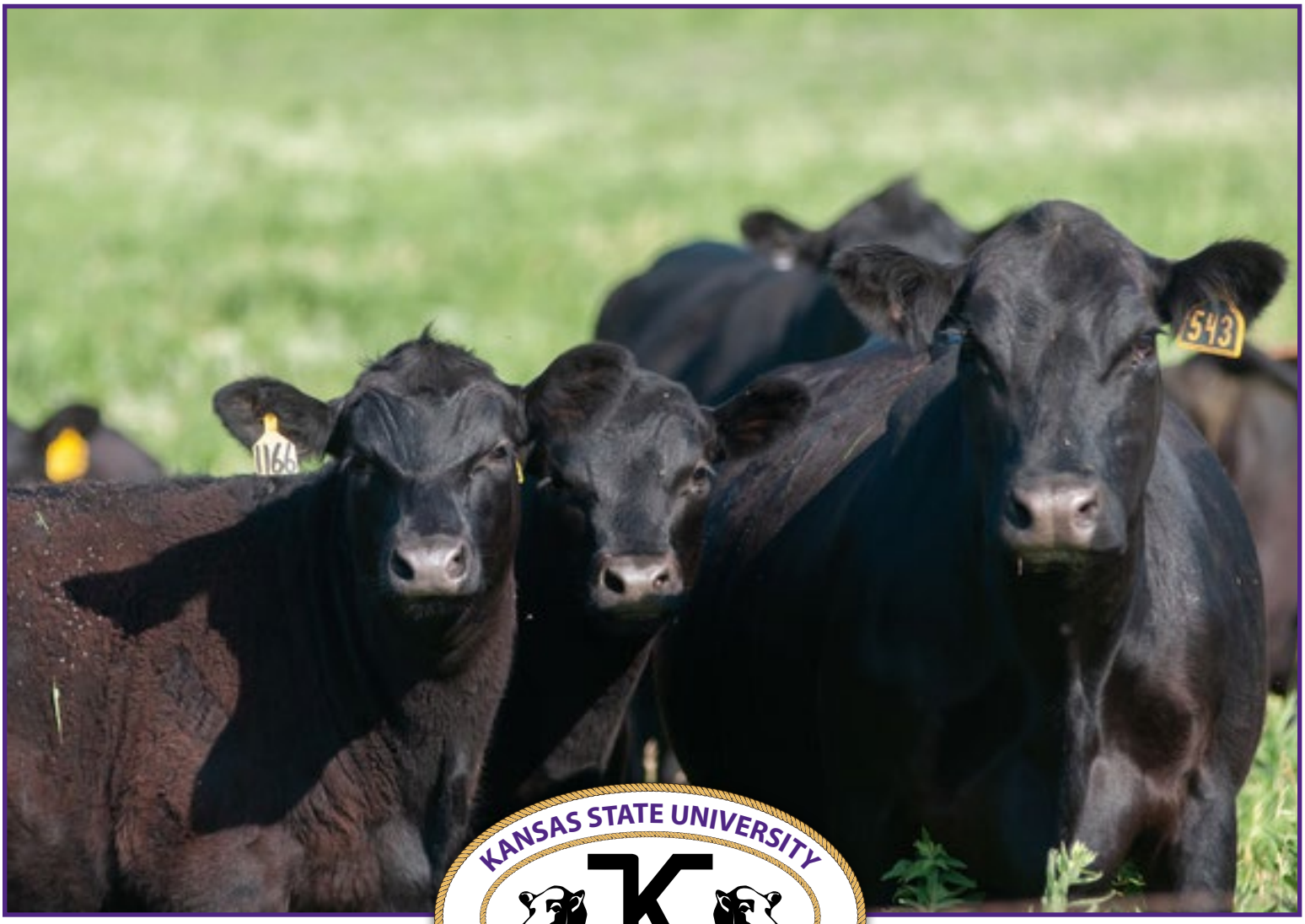

CATTLEMEN'S DAY 2026

BEEF CATTLE RESEARCH

K-STATE Research and Extension

KANSAS STATE UNIVERSITY AGRICULTURAL EXPERIMENT STATION AND COOPERATIVE EXTENSION SERVICE

Table of Contents

Beef Cattle Management

Beef Cattle Reproduction

Beef Cattle Nutrition

Meat Science

Assessment of Protein and Fiber Content of Kansas Grasslands Enrolled in the Conservation Reserve Program

J.M. Warner, A.G. Schwartz, B.J. Fraser, J.W.L. Banks, J.K. Farney, J.W. Waggoner, and S.K. Johnson

Abstract

The objective was to assess the nutrient composition of standing Conservation Reserve Program (CRP) forages across Kansas throughout the year in relation to various environmental and management factors impacting forage quality. Forage samples (n = 294) were collected from a total of 25 different sites across 16 counties in Kansas over a two-year period. Samples were collected monthly and analyzed in a single commercial laboratory to determine changes in nutrient composition throughout the year. Crude protein, acid detergent fiber, neutral detergent fiber, and total digestible nutrients are reported. While nutrient composition varied considerably by month, protein and fiber content, and subsequent energy measurements generally followed typical seasonal patterns for warm-season forages. In May, forage samples collected from eastern Kansas were greater in total digestible nutrients ($P \leq 0.05$) compared to northwest Kansas. Understanding the nutrient composition of CRP forages is essential for effective livestock management and to make informed policy decisions. These data will help address a significant gap in the current literature.

Introduction

Throughout the United States, the number of acres of intact native prairie grasslands has decreased considerably in recent years. The Conservation Reserve Program (CRP) was established by the U.S. Department of Agriculture in the 1985 Food Security Act. Managed through the Farm Service Agency, the CRP program contracts with participants who remove highly erodible land from agricultural production and instead establish grassland forage species in return for financial payment. In 2024, Kansas was among the top five states for land in CRP acreage. Each year, CRP lands may be released for livestock grazing or haying primarily due to drought or other similar events that reduce forage availability. Although CRP lands are a critical forage resource for beef cattle, nutrient composition data of standing CRP forages are not readily available. Nutrient content information is essential for effective nutrition management of beef cattle when utilizing CRP forages. Growing season length, soil type, years of enrollment in CRP, average annual precipitation, and management practices may all affect forage quality. The objective of this collaborative, statewide field study was to measure the nutrient content of standing CRP forages throughout the year relative to factors that may influence sample quality.

Experimental Procedures

This project was a collaborative initiative among Kansas State University Research and Extension agents and Extension Beef Cattle specialists within the Livestock Program Focus Team. Preliminary data from this project were reported previously (Schwartz et al., 2025). Agents and specialists identified cooperating producers located within local Extension units throughout Kansas that owned or directly managed lands enrolled in

the CRP program and requested permission to access lands for sample collection. A total of 12 different agents and specialists representing 19 different producers across 16 counties throughout Kansas participated in the project. Of the counties from which samples were collected, an equal proportion (n = 8/region) were from the eastern and northwestern regions of the state. Eastern region counties included Chase, Greenwood, Jackson, Jefferson, Montgomery, Nemaha, Pottawatomie, and Wabaunsee. Northwestern region counties included Barton, Cheyenne, Gove, Logan, Phillips, Rooks, Thomas, and Trego. A total of 294 samples were collected during a 23-month period, from February 2023 to December 2024, and analyzed.

All personnel used 0.96 ft^2 sampling hoops, and hand clipped all forage within the hoop to a height of approximately 1-in. above the ground surface. All nutrient composition data presented are the result of both current and any previous year's vegetation from all forage species, except woody species. All samples were analyzed by a commercial laboratory (SDK Laboratories, Inc., Hutchinson, KS) for wet chemistry analysis of protein, fiber components, and macrominerals. Units of energy composition were subsequently calculated from fiber content.

Data were analyzed using SAS (SAS, Inc., Cary, NC), and the MEANS procedure was used to calculate simple means, standard deviations, and minimum and maximum values for all nutrients analyzed. Structured mean comparisons were made between regions for the primary growing season months (April – September) with the sample as the experimental unit for analysis of crude protein (CP) and total digestible nutrients (TDN). For these comparisons, a mixed effects model was used with the MIXED procedure. The model included the fixed effect of region with Extension personnel, year, producer, precipitation, soil type, and previous management history as random effects. For these comparisons, means were declared significant at a P-value ≤ 0.05, and tendencies were declared at a P-value > 0.05 and ≤ 0.10.

Results and Discussion

Counties from both the eastern and northwestern regions of the state were included in the analysis, representing substantially different precipitation gradients, soil types, and growing season lengths. Data for CP are reported in Table 1 and demonstrate that concentrations generally increase during the growing season and decrease during the winter months. During the primary growing season months, samples analyzed did not differ ($P \geq 0.05$) in CP content, but peaked earlier for samples collected from eastern Kansas (Figure 1). Acid detergent fiber and neutral detergent fiber concentrations (Table 2) on a dry matter (DM) basis were generally highest during winter months when forages were dormant and appeared to decrease as plants entered the vegetative stage during the growing season. This matches the general increase in CP concentration during this time. As with CP, forage TDN for samples from eastern Kansas appeared to reach maximal concentrations (approximately 50%, DM basis) in May, while concentrations peaked in June for samples from northwestern Kansas (Figure 2). During May, TDN concentrations (% DM basis) were higher ($P \leq 0.05$) for eastern (51.1) relative to northwestern (39.6) Kansas. Interestingly, statistical differences were not observed during other months.

Implications

Understanding the nutrient composition of Kansas CRP forages that may be released for livestock grazing or haying is critical for: 1) assisting producers in making informed management decisions, 2) guiding Extension personnel and nutritionists in developing sound nutrition programs, and 3) aiding CRP land management personnel when making local forage accessibility decisions. These data are valuable for improving the completeness and accuracy of feedstuff composition tables, specifically for diet formulation software programs used by Extension and industry personnel.

Acknowledgments

This research is a contribution from, and funding is also provided by, the Kansas State University Agricultural Experiment Station and Cooperative Extension Service, Livestock Program Focus Team. Additional funding was provided in part through the Hatch Act. The authors thank and extend appreciation to all participating Extension agents for their assistance with tract identification and sample collection, including: C. Bartels, S. Blocker, A. Boor, R. Brooke, J. Falk-Jones, K. Luman, R. Mosteller, W. Powell, B. Sims, and S. Spencer. All cooperating producers are greatly appreciated for their participation in the project and for allowing access to their property for sample collection.

References

Schwartz, A.G., B.J. Fraser, J.W.L. Banks, S.K. Johnson, and J.M. Warner. 2025. Assessment of nutrient content of Kansas grasslands enrolled in the Conservation Reserve Program. Kansas Agricultural Experiment Station Research Reports 11(1) *https://doi.org/10.4148/2378-5977.8660*

Table 1. Descriptive statistics of crude protein content (% dry matter basis) of Conservation Reserve Program forage samples collected for analysis by region and month

	Samples (number)	Mean	Median	Standard deviation	Minimum	Maximum
Eastern Kansas						
January	2	3.5	---	0.1	3.4	3.6
February	4	2.9	---	0.6	2.2	3.6
March	12	4.1	3.8	1.3	2.7	7.4
April	15	5.2	4.2	2.7	2.0	12.6
May	17	7.4	6.5	3.0	4.1	16.0
June	14	6.4	---	1.5	4.0	9.6
July	21	5.0	4.8	1.2	3.5	8.6
August	11	5.2	---	1.6	3.0	8.1
September	20	3.9	3.5	1.8	1.7	9.3
October	17	4.0	3.8	2.1	1.7	10.0
November	15	3.9	3.2	1.8	2.3	7.9
December	11	3.3	3.2	1.9	1.6	8.2
Northwestern Kansas						
January	---	---	---	---	---	---
February	6	3.0	---	0.6	2.2	3.7
March	15	3.5	3.1	2.3	1.8	10.8
April	13	3.5	2.4	2.0	1.9	7.8
May	18	3.7	3.2	2.2	1.8	11.7
June	4	6.6	---	6.4	2.3	16.0
July	23	4.0	---	1.0	2.8	6.4
August	18	3.9	---	0.9	2.7	5.6
September	12	3.0	3.0	0.8	2.2	5.3
October	11	3.3	3.1	1.2	2.2	6.5
November	8	3.2	---	0.7	2.2	4.6
December	7	3.2	---	0.6	2.2	4.0

Table 2. Descriptive statistics of acid detergent fiber (ADF) and neutral detergent fiber (NDF) content of Conservation Reserve Program forage samples collected for analysis by region and month[1] (% dry matter basis)

Number of samples	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
East	2	4	12	15	17	14	21	11	20	17	15	11
Northwest	---	6	15	13	18	4	23	18	12	11	8	7
ADF East												
Mean	48.9	48.1	49.3	46.7	39.7	39.2	41.2	45.4	44.8	45.4	44.0	49.4
Standard deviation	1.9	1.9	2.5	6.1	5.8	5.6	4.0	1.9	3.2	4.7	4.3	4.9
Minimum	47.6	46.8	46.3	30.7	27.3	30.3	33.5	41.4	37.6	39.0	37.8	38.5
Maximum	50.3	50.9	53.9	52.9	50.0	45.7	48.5	47.7	50.8	54.9	51.1	56.8
ADF Northwest												
Mean	---	50.9	50.6	50.0	46.3	40.9	45.8	45.1	47.3	47.7	49.3	51.2
Standard deviation	---	2.2	2.5	3.6	5.6	11.2	4.3	3.6	5.1	2.9	4.6	1.9
Minimum	---	48.4	45.3	41.5	36.2	24.1	39.2	37.4	40.5	42.0	40.4	47.8
Maximum	---	53.9	54.4	53.4	56.2	47.5	52.3	50.5	57.5	50.4	54.0	53.4
NDF East												
Mean	72.2	66.9	66.9	67.6	63.1	62.9	65.1	64.6	64.9	67.7	69.6	68.4
Standard deviation	1.3	3.1	4.2	6.0	4.9	4.3	3.4	6.0	4.1	5.6	4.8	5.4
Minimum	71.3	64.2	60.5	54.4	51.9	57.3	59.6	51.3	58.9	48.4	58.1	59.0
Maximum	73.2	71.4	74.1	73.9	70.1	67.4	70.6	71.9	75.7	75.8	74.3	73.5
NDF Northwest												
Mean	---	70.3	68.4	69.8	68.3	62.1	66.4	65.4	67.8	67.9	69.3	70.4
Standard deviation	---	4.1	5.0	4.7	5.4	14.9	3.6	3.3	5.4	2.5	4.7	2.1
Minimum	---	64.2	61.0	60.7	58.7	40.8	61.7	60.8	61.8	64.4	60.5	66.2
Maximum	---	74.0	75.5	75.5	75.9	72.5	73.8	71.6	77.5	71.8	74.5	72.3

[1]Jan = January; Feb = February; Mar = March; Apr = April; Jun = June; Jul = July; Aug = August; Sep = September; Oct = October; Nov = November; Dec = December.

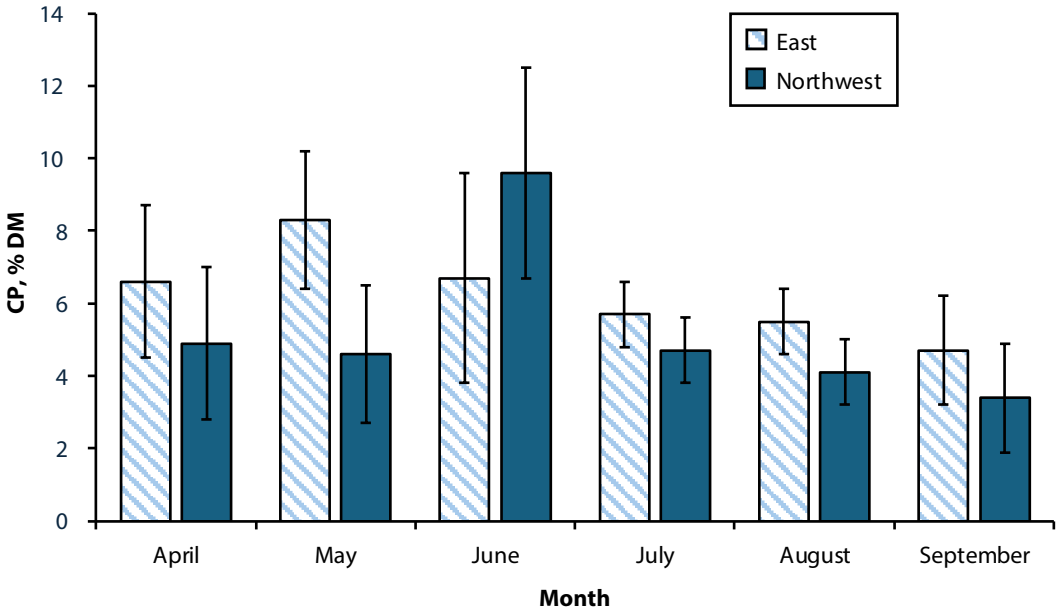

Figure 1. Conservation Reserve Program forage crude protein (CP) content (% dry matter [DM] basis) in Kansas by region during key growing season months. Means within a month without superscript labels are not different at $P > 0.10$.

The Effect of Arrival Vaccine Combination on Performance and Efficiency During the Receiving and Backgrounding Phase

M.C. Weigand, D.A. Blasi, and A.J. Tarpoff

Abstract

A 56-day backgrounding trial was conducted to assess the effects of three arrival vaccine combinations on growth performance and efficiency during the receiving and backgrounding periods. Crossbred high-risk heifer calves (n = 393; initial body weight [BW] = 499 ± 38 lb) were blocked by truckload (4) and stratified by initial BW within block and allocated into one of nine pens. Pens were randomly assigned to one of three treatments to provide a total of 12 replicates per treatment for a total of 36 pens. All calves were fed a common diet composed of 40.00% Sweet Bran (Cargill Animal Nutrition, Blair, NE), 30.01% warm-season grass hay, 24.37% dry-rolled corn, and 5.63% pellet supplement. This ration was formulated to provide 53 Mcal net energy for gain and offered at *ad libitum* intake. Feed bunks were read at 7:00 a.m. each day and were targeted to be empty when feed was delivered at 8:00 a.m. Vaccine treatment combinations were designed to include a 5-way modified live virus vaccine, a 7-way clostridial, and respiratory and somnus bacterins. Treatments were: Pyramid (Pyramid 5 + Presponse SQ [Boehringer Ingelheim, Ridgefield, CT] and Bovilis Vision 7 Somnus with Spur [Merck Animal Health, Rahway, NJ]); Stimulator (Stimulator 5 [Bimeda, Schaumburg, IL], Pro-Bac 4 [Bimeda, Schaumburg, IL], and Bovilis Vision 7 with Spur [Merck Animal Health, Rahway, NJ]); and Bovi-Shield Gold (Bovi-Shield Gold One Shot [Zoetis Inc., Parsippany, NJ] and Bovilis Vision 7 Somnus with Spur). All employees responsible for the care and feeding of the animals, as well as the data analyses, were blinded to treatments until all analyses were complete. At the conclusion of the 56-day study, final BW, average daily gains, feed efficiency, and water usage did not differ ($P \geq 0.35$) between treatments. No differences ($P \geq 0.10$) in morbidity or mortality across treatments were detected. Arrival vaccine combinations did not affect cattle's ability to perform or interfere with their health outcomes during the early feeding period.

Introduction

Newly received cattle face many challenges upon arrival at feedyards or backgrounding facilities. Stressors such as weaning, transportation, diet change, and pathogen exposure are just a few of the changes that may occur during the transition period from dam to a confined setting. The purpose of a vaccine is to provide future protection from pathogens to which an animal may be subject. Oftentimes, cattle are in a high-stress state prior to or during administration of vaccines, which can affect the animal's ability to mount a strong immune response to those antigens. Other factors, such as adjuvant type or number of injections, specifically related to endotoxin staking (the administration of multiple gram-negative bacteria containing vaccine at one time), can also play a role in the animal's ability to mount a response, as well as the animal's propensity to get up on feed during the receiving period. Aluminum salts, oil-based emulsions, saponins, or monophosphoryl lipid A would be considered some of the most common adjuvant types used, and although they differ in terms of modes of action, they all work to help

stimulate an immune response to the antigens present in the vaccine. The number of injections during a processing event can vary depending on the operation, veterinary recommendation, and potential for disease exposure. Oftentimes, two or more gram-negative vaccines are given in a production setting on top of other injections such as modified live virus vaccines, antibiotics, and injectable dewormers (Richeson et al., 2019). Endotoxins are produced from gram-negative bacteria that die and break down in the system, and excessive amounts of endotoxin in the body can be fatal. Higher endotoxin levels have been known to cause "vaccine sweat" post-vaccination. This can also lead to cattle taking longer to get up on feed and appear to show more clinical signs of illness postvaccination. Given the vast array of options for vaccination protocol combinations, the objective of this study was to evaluate a direct comparison of various product lines on their impact on feed intake early in the feeding period.

Experimental Procedures

A total of 393 crossbred heifer calves (body weight [BW] = 499 ± 38 lb) were purchased at auction markets in Tennessee, assembled at an order buyer's facility in Dickson, TN, and then shipped 674 miles to the Kansas State University Beef Stocker Unit over a 9-day period from October 9 to October 17, 2024. The heifers were used in a randomized complete block design to analyze the effect of arrival vaccine combination on performance and efficiency during a 56-day receiving trial. Heifer calves were labeled high-risk due to the long transportation time and comingling at the order buyer's facility. Heifers were blocked by truckload (4), stratified by individual arrival (day -1) weight within load, and assigned to pens containing 10 or 11 head. Pens within each block were randomly assigned to one of three treatments, which equaled 12 pens/treatment for a total of 36 pens. Cattle were weighed immediately on arrival (day -1) and individually identified using both visual and electronic identification tags. Heifers were then offered warm-season grass hay at 1% of BW (dry matter [DM] basis), had *ad libitum* access to water, and were allowed to rest for 24 hours.

The following day (day 0), all heifers were individually weighed again and received antibiotic metaphylaxis with Tulathromycin (Macrosyn; Bimeda, Schaumburg, IL). Heifers were treated for internal and external parasites with a combination deworming strategy using levamisole oral suspension (Levamed; Bimeda, Schaumburg, IL) and ivermectin pour-on (Bimectin; Bimeda, Schaumburg, IL) and assigned a tag with a pen number. Farm staff was blinded to vaccine treatments during the entire 56-day receiving period. Prior to the trial start date, vaccine protocols were relabeled with a color and letter (White A, Red B, and Blue C) for the purpose of animal allocation and vaccine administration during processing and data analysis. Vaccination treatments were: White A = Pyramid (Pyramid 5 + Presponse SQ [Boehringer Ingelheim, Ridgefield, CT] and Bovilis Vision 7 Somnus with Spur [Merck Animal Health, Rahway, NJ]); Red B = Stimulator (Stimulator 5 [Bimeda, Schaumburg, IL], Pro-Bac 4 [Bimeda, Schaumburg, IL], and Bovilis Vision 7 with Spur [Merck Animal Health, Rahway, NJ]) and Blue C = Bovi-Shield Gold (Bovi-Shield Gold One Shot [Zoetis Inc., Parsippany, NJ] and Bovilis Vision 7 Somnus with Spur). Throughout the trial, heifers were observed twice daily for clinical signs of respiratory illness during the first 21 days and then once daily for the remainder of the study. Clinical illness scores (CIS) and rectal body temperatures were used to identify and confirm illness. The CIS system was assessed as 1- normal, 2- mild depression, 3- severe depression, and 4- moribund. Respiratory illness was treated with a first treatment of florfenicol (Norfenicol; Norbrook, Lenexa, KS) and a vitamin and mineral drench (Bovitalize; Bimeda, Schaumburg, IL), with a second treatment of

enrofloxacin (Enroflox 100; Norbrook, Lenexa, KS), and a third treatment of oxytetracycline (Noromycin 300 LA; Norbrook, Lenexa, KS). Heifers that continued to show signs of illness after the third treatment were declared as chronic and removed from the experiment. During the trial, five animals were found dead in pen (White A - 2, Red B - 1, and Blue C - 2). Necropsy confirmed animal death was related to bronchopneumonia linked to bovine respiratory disease complex. A total of 22 animals were removed from the study including 19 due to chronic respiratory cases (A - 6, B - 9, and C- 4), two for lameness (B - 1 and C - 1), and one for chronic bloat (Treatment A).

To measure water usage, iPERL water meters (SENSUS, Morrisville, NC) were connected to individual automatic waterers (Lil' Spring 3000; Miraco Livestock Water Systems, Grinnell, IA) for each pen. To measure DM intake, all calves were fed a common diet composed of 40.00% Sweet Bran (Cargill Animal Nutrition, Blair, NE), 30.01% prairie hay, 24.37% dry-rolled corn, and 5.63% pellet supplement. This ration was formulated to provide 53 Mcal net energy for gain and offered at *ad libitum* intake. Feed bunks were read at 7:00 a.m. each day and were targeted to be empty when feed was delivered at 8:00 a.m. When a feed refusal was present, the uneaten feed was weighed, a sample was taken for DM determination, the feed was not returned to the bunk, and a feed call adjustment was made for that day. Pen weights were collected on days 0, 28, and 56 of the study using a pen scale (Rice Lake Weighing Systems, Rice Lake, WI). Pen weights and head counts were used to determine the average weight of individual animals to calculate average daily gain (ADG) for the study.

Performance, DM intake, and water usage data were analyzed using the MIXED procedure of SAS (version 9.4; SAS Institute., Cary, NC). The model for BW, ADG, and feed efficiency included treatment as a fixed effect and block as a random effect. For DM intake and water usage, the initial model included fixed effects for treatment, day, and treatment ′ day. No treatment ′ day interactions were present ($P = 0.82$); therefore, the final model included a fixed effect of treatment and random effect of block. Health data were analyzed as binomial proportions of first, second, and third respiratory treatment and mortality using the GLIMMIX procedure of SAS (version 9.4; SAS Institute, Cary, NC). The model included fixed effects of treatment and random effects of block.

Results and Discussion

Following the 56-day backgrounding period, heifer final BW and ADG did not differ ($P \geq 0.35$; Table 1) between treatments. DM intake and feed efficiency showed no difference ($P \geq 0.53$) among treatments. Additionally, water usage did not differ ($P = 0.51$; Table 1) among treatments.

Implications

These data suggest that the combination of vaccine treatments used upon arrival in this study had no negative effects on the growth performance, feed efficiency, or health outcome of heifers. It is important to consider the health status of the cattle being vaccinated, as well as the number of injections given during a processing event.

Acknowledgments

The authors would like to thank Bimeda Animal Health for the support of this trial.

References

Richeson, J.T., H.D. Hughes, P.R. Broadway, and J.A. Carroll. 2019. Vaccination management of beef cattle: Delayed vaccination and endotoxin stacking. Veterinary Clinics of North America: Food Animal Practice 35(3):575-592. https://doi.org/10.1016/j.cvfa.2019.07.003

Table 1. Effect of arrival vaccine on growth performance, feed intake, feed efficiency, and water usage of newly received beef heifers

	Treatment[1]				
Item	Pyramid	Stimulator	Bovi-Shield Gold	SEM[2]	*P*-value[3]
Number of observations	9	9	9		
Number of heifers	122	120	124		
Body weight, lb					
day 0	500	499	499	2.4	0.82
day 28	595	589	601	4.9	0.16
day 56	675	672	682	5.0	0.36
Average daily gain, lb/day					
0-28	3.41	3.23	3.67	0.159	0.16
28-56	2.83	2.96	2.88	0.168	0.71
0-56	3.12	3.09	3.27	0.092	0.35
Dry matter intake, lb/day					
0-14	10.11	10.34	10.49	0.287	0.65
15-56	16.66	16.79	17.24	0.414	0.59
0-56	15.02	15.18	15.55	0.359	0.57
Gain:feed, lb/lb					
0-56	0.21	0.20	0.21	0.005	0.53
Feed:gain, lb/lb					
0-56	4.82	4.92	4.77	0.106	0.46
Water usage, gal/day					
0-14	4.54	4.48	4.86	0.200	0.36
15-56	5.08	5.13	5.31	0.249	0.62
0-56	4.94	4.97	5.20	0.171	0.51

[1] Vaccine treatments applied on day 0: Pyramid (Pyramid 5 + Presponse SQ [Boehringer Ingelheim, Ridgefield, CT] and Vision 7 Somnus [Merck Animal Health, Rahway, NJ]); Stimulator (Stimulator 5 [Bimeda, Schaumburg, IL], Pro-Bac 4 [Bimeda, Schaumburg, IL], and Vision 7 [Merck Animal Health, Rahway, NJ]); and Bovi-Shield Gold (Bovi-Shield Gold One Shot [Zoetis Inc., Parsippany, NJ] and Vision 7 Somnus [Merck Animal Health, Rahway, NJ]).

[2] Largest standard error of the mean.

[3] Treatment main effect.

Table 2. Effect of arrival vaccine on health of newly received beef heifers

	Treatment[1]				
Item	Pyramid	Stimulator	Bovi-Shield Gold	SEM[2]	*P*-value[3]
Morbidity, %					
Treated once[4]	52.67	45.04	41.22	0.327	0.17
Treated twice[5]	25.95	27.48	16.03	0.264	0.10
Treated thrice[6]	7.63	13.74	7.63	0.355	0.37
Chronic[7]	4.58	7.63	3.05	0.533	0.76
Mortality,[8] %	1.53	0.76	1.53	1.049	1.00

[1] Vaccine treatments applied on day 0. Pyramid (Pyramid 5 + Presponse SQ [Boehringer Ingelheim, Ridgefield, CT] and Vision 7 Somnus [Merck Animal Health, Rahway, NJ]); Stimulator (Stimulator 5 [Bimeda, Schaumburg, IL], Pro-Bac 4 [Bimeda, Schaumburg, IL], and Vision 7 [Merck Animal Health, Rahway, NJ]); and Bovi-Shield Gold (Bovi-Shield Gold One Shot [Zoetis Inc., Parsippany, NJ] and Vision 7 Somnus [Merck Animal Health, Rahway, NJ]).

[2] Largest standard error of the mean.

[3] Treatment main effect.

[4] Percentage within treatment of heifers treated once for bovine respiratory disease (BRD).

[5] Percentage within treatment of heifers treated a second time for BRD out of total population (heifers treated twice ÷ total population).

[6] Percentage within treatment of heifers treated a third time for BRD out of total population (heifers treated thrice ÷ total population).

[7] Percentage within treatment of heifers removed from the experiment due to BRD (removed heifers ÷ total population).

[8] Percentage within treatment of heifers within treatment that died from BRD-related illness.

Evaluation of Synovex One Grower Implantation on Pre-weaning Performance of Suckling Beef Steers

J. Jacquez, J.R. Jaeger[1], P.L. Dahmer, K.R. Harmoney, L.R. Corah, and J.M. Warner

Abstract

The objective of this study was to evaluate the effects of implanting beef steer calves with Synovex One Grower (Zoetis, Parsippany, NJ) on pre-weaning growth performance. Spring-born, Angus-sired steer calves (n = 306) from predominantly Angus-based cows were utilized over three years. Each year, in a completely randomized design, steers were assigned based on dam age and calving date to one of two treatments: 1) non-implanted control (CON) or 2) implanted with Synovex One Grower supplying 150 mg trenbolone acetate and 21 mg estradiol benzoate (IMP). Each year, steers were assigned to treatments in May or June (194 ± 51 lb of initial body weight [BW]; 49 ± 18 days of age) and grazed on native mixed grass pastures alongside their dams, with the trial ending in late July or August. Trial duration was 83, 89–92, and 69 days for years 1, 2, and 3, respectively. Data were analyzed using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC) with significance declared at $P \leq 0.05$. The experimental unit was an individual steer, with 154 and 152 replicates for CON and IMP treatments, respectively. By design, neither cow age nor initial calf BW was different ($P \geq 0.62$) between treatments. Average daily gain (ADG) was higher ($P < 0.01$) for IMP compared to CON steers at 2.62 and 2.38 lb, respectively. This resulted in greater ($P < 0.01$) total BW gain for IMP relative to CON steers at 211 versus 191 lb, respectively. Concurrently, IMP steers had greater ($P < 0.01$) ending BW (400 lb) compared to CON steers (383 lb). Data suggest an extended-release trenbolone acetate/estradiol combination implant improves pre-weaning performance of suckling steers during the initial period of hormone release when administered at 50 days of age.

Introduction

Maximizing pre-weaning growth is critical for beef cow-calf producers who market calves at weaning. Calves with increased average daily gain (ADG) prior to weaning enter subsequent production phases at heavier weights, ultimately leading to greater final weights at harvest. One approach to enhancing pre-weaning growth is the use of anabolic implants, which have been shown to stimulate protein deposition and muscle growth and ultimately weight gain in conjunction with endogenous hormone production. Combination anabolic implants, such as Synovex One Grower (Zoetis, Parsippany, NJ), contain trenbolone acetate (TBA) and estradiol benzoate (EB), which are compounds that mimic natural anabolic hormones to promote tissue growth. While extensively studied in growing and finishing cattle, less research has been conducted with combination implants in suckling calves. Administration of implants to suckling calves often occurs at young ages when other management practices, such as castration and vaccination, are conducted, and this often coincides with periods of rapid early growth of the calf. Likewise, extended or sustained-release implants that

[1] Department of Animal Science, South Dakota State University, Brookings, SD

provide a longer duration of hormone release may increase pre-weaning growth more than conventional implants, but little is known about what growth responses due to implanting may be seen during the initial period of hormone release. Therefore, the objective of this study was to evaluate the effects of implanting beef steer calves with Synovex One Grower on growth performance from pre-weaning to approximately 135 days of age when administered at approximately 50 days of age.

Experimental Procedures

This study was conducted over three years at the Kansas State University Agricultural Research Center in Hays, KS. A total of 306 spring-born, Angus-sired steer calves from predominantly Angus-based cows were utilized. A total of 95 steers were used in 2019, 121 steers in 2021, and 90 steers in 2023. In a completely randomized design, each year calves were assigned based on dam age (Table 1) and calving date to one of two treatments: non-implanted control (CON) or implanted with Synovex One Grower, containing 150 mg of TBA and 21 mg of EB (IMP). Implant administration occurred in May or June when calves were 49 ± 18 days of age and had an initial body weight (BW) of 194.0 ± 50.7 lb (Table 1). Following treatment allocation, calves remained with their dams and grazed native mixed-grass pastures for the duration of the trial. No other supplement was provided to cow-calf pairs during the summer grazing period other than free-choice salt and mineral. The length of the grazing period varied by year due to forage production influencing the timing of weaning and consisted of 83 days in year 1, 89–92 days in year 2, and 69 days in year 3. Calf BW was obtained by using single-day weights at the beginning and end of the trial period each year. Statistical analyses were conducted using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC) with individual steer as the experimental unit (CON, n = 154; IMP, n = 152). The statistical model included the fixed effect of implant treatment with year as a random effect. Significance was declared at $P \leq 0.05$.

