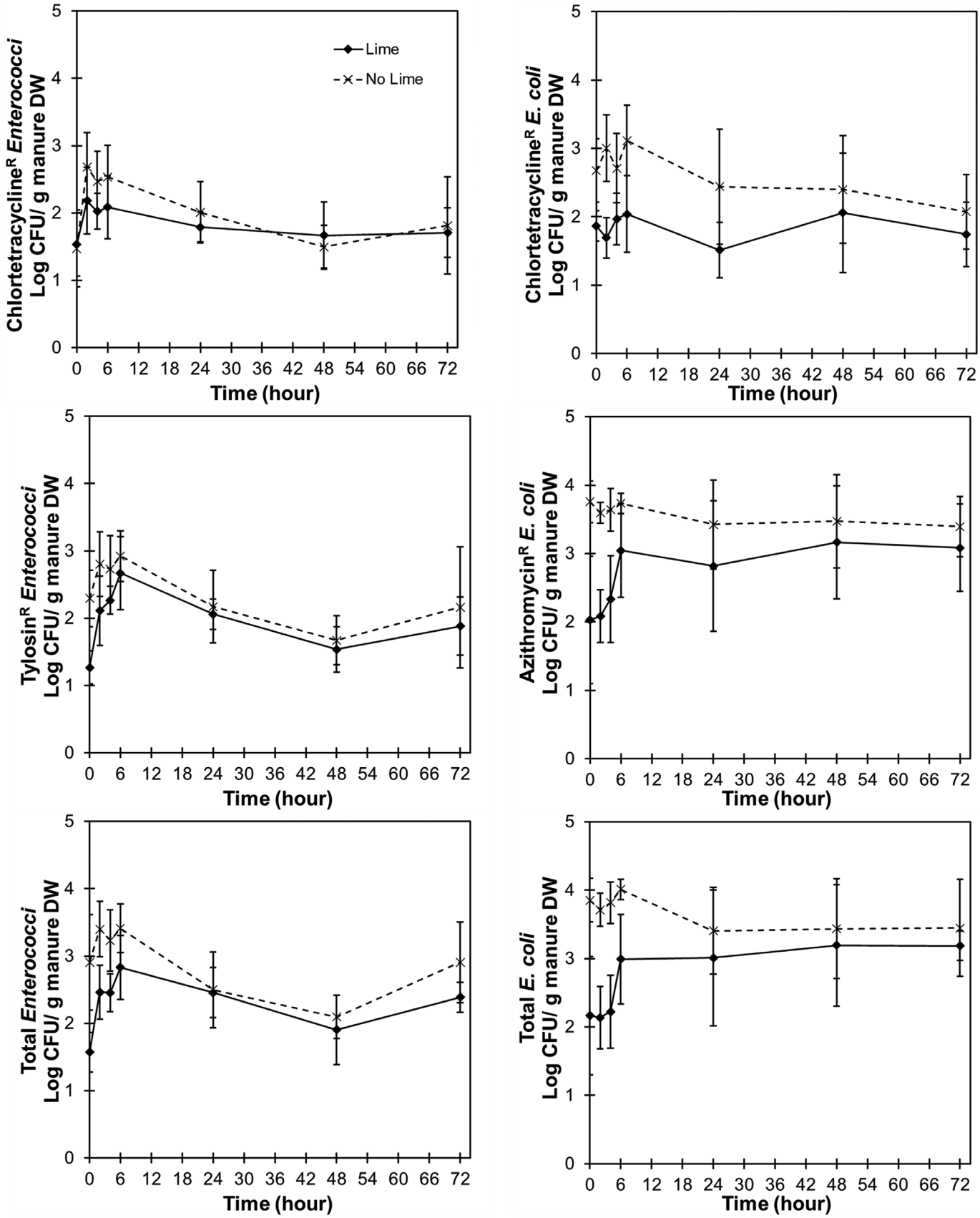


Figure 2. Effects of lime amendment on A) Tetracycline$^R$ *Enterococci*, (B) Macrolide$^R$ *Enterococci*, (C) Total *Enterococci*, (D) Tetracycline$^R$ *E. coli*, (E) Macrolide$^R$ *E. coli* and (F) Total *E. coli* as a function of time.

**Table 2. rANOVA and LSD tests on the effects of lime amendment and sampling time on ARG concentrations in beef cattle feedlot pen floor surface materials**

| | | [a]Time (hour) | | | | | | | *P*-value | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0.5 | 2 | 4 | 6 | 24 | 48 | 72 | Lime × time | Lime | Time |
| 16S rRNA | Lime | 11.15 | 10.69 | 10.89 | 11.34 | 11.16 | 11.32 | 11.15 | 0.29 | 0.06 | 0.38 |
| | Control | 11.60 | 11.59 | 11.63 | 11.59 | 11.64 | 11.55 | 11.58 | | | |
| *erm*(B) | Lime | 5.91 | 5.90 | 5.78 | 4.94 | 5.90 | 5.74 | 5.92 | 0.02 | 0.05 | 0.01 |
| | Control | 4.59 | 4.89 | 4.99 | 4.99 | 4.69 | 5.95 | 5.88 | | | |
| *erm*(C) | Lime | 6.41 | 6.29 | 6.75 | 6.73 | 6.64 | 7.00 | 6.73 | 0.30 | 0.07 | 0.02 |
| | Control | 7.08 | 7.11 | 7.21 | 7.00 | 7.35 | 7.33 | 7.33 | | | |
| *erm*(F) | Lime | 7.80 | 7.13 | 7.31 | 7.23 | 6.87 | 7.23 | 7.39 | 0.01 | 0.90 | 0.03 |
| | Control | 7.03 | 7.18 | 7.52 | 6.71 | 7.27 | 7.79 | 7.55 | | | |
| *tet*(D) | Lime | 3.76 | 3.58 | 3.41 | 3.05 | 3.22 | 3.15 | 3.64 | 0.09 | 0.25 | 0.40 |
| | Control | 2.61 | 3.73 | 3.11 | 2.96 | 3.46 | 3.01 | 3.71 | | | |
| *tet*(O) | Lime | 6.49 | 6.66 | 7.15 | 7.74 | 7.14 | 7.76 | 6.95 | 0.23 | 0.06 | 0.16 |
| | Control | 7.53 | 7.32 | 7.66 | 7.35 | 7.42 | 7.74 | 7.76 | | | |
| *tet*(X) | Lime | 6.63 | 6.35 | 6.57 | 6.86 | 6.49 | 6.71 | 6.68 | 0.76 | 0.06 | 0.64 |
| | Control | 6.76 | 6.83 | 6.93 | 6.93 | 7.00 | 7.22 | 6.94 | | | |
| blaTEM | Lime | 5.16 | 5.09 | 5.61 | 5.66 | 5.49 | 5.62 | 5.44 | 0.86 | 0.30 | 0.68 |
| | Control | 5.98 | 5.63 | 6.23 | 5.71 | 5.92 | 5.78 | 5.73 | | | |
| *IntI*1 | Lime | 8.23 | 8.13 | 8.52 | 8.73 | 8.55 | 8.74 | 8.31 | 0.05 | 0.03 | 0.03 |
| | Control | 8.65 | 8.70 | 8.73 | 8.63 | 8.86 | 8.88 | 8.93 | | | |

[a] Mean absolute gene abundance (Log copies $g^{-1}$ manure dry weight)

by about 2 orders of magnitude for up to 6 hours. Similar to *Enterococci*, the distinction between treatment and control for *E. coli* also decreased after the initial hours.

The rANOVA results revealed significant effects of lime amendment for the *intI1* gene (Table 2, $P = 0.03$). At the $P < 0.10$ level, the concentrations of 16S rRNA, *erm*(B), *erm*(C), *tet*(O) and *tet*(X) were significantly impacted by lime amendment compared to control. All genes had significantly lower concentrations in the lime amendment pens compared to the control pens, except for the *erm*(B) gene.