Results and Discussion

Implanting spring-born, Angus-sired steer calves with Synovex One Grower at approximately 50 days of age significantly improved pre-weaning growth performance compared to non-implanted controls (Table 1). Across three years, IMP steers had greater ($P < 0.01$) ADG (2.62 lb) than CON steers (2.38 lb). This enhanced rate of gain translated to increased ($P < 0.01$) total BW gain over the trial period, with IMP steers gaining an average of 211 lb compared to 191 lb for CON steers. Treatments were assigned in a completely randomized design, and there were no differences ($P \geq 0.62$) in initial calf BW or dam age between groups, supporting that the observed performance differences were likely due to the implant treatment. Furthermore, by the end of the grazing season, IMP steers reached a higher ($P < 0.01$) ending BW (400 lb) than CON steers (383 lb). These improvements were consistent across the three years, despite variation in trial durations (ranging from 69 to 92 days), suggesting a robust and repeatable response to the implant.

Implications

Administering Synovex One Grower implants to beef steer calves at approximately 50 days of age significantly improved ADG and weaning weight during the early period of hormone release, suggesting extended-release implants may offer a practical strategy to increase performance even with shorter time periods of implant administration that are less than the entire length of hormone release.

Acknowledgments

This research is a contribution of the Kansas State University Agricultural Experiment Station and Cooperative Extension Service. The authors thank the staff of the Agricultural Research Center in Hays, KS, for their care and management of the cattle used in the experiment and their assistance with data collection. Appreciation is expressed to Zoetis (Parsippany, NJ) for their support of this research.

Table 1. Effect of Synovex One Grower implantation on suckling calf performance

	Treatment			
Item	**CON[1]**	**IMP[2]**	**SEM[3]**	***P*-value**
Cow age[4], year	5.20	5.19	1.06	0.95
Initial calf age, day	46	47	11	0.46
Initial calf body weight (BW), lb	192	191	32	0.62
Ending calf BW, lb	383	400	25	≤ 0.01
Total calf BW gain, lb	191	211	17	≤ 0.01
Calf average daily gain, lb	2.38	2.62	0.10	≤ 0.01

[1]CON = non-implanted control.
[2]IMP = implanted with Synovex One Grower.
[3]SEM = standard error of the mean.
[4]Average cow age at trial initiation across all years.

Effects of 28-day Rotation of Monensin and Laidlomycin Propionate on Commercial Cattle Performance During the Growing Phase

M.L. Bemisderfer, C.J. Schneider,[1] L.R. Thompson, and H.E. Larson

Abstract

The rotation of ionophores in feedlot cattle diets has been suggested to enhance performance, but short-term rotations have not consistently shown benefits and are not compliant with feeding instructions for continuous feeding. This study evaluated the influence of multiple 28-day rotations of ionophores on the performance of heifers in a commercial feedlot during the growing phase. Data were collected from 584 crossbred heifers (initial body weight = 639 ± 57 lb) blocked by arrival date. Within each block, heifers arrived in groups that were randomly divided into two pens. Pens within each group (n = 10) were randomly assigned to receive either consistent dietary monensin inclusion at 18.8 g/ton dry matter (DM [MON]) or alternating dietary inclusion of monensin (18.8 g/ton DM) and laidlomycin propionate (7.4 g/ton DM) every 28 days, repeated twice during the 112-day trial (ROT). The basal growing diet contained steam-flaked corn (43.5% DM), mixed hay (25.7% DM), wet distillers grains (18.4% DM), alfalfa hay (6.7% DM), supplement (4.9% DM), and corn oil (0.8% DM). Pen weights were recorded every 28 days, and DM intake (DMI) was calculated from daily feed delivery records. Across days 0–56, ROT heifers tended to have improved feed:gain compared with MON ($P = 0.06$), with no difference in average daily gain (ADG) or DMI ($P > 0.10$). Across days 0–84, feed:gain tended to be improved for ROT ($P = 0.06$) with no differences in ADG or DMI ($P > 0.10$). Over the full 112-day trial, ADG ($P < 0.01$) and feed:gain ($P < 0.01$) were improved for ROT compared to MON with no differences in DMI ($P > 0.10$). These results suggest that two 28-day rotations of monensin and laidlomycin propionate during the growing phase can improve feed efficiency and ADG in limit-fed feedlot heifers compared to consistent monensin feeding.

Introduction

Ionophores are commonly included in feedlot diets to improve feed efficiency by altering ruminal fermentation. Because ionophores differ in their ionic selectivity and effects on ruminal microbes, it has been proposed that management strategies combining these mechanistic distinctions could enhance ruminal fermentation and improve cattle performance. Ionophore rotation in beef cattle diets has been investigated since the 1980s, with some studies reporting improvements in feed conversion of up to 6% (Morris et al., 1990; Shreck et al., 2016). Ionophore label instructions require "continuous feeding," which the Food and Drug Administration (FDA) defines as a minimum duration of 14 consecutive days. Experimental evidence indicates that the ruminal microbial and fermentation responses to monensin may change approximately 14–42 days after initiation (Crossland et al., 2017; Guan et al., 2006). Short-term rota-

[1] Cornbelt Livestock Services, Rock Falls, IL

tion studies with daily or weekly rotation intervals have not demonstrated consistent performance benefits (Casey et al., 1994; Morris et al., 1990). Accordingly, a 28-day rotation interval was selected for this study to coincide with this response window and to align with feedyard management schedules. The objective of this study was to investigate the influence of multiple 28-day rotations of dietary monensin (Rumensin 90; Elanco, Indianapolis, IN) to laidlomycin propionate (Cattlyst 50G; Phibro Animal Health Corporation, Teaneck, NJ) during a 112-day growing period on feedlot heifer performance.

Experimental Procedures

The trial was conducted from August 12, 2024, to December 30, 2024, at Clark County Feeders, a commercial feedyard located in Minneola, Kansas. Cattle were received on a rolling basis, resulting in three trial enrollment dates staggered every 14 days. Heifers were housed in drylot pens that allotted 21.5 ± 8.3 in./head of bunk space. Each pen was equipped with an automatic water tank.

A total of 584 commercial beef heifers were enrolled with an average initial body weight (BW) of 639 ± 57 lb. Heifers arrived at the feedyard in three arrival date blocks staggered 14 days apart. Within each block, heifers arrived in groups that were randomly divided into two pens, resulting in an average of 59 ± 15 animals per pen (n = 10). Dietary treatment was randomly assigned to pens within group within block. Following processing, all heifers were acclimated to the facility on a standard commercial starter ration containing decoquinate (Deccox; Phibro Animal Health Corporation) for 28 days with no ionophore included in the ration. After the 28-day acclimation period, cattle were started on one of two dietary treatments: 1) MON: basal diet (57.2 Mcal/cwt net energy for gain (NEg) and 14.3% crude protein) containing 18.8 g/ton dry matter (DM) monensin for 112 days, or 2) ROT: basal diet (57.2 Mcal/cwt NEg and 14.3% crude protein) with the ionophore source alternated every 28 days between 18.8 g/ton DM monensin and 7.4 g/ton DM laidlomycin propionate. The rotation of dietary ionophore inclusion for ROT occurred twice, resulting in two complete 28-day feeding periods for each ionophore and a total feeding period of 112 days (Table 1).

Throughout the trial, cattle were limit-fed to achieve a targeted average daily gain (ADG) of approximately 3.0 lb per animal per day with feed delivered twice daily (morning and afternoon). The basal growing diet was 72.2% DM and formulated on a DM basis to contain 43.5% steam-flaked corn, 25.7% mixed hay, 18.4% wet distillers grains, 6.7% alfalfa hay, 4.9% pelleted protein blend, and 0.8% corn oil (Table 2). Diet composition was consistent across treatments except for the ionophore source. Ionophores were added to the ration using a micro machine. Diets were manufactured on-site and delivered to each pen using commercial-grade horizontal rotary feed mixer trucks.

On day 0 and day 112, pen weights were recorded using a platform pen scale prior to morning feeding to obtain shrunk weights. Interim pen weights were collected at 28-day intervals using the facility's platform pen scale and were adjusted to 96% of the recorded value to approximate shrunk weights and account for gut fill. Dry matter intake (DMI) was determined from daily feed delivery records maintained by the AMS management platform (Turnkey Computer Systems, Loveland, CO).

Data were analyzed as a randomized block design with pen as the experimental unit. Performance models included the fixed effect of treatment with a random effect of placement block. The feed-to-gain ratio was analyzed as gain-to-feed ratio and converted. Prespecified pen-level covariates (bunk space, headcount) were screened as fixed effects and were not retained ($P > 0.10$). Statistical significance was declared at $P \leq 0.05$, with tendencies at $0.05 < P \leq 0.10$. Analyses were performed in R (version 4.4.1; R Core Team, 2024) using lme4, car, and emmeans.

Results and Discussion

Over the entire 112-day growing period, rotating monensin and laidlomycin propionate every 28 days improved ADG ($P < 0.01$) and feed efficiency (feed:gain) ($P < 0.01$) compared with consistent monensin feeding, while DMI remained unaffected ($P > 0.10$) (Table 3). The results demonstrate that alternating ionophores at 28-day intervals can enhance animal performance by 8.7% in commercial feedlot settings, which is consistent with earlier reports of rotational benefits.

The performance response to rotation appeared to improve as the trial progressed. As expected, across days 0-28, when no ionophore differences between treatments were introduced, no treatment differences were observed for ADG, DMI, or feed:gain (Table 3), thereby demonstrating effective allocation of cattle groups to pens within each block. Across days 0-56, when MON cattle had been exposed to 56 days of dietary monensin and ROT cattle had been exposed to 28 days of dietary monensin followed by 28 days of dietary laidlomycin propionate, ROT had a tendency for improved feed:gain compared to MON ($P = 0.06$). The ADG was numerically greater for ROT (3.76 versus 3.44 lb/day; $P = 0.16$), and DMI did not differ between treatments ($P > 0.10$) (Table 3). Across days 0-84, after ROT cattle had received 56 total days of monensin inclusion diet with an interim 28-day rotation of laidlomycin propionate inclusion diet, feed:gain again tended to be greater for ROT ($P = 0.06$), while ADG and DMI did not differ ($P > 0.10$) (Table 3). The tendency for improved feed:gain for ROT heifers was driven by similar DMI between treatments and a numeric improvement in ADG for ROT.

These interim responses indicate that during the early phase (days 0-56), responses were minimal, but differences became more apparent following repeated cycles of ionophore alternation. Possible explanations include enhanced responses in less efficient cattle later in the growing phase and/or shifts in rumen microbial populations due to repeated exposure to alternating ionophores. Importantly, intake did not differ between treatments, indicating that improvements in gain and efficiency are reflective of differences in nutrient utilization rather than changes in consumption. It should also be considered that the interim weights collected were not true shrunk measures but were instead adjusted using a 4% shrink, and additional variability may be present due to the weight collection methods.

Overall, these findings provide novel evidence that ionophore rotation using laidlomycin propionate in the growing phase can be a practical tool for improving cattle performance under commercial conditions. Because the FDA defines continuous feeding as 14 days or longer, the 28-day intervals used in this study represent a label-compliant approach to alternating monensin and laidlomycin propionate in commercial feedyard rations. Additional research is warranted to better understand the biological basis for these responses and to evaluate the consistency of benefits across production phases.

Implications

Rotating monensin and laidlomycin propionate every 28 days during the growing phase improved gain of limit-fed beef heifers by 8.7% compared with consistent monensin feeding, indicating a label-compliant strategy with potential performance value for feedlot producers.

Acknowledgments

Authors would like to thank Clark County Feeders (Minneola, KS) for providing us with the cattle and resources necessary to conduct our research, and Zoetis (Parsippany, NJ) for generously donating vaccinations, implants, and Cattlyst 50G to support the project.

References

Casey, N.H., R.H. Wessels, and H.H. Meissner. 1994. Feedlot growth performance of steers on salinomycin, monensin and a daily rotation between the two. Journal of the South African Veterinary Association 65(4):160–163.

Crossland, W.L., L.O. Tedeschi, T.R. Callaway, M.D. Miller, W.B. Smith, and M. Cravey. 2017. Effects of rotating antibiotic and ionophore feed additives on volatile fatty acid production, potential for methane production, and microbial populations of steers consuming a moderate-forage diet. Journal of Animal Science 95(10):4554–4567. *https://doi.org/10.2527/jas2017.1665*

Guan, H., K.M. Wittenberg, K.H. Ominski, and D.O. Krause. 2006. Efficacy of ionophores in cattle diets for mitigation of enteric methane. Journal of Animal Science 84(7):1896–1906. *https://doi.org/10.2527/jas.2005-652*

Morris, F. E., M.E. Branine, M.L. Galyean, M.E. Hubbert, A.S. Freeman, and G.P. Lofgreen. 1990. Effect of rotating monensin plus tylosin and lasalocid on performance, ruminal fermentation, and site and extent of digestion in feedlot cattle. Journal of Animal Science 68(10):3069-3078. *https://doi.org/10.2527/1990.68103069x*

Shreck, A.L., E.J. Behlke, Z.D. Paddock, L.O. Burciaga-Robles, S.L. Parr, C.W. Booker, S.J. Hannon, H.S. Raaphorst, L. Byers, R.D. Rademacher, M.J. Quinn, and M.L. May. 2016. Effect of daily rotational feeding of lasalocid and monensin to yearling feedlot steers fed in western Canada. The Professional Animal Scientist 32(5):561–569. *https://doi.org/10.15232/pas.2015-01489*

Table 1. Ionophore included in ration by day for treatment groups

Days on feed	MON[1]	ROT
1-28	Monensin	Monensin
29-56	Monensin	Laidlomycin propionate
57-84	Monensin	Monensin
85-112	Monensin	Laidlomycin propionate

[1] MON = Monensin treatment; ROT = Rotational ionophore treatment.

Table 2. Ingredient and nutrient composition of ration (dry matter basis)

	% of dry matter (DM)	
Ingredient	**MON[4]**	**ROT**
Steam-flaked corn	43.5	43.5
Ground mixed hay[1]	25.7	25.7
Wet distillers grains	18.4	18.4
Alfalfa hay	6.7	6.7
Pelleted protein blend	4.9	4.9
Corn oil	0.8	0.8
Monensin[2], g/ton DM	18.8	18.8[a]
Laidlomycin propionate[3], g/ton DM	---	7.4[b]

[1] Blend of sorghum hay and wheat straw.
[2] Monensin in form of Rumensin 90 (Elanco Animal Health, Greenfield, IN).
[3] Laidlomycin propionate in form of Cattlyst 50G (Phibro Animal Health Corp, Teaneck, NJ).
[4] MON = Monensin treatment; ROT = Rotational ionophore treatment.
[a] Day 1-28, 57-84.
[b] Day 29-56, 85-112.

Table 3. Cumulative cattle performance across multiple 28-day periods of study of monensin (MON) versus rotational ionophore treatment (ROT) heifers

Days on feed	Item[1]	MON	ROT	SEM[2]	*P*-value
1-28[a]	ADG, lb/day	3.53	3.63	0.26	0.71
	DMI, lb/day	18.50	18.70	0.70	0.84
	Feed:gain	5.26	5.10	0.24	0.61
1-56[b]	ADG, lb/day	3.44	3.76	0.17	0.16
	DMI, lb/day	20.40	20.60	0.68	0.64
	Feed:gain	5.88	5.32	0.22	0.06
1-84[c]	ADG, lb/day	3.27	3.39	0.09	0.20
	DMI, lb/day	21.80	21.90	0.68	0.95
	Feed:gain	6.54	6.21	0.12	0.06
1-112[d]	ADG, lb/day	3.12	3.39	0.09	<0.01
	DMI, lb/day	23.00	23.10	0.72	0.78
	Feed:gain	7.14	6.58	0.14	<0.01

[1] ADG = average daily gain, DMI = dry matter intake.
[2] Standard error of the mean.
[a] From day 1-28, MON and ROT both received monensin for 28 days.
[b] From day 1-56, MON received monensin for 56 days; ROT received monensin for 28 days followed by laidlomycin propionate for 28 days.
[c] From day 1-84, MON received monensin for 84 days; ROT received 56 total days of monensin with an interim 28 days laidlomycin propionate.
[d] From day 1-112, MON received monensin for 112 days; received monensin for a total of 56 days and laidlomycin propionate for a total of 56 days alternating ionophore inclusion every 28 days.

Use of Unmanned Aerial Vehicle Technologies with Thermal Imaging to Assess Surface Moisture in Pens of Cattle Offered Energy-dense vs. Low-energy Feeding Programs

L. Diller, L. Thompson, D. Blasi, and H. Larson

Abstract

An experiment was conducted to determine if feedlot pen moisture can be detected using unmanned aerial vehicle (UAV) technologies. Steers were fed either an energy-dense, limit-fed diet or a low-energy, *ad libitum*-fed diet to create differences in the conditions of pen surfaces. The objectives were to: 1) characterize pen surface moisture levels as determined by different feeding programs; and 2) evaluate associations between UAV thermal images and pen surface moisture. Six dirt-floor pens (30 × 50 ft) at the Kansas State University Stocker Unit (Manhattan, KS) housed 14 dairy-beef crossbred steers each (Body weight = 930 ± 85 lb). Pens were assigned to either an energy-dense 64 Mcal/cwt net energy for gain (NEg) limit-fed ration (LIMIT; n = 3) or a low-energy 50 Mcal/cwt NEg *ad libitum* ration (ADLIB; n = 3), and each pen was divided into 15 sampling quadrants (10 × 10 ft). For three consecutive days, a UAV (AUTEL EVO 2) equipped with a thermal sensor (H20T) was flown at an altitude of 100 ft to capture images during morning feeding. Images were processed with Pix4D and ArcGIS, and average luminosity using minimum and maximum red, green, and blue (RGB) ([minRGB + maxRGB]/2) values per quadrant were obtained in Photoshop. Pen floor grab samples (n = 3/quadrant) were analyzed for moisture. Moisture was analyzed using a linear mixed model with fixed effect of treatment and random effects of pen, quadrant nested within pen, and day ($P = 0.025$). Pen moisture was then tested for association with luminosity values from UAV thermal images using a linear mixed model. Luminosity was associated with moisture ($P < 0.001$), supporting its utility as a predictive metric. The equation using luminosity to predict pen floor moisture demonstrated excellent predictive accuracy (Lin's concordance correlation coefficient = 0.98). Results indicate UAV thermal images can characterize pen-level surface moisture, and luminosity values effectively predict pen floor moisture.

Introduction

Beef cattle are often housed in open dirt pens that accumulate manure, urine, and wasted feed. Depending upon management, pen condition can affect cattle performance, animal health, animal welfare, and the surrounding environment. Pen floor conditions are influenced by diet composition, stocking density, and weather. The combination of these variables directly affects moisture, nutrient accumulation, and surface temperature. Excessive moisture can reduce animal comfort, increase the risk of lameness and digital dermatitis, and elevate pathogen prevalence (Berry and Miller, 2005; Cortes et al., 2021). Conversely, overly dry surfaces contribute to dust generation, which negatively affects air quality and animal well-being (Grandin, 2016).

Traditional pen assessment relies on visual evaluation or score, which is labor-intensive, subjective, and provides limited spatial resolution. Remote sensing technologies, including unmanned aerial vehicles (UAV) equipped with thermal sensors, offer an opportunity to rapidly characterize surface conditions. Limited research has evaluated whether UAV imagery can reliably predict nutrient and moisture conditions in cattle pens. The objectives of this trial were to characterize the pen surface moisture level of cattle pens managed with energy-dense, *ad libitum* or low-energy, limit-fed feeding programs, and to evaluate the association of luminosity derived from thermal images taken using UAV technologies with the pen surface moisture level.

Experimental Procedures

The study was conducted in the summer using six outdoor dirt-surfaced feedlot pens (30 × 50 ft) at the Kansas State University Stocker Unit (Manhattan, KS). Each pen housed 14 dairy × beef crossbred steers (Body weight [BW] = 930 ± 85 lb) on days 111, 112, and 113 of the backgrounding phase. Pens were assigned to one of two dietary treatments: 1) LIMIT: energy-dense limit-fed finishing ration formulated to 64 Mcal/cwt net energy for gain (NEg) or 2) ADLIB: low-energy *ad libitum* ration formulated to 50 Mcal/cwt NEg. The diet composition of the LIMIT ration consisted of dry rolled corn (59%), wet corn gluten (30%), prairie hay (7%), and supplement (4%). The diet composition of the ADLIB ration consisted of dry rolled corn (24%), wet corn gluten (40%), prairie hay (30%), and supplement (6%).

Before sample collection, each pen was divided into 15 quadrants (10 × 10 ft). Sample collection and UAV imaging directly followed morning feeding to capture surface images of the pen while the cattle were occupied at the bunk. Three grab samples (approximately 0.55 lb) of the pen surface material were collected per quadrant and analyzed individually for moisture (dry matter %). Replicates were averaged by quadrant to provide descriptive variables of surface moisture of the pen by quadrant.

An AUTEL EVO II UAV equipped with a thermal sensor (H20T) was flown at an altitude of 100 ft in preplanned flights to take thermal images of the pen surfaces. Relevant pen images were stitched together and processed using Pix4D and visualized in ArcGIS. Quadrant-specific luminosity values were extracted in Adobe Photoshop to provide a unitless measure of relative brightness, calculated from the red, green, and blue (RGB) channels ([minRGB+maxRGB]/2), for statistical analysis.

Sample collection and imaging were conducted across three consecutive days. Weather and temperature were consistent on days 1 and 2, providing stable pen surface conditions. Before day 3 sample and image collection, rainfall occurred, which altered pen moisture levels. On day 3, pens (n = 2) were sampled for moisture analysis, and UAV imaging was completed for all pens. For statistical analysis, pens without direct samples on day 3 were excluded from the dataset.

Statistical analyses were conducted in R version 4.4.2. Linear models were constructed using the lmer function of the lme4 package in R. Moisture was first analyzed using a linear mixed model with fixed effect of treatment and random effects of pen, quadrant nested within pen, and day. When a significant association between treatment and moisture was determined, moisture was then tested for association with luminosity. The relationship was modeled using a linear mixed model with fixed effects of treatment and luminosity and random effects of pen, quadrant nested within pen, and day. The epiR package in R was used to calculate Lin's concordance correlation coefficient (Lin's

CCC) between the actual measured moisture and the luminosity predicted moisture to understand the precision and accuracy between moisture and luminosity. Significance was declared at $P \leq 0.05$. Trends were noted at $0.05 < P \leq 0.10$. Lin's CCC values were declared at: > 0.9 excellent; 0.8 - 0.9 good; 0.6 to 0.8 moderate; below 0.6.

Results and Discussion:

Treatment influenced the pen surface moisture. LIMIT resulted in 10% lower ($P < 0.001$) pen-surface moisture than ADLIB (42.1 versus 52.1 ± 8.3%, respectively). Luminosity value consequently was higher ($P = 0.003$) in LIMIT compared to ADLIB (87.4 versus 55.1 ± 7.9, respectively). This outcome supports previous observations that *ad libitum* feeding increases manure output and consequently the surface moisture of the pen accumulation relative to limit-fed cattle. Findings are consistent with previous reports that nutrient intake and feeding strategy directly affect pen condition through differences in excreted manure volume and composition.

When luminosity derived from UAV thermal imagery was added as a fixed effect into the original model, both treatment and luminosity were predictors of pen surface moisture. When predicted by luminosity ($P < 0.001$), LIMIT had lower ($P = 0.014$) surface moisture of the pen compared to ADLIB (43.8 versus 49.8 ± 7.9%). Therefore, luminosity had a strong negative association with measured pen surface moisture. This relationship explains the link between lighter image tones and drier surfaces, indicating that UAV-based imaging can provide a non-invasive proxy for moisture assessment.

Model predictions of the pen by day mean moisture content were closely aligned with observed values, with residuals generally within ±5% across days and treatments. The agreement between observed and predicted values was exceptionally high (Lin's CCC = 0.98; Figure 1). This level of predictive accuracy demonstrates the strong potential of UAV thermal image-derived luminosity as a tool for quantifying cattle pen-surface moisture conditions.

Weather conditions were stable during days 1 and 2, providing consistent baselines for moisture and imaging. However, rainfall before day 3 increased overall moisture levels (Figure 1), which was evident in both direct sampling and UAV imagery. These weather-related differences highlight how external environmental factors influence pen conditions and the potential utility of UAV monitoring for capturing changes and the rate of dissipation due to precipitation events.

These findings demonstrate that UAV-derived imagery can distinguish surface moisture influenced by feeding program and accurately predict surface moisture across days and environmental conditions. Integrating this approach into routine feedlot management could allow facilities to identify wetter pen conditions, guide decisions around cleaning, bedding, or drainage, and ultimately improve cattle health and comfort while mitigating the risk of nutrient runoff.

Implications

The UAV thermal image-derived luminosity values provide a practical tool to confidently (Lin's CCC = 0.98) quantify the pen surface moisture and detect feeding program effects, offering precision management opportunities to improve animal health and environmental outcomes.

References

Berry, E.D., and D.N. Miller. 2005. Cattle feedlot soil moisture and manure content: II. Impact on *Escherichia coli* O157. Journal of Environmental Quality 34(2):656–663. https://doi.org/10.2134/jeq2005.0656

Cortes, J.A., A. Thomas, S. Hendrick, E. Janzen, E.A. Pajor, and K. Orsel, 2021. Risk factors of digital dermatitis in feedlot cattle. Translational Animal Science 5(3): txab075. https://doi.org/10.1093/tas/txab075

Gaughan, J.B., S.M. Holt, and R.H. Pritchard. 2009. Assessment of housing systems for feedlot cattle during summer. The Professional Animal Scientist 25(5):633–639. https://doi.org/10.15232/S1080-7446(15)30767-1

Grandin, T. 2016. Evaluation of the welfare of cattle housed in outdoor feedlot pens. Veterinary and Animal Science 1–2:23–28. https://doi.org/10.1016/j.vas.2016.11.001

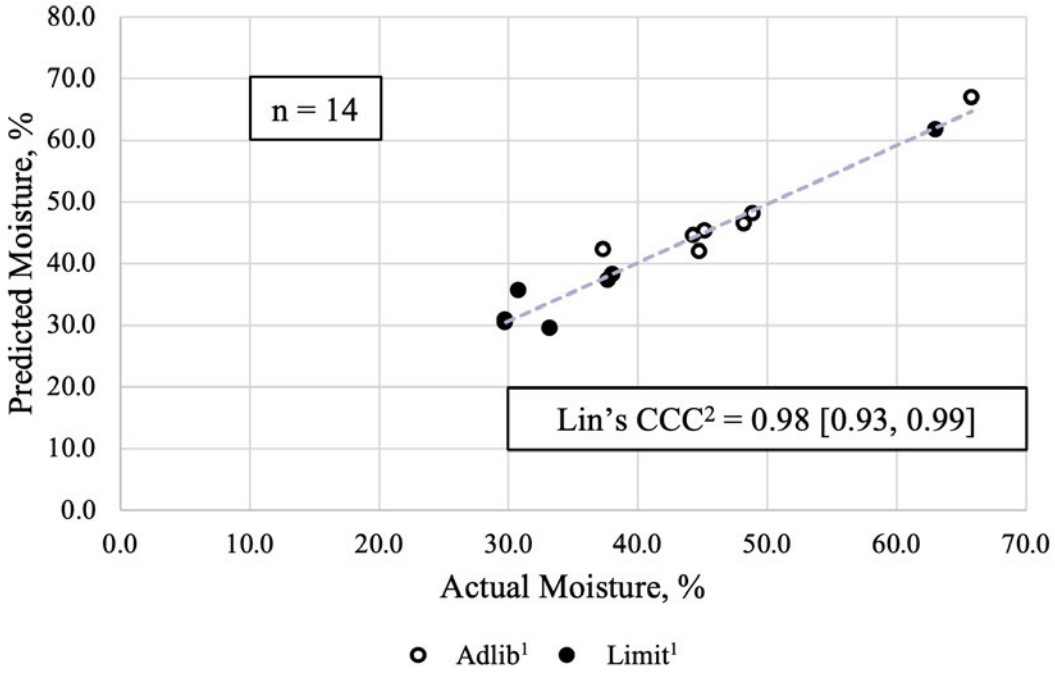

Figure 1. Relationship between observed and predicted mean moisture values for pen by day

[1] Treatment: ADLIB = low-energy *ad libitum* (50 Mcal/cwt net energy for gain [NEg]); LIMIT = energy-dense limit-fed (64 Mcal/cwt NEg).

[2] Lin's concordance correlation coefficient: > 0.9 excellent; 0.8 - 0.9 good; 0.6 to 0.8 moderate; below 0.6.

Effects of Alternative Feed Timing on Growth Performance and Water Usage of Growing Beef × Dairy Heifers Fed a High Roughage Diet

C. H. Stoskopf, C. D. Weir, W.C. Ellis, T. A. Rowe, W. R. Hollenbeck, A. J. Tarpoff, and D. A. Blasi

Abstract

An 84-day feeding study was conducted to determine the effects of feed timing of high-roughage diets on growth performance, water usage, and heat stress exposure on beef × dairy heifers. A total of 260 heifers (initial body weight 459 ± 29 lb) were blocked by weight and randomly assigned to 20 pens, each containing 13 head. Pens were randomly assigned to one of two experimental treatments: fed at 7:00 a.m. (AM) or fed at 7:00 p.m. (PM). Heifers were offered feed for *ad libitum* intake with *ad libitum* access to water. At the conclusion of the study, final body weight, average daily gain, dry matter intake, and feed efficiency did not differ ($P \geq 0.47$) between the treatments. Water consumption was greater ($P < 0.01$) for AM heifers compared to PM (10.88 versus 10.36 gal/head/day, respectively). These data suggest that shifting feed timing of high roughage growing diets does not affect growth performance in beef × dairy heifers but could afford producers the opportunity to reduce water usage.

Introduction

High-roughage diets are the industry standard when transitioning freshly weaned calves to the feedlot. During this transition time, growing cattle face environmental stressors, such as heat stress, that can reduce animal comfort and performance. Enteric heat production from ruminal fermentation peaks 4 to 6 hours after feeding, often coinciding with the hottest part of the day, adding to the heat stress conditions of the outside environment. Implementing shade structures could mitigate the effects of heat stress; however, those structures represent a costly investment and may not be economically viable for some producers. Shifting feeding time, consequently shifting peak fermentation, to the evening may be an effective alternative to mitigate added heat stress without the added cost of shade structures. Therefore, the objective of this study was to evaluate the effects of altered feed timing (morning versus evening) on growth performance and water usage in growing fed beef × dairy heifers fed for *ad libitum* intake.

Experimental Procedure

A total of 260 black-hided beef × dairy heifers (initial body weight [BW] = 459 ± 29 lb) were purchased in southwest Kansas and transported to the Kansas State University Beef Stocker Unit in late May 2025. Heifers were placed in a randomized, complete-block design and were fed for 84 days. Heifers were fed a common diet for two days with *ad libitum* access to water. On day 1, heifers were individually weighed in a hydraulic chute (Silencer, Moly Manufacturing Inc., Loraine, KS) and assigned a visual identification ear tag. Heifers arrived with electronic identification tags, and their individual numbers were recorded. Heifers were blocked by weight (light and heavy).

Within the block, heifers were stratified by weight and randomly assigned to 20 pens containing 12 or 13 head. Pens were randomly assigned one of two treatments (10 reps per treatment). The experimental treatments were fed a high-roughage diet formulated to provide 50 Mcal of net energy for gain/100 lb dry matter (DM) for *ad libitum* intake at either 7:00 a.m. (AM) or 7:00 p.m. (PM). Refusals were targeted at 10% and daily feed calls were made 30 minutes before feeding to adjust feed allotments. Pen weights were collected every 14 days to monitor growth performance. During pen weights, feed that remained in the bunk was collected and weighed to determine feed refusal and adjust DM intake.

Water usage data was collected using individual water meters (SENSUS, Morrisville, NC) connected to each water tank in the pen. The total daily water usage of the pen was divided by the number of head in each pen to determine gal/head/day. Temperature, relative humidity, wind speed, and solar radiation were collected four times/day (1:00 a.m., 7:00 a.m., 1:00 p.m., and 7:00 p.m.) using a Davis weather station (Vantage Pro 2; Davis Instruments Corporation, Hayward, CA). Weather condition data were used to quantify heat stress exposure using the comprehensive climate index (CCI) adopted from Mader et al. (2010).

Results and Discussion

At the conclusion of the 84-day feeding period, final BW, DM intake, average daily gain, and gain:feed did not differ ($P \geq 0.47$) between AM and PM. Water usage was greater ($P < 0.01$) for AM heifers compared to PM. Heifers fed at 7:00 a.m. consumed 0.52 gal/head/day more than heifers fed in the evening. Offering feed for *ad libitum* intake allowed cattle to have access to feed at any time during the day and night.

The lack of treatment differences in growth performance could reflect the heifer's ability to regulate intake using their own natural feeding patterns. Cattle fed for *ad libitum* intake typically consume one large meal when feed is delivered and 8 to 9 hours later with smaller meals throughout the day (Schwartkopf-Genswein et al., 2003). During the afternoon, when CCI typically reached its maximum, heifers were often not eating, which could have reduced potential negative effects associated with heat stress and the added heat from ruminal fermentation.

Weather conditions during the study were relatively mild, and CCI values indicated limited exposure to mild and moderate heat stress. This is likely attributed to the lack of treatment differences. The mild CCI values observed were likely not enough to modify heifer behavior, and thus, heifers continued with normal diurnal patterns of eating and drinking.

Implications

Results from this experiment suggest that shifting the time of feeding high-roughage diets fed for *ad libitum* intake does not affect the growth performance of growing beef × dairy heifers under a mild heat load. However, shifting feed time did reduce water consumption when heifers were fed in the evening. This could provide producers in the High Plains region who are facing water sustainability issues an opportunity to conserve water without sacrificing animal performance.

References

Mader, T.L., L.J. Johnson, and J.B. Gaughan. 2010. A comprehensive index for assessing environmental stress in animals. Journal of Animal Science 88:2153-2165. *doi: 10.2527/jas.2009-2586*

Schwartzkopf-Genswein, K.S., K.A. Beauchemin, D.J. Gibb, D.H. Crews Jr., D.D. Hickman, M. Streeter, and T A. McAllister. 2003. Effect of bunk management on feeding behavior, ruminal acidosis and performance of feedlot cattle: A review. Journal of Animal. Science 81(14, Supplement 2): E149-E158. *doi.org/10.2527/2003.8114_suppl_2E149x*

Table 1. Growth performance and water usage of growing beef × dairy heifers fed a high roughage diet for *ad libitum* intake

	Treatment[1]			
Item	**AM**	**PM**	**SEM[2]**	***P*-value**
Initial body weight, lb	459	459	28.708	0.78
Final body weight, lb	665	664	13.930	0.98
Average daily gain, lb/day	2.44	2.44	0.368	0.99
Dry matter intake, lb/day	18.56	18.35	0.783	0.47
Gain:feed, lb/lb	0.14	0.13	0.002	0.51
Feed:gain, lb/lb	7.60	7.52	0.080	0.89
Water usage, gal/day[3]	10.88[a]	10.36[b]	0.108	< 0.01

[1] AM = feed delivered at 7:00 a.m.; PM = feed delivered at 7:00 p.m.
[2] Largest standard error of the means.
[3] Calculated by dividing total daily pen water usage by number of head in pen.
[ab] Within row, means with uncommon superscripts differ ($P \leq 0.05$).

Table 2. Weather conditions collected at the Kansas State Beef Stocker Unit during summer 2025

Item[1]	May	June	July	August	Overall
Temperature, F°					
Mean	72 ± 10	76 ± 9	80 ± 8	79 ± 9	78 ± 9
Maximum	86	94	95	97	97
Minimum	59	53	62	59	53
Relative Humidity, %					
Mean	61 ± 15	67 ± 11	69 ± 9	67 ± 10	67 ± 10
Maximum	79	81	80	95	95
Minimum	41	27	43	43	27
Wind speed, mi/hour					
Mean	6 ± 3	7 ± 6	6 ± 4	6 ± 4	6 ± 15
Maximum	11	24	17	18	24
Minimum	2	0	0	0	0
Solar radiation, W/m^2					
Mean	360 ± 342	273 ± 312	234 ± 302	212 ± 296	245 ± 305
Maximum	684	766	978	931	978
Minimum	0	0	0	0	0
CCI, C°[2]					
Mean	21 ± 9	24 ± 7	26 ± 6	26 ± 6	25 ± 7
Maximum	32	37	41	38	41
Minimum	7	6	12	13	6

[1] Weather data collected by Davis Weather station.
[2] Comprehensive climate index (CCI) equation adopted from Mader et al. (2010).

Effects of Alternative Feed Timing on Growth Performance and Water Usage in Limit Fed Growing Beef × Dairy Heifers

C.H. Stoskopf, C.D. Weir, W.C. Ellis, T.A. Rowe, W.R. Hollenbeck, A.J. Tarpoff, and D.A. Blasi

Abstract

An 84-day study was conducted to determine the effects of alternative feeding timing on growth performance and water usage during heat stress conditions in limit-fed growing beef × dairy heifers. A total of 257 beef × dairy heifers (initial body weight [BW] = 470 ± 28 lb) were blocked by weight. Within the block, heifers were stratified by arrival BW and randomly assigned to 20 pens containing 12 or 13 head. Within the block, pens were randomly allocated to one of two treatments (10 replications per treatment). Cattle were fed a diet formulated to provide 60 Mcal of net energy for gain/100 lb of dry matter (DM), limit fed at 2.2% BW (DM basis) at either 7:00 a.m. (AM) or 7:00 p.m. (PM). Individual BW was measured at the beginning and end of the feeding period. Pen weights were measured every 14 days and used to adjust feed delivery to limit-fed pens for the following 14 days. Final BW, average daily gain, gain:feed, and DM intake did not differ $P \geq 0.62$ between AM and PM heifers. Water usage was greater ($P < 0.01$) for AM heifers compared to PM heifers. Overall, producers could offer limit-fed diets in the evening to reduce water usage without sacrificing growth performance.

Introduction

Limit feeding a high-energy diet with corn coproduct inclusions can improve growing cattle performance, efficiency, and reduce water usage compared to a traditional growing diet fed for *ad libitum* intake. Environmental conditions, particularly heat stress, can reduce animal comfort and subsequently reduce animal performance. DeBord et al. (2024) observed that limit-fed cattle had reduced instances of heat stress compared to cattle fed for *ad libitum* intake. Because enteric heat production from ruminal fermentation peaks 4 to 6 hours after feeding (Yost, 2024), limit feeding higher energy rations could shift peak ruminal fermentation to earlier in the day when temperatures have not reached heat stress conditions. Additionally, limit feeding and providing shade during the summer months have been shown to improve cattle performance and reduce water usage (DeBord et al., 2024). However, shade structures represent a costly investment for producers and may not be economically viable. Shifting the feeding time to the evening could also help mitigate the added heat stress from fermentation without the added cost of shade structures. Therefore, the objective of this study was to evaluate the effects of altered feed timing (morning versus evening) on growth performance and water usage of growing limit-fed beef × dairy heifers.

Experimental Procedures

A total of 257 black-hided dairy-derived beef heifers (initial body weight [BW] = 470 ± 28 lb) were purchased from a single source in southwest Kansas and transported to the Kansas State University Beef Stocker Unit. Upon arrival, heifers were put into 13-head pens by order of arrival. Heifers were offered warm-season grass hay at 1.0% of body

weight (dry matter [DM] basis) with *ad libitum* access to water. The following day, each heifer was individually weighed in a hydraulic squeeze chute (Silencer, Moly Manufacturing Inc., Loraine, KS) and assigned an individual visual identification ear tag. Heifers were blocked into two groups by weight. Within the block, heifers were stratified by weight and randomly assigned to 20 pens containing 13 head. Within the block, pens were randomly assigned one of two treatments (10 replications per treatment). The cattle in the experimental treatments were limit fed a diet formulated to provide 60 Mcal of net energy for gain/100 lb DM at 2.2% BW (DM basis) at either 7:00 a.m. (AM) or 7:00 p.m. (PM). Diets were mixed and delivered using a Roto-Mix feed wagon (Model #414B; Roto-Mix, Dodge City, KS). Pen weights were conducted every 14 days to adjust feed deliveries and calculate growth performance. Pen weights were conducted an hour before feeding (6:00 a.m. for the 7:00 a.m. feeding and 6:00 p.m. for the 7:00 p.m. feeding).

Water consumption was monitored with individual water meters (SENSUS, Morrisville, NC) connected to each water tank. The total daily water usage was divided by the number of head in each pen to determine gal/head/day. Weather conditions were measured four times/day (1:00 a.m., 7:00 a.m., 1:00 p.m., and 7:00 p.m.) using a Davis weather station (Vantage Pro 2; Davis Instruments Corporation, Hayward, CA) located in the center of the feedlot. Weather condition measurements were used to calculate a comprehensive climate index (CCI) to quantify heat stress exposure.

Results and Discussion

Final BW, average daily gain, DM intake, and feed:gain did not differ ($P \geq 0.62$, Table 1) between the AM and PM treatments. Mader et al. (2010) determined that cattle experience heat stress conditions at times when the CCI exceeds 25. Table 2 outlines the weather conditions during the summer months of our study. Only during July and August did the CCI exceed a CCI of 25 at 26.2 in both months. A CCI between 25 and 30 represents mild heat stress exposure and only occurred during peak sun exposure in the mid-afternoon. Because the environmental conditions during our study never reached conditions to induce moderate to severe heat stress, cattle comfort and performance were likely not affected. As mentioned, enteric heat production from ruminal fermentation generally peaks 4 to 6 hours after feeding. The AM heifers typically consumed their daily feed allotment 2 to 4 hours after feeding; subsequently, peak fermentation would have been between 1:00 p.m. and 3:00 p.m. The highest CCI in our study peaked between 3:00 p.m. and 5:00 p.m. The differences between peak enteric heat production and CCI likely helped further reduce heat stress exposure. Subsequently, PM heifers never experienced a CCI greater than 25.

Water usage was greater ($P < 0.01$) for AM heifers compared to PM heifers. Heifers fed at 7:00 a.m. on average used 0.88 gal/head/day more than PM heifers. In the High Plains region, the rate of depletion of available groundwater for agricultural use has steadily decreased over the years (Tollefson, 2025). New efforts in management practices by producers to reduce water usage have become paramount in many parts of the region as an attempt to maintain water sustainability. Shifting the feed timing to the evening when heat exposure is minimized can help producers reduce their water usage without sacrificing cattle growth performance.

Implications

Our results suggest that shifting the feeding to evening hours does not negatively affect the growth performance of growing beef × dairy heifers, but it does reduce water usage.

References

Debord, Z.L., Z.M. Duncan, M.G. Pflughoeft, K.J. Suhr, W.C. Ellis, W.R. Hollenbeck, S.P. Montgomery, T.J. Spore, E.C. Titgemeyer, D.A. Blasi, and A.J. Tarpoff. 2024. Effect of shade and limit feeding in growing beef heifers during periods of heat stress. Translational Animal Science 8:txae161. *doi: 10.1093/tas/txae161*

Mader, T.L., L.J. Johnson, and J.B. Gaughan. 2010. A comprehensive index for assessing environmental stress in animals. Journal of Animal Science 88:2153-2165. *doi: 10.2527/jas.2009-2586*

Tollefson J. 2025. Groundwater levels fall across western, south-central Kansas. Kansas Geological Survey. *https://kgs.ku.edu/news/article/groundwater-levels-fall-across-western-south-central-kansas*. (Accessed September 8, 2025)

Yost, J. 2024. Managing heat stress of beef animals. The Ohio State University. Ohio BEEF Cattle Letter. *https://u.osu.edu/beef/2024/06/26/managing-heat-stress-of-beef-animals/*. (Accessed September 8, 2025)

Table 1. Growth performance and water usage of growing limit fed beef × dairy heifers

	Treatment[1]			
Item	**AM**	**PM**	**SEM[2]**	***P*-value**
Initial body weight, lb	470	470	9.163	0.99
Final body weight, lb	643	644	12.626	0.95
Average daily gain, lb/day	2.06	2.07	0.075	0.93
Dry matter intake, lb/day	12.08	12.28	0.281	0.63
Gain:feed, lb/lb	0.17	0.17	0.006	0.81
Feed:gain, lb/lb	5.89	6.07	0.248	0.62
Water usage, gal/day[3]	10.42[b]	9.54[a]	0.100	< 0.01

[1] AM = fed at 7:00 a.m.; PM = fed at 7:00 p.m.
[2] Largest standard error of the means.
[3] Calculated by dividing total daily pen water usage by number of head in pen.
[a,b] Within row, means with uncommon superscripts differ ($P \leq 0.05$).

Table 2. Weather conditions collected at the Kansas State Beef Stocker Unit during summer 2025

Item[1]	May	June	July	August	Overall
Temperature, F°					
Mean	72.3 ± 10.1	75.8 ± 8.9	79.9 ± 7.9	78.9 ± 8.9	78.0 ± 8.8
Maximum	86	94	95	97	97
Minimum	59	53	62	59	53
Relative humidity, %					
Mean	60.6 ± 15	66.5 ± 10.9	68.5 ± 9.2	66.7 ± 10.4	67.2 ± 10.4
Maximum	79	81	80	95	95
Minimum	41	27	43	43	27
Wind speed, mi/h					
Mean	5.8 ± 3.0	7.1 ± 6.0	6.25 ± 3.81	5.6 ± 4.4	6.4 ± 4.8
Maximum	11	24	17	18	24
Minimum	2	0	0	0	0
Solar radiation, W/m^2					
Mean	359.7 ± 341.9	272.8 ± 311.5	233.6 ± 301.7	211.7 ± 296.4	245.5 ± 305.2
Maximum	684	766	978	931	978
Minimum	0	0	0	0	0
CCI, C°[2]					
Mean	20.6 ± 9.4	23.6 ± 6.7	26.2 ± 6.5	26.2 ± 6.0	25.1 ± 6.7
Maximum	32	37	41	38	41
Minimum	7	6	12	13	6

[1] Weather data collected by Davis Weather station.
[2] Comprehensive climate index (CCI) equation adopted from (Mader et al., 2010).

Interactive Effects of Body Weight and Body Condition Score on Enteric Methane Emissions in Grazing Beef Cows

C.M. Salisbury, J.M. Warner, and L.R. Thompson

Abstract

Enteric methane emissions from beef cattle are both an environmental concern and a marker of digestive inefficiency; however, the role of animal-level traits such as body weight (BW) and condition in shaping these emissions remains underexplored. This study evaluated how BW and body condition score (BCS), both independently and interactively, influence methane production and emission efficiency in mature beef cows during spring grazing. Data were collected from a supplementation trial on native pasture using automated feeders and GreenFeed systems to measure individual supplement intake and gas emissions. Cows were weighed and scored monthly and categorized based on BCS changes over time (maintained, gained, or lost). A linear model explained 43% of the variation in methane output. Methane emissions increased with BW (0.79 g/day/lb; $P = 0.028$) and tended to increase with BCS (173.3 g/day/unit; $P = 0.068$). A significant BW × BCS interaction ($P = 0.050$) indicated that the emission effect of increasing BCS diminished in heavier cows. When methane was expressed relative to intake, cows maintaining BCS had the lowest emissions (185 g/lb of supplement dry matter intake), followed by cows that lost (198 g/lb) or gained (219 g/lb) condition. Similar trends were observed for methane per unit BW, although group differences were not statistically significant ($P = 0.24$). These findings suggest that moderate cow size and stable body condition are associated with improved emission profiles. Management strategies that support consistent BCS in moderate-sized cows may help balance productivity and environmental sustainability in pasture-based systems.

Introduction

Improving digestive efficiency in beef cattle supports both animal performance and more sustainable, cost-effective operations. Methane, a byproduct of rumen fermentation, is a key environmental concern due to its high global warming potential, 28 times greater than that of carbon dioxide over a 100-year period. Rumen fermentation accounts for roughly 30% of total methane emissions in the U.S. (EPA, 2021). Although methane production represents an energy loss in cattle, its role in climate change has renewed interest in developing strategies to reduce emissions (Hristov et al., 2013). To be effective, these strategies must not only reduce emissions or prevent increases through indirect pathways but also remain practical and economically viable for producers (Thompson and Rowntree, 2020). One underexplored approach is to consider how individual animal characteristics influence methane output. Specifically, body weight (BW) and body condition score (BCS) together define cow size and energy reserves, and are linked to digestion and feed intake dynamics. Since methane production is closely tied to the amount and efficiency of feed fermented in the rumen, cow size is expected to influence emissions. While BCS is a simple visual tool to monitor fat reserves, BW reflects total metabolic demand. Understanding how BW and BCS interact to affect methane emissions can help identify management strategies that

optimize both productivity and environmental outcomes. While prior research has established links between cow size, feed intake, and methane production, few studies have quantified how BW and BCS interact to shape absolute methane emissions and emission efficiency under practical grazing conditions. Initial evidence suggests that higher BW and BCS may both contribute to increased emissions, but the interaction between these variables and how they affect methane per unit of intake or BW remains poorly defined. Furthermore, it is unclear whether cows that maintain, gain, or lose condition over time differ meaningfully in methane emissions, which has direct implications for management decisions. The objective of this study was to evaluate how BW and BCS, both independently and interactively, influence enteric methane production and emission efficiency in beef cows during spring grazing. We also assessed whether temporal patterns in BCS change (gain, loss, maintenance) correspond with differences in methane emissions, to inform management strategies that align productivity with environmental stewardship.

Experimental Procedures

This retrospective analysis used data collected during the first year of a two-year supplementation study conducted at the Kansas State University Purebred Beef Unit. The original study evaluated the effects of a monensin-containing supplement on methane emissions, forage intake, and cow-calf performance in mature spring-calving beef cows managed on native pasture. Data used in the present analysis were collected between January and June 2025 and only include cows offered a non-monensin-containing supplement.

Cows (BW = 1,219.6 ± 145.9 lb: Initial BCS = 4.6) were acclimated to automated feeding and gas measurement equipment, including SmartFeed Pro supplement feeders and GreenFeed emission monitoring systems (Automated head-chamber system [AHCS]; C-Lock Inc., Rapid City, SD), prior to the start of the spring supplementation period. During the supplementation period, cows were offered up to 1.5 lb/head/day of supplement (Table 1) with actual intake averaging 0.90 lb/head/day. Enteric methane and carbon dioxide production were determined using two AHCS. Visits were set for a maximum of six drops per visit (approximately 36 g/drop) with 30-second intervals between each drop and a minimum of four hours between each visit to encourage animals to space visits out across the day. Only visits greater than three minutes in duration were used for subsequent analyses as recommended by Velazco et al. (2016). Both BCS and BW were recorded monthly by two trained observers using a standard 9-point scale. Supplement intake was continuously monitored using the SmartFeed Pro system, and individual average daily intakes were calculated across the supplementation period.

For the present analysis, we examined how BW and BCS, as well as their interaction, influenced methane emissions in beef cows during the spring grazing period. Repeated monthly measurements were collected, and a statistical model was used to evaluate how these factors affected both total methane output and emission efficiency. To better reflect management implications, cows were grouped each month into BCS change categories (loss, maintain, or gain), and methane efficiency was compared across these groups using mixed models and graphical summaries. Model diagnostics, including residual plots and information criteria, were examined to confirm the appropriate model fit and assumptions.

Results and Discussion

A statistical model to evaluate how BW and BCS interact to influence methane emissions in beef cows, based on repeated monthly measurements during the spring grazing period, was used. The model explained 43% of the variation in methane output. Heavier cows were observed to emit more methane, regardless of body condition, with emissions increasing by 0.79 g for each additional pound of BW ($P = 0.028$). Higher BCS also tended to increase emissions, with an estimated effect of 173.3 g/day/BCS unit ($P = 0.068$); however, this effect diminished at higher BW due to a significant negative interaction (−0.14, $P = 0.050$). In practical terms, methane output is already elevated in heavier animals, so further increases in BCS have less additional impact. These results suggest that cows with moderate BW and BCS offer a better balance between production efficiency and environmental impact. Previous research exploring the effects of cow BW on weaning weights would further suggest that weaning performance will likely be improved as well (Thompson and Rowntree, 2020).

When methane was expressed as an efficiency ratio (Table 2), cows that maintained BCS across months had the lowest emissions per unit of supplement intake (methane/dry matter intake = 185 g/lb of supplement intake), while cows that gained condition had the highest emissions (methane/dry matter intake = 219 g/lb of supplement intake). Cows that lost condition had intermediate emission rates (methane/dry matter intake = 198 g/lb of supplement intake). Although mixed model comparisons across groups did not reach statistical significance ($P = 0.24$), the direction of differences was consistent across months and animals and more research is required to explore this relationship. Methane per unit of body weight followed a similar pattern, with maintainers averaging 0.15 g/lb, gainers 0.18 g/lb, and losers 0.16 g/lb. These results suggest that cows that were in moderate and stable body condition emitted 15 - 20% less methane per unit of supplement intake compared to cows gaining condition, even though absolute daily methane production varied across months, ranging from approximately 135 g/day in February to 300 - 360 g/day in May. This indicates that it is energetically expensive to improve the body condition of beef cows in spring months when the quality of standing forage is poor, and supplemental feed is required.

Implications

Results from this study suggest that managing cows for moderate body weight and stable body condition can reduce methane emissions. Heavier cows emitted more methane overall, and although cows in better condition tended to produce more methane, this effect was less pronounced in larger animals. Notably, cows that maintained their condition throughout the grazing period were more efficient, producing less methane per pound of supplement intake than those that gained or lost condition. These findings indicate that prioritizing moderate-sized cows that maintain condition through consistent management may support both production goals and environmental sustainability.

References

EPA. 2021. Inventory of U.S. greenhouse gas emissions and sinks. EPA 430-R-21-005. Environmental Protection Agency. Washington, D.C. *https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2019*

Hristov, A.N., J. Oh, J.L. Firkins, J. Dijkstra, E. Kebreab, G. Waghorn, H.P.S. Makkar, A.T. Adesogan, W. Yang, C. Lee, P.J. Gerber, B. Henderson, and J.M. Tricarico. 2013. Mitigation of methane and nitrous oxide emissions from animal operations: I. A review of enteric methane mitigation options. Journal of Animal Science 91:5045–5069. *doi:10.2527/jas.2013-6583*

Thompson, L.R., and J.E. Rowntree. 2020. Invited review: Methane sources, quantification, and mitigation in grazing systems. Applied Animal Science 36(4):556–573. *doi:10.15232/aas.2019-01951*

Velazco, J.I., D.G. Mayer, S. Zimmerman, and R.S. Hegarty. 2016. Use of short-term breath measures to estimate daily methane production by cattle. Animal 10(1):25–33. *doi: 10.1017/S1751731115001603*

Table 1. Supplement Cube

Ingredient	Dry matter, %
Soybean meal	45.5
Distillers grains	15.0
Protein supplement	8.9
Salt	6.7
Wheat middling	6.5
Molasses	5.0
Vitamins and minerals	12.5
Nutrient composition	
Dry matter, % as fed	91.2
Crude protein	30.0
Acid detergent fiber	6.5
Total digestible nutrients	55.5

Table 2. Impact of body condition score changes over the spring grazing period on enteric methane emissions

	Body condition score change group[1]				
Item	LOSS	MAIN	GAIN	SEM[2]	*P*-value
Methane g/day	191.0[a]	196.1[a]	276.9[b]	13.5	0.03
Methane g/day/lb of supplement dry matter intake	198.0	185.0	219.0	10.0	0.24

[ab] Values within a row with different superscripts differ ($P < 0.05$).

[1] LOSS = lost body condition score; MAIN = maintained body condition score; GAIN = gained body condition score.

[2] Standard error of the mean.

Field Validation of a Mob Composite Sampling Protocol to Estimate Herd Parasitism in Cattle

A. Gibbons, G.I. Crawford,[1] J. Slightom,[1] and H.E. Larson

Abstract

Field detection of parasite loads and their potential resistance to anthelmintic drugs often involves fecal egg count tests. The project's objective was to evaluate the industry standard fecal sampling protocol of individual samples (IDV) against a mob composite sampling approach (MOB) that would reduce the number of samples needed to identify nematode fecal egg count rates in beef cattle. Fecal samples (n = 1,060) were collected from cattle (both calf-fed and yearling) upon arrival in commercial feedlots (n = 12) and sale barns (n = 1). Sample sets were collected by pen (n = 53), with pen sizes varying from 64 to 225 animals depending on the commercial operation. Samples were collected from 20 different individual fresh fecal pats deposited on the floor of each pen (IDV). The MOB samples (n = 106) were further processed to yield two composite samples, each representing 10 of the original pen-collected samples. The IDV (n = 20 per pen) and MOB samples (n = 2 per pen) were analyzed by microscope to determine eggs/3 g (ep3g) count value. IDV and MOB samples were averaged by pen and then compared using Lin's concordance correlation. Analysis revealed a 91.7% agreement in mean fecal egg counts (ep3g) between the MOB and IDV methods, with a 95% confidence interval ranging from 86.4% to 95.0%. Results suggest that the average of two 10-sample MOB samples offers an acceptable method for assessing parasite loads in commercial feedlot operations. This mob sampling approach has the potential to enhance the number of parasite load evaluations conducted in newly received cattle by requiring fewer samples, thereby decreasing the time and diagnostic costs. This will allow producers the chance to evaluate their current deworming protocol in their operation efficiently, at a reduced cost.

Introduction

Cattle placed in feedlots frequently carry a high internal parasite load, which can lead to poor growth, suppressed immune function, and significant economic loss. Fecal egg count reduction tests (FECRT) are the preferred field assay for detecting the presence of herd-level gastrointestinal nematodes in ruminants (Coles et al., 1992; Coles et al., 2006) and the effectiveness of anthelmintic drugs used to treat them. The diagnostic practice is conducted by examining fecal samples under a microscope, which allows for the identification of nematodes, roundworms, mites, and protozoa based on egg size and shape. Fecal egg count tests involve sampling fecal pats from about 15-20 individual animals to represent a larger cattle herd (Coles et al., 1992). When testing for drug efficacy, FECRT require sample collections before anthelmintic treatment to provide a baseline infection level of the herd prior to drug application. Sample collection is repeated 10-14 days after anthelmintic drug application for evidence of drug effectiveness in reducing fecal egg counts.

[1] Merck Animal Health, Rahway, NJ

Industry insights estimate that less than 1% of cattle on feed are surveyed for nematodes. Full FECRT were not reported in this trial as all cattle had 100% drug efficacy after 10-14 days. Instead, the results presented represent samples collected prior to anthelmintic drug application. The trial was performed with the goal of evaluating the efficacy of a mob composite sampling approach against existing industry fecal sampling protocols for estimation of herd fecal egg counts. The goal of the trial was to develop a methodology that would simplify sampling requirements, increasing the number of cattle sampled for identification of nematode fecal egg counts.

Experimental Procedures

Seven individuals collected fecal pat samples (n = 1,060) from selected individual cattle from known regions with a high prevalence of internal parasites, which were placed at feedyard (n = 12) or sale barn (n = 1) locations. Samples were collected from 53 pens ranging from 64 to 225 head per pen of either calf-fed or yearling cattle. After collection, samples were brought to one of the two locations for analysis: 1) Merck Animal Health Diagnostic Laboratory, Lawrence, KS, or 2) Kansas State University, Olathe, KS.

When collecting individual fecal pat samples, 0.5 fluid oz of fecal material was collected from three different locations on a fecal pat and then combined. The 1.5 fluid oz of combined sample represents one fecal pat within one pen. The process was repeated 20 times per pen, resulting in 20 individual samples per pen. Industry standard sample (IDV) processing began with the 20 fecal pat samples collected per pen. After thorough mixing, 3 g from each fecal pat sample were separated into a smooth-sided cup and prepared for microscopy using the modified Wisconsin procedure (Bliss and Kvasnicka, 1997). The process was repeated for each sample collected in each pen.

The MOB sample processing began by splitting the 20 fecal pat samples collected per pen into two groups of 10. To create a composite of the two 10-sample groups, 3 g from each sample were separated into a smooth-sided cup, resulting in two 30-g composite samples, which were prepared for microscopy using the same procedure as described for IDV samples. Individual eggs were identified by size and shape in each sample using microscopic techniques. Total nematode presence in the fecal material was recorded as the sum of eggs identified (ep3g). The IDV and MOB samples were averaged by pen for each sampling method.

The correlation between pen average fecal egg count values for the MOB method and pen average fecal egg count values for IDV method was analyzed with Lin's Concordance Correlation Coefficient (CCC) using the epiR package in R. To assess the limits of agreement between MOB and IDV, a Bland-Altman plot was used. Before Bland-Altman test analysis, a log transformation was applied to the raw data due to the positive nature of fecal egg counts.

Results and Discussion

The infection rates of the samples evaluated in this study ranged from three to 390 eggs/3 g of fecal material (ep3g) based on IDV techniques, and two to 444 ep3g for MOB techniques. Lin's CCC correlation analysis determined 91.7% agreement between the IDV method and the MOB method, with a 95% confidence interval ranging from 86.4% to 95%. This correlation indicates good agreement between the field detection methods, allowing for a high degree of confidence in herd fecal egg count identification using this MOB sampling technique compared to the IDV method. The Bland-Altman analysis determined that MOB method counts reported 6 eggs/3 g less than IDV count values. This difference is estimated to minimally impact the effectiveness of fecal egg count tests, which are typically used to make anthelmintic treatment decisions based on the presence of parasites or not. The IDV and MOB methods have flaws and variability, so some differences between methods were expected when analyzing the results.

Decreasing sample analysis from 20 samples to two samples has the potential to significantly decrease diagnostic costs, which could be an encouragement to increase samples collected for nematode infection estimation in U.S. cattle herds. Increasing the number of herds sampled for nematodes would create an opportunity to increase the overall understanding of drug efficacy and support the responsible use of anthelmintic drugs for treating nematode infections in U.S. beef cattle populations.

Implications

Results indicate that a mob sampling method using two composite samples, each representing 10 fecal pats, can evaluate parasite loads with 91.7% confidence in received cattle, thereby decreasing processing time and analysis costs of herd parasitism diagnostics.

Acknowledgments

This research was funded by Merck Animal Health. The authors would like to extend a thank you to those who assisted in sample and data collection.

References

Bliss, D.H. and W.G. Kvasnicks. 1997. The fecal examination: a missing link in food animal practice. Compendium on Continuing Education for the Practicing Veterinarian 19(4): S104–S109.

Coles, G.C., C. Bauer, F.H. Borgsteede, S. Geerts, T.R. Klei, M.A. Taylor, and P.J. Waller. 1992. World Association for the Advancement of Veterinary Parasitology (W.A.A.V.P.) methods for the detection of anthelmintic resistance in nematodes of veterinary importance. Veterinary Parasitology 44(1-2):35–44. *https://doi.org/10.1016/0304-4017(92)90141-u*

Coles, G.C., F. Jackson, W.E. Pomroy, R.K. Prichard, G. von Samson-Himmelstjerna, A. Silvestre, M.A. Taylor, and J. Vercruysse. 2006. The detection of anthelmintic resistance in nematodes of veterinary importance. Veterinary Parasitology 136(3-4):167-185. *doi:10.1016/j.vetpar.2005.11.019*

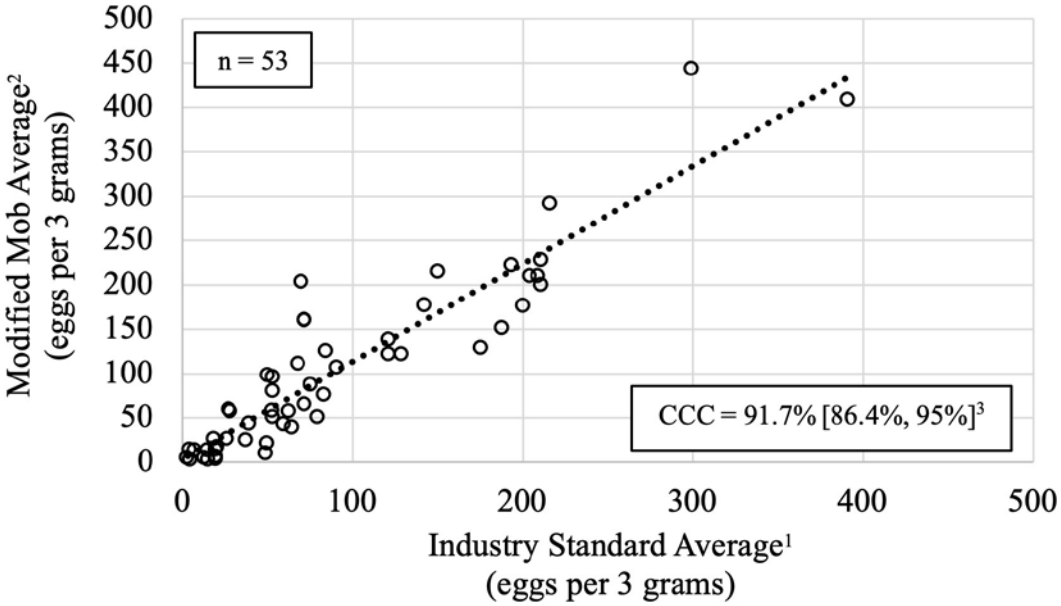

Figure 1. Correlation between Industry Standard Average and Modified Mob Average
[1]Industry standard (IDV) = average of 20 fecal pat samples collected per pen.
[2]Modified mob (MOB) = average of 2 composite samples each comprised of 10 of the original pen samples.
[3]Lin's concordance correlation coefficient (CCC) analysis for agreement between IDV and MOB methods with a 95% confidence interval.

Genetic Parameter Estimation for Breeding Soundness Examination Traits in Angus Bulls

D.M. Ellinghuysen, A.S. Tarochione,[1] A.R. Hartman, M.W. Semler,[2] D.M. Grieger, R.L. Weaber, J.M. Bormann, and M.M. Rolf

Abstract

Scrotal circumference and semen quality traits such as motility, motility score, primary abnormalities, secondary abnormalities, and normal sperm are widely used as phenotypic indicators of bull fertility during a breeding soundness examination (BSE); however, the genetic relationships of these traits are not fully understood. The objectives of this study were to estimate heritabilities, repeatabilities, phenotypic correlations, and genetic correlations between scrotal circumference and semen quality traits to better understand their potential application in a genetic evaluation for improved bull fertility. Eleven purebred Angus operations provided 5,877 BSE records from 4,996 Angus bulls for use in this study. Heritability estimates ranged from 0.05 to 0.36. Repeatability estimates were moderately to highly repeatable, ranging from 0.22 to 0.70. Estimates for phenotypic correlations ranged from no correlation (0.0) to highly correlated (0.94). Low to moderate genetic correlations were estimated between scrotal circumference and semen quality traits, while stronger correlations were estimated between percentage of primary abnormalities and the motility traits. Many genetic correlations had high standard errors, making them not significantly different from zero, and several relationships between semen quality traits were not estimable. These results indicate that it is feasible to improve bull fertility with genetic selection; however, further research is needed to determine the best methodology for developing a genetic evaluation.

Introduction

The breeding soundness examination (BSE) is the most common method for assessing bull fertility. There are three key components of a BSE: a physical examination, reproductive tract examination, and semen quality evaluation (Hopper, 2014). However, BSEs are often only performed before the breeding season, before the sale of the animal, or when a bull's fertility is in question. Additionally, a BSE only measures a bull's fertility on the examination day and may not be representative of his average fertility level throughout the breeding season (Koziol and Armstrong, 2018). The subjective nature of semen quality assessment of the BSE can also introduce biases due to differences in equipment, training, and attention to detail of the practicing veterinarian or technician (Hopper, 2014). There are technologies available that can provide more objective measurements of sperm quality, but they are expensive to purchase and often are only owned by artificial insemination semen collection facilities (Tanga et al., 2021). Nevertheless, BSE data can be made readily available by seedstock producers for a large number of bulls, which would be beneficial for a large-scale genetic evaluation. Several studies have reported low to moderate genetic correlations for scrotal circumference and semen quality traits using BSE data; however, those analyses did not

[1] Iowa State University, Ames, IA
[2] West Texas A&M, Canyon, TX

include multiple BSE records on a single bull (Smith et al., 1989; Christmas et al., 2001; Garmyn et al., 2011). Therefore, our objective was to estimate heritability and repeatability for scrotal circumference and semen quality traits using BSE data in a repeated records model and examine the relationships between traits.

Experimental Procedures

Eleven purebred Angus breeders provided 5,877 BSE records on 4,996 bulls. While each bull had one BSE, 651 bulls had at least one additional BSE, with a maximum of five exams. Most of the additional exams were for bulls that had failed their initial BSE, but some bulls had additional records from a subsequent breeding season. The data included measurements of scrotal circumference, percentage of progressive motility, gross motility score, percentage of primary abnormalities, percentage of secondary abnormalities, percentage of normal spermatozoa, and percentage of abnormal spermatozoa. Most operations did not report every measurement listed, but rather a combination of the traits. Different veterinarians or technicians conducted the BSEs; however, only a single veterinarian or technician performed all the exams for each operation on a particular day.

Data were filtered to ensure that all measurements recorded as percentages were treated as missing if they were not between 0 and 100. Scrotal circumference measurements needed to be larger than zero, or they were treated as missing. Traits that were not reported by the producer but could be calculated from the existing data were added to the dataset. For example, if normal spermatozoa were not directly reported, it was calculated by subtracting the percentage of primary abnormalities, the percentage of secondary abnormalities, or the percentage of abnormal spermatozoa from 100. Additionally, for breeders who reported motility, but not motility score, motility score was generated based on the guidelines provided by the Society for Theriogenology, with the following classifications (Hopper, 2014): greater than or equal to 70% motility was considered "very good," 50-69% motility was "good," 30-49% motility was "fair," and less than 30% was classified as "poor." The generated motility score was added to the producer-provided motility score for analysis.