## Conclusion

Land application of animal manure can potentially introduce antimicrobial resistance to the environment. Alkaline stabilization through addition of hydrated lime was tested for its effectiveness on the reduction of ARB and ARGs in pen floor surface materials. The pH ≥ 12 was attained as required by the US Environmental Protection Agency for pathogen reduction. Lime amendment was able to significantly reduce the levels of total and resistant *E. coli* and *Enterococci* in pen floor surface materials. The effects of lime amendment on ARGs were less pronounced, although the ARG concentrations in lime treated pens were generally lower than those in control pens. Although the lime amendment on pen floor surface resulted in pH elevation that meets the alkaline stabilization specification for class B biosolids, fecal indicator bacteria were still present in beef cattle manure at substantial levels. Further research is needed to determine how lime amendment may affect other properties of manure, such as nutrient levels.

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# Quality Parameters of Wet and Dry Aged Beef Loins from Cattle Fed High Doses of Vitamin E

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### Summary with Implications

*The objective of this experiment was to determine if dietary supplementation of high doses of vitamin E (alpha-tocopherol; 2,200 IU per day for 100 days) can impact quality attributes of wet and dry-aged beef strip loins. Steaks from beef cattle supplemented with high doses of vitamin E exhibited less lipid oxidation after wet or dry aging, took longer time to discolor during retail display, and sustained redder color for a longer period under retail display conditions compared to controls. Free amino acids related to positive beef flavor attributes were higher for dry-aged loins compared to traditional wet aged samples loins. In dry-aged beef, trained sensory panelists found fewer negative flavors in beef from cattle fed high doses of vitamin E compared to controls. Dietary supplementation of high vitamin E levels can reduce lipid oxidation during wet or dry aging, improve color stability during retail display, reduce off flavors and maintain red color for a longer period under retail display conditions compared to controls.*

### Introduction

There has been an increase in interest in dry aging of beef which can provide enhanced textures and flavors when compared to traditional wet-aged beef. Dry aging can be considered an art and a science, and because multiple factors play prominent roles in this process, there is limited objective research that can be used by processors for guidance. Dry-aged beef is recognized for its unique flavor notes; however, the prolonged exposure to oxygen can create notable limitations. The oxidation of lipids can create negative flavors. Since oxidation is an autocatalytic process, delaying its initiation and propagation can reduce overall lipid peroxidation. The hypothesis for this experiment was that using high supplementation levels of vitamin E would result in high vitamin E content after prolonged aging, thus suppressing lipid and pigment oxidation in dry-aged beef. Vitamin E is a lipo-soluble antioxidant that has shown efficacy in delaying lipid oxidation in meat products when fed to beef cattle. For this experiment, high doses of vitamin E were fed to beef cattle to mitigate oxidation of meat during and after prolonged exposure to oxidative environments. Research suggests that lipid oxidation and pigment oxidation are closely related. Thus, suppressing lipid oxidation could result in extended color stability. Flavor is the main reason for dry aging; therefore, an extensive analysis was needed to evaluate flavor of dry-aged beef from cattle fed high doses of vitamin E.

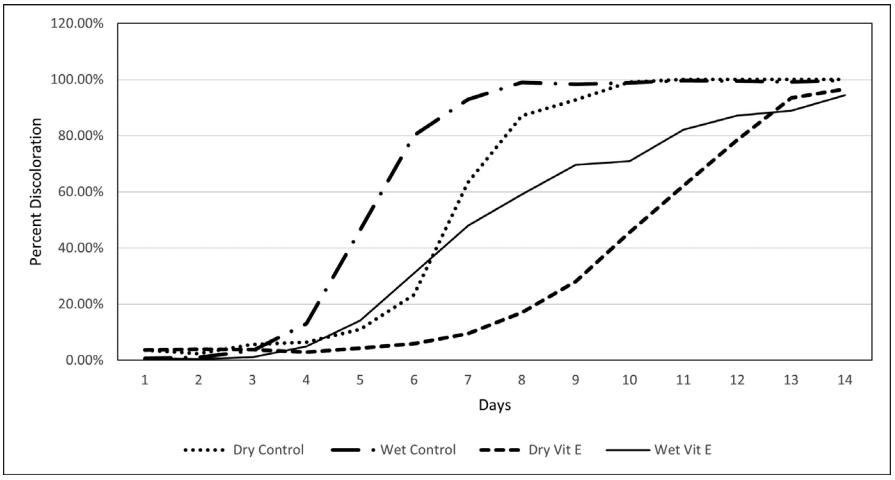


Figure 1. Subjective percent discoloration of all treatments (wet or dry aged) during 14 d of simulated retail display.

### Procedure

Cattle (n = 150; 10/pen) were grain-finished with the dietary addition of 2,200 IU of vitamin E (α-tocopherol) per day for the last 100 days of feeding. One Low Choice carcass was selected per pen (n = 12). Low Choice carcasses (n = 12) were randomly selected from commercial production and were used as controls. Strip loins from cattle fed vitamin E and controls were randomly assigned to wet or dry aging for 42 days at 50% relative humidity. After aging, the longissimus lumborum muscle of a 0.5-inch steak from each loin was isolated and cut into equal one inch by two-inch pieces. One half was vacuum packaged and immediately frozen at -112 F and the other was subjected to retail display conditions for 8 days on Styrofoam® trays covered with an oxygen permeable polystyrene film. Lipid oxidation was measured using thiobarbituric acid reactive substances (TBARS) on days 0 (24 h post-harvest) and 42 of aging and after 8 days of retail display (after aging). Free amino acids were measured on days 0 (24 h post-harvest) and day 42 of aging. For subjective and objective color measurements, day 42 steaks were placed on Styrofoam® trays wrapped in an oxygen permeable polystyrene film and subjected to retail conditions for 14 days at 37 F. Graduate student panelists rated the percent discoloration for all steaks every day at the same time. Reference images of percent discoloration ranging from 5 % to

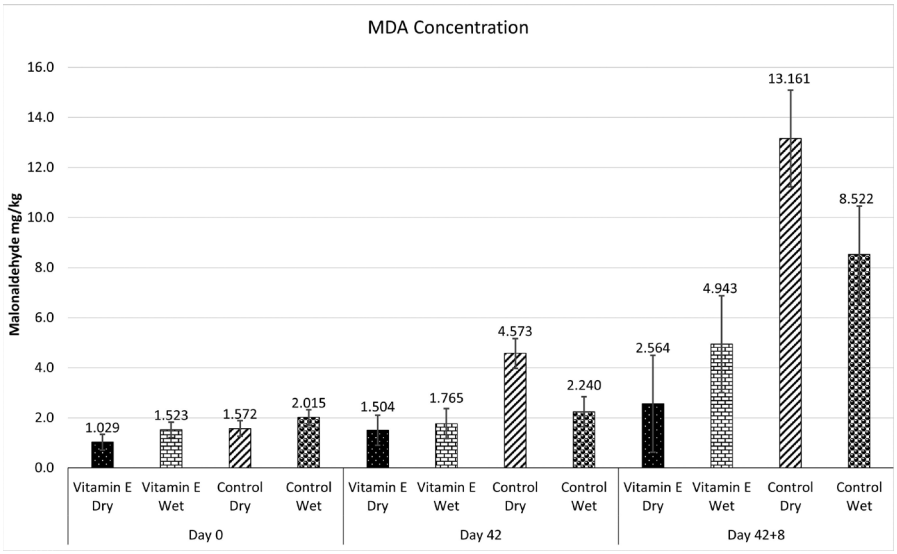


Figure 2. Oxidative rancidity measured with thiobarbituric acid reactive substances for all treatments (wet or dry aged) on day 0, 42, and 42+8 days of simulated retail display.