All phenotypic correlations between fertility traits were estimated using the CORR procedure of SAS. Genetic parameters were estimated using single-step genomic best linear unbiased prediction methodologies with the BLUPF90+ suite of programs (Misztal et al., 2014). This is the same statistical software used by the American Angus Association for their genetic evaluations. Model selection for the bull fertility traits was performed in the BLUPF90+ suite using a forward selection procedure, and model fit was evaluated using the likelihood ratio test. The final models included variables of contemporary group, age, genotypes, and pedigree information. For this study, bulls were put into contemporary groups based on the operation they came from and the date the BSE was performed to account for multiple operations providing multiple years of data. The American Angus Association provided a date of birth, genotypic information, and a three-generation pedigree for all the bulls. Age was only included as a variable in the scrotal circumference and percentage of secondary abnormalities prediction models. Animal was a random variable in all models.

Results and Discussion

The heritability estimates with their standard errors, as well as repeatability estimates from multivariate genetic analyses, are presented in Table 1. Heritability describes the proportion of phenotypic variation that can be attributed to genetic differences, showing how strongly related the genetic breeding values are to the observed phenotypic traits. Scrotal circumference was moderately heritable, and semen quality traits such as motility and morphology were lowly heritable. This result was expected, because scrotal circumference is more of a growth trait and less influenced by the environment, while semen quality traits are strongly affected by many outside factors, including bull age, health, nutrition, social interactions, and temperature. Although semen quality traits had low heritability, the estimates were still greater than zero, suggesting potential for genetic improvement in fertility.

Repeatability measures the consistency of repeated records for the same trait. Repeatability was moderate for motility, motility score, percentage of secondary abnormalities, and normal spermatozoa. Scrotal circumference and percentage of primary abnormalities were highly repeatable. These results suggest that individual bulls tend to produce consistent records for these reproductive traits over time.

Table 2 summarizes the genetic and phenotypic correlations between scrotal circumference and semen quality traits measured during the BSE. Genetic correlations measure the strength of the relationship between breeding values for two traits. A favorable genetic correlation was observed between scrotal circumference and the presence of normal spermatozoa. This is beneficial for producers because scrotal circumference is easily measured, and it is easy to select for larger scrotal circumference, which can lead to more normal spermatozoa being produced. In contrast, genetic correlations between scrotal circumference and the primary and secondary abnormality traits were not significantly different from zero, likely due to limited abnormality records. Weak and unfavorable correlations were also detected between scrotal circumference and motility traits. This finding was unexpected because if scrotal circumference can lead to more normal sperm cells, then those sperm should be able to move better with better motility. However, that was not the relationship observed between motility and scrotal circumference. These results suggest that additional research is needed to determine the optimal scrotal circumference range for maximizing semen quality. Favorable correlations were identified between the percentage of primary abnormalities and motility traits, consistent with the expectation that sperm with normal morphology are more likely to exhibit higher motility. Not every genetic correlation could be estimated in this study; however, all phenotypic correlations between the traits were obtained. Many of the phenotypic correlations were consistent with the genetic relationships observed, including inverse associations between motility traits and the percentage of primary abnormalities. In other words, an increase in motility of sperm was associated with a decrease in abnormal sperm morphology. This was similar to an increase in normal spermatozoa being related to a decrease in sperm abnormalities.

Implications

These results indicate that it is feasible to improve bull fertility through genetic selection; however, further research is needed to determine the best methods for developing a commercially available genetic evaluation.

Acknowledgments

The authors would like to thank the Angus producers who provided their breeding soundness examination data for this project.

References

Christmas, R.A., D.W. Moser, M.F. Spire, J.M. Sargent, and S.K. Tucker. 2001. Genetic relationships among breeding soundness traits in yearling bulls. Kansas Agricultural Experiment Station Research Report of Progress 873, pages 1-3. *doi:10.4148/2378–5977.1712*

Garmyn, A.J., D.W. Moser, R.A. Christmas, and J. Minick Bormann. 2011. Estimation of genetic parameters and effects of cytoplasmic line on scrotal circumference and semen quality traits in Angus bulls. Journal of Animal Science 89(3):693–698. *doi:10.2527/jas.2010-3534*

Hopper, R.M., ed. 2014. Bovine reproduction. John Wiley & Sons, Inc, Hoboken, NJ. Available from: *http://doi.wiley.com/10.1002/9781118833971*

Koziol, J.H. and C.L. Armstrong. 2018. Manual for breeding soundness examination of bulls. Second ed. Society for Theriogenology.

Misztal, I., S. Tsuruta, D. Lourenco, Y. Masuda, I. Aguilar, A. Lagarra, and Z. Vitezica. 2014. Manual for BLUPF90 family of programs. University of GA, Athens. Available from: *https://nce.ads.uga.edu/html/projects/programs/docs/blupf90_all8.pdf*

Smith, B.A., J.S. Brinks, and G.V. Richardson. 1989. Estimation of genetic parameters among breeding soundness examination components and growth traits in yearling bulls. Journal of Animal Science 67(11):2892–2896. *doi:10.2527/jas1989.67112892x*

Tanga, B.M., A.Y. Qamar, S. Raza, S. Bang, X. Fang, K. Yoon, and J. Cho. 2021. Semen evaluation: Methodological advancements in sperm quality-specific fertility assessment – A review. Animal Bioscience 34(8):1253–1270. *doi:10.5713/ab.21.0072*

Table 1. Average heritability estimates ± standard errors and repeatability estimates calculated from bivariate single-step genomic best linear unbiased predictions

Trait	Heritability ± standard error	Repeatability
Scrotal circumference	0.36 ± 0.03	0.68
Percent motility	0.10 ± 0.03	0.31
Motility score	0.05 ± 0.02	0.30
Percent primary abnormalities	0.09 ± 0.03	0.70
Percent secondary abnormalities	0.09 ± 0.03	0.44
Percent normal sperm	0.06 ± 0.01	0.22

Table 2. Genetic correlations ± standard errors above the diagonal, and phenotypic correlations below the diagonal between Angus bull reproductive traits using a bivariate single-step genomic best linear unbiased prediction

	SC[1]	%MOT[2]	MOTSC[3]	%PRIM[4]	%SEC[5]	%NORM[6]
SC		-0.16 ± 0.13	-0.02 ± 0.14	0.00 ± 0.15	-0.03 ± 0.16	0.21± 0.12
%MOT	-0.21*		---	-0.73 ± 0.33	dnc	dnc
MOTSC	0.00	0.94*		-0.98 ± 0.50	dnc	dnc
%PRIM	0.00	-0.45*	-0.47*		0.25 ± 0.29	dnc
%SEC	-0.03	-0.40*	-0.40*	0.01		dnc
%NORM	0.18*	0.56*	0.72*	-0.85*	-0.73*	

* Correlation is significantly different from zero at $P < 0.0001$; -- Correlation was not estimated; dnc: Model did not converge.
[1] SC: Scrotal circumference.
[2] %MOT: Percentage of progressive motility.
[3] MOTSC: Motility score.
[4] %PRIM: Percentage of primary abnormalities.
[5] %SEC: Percentage of secondary abnormalities.
[6] %NORM: Percentage of normal spermatozoa.

A Preliminary Study: The Effects of Vaginal Flushing in Cattle on Mitigating Vaginitis Induced by a Controlled Internal Drug Release (CIDR)

S.B. Noel, D.M. Ellinghuysen, A.G. Schwartz, L.B. Rangel, S.H. Flax, R. Adams, T. Miller, and N.W. Dias

Abstract

The use of controlled internal drug release (CIDR) devices in beef heifer timed-artificial insemination (TAI) protocols has been shown to induce various degrees of vaginitis, reducing fertility when using TAI. The objective of this experiment was to characterize CIDR-induced vaginitis in beef heifers by quantifying polymorphonuclear leukocyte (PMN) cells in the vagina before CIDR insertion, after CIDR removal, and three days post-CIDR removal. Furthermore, our objective was to evaluate the effects of flushing the vaginas of beef heifers with saline solution immediately after CIDR withdrawal, followed by immediate removal of flush content, on reducing the proportion of PMN in the vaginas by the day of TAI. Beef heifers (n = 19) from the Kansas State University Heifer Development Unit were enrolled in the study. The heifers were stratified by weight and randomly assigned to one of three groups: CIDR and Flush (n = 7), CIDR (n = 7), and negative control (n = 5). The presence of vaginitis was assessed before inserting the CIDRs using a 1-4 vaginitis scoring system that evaluated color and irritation of the vaginal mucosa. On day 0, heifers included in CIDR treatments received an intravaginal CIDR device. On day 7, CIDRs were removed and assigned a CIDR score. A sterile saline flush solution was used in the treatment group, CIDR and Flush, to lavage the vagina at CIDR removal in conjunction with using a Metricheck device to manually remove the flush from the vagina. Additionally, vaginal cytology samples were collected from all heifers on days 0, 7, and 10 using a sterile cotton swab. A difference ($P < 0.05$) in the average PMN was observed between collection days. However, no significant effects were observed for treatment ($P = 0.92$) or treatment × day interactions ($P = 0.75$).

Introduction

The vaginal microbiome of synchronized heifers is dynamic and changes in response to environmental inputs, such as the use of intravaginal controlled internal drug release (CIDR) devices (Gonzalez Moreno et al., 2016). The use of CIDRs in synchronized protocols in the beef cattle industry has been shown to induce vaginitis by recruiting an inflammatory response that increases the abundance of polymorphonuclear leukocyte (PMN) cells. The inflammatory response originates in the vagina; however, given the open state of the cervix, as is commonly observed during estrus, it is hypothesized that PMN may migrate into the uterus and can adversely affect fertility by triggering an early inflammatory response to spermatozoa used in artificial insemination. Previous research indicated an increase in PMN at CIDR removal, characterizing a CIDR-induced vaginitis phenotype. Furthermore, lower conception rates to timed artificial insemination (TAI) were observed in beef females as the intensity of vaginitis increased (Dias et al., 2019). A greater incidence of CIDR-induced vaginitis presents management

implications for fertility at TAI. The objective of this experiment was to characterize CIDR-induced vaginitis in beef heifers by quantifying inflammatory cells in the vagina on day 0, day 7, and day 10, and to evaluate if flushing the vagina with a saline solution after CIDR removal would reduce PMN cells on day 10 compared to unflushed heifers that received a CIDR. We hypothesized that the use of a CIDR would result in an increased proportion of PMN at CIDR withdrawal when compared to control heifers not receiving a CIDR. Furthermore, we hypothesized that heifers that receive a vaginal flush with sterile saline solution immediately after withdrawal would have a reduced proportion of PMN on day 10 when compared to heifers that received a CIDR but received no vaginal flush.

Experimental Procedures

Beef heifers (n = 19) from the Kansas State University Heifer Development Unit were enrolled in this study. Heifers were stratified by weight to categorize maturity and then randomly assigned to CIDR (n = 7), CIDR with Flush (n = 7), or a negative control (n = 5). This study focused on the timing of events of a 7-day CO-SYNCH+CIDR protocol, without the use of pharmacological injections. The progesterone from CIDR devices was the only exogenous form of hormone applied to treatment heifers.

All heifers had their vaginas inspected for signs of vaginitis on days 0 and 10 and were assigned a score from 1-4, where 1 = clean, pink mucosa with no mucus or secretion, 2 = clean, pink mucosa with clear mucus or secretion, 3 = reddened mucosa with small amounts of yellow mucus or purulent secretion, and 4 = reddened mucosa with large amounts of yellow mucus or purulent secretions, and blood. Control heifers also received a vaginitis score on day 7. At CIDR removal on day 7, each device was assigned a 1–4 CIDR score to assess CIDR-induced vaginitis, where 1 = clean, no mucus; 2 = clear with mucus; 3 = purulent secretion; 4 = purulent and bloody secretion combination. These scoring systems provided chute-side evaluation of vaginitis.

Vaginal swabs were collected on days 0, 7, and 10 to generate vaginal cytology slides to evaluate the abundance of PMN in the vaginal microbiome during the estrous synchronization protocol. Samples were collected by removing fecal material with a paper towel, spreading the vulvar labia apart, and inserting and rotating a sterile cotton swab against the vaginal mucosa for material collection. Then, the sample was transferred onto a microscopy slide by rotating the tip of the cotton swab onto the microscopy slide. Each slide was individually stained using modified Giemsa and then dried for analysis. Once the slides dried, vertical lines were drawn to separate the microscopy slide into three even, equal-sized chambers. Slides were analyzed for the proportion of epithelial cells and PMN by counting 100 cells per slide chamber (i.e., 37 PMN, 63 epithelial cells = 37% PMN). The final proportion of PMN per slide was calculated as the average percent PMN of the three slide chambers.

On day 7, heifers in CIDR with Flush were subjected to vaginal flush. Prior to the vaginal flush, the vulva was cleaned using paper towels, the vulvar labia were spread apart, and a bottle containing sterile saline was inserted into the vestibule. Saline was infused by squeezing the bottle until the entire volume was infused into the vagina. Following vaginal flush, contents were manually removed using a Metricheck device.

All statistical analyses were performed in SAS version 9.4. The GLIMMIX procedure of SAS, with the heifer as the experimental unit, was used to assess vaginitis scores on day 10. The MIXED procedure was used to analyze the average PMN cells over the length of the trial. The level of significance was set at $P < 0.05$ with tendency set at $0.05 \leq P \leq 0.10$.

Results and Discussion

The average for vaginitis scores, CIDR scores, and vaginal PMN abundance per treatment are summarized in Table 1. Additionally, the average proportion of vaginal PMN by day is summarized in Figure 1. There was an effect of day ($P < 0.01$) on the proportion of vaginal PMN, with samples collected on days 7 and 10 having greater proportions of PMN when compared to samples collected on day 0. However, there were no effects of treatment ($P > 0.10$), or an interaction between treatment and day ($P > 0.10$) on the proportion of vaginal PMN. Overall, the proportion of vaginal PMN increased with the progression of the experiment, with the greatest proportion of PMN found on day 10.

Heifers that received a CIDR had purulent or bloody secretions in their CIDR (CIDR scores 3.1 and 3.3 for CIDR and Flush groups, respectively), as it is characteristic of a CIDR-induced vaginitis. Accordingly, these heifers showed an increased proportion of vaginal PMN on day 7 when compared to day 0, indicating that the use of a CIDR indeed induced the vaginitis. We hypothesized that flushing the vagina of heifers immediately after CIDR removal would result in a decreased vaginitis score on day 10 when compared to heifers that received a CIDR but received no flush. Both groups of heifers had reduced vaginitis scores on day 10 when compared to CIDR scores on day 7, indicating that flushing the vagina had no additional effect on decreasing the vaginitis score by day 10. Intriguingly, the proportion of vaginal PMN increased on day 10 when compared to day 7, which does not agree with our observations of decreased vaginitis scores on day 10.

The most confusing result from our experiment is that control heifers that received no CIDR also expressed an increased proportion of vaginal PMN as the experiment progressed. This is intriguing because these heifers did not receive the source of inflammation and had no signs of vaginitis throughout the experiment. Such discrepancies in PMN results for control heifers could partially be explained by differences in vaginal PMN according to the stage of the reproductive cycle. Furthermore, the visual identification of cells under the microscope can be a subjective measurement and could have partially influenced these results. Our research group is actively seeking more objective analyses of the abundance of vaginal PMN to better characterize this phenotype. Nevertheless, we conclude that the use of a CIDR induces vaginitis, as characterized by purulent secretions present in the CIDR at withdrawal. Additionally, we conclude that signs of vaginitis are naturally decreased following CIDR withdrawal, with no additional effects of flushing the vaginas at CIDR withdrawal on decreasing signs of vaginitis by day 10.

Implications

This study highlights opportunities for future research and practical applications in beef cattle reproductive management, such as reducing CIDR-induced vaginal inflammation and identifying when PMN levels peak can optimize the interventions and improve outcomes.

Acknowledgments

Appreciation is expressed to the Dr. Mark and Kim Young Undergraduate Research Fund in Animal Science for supporting this research project. Additional appreciation is expressed to the Kansas State University Heifer Development Unit for animal care.

References

Dias N.W., A. Sales, C. Timlin, S. Pancini, J. Currin, and V.R.G. Mercadante. 2019. PSII-21 Vaginitis incidence and effects on fertility of beef females enrolled on estrus synchronization protocols using a controlled internal drug release (CIDR) device. Journal of Animal Science 97(Supplement 3): 242. *doi:10.1093/jas/skz258.491*

Gonzalez Moreno, C., C. Fontana, P.S. Cocconcelli, M.L. Callegari, and M.C. Otero. 2016. Vaginal microbial communities from synchronized heifers and cows with reproductive disorders. Journal of Applied Microbiology 121(5):1232–1241. *https://doi.org/10.1111/jam.13239*

Table 1. Average vaginitis score, CIDR score, and percentage of polymorphic nuclear cells (PMN)

	Average vaginitis score[1]			Average CIDR score[2]			Average PMN cells (%)		
Group	**Control**	**CIDR**	**Flush**	**Control**	**CIDR**	**Flush**	**Control**	**CIDR**	**Flush**
Day 0	1	1.3	1.1				7.0	6.2	5.2
Day 7	1				3.1	3.3	24.2	20.4	23.6
Day 10	1	1.4	1.6				27.6	29.7	28.5
P-value							TRT[3] = 0.9183 Day <0.0001 TRT × Day = 0.7476		

[1] There were no differences between groups for vaginitis scores.
[2] There were no differences between groups for CIDR scores.
[3] TRT = Treatment.

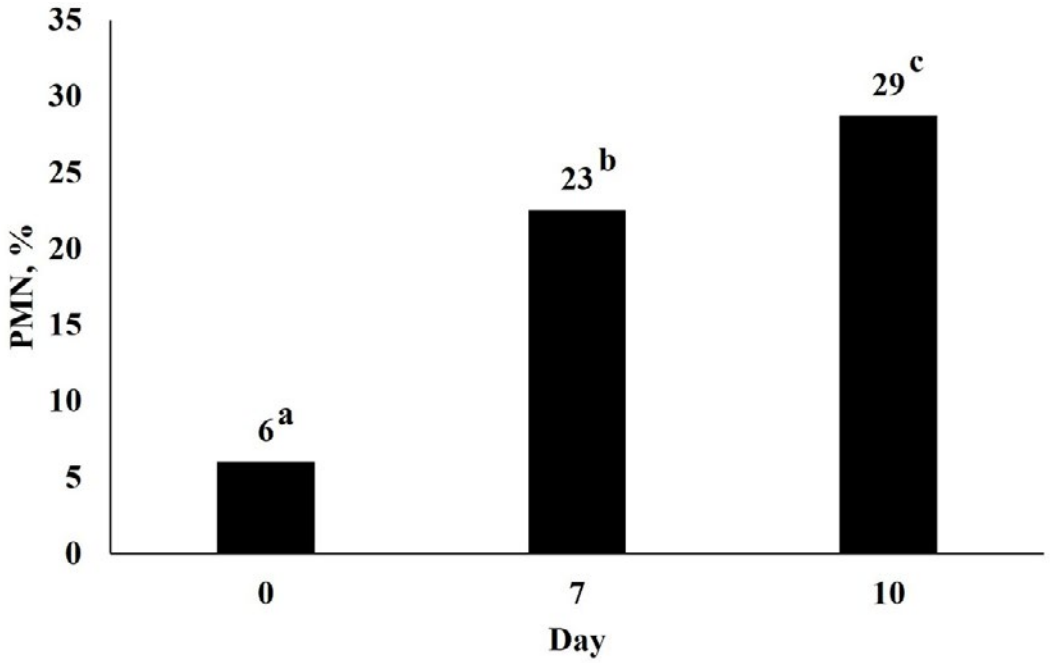

Figure 1. The overall average percentage of polymorphonuclear (PMN) leukocyte cells on each day of the trial. Means with uncommon superscripts differ ($P < 0.05$).

Evaluating the Relationship Between Anogenital Distance, Reproductive Tract Score, and Fertility to Timed-artificial Insemination in Commercial *Bos taurus* Beef Heifers

A.G. Schwartz, D.M. Ellinghuysen, S.H. Flax, S.M. Zoca,[1] S. Johnson, and N.W. Dias

Abstract

Previous studies have found an inverse correlation between anogenital distance (AGD) and fertility in beef and dairy cattle, with greater fertility observed in females with shorter AGD. It has been previously demonstrated that heifers with mature reproductive tracts, as assessed by reproductive tract scores (RTS), have improved fertility to artificial insemination programs. The objective of this study was to explore the relationship between AGD, RTS, and conception rates to timed artificial insemination (TAI) in *Bos taurus* commercial yearling beef heifers (n = 884). All heifers were assigned an RTS on a scale from one to five at least two days before the beginning of the TAI protocol. Reproductive tract scores were determined based on uterine horn diameter and uterine tone: 1 = immature, <20 mm diameter and no tone; 2 = 20 - 25 mm diameter and no tone; 3 = 20 - 25 mm diameter with slight tone; 4 = 30 mm diameter with good tone; and 5 = >30 mm diameter with good tone. Heifers from eight different locations in Kansas and Tennessee were used during the 2023 and 2024 breeding seasons. All heifers were enrolled in a controlled internal drug release (CIDR)-based estrus synchronization protocol and received TAI. Pregnancy status was determined by transrectal ultrasonography approximately 45 days post-TAI. The AGD was defined as the distance from the middle of the anus to the base of the clitoris, and was assessed using digital calipers at CIDR insertion, withdrawal, TAI, or pregnancy diagnosis based on location. There was an effect of RTS ($P < 0.05$), but no effect of AGD ($P > 0.05$) on conception rates to TAI, and there was no difference in average AGD between heifers that were diagnosed as pregnant or open to TAI ($P = 0.15$; 83.09 mm, and 84.07 mm, respectively). We conclude that RTS is a more accurate assessment of beef heifer fertility to TAI than AGD.

Introduction

Research in Holstein cattle from Canada has found an inverse relationship between the anogenital distance (AGD) and the probability of pregnancy to timed-artificial insemination (TAI) protocols. While AGD has been studied in humans, rodents, and a few livestock species other than cattle, there is a lack of research in beef cattle. In other species, AGD has been found to be influenced by the concentration of androgens that the female fetus is exposed to during gestation. Research from Nebraska and Jordan has identified beef and dairy cattle with naturally high androgens and impaired folliculogenesis compared to their herd mates. Since little research has been conducted in beef cattle on AGD, our objective was to collect data on AGD and pregnancy outcomes in

[1] Department of Animal Science, University of Tennessee, Knoxville, Tennessee

beef heifers enrolled in a fixed-time artificial insemination protocol. Another objective was to compare the use of AGD and reproductive tract scores (RTS) on the predictability of heifer fertility to TAI. We hypothesized that beef heifers with shorter AGD would have improved fertility to TAI when compared to heifers with longer AGD. The use of AGD in beef heifers may be able to help producers identify sub-fertile heifers, non-invasively identify cattle with high androgen concentrations, and improve management decisions for replacement heifers.

Experimental Procedure

Commercial *Bos taurus* yearling heifers (n = 888) from eight locations throughout Kansas and Tennessee were enrolled in a controlled internal drug release-based TAI estrous synchronization protocol. At least two days before the start of the TAI protocol, heifers were evaluated for RTS through transrectal palpation. The RTS scores were given on a scale of one through five based on uterine horn diameter, tone of the reproductive tract, and ovarian structures. The scoring system for RTS was: 1 = immature, <20 mm diameter and no tone, no palpable ovarian structures; 2 = 20 - 25 mm diameter and no tone, 8 mm follicles on ovary; 3 = 20 - 25 mm diameter with slight tone, 8 - 10 mm follicles on ovary; 4 = 30 mm diameter with good tone, 10 mm follicles or possible corpus luteum on ovary; and 5 = >30 mm diameter with good tone, greater than 10 mm follicles or corpus luteum present on ovary. The AGD was measured with digital calipers and was defined as the distance between the middle of the anus to the base of the clitoris. Heifers were retrospectively assigned to a quartile based on AGD for each location: Q1 heifers had the shortest 25% AGD, Q2 had an AGD of 26 - 50%, Q3 had an AGD of 51 - 75%, and Q4 had the longest AGD of 76% - 100%. Body weight (BW) was collected depending on the location during at least one day of the synchronization protocol. Pregnancy to TAI was determined through transrectal ultrasound approximately 45 days after TAI. Models of pregnant and nonpregnant heifers were analyzed with the GLIMMIX procedure in the 9.4 version of SAS.

Results and Discussion

Pregnant versus open heifers least square means are found in Table 1. Table 2 shows the percentage of pregnant heifers by AGD quartile and RTS. There was a difference ($P < 0.05$) for RTS between open heifers (3.72) compared to pregnant heifers (3.87). Trained technicians' ability to accurately score the reproductive tract prior to the breeding season allows for the culling of immature heifers before the breeding season. The average AGD of open heifers was 84.07 mm, while it was 83.09 mm for pregnant heifers, which was not significant ($P > 0.05$). Figure 1 shows the trendline for AGD and the probability of pregnancy based on the AGD length. Weights from six of the locations are included. Open heifers had an average weight of 806 lb while the pregnant heifers had an average weight of 813 lb. Although there was a numeric difference of 7 lb, there was no statistical difference ($P > 0.05$). A combined model of RTS and AGD was used to determine the probability of pregnancy when both variables were considered. Heifers that had an AGD over the average (84 mm) had a decreased probability of 1.2% of being pregnant for each mm over the average. The RTS was associated with pregnancy odds. Compared to RTS 1, the odds of pregnancy were generally higher for heifers with greater RTS, with differences ($P < 0.05$) observed between RTS 2 and 5, and RTS 3 and 5. Heifers that had a shorter AGD and higher RTS have a greater probability of becoming pregnant in the first round of TAI. Our results indicate that the average RTS is more related to TAI pregnancy rates than average AGD. However,

when ranking females according to AGD within locations, the use of RTS and AGD ranking had a stronger prediction of pregnancy to TAI. We conclude that RTS is a better tool for identifying fertile heifers than AGD. However, AGD might be used as a second layer of selection to increase accuracy.

Implications

The RTS was a better predictor of pregnancy in virgin beef heifers than AGD. However, when both assessments were combined, there was greater prediction power for pregnancy to TAI.

Acknowledgments

We would like to thank all the producers for allowing us to use their herds for research and Dr. Zoca at the University of Tennessee for his collaboration on this project.

Table 1. Least square means of open and pregnant heifers

Variable	Open	Pregnant	*P*-value
RTS[1]	3.72[a] ± 0.24	3.87[b] ± 0.24	< 0.01
AGD,[2] mm	84.07 ± 1.93	83.09 ± 1.94	0.15
Weight, lb	806 ± 16	813 ± 16	0.37

[ab] Rows with uncommon superscripts differ ($P < 0.05$).

[1] Reproductive tract score: 1 = immature, <20 mm diameter and no tone, no palpable ovarian structures; 2 = 20 - 25 mm diameter and no tone, 8 mm follicles on ovary; 3 = 20 - 25 mm diameter with slight tone, 8 - 10 mm follicles on ovary; 4 = 30 mm diameter with good tone, 10 mm follicles or possible corpus luteum on ovary; and 5 = >30 mm diameter with good tone, greater than 10 mm follicles or corpus luteum present on ovary.

[2] Anogenital distance.

Table 2. Percent pregnant by reproductive tract score (RTS) and anogenital distance (AGD) quartile

	AGD Q1[1]		AGD Q2		AGD Q3		AGD Q4	
RTS[2]	Pregnancy, %	n[3]	Pregnancy, %	n	Pregnancy, %	n	Pregnancy, %	n
1	0.00	1	100.00	1	-	-	100.00	1
2	63.64	11	41.67	12	31.25	16	22.22	9
3	48.10	79	48.57	70	43.59	78	43.04	79
4	57.38	61	40.00	70	57.38	61	46.15	52
5	56.25	64	56.25	64	47.06	68	45.12	82

[1] Anogenital distance (AGD) quartile: Q1 heifers had the shortest 25% AGD, Q2 had an AGD of 26- 50%, Q3 had an AGD of 51 - 75%, and Q4 had the longest AGD of 76% - 100%.

[2] Reproductive tract score: 1 = immature, <20 mm diameter and no tone, no palpable ovarian structures; 2 = 20 - 25 mm diameter and no tone, 8 mm follicles on ovary; 3 = 20 - 25 mm diameter with slight tone, 8 - 10 mm follicles on ovary; 4 = 30 mm diameter with good tone, 10 mm follicles or possible corpus luteum on ovary; and 5 = >30 mm diameter with good tone, greater than 10 mm follicles or corpus luteum present on ovary.

[3] Number of heifers within RTS and AGD Quartile.

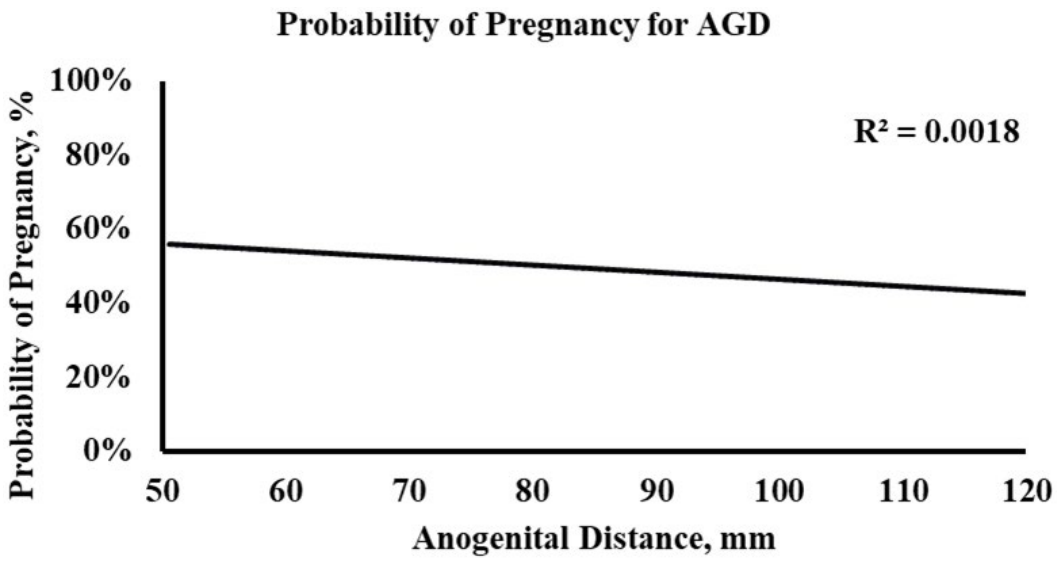

Figure 1. Predicted probability of pregnancy (%) as a function of anogenital distance (mm). The solid line represents the fitted regression model ($R^2 = 0.0018$).

Effects of an Alleyway Brush on the Behavior of Commercial Beef Heifers and Cows During a 7-day CO-Synch + CIDR Protocol and Pregnancy Outcomes

D.M. Ellinghuysen, A.G. Schwartz, C.A. Gruis, S.B. Noel, N. Steinkamp, V. Axman, A. Carlson, J. Boneau, S.H. Costa, E.A. Briggs, S.K. Johnson, and N.W. Dias

Abstract

Temperament is one factor that can influence the success of estrus synchronization (ES) protocols. This study explored whether exposure to a cattle brush device during ES handling events could improve temperament and pregnancy outcomes in beef cows and heifers. A total of 71 heifers and 162 cows from the Agricultural Research Center in Hays, KS, were stratified by reproductive or physiological status and randomly assigned to the treatment (TRT) or control (CTRL) groups. On days 0, 7, and 10 of the ES protocol, TRT animals encountered a spring-mounted brush in the alleyway before entering the chute. The brush was removed for CTRL animals. Chute score (CS) and exit velocity (EV) were recorded on days −10, 0, 7, and 10. Estrotect indicators were applied on day 7 and evaluated on day 10 to measure estrus response. Pregnancy was diagnosed via transrectal ultrasonography 33 days post-timed artificial insemination (TAI) for heifers and 68 days for cows. No treatment differences in CS were observed on days -10, 0, or 7 ($P > 0.10$). However, on the day of TAI, TRT heifers had lower CS ($P < 0.01$) and box scores ($P < 0.01$) than CTRL heifers, while TRT cows tended to have lower CS values ($P < 0.10$). Exit velocity did not differ between groups, but both cows and heifers showed a day effect ($P < 0.01$). Estrotect scores were unaffected by treatment ($P > 0.10$). Pregnancy rates were similar between the TRT and CTRL groups for heifers and cows ($P > 0.10$). However, estrus expression positively influenced pregnancy outcomes in heifers ($P < 0.01$) and cows ($P < 0.05$). Days postpartum also tended to affect cow pregnancy rates ($P < 0.10$). Additional research is needed to determine the effects of positive reinforcement with a brush on reproductive production measures.

Introduction

Beef producers in the United States have been slow to adopt advanced reproductive technologies, with only 11.6% of operations using artificial insemination and 7.3% implementing an estrus synchronization (ES) protocol (USDA, 2020). However, the use of an ES protocol can help increase the number of females calving at the beginning of the season. This results in greater days postpartum for cows in their subsequent breeding season, allowing more postpartum recovery days and a more uniform calf. Many factors affect the success of an ES protocol, including pubertal status, nutrition, genetics, environmental factors, and temperament of the cattle. Temperament refers to an animal's behavioral response to handling by humans (Fordyce et al., 1988). It has previously been reported that cattle with excitable temperaments can have lower pregnancy rates than their calmer contemporaries (Cooke et al., 2011; Dias et al., 2022). A recent study at Kansas State University found that acclimating commercial beef heifers to the working facility and human interaction prior to the handling events of an ES

protocol led to potential improvements in heifer temperament and increased pregnancy rates, compared to heifers that were not acclimated (Tastad, 2025). This suggests that interventions aimed at reducing stress and improving welfare during handling could mitigate negative effects on reproductive outcomes. Building on this idea, strategies that provide positive reinforcement during handling may offer an additional approach to improving reproductive success. Therefore, the objective of this study was to explore the effects of using a cattle brush device as positive reinforcement during the handling events of the ES protocol on temperament and pregnancy rates of beef cows and heifers to fixed-timed artificial insemination (TAI). The hypothesis is that beef females exposed to the cattle brush during the handling events of the ES would have improved temperament by completion of the estrus synchronization protocol and improved conception rates to TAI.

Experimental Procedures

Commercial beef heifers (n = 71) and cows (n = 162) from the Agricultural Research Center in Hays, KS, were enrolled in the experiment. On the day of enrollment (day -10), heifers were given a reproductive tract score (RTS) and chute score (CS). Reproductive tract scores were based on the five-point scoring system described by Anderson et al. (1991). Upon entering the chute, heifers were evaluated for their behavior and given a CS based on a five-point scale, where 1 = calm and motionless; 2 = restless movements; 3 = frequent movement and vocalization; 4 = constant movement, vocalization, shaking, and struggling; 5 = violent and continuous struggling (Cooke et al., 2011). The same scoring system was used for the artificial insemination breeding box score measurement on the day of TAI. Heifers were then stratified by RTS and CS. For the cow experiment, females were stratified by days postpartum, body condition score, age, and CS. All animals were assigned to either the treatment (TRT) or control (CTRL) group, represented by a different-colored ear tag placed in their left ear.

After being assigned to a group, animals were released from the chute, and their exit velocity (EV) was recorded using infrared timing beams. The timer started as the animal exited the chute and passed the first beam and stopped when the second beam was crossed. For heifers, beams were spaced 138 in. apart; for cows, 103 in. Spacing varied by facility, but EV was consistently calculated as distance (in.) divided by time (seconds). Although cows and heifers were housed at separate locations, animals within each location were co-mingled and grazed together.

All females were enrolled in a 7-day CO-Synch + controlled internal drug release (CIDR) TAI protocol (Lamb et al., 2006). On day 0, each animal received an intramuscular injection of Fractel (gonadorelin injection; Zoetis Animal Health, Parsippany, NJ) and had an EAZI-BREED CIDR (Zoetis Animal Health, Parsippany, NJ) inserted into their vagina. On day 7, females were given a 5 mL Lutalyse injection (prostaglandin F2 alpha; Zoetis Animal Health, Parsippany, NJ), the CIDR was removed, and an Estrotect breeding indicator (Rockway, Inc. Spring Valley, WI) was placed just in front of the female's tailhead. The TIA was performed 54 ± 2 hours later (day 10) for the heifers and 63 ± 3 hours for the cows. All females received a second injection of Factrel at TAI, and Estrotect patches were scored based on the percentage rubbed off before going under the alleyway brush. Pregnancy status was measured via transrectal ultrasonography approximately 33 days post-TAI for the heifers and 68 days after breeding for the cows.

On days 0, 7, and 10 of the experiment, cattle in the TRT group were exposed to a brush positioned in the alleyway of the chute. The brush was mounted on a spring, allowing flexible movement as animals walked beneath or interacted with it. This spring-loaded brush was attached to an adjustable steel arm clamped to the alleyway, enabling both height adjustments and easy removal when needed. For each session, the brush was set to approximate the shoulder height of heifers and cows in the TRT groups. During CTRL sessions, the brush was removed from the alleyway. Cattle were processed through the chute in groups of 10, alternating between the TRT and CTRL groups to prevent any one group from consistently being worked at the end of the day.

All data were analyzed using SAS software v. 9.4 (SAS Institute Inc., Cary, NC, USA). Two sample t-tests were used to analyze differences between the two treatment groups for individual traits on each day. Pregnancy rates to the ES protocol were analyzed with the GLIMMIX procedure, with the heifer as the experimental unit. Repeated measures of CS and EV were analyzed using the MIXED procedure. Statistical significance was declared at $P < 0.05$, and tendencies were considered when $0.05 \leq P \leq 0.10$.

Results and Discussion

The results of the heifer portion of the experiment are reported in Table 1, while the cow results are shown in Table 2. No differences in CS were observed between TRT and CTRL animals on days -10, 0, and 7 ($P > 0.10$). However, on the day of TAI, the TRT heifers exhibited lower CS ($P < 0.01$) and box score ($P < 0.01$) measurements compared to their CRTL counterparts. The TRT cows tended to have lower CS values ($P < 0.10$) than the cows in the CTRL on day 10. Chute scores decreased throughout the trial period for both the cows and heifers, aligning with previous studies (Dias et al., 2022; Tastad, 2025) and potentially indicating that the females may have acclimated to the working facilities. Nevertheless, the females in this study exhibited adequate temperament, with average CS ranging from 1.07 to 1.97. There may have been more significant improvements in behavior if females had displayed more excitable temperaments.

For EV, no differences were observed between treatments of cows or heifers. However, there was an effect of day ($P < 0.01$) for both. Heifers exhibited similar average EV on days -10, 0, and 7, but they were slower ($P < 0.01$) on day 10. For the cows, EV became faster during the first three days of the ES protocol, but they also showed slower EV on the day of TAI (day 10; $P < 0.01$). The slower EV on day 10 might be attributed to the animals exiting the breeding box instead of the regular chute.

There were no treatment differences ($P > 0.10$) for Estrotech score in the cows or heifers. The average pregnancy rate between groups was not affected by treatment for the cows ($P > 0.10$) or heifers ($P > 0.10$). But, whether the cows ($P < 0.05$) or heifers ($P < 0.01$) showed signs of estrus had a significant effect on pregnancy outcome. The number of days postpartum ($P > 0.10$) recovery that a cow had also tended to impact the average pregnancy rate. These results were not surprising, as previous research indicated that estrus expression is a strong predictor of conception rates in synchronized breeding programs, and adequate postpartum recovery is critical for successful rebreeding (Bucher, 2009).

Implications

Bovine temperament can be improved by sequential handling events, but additional research is needed to determine the effects of positive reinforcement with a brush in the chute alley on reproductive production measures.

Acknowledgments

The authors would like to extend their appreciation to the employees of the Agricultural Research Center in Hays, KS, for their care of the animals and for assisting in this research.

References

Anderson, K.J.D., D.G. LeFever, J.S. Brinks, and K.G. Odde. 1991. The use of reproductive tract scoring in beef heifers. Agri-Practice 12:19–26.

Bucher A., R. Kasimanickam, J.B. Hall, J.M. Dejarnette, W.D. Whittier, W. Kähn, and Z. Xu. 2009. Fixed-time AI pregnancy rate following insemination with frozen-thawed or fresh-extended semen in progesterone supplemented CO-Synch protocol in beef cows. Theriogenology 71:1180-1185. *doi:10.1016/j.theriogenology.2008.12.009*

Cooke, R.F., D.W. Bohnert, M. Meneghetti, T.C., Losi, and J.L.M. Vasconcelos. 2011. Effects of temperament on pregnancy rates to fixed-timed AI in *Bos indicus* beef cows. Livestock Science 142(1–3):108–113. *doi.org/10.1016/j.livsci.2011.06.024*

Dias, N.W., C.L. Timlin, F.V. Santilli, K.M. Harvey, R.F. Cooke, S. Clark, J.F. Currin, and V.R. Mercadante. 2022. Effects of temperament on reproductive performance of *Bos taurus* heifers enrolled in the 7-day CO-Synch + controlled internal drug release protocol. Translational Animal Science 6(4):1-6. *doi.org/10.1093/tas/txac156*

Fordyce, G., R.M. Dodt, and J.R. Wythes. 1988. Cattle temperaments in extensive beef herds in northern Queensland. 1. Factors affecting temperament. Australian Journal of Experimental Agriculture 28(6):683-688. *doi.org/10.1071/ea9880683*

Lamb, G.C., J.E. Larson, T.W. Geary, J.S. Stevenson, S.K. Johnson, M.L. Day, R.P. Ansotegui, D.J. Kesler, J.M. DeJarnette, and D.G. Landblom. 2006. Synchronization of estrus and artificial insemination in replacement beef heifers using gonadotropin-releasing hormone, prostaglandin F2α, and progesterone. Journal of Animal Science. 84(11):3000–3009. *doi:10.2527/jas.2006-220*

Tastad, S.H. 2025. Reproductive performance of beef heifers following timed-artificial insemination: the role of temperament and acclimation to human handling and the handling facility. Thesis, Kansas State University. *https://hdl.handle.net/2097/44942*

USDA. 2020. Beef 2017, Beef Cow-calf Management Practices in the United States, 2017, report 1. USDA–APHIS–VS–CEAH–NAHMS. Fort Collins, CO. #.782.0520.

Table 1. Average chute score, box score, exit velocity, estrus detection patch score, and percentage of heifers found pregnant to an estrus synchronization protocol by group

	Average chute score		Average box score		Average exit velocity (in./second)		Average estrus detection patch score		TAI[1] pregnancy rate (%)	
Heifer group	**CTRL[2]**	**TRT[3]**	**CTRL**	**TRT**	**CTRL**	**TRT**	**CTRL**	**TRT**	**CTRL**	**TRT**
Day -10	1.97	1.97			69.69	73.62				
Day 0	1.92	1.77			68.90	65.75				
Day 7	1.92	1.94			69.69	70.08				
Day 10 (TAI)	1.50[b]	1.23[a]	2.33[b]	1.69[a]	110.24	116.14	3.11	3.06		
Day 43									44.0	40.0
P-value	TRT = 0.2185 Day < 0.0001 TRT × Day = 0.3526		TRT = 0.0115		TRT = 0.7422 Day < 0.0001 TRT × Day = 0.8283		TRT = 0.7360		TRT = 0.6254 Estrus = 0.0055	

[ab]Means within a row with uncommon superscripts differ ($P < 0.05$).
[1] TIA = Fixed-time artificial insemination.
[2] CRTL = Control.
[3] TRT = Treatment.

Table 2. Average chute score, box score, exit velocity, estrus detection patch score, and percentage of cows found pregnant to an estrus synchronization protocol by group

	Average chute score		Average box score		Average exit velocity (in./ second)		Average estrus detection patch score		TAI[1] pregnancy rate (%)	
Cow group	**CTRL[2]**	**TRT[3]**	**CTRL**	**TRT**	**CTRL**	**TRT**	**CTRL**	**TRT**	**CTRL**	**TRT**
Day -10	1.93	1.94			94.88	100.79				
Day 0	1.47	1.51			81.89	84.25				
Day 7	1.43	1.39			72.83	77.95				
Day 10 (TAI)	1.07[x]	1.19[y]	1.37	1.35	215.35	245.28	3.10	2.86		
Day 78									48.1	46.8
P-value	TRT = 0.3152 Day <0.0001 TRT × Day = 0.4319		TRT = 0.8274		TRT = 0.2439 Day <0.0001 TRT × Day = 0.3237		TRT = 0.2972		TRT = 0.9046 DPP[4] = 0.0782 Estrus = 0.0390	

[xy] Means within a row with uncommon superscripts differ ($0.05 \leq P \leq 0.10$).
[1] TIA = Fixed-time artificial insemination.
[2] CRTL = Control.
[3] TRT = Treatment.
[4] DPP = Days postpartum.

Effects of Incorporation of Ruminally Protected Methionine into a Commercial Mineral Supplement on Growth Performance of Grazing Beef Steers in the Kansas Flint Hills

R.R. Donaldson, C D. Weir, Z.M. Duncan, W.C. Ellis, W R. Hollenbeck, E C. Titgemeyer, K. Peel, and D.A. Blasi

Abstract

Forage-based diets for grazing cattle are often deficient in methionine, an essential amino acid required for protein synthesis and metabolism. In the Kansas Flint Hills, seasonal declines in forage quality further reduce metabolizable methionine supply to the small intestine, which may restrict animal growth. This study evaluated the effects of incorporating ruminally protected methionine into a commercial mineral supplement on growth performance of beef calves grazing native tallgrass prairie. A total of 360 crossbred steers (initial body weight [BW] = 611 ± 7 lb) were allotted to 18 pastures in a 90-day grazing trial. Pastures were randomly assigned to receive a control mineral (NoMet) or a mineral containing a rumen-protected methionine analog (Met [MetaSmart, Adisseo, Alpharetta, GA]). Mineral was provided *ad libitum* throughout the trial, and growth performance and mineral consumption were recorded. Final BW and average daily gain did not differ ($P \geq 0.67$) between treatments, with steers gaining 2.51 lb/day (No Met) and 2.55 lb/day (Met). Mineral intake was greater ($P < 0.01$) for control steers compared to those receiving methionine. No health differences were observed between treatments. These findings suggest that supplementation with ruminally protected methionine did not enhance growth performance of steers grazing in the Flint Hills but reduced mineral intake without compromising performance.

Introduction

Methionine is an essential amino acid, meaning cattle cannot synthesize it in sufficient quantities; therefore, it must be supplied through the diet. This amino acid plays a vital role in protein synthesis and various metabolic processes. However, methionine provided by the diet is degraded by rumen microbes and is not absorbed by the animal in the small intestine. Supplementing ruminally protected methionine has been shown to improve growth performance in feedlot cattle by increasing metabolizable methionine to the small intestine. However, there has been limited research evaluating the effects in grazing beef cattle. Methionine is commonly noted as the first limiting amino acid in forage-based diets. Its deficiency is particularly relevant in regions such as the Kansas Flint Hills, which is one of the largest areas of tallgrass prairie in the United States, known for its abundant forage resources. Kansas Flint Hills pastures display seasonal shifts in quality. As grasses mature, the supply of essential amino acids, including methionine, decreases particularly during the mid- to late summer grazing season. Therefore, the objective of this study was to evaluate whether incorporating ruminally protected methionine into a mineral supplement would affect growth performance in grazing beef cattle.

Experimental Procedures

A total of 360 crossbred steers (initial body weight [BW] = 611 ± 7 lb) were shipped to the Kansas State Beef Stocker Unit for a 90-day grazing trial. The Beef Stocker Unit is divided into 18 pastures ranging from 40 to 70 acres. Prior to the start of the trial, two prescribed spring burns were applied April 3 and 6, 2025 on all pastures. Upon arrival steers were housed in 13 head pens and limit-fed a common growing diet at 2.0% of BW (dry matter [DM] basis) for 5 days. On day -1, steers were individually weighed in a hydraulic squeeze chute (Silencer, Moly Manufacturing, LLC, Lorraine, KS), given an visual identification tag, an electronic radio frequency identification tag, and treated for external and internal parasites (Safeguard, Merck Animal Health, Rahway, NJ, and Clean Up II, Elanco Animal Health, Greenfield, IL). On day 0, steers were administered a subcutaneous implant in the ear (Revalor-G, Merck Animal Health, Rahway, NJ) and given a pasture identification tag. Steers were then blocked into two groups by weight and randomly assigned to one of 18 pastures at a targeted stocking rate of 250 lb of live weight/acre.

Pastures were randomly assigned to one of two mineral supplements: a free choice mineral (NoMet; Table 1) or a free choice mineral supplement that contained an isopropyl ester of methionine hydroxy analogue (Met [MetaSmart, Adisseo, Alpharetta, GA]; Table1). Mineral was offered for *ad libitum* consumption throughout the trial. Prior to the start of the trial, mineral feeders (Bull Master, F&B Mann Products, Waterville, KS) were placed near water tanks with flaps up and were not moved for the duration of the grazing period. A 10-day acclimation period was established to ensure adequate mineral consumption for all pastures; during that time all pastures were fed a commercial salt premix. Once steers had acclimated to feeders, flaps were placed down, and treatments were applied to respective pastures. Because mineral consumption was greater than expected, on day-53 a salt block was placed next to the feeders in each pasture in order to slow mineral intake. Mineral feeders were checked daily and refilled as needed per pasture. Steers were checked daily for clinical signs of lameness, pinkeye, and respiratory disease.

Growth performance and mineral consumption data were analyzed using the MIXED procedure of SAS (SAS 9.4 SAS Inst. Inc., Cary, NC). The model for growth performance included treatment as a fixed effect. The model for mineral consumption included fixed effects of treatment, week, and treatment × week. However, no treatment × week interactions were observed ($P = 0.99$) so main effects of treatment are presented.

Results and Discussion

Following the grazing period, final BW and average daily gain did not differ ($P \geq 0.67$; Table 2) between treatments. Steers in the NoMet treatment gained 2.51 lb/day and Met steers gained 2.55 lb/day. Additionally, no steers were treated for bovine respiratory disease and only three were treated for pinkeye.

Mineral consumption was greater ($P < 0.01$, Table 2) in NoMet steers compared to Met steers. Additionally, mineral consumption for both treatments was greater ($P \leq 0.01$; Figure 1) from weeks 3 to 6 compared to weeks 1, 2, 7, 8, 9, 10, and 11. The depression in mineral consumption from weeks 6 to 11 correlated with the placement of salt blocks in the pasture and was by design. The initial lower mineral intakes in weeks 1 and 2 were likely while cattle were adjusting to the new mineral and mineral

feeders. Mineral intake was formulated at 4 oz/head/day; however, both treatments exceeded that intake at 7.56 and 5.56 oz/head/day (NoMet and Met, respectively). The overall decrease in mineral consumption in Met steers could reflect palatability differences in the mineral supplements; however, mineral intake was still adequate.

Implications

Feeding a free choice mineral that contained a methionine hydroxy analogue (MetaSmart) did not improve growth performance of steers grazing in the Flint Hills. However, mineral consumption was reduced when methionine was added to the mineral without any negative effects on performance, which could allow producers to reduce mineral consumption without sacrificing weight gains.

Table 1. Composition of mineral treatments

	Treatment	
Ingredient, % as fed	**NoMet**	**Met**
Calcium carbonate	31.03	31.03
Salt	25.13	25.13
Distillers grains	20.52	11.71
Molasses, 5% fat	2.00	17.99
Dicalcium phosphate	17.99	2.00
Beef MFG TM II	1.25	1.25
Mineral oil	0.75	0.75
Selenium 0.4% premix	0.55	0.55
Iron oxide	0.50	0.50
Vitamin A 650,000 IU	0.01	0.01
Beef MFG vitamin premix	0.20	0.20
Flavor, dry dairy AP	0.03	0.03
Magnesium oxide bulk	0.03	0.03
MetaSmart[1]	---	8.81

[1] Methionine hydroxy analogue (Adisseo, Alpharetta, GA).

Table 2. Growth performance and mineral intake of grazing crossbred steers

	Treatment[1]			
Item	**NoMet**	**Met**	**SEM[2]**	***P*-value**
Number of head	180	180		
Number of pastures	9	9		
Initial body weight, lb	612	611	2.387	0.75
Final body weight, lb	837	840	5.805	0.74
Average daily gain, lb/day	2.51	2.55	0.069	0.67
Mineral intake, oz/head/day	7.56[a]	5.56[b]	0.463	< 0.01

[ab] Within row, means with different superscripts differ ($P < 0.05$).
[1] NoMet = no added methionine to commercial, free choice mineral, Met = hydroxyl methionine analog (Adisseo, Alpharetta, GA) added to commercial, free choice mineral.
[2] Largest standard error of the mean.

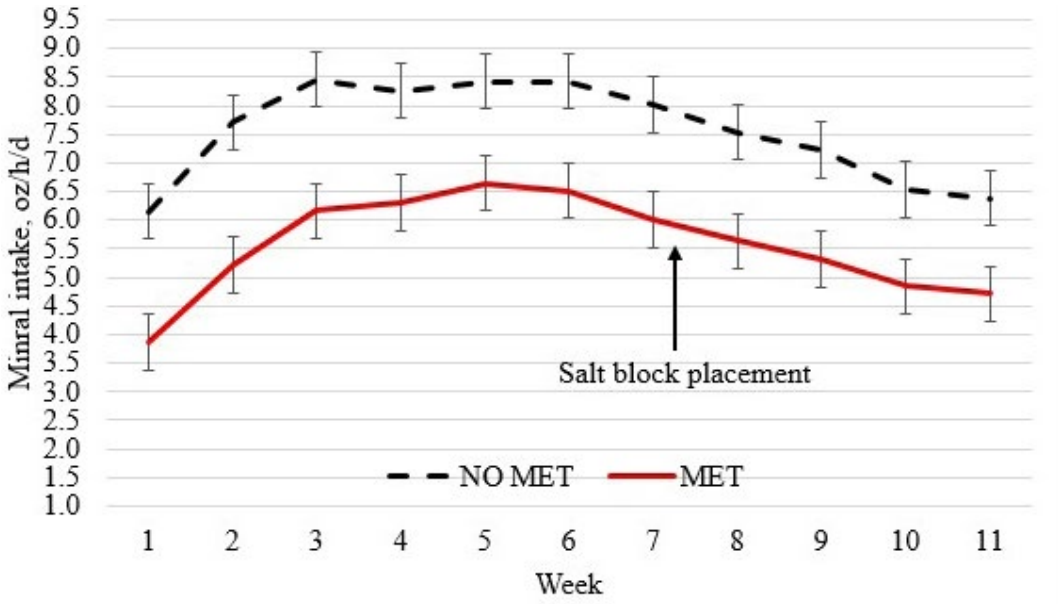

Figure 1. Mineral consumption of grazing crossbred steers over 90 d. No Met = no added methionine to commercial, free choice mineral, MET = hydroxyl methionine analog added to commercial, free choice mineral. Treatment: $P < 0.01$, Week: $P < 0.01$, Treatment × week: $P = 0.99$. SEM = 0.483.

Effects of Short Duration Omega-3 Based Fatty Acid Supplementation to Developing Heifers on Growth, Intake, and Reproduction

M.C. Sollors, A.G. Schwartz, B.J. Fraser, and J.M. Warner

Abstract

This study evaluated the effect of short-duration omega-3 fatty acid supplementation around the time of breeding on growth performance, feed intake, and reproduction of beef replacement heifers. Weaned, spring-born heifers (n = 85) of either Angus, Simmental, or Hereford breeding were used over two years and assigned to one of two treatments each year in a completely randomized design. Heifers were allocated based on body weight (BW) and age and were either non-supplemented (NOSUPP) or supplemented with an extruded flaxseed and algae-based supplement designed to provide omega-3 fatty acids (SUPP). On a dry-matter basis, heifers in year one received 0.48 lb/head/day of the omega-3 supplement, and heifers in year two received 0.72 lb/head/day. In year one, there were 27 SUPP heifers and 26 NOSUPP heifers. In year two, there were 19 and 13 head for SUPP and NOSUPP treatment groups, respectively. Within a year, heifers were managed as a common group and individually fed a forage-based growing diet in precision intake management bunks, with the omega-3 fatty acid-based supplement mixed into the diet of SUPP heifers. Supplementation treatments began around the start of the breeding season, which included artificial insemination (AI) and natural service breeding. Data were analyzed using the GLIMMIX procedures of SAS with the individual heifer as the experimental unit. Average daily gain was improved ($P = 0.01$) by omega-3-based supplementation with little impact on dry matter intake or feed efficiency. Neither AI nor total pregnancy rates were influenced ($P \geq 0.70$) by supplementation. Data suggest that omega-3 supplementation in forage diets for developing replacement heifers at various levels and durations may influence BW gain with little effect on reproduction in well-developed heifers.

Introduction

Sufficient growth and development before first service are critical to ensure replacement heifers have active estrous cycles and conceive early in their first breeding season. Nutrition during the post-weaning period through the start of the breeding season influences reproduction through direct effects on growth and reproductive development. In many Midwest production systems, it is typical for heifers to be developed before the breeding season on diets consisting of stored forages, grain processing by-products, and concentrates, which are naturally low in omega-3 fatty acids. Such fatty acids have been shown to have potential positive effects on reproduction, yet finding readily available sources to incorporate into diets is often challenging. Likewise, strategic protein or energy supplementation around the start of the breeding season has been evaluated as a method to improve conception rates; however, little work has been done focusing on this approach with sources of omega-3 fatty acids. Our objective was to evaluate the strategic, short-term supplementation of a commercial source of omega-3 fatty acids in developing replacement heifers at the start of breeding on growth and reproduction.

Experimental Procedures

This two-year study was conducted in 2024 and 2025 at the Kansas State University Precision Feed Intake facility with spring-born heifers (Angus, Simmental, or Hereford) originating from the Purebred Beef Unit herd. Trial duration was from April 9 to June 5 (56 days) and April 4 to June 10 (68 days) in 2024 and 2025, respectively. Heifers (n = 85 total) were weaned from their dams in September of the previous year, managed in open, earthen dry lot pens, and fed a forage-based diet designed to achieve an average daily gain (ADG) of approximately 1.5 lb. At trial initiation, heifers were weighed over two consecutive days, with weights averaged to determine initial body weight (BW). In a completely randomized design, heifers were assigned based on BW and age to one of two treatments: non-supplemented control (NOSUPP) or supplemented (SUPP) with an extruded flaxseed and algae-based supplement designed to provide omega-3 fatty acids (Better Fed Foods/NBO3, Manhattan, KS). On a dry matter basis, heifers in 2024 received 0.48 lb/head/day of the omega-3 supplement, and heifers in 2025 received 0.72 lb/head/day.

Average age across both years at trial initiation was 414 ± 25 days, and 415 ± 26 days for SUPP and NOSUPP heifers, respectively. Before collecting initial BW at the start of the trial, heifers were fitted with electronic identification ear tags and were trained to consume feed from Insentec precision intake management bunks (Hokofarm, Emmeloord, the Netherlands). Upon trial initiation in both years, all heifers were placed in a single pen and managed as a common group throughout the study. Heifers could only consume feed from bunks to which their corresponding treatment groups were assigned. Within a year, all heifers were fed a common diet that was mixed and delivered daily, and heifers assigned to the SUPP treatment received the omega-3 fatty acid-based supplement mixed into the base ration. Diet ingredient compositions are presented in Table 1. In year two, more than one base diet was fed due to ingredient availability and logistical constraints.

During the two-year study, the SUPP treatment consisted of 46 heifers, 27 in year one and 19 in year two. The NOSUPP treatment consisted of 39 heifers, 26 in year one and 13 in year two. In both years, estrus was synchronized using the Select Synch + controlled internal drug release (CIDR) and timed artificial insemination (AI) protocol. All heifers in both years were inseminated by a single technician if either displaying estrus within the first three days following administration of prostaglandin and removal of the CIDR or no later than 84 hours afterward. In year one, omega-3 fatty acid supplementation started five days following the date of the first timed AI and continued for 10 days. In year two, omega-3 supplementation began 10 days before the start of the first timed AI and continued throughout the entire trial period. In both years, heifers that failed to conceive from the first AI service then received a second AI service upon display of estrus. Following the second AI service, heifers were exposed to Angus sires for natural service for a minimum of 45 days. Upon completion of the feeding period and collection of ending weights, heifers were transported to nearby native Flint Hills pastures for summer grazing. Pregnancy status was determined via rectal palpation by a single trained technician.

Data were analyzed using the GLIMMIX procedure of SAS (SAS, Inc., Cary, NC) with the individual heifer as the experimental unit. The model included the fixed effect of omega-3-based supplementation, with year and breed considered as random effects.

Reproduction data were evaluated as a binomial response measurement. Least square means were declared significant at a *P*-value ≤ 0.05, with tendencies declared at a *P*-value > 0.05 and ≤ 0.10.

Results and Discussion

Heifer performance and reproduction data are reported in Table 2. The age between NOSUPP (415 days) and SUPP (414 days) treatments was similar as intended. Likewise, initial BW was not different ($P = 0.44$) between NOSUPP (873 lb) and SUPP (853 lb) heifers by design. Average daily gain was greater ($P = 0.01$) in SUPP heifers (2.31 lb per day) than in NOSUPP heifers (1.92 lb per day), likely due to protein and energy being supplied from the omega-3 based supplement in addition to that provided in the basal diet. As a result, total BW gain was also increased ($P = 0.01$) in SUPP heifers (146 lb) relative to non-supplemented females (121 lb). Although ADG and total gain were increased, ending BW was not different ($P = 0.76$) between treatments, likely due to weight variability across treatment groups at the start of the trial, which resulted in a slight numerical difference in initial BW between SUPP and NOSUPP heifers. Dry matter intake, which accounted for the supplement, was not different ($P = 0.25$) between treatments. Concurrently, feed efficiency was not impacted ($P = 0.24$) by supplementation at 0.105 and 0.114 lb for NOSUPP and SUPP, respectively. First-service AI conception rates were not influenced by supplementation ($P = 0.94$), and overall pregnancy rates were also not different ($P = 0.70$) between treatments at 85.7% and 88.6% for NOSUPP and SUPP, respectively.

The improvement in ADG in response to supplementation is consistent with that typically observed when growing cattle consuming forage-based diets are supplied with additional protein and energy, with the magnitude of the increase related to many factors such as basal diet protein, fat, and digestible fiber content. Results from this dataset suggest that omega-3 supplementation of this form may positively impact performance across a range of inclusion levels and feeding durations. While these data suggest dietary inclusion has minimal impact on conception rates under the conditions of this study, effects of omega-3 supplementation on reproduction in beef heifers warrant further exploration as responses are likely due to numerous factors, including overall plane of nutrition, diet protein and energy levels, population size evaluated, and puberty attainment prior to breeding.

Implications

Data indicate that relatively short-term supplementation of an omega-3 based fatty acid supplement around the start of the breeding season may improve growth rates of replacement heifers fed forage-based diets. In heifers that are well-developed before the start of the breeding season, reproductive responses to supplementation are likely more variable.

Acknowledgments

The authors extend appreciation to Shane Werk, former Purebred Beef Unit Manager, and all student employees of the unit for their assistance with daily care and management of the cattle represented in this report, as well as data collection. Appreciation is also extended to Better Fed Foods/NBO3, Manhattan, KS, for their support of this research.

Table 1. Ingredient composition of diets fed to growing replacement heifers by year[1]

	Year 1	Year 2		
Ingredient, %	**Diet 1**	**Diet 1[2]**	**Diet 2[3]**	**Diet 3[4]**
Grass hay	31.3	37.3	37.2	---
Corn silage	21.7	23.9	23.9	73.1
Sweet Bran	25.7	---	---	---
DDGS[5]	---	---	---	24.3
Wheat middlings	---	---	20.0	---
Corn germ meal	---	19.8	---	---
Dry rolled corn	13.6	16.4	16.3	---
Supplement	7.7	2.6	2.6	2.6
Diet dry matter, %	63.4	63.3	63.5	39.8
Omega-3 supplement, lb[6]	0.48	---	0.72	0.72

[1] All values on a 100% dry matter basis, except for diet dry matter.
[2] Diet 1 fed from 4/04/25 to 5/11/25.
[3] Diet 2 fed from 5/12/25 to 5/23/25.
[4] Diet 3 fed from 5/24/25 to 6/10/25.
[5] Corn dried distillers grains with solubles.
[6] Amounts included on a per head per day basis.

Table 2. Performance and reproduction of heifers by supplementation treatment

	Treatment			
Item	**NOSUPP[1]**	**SUPP[2]**	**SEM[3]**	***P*-value**
Initial age, days	415	414	---	---
Initial body weight, lb	873	853	24.3	0.44
Ending body weight, lb	988	997	27.6	0.76
Total body weight gain, lb	121	146	9.8	0.01
Average daily gain, lb	1.92	2.31	0.15	0.01
Dry matter intake, lb per day	19.2	20.1	0.78	0.25
Gain:feed, lb	0.105	0.114	0.008	0.24
Artificial insemination pregnancy, %[4]	60.0	59.0	0.11	0.94
Total pregnancy, %[5]	85.7	88.6	0.08	0.70

[1] NOSUPP = heifers not supplemented with an omega-3 based fatty acid supplement.
[2] SUPP= heifers supplemented with an omega-3 based fatty acid supplement.
[3] SEM = standard error of the mean.
[4] Heifers conceiving to AI on first service divided by the total within each treatment.
[5] Heifers conceiving to either AI or natural service divided by the total within each treatment.

The Effects of Feeding Strategies on Performance and Liver Abscess Prevalence on Growing Beef × Dairy Steers

W.C. Ellis, Z.M. Duncan, C.D. Weir, M C. Weigand, S.P. Montgomery, J. Waggoner, A J. Tarpoff, W.R. Hollenbeck, E.C. Titgemeyer, and D.A. Blasi

Abstract

A 126-day backgrounding study was conducted to evaluate the effects of feeding strategy on growth performance and liver abscess (LA) prevalence in growing beef × dairy steers. A total of 529 beef × dairy crossbred steers (initial body weight [BW] = 650 ± 16.9 lb) were blocked by weight, stratified by arrival BW within block, and assigned to pen. Pens were randomly assigned to one of five treatments; 50 NEg (Mcal/100 lb) diet targeting 2 lb of gain per day (50-2 lb), a 60 NEg (Mcal/100 lb) diet targeting 2 or 3 lb of gain per day (60-2 lb and 60-3 lb, respectively), or a 64 NEg diet fed for *ad libitum* intake with or without tylosin phosphate (64-ALT and 64-ALNT, respectively; Tylovet 100, Huvepharma, Peachtree City, GA). Individual BW and LA prevalence were measured at beginning and end of the feeding period. Cattle were weighed for feed call adjustments, starting on day 14 and every seven days until day 42 when weights were recorded every 14 days. At the completion of the feeding period, final BW, average daily gain, and dry matter intake differed ($P < 0.01$). Feed:gain was greatest for the 50-2 lb treatment ($P < 0.01$) and similar among the other four treatments ($P \geq 0.20$). Prevalence of LA differed ($P = 0.05$), being least for steers fed 60-3 lb than for steers fed 64-ALNT or 64-ALT treatments. Overall, the use of limit feeding a 60 NEg diet can reduce the prevalence of LA when compared with feeding a higher energy diet *ad libitum*.

Introduction

Total cattle on feed in the United States has declined in recent years, resulting in record-high live cattle prices. As a result, the placement of beef × dairy cattle has increased in feedlots due to a consistent supply from dairy producers. Sexed semen has allowed dairy producers to breed less productive cows to beef sires to increase the value of their calves. One issue associated with beef × dairy cattle is their increased susceptibility to developing liver abscesses (LA; Grimes et al., 2024). Liver abscesses result in trim and organ loss, which represent annual economic losses of $400 million (Broadway et al., 2024). The formation of LA has been theorized to result from the translocation of *Fusobacterium necrophorum* from the rumen to the portal vein as a result of ruminal acidosis (Nagaraja and Chengappa, 1998). Historically, cattle fed diets with a high inclusion of rapidly fermentable carbohydrates can be subjected to ruminal acidosis. The inclusion of roughage and corn coproducts can be used to maintain ruminal pH and improve buffering capacity, lowering the risk of ruminal acidosis in high-grain diets. Tylosin phosphate is a macrolide antibiotic that has been commonly used in feedlots for the control of LA for nearly 60 years.

Beef × dairy calves are raised on ranches and start on concentrate-based diets as young as 60 days of age. Prolonged feeding of cereal grains could predispose beef × dairy cattle

to greater LA prevalence compared to native beef cattle. The objectives of this study were: 1) to determine the effects of growing strategy and roughage inclusion in the diet on growth performance and LA prevalence in beef × dairy steers; and 2) to compare the effects of the inclusion of tylosin phosphate on LA prevalence in growing beef × dairy calves fed a high-concentrate diet.

Experimental Procedures

A total of 529 beef × dairy crossbred steers (initial body weight [BW] = 650 ± 16.9 lb) were purchased in Texas and transported to the Kansas State University Beef Stocker Unit on March 20, 2024, and used in a 126-day growing study. Steers were placed in pens containing 12 to 14 head and limit fed a common growing diet at 2.2% of BW (dry matter [DM] basis) On day -1, steers were individually weighed in a hydraulic chute (Silencer, Moly MFG, Lorraine, KS) and given a visual identification tag. The following day, steers were blocked by weight (heavy and light), stratified by individual BW, and assigned to pens containing 12 to 14 head. Steers were given a pen tag, and treated for internal (Safe-Guard, Merck, Rahway, NJ) and external (Clean-Up II, Elanco, Greenfield, IN) parasites. Treatments were randomly assigned to each pen with a total of eight pens/treatment. Treatments (Table 1) included a 50 NEg (Mcal/100 lb DM) diet targeting 2 lb of gain per day (50-2 lb), 60 NEg (Mcal/100 lb DM) diet targeting a 2 or 3 lb of gain per day (60-2 lb and 60-3 lb, respectively), or a 64 NEg (Mcal/100 lb DM) diet fed for *ad libitum* intake with or without tylosin phosphate (64-ALT and 64-ALNT, respectively; Tylovet, Huvepharma, Peachtree City, GA). Only the 64-ALT treatment received tylosin phosphate. Pens were identical in size (30 × 50 ft) with a packed soil floor and a concrete bunk apron (30 × 12 ft). Steers in all pens were provided *ad libitum* access to water.