**Table 1. Trained sensory analysis results based on a 0-to-15-point scale (zero lowest and 15 highest intensity)**

| | Positive Flavors | | | Negative Flavors | | |
|---|---|---|---|---|---|---|
| Treatment | Umami | Roasted | Buttery | Rancid | Putrid | Sour |
| Vitamin E dry aged | 4.889 | 8.750 | 0.667 | 0.000 | 0.000[b] | 1.778 |
| Control dry aged | 4.361 | 8.639 | 0.661 | 0.056 | 0.167[a] | 2.056 |

[a, b] Means with different superscripts differ. *P*-value = 0.0369, SEM = 0.0372.

100 % were available every day. Objective color measurements were taken with a Minolta Chromameter measuring a* values which represent redness. The measurement diameter was 0.31-inch with an 0.43-inch illumination diameter. The assigned illuminant was D65 and the standard observer was 2 degrees. Trained sensory analysis was done at Texas A & M University. A group of 6 panelists analyzed a steak from all loin samples and did descriptive sensory analysis.

## Results

### *Subjective and Objective Color*

There was a three-way interaction for discoloration between vitamin E inclusion (control vs high vitamin E), aging type (dry vs wet aging), and retail display day (P < 0.0001) for the last 10 days of retail display (Figure 1). Wet-aged controls discolored fastest, followed by dry-aged controls and wet-aged vitamin E samples. Dry-aged vitamin E samples had the lowest amount of discoloration.

There were aging type-by-day and aging-by-vitamin E inclusion interactions for a* values (P < .0001 and P = 0.0104, respectively). Generally, vitamin E-treated samples sustained higher redness values for longer times and dry-aged samples took longer to discolor compared to wet-aged samples.

### *Lipid Oxidation*

On day 0, control and vitamin E inclusion loins did not differ (Figure 2) in lipid oxidation (*P* = 0.936). On day 42, control dry-aged and control wet-aged loins had the highest TBARS values and vitamin E wet and dry-aged loins had lower TBARS values (*P* = 0.043). Similarly, after 8 days of retail display post-aging, control dry-aged and control-wet aged steaks had the highest TBARS values and vitamin E wet and dry-aged steaks tended to have lower TBARS values (*P* = 0.085).

### *Free Amino Acids and Sensory Analysis*

Free amino acids related to positive beef flavor attributes such as glycine (P = 0.0001), isoleucine (P = 0.0461), valine (P = 0.0147), and glutamate (P < 0.0001) were greater for samples dry-aged for 42 days compared to wet-aged samples. Trained sensory panelists generally noted slightly more positive flavor notes such as umami, roasted, and buttery on steaks from dry-aged beef fed vitamin E. More negative flavor notes such as rancid, putrid, and sour were noted in dry-aged control loins compared to loins from dry-aged beef fed vitamin E.

## Conclusion

Dietary supplementation of high levels of vitamin E reduced discoloration and maintained redness during retail display of dry-aged beef steaks. Additionally, vitamin E reduced lipid oxidation in dry-aged beef and free amino acids related to positive beef attributes were higher in dry aged beef compared to wet aged beef. Supplementing high levels of vitamin E to beef cattle reduced lipid and pigment oxidation after prolonged aging. The beef from vitamin E supplemented cattle had fewer negative flavors produced by oxidation while maintaining the unique flavor characteristics of dry-aged beef.

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# Beef Quality and Oxidative Stability from Cattle Fed High Levels of Vitamin E

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## Summary with Implications

*Meat color is a major factor for consumer meat purchasing decisions. Aging beef, which can improve tenderness, has been shown to accelerate discoloration in fresh beef, shortening retail display time, and generating negative flavor attributes. The objective of this study was to evaluate supplementing cattle high levels (2,200 International Units/day) of Vitamin E to sustain meat quality during prolonged retail display in beef strip loins after 2 or 14 days aging compared to commercially-produced loins selected as controls. Results showed a treatment x age effect for Warner-Bratzler shear force and free calcium content, primarily due to aging. A dietary treatment x age x day interaction in redness (a*) and subjective discoloration occurred. High vitamin E samples exhibited more acceptable color scores compared to Control samples throughout retail display. As aging increased (14 days vs 2 days), Vitamin E samples sustained color better than Control samples, as shown by delta E (overall color change) values. A dietary treatment x day effect in lipid oxidation occurred with Vitamin E samples having significantly less malonaldehyde than Control samples. No differences in slice shear force, moisture, fat, or ash content were found. Supplementing high levels of Vitamin E to cattle resulted in sustained meat color and oxidative stability compared to commercially-produced cattle.*

## Introduction

Meat color is a major factor in initial meat purchasing decisions. Consumers prefer a bright, cherry-red color in fresh beef as it is a perceived indicator of freshness and wholesomeness. Fresh beef is often discounted at retail when surface lean exceeds 20% discoloration. It has been reported that 15% of retail beef is discounted due to discoloration, resulting in an economic loss of over $1 billion annually. In addition, the onset of lipid oxidation coincides with discoloration, generating flavor attributes associated with decreased palatability. Methods used to improve meat quality, such as postmortem aging, have been shown to accelerate the rate of discoloration and lipid oxidation. Maintaining beef color quality (color and lipid oxidation) can increase time in retail display for consumers to purchase product at its peak freshness. An effective method to retard oxidation of meat is supplementation of antioxidants, such as vitamin E, to cattle. However, the impact of high levels of Vitamin E inclusion in cattle rations on sustained color stability across extended retail display has not been well studied. Therefore, an investigation into cattle supplemented with and without high levels of Vitamin E in prolonged retail display is needed.

## Procedure

Cattle (n=150) across 15 pens were grain-finished with 2,200 International Units (IU) of Vitamin E (α-tocopherol) per day for the final 100 days on feed. One Low-Choice strip loin (*Longissimus Lumborum*) was randomly selected from 9 of the pens. Nine Low-Choice strip loins were selected from commercial production at the packing plant as a control treatment, totaling nine loins per treatment (total n = 18). Loins were split in half and randomly assigned to wet age for 2 or 14 days postmortem under vacuum-packaging. After aging, loin sections were opened, and two 1-inch thick steaks were cut: one steak for tenderness measurements at 0 d of retail display, and one for instrumental color and subjective color analysis across 14 days of retail display. Four half-inch steaks were also fabricated, split in half, and randomly assigned to one of the following: 1) laboratory analysis including proximate composition and free calcium ($Ca^{2+}$) concentration or 2) assigned to 0, 4, 7, 10, 12, or 14 days retail display for lipid oxidation. After fabrication, all steaks used for retail display were placed on foam trays, overwrapped with oxygen permeable film, and placed under simulated retail display conditions up to 14 d at 37°F. The same fabrication scheme was used after 14 days of aging.

For all tenderness steaks, internal raw temperature and weight were recorded. Steaks were cooked to 80°F and turned over until they reached a target temperature of 160°F on an indoor electric grill (Hamilton Beach- 31605A, Hamilton Beach Brands, Glen Allen, VA). After cooking, internal temperature and weight were recorded. A single slice from the hot steak was removed parallel to the muscle fibers, and sheared using a Food Texture Analyzer with a Slice-Shear blade to determine slice shear force (SSF). The steak was then bagged and stored in the cooler (33°F) for approximately 24 hours. Six cores (1/2- inch diameter) were removed parallel to the muscle fiber orientation and were sheared with a Food Texture Analyzer with a Warner-Bratzler blade to determine Warner-Bratzler shear force (WBSF).