On days 0 and 126, steers were shaved on the right side from the 9th to 13th rib. Isopropyl alcohol (70%) was applied and each intercostal space was viewed using a convex, portable ultrasound (Clarius C3HD3VET convex scanner, Vancouver, BC, Canada) to identify any visible LA. Prevalence of LA was calculated for each pen as the number of steers with at least one LA divided by the total number of steers. Pen weights were measured using a pen scale (Rice Lake Weighing System, Rice Lake, WI) on days 0, 14, 21, 28, 35, 42, 56, 70, 84, 98, 112, and 126. Pen weights were used to adjust feed calls for each pen being fed 50-2 lb, 60-2 lb, and 60-3 lb using a programmed gain calculator (Galyean, 2019). On day 126, cattle were individually weighed after a 12-hour fast to account for gut fill and had an ultrasound for LA, and a pen weight was collected.

Results and Discussion

At the conclusion of the 126-day feeding period, final BW and average daily gain (ADG) were lowest for 50-2 lb and 60-2 lb, intermediate for 60-3 lb, and greatest for 64-ALT and 64-ALNT ($P < 0.01$; Table 2). Overall ADG were 2.70, 2.58, 3.30, 3.80, and 3.78 for 50-2 lb, 60-2 lb, 60-3 lb, 64-ALNT, and 64-ALT, respectively. The higher-than-expected gains for the 50-2 lb, 60-2 lb, and 60-3 lb treatments could be attributed to unclear nutrient requirements for growing beef × dairy cattle. The program gain calculator is based on historical data of native beef cattle; therefore, adjustments may be needed for beef × dairy cattle. DM intake was least for 60-2 lb ($P < 0.01$), intermediate for 50-2 lb and 60-3 lb, and greatest for 64-ALNT and 64-ALT. Differences in DM intake can be attributed to the study design. Steers fed 50-2 lb, 60-2 lb, and 60-3 lb treatments were limit fed to achieve specific rates of gain. Feed:gain was highest ($P < 0.01$) for 50-2 lb steers compared with the other treatments,

and feed:gain did not differ ($P \geq 0.20$) among steers fed 60-2 lb, 60-3 lb, 64-ALNT, and 64-ALT. The use of a high-roughage diet and a low program feeding regimen can reduce the risk of metabolic upset and aid in rumen development but may come at a cost to feed efficiency. Previous data (Feitoza et al., 2025) did not suggest the inclusion of tylosin phosphate affects feedlot cattle performance. Similarly, this study observed no effect of tylosin phosphate on the performance of growing beef × dairy steers.

At the beginning of the feeding period, no steers had visible LA (Table 2). At the conclusion of the feeding period, LA prevalence was least ($P \leq 0.05$) for the 60-3 lb treatment when compared with 64-ALT and 64-ALNT. Prevalence of LA for 50-2 lb, 60-2 lb, 60-3 lb, 64-ALNT and 64-ALT treatments was 10.4%, 11.4%, 7.55%, 20.56%, and 19.95%, respectively. The use of roughages, corn co-products, and controlled intake of cereal grains can help maintain normal ruminal pH, which may aid in the prevention of acidosis and thus possibly reduce the risk of LA formation. Cattle fed 64-ALNT had a 20.56% LA prevalence. When intake was limited and roughage and corn co-product inclusion in the diet increased by 10% (60-3 lb) we observed a decrease of LA prevalence. Liver abscess prevalence was unaffected by the addition of tylosin phosphate to the diet containing 64 Mcal Neg/100 lb. Public concern has grown in recent years over feeding antibiotics to cattle, and pressure has been put on producers to reduce the length/quantity of antibiotics they use. In our experiment, LA prevalence was 20.6% and 20.0% ($P = 0.78$) when steers were fed 64-ALNT and 64-ALT, respectively, suggesting tylosin phosphate was not effective in reducing LA prevalence in beef × dairy steers during the growing period.

Implications

When compared to *ad libitum* feeding of a 64 NEg diet, limit feeding a 60 NEg diet can reduce the incidence of LA without sacrificing feed conversion in growing beef × dairy steers. However, as expected, *ad libitum* feeding of the 64 NEg diet led to greater growth rates than limit feeding of the 50 or 60 NEg diets.

Acknowledgments

The authors thank Micro Technologies and Huvepharma for their contributions to and support of this study.

References

Broadway P.R., T.G. Nagaraja, T.E. Lawrence, M.L. Galyean, and K.E. Hales. 2024. Liver abscesses – New perspectives on a historic fed-cattle issue. Applied Animal Science 40(3):237-243. *doi:10.15232/aas.2023-02498*

Feitoza, L.F.B.B., A.N. Baker, R.L. Thorn, L.S. Monteiro, F. Nasiu, T.G. Nagaraja, Q. King, J.S. Drouillard. 2025. Targeted durations of tylosin phosphate on incidence and severity of liver abscesses in feedlot cattle. Applied Animal Science 41(1):1-9. *doi.org/10.15232/aas.2024-02574*

Galyean, M. L., Programmed gain calculations. Texas Tech University. *https://www.depts.ttu.edu/afs/home/mgalyean/* (Accessed September 2, 2025).

Grimes B.B., T.J. McEvers, T.C. Tennant, J.W. Johnson, and T.E. Lawrence. 2024. Relationship of liver abnormalities with carcass performance and value. Applied Animal Science 40(3):358-375. *doi:10.15232/aas.2023-02482*

Nagaraja T.G. and M.M. Chengappa. 1998. Liver abscesses in feedlot cattle: A review. Journal of Animal Science 76(1):287-298. *doi:10.2527/1998.761287*

Table 1. Experimental diets

	Treatment[1]				
Ingredient, % dry matter	50-2 lb	60-2 lb	60-3 lb	64-ALNT	64-ALT
Dry-rolled corn	24.37	41.38	41.38	58.91	58.91
Sweet Bran[2]	40.00	40.00	40.00	30.00	30.00
Prairie hay, chopped	30.00	13.00	13.00	7.00	7.00
Control supplement[3]	5.63	5.62	5.62	4.09	---
Tylosin supplement[4]	---	---	---	---	4.09

[1] 50-2 lb: formulated to contain 50 Mcal of net energy for gain (NEg)/cwt dry matter (DM) and fed to achieve 2 lb of gain/day; 60-2 lb: formulated to contain 60 Mcal of NEg/cwt DM and fed to achieve 2 lb of gain/day; 60-3 lb: formulated to contain 60 Mcal of NEg/cwt DM and fed to achieve 3 lb of gain/day; 64-ALNT: formulated to contain 64 Mcal of NEg/cwt DM and fed *ad libitum* without tylosin phosphate; 64-ALT: formulated to contain 64 Mcal of NEg/cwt DM and fed *ad libitum* with tylosin phosphate (Tylovet 100: Huvepharma, Peachtree City, GA).
[2] Cargill Corn Milling (Blair, NE).
[3] Supplement pellet formulated to contain (DM basis) 11.29% crude protein, 0.63% phosphorus, 4.7% salt, 0.73% potassium, 3.41% fat, and 429.69 g/ton monensin (Rumensin; Elanco, Greenfield, IN).
[4] Supplement pellet formulated to contain (DM basis) 10.57% crude protein, 0.62% phosphorus, 4.7% salt, 0.68% potassium, 3.41% fat, 429.69 g/ton monensin (Rumensin; Elanco, Greenfield, IN), and 193.37 g/ton tylosin phosphate (Tylovet 100: Huvepharma, Peachtree City, GA).

Table 2. Effects of growing strategy on growth performance and liver abscess prevalence of growing beef × dairy steers

	Treatment[1]						
Item,	**50-2 lb**	**60-2 lb**	**60-3 lb**	**64-ALNT**	**64-ALT**	**SEM[2]**	***P*-value[3]**
Number of pens	8	8	8	8	8		
Number. of steers	106	105	106	107	105		
Body weight, lb							
Day 0	650	651	651	650	651	16.9	1.00
Day 126	990[a]	976[a]	1,067[b]	1,129[c]	1,121[c]	17.7	< 0.01
Average daily gain, lb/day	2.70[a]	2.58[a]	3.30[b]	3.80[c]	3.74[c]	0.052	< 0.01
Dry matter intake, lb/day	18.03[b]	15.52[a]	20.30[c]	22.73[d]	22.71[d]	0.231	< 0.01
Gain:feed lb/lb	0.15[a]	0.17[b]	0.16[b]	0.17[b]	0.16[b]	0.002	< 0.01
Feed:gain lb/lb	6.69[a]	6.03[b]	6.16[b]	5.98[b]	6.08[b]	0.104	< 0.01
Liver abscess prevalence,[4] %							
Start of growing period	0	0	0	0	0		
End of the growing period	10.4[ab]	11.4[ab]	7.5[b]	20.6[a]	20.0[a]	3.9	0.05

[abcd] Within row, means with unlike superscripts differ ($P < 0.05$).
[1] 50-2 lb: formulated to contain 50 Mcal of net energy for gain (NEg)/cwt dry matter (DM) and fed to achieve 2 lb of gain/day; 60-2 lb: formulated to contain 60 Mcal of NEg/cwt DM and fed to achieve 2 lb of gain/day; 60-3 lb: formulated to contain 60 Mcal of NEg/cwt DM and fed to achieve 3 lb of gain/day; 64-ALNT: formulated to contain 64 Mcal of NEg/cwt DM and fed *ad libitum* without tylosin phosphate; 64-ALT: formulated to contain 64 Mcal of NEg/cwt DM and fed *ad libitum* with tylosin phosphate (Tylovet 100: Huvepharma, Peachtree City, GA).
[2] Largest standard error of the mean.
[3] Treatment main effect.
[4] Liver abscess prevalence = (steers positive for at least one liver abscess/total head count in pen) × 100.

Effects of Dietary Inclusion of an Omega-3 Fatty Acid-based Supplement on Biological Parameters and Sperm Characteristics of Developing Beef Bulls

A.G. Schwartz, B.J. Frazer, D.M. Ellinghuysen, J. Zimmermann, E. Bortoluzzi, A. Bassett, S.M. Zoca,[1] N.W. Dias, and J.M. Warner

Abstract

The objective was to evaluate including an omega-3 fatty acid-based supplement in the diet of growing beef bulls on biological parameters and sperm characteristics. Weaned beef bull calves (n = 39) of Angus, Hereford, or Simmental breeding were stratified by body weight and age, and then the calves were assigned to one of three dietary treatments in a completely randomized design. Treatments consisted of including an omega-3-based supplement at one of three levels to a common corn silage-based diet at 0.00 (CON), 0.48 (MOD), or 0.96 (HI) lb/head/day (dry matter basis). Managed as a common group and individually fed in precision intake management bunks, bulls (n = 13 per treatment) were supplemented for 80 days from late November 2024 to February 2025. Data were analyzed using the GLIMMIX procedures of SAS with the individual animal as the experimental unit. There was no difference ($P > 0.05$) in the percentage of morphologically normal sperm or progressive motility among treatments. A tendency for increased motility ($P = 0.10$) was observed for the HI treatment relative to CON. Day effects were observed as age increased and bulls grew for weight, average daily gain, body condition score, and scrotal circumference. Semen characteristics varied by day of collection but generally improved as bulls matured. Data suggest an omega-3 fatty acid-based supplement in the basal diet of developing beef bulls may influence semen quality under dietary levels and duration of feeding in this experiment. These findings support future work investigating omega-3 supplementation as a strategy to offset impaired semen quality associated with overfeeding and obesity-like metabolism in young bulls, as well as supplying such fatty acids in development diets that are otherwise naturally devoid.

Introduction

For seedstock bull calves being retained as future herd sires, the period between weaning and first service is critical for growth and sexual maturation. In typical Midwestern production systems, it is common for bulls to be developed postweaning on diets consisting of grass hays, silages, concentrates, and corn-processing by-products, which are naturally low in omega-3 fatty acids. Omega-3 fatty acids have been shown to have anti-inflammatory properties in many species. Bulls being developed at high rates of gain prior to first service may be at greater risk of experiencing metabolic stress, which can negatively impact semen quality. However, research evaluating the impact of omega-3 supplementation in modern developing bull diets on semen characteristics is generally limited. Therefore, our objectives were to evaluate the impact of including an omega-3 fatty acid-based supplement in the diet of developing beef bulls on growth and semen characteristics.

[1] Department of Animal Science, University of Tennessee, Knoxville, Tennessee

Experimental Procedures

Weaned beef bull calves (n = 39, initial body weight [BW]= 737 ± 111 lb, initial age = 282 ± 25 days) of Angus, Hereford, or Simmental breeding from the Kansas State University Purebred Beef Unit were used for this experiment. Following removal from their dams in September, bulls were fitted with electronic identification tags, adapted to a total mixed ration growing diet, and then entered the Kansas State University Precision Feed Intake facility, where they were fed in precision intake management bunks. After an adaptation period of at least 21 days, bulls were weighed on three consecutive days, with the average BW of the first two days used to assign bulls to treatments on day 0, while the average of all three days was used as initial BW. In a completely randomized design, bulls were stratified by BW and age and assigned to one of three dietary treatments: 0.00 (CON), 0.48 (MOD), or 0.96 (HI) lb/head/day (dry matter basis) of an extruded flaxseed and algae-based supplement providing omega-3 fatty acids (Better Fed Foods/NBO3, Manhattan, KS). The supplement (32.26% crude protein, 18.85% fat, 19.76% neutral detergent fiber, 11.28% acid detergent fiber, dry matter basis) was added to a corn silage-based diet, which was mixed and delivered to bulls across all treatments daily (Table 1). Corn germ meal was added along with the omega-3 based supplement to provide similar dietary crude protein levels. Bulls across all three treatments were managed as a common group and individually fed in precision intake management bunks (n = 13 per treatment) throughout the experiment. Treatments were applied for 80 days from late November 2024 to February 2025, during which the average temperature was 31°F. Ration samples were collected weekly and compiled into periods consisting of three weeks each. The composited samples were analyzed in a commercial laboratory (SDK Laboratories, Hutchinson, KS) using wet chemistry techniques for dry matter, protein, fiber components, fat, calculated energy concentration, and macro minerals.

Blood samples were collected on days -5, 53 or 55, and 80 via coccygeal venipuncture for analysis of fatty acid concentrations. Scrotal circumference (SC) was collected on day -4, 53 or 55, and day 76. Breeding soundness exams were conducted by trained personnel at the Kansas Artificial Breeding Services Unit on day 53 or 55, 76, and 101. Semen collected via electroejaculation from the breeding soundness exams was analyzed by a computer-assisted semen analysis (CASA) machine. Seminal plasma was collected immediately from an aliquot of the ejaculate by centrifugation of the ejaculate. The remaining ejaculate was placed in a water bath at 95°F for three hours as a sperm resilience stress test, and the remaining seminal plasma was collected. All seminal plasma samples were immediately frozen in liquid nitrogen and later stored in -112°F for later analysis of reaction oxygen species. Individual BW was collected on three consecutive days upon completion of the supplementation period, and weights were averaged for determination of ending BW, with a single mid-trial weight taken on day 53 or 55. Body condition score (BCS) was assessed at both trial initiation and conclusion. Thermal images of the face of the bull and both testes were taken on day -5 and 79 to evaluate thermoregulation of the testes. Carcass ultrasound was conducted by a commercial technician on day -4 and 80 for the collection of ribeye area, subcutaneous back fat between the 12th and 13th rib, and intramuscular fat.

Data were analyzed using the GLIMMIX procedure of SAS (SAS, Inc., Cary, NC) with variables collected multiple times throughout the study analyzed as repeated measures. The individual bull was considered the experimental unit. The model included the fixed

effects of supplementation and day of collection with breed as a random effect. Least square means were declared significant at a *P*-value ≤ 0.05, and tendencies were declared at a *P*-value > 0.05 and ≤ 0.10.

Results and Discussion

Ingredient and nutrient composition of the base and treatment diets is presented in Table 1. Diets were formulated to have similar protein and energy across treatments, with only the fatty acid composition varying across treatments. Variables measured multiple times throughout the experiment are reported in Table 2. There was no difference ($P > 0.05$) for BW, average daily gain (ADG), or BCS among supplementation groups. Bulls increased from their initial BW of 737 lb at the start of the trial to 1,003 lb at the end. The performance data collected did not differ by supplementation group, indicating that supplementation did not influence overall growth or body condition. However, as expected, these parameters increased with the progression of the experiment. Analysis of sperm characteristics was done with a CASA machine for morphology, motility, and progressive motility of the sperm cells at day 53 or 55, 80 and 101. There were no differences for the percentage of morphologically normal sperm as influenced by omega-3 fatty acid supplementation ($P > 0.05$). There was, however, a lower percentage of morphologically normal spermatozoa in samples from the first collection compared to the collections on day 80 and 101. Interestingly, there was a tendency ($P = 0.10$) for motility to be greater for HI compared to CON bulls for all collections. Likewise, a day effect was observed for motility with sperm collected at day 101 having increased motility ($P < 0.05$) compared to day 53 or 55, and day 80, regardless of treatment. There was no supplementation effect on the progressive motility of sperm, but a day effect was observed with progressive motility increasing from day 53 or 55 to day 80. However, progressive motility decreased ($P < 0.05$) from day 80 to day 101 representing the first 21 days after omega-3 supplementation was stopped. Ribeye area, rib fat thickness, and intramuscular fat did not differ among supplementation treatments ($P > 0.05$). There was an increase in all carcass traits by the end of the trial due to gain and muscle development. Thermography of the testes, fatty acid composition of blood plasma, and reactive oxygen species in seminal plasma are currently being analyzed to help elucidate the effects that omega-3 supplementation, particularly its antioxidant properties, has on oxidative stress and ultimately sperm function in developing beef bulls.

Implications

Results suggest that omega-3 supplementation may impact sperm cell motility in young bulls within the inclusion levels and duration of this experiment, which may ultimately help counter the negative effects of overfeeding on semen quality in developing bulls.

Acknowledgments

The authors extend appreciation to Shane Werk, former Purebred Beef Unit Manager, and all student employees of the unit for their assistance with daily care and management of the cattle represented in this report as well as data collection. Appreciation is also expressed to the Kansas Artificial Breeding Services Unit for their time and assistance in performing breeding soundness exams. Appreciation is also extended to Better Fed Foods/NBO3, Manhattan, KS, for their support of this research.

Table 1. Ingredient and nutrient composition of diets fed to developing bulls[1]

Ingredient, %	BASE[2]	CON[3]	MOD[3]	HI[3]
Corn silage	34.3	34.3	34.3	34.3
DDGS[4]	22.2	22.2	22.2	22.2
Dry rolled corn	20.9	20.9	20.9	20.9
Grass hay	14.7	14.7	14.7	14.7
Supplement	7.9	7.9	7.9	7.9
Nutrient, %				
Dry matter	57.40	59.73	58.58	60.53
Crude protein	12.47	13.07	12.61	13.47
Acid detergent fiber	18.79	17.87	18.08	17.81
Neutral detergent fiber	31.79	31.01	31.13	32.09
Fat	4.95	4.76	4.93	5.76
Calcium	0.92	0.87	0.80	0.76
Phosphorus	0.47	0.48	0.45	0.47
Corn germ meal[5]	---	1.98	1.29	1.19
Omega-3 supplement[5]	---	---	0.48	0.96

[1] All values on a 100% dry matter basis.
[2] Base ration fed to all treatment groups.
[3] CON = 0.00, MOD = 0.48, and HI = 0.96 lb/head/day (dry matter basis) of an extruded flaxseed and algae-based supplement providing omega-3 fatty acids (Better Fed Foods/NBO3, Manhattan, KS).
[4] Corn dried distillers grains with solubles.
[5] Amounts included on a per head per day basis.

Table 2. Effects of omega-3 supplementation and day of collection on growth, carcass characteristics, and semen parameters

	Supplementation[1]					Day[2]					
Item	CON[3]	MOD[4]	HI[5]	SEM[6]	*P*-value	0	53 or 55	80	101	SEM[6]	*P*-value
Initial body weight, lb	732	736	744	32	0.96	---	---	---	---	---	---
End body weight, lb	981	1,009	1,018	35	0.73	---	---	---	---	---	---
ADG,[7] lb	3.47	3.55	3.53	0.20	0.96	---	3.05[a]	3.99[b]	---	0.25	0.04
BCS[8]	5.5	5.5	5.5	0.13	0.86	4.69[a]	5.79[b]	6.05[b]	---	0.11	<0.01
SC,[9] in.	13.39	13.46	13.74	0.24	0.57	10.83[a]	13.96[b]	14.50[c]	14.83[d]	0.15	<0.01
Morph. normal,[10] %	56.80	68.12	70.38	6.56	0.30	---	51.05[a]	68.05[b]	76.20[b]	4.87	<0.01
Motile, %	45.50[†]	54.06	60.45[†]	4.84	0.10	---	43.57[a]	51.96[a]	64.47[b]	3.68	<0.01
Progressively motile, %	27.43	32.32	40.28	4.67	0.16	---	31.90[a]	42.56[b]	25.59[a]	3.68	<0.01
Ribeye area, square in.	4.44	4.56	4.54	0.16	0.84	3.78[a]	---	5.09[b]	---	0.09	<0.01
Ribfat,[11] in.	0.19	0.20	0.19	0.01	0.78	0.15[a]	---	0.23[b]	---	0.01	<0.01
Intramuscular fat, %	2.28	2.58	2.43	0.21	0.60	2.21[a]	---	2.65[b]	---	0.13	<0.01

[abcd] Means with unlike superscripts differ at $P \leq 0.05$.

[†] Means with like superscripts trend toward significance ($0.05 \leq P \geq 0.10$).

[1] Supplementation = mean values for all bulls across all collections.

[2] Day = mean values for all bulls across supplement levels.

[3] CON = non-supplemented.

[4] MOD = supplemented with 0.48 lb/head/day (dry matter basis) of an omega-3 based supplement (Better Fed Foods/NBO3, Manhattan, KS).

[5] HI = supplemented with 0.96 lb/head/day (dry matter basis) of an omega-3 based supplement (Better Fed Foods/NBO3, Manhattan, KS).

[6] SEM = standard error of the mean.

[7] ADG = average daily gain.

[8] BCS = body condition score.

[9] SC = scrotal circumference.

[10] Morph. normal = percentage of morphologically normal sperm.

[11] Measured between the 12th and 13th rib.

Effect of Pyramid Enzyme on the Performance of Finishing Cattle Fed Sorghum-based Diets

E.R. Kiselewski, S.A. Sexton-Bowser, L.S. Monteiro, J.K. Farney, and J.S. Drouillard

Abstract

In some regions of the Ogallala Aquifer, irrigation water is being withdrawn in amounts that exceed the natural recharge rate, resulting in declining water levels. Substituting sorghum for corn and other crops with high water demand is a practical strategy for decreasing water use. Sorghum generally is regarded as being inferior to corn, limiting its use in beef feedlots. The objective of this study was to evaluate the effect of supplementing Pyramid PowerGrower Ruminant (Pyramid Feeds, Scott City, KS) as an additive to improve sorghum use in feedlot cattle. This enzyme was incorporated into the diet at 1.5 lb/ton (86% dry matter basis). Cattle were fed diets consisting of ground sorghum, sorghum-based distillers grains, corn silage, and the enzyme supplement for a period of 148 days. Digestibility of diet components was estimated using acid detergent insoluble ash as an internal marker. There were small, but non-significant, improvements in performance and diet digestion with enzyme supplementation.

Introduction

The Great Plains region produces a majority of slaughter cattle in the U.S. Within eight states (South Dakota, Wyoming, Colorado, Kansas, Nebraska, New Mexico, Oklahoma, and Texas) in the Great Plains region spanning 173,746 mi^2 is the Ogallala Aquifer. The Ogallala Aquifer provides 30% of irrigated water and 70% of the groundwater in the U.S. Irrigation in the High Plains has contributed to significant groundwater depletion, as water is being withdrawn from the aquifer at a rate exceeding its natural recharge rate. With ongoing depletion, water conservation efforts have become more prominent. One option to reduce water usage is to cultivate sorghum, which can be grown in semiarid regions and withstands extended periods of drought. Compared to corn, grain sorghum has a lower water requirement throughout the growing period. Sorghum is the fifth most produced cereal grain globally. Sorghum has been found to be less ruminally digestible than corn and has been less desirable for feedlot use. Sorghum is characterized by an extensive starch-protein matrix that can adversely affect the nutritive value and digestibility of the grain. The use of exogenous enzymes that target disruption of this matrix may be a practical means of improving digestibility and animal performance. There is limited research utilizing exogenous enzymes to increase sorghum digestibility within sorghum-based finishing diets.

Experimental Procedures

From January to June 2025, a randomized complete block design experiment was conducted at the Southeast Research and Extension Center (Mound Valley, KS). Crossbred yearling steers (n = 280; body weight = 974 ± 33.5 lb) were transported to the research center. Upon initiation of the experiment, steers were weighed and identified using visual ear tags and radio frequency identification ear tags. Animals were vaccinated for viral and clostridial pathogens, treated for internal and external parasites,

and implanted with a long-acting steroidal implant. Steers were randomly allocated to treatment blocks based on the order of processing. Steers were housed in 36 earth-surfaced feedlot pens measuring 50 × 100 ft and were fed one of two treatment diets. They were randomly allocated to 18 blocks. The treatments were a control diet with no added enzyme, or a diet supplemented with Pyramid PowerGrower Ruminant (Pyramid Feeds, Scott City, KS) as an additive to improve sorghum utilization in feedlot cattle (Table 1). This enzyme was incorporated into the diet at 1.5 lb/ton (86% dry matter basis). Cattle were fed diets consisting of ground sorghum, sorghum-based distillers grains, corn silage, and the enzyme supplement for a period of 148 days. Cattle were fed once daily in the morning, *ad libitum*. Daily feed bunk scores were taken, and ingredient dry matter samples were determined weekly. Rejected feed samples were taken every Monday and Thursday to determine actual dry matter intake values for each 3- or 4-day interval.

Fecal samples and feed were collected to determine nutrient content and digestibility by using acid detergent insoluble ash as an internal marker. Digestibility was calculated with this equation:

$$\text{Digestibility \%} = 100 - \left[100 \times \frac{\text{Marker concentration in feed}}{\text{Marker concentration in feces}} \times \frac{\text{Nutrient concentration in feed}}{\text{Nutrient concentration in feces}}\right]$$

After a period of 148 days on feed, the steers were shipped to Tyson Foods in Holcomb, Kansas, for carcass data collection. On the day of harvest, hot carcass weight and incidence of liver abscesses were recorded. After a refrigeration period of 96 hours, camera imaging was used to acquire carcass measurements, including ribeye area, 12th rib subcutaneous fat, marbling score, percent kidney, pelvic, and heart fat, and U.S. Department of Agriculture quality and yield grades.

Data were analyzed using the GLIMMIX procedure of the Statistical Analysis System (SAS 9.4, Cary, NC). Treatment was the fixed effect, experimental unit was the feedlot pen, and random effect was block. Initial body weight was used as a covariate in the statistical models. Statistical tendencies were determined at $0.05 < P < 0.10$, and statistical significance was declared at $P \leq 0.05$.

Results and Discussion

There were subtle, but nonsignificant, differences between the performance measurements, carcass characteristics, and nutrient digestibility between the two treatment groups ($P > 0.10$). Performance data are shown in Table 2, carcass data in Table 3, and nutrient digestibility in Table 4. Despite dry matter digestibility not having a statistical difference, there was 2% higher digestibility in the enzyme treatment compared to the control treatment. Considering that there were nonsignificant differences in nutrient digestibility, it is expected that there would be no detectable differences in average daily gain (ADG) or feed:gain. The final body weight in the enzyme group (1,354.5 lb) was numerically greater than the control group (1,343.9 lb), which was not statistically significant, and this numerical difference could be attributed to a 3-lb heavier body weight at the initiation of the study. Taking into account that there were no detectable differences between ADG, feed:gain, or final body weight, it follows that there were not significant differences between carcass characteristics. Quality grade is strongly impacted by marbling score and based on there being no statistical differences between marbling scores between treatments (568 vs. 552), it is consistent with expec-

tations that there would be no treatment effects on quality grades. Within the control group, there was a numerically higher percentage of prime and premium choice cattle compared to the enzyme treatment (64.5% compared to 61.2%). Differences in yield grade were not expected, considering carcass characteristics did not have a significant effect.

Implications

Feeding Pyramid PowerGrower Ruminant (Pyramid feeds, Scott City, KS) resulted in modest but nonsignificant improvements in cattle performance, nutrient digestibility, and carcass characteristics.

Acknowledgments

Funding for this study was provided by Pyramid Feeds (Scott City, KS) and the Kansas Grain Sorghum Commission. The authors would like to extend their appreciation to the technical crew at the K-State Southeast Research and Extension Center; fellow graduate students Harleigh Johnson, Stephan Knecht, Ludmila de Souza Montiero, and Firman Nasiu; and undergraduate student employees within the Preharvest Food Safety Laboratory for their assistance in conducting this experiment.

Table 1. Composition and nutrient analysis of finishing diets (% of dry matter)

Item	Control diet	Enzyme diet[1]
Ground sorghum	59.62	59.62
Sorghum-based DDGS[2]	25.00	25.00
Corn silage	12.00	12.00
Supplement[1,3]	3.38	3.38
Nutrient composition, analyzed		
Starch, %	43.20	43.20
Crude protein, %	18.85	18.85
Neutral detergent fiber, %	19.44	19.44

[1] Enzyme supplement includes Pyramid Powergrow Ruminant (Pyramid Feeds, Scott City, Kansas) in lieu of ground corn at a rate of 1.5 lb/ton of feed (86% dry matter basis). Enzyme blend consisted of the following components: 5,000 HCU/g beta mannanase; 1,200 SKB/g fungal amylase; 600 BAU/g bacterial amylase; 250 XU/g xylanase; 500 HUT/g fungal protease; 800 PC/g neutral protease; and 1,100 CU/g cellulase (values were determined from product specification document provided by Pyramid Feeds).

[2] Distillers dried grains with solubles.

[3] Supplement was formulated to provide on a dry matter basis; 1,000 IU/lb vitamin A**;** 7 IU/lb vitamin E; 10 ppm copper; 40 ppm zinc; 0.50 ppm iodine; 0.10 ppm cobalt; 0.10 ppm selenium; 40 ppm manganese; 30 g/ton Rumensin; 6 g/ton Tylan; and 300 mg/ton Optaflexx was fed the last 33 days on feed.

Table 2. Effects of enzyme blend on performance of feedlot steers fed sorghum-based diets with or without added enzymes

Item	Control	Enzyme[1]	SEM[2]	*P*-value
Initial body weight, lb	973.0	975.8	7.90	0.81
Final body weight, lb	1,343.9	1,354.5	7.66	0.34
Dry matter intake, lb/day	25.55	25.63	0.254	0.83
Average daily gain, lb/day	2.50	2.57	0.052	0.34
Feed:gain	10.30	10.02	0.179	0.29

[1] Pyramid Powergrow Ruminant (Pyramid Feeds; Scott City, Kansas) included at the rate of 1.5 lb/ton of complete diet (86% dry matter basis). Enzyme blend consisted of the following components: 5,000 HCU/g beta mannanase; 1,200 SKB/g fungal amylase; 600 BAU/g bacterial amylase; 250 XU/g xylanase; 500 HUT/g fungal protease; 800 PC/g neutral protease; and 1,100 CU/g cellulase (values were determined from product specification document provided by Pyramid Feeds).
[2] Standard error of the mean.

Table 3. Effects of an enzyme blend on carcass characteristics of feedlot steers fed sorghum-based diets with or without added enzyme

Item	Control	Enzyme[1]	SEM[2]	*P*-value
Hot carcass weight, lb	853.4	860.1	4.87	0.34
Marbling score[3]	568	552	12.3	0.32
12th rib fat thickness, in.	0.47	0.48	0.016	0.80
Ribeye area, in.^{2}	13.1	13.3	0.12	0.14
Kidney, pelvic, heart fat, %	1.84	1.82	0.015	0.47
Prime, %	24.3	22.9	4.18	0.79
Premium Choice, %	40.2	38.3	4.42	0.76
Low Choice, %	28.1	30.3	4.12	0.71
Select, %	6.4	8.1	1.97	0.51
Yield Grade 1, %	2.1	0.7	1.20	0.42
Yield Grade 2, %	37.4	40.0	4.18	0.66
Yield Grade 3. %	53.1	52.1	4.16	0.85
Yield Grade 4, %	7.4	6.5	1.79	0.70
Yield Grade 5, %	0.0	0.7	0.50	0.33
Abscessed livers, %	10.5	15.3	2.89	0.25

[1] Pyramid Powergrow Ruminant (Pyramid Feeds; Scott City, Kansas) included at the rate of 1.5 lb/ton of complete diet (86% dry matter basis). Enzyme blend consisted of the following components: 5,000 HCU/g beta mannanase; 1,200 SKB/g fungal amylase; 600 BAU/g bacterial amylase; 250 XU/g xylanase; 500 HUT/g fungal protease; 800 PC/g neutral protease; and 1,100 CU/g cellulase (values were determined from product specification document provided by Pyramid Feeds).
[2] Standard error of the mean.
[3] Slight amount of marbling, 300-399; small amount of marbling, 400-499; modest amount of marbling 500-599; moderate amount of marbling, 600-699.

Table 4. Effects of an enzyme blend on digestibility of diet components in feedlot steers fed sorghum-based diets with or without added enzymes

Digestibility, %[1]	Control	Enzyme[2]	SEM[3]	*P*-value
Dry matter	72.8	74.3	1.63	0.44
Organic matter	74.1	75.5	1.63	0.49
Starch	89.6	91.3	1.08	0.15
Protein	69.7	70.7	1.91	0.67
Neutral detergent fiber	64.4	65.1	1.95	0.77

[1] Samples were analyzed by SDK Laboratories (Huchinson, KS).
[2] Powergrow Ruminant (Pyramid Feeds; Scott City, Kansas) included at the rate of 1.5 lb per ton of complete diet (86% dry matter basis). Enzyme blend consisted of the following components: 5,000 HCU/gm beta mannanase; 1,200 SKB/gm of fungal amylase; 600 BAU/gm of bacterial amylase; 250 XU/gm of xylanase; 500 HUT/gm of fungal protease; 800 PC/gm of neutral protease; 1,100 CU/gm of cellulase (values were determined from product specification document provided by Pyramid Feeds).
[3] Standard error of the mean.