Free calcium was analyzed via inductively coupled plasma spectroscopy following high-speed centrifugation. Calcium concentration was quantified using an inductively- coupled plasma emission spectrometer (iCAP 6500 Radial; Thermo Electron, Cambridge, UK) with appropriate calcium concentration standards. Proximate composition (moisture and ash %) was measured via Thermogravimetric Analyzer. Fat content was measured via ether extraction using a Soxhlet apparatus, and protein content was calculated by differences. Lipid oxidation, or thiobarbituric acid reactive substance value (TBARS), was measured via the amount of mg of malonaldehyde per kg of muscle tissue subjected to retail display periods of 0, 4, 7, 10, 12, and

**Table 1. Tenderness and Meat Quality Attributes from loins of cattle fed either Vitamin E or Control Diets.**

| Variable | | Treatment | Days Aged 2 | Days Aged 14 | SEM[1] | *P*-Value |
|---|---|---|---|---|---|---|
| Tenderness (lbs of force) | Slice-Shear Force | Control | 66.51 | 33.53 | 9.63 | 0.32 |
| | | Vitamin E | 79.68 | 54.15 | | |
| | Warner-Bratzler Shear Force | Control | 12.76[a] | 8.71[b] | 0.90 | 0.006 |
| | | Vitamin E | 11.49[a] | 10.10[b] | | |
| Free Calcium (µm) | | Control | 50.85[ab] | 59.07[a] | 5.35 | 0.01 |
| | | Vitamin E | 40.72[b] | 59.70[a] | | |

| Proximate Composition (%) | Control | Vitamin E | SEM[1] | *P*-Value |
|---|---|---|---|---|
| Moisture | 71.43 | 71.68 | 0.65 | 0.07 |
| Protein | 20.84[A] | 20.14[B] | 0.27 | <0.0001 |
| Fat | 6.61 | 7.08 | 0.65 | 0.38 |
| Ash | 1.13 | 1.10 | 0.03 | 0.92 |

[a-b] Means within the same variable with different superscripts denote dietary Treatment* days of Aging effect ($P < 0.05$).

[A-B] Means within the same variable with different superscripts denote dietary Treatment differences ($P < 0.05$).

[1] Standard Error of the Mean

14 days. Instrumental color was measured daily for 7 d using a Minolta Colorimeter (CR- 400, Minolta Camera Company, Osaka, Japan). The D65 illuminant setting and 2° observer with an 8 mm diameter measurement area were used. Color values were obtained by averaging 6 readings from various areas of the steak surface. Instrumental color was measured via colorimeter measuring L* (lightness), a* (redness), and b* (yellowness). Delta E (overall color change across two time points) values were calculated using the following equation: $\Delta E=[(\Delta L^{*2})+(\Delta a^{*2})+(\Delta b^{*2})]^{0.5}$. This value was calculated across day 0 and day 14 of retail display. Subjective discoloration was also evaluated daily during retail display by a panel of five trained panelists using a percentage scale where 0% meant no discoloration and 100% meant complete surface discoloration.

Proximate composition was analyzed as a completely randomized design for samples aged 2 d. Tenderness and calcium data were analyzed as a split-plot design, with dietary treatment as the whole-plot and aging period as the split-plot. Lipid oxidation (TBARS) data were analyzed as a split-split plot design with dietary treatment as the whole- plot, aging period as the split-plot and day of retail display as the split-split plot. The L*, a*, b* values and subjective discoloration data were analyzed as a split-split-plot design, with dietary treatment as the whole-plot, aging period as the split-plot, with day of retail display as the split-split-plot. Given measurements for color were evaluated on consecutive days on the same sample, days of retail display for L*, a*, b*, and subjective discoloration values were considered as a repeated measure. Loin was considered the experimental unit. Data were analyzed using the PROC GLIMMIX procedure of SAS with the LS MEANS statement. Statistical significance was determined at $P < 0.05$ with trends distinguished between 0.051–0.10.

## Results

A dietary treatment x days of aging interaction ($P < 0.05$) was seen for Warner-Bratzler shear force. Increased days of aging lowered shear force values (more tender), regardless of dietary treatment (Table 1). At 14 days of aging, control samples had lower shear force compared to Vitamin E samples although difference was not statistically significant. No differences were found in SSF values across treatments or aging ($P > 0.05$). In addition, a dietary treatment x days of aging interaction ($P = 0.01$) was found in free calcium concentration, where 14-day aged samples had greater free calcium compared to 2 day aged vitamin E samples (Table 1). This was expected as calcium is released from organelles upon aging. However, minute differences did not result in different shear force values. There was greater ($P < .0001$) protein content in control loins compared to Vitamin E loins (Table 1). However, the numerical difference is of little practical importance. Differences in protein content may be due to calculated differences in proximate composition after determining moisture, fat, and ash content.

A dietary treatment x day of aging x day of retail display interaction ($P = .001$) was found in muscle redness (a*) values (Table 2). In general, redness values decreased as days of aging and days of retail display

**Table 2. Analysis of Objective Redness (a*) scores and Subjective Discoloration during Retail Display.**

| Variable | Treatment | Age | Days of Retail Display | | | | | | | | SEM | *P*-Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | | |
| a*[1] | Control | 2 | 16.55$^{b}$ | 14.94$^{c}$ | 13.05$^{c}$ | 11.48$^{d}$ | 10$^{e}$ | 8.94$^{f}$ | 8.50$^{f}$ | 7.97$^{g}$ | 0.75 | 0.001 |
| | Vitamin E | 2 | 17.90$^{a}$ | 17.56$^{a}$ | 17.41$^{ab}$ | 17.03$^{ab}$ | 16.18$^{b}$ | 15.45$^{bc}$ | 13.89$^{e}$ | 12.60$^{c}$ | | |
| | Control | 14 | 12.35$^{cd}$ | 10.10$^{e}$ | 8.21$^{f}$ | 7.23$^{gh}$ | 6.67$^{h}$ | 6.87$^{h}$ | 7.41$^{gh}$ | 7.88$^{g}$ | | |
| | Vitamin E | 14 | 15.38$^{bc}$ | 13.91$^{e}$ | 12.48$^{d}$ | 11.13$^{de}$ | 10.92$^{de}$ | 11.46$^{d}$ | 11.55$^{d}$ | 11$^{de}$ | | |

| | Treatment | Age | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | SEM | *P*-Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Percent Discoloration (%) | Control | 2 | 5.00$^{mnop}$ | 8.14$^{lmno}$ | 22.54$^{ijk}$ | 39.70$^{h}$ | 54.32$^{g}$ | 71.14$^{f}$ | 81.78$^{cde}$ | 87.60$^{bcd}$ | 5.44 | <0.0001 |
| | Vitamin E | 2 | 0$^{p}$ | 0$^{p}$ | 0$^{p}$ | 0$^{p}$ | 0.01$^{mnop}$ | 7.58$^{lmno}$ | 20.68$^{jkl}$ | 35.42$^{hi}$ | | |
| | Control | 14 | 21.79$^{jk}$ | 53.85$^{g}$ | 77.17$^{def}$ | 93.50$^{abc}$ | 98.07$^{ab}$ | 97.31$^{ab}$ | 97.61$^{ab}$ | 99.51$^{a}$ | | |
| | Vitamin E | 14 | 14.10$^{klm}$ | 31.84$^{hij}$ | 54.61$^{g}$ | 66.18$^{fg}$ | 66.10$^{fg}$ | 72.45$^{ef}$ | 85.97$^{bcd}$ | 93.57$^{abc}$ | | |

[a-p] Means within the same variable with different superscripts denote treatment*age*day interactions ($p < 0.05$).

[1] a*: Red to Green color space; + value (red),—value (green)

[2] SEM: Standard error of the Mean

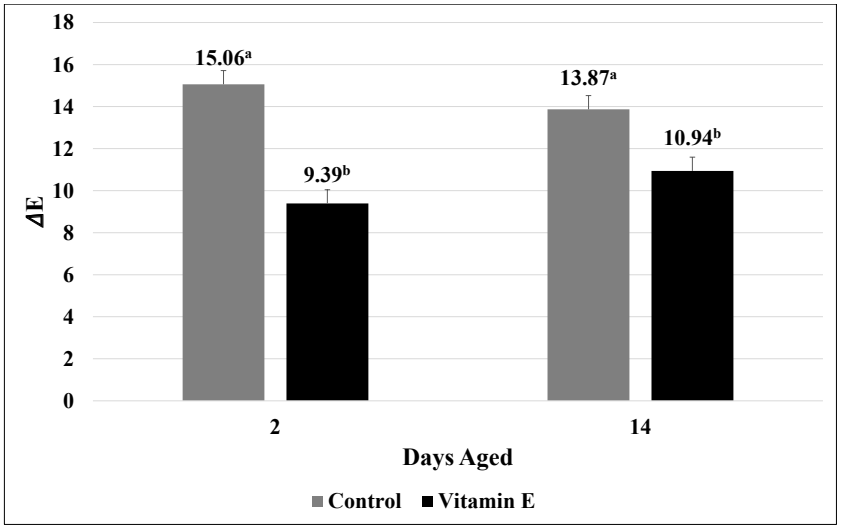


Figure 1. Delta E (ΔE) values of loins from cattle fed with or without Vitamin E [SEM: 0.92].

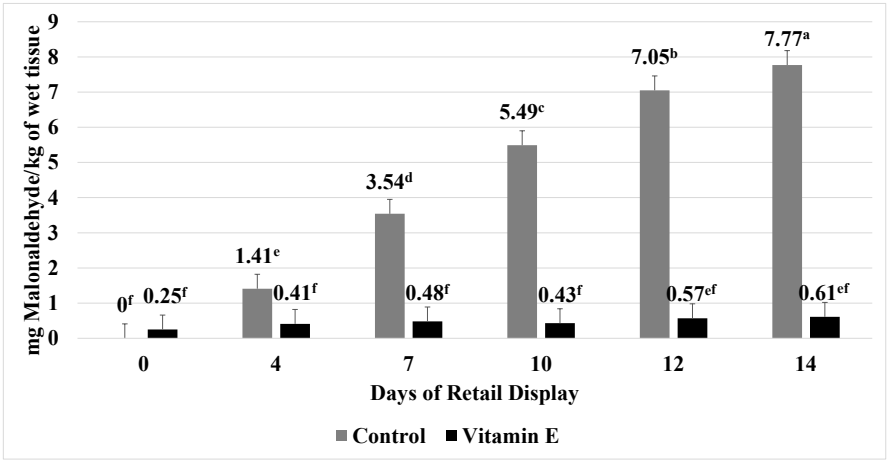


Figure 2. Thiobarbaturic Acid Reactive Substances (TBARS) of loins from cattle fed with or without Vitamin E [SEM (mg Malonaldehyde/kg wet tissue: 0.41)].

increased. At 0 d of retail display, there were no differences across treatments. As retail display time increased, however, control samples significantly decreased in a* values compared to Vitamin E loins, which maintained acceptable color throughout retail display after 2 d of aging. At 14 d aging, Vitamin E loins had a lower redness scores compared to 2 d aging, but maintained superior a* values when compared to control samples at 2 and 14 d aging. This is supported by a significant dietary treatment x days of age interaction ($P = 0.04$) in delta E values (gross color change from initial to end of retail display), as control loins had a greater overall change in color from the beginning of retail display compared to Vitamin E loins (Figure 1). There were no differences ($P > 0.05$) in L* or b* values. A dietary treatment x days of aging x days of retail display interaction ($P < .0001$) was found in subjective discoloration (Table 2). After 14 d of retail display, control samples aged 2 d had greater discoloration than Vitamin E samples aged 2 d. At 2 d of aging, Vitamin E loins did not surpass 20% (the threshold of discoloration meriting discounts) until day 13 of retail display, compared to control loins surpassing this discount threshold of discoloration at 9 days of retail display. After 14 days of aging, Vitamin E samples exhibited greater percent discoloration across fewer days of retail display but maintained noticeably lower percent discoloration compared to control loins. These data suggest that vitamin E supplemented beef, when aged,

is not as effective at retaining meat color under prolonged retail display as vitamin E supplemented beef aged just 2 d.

When examining lipid oxidation (Figure 2), a dietary treatment x day of aging interaction ($P < .0001$) was found. In general, lipid oxidation increased as days of retail display increased. Comparing dietary treatments, control samples showed exponentially (~11 times) greater malonaldehyde content compared to Vitamin E loins after retail display, as lipid oxidation remained relatively low in Vitamin E steaks throughout retail display (0.61 mg malonaldehyde/kg wet tissue).

## Conclusions

Supplementing Vitamin E greatly reduced color and lipid degradation in meat, as only prolonged stages of retail display produced accelerated discoloration and lipid oxidation. Although Vitamin E supplementation did not enhance meat tenderness, it did not negatively impact meat tenderness. Vitamin E was shown to be an effective method at slowing the rate of discoloration in fresh beef, providing additional days of retail display for consumer purchasing after prolonged days of retail display. However, increased aging is shown to lower the efficacy of Vitamin E, as seen by prolonged retail display.

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# Beef Quality following Prolonged Aging after Supplementing High Levels of Vitamin E

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## Summary with Implications

*Increased postmortem aging of beef can accelerate discoloration, shortening retail display time, inducing oxidation of lipids and proteins, and generating negative flavor attributes. This study was conducted to evaluate supplementation of high levels (2,200 International Units/head/day for 100 d) of Vitamin E (α-tocopherol) when feeding cattle as a strategy to sustain meat color quality in beef strip loins after prolonged aging. Results showed significantly less discoloration in loins from animals fed high levels of Vitamin E across 3, 6, and 9 weeks of aging. In addition, loins from cattle fed high levels of Vitamin E exhibited significantly greater redness (a*) values across 3, 6, and 9 weeks of aging. Lastly, cattle fed Vitamin E exhibited significantly less lipid oxidation compared to control fed cattle at 3, 6, and 9 weeks of aging. Feeding high levels of Vitamin E to cattle sustains meat color and oxidative stability following prolonged aging, like what may occur during export.*

## Introduction

Acceptable color of fresh beef in the retail case is major factor used by consumers when making purchasing decisions. In commodity export products, which undergo multiple weeks of vacuum-packaged aging, fresh beef is susceptible to accelerated discoloration and oxidation of lipids. This can result in reduced shelf life for fresh beef to be sold at its peak quality. Previous research has reported that daily supplementation of vitamin E (α —tocopherol) at 300 international units (IU) to feedlot cattle is an effective method to delay oxidative reactions in fresh beef. However, there is limited information on the impact of supplementing high Vitamin E (2,200 IU/head/day) on the quality of beef after prolonged aging like what occurs with exported products. Therefore, an investigation into cattle supplemented with levels of Vitamin E, across beef aged moderate to long periods of time may increase the understanding of meat quality as it relates to retaining ideal meat color in commodity export products.