Determining the Effect of Electromagnetic Field-assisted Freezing on Shelf-stability of Beef Striploins

J.T. Looper, S.R. Hene, S.D. Lee, B.N. Flanders, T.G. O'Quinn, M.D. Zumbaugh, and M.D. Chao

Abstract

The objective of this study was to determine the effect of electromagnetic (EM) field-assisted freezing on beef color stability during the display of previously frozen beef striploins. Striploins were collected from both sides of 12 USDA Choice carcasses and halved into two equal parts (n = 48). Halves were randomly assigned to 0, 2, 4, or 8 kV of EM field and frozen under the designated treatment in a walk-in -4°F freezer for 24 hours. Following treatment, striploin halves were thawed for 72 hours to at least 32°F, fabricated into steaks, and one 1-in. steak and four ½-in. steaks from each portion were overwrapped and subjected to a 10-day simulated display. Instrumental and descriptive color measurements were taken daily. Representative steaks from each portion were frozen and powdered for lipid oxidation and antioxidant capacity analysis on days 0, 4, 7, and 10. During the display period, 4 kV samples showed less discoloration than those from 0, 2, or 8 kV treatments on days 9 and 10. For instrumental color, a^* (redness) and b^* (yellowness) were the highest ($P < 0.01$) in 4 kV samples, followed by 0 kV and 2 kV, with samples from 8 kV having the lowest values ($P < 0.01$). On the other hand, L^* (lightness) values for 0 kV and 2 kV samples were higher ($P < 0.01$) than values from 4 kV and 8 kV. A treatment effect was found for hydrophilic, lipophilic, and total antioxidant capacity values, with the 4 kV treatment having the highest hydrophilic antioxidant capacity, and the 0 kV treatment being highest for the lipophilic portion ($P < 0.01$). However, no treatment effect was found for the lipid oxidation measurement ($P > 0.10$). The improvement in post-thaw color stability and antioxidant capacity from 4 kV could be due to an EM field treatment that resulted in less cellular damage during freezing; however, further research is needed to investigate the mechanisms causing increased antioxidant capacity.

Introduction

Freezing beef has become an increasingly important practice for packers due to fluctuating beef prices. While freezing is one of the few preservation methods that retains most of the fresh product quality, freezing is well documented to negatively affect the overall quality of meat. The formation of ice crystals can tear through and disrupt the structural and cellular components of muscle tissue; thus, previously frozen beef products tend to discolor more quickly than their fresh, never frozen counterparts, decreasing consumer acceptance and product shelf-life. As meat products are frozen more slowly, these negative qualities become more pronounced due to ice crystals forming from the creation of one nucleus that has the ability to attract more water molecules and thus create larger ice crystals, resulting in greater structural damage.

To address the negative effects of slow freezing, processing aids such as the incorporation of an electromagnetic (EM) field during the freezing process have been investigated. Previous studies have reported EM fields as a promising intervention for cellular

damage control and ice crystal reduction. However, many of these studies overlooked the potential of this technology to extend the shelf life of beef. Thus, the objective of this study was to determine the effect of EM field assisted freezing on beef color stability and lipid oxidation during the retail display of previously frozen beef striploins.

Experimental Procedures

Striploins (SL) were collected from both sides of 12 USDA Choice carcasses at a commercial processing facility in Kansas over a four-day period. Whole SLs were processed on-site, vacuum packaged, and transported to the Kansas State University Meat Laboratory. On each day of collection, six striploins were halved, and each half was randomly assigned to one of four freezing treatments: 0 kV, 2 kV, 4 kV, or 8 kV. Halves were then frozen for 24 hours in a walk-in freezer at -4°F under the designated continuous EM field treatment. Following treatment, SLs were vacuum packaged and stored in the same freezer for 8 days before thawing in a walk-in cooler set at 36°F for 72 hours. All samples were thawed to at least 32°F in the geometric center, purge was collected from the vacuum package, and swabs were taken from an approximate 4 × 4 in. square for aerobic plate count (APC). The SL halves were immediately fabricated into steaks, and one 1-in. steak and four ½-in. steaks from each portion were over-wrapped and subjected to a 10-day simulated retail display under continuous fluorescent lighting. Instrumental L^* (lightness), a^* (redness), and b^* (yellowness) color measurements were taken using a HunterLab MiniScan EZ spectrophotometer on each day of display. Subjective color (percent discoloration) was also determined daily by trained panelists. Following days 0, 4, 7, and 10, one ½-in. steak from each portion was frozen with liquid nitrogen, powdered, and stored at -112°F for further analysis. These powdered samples were used to measure thiobarbituric acid reactive substances (TBARS) to determine lipid oxidation, and oxygen radical absorbance capacity (ORAC) to determine hydrophilic and lipophilic antioxidant capacity.

Results and Discussion

During the display period, an interaction between display day and EM field treatment was observed for percent discoloration ($P < 0.05$). All treatments maintained a similar level of discoloration until days 9 and 10, in which the 4 kV samples exhibited less discoloration than the 0, 2, and 8 kV treatments ($P < 0.05$; Figure 1). Main effects for treatment and display were found for L^*, a^*, and b^* ($P < 0.01$). For the display effect, overall a^* and b^* decreased steadily throughout the 10-day display while samples became increasingly lighter until day 4 and then remained constant throughout the remainder of display for all treatments ($P < 0.01$). For the treatment effect, a^* and b^* were the highest in the 4 kV group, followed by 0 and 2 kV, while the 8 kV group had the lowest values ($P < 0.01$; Table 1). The L^* values for 0 and 2 kV groups were higher than values from the 4 and 8 kV treatments ($P < 0.01$; Table 1). Finally, no differences in APC for swabs and purge were observed among the EM field treatments ($P > 0.05$). A day effect was found for antioxidant capacity and lipid oxidation values, with lipid oxidation and antioxidant capacity increasing over time ($P < 0.01$; Table 1). Interestingly, a treatment effect was found for hydrophilic, lipophilic, and total antioxidant capacity ($P < 0.01$). The 4 kV treatment had a higher antioxidant capacity for the hydrophilic portion than those from the 0, 2, and 8 kV treatments ($P < 0.01$; Table 1). For the lipophilic portion, the 0 kV treatment measured higher antioxidant capacity than those from the 2, 4, and 8 kV treatments ($P < 0.01$; Table 1). As a result, total antioxidant capacity for the 4 kV treatment was higher ($P < 0.01$) than those from 2 and 8 kV but was not different from those for the 0 kV treatment (Table 1).

The data showed that the 4 kV treatment appeared to increase hydrophilic antioxidant capacity in the sarcoplasm through an unknown mechanism, and this increase in hydrophilic antioxidants was capable of further delaying myoglobin oxidation. It is possible that the 4 kV treatment was most effective in decreasing the overall ice crystal size, thus reducing structural damage and preventing the leakage of reactive oxygen species out of various cellular compartments.

Implications

The 4 kV group showed better color stability objectively and subjectively throughout the display period, and differences in visual shelf life could not be attributed to microbial load differences. The 4 kV treatment provided a higher level of hydrophilic antioxidant capacity throughout the display. This retention in color stability provides economic incentives for beef processors; however, it is unclear as to what mechanisms caused an increase antioxidant capacity in the 4 kV treatment. Further research is needed to investigate the mechanisms that could affect color retention and antioxidant capacity in EM field-assisted frozen beef.

Acknowledgments

This research was funded by the National Cattlemen's Beef Association, a contractor to the Beef Checkoff.

Table 1. Main effect of electromagnetic field treatments on instrumental color, oxygen radical absorbance capacity (ORAC), and lipid oxidation assay of beef striploins

	0 kV	2 kV	4 kV	8 kV	SEM[1]	*P*-value[2]
*L** value	38.36[a]	38.43[a]	37.34[b]	37.67[b]	0.20	<0.01
*a** value	16.60[b]	16.28[bc]	17.17[a]	16.15[c]	0.15	<0.01
*b** value	16.18[b]	16.02[bc]	16.56[a]	15.77[c]	0.16	<0.01
Lipophilic ORAC (TE[3]/g meat)	0.54[a]	0.31[b]	0.36[b]	0.35[b]	0.04	<0.01
Hydrophilic ORAC (TE/g meat)	10.28[b]	10.10[b]	11.87[a]	9.19[b]	0.67	<0.01
Total ORAC (TE/g meat)	10.82[ab]	10.41[b]	12.23[a]	9.54[b]	0.68	<0.01
Lipid oxidation (mg MDA[4]/kg meat)	1.39	1.63	1.39	1.54	0.12	0.10

[1]SEM = standard error of least-squares means.
[2]Least-square means within a row without common superscripts differ ($P < 0.05$).
[3]TE = Trolox equivalent.
[4]MDA = malondialdehyde.

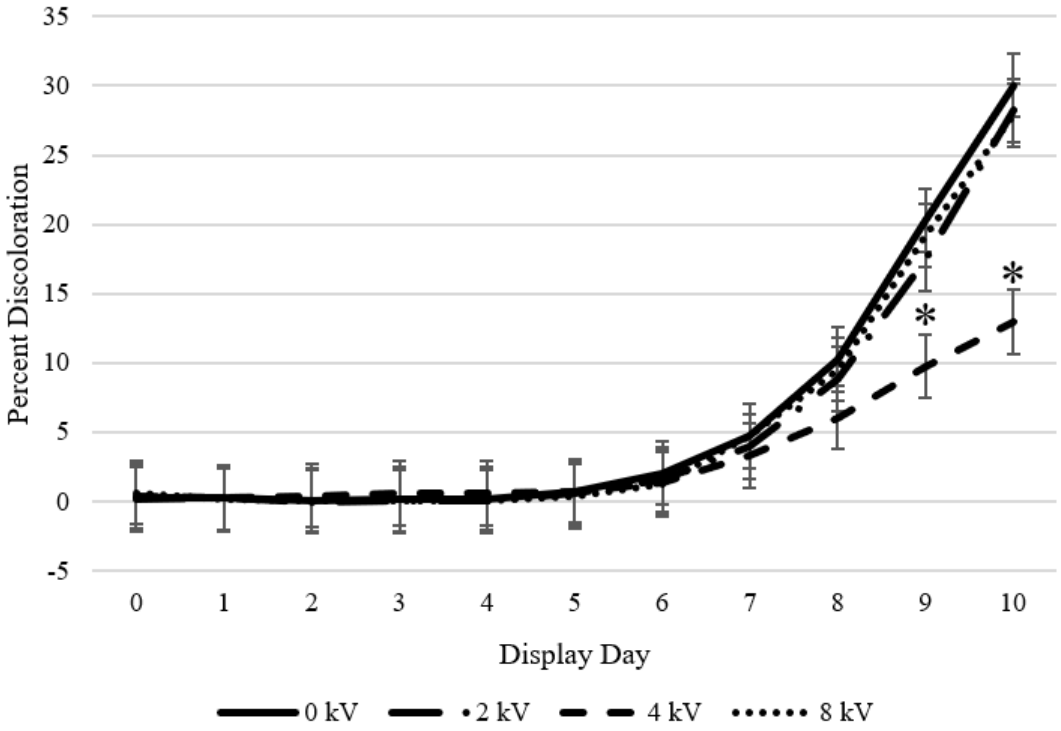

Figure 1. Interaction of display day and electromagnetic field-assisted freezing voltages on the percentage of beef striploin discoloration. The * indicate days (9 and 10) where there were significant differences in discoloration percentage in which samples from 4 kV have a lower percent discoloration compared to those from the other treatments ($P < 0.05$).

The Effects of Aging Period and Freezing Sequence on Desmin Degradation of *Longissimus lumborum, Semitendinosus,* and *Biceps femoris* Steaks

T.M. Dieball, G.E. Huber, S.F. Stickley, K.M. Gundersen[1], K.R. Maddock Carlin[1], M.D. Zumbaugh, J.L. Vipham, T.G. O'Quinn, and E.S. Beyer

Abstract

The objective of this study was to examine the impact of freezing and aging sequence on the degradation of desmin within three beef muscles across two aging periods. The *longissimus lumborum* (LL), *semitendinosus* (ST), and *biceps femoris* (BF) were fabricated, sliced into 1-in. steaks and assigned to one of four treatment combinations: age (21 days) then freeze, freeze then age (21 days), age (28 days) then freeze, or freeze then age (28 days). After treatment, steaks were ground and stored at -80˚F. Samples were thawed for protein extraction and desmin analysis. Sarcoplasmic proteins were removed, and then myofibrillar proteins, including desmin, were solubilized in sodium dodecyl sulfate buffer with protease inhibitors. Extracted proteins were analyzed via Western blotting. Polyacrylamide gels were prepared, and equal volumes of samples were loaded for electrophoresis. Proteins were transferred onto polyvinylidene membranes, blocked, and probed with primary and secondary antibodies. Bands were visualized using chemiluminescent detection and imaged with a FluorChem FC2 CCD camera. Band intensities were quantified to determine the percentage of intact and degraded desmin. There was no difference ($P > 0.05$) in intact desmin among the three muscles. The BF had a greater amount ($P < 0.05$) of degraded desmin. A two-way interaction ($P < 0.05$) was observed between freezing treatment and aging period when all muscles were combined. The 28-day freeze-then-age samples had a lower percentage ($P < 0.05$) of intact desmin compared to the 21-day age-then-freeze samples. This translated into the 21-day age-then freeze samples having the lowest percentage ($P < 0.05$) of degraded protein in bands 3 and 4. Overall, the freezing and aging sequence did not significantly impact degradation; however, extended aging increased degradation. In a previous study on the loins, there were no differences in instrumental tenderness. Thus, even with increased protein degradation, the change was not enough to affect tenderness.

Introduction

Freezing is one of the most widely used practices in the industry to maintain quality and extend beef shelf life (Kim et al., 2015). Freezing is believed to improve tenderness by the well accepted mechanism of ice crystal formation and the less studied mechanism of reducing calpastatin activity. Calpastatin is the endogenous inhibitor of the prominent enzyme, μ-calpain. Therefore, calpastatin inactivation could allow for greater proteolysis during aging, potentially impacting overall palatability (Khan et al., 2016). While most of the beef industry ages meat after harvest and before freezing, reversing the order has been hypothesized to improve tenderness by enhancing proteolytic activity; however,

[1] Animal Sciences, North Dakota State University, Fargo, ND.

the true impact on palatability remains unknown (Beyer et al., 2024; Setyabrata et al., 2019).

Protein degradation is critical to post-mortem tenderness improvement, heavily driven by enzymatic activity (Koohmaraie, 1996). One key structural protein, desmin, helps maintain muscle fiber integrity and is used as an indicator of tenderness during post-mortem proteolysis (Huff-Lonergan and Lonergan, 2005). During aging, desmin is degraded by proteolytic enzymes, such as μ-calpain, which weakens the cytoskeletal framework and improves tenderness (Huff-Lonergan and Lonergan, 2005). Freezing and thawing cycles can accelerate these processes by either inactivating enzymatic inhibitors or creating stress on the cytoskeleton, further promoting desmin degradation and potentially enhancing tenderness (Warner et al., 2017). In this study, desmin served as an indirect measure of μ-calpain activity to illuminate the freezing impact on calpastatin activity.

While the common aging period for beef carcasses is close to 21 days, some muscles remain tough and less palatable even at longer aging periods, leaving an opportunity to improve tenderness by reversing the freezing and aging order (Grayson et al., 2014). Therefore, the motivation for this study was to determine whether reversing the freezing and aging sequence could improve tenderness and increase proteolytic activity of particularly tougher muscles. To evaluate this mechanism, desmin was selected as a marker protein because its degradation reflects post-mortem proteolytic activity. Thus, this study aimed to assess how freezing and aging sequences influence desmin degradation in three different beef muscles.

Experimental Procedures

Beef carcasses (n = 12) graded USDA Choice, A maturity were selected from a Midwestern beef plant. Trimmed strip loins (Institutional Meat Purchase Specifications [IMPS] #180) and goosenecks (IMPS #170) were collected from the right side of each carcass (NAMI, 2014). The strip loins and goosenecks were transported to North Dakota State University and fabricated the day after collection. The *semitendinosus* (ST) and *biceps femoris* (BF) were separated from the goosenecks. The strip loins, ST, and BF were denuded and sliced into 1-in. steaks. Each steak was randomly assigned a four-digit code with a tag and allocated to either age-then-freeze (AF) for 21 or 28 days or freeze-then-age (FA) for 21 or 28 days. Steaks were then randomly assigned to an assay. All steaks were aged between 34 to 40˚F in the absence of light. Steaks were blast frozen in a freezer and held at -4˚F for 91 days, then placed in a refrigerator to thaw for 24 hours prior to use (if applicable). Steaks designated for protein analysis were ground and stored in a -80˚F freezer. Samples were thawed on ice and processed for desmin extraction. Samples were washed in post-rigor extraction buffer containing protease inhibitors to remove sarcoplasmic proteins, then centrifuged. Pellets were solubilized in phosphate buffer with 2% sodium dodecyl sulfate, homogenized, incubated 30 minutes, and clarified by centrifugation. The supernatant was then retained. Desmin degradation was assessed using myofibrillar protein extraction followed by Western blot analysis. Polyacrylamide gels (12.5% separating, 5% stacking) were prepared, and equal volumes of protein samples were loaded for electrophoresis. All gels did contain a reference sample for comparison. Proteins were transferred onto polyvinylidene membranes, blocked, and probed with primary and secondary antibodies. Bands were visualized using chemiluminescent detection and imaged with a FluorChem FC2 CCD camera under autoexposure. Band 1 was used to determine the total concentration of intact

desmin, while Bands 3 and 4 were used to determine the concentration of degraded desmin. Statistical analysis was conducted using SAS with PROC GLIMMIX. The experimental unit was the individual carcass. Fixed effects included muscle, freezing treatment, and aging period. Data were analyzed as a split-split plot design, where the whole-plot factor was muscle, the subplot factor was aging period, and the sub-subplot factor was freezing treatment. An alpha level of 0.05 was set for statistical significance.

Results and Discussion

Tables 1 and 2 show the abundance of multiple molecular weights of desmin indicating different levels of degradation. Band 1 was utilized to determine the amount of intact desmin which could infer less proteolytic activity and structural degradation. Bands 3 and 4 were utilized to determine the amount of degraded desmin indicating a greater amount of proteolytic breakdown. Desmin degradation revealed an interaction between freezing treatment and aging period across all muscles combined. Specifically, the 28-day FA samples had a lower percentage ($P < 0.05$) of intact desmin compared to the 21 and 28-day AF samples, indicating more proteolytic activity occurred. Similarly, the 28-day FA steaks had a greater ($P < 0.05$) amount of degraded desmin in bands 3 and 4 compared to the 21-day AF steaks. Desmin degradation is associated with post-mortem tenderization (Huff-Lonergan and Lonergan, 2005). The greater degradation observed in the 28-day FA treatment may indicate that proteolytic systems such as μ-calpain remain active and can act more extensively when aging follows freezing, particularly over extended storage times.

There was no difference ($P > 0.05$) for intact desmin among the three different muscles. However, the BF had a greater amount ($P < 0.05$) of degraded desmin compared to the LL and ST for Bands 3 and 4. These results show a conflicting relationship of proteolytic activity; however, other studies have found similar results where the degraded desmin was more sensitive than the intact desmin (Kim et al. 2015).

These results demonstrate that increasing the aging period in combination with a freeze-then-age sequence promotes greater overall degradation of the desmin protein. This outcome suggests that underlying biochemical changes are occurring at the structural protein level.

Implications

The results indicate reversing the typical aging and freezing order increases desmin degradation only when combined with additional aging time.

Acknowledgments

This project was funded by the National Cattlemen's Beef Association.

References

Beyer, E.S., L.K. Decker, E.G. Kidwell, A.L. McGinn, M.D. Chao, M.D. Zumbaugh, J.L. Vipham, and T.G. O'Quinn. 2024. Evaluation of fresh and frozen beef strip loins of equal aging periods for palatability traits. Meat and Muscle Biology 8(1):16903, 1-13. doi: *https://doi.org/10.22175/mmb.16903*

Grayson A.L., D.A. King, S.D. Shackelford, M. Koohmaraie, and T.L. Wheeler. Freezing and thawing or freezing, thawing, and aging effects on beef tenderness. 2014. Journal of Animal Science. 92(6):2735-2740. *doi: 10.2527/jas.2014-7613*

Huff-Lonergan, E., and S.M. Lonergan. 2005. Mechanisms of water-holding capacity of meat: The role of postmortem biochemical and structural changes. Meat Science 71(1):194–204. *doi:10.1016/j.meatsci.2005.04.022*

Khan M.I., S. Jung, K.C. Nam, and C. Jo. 2016. Postmortem aging of beef with a special reference to the dry aging. Korean Journal for Food Science of Animal Resources 36(2):159-69. *doi: 10.5851/kosfa.2016.36.2.159*

Kim, Y.H., C. Liesse, R. Kemp, and P. Balan. 2015. Evaluation of combined effects of ageing period and freezing rate on quality attributes of beef loins. Meat Science 110:40–45. *https://doi.org/10.1016/j.meatsci.2015.06.015*

Koohmaraie, M. 1996. Biochemical factors regulating the toughening and tenderization processes of meat. Meat Science 43(Supplement1):193-201. *doi:10.1016/0309-1740(96)00065-4*

Setyabrata, D., and Y. H. Brad Kim. 2019. Impacts of aging/freezing sequence on microstructure, protein degradation and physico-chemical properties of beef muscles. Meat Science 151:64–74. *https://doi.org/10.1016/j.meatsci.2019.01.007*

Warner, R.D., P.L. Greenwood, D.W. Pethick, and D.M. Ferguson. 2010. Genetic and environmental effects on meat quality. Meat Science 86:171-183. *doi: 10.1016/j.meatsci.2010.04.042*

North American Meat Institute. 2014. The meat buyer's guide. 8th ed. North American Meat Institute, Washington D.C.

Table 1. Least square means of relative band concentrations of desmin within steaks with two freezing treatments, two aging periods, and three muscles

Freezing treatment	Aging period	Band 1[1]	Band 3[2]	Band 4[2]
Age-then-freeze samples	21	1.01[a]	0.12[b]	0.24[b]
	28	0.92[ab]	0.14[ab]	0.34[ab]
Freeze-then-age samples	21	0.78[bc]	0.14[ab]	0.32[ab]
	28	0.59[c]	0.17[a]	0.44[a]
SEM[3]		0.07	0.01	0.04
P-value		<0.05	<0.05	<0.05

[abc] Means within the same column without a common superscript differ ($P < 0.05$).
[1] Band 1: Intact desmin.
[2] Bands 3 and 4: Degraded desmin.
[3] Standard error (largest) of the least squares means.

Table 2. Least square means of relative band concentrations of desmin within steaks within three muscles

Muscle	Band 1[1]	Band 3[2]	Band 4[2]
Biceps femoris	0.77	0.27[a]	0.74[a]
Longissimus lumborum	0.90	0.10[b]	0.16[b]
Semitendinosus	0.80	0.06[c]	0.10[b]
SEM[3]	0.06	0.01	0.04
P-value	0.32	<0.05	<0.05

[abc] Means within the same column without a common superscript differ ($P < 0.05$).
[1] Band 1: Intact desmin.
[2] Bands 3 and 4: Degraded desmin.
[3] SE (largest) of the least squares means.

The Cold Chain Question: Effects of Fresh, Frozen, and Thawed Beef Trim on Ground Beef Color and Consumer Perception

S.F. Stickley, G.E. Huber, T.M. Dieball, C.A. Effling, M.J. Prester, L.M. Frink, S.L. Witberler, K.E. Wallace, M.D. Zumbaugh, J.L. Vipham, T.G. O'Quinn, and E.S. Beyer

Abstract

Ground beef is the most widely consumed beef product in the United States, with consumer purchasing decisions heavily influenced by visual appearance. Increasing reliance on imported lean trim, often shipped frozen, raises questions about how cold chain management affects ground beef quality. This study evaluated the effects of fresh, frozen, and thawed beef trim (50%, 80%, 90% lean) ground into 80% lean patties on ground beef color, lipid oxidation, and consumer perception. Consumer visual panelists assessed the appearance desirability and purchase intent, while the instrumental measures included lipid oxidation (Thiobarbituric Acid Reactive Substances; TBARS), CIE L^* (lightness) and a^* (redness) color values, and oxymyoglobin (bright cherry-red color) percentage. Patties containing fresh trim or fresh trim combined with frozen/thawed trim were rated highest ($P < 0.05$) for appearance and purchase intent, whereas exclusively frozen treatments were least preferred ($P < 0.05$). Lipid oxidation was greatest ($P < 0.05$) in frozen treatments and lowest ($P < 0.05$) in all-fresh trim, with instrumental color results supporting these trends. These findings demonstrate that the use of frozen lean trim negatively affects ground beef color and consumer acceptance, highlighting the importance of cold chain management strategies in maintaining product quality.

Introduction

Ground beef is a versatile, affordable staple for consumers, making it the most widely consumed beef product in the United States. Maintaining its color stability and extending shelf life are therefore vital for consumer satisfaction and industry profitability. Ground beef is produced from a balance of lean and fat trimmings (90%, 50%), but recent shifts in cattle markets have made maintaining that balance increasingly more difficult. In 2025, reduced beef and dairy cow harvest decreased domestic lean trim supplies, while heavier fed cattle added more fat but little lean (USDA Agricultural Marketing Service, 2025a, 2025b). This imbalance in the United States domestic market has led to a reliance on the importation of lean trim from international markets such as Australia, Brazil, and New Zealand (USDA Agricultural Marketing Service, 2025b). Imported trim is often shipped frozen, which supports supply consistency but may alter product quality (Rehman et al., 2024). These factors can directly influence meat color, an important driver of consumer purchase intent (Lybarger et al., 2023). Little research has been conducted focusing on the cold chain management strategies of beef trim, specifically, how fresh, frozen, and thawed materials affect consumer-perceived quality and objective measures of quality. Therefore, the objective of this study was to evaluate the impact of varying combinations of fresh, frozen, and thawed beef trim on the resulting quality characteristics of ground beef.

Experimental Procedures

Boxes of beef trim of various (50%, 80%, 90%) lean percentages were procured from a commercial processing facility and brought to the Kansas State University Meat Laboratory under refrigeration (36 – 39°F). Boxes were either held fresh at 36 – 39°F, frozen at -4°F, or thawed in the absence of light from a previously frozen state at 36 – 39°F for eight days. An equal number of boxes representing each lean percentage were assigned to a cold chain treatment. Using these raw materials, the following treatments were created: frozen 50%: frozen 90% (FZ50FZ90), frozen 50%: fresh 90% (FZ50FR90), fresh 50%: frozen 90% (FR50FZ90), frozen 80% (FZ80), fresh 50%: thawed 90% (FR50TH90), thawed 50%: fresh 90% (TH50FR90), thawed 50%: thawed 90% (TH50TH90), fresh 50%: fresh 90% (FR50FR90), fresh 80% (FR80), and thawed 80% (TH80).

For treatments containing trim of two combined lean points, 15 lb of 50% lean and 60 lb of 90% lean were weighed using a platform scale (Model BBA236; Mettler Toledo, Columbus, OH) to reach the desired lean point (80% lean). Trim was first coarse ground through a 3/8-in. plate using a grinder (Model #3344; Hobart, Troy, OH), then transferred to a mixer-grinder (Model # 4246; Hobart, Troy, OH). When applicable, lean points were combined and mixed for 2 minutes, and then fine ground through a 1/8-in. plate. Approximately 10 lb of product collected sequentially from the grinder represented one batch (n = 4 batches per processing day). Each batch was formed into 1/3 lb patties, with the final 5 patties being selected for evaluation. The first package (three patties) was assigned to lab analyses. The second package (two patties) was designated for shelf-life evaluations, including consumer visual panels and objective color measurements. Due to time and labor constraints, the patty fabrication process was repeated the following day to produce a total of 8 batches per treatment. All packages were placed randomly into coffin-style cases (Model DMF8; Tyler Refrigeration Corp., Niles, MI) at 36 – 39°F under fluorescent lights (32 W Del-Warm White 3,000 K; Philips Lighting Company, Somerset, NJ).

For all sensory evaluations, panelists recorded responses on electronic tablets (Fire HD 8; Amazon, Seattle, WA) using a digital survey (Qualtrics, Provo, UT). Consumer visual panels were conducted on packages designated for shelf-life evaluation on day 3 of retail display. Each consumer (n = 64) visually evaluated one package per treatment, presented in random order within a retail display case, using a 100-point continuous line scale for overall appearance desirability (Lybarger et al., 2023). Afterward, consumers indicated purchase intent (yes/no). If the response was "No," they were asked whether they would purchase the package at a discounted price (yes/no). Objective measurements such as lipid oxidation, CIE L^* (lightness) and a^* (redness), and spectral data were also collected each day of display. Lipid oxidation was measured using the Thiobarbituric Acid Reactive Substances (TBARS) assay as outlined by Ahn et al. (1998) on packages designated for lab assays after 0 + 3 days of display. Color data were collected using a Hunter Lab Miniscan spectrophotometer (Illuminant A, 1-in aperture, 10° observer; Hunter Lab Associates Laboratory, Reston, VA) to calculate the percent oxymyoglobin (bright cherry-red color) present using the methods outlined in King et al. (2023).

Results and Discussion

Results from consumer evaluations, found in Table 1, showed FZ50FR90, FR50FR90, and FR80 samples were rated the highest ($P < 0.05$) by consumers for appearance liking and had the greatest ($P < 0.05$) percentage of consumers who would purchase the samples at retail. Samples produced from only thawed trim were rated lower ($P < 0.05$) than samples made from thawed trim combined with fresh trim. However, these treatments still rated higher ($P < 0.05$) for appearance liking than FR50FZ90, which was also rated higher ($P < 0.05$) than FZ50FZ90 and FZ80. The percentage of consumers who would purchase at retail price followed a similar trend. Treatments from all fresh trim and fresh lean trim with frozen fat trim were the highest ($P < 0.05$), followed by thawed trim treatments. Within the samples made from thawed trim, TH50FR90 and FR50TH90 had a higher ($P < 0.05$) percentage of consumers willing to purchase at retail than TH50TH90. Samples from frozen lean and fresh fat trim (FR50FZ90) were more likely to be purchased at retail ($P < 0.05$) than samples derived from only frozen trim (FZ50FZ90), with FZ80 samples being similar ($P > 0.05$) to both combinations. These findings indicate consumers preferred treatments derived from fresh or thawed trim to frozen trim. As expected, TBARS values, shown in Table 1, showed an inverse trend to consumer preferences. For frozen trim, oxidation was greatest ($P < 0.05$) in FZ80, followed by FZ50FZ90, which exceeded the oxidation of FR50FZ90 ($P < 0.05$). The TH80 treatment was higher ($P < 0.05$) than TH50FR90, with FR50TH90 being similar to both ($P > 0.05$). The lowest oxidation occurred in FR50FR90, which was only similar to TH50TH90. These results align with consumer data, as treatments combining frozen lean showed greater oxidation and reduced purchase intent.

Over the entire retail display period, FZ80 samples had the highest ($P < 0.05$) L^* values, being the lightest in color (Figure 1). On days 0, 2, 3, 4, and 5, FZ50FZ90 and FR50FZ90 were brighter ($P < 0.05$) than all other treatments except FZ80 throughout display. In contrast, TH50TH90 samples had the lowest ($P < 0.05$) L^* values from day 2 through the end of display, indicating these samples were the darkest. All treatments containing thawed trim showed an increase ($P < 0.05$) in a^* values (Figure 2) on days 4 and 5, a trend consistent with the percentage of oxymyoglobin (Figure 3). Lybarger et al. (2023) found a^* and oxymyoglobin to be highly correlated to consumer purchase intent, which aligns with the present work as FR50FR90, FR80, and FZ50FR90 had the highest ($P < 0.05$) a^* values and percentage of oxymyoglobin on the day of consumer evaluation, which showed these treatments to have the greatest consumer appearance liking and purchase intent.

Implications

These results suggest grinding trim from a frozen state rather than incorporating fresh or thawed trim reduces consumer purchase intent, increases oxidation, and leads to reduced color stability, emphasizing the risks of frozen trim in ground beef quality.

Acknowledgments

Research coordinated by the National Cattlemen's Beef Association, a contractor to the Beef Checkoff.

References

Ahn, D.U., D.G. Olson, C. Jo, X. Chen, C. Wu, and J.I Lee. 1998. Effect of muscle type, packaging, and irradiation on lipid oxidation, volatile production, and color in raw pork patties. Meat Science 49(1):27–39. doi: *https://doi.org/10.1016/S0309-1740(97)00101-0*

King, D.A., M.C. Hunt, S. Barbut, J.R. Claus, D.P. Cornforth, P. Joseph, Y.H. Brad Kim, G. Lindahl, R.A. Mancini, M.N. Nair, K.J. Merok, A. Milkowski, A. Mohan, F. Pohlman, R. Ramanathan, C.R. Raines, M. Seyfert, O. Sørheim, S.P. Suman, and M. Weber. 2023. American Meat Science Association guidelines for meat color measurement. Meat and Muscle Biology 6(4):12473, 1-81. doi: *https://doi.org/10.22175/mmb.12473*

Lybarger, K.R., E.S. Beyer, K.J. Farmer, L.A. Egger, L.N. Drey, M.C. Hunt, J.L. Vipham, M.D. Zumbaugh, M.D. Chao and T.G. O'Quinn. 2023. Determination of consumer color and discoloration thresholds for purchase of representative retail ground beef. Meat and Muscle Biology 7(1):16757, 1-19. doi: *https://doi.org/10.22175/mmb.16757*

Rehman, S.U., J.K. Seo, M. Romanyk, D.J. Shin, and Y.H.B. Kim. 2024. Impacts of stepwise aging/freezing process and repeated freezing on meat quality, physico-chemical and biochemical properties, and sensory attributes of beef loins. Meat and Muscle Biology, 8(1):18294, 1-18. doi: *https://doi.org/10.22175/MMB.18294*

USDA Agricultural Marketing Service. 2025a. Estimated weekly meat production under federal inspection. *www.ams.usda.gov/market-news/livestock-poultry-grain*

USDA Agricultural Marketing Service. 2025b. Imported meat passed for entry in the U.S. by country. *www.ams.usda.gov/market-news/livestock-poultry-grain*

Table 1. Least-squares means for consumer appearance liking, percentage of consumers who would purchase at a retail or discounted price, and Thiobarbituric Acid Reactive Substances (TBARS) on day 3 of retail display

Treatment[1]	Appearance liking[3]	% Retail[4]	% Discounted[5]	TBARS[6]
FZ50FZ90	17.78^{e}	3.1^{f}	14.5^{cd}	2.71^{b}
FZ50FR90	81.69^{a}	93.8^{a}	75.0^{ab}	0.68^{e}
FR50FZ90	29.85^{d}	14.1^{e}	23.6^{bcd}	2.26^{c}
FZ80	14.35^{e}	4.7^{ef}	4.9^{d}	3.06^{a}
FR50TH90	59.77^{b}	56.3^{bc}	46.4^{abc}	0.78^{de}
TH50FR90	62.94^{b}	67.2^{b}	76.2^{a}	0.67^{e}
TH50TH90	42.67^{c}	32.8^{d}	39.5^{abc}	0.55^{ef}
FR50FR90	85.66^{a}	95.3^{a}	33.3^{abcd}	0.40^{f}
FR80	84.82^{a}	95.3^{a}	66.7^{abc}	0.65^{e}
TH80	47.81^{c}	45.3^{cd}	40.0^{abc}	1.00^{d}
SEM[2]	5.72	6.2	27.2	0.12
P - value	< 0.01	< 0.01	< 0.01	<0.01

[a-f]Least-squares means within the same column without a common superscript differ ($P < 0.05$).
[1]FZ50FZ90 = frozen 50%: frozen 90%; FZ50FR90 = frozen 50%: fresh 90%; FR50FZ90 = fresh 50%: frozen 90%; FZ80 = frozen 80%; FR50TH90 = fresh 50%: thawed 90%; TH50FR90 = thawed 50%: fresh 90%; TH50TH90 = thawed 50%: thawed 90%; FR50FR90 = fresh 50%: fresh 90%; FR80 = fresh 80%; and TH80 = thawed 80%.
[2]Standard error (largest) of least-squares means. SEM = standard error of the mean.
[3]Sensory scores: 0 = extremely dislike; 100 = extremely like.
[4]Percentage of consumers who would purchase at retail price.
[5]Percentage of the consumers who would not purchase at retail price but would purchase at a discounted price.
[6]TBARS values reported as mg MDA/kg.