## Procedure

Cattle (n=150; 10/pen) across 15 pens were grain-finished and supplemented with 2,200 IU per day of Vitamin E as a dietary treatment for the final 100 days on feed. One Low-Choice strip loin (*Longissimus Lumborum*) was selected from a carcass from each pen along with fifteen Low-Choice strip loins selected from commercial packing plant production as a control treatment, totaling 15 loins per treatment (n = 30). Loins were split into three equal portions and sections were randomly assigned to 3, 6, or 9 weeks of wet aging using vacuum-packaging. After aging, loin sections were opened, and fabricated in the following manner. One, 1-inch thick steak was cut for instrumental color and subjective color analysis during 7 days of retail display. Fat caps from the 1-inch steaks were trimmed off, vacuum-packaged, and evaluated for fatty acid analysis. Two, half-inch steaks were also fabricated and cut in half [one half section for laboratory proximate analysis and three half sections for lipid oxidation after 0, 4, or 7 days of retail display]. After fabrication, all steaks to be used for retail display were placed on foam trays, overwrapped with oxygen permeable film, and placed under simulated retail display conditions up to 7 d at 37°F. The same fabrication scheme was used for all aging periods. Fatty acid profile was measured via gas chromatography. Proximate composition, including moisture and ash (%), were measured via Thermogravimetric Analyzer. Fat content was measured via ether extraction, and protein content was calculated by difference. Lipid oxidation was measured on steaks held at 0, 4, and 7 days of retail display (37°F with continuous florescent lighting) using Thiobarbituric acid reactive substance values (TBARS) methodology, calculated by the amount of mg of malonaldehyde per kg of muscle tissue. Instrumental color was measured using a colorimeter to record L* (lightness), a* (redness), and b* (yellowness) on steaks held for 7 days of retail display. Instrumental color was recorded daily. Delta E (overall color change over time) values were calculated using the following equation: $\Delta E=[(\Delta L^{*2})+(\Delta a^{*2})+(\Delta b^{*2})]^{0.5}$. Delta E was used to determine the overall color change from the initial (day 0) to the final (day 7) day of retail display. Subjective discoloration was also evaluated daily during retail display by a panel of five trained panelists using a percentage scale where 0% meant no discoloration and 100% meant complete surface discoloration.

Lipid oxidation (TBARS) data were analyzed as a split-split plot design with dietary treatment as the whole- plot, aging period as the split-plot and day of retail display as the split-split plot. The L*, a*, b* values and subjective discoloration data were analyzed as a split-split-plot design with day of retail display considered as a repeated measure. Fatty acid profile and proximate composition were analyzed as a completely randomized design. Loin was considered the experimental unit. Data were analyzed using the PROC GLIMMIX procedure of SAS with the LS MEANS statement. Statistical significance was determined at $P < 0.05$ with trends discussed when the $P$-value was between 0.051 and 0.10.

## Results

Differences in subcutaneous fatty acid content (Table 1) were found ($P < 0.05$). Of interest, control loins had greater branched chain fatty acids (BCFA), cis-monounsaturated fatty acids (cis MUFA),

**Table 1. Analysis of Proximate Composition and Subcutaneous fat of strip loins from cattle fed commercial diet with or without 2,200 IU of Vitamin E.**

| Variable | Treatment | | SEM | *P*-value |
|---|---|---|---|---|
| Proximate Composition | Control | Vitamin E | | |
| Protein | 20.76[b] | 23.43[a] | 0.27 | <.0001 |
| Moisture | 70.23 | 68.40 | 0.65 | 0.07 |
| Fat | 7.84 | 7.00 | 0.65 | 0.38 |
| Ash | 1.18 | 1.17 | 0.03 | 0.92 |
| Fatty Acids Composite, % | | | | |
| SFA | 40.91[b] | 43.52[a] | 0.65 | .008 |
| BCFA | 1.16[a] | 0.96[b] | 0.04 | .0013 |
| cis MUFA | 48.41[a] | 45.42[b] | 0.83 | .0168 |
| t16:1 | 0.36[a] | 0.32[b] | 0.01 | .0019 |
| t18:1 | 3.30 | 4.10 | 0.31 | .08 |
| Atypical Dienes | 0.48[a] | 0.40[b] | 0.02 | .002 |
| CLA | 0.62[a] | 0.50[b] | 0.02 | .0011 |
| n-6 PUFA | 2.83[a] | 2.33[b] | 0.13 | .0096 |
| n-3 PUFA | 0.23[a] | 0.19[b] | 0.01 | .0066 |

[a-b] Means within the same row with different superscripts denote dietary treatment differences ($P < 0.05$).

SFA: Saturated Fatty Acids

BCFA: Branch-Chained Fatty Acids

cis MUFA: cis-Monounsaturated Fatty Acids

t16:1: Trans isomers of 16:1—Palmitoleic Acid

t18:1: Trans isomers of 18:1—Oleic Acid

CLA: Conjugated Linoleic Acid

n-6/n-3: omega-6/omega-3

PUFA: Polyunsaturated Fatty Acid

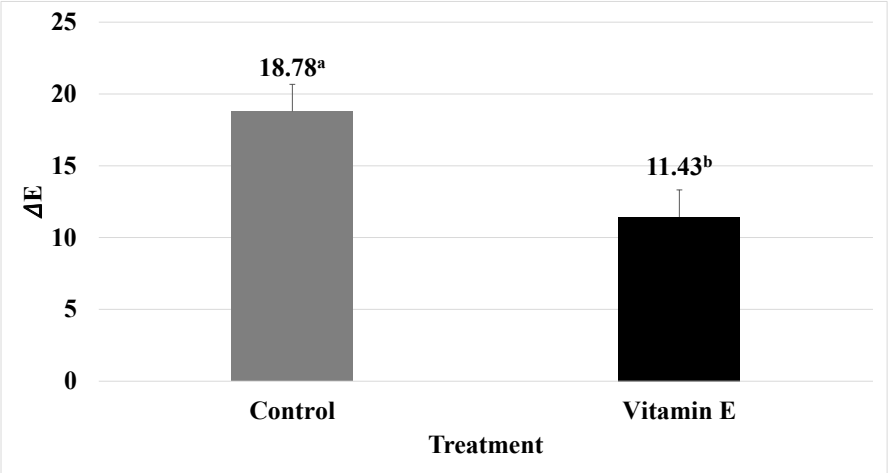


Figure 1: Delta E (ΔE) values of loins from cattle fed with or without Vitamin E [SEM: 1.89].

trans isomers of palmitoleic (16:1) and oleic (18:1) acid, atypical dienes, conjugated linoleic acid (CLA), and omega-6 and omega-3 polyunsaturated fatty acids (n-6/n-3 PUFA). Loins from cattle fed Vitamin E had greater saturated fatty acid (SFA) content. The increase in unsaturated fats in meat can increase the rate of oxidation of lipids and discoloration in meat. In addition, there was a significant difference ($P < 0.05$) in protein content (Table 1), as samples from cattle fed Vitamin E had greater protein composition compared to controls (23.43 and 20.76, respectively). While protein content was significant, it was calculated using the overall means of moisture, fat, and ash, and is of little practical significance to the overall scope of the study. Differences in fatty acid and proximate composition might be related to the different cattle populations sampled, as all control samples were randomly chosen by quality grade at the packing plant and the vitamin E-fed cattle were selected from a controlled population of cattle given their known dietary treatment.

Examining meat color, there were no differences ($P > 0.05$) in lightness (L*) values (Table 2). A dietary treatment x day of retail display interaction ($P < .0001$) in redness (a*) value was found, as steaks from Vitamin E-fed cattle exhibited greater, more acceptable red color throughout retail display compared to control samples. These data were supported by a significant difference ($P = .0008$) in delta E values, as Control loins had a larger delta E values compared to Vitamin E samples (18.78 and 11.43, respectively; Figure 1). Larger delta E values indicate a larger change in overall color over time. A dietary treatment x days of aging x days of retain display interaction ($P < .0001$) was found for subjective discoloration. In general, percent discoloration gradually increased as aging period and retail display increased, regardless of treatment type. Loins from cattle fed high levels of Vitamin E had significantly lower percent discoloration in steaks across 3, 6, and 9 weeks of aging. Given that meat is typically discounted when reaching 20% of discoloration, it was interesting to see that beef fed Vitamin E only surpassed this threshold after 6 days of retail display following 6 and 9 weeks of aging. The threshold was not exceeded for vitamin E samples

**Table 2. Analysis of Objective Redness (L*, a*, b*) scores and Subjective Discoloration during Retail Display.**

| Variable | Treatment | Days of Retail Display | | | | | | | | SEM | *P*-Value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | |
| L*[1] | Control | 45.75 | 44.90 | 44.68 | 44.29 | 43.51 | 43.63 | 43.40 | 44.10 | .89 | .5708 |
| | Vitamin E | 46.70 | 45.84 | 45.45 | 45.54 | 45.00 | 44.40 | 44.15 | 43.83 | | |
| a*[1] | Control | 20.51$^{a}$ | 20.21$^{a}$ | 18.77$^{bc}$ | 17.77$^{d}$ | 15.90$^{e}$ | 13.16$^{f}$ | 11.12$^{g}$ | 9.59$^{h}$ | .31 | <.0001 |
| | Vitamin E | 20.65$^{a}$ | 20.39$^{a}$ | 19.30$^{b}$ | 18.18$^{cd}$ | 17.39$^{d}$ | 15.64$^{e}$ | 13.15$^{f}$ | 11.98$^{g}$ | | |
| b*[1] | Control | 9.30 | 9.48 | 8.88 | 8.68 | 8.13 | 7.97 | 7.88 | 7.81 | .38 | .10 |
| | Vitamin E | 10.14 | 10.24 | 9.65 | 9.34 | 9.12 | 8.78 | 8.32 | 7.82 | | |

| | Treatment | Age | Days of Retail Display | | | | | | | | SEM | *P*-Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | |
| Percent Discoloration (%) | Control | 3 | 0.51$^{E}$ | 0.60$^{E}$ | 0.60$^{E}$ | 1.47$^{E}$ | 5.60$^{E}$ | 23.13$^{CD}$ | 29.71$^{CD}$ | 39.31$^{C}$ | 7.54 | <.0001 |
| | Vitamin E | 3 | 0$^{F}$ | 0$^{F}$ | 0$^{F}$ | 0.04$^{F}$ | 0.38$^{E}$ | 0.56$^{E}$ | 3.71$^{E}$ | 13.22$^{D}$ | | |
| | Control | 6 | 0$^{F}$ | 0$^{F}$ | 0.36$^{F}$ | 0.96$^{E}$ | 14.31$^{D}$ | 55.44$^{B}$ | 81.58$^{A}$ | 87.60$^{A}$ | | |
| | Vitamin E | 6 | 0$^{F}$ | 0$^{F}$ | 0$^{F}$ | 0.13$^{F}$ | 1.18$^{E}$ | 8.69$^{DE}$ | 29.11$^{CD}$ | 52.89$^{B}$ | | |
| | Control | 9 | 0$^{F}$ | 0.04$^{F}$ | 0.20$^{F}$ | 0.93$^{E}$ | 4.38$^{E}$ | 35.80$^{C}$ | 77.53$^{AB}$ | 95.29$^{A}$ | | |
| | Vitamin E | 9 | 0.04$^{F}$ | 0.04$^{F}$ | 0.04$^{F}$ | 0.04$^{F}$ | 0.67$^{E}$ | 13.00$^{D}$ | 34.27$^{C}$ | 59.73$^{B}$ | | |

[a-g] Means within the same variable with different superscripts denote treatment*day interactions ($p < 0.05$).[1 A-F] Means within the same variable with different superscripts denote dietary treatment x age x day differences ($p < 0.05$).

[1] L*: Black to white color space; 100 = light (white), 0 = dark (black); a*: Red to Green color space; + value (red),—value (green); b*: Yellow to blue color space; + value = yellow,—value = blue.

[2] SEM: Standard error of the Mean

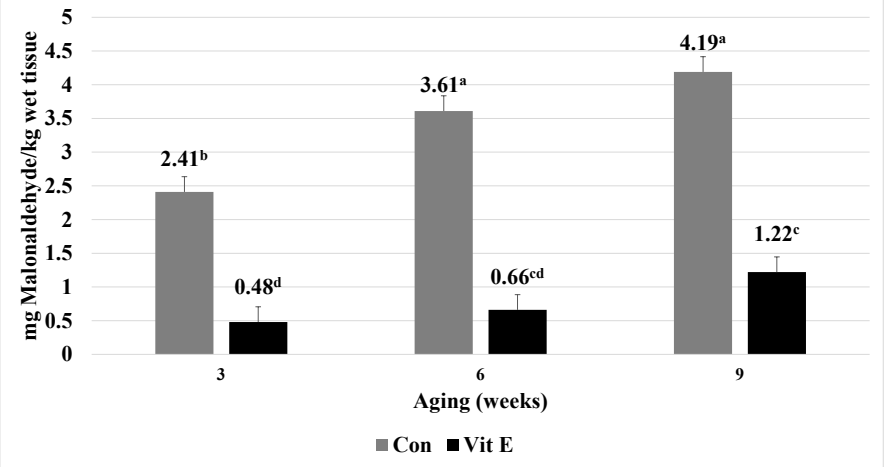


Figure 2: Thiobarbaturic Acid Reactive Substances (TBARS) of loins from cattle fed with or without Vitamin E [SEM (mg Malonaldehyde/kg wet tissue: 0.2263)].

with 3 weeks of aging. For comparison, control steaks surpassed 20% discoloration after 5 days of retail display regardless of aging period. Furthermore, a treatment x age interaction ($P = 0.03$) was found for lipid oxidation (Figure 2). Regardless of treatment, lipid oxidation increased as aging time increased. Beef from cattle supplemented with Vitamin E had less than one third the malonaldehyde content compared to control samples (1.22 and 4.19 mg per kg of wet tissue, respectively) after 9 weeks of aging.

## Conclusions

Overall, supplementing high levels of Vitamin E to cattle maintained meat color and oxidative stability, as shown by greater redness (a*) scores, lower percentage discoloration and total color change (delta E), and reduced lipid oxidation. The results from this study provide an industry application for product which undergoes prolonged aging, as occurs during export, to be retain ideal meat quality.

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# Fate of *Salmonella* in Beef Steaks during Sous Vide Cooking

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### Summary with Implications

*Sous vide cooking meat products has become a popular in-home method of food preparation. Previous research from UNL Meat Science using generic E. coli demonstrated the potential risk of sous vide cooking at temperatures recommended by some popular press items. To increase the understanding of the safety concerns of cooking beef products to temperatures below USDA-Food Safety and Inspection Service (FSIS) guidance temperatures, the experiment was conducted with Salmonella. Steaks were internally inoculated with three serovars of Salmonella, and sous vide cooked to internal temperatures of 115, 125, and 130° F. At least a 5 $log_{10}$ reduction was achieved after various holding times for 125 and 130° F. Cooking at 115° F only achieved a 2.01 $log_{10}$ reduction after 420 minutes of holding. These results add to the understanding of the risks associated with sous vide cooking beef at temperatures below those recommended by USDA-FSIS.*

### Introduction

Sous vide is a popular cooking method that uses circulating water baths to heat foods sealed in bags or containers, resulting consistent internal doneness of the product. It is commonly used for cooking meat products to prevent over-cooking or to improve tenderness. Potentially hazardous time and temperature combinations for sous vide cooking meat have become common in popular cooking media; therefore, addressing the viability of low temperature and long-time sous vide cooking procedures is necessary. Previous research from UNL Meat Science highlighted safety concerns with sous vide cooking beef steaks containing non-pathogenic *E. coli* at low temperatures (*2021 Nebraska Beef Cattle Report*, pp. 72–73). Since *Salmonella* is established by USDA-FSIS as the most relevant microorganism monitored in ready-to-eat products when validating an individual cooking process, an experiment was conducted using this pathogen in sous vide cooked steaks. The objective was to evaluate the safety of low temperature sous vide cooking using beef inoculated with *Salmonella*.



### Procedure

The experiment was replicated three times with two steaks sampled at each individual sampling time. One-inch steaks were cut from beef semitendinosus muscles (eye of round) and frozen under vacuum until the start of each replication. Steaks were thawed (48 hours, 39° F), exposed to UV light for 15 minutes on each side to reduce natural microflora, and submerged in liquid inoculum (1 liter each of *Salmonella* Typhimurium, Enteritidis, and Heidelberg overnight culture). Each steak was internally inoculated with a pin pad inserted three times into each side of each steak while submerged to achieve at least 7 $log_{10}$ cfu/g. Steaks were air-dried (15 min, 73° F) following inoculation to allow for bacterial attachment, individually vacuumed sealed, and immediately cooked in sous vide water baths. For cooked steaks, holding time started once the steak reached the target internal temperature. Within each replication, duplicate steak samples were taken from raw, inoculated steaks and at each of the following hold time/temperature combinations: 150 min/115° F, 420 min/ 115° F, 150 min/125° F, 193.5 min/125° F, 258 min/125° F, 322.5 min/125° F, 64.5 min/130° F, 86 min/130° F, and 107.5 min/130° F. The median sampling time for 130° F was taken from the USDA FSIS *Salmonella* Compliance Guidelines for Small and Very Small Meat and Poultry Establishments that Produce Ready-to-Eat (RTE) Products and Revised Appendix A 5 $log_{10}$ reduction table, and the other times were +/- 25% of the median time. The 258 min sampling time for 125° F was extrapolated from the table in USDA Appendix A. The 115° F sampling times represented sous vide manufacturer's cooking guidance and an all-day cooking process. Core samples (25 g) were homogenized with buffered peptone water, serially diluted, and plated onto xylose lysine deoxycholate agar. *Salmonella* colonies were counted after incubation (24 hours, 95° F) and converted into $log_{10}$ cfu/g. Reductions were determined by subtracting concentrations at each sampling time from the raw sample. Data were analyzed using PROC GLM contrasts in SAS 9.4. Statistical comparisons between each temperature were not made.

### Results

Cooking at 130° F achieved a 5.72 $log_{10}$ reduction after 64.5 minutes holding time ($P < 0.01$; Table 1) and increased to 6.74 $log_{10}$/g reduction at 86 and 107.5 minutes holding times. A 6.26 $log_{10}$ reduction ($P < 0.01$) was achieved after 150 minutes of holding at 125° F, and a final reduction of 7.28 $log_{10}$ ($P < 0.01$) was achieved after 322.5 minutes of holding time. Cooking at 115° F only achieved a 2.01 $log_{10}$ reduction ($P < 0.01$) after 420 minutes of holding time. Collectively, these data increase the support for the validity of time and temperature combination from USDA Appendix A for the reduction of *Salmonella* in beef at 130° F. Sous vide cooking at 125° F could potentially lead to safe products, but further validation of individual processes as a part of a food safety plan would be necessary. Sous vide cooking at 115° F does not result in adequate reductions of *Salmonella* concentrations and creates a potentially hazardous product. Further investigation is needed to determine if other heat tolerant pathogens could potentially grow at sous

**Table 1. Concentration of *Salmonella* ($log_{10}$ CFU/g) during sous vide cooking.**

| Holding time (min) | $log_{10}$ CFU/g | Total Reduction |
|---|---|---|
| 115° F holding temperature | | |
| 0 | 7.44[a] | n/a |
| 150 | 7.18[a] | 0.26 |
| 420 | 5.43[b] | 2.01 |
| 125° F holding temperature | | |
| 0 | 7.83[a] | n/a |
| 150.0 | 1.57[bc] | 6.26 |
| 193.5 | 0.95[bd] | 6.88 |
| 258.0 | 1.64[c] | 6.19 |
| 322.5 | 0.55[d] | 7.28 |
| 130° F holding temperature | | |
| 0 | 7.71[a] | n/a |
| 64.5 | 1.99[b] | 5.72 |
| 86.0 | 0.97[c] | 6.74 |
| 107.5 | 0.97[c] | 6.74 |

[a-d]Concentrations with different superscripts within each temperature treatment were different ($P < 0.05$).

vide cooking temperatures below those recommended in USDA Appendix A. Data from this report should not be used as a part of food safety documentation for sous vide cooking meat without further validation studies, but this document does provide insight on thermal lethality and potential dangers associated with sous vide cooking methods with low temperatures.

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# Statistics Used in the Nebraska Beef Cattle Report and Their Purpose

The purpose of beef cattle and beef product research at UNL is to provide reference information that represents the various populations (cows, calves, heifers, feeders, carcasses, retail products, etc) of beef production. Obviously, the researcher cannot apply treatments to every member of a population; therefore he/she must sample the population. The use of statistics allows the researcher and readers of the Nebraska Beef Cattle Report the opportunity to evaluate separation of random (chance) occurrences and real biological effects of a treatment. Following is a brief description of the major statistics used in the beef report. For a more detailed description of the expectations of authors and parameters used in animal science see Journal of Animal Science Style and Form at: http://jas.fass.org/misc/ifora.shtml.

—**Mean:** Data for individual experimental units (cows, steers, steaks) exposed to the same treatment are generally averaged and reported in the text, tables and figures. The statistical term representing the average of a group of data points is mean.

—**Variability:** The inconsistency among the individual experimental units used to calculate a mean for the item measured is the variance. For example, if the ADG for <u>all</u> the steers used to calculate the mean for a treatment is 3.5 lb then the variance is zero. But, this situation never happens! However, if ADG for individual steers used to calculate the mean for a treatment range from 1.0 lb to 5.0 lb, then the variance is large. The variance may be reported as standard deviation (square root of the variance) or as standard error of the mean. The standard error is the standard deviation of the mean as if we had done repeated samplings of data to calculate multiple means for a given treatment. In most cases treatment means and their measure of variability will be expressed as follows: 3.5 ± 0.15. This would be a mean of 3.5 followed by the standard error of the mean of 0.15. A helpful step combining both the mean and the variability from an experiment to conclude whether the treatment results in a real biological effect is to calculate a 95% confidence interval. This interval would be twice the standard error added to and subtracted from the mean. In the example above, this interval is 3.2–3.8 lb. If in an experiment, these intervals calculated for treatments of interest overlap, the experiment does not provide satisfactory evidence to conclude that treatments effects are different.

—***P* Value:** Probability (*P* Value) refers to the likelihood the observed differences among treatment means are due to chance. For example, if the author reports $P \leq 0.05$ as the significance level for a test of the differences between treatments as they affect ADG, the reader may conclude there is less than a 5% chance the differences observed between the means are a random occurrence and the treatments do not affect ADG. Hence we conclude that, because this probability of chance occurrence is small, there must be difference between the treatments in their effect on ADG. It is generally accepted among researchers when *P* values are less than or equal to 0.05, observed differences are deemed due to important treatment effects. Authors occasionally conclude that an effect is significant, hence real, if *P* values are between 0.05 and 0.10. Further, some authors may include a statement indicating there was a tendency or trend in the data. Authors often use these statements when *P* values are between 0.10 and 0.15, because they are not confident the differences among treatment means are real treatment effects. With *P* values of 0.10 and 0.15 the chance random sampling caused the observed differences is 1 in 10 and 1 in 6.7, respectively.

—**Linear & Quadratic Contrasts:** Some articles contain linear (L) and quadratic (Q) responses to treatments. These parameters are used when the research involves increasing amounts of a factor as treatments. Examples are increasing amounts of a ration ingredient (corn, by-product, or feed additive) or increasing amounts of a nutrient (protein, calcium, or vitamin E). The L and Q contrasts provide information regarding the shape of the response. Linear indicates a straight line response and quadratic indicates a curved response. P-values for these contrasts have the same interpretation as described above.

—**Correlation (r):** Correlation indicates amount of linear relationship of two measurements. The correlation coefficient can range from -1 to 1. Values near zero indicate a weak relationship, values near 1 indicate a strong positive relationship, and a value of -1 indicates a strong negative relationship.

# Animal Science
# http://animalscience.unl.edu

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Quality Assurance
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Veterinary Medicine

**Scholarships**: The Animal Science Department also offers scholarships to incoming freshmen and upperclassmen. The department awards over $30,000 each year to Animal Science students.

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