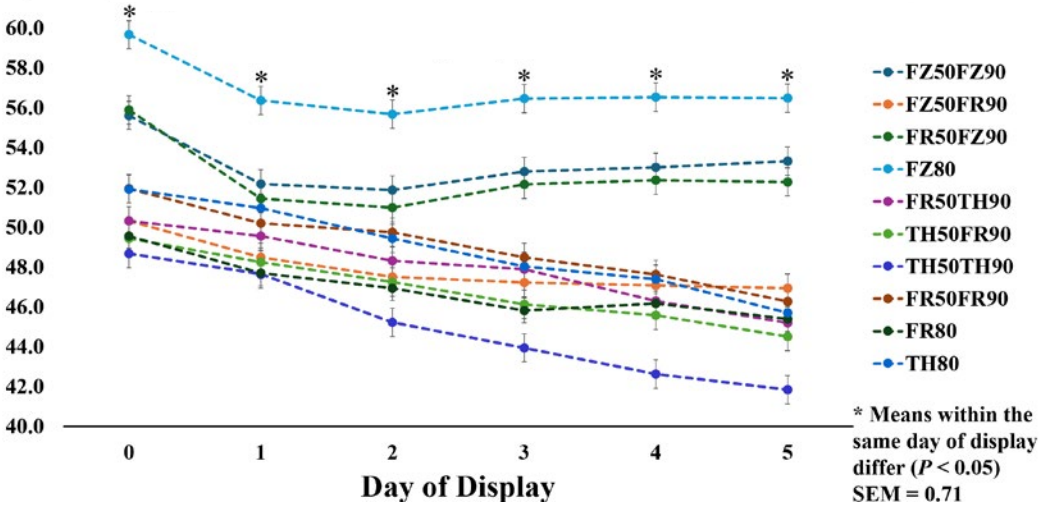

Figure 1. *L values by treatment across a retail display period**

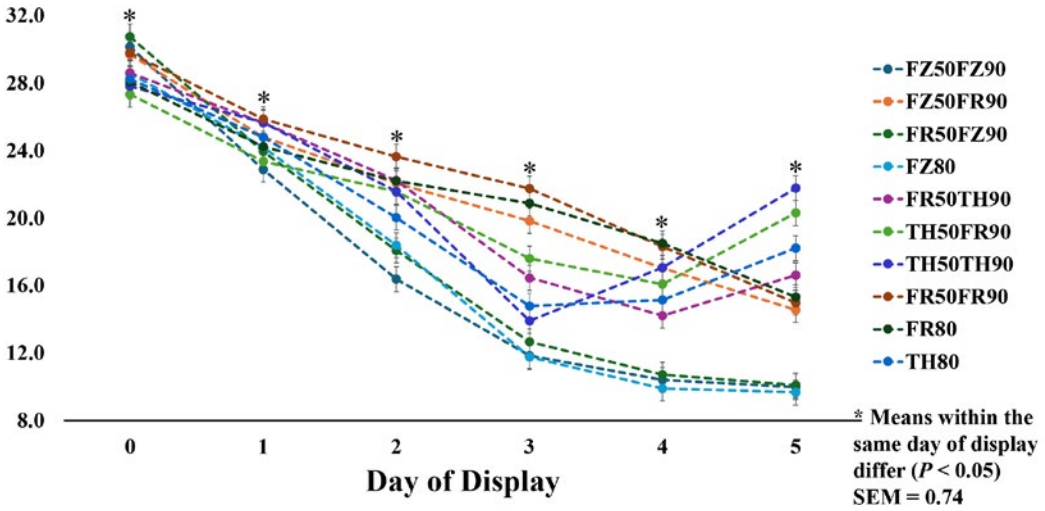

Figure 2. *a values by treatment across a retail display period**

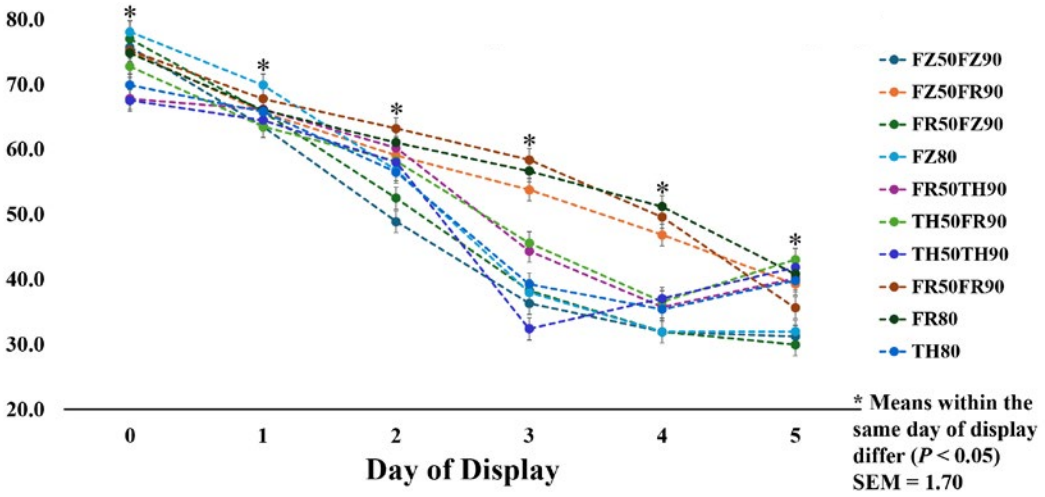

Figure 3. Percentage of oxymyoglobin by treatment across a period of retail display.

What's the Beef with Consumer Appeal?

K.G. Garrett, S.L. Witberler, G.E. Huber, E.S. Beyer, J.L. Vipham, M.D. Zumbaugh, and T.G. O'Quinn

Abstract

The objective of this study was to determine the specific color consumers most prefer as the appealing bright, cherry-red beef color. Color samples were created from an original hexadecimal color code value that was assumed to be the most ideal bright, cherry-red beef color to encompass variations of beef color consumers may experience in a retail setting. A 5 × 5 color grid was designed from the original hex that examined darker tones of red to the left, brighter shades vertically, lighter hues to the right, and duller tones downward from the central hex. Each distinguishing trait of darkness, brightness, lightness, and dullness contained two samples of each color deriving from the original hex to produce nine base color squares. From the nine basic colors, four additional hexes were developed stemming from two traits within each quadrant. Consumers were given a survey with 10 randomly selected color samples and evaluated for their overall liking of the color, and they were asked if they would purchase beef steaks in retail if it were the given color. For consumer liking results, samples were compared horizontally (A, B, C, D, and E) based on darkness to lightness and vertically based on brightness to dullness. For row A, A2 resulted in a higher ($P < 0.05$) overall liking score compared to A1 (darkest) and A5 (lightest), being similar ($P > 0.05$) to A3 and A4. As the hexes became duller than row C, the consumers shifted their overall liking scores to favor the lighter hexes. Overall, the results indicate consumers favor moderately light and bright hexes over dark hexes, regardless of brightness, with extremes in lightness and especially darkness being undesirable to consumers.

Introduction

Meat color is a major factor influencing consumer purchasing decisions for beef in the retail case (Harr et al., 2022). Consumers typically associate a bright, cherry-red color with fresh, high-quality products, which influences the decision to purchase (Killinger et al., 2004). Retailers and meat processors strive to maintain this optimal color to maximize sales and meet consumer expectations. Although this preferred beef color is recognized, minimal research has been conducted to precisely define the specific hexadecimal code value that consumers prefer. Establishing a standardized color reference could provide valuable insights for the meat industry, bridging the gap between consumer perception and color identity.

Experimental Procedures

Color samples (n = 25) were developed to represent variations of beef originating from a hexadecimal code (hex) that was presumed to be the ideal bright, cherry-red beef color. To explore the influence of color attributes on consumer perceptions, the original hex was systematically modified by adjusting the brightness and contrast levels, resulting in a 5 × 5 color grid. The color sample development encompassed horizontal (A, B, C, D, and E) and vertical (1, 2, 3, 4, and 5) adjustments. From the central hex, two successive samples were generated to the left, each incrementally darker, simulating darker-red tones. Conversely, the two samples to the right were progressively lighter, depicting paler-red hues. Similarly, moving upward from the central hex, two samples were

incrementally brightened to enhance vibrancy, while two samples downward from the central hex were dulled to represent muted red tones. With nine colors creating a base, four additional hexes were developed based on the interaction of two traits. For dark, bright red, samples A1, A2, B1, and B2 were designed. Light, bright reds were formed in samples A4, A5, B4, and B5. Dark, dull reds were created as D1, D2, E1, and E2. Lastly, light, dull reds were represented from samples D4, D5, E4, and E5. A comprehensive survey using a square sample of each color against a black background was formed using the Qualtrics platform. Consumers (n = 192) were presented with a random selection of ten color samples out of the 25 developed. For each sample, consumers were asked to evaluate the color as if they were purchasing beef at retail by determining their overall liking and purchasing intent. The overall liking was determined using a 100-point line scale where 0 indicated extremely dislike, and 100 signified extremely like. Also, consumers were asked if they would purchase a beef steak (yes/no) with the selected color to determine purchasing intent. To ensure consistency, the survey was conducted on electronic tablets with a constant screen brightness. Data were analyzed using SAS PROC GLIMMIX as a completely randomized design using the SLICE function to restrict comparisons within rows and columns. Alpha was set at 0.05.

Results and Discussion

For the consumer liking results (Figure 1), samples were compared horizontally based on darkness to lightness and vertically based on brightness to dullness. For horizontal comparisons, each row (A, B, C, D, and E) contained samples numbered 1 - 5, with each compared to the others. For row A, A2 resulted in a higher ($P < 0.05$) overall liking score compared to A1 (darkest) and A5 (lightest) and was similar ($P > 0.05$) to A3 and A4. In row B, B2, B3, B4, and B5 were all scored similar ($P > 0.05$) and higher ($P < 0.05$) than B1, which was the darkest. Similarly, for row C, C3 was rated higher ($P < 0.05$) than C1 (darkest), and C5 (lightest), while being similar ($P > 0.05$) to C2 and C4. As the hexes became duller than C, the consumers shifted their overall liking scores to favor the lighter hexes. In row D, the consumers rated D3 and D4 higher ($P < 0.05$) than D1 and D2, which were the two darkest hexes. Following the same trend, for row E, E3, E4, and E5 were all rated higher ($P < 0.05$) than the darkest hexes of E1 and E2.

Additionally, the color samples were analyzed vertically, comparing brightness to dullness, within columns 1, 2, 3, 4, and 5 (Figure 1). In column 1, the darkest column, consumers preferred A1, the brightest hex, ($P < 0.05$) and decreased in liking descending to E1 (dullest). Similarly, column 2 displayed the same behavior, with consumers favoring ($P < 0.05$) the brightest hex and decreasing liking down the column. For column 3, A3, B3, C3, and D3 were all rated higher ($P < 0.05$) than E3 (dullest). In the lighter-colored column 4, consumers preferred brighter hexes over the duller hexes. The brighter shades of A4, B4, and C4 were similar ($P > 0.05$) and all preferred ($P < 0.05$) over the duller hexes of D4 and E4. In column 5, B5 was rated higher ($P < 0.05$) than A5 (brightest), D5, and E5 (dullest), with C5 being similar ($P > 0.05$). The consumer purchasing intent results demonstrated similar findings as the consumer liking results.

For both consumer liking and purchasing intent scores (Figure 2), consumers favored the moderately light and bright hexes over the dark hexes regardless of brightness. However, as the hexes became duller, the consumers became even more critical of the

darker hexes. The assumed descriptor of bright, cherry-red beef preferred by consumers was identified as brighter-colored (Hex number: #C10100) beef that was moderate in darkness, with the extremes in lightness and especially darkness not being desirable to consumers.

Implications

Consumers prefer moderately light and bright shades of beef color over darker hues. As beef color becomes darker, consumers become more critical regardless of brightness.

References

Harr, K.M., E.S. Beyer, K.J. Farmer, S.G. Davis, M.D. Chao, J. L. Vipham, M.D. Zumbaugh, and T.G. O'Quinn. 2022. Impact of disclosing fat content, primal source, and price on consumer evaluation of ground beef. Meat and Muscle Biology 6(1):15482, 1–17. https://doi.org/10.22175/mmb.15482

Killinger, K.M., C.R. Calkins, W.J. Umberger, D.M. Feuz, and K.M. Eskridge. 2004. Consumer visual preference and value for beef steaks differing in marbling level and color. Journal of Animal Science 82(11):3288–3293. https://doi.org/10.2527/2004.82113288x

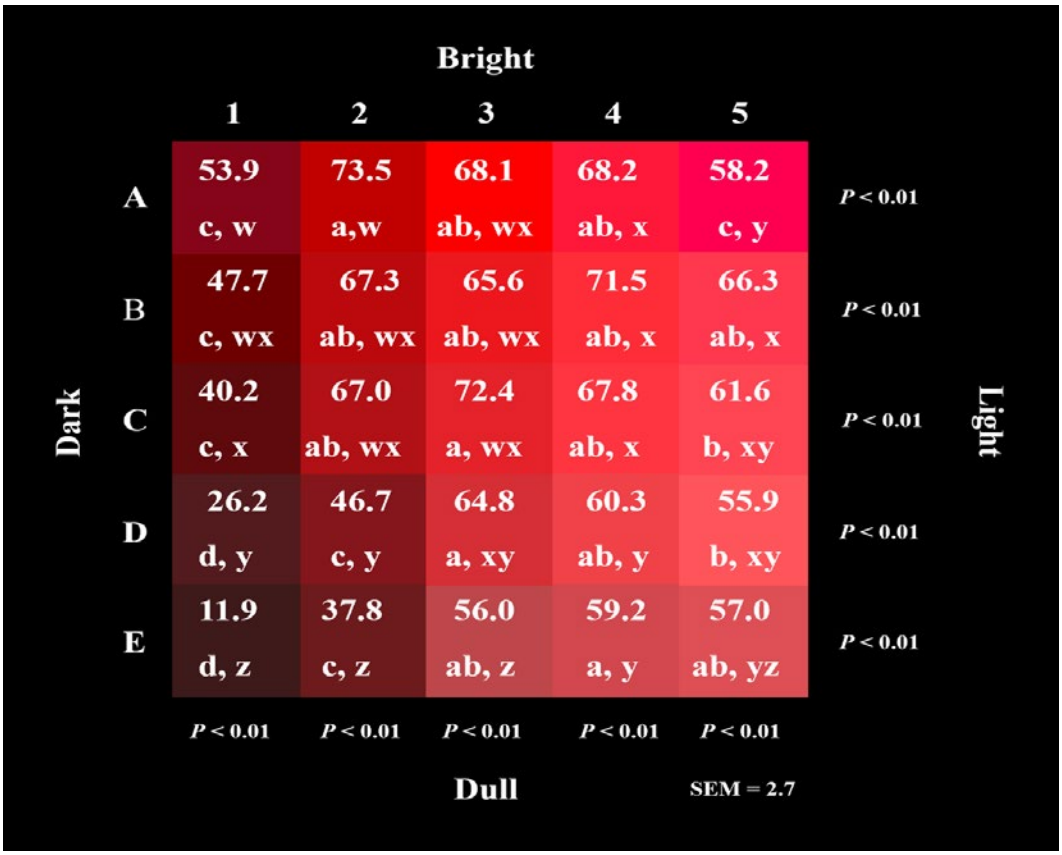

Figure 1. Consumer liking results of the various shades of beef color. Scale: 0 = extremely dislike, 100 = extremely like.

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

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

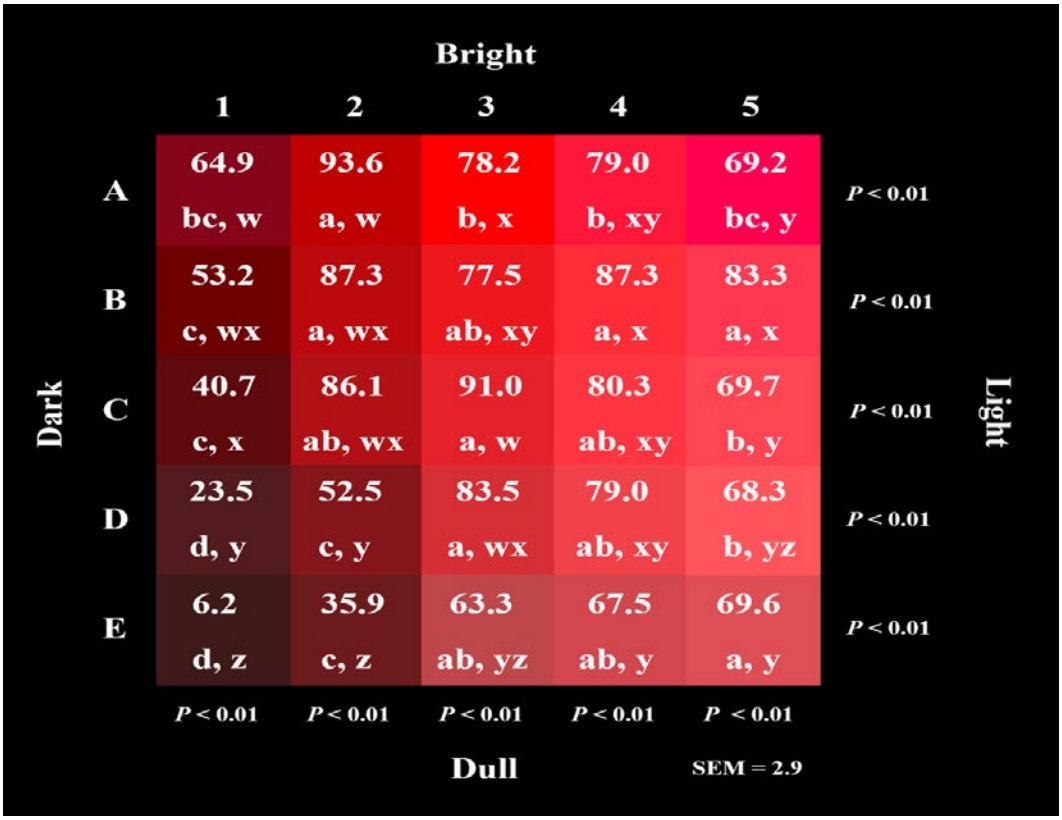

Figure 2. Consumer purchase intent results of the various shades of beef color. Values indicate percent of consumers who indicated they would purchase.

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

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

Hey Good Looking, How Have You Been Cooking? The Role of Cooking Method on Cooked Color and Palatability of Beef Steaks

G.E. Huber, S.F. Stickley, T.M. Dieball, C.A. Effling, M.D. Zumbaugh, J.L. Vipham, T.G. O'Quinn, and E.S. Beyer

Abstract

Cooking method and degree of doneness (DOD) are crucial in determining beef palatability, affecting key sensory attributes such as juiciness, tenderness, flavor, and color. While various cooking methods are commonly used to prepare beef, their impact on appearance at different DOD remains a point of interest, as consumers often rely on both internal and external color to assess doneness, shaping their expectations and overall eating experience. Thus, the objective of this study was to determine the palatability and appearance differences between six cooking methods and two DOD. Paired beef strip loins were denuded into the *longissimus lumborum* (LL) and sliced into 1-in. steaks, and then randomly assigned one of six cooking methods (sous vide, oven, grill, flat-top, clamshell, or air fryer) and a DOD (medium rare [MR, 145°F] or well done [WD, 170°F]). Steaks were aged 21 days at 40°F in the absence of light and then frozen at 40°F until use. Steaks were thawed for 24 hours and then cooked to their designated DOD, where end-point temperatures were monitored with a Thermapen. Consumers (n = 96 per DOD, n = 192 total) evaluated six samples using a 100-point line scale for juiciness, tenderness, flavor, overall liking, and overall appearance. Acceptability (acceptable/unacceptable) was determined for each trait. Consumers were asked about the visual expectations by determining (yes/no) if the steak's appearance matched the expected DOD. Consumers determined oven steaks were juicier and more tender ($P < 0.05$) than all other cooking methods, although overall liking did not differ ($P > 0.05$). Across methods, MR steaks were consistently rated higher ($P < 0.05$) than WD for juiciness, tenderness, flavor, and appearance, except for flat-top flavor ratings. Cooking method influenced the appearance ratings and visual expectations of DOD, suggesting that despite similar endpoint temperatures, differences in internal and external color influenced consumer perception and acceptability.

Introduction

Meat color is widely recognized as one of the most important attributes for consumers, spanning from purchase through consumption (Beyer et al., 2024; Prill et al., 2019a). While raw meat color has been extensively studied, the cooked color of whole muscles remains relatively underexplored. Cooked color refers to the visual appearance of a steak, both internally and externally (Beyer et al., 2024). This trait directly impacts the eating experience by shaping consumer expectations of quality (Prill et al., 2019b). Importantly, it is the final pigment state at the time of consumption rather than the initial internal color that most strongly influences perception (Garber et al., 2000). Because of its central role in consumer satisfaction and perceived product quality, further research on cooked color is warranted.

Cooked color also represents a continuum of degrees of doneness, each carrying specific consumer expectations (Prill et al., 2019b). The concept of DOD was developed to standardize consistency in steak preparation, whether ordered at restaurants or cooked at home (Prill et al., 2019a). Defined by a range of internal peak temperatures from rare to well-done, these categories generally correspond with predictable internal colors (Prill et al., 2019a). The DOD is particularly important because it aligns with consumer preferences for flavor, texture, juiciness, and color, all of which contribute to the eating experience (Prill et al., 2019b).

Besides intrinsic carcass factors and DOD, the cooking method is the next most influential factor for palatability. While some studies have evaluated the impact of cooking method on beef flavor, internal or external color remains unmeasured. Cooking method is one of the primary factors that consumers have control over in producing a highly palatable beef product for consumption (Vierck et al., 2021). Different heat-transfer mechanisms and surface heating profiles can produce steaks that reach the same DOD yet differ in surface browning, internal color, and external appearance, differences consumers readily perceive as changes in palatability (Miller et al., 2023; Sepulveda et al., 2019; Prill et al., 2019b). While various cooking methods are commonly used to prepare beef, their impact on palatability and appearance at different DOD remains a point of interest. Therefore, the goal of this study was to determine the palatability and appearance differences between six cooking methods and two degrees of doneness.

Experimental Procedures

Paired beef strip loins (n = 12; Institutional Meat Purchase Specifications #180 [North American Meat Institute, 2014]). were collected at a commercial beef processing plant (USDA Choice, A Maturity) and transported to Kansas State University. Strip loins were denuded into the *longissimus lumborum* (LL) and sliced into 1-in. steaks. Steaks were randomly assigned to one of six cooking methods (sous vide, oven, grill, flat-top, clamshell, or air fryer) and a DOD (medium rare [MR, 145°F] or well done [WD, 170°F]). Steaks were aged for 21 days at 39.2°F in the absence of light and then frozen at -40°F until use. Prior to cooking, all steaks were thawed under refrigeration for 24 hours at a temperature of 35-40°F to ensure even and consistent internal temperatures during thermal preparation. Following thawing, steaks were cooked using one of the six previously described cooking methods. Each cooking method was carefully standardized in a preliminary study to ensure repeatability and accurate comparisons between treatments. Steaks were cooked to either a MR or WD degree of doneness, with internal temperatures verified using calibrated thermocouples or digital thermometers. For all cooking methods, endpoint temperatures were verified by inserting a Thermapen digital thermometer into the geometric center of each steak. Final internal temperature targets were 145°F for MR and 170°F for WD, consistent with industry standards.

Steaks designated for air frying were cooked at 400°F using a preheated Chefman ExacTemp Digital Air Fryer with temperature probe (Type K Thermaworks probe), continuously monitored and inserted into the geometric center of each steak. Steaks were flipped once during cooking, with MR steaks flipped at an internal temperature of 90°F and WD steaks at 115°F. Cooking continued until internal target temperatures of 135°F for MR and 165°F for WD were reached, steaks were removed from the air fryer, and final endpoint temperatures were recorded. Oven (Blodgett Dual Flow) and grill (Char-Broil Grill2Go X200) steaks were prepared at an ambient cooking temperature

of 350°F. Steaks were flipped once during the cooking process, with MR steaks turned at 85°F and WD steaks at 95°F. Cooking proceeded until internal temperatures reached 135°F for MR and 165°F for WD, where steaks were removed from the heat. Final endpoint temperatures were monitored using a Thermapen digital thermometer to ensure consistency across replicates. Flat-top (CPG Electric Countertop Griddle) steaks were cooked at 350°F, with surface temperature verified using an infrared thermometer. Steaks were cooked using a Cast Iron Construction Grill Press to aid in cooking. The MR steaks were flipped at an internal temperature of 85°F and removed at 135°F, while WD steaks were flipped at 90°F and removed at 165°F. Internal temperatures were recorded using a Thermapen inserted into the geometric center of each steak. Clamshell (Cuisinart Gridler Deluxe) steaks were cooked at 350°F between two heated plates without flipping, allowing for the simultaneous cooking of both sides. Steaks were monitored using a Thermapen thermometer and removed once internal temperatures of 135°F (MR) or 165°F (WD) were achieved. Sous vide (Anova Sous Vide Precision Cooker) steaks were vacuum-sealed, placed in food-grade plastic bags, and submerged in a water bath maintained at a constant temperature of 135°F for MR and 155°F for WD. All sous vide samples were cooked for one hour. Following the water bath, steaks were removed from their packaging and seared on a preheated flat-top at 350°F for approximately 30 seconds per side. After searing, internal temperatures were measured using a Thermapen, with MR steaks removed from the flat-top at 140°F and WD steaks at 167°F.

Consumers (n = 96 per DOD, n = 192 total) evaluated six samples (one per cooking method within each DOD) using a 100-point line scale and anchors were designated on both ends as well as at the midway point with descriptive terms for each, with 0 being extremely dry, tough, and dislike extremely and 100 being extremely juicy, tender, and like extremely. Acceptability (acceptable/unacceptable) was determined for each trait. Consumers were asked about the visual expectations by determining (yes/no) if the steak's appearance matched the expected DOD. Data were analyzed using SAS PROC GLIMMIX using a split-plot design, with cooking method as a whole-plot factor and DOD as the subplot factor. Alpha was set at 0.05.

Results and Discussion

All consumer sensory results data are found in Table 1. The consumers determined the oven steaks were juicier ($P < 0.05$) than the flat-top, air fryer, sous vide, and grill steaks, while being rated similar ($P > 0.05$) for juiciness compared to clamshell, consistent with the findings of Vierck et al. (2021) where oven and grill steaks were rated more tender and juicer ($P < 0.05$) than clamshell steaks. Similarly, oven samples were rated the most tender ($P < 0.05$) compared to all other cooking methods. There was an interaction ($P < 0.05$) between cooking method and DOD for flavor liking. The MR grill steaks had a higher ($P < 0.05$) flavor rating compared to all cooking methods within the WD DOD, as well as the MR sous vide and clamshell steaks. Vierck et al. (2021) also found that consumers rated grill steaks higher than clamshell steaks, consistent with the findings in this study. Within each cooking method, besides the flat-top, consumers rated the MR samples higher for flavor liking ($P < 0.05$) compared to the WD samples. The flat-top samples were rated similarly ($P > 0.05$) between the MR and WD DOD. Even though consumers found differences ($P < 0.05$) in juiciness, tenderness, and flavor liking among the cooking methods, these did not ($P > 0.05$) illicit an impact on the

overall liking scores. Consumers rated the highest ($P < 0.05$) percentage of steaks from the oven and clamshell as acceptable for juiciness. Similar to the overall liking results, the percentage of consumers who rated samples as acceptable for the remaining traits were similar ($P > 0.05$) among cooking methods.

DOD influenced all sensory attributes evaluated by consumers ($P < 0.05$). As expected, the MR steaks were rated higher ($P < 0.05$) than WD steaks for all traits: juiciness, tenderness, flavor, overall liking, and overall appearance. Subsequently, the percentage of consumers that rated each sample as acceptable for all traits (juiciness, tenderness, flavor, overall liking, and overall appearance) was higher ($P < 0.05$) in the MR samples than the WD.

This study aimed to understand the effect of cooking method on appearance rating and acceptability. Oven and flat-top steaks had a higher ($P < 0.05$) overall appearance rating compared to the clamshell, sous vide, and air fryer steaks, while being similar ($P > 0.05$) to the grill. However, there was an interaction ($P < 0.05$) for the visual expectation of the steaks when consumers were asked if it met their criteria for a MR or WD DOD. The WD air fryer steaks resulted in a higher ($P < 0.05$) percentage of consumers who determined it met their visual expectations compared to all treatment and DOD combinations, besides ($P > 0.05$) the sous vide cooked to a WD DOD.

Although consumers perceived juiciness, tenderness, flavor, and overall appearance differently for some cooking methods, the cooking method had no effect on overall liking. While the MR DOD rated higher than the WD DOD for almost all sensory traits, consumers found no difference between the two DODs for flavor liking scores within the flat-top steaks. Most interestingly, consumers determined differences in appearance within each DOD, indicating that while each cooking method resulted in similar end point temperatures, the cooking method impacted internal and external color, influencing the consumer's preference. This was supported by the interaction between DOD and cooking method for visual expectations where consumers determined that DOD and cooking method influenced the visual DOD.

Implications

While this project identified a relationship between cooking method, DOD, and consumer preferences, the cooked color attributes must be explored to understand the comprehensive implications for the consumer and food service industry.

References

Beyer, E.S., K.J. Farmer, E.G. Kidwell, S.G. Davis, K.M. Harr, M.D. Chao, M.D. Zumbaugh, J.L. Vipham, M.C. Hunt, and T.G. O'Quinn. 2024. Change in myoglobin denaturation and physiochemical properties among three degrees of doneness and three beef whole muscles. Meat and Muscle Biology 8(1):16919, 1-12. doi: *https://doi.org/10.22175/mmb.16919*

Garber, L.L., E.M. Hyatt, and R.G. Starr. 2000. The effects of food color on perceived flavor. Journal of Marketing Theory and Practice 8:59–72. *doi:10.1080/10696679.2000.11501880*

Miller, R.K., R.A. Gray, C.R. Kerth, K. Adhikari, and J. Neal. 2023. Descriptive beef flavor attributes and consumer acceptance relationships for heavy beef eaters. Meat and Muscle Biology 7(1):14449, 1-15. doi: *https://doi.org/10.22175/mmb.14449*

North American Meat Institute. 2014. The meat buyer's guide. 8th ed. North American Meat Institute, Washington D.C.

Prill, L.L., L.N. Drey, E.A. Rice, B.A. Olson, J.M. Gonzalez, J.L. Vipham, M.S. Chao, P. Bass, M. Colle, and T. O'Quinn. 2019a. Do published cooking temperatures correspond with consumer and chef perceptions of steak degrees of doneness? Meat and Muscle Biology 3(1):510–525. doi: https://doi.org/10.22175/mmb2019.09.0040

Prill, L.L., L.N. Drey, B.A. Olson, E.A. Rice, J.M. Gonzalez, J.L. Vipham, M.D. Chao, P. D. Bass, M.J. Colle, and T. G. O'Quinn. 2019b. Visual degree of doneness impacts beef palatability for consumers with different degree of doneness preferences. Meat and Muscle Biology 3(1). doi: https://doi.org/10.22175/mmb2019.07.0024

Sepulveda, C.A., A. Garmyn, J. Legako, and M.F. Miller. 2019. Cooking method and USDA quality grade affect consumer palatability and flavor of beef strip loin steaks. Meat and Muscle Biology 3(1):375–388. doi: https://doi.org/10.22175/mmb2019.07.0031

Vierck, K.R., J.F. Legako, and J. C. Brooks. 2021. Evaluation of dry-heat cookery method on volatile flavor compound development and consumer evaluation of six beef muscles. Meat and Muscle Biology 5(1):20, 1–14. doi: https://doi.org/10.22175/mmb.11710

Table 1. Least squares means (n = 12) of consumer (n = 96) sensory panelist palatability ratings[1] for six cooking methods and two degrees of doneness

	Juiciness	Tenderness	Flavor	Overall liking	Overall appearance
Degree of doneness					
Medium rare, 145°F	68.22^{a}	67.83^{a}	66.23^{a}	67.04^{a}	67.15^{a}
Well-done, 170°F	47.18^{b}	56.40^{b}	56.12^{b}	54.62^{b}	58.43^{b}
SEM[2]	1.92	1.94	2.52	2.48	2.73
P-value	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Cooking method					
Sous vide	53.02^{c}	62.41^{b}	60.16^{ab}	60.25	60.51^{bc}
Oven	66.22^{a}	69.16^{a}	63.82^{a}	65.11	66.42^{a}
Flat-top	58.43^{bc}	61.22^{b}	56.88^{a}	62.30	66.42^{a}
Air fryer	53.51^{c}	58.57^{b}	56.88^{b}	56.70	58.98^{c}
Grill	52.94^{c}	58.57^{b}	63.77^{a}	60.47	63.86^{ab}
Clamshell	62.09^{ab}	62.75^{b}	58.03^{b}	60.17	60.56^{bc}
SEM[2]	3.14	2.40	2.56	2.55	2.24
*P-v*alue	< 0.01	< 0.01	0.01	0.05	< 0.01

^{abc} Means within the same column without a common superscript differ ($P < 0.05$).
[1]Sensory scores: 0 = extremely dry/tough/dislike; 50 = neither dry nor juicy, neither tough nor tender, neither like nor dislike; 100 = extremely juicy/tender/like extremely.
[2]SEM (largest) of the least squares means.

Consumer Preferences for Eating Quality of USDA Prime Beef Differentiated into Tiers

C.A. Effling, L.M. Frink, M.J. Prester, S.L. Witberler, K.E. Wallace, G.E. Huber, S.F. Stickley, E.S. Beyer, M.D. Zumbaugh, J.L. Vipham, and T.G. O'Quinn

Abstract

USDA Prime carcass numbers have risen steadily since the early 2000s, but the grade remains undifferentiated in value-based marketing programs. As Prime availability grows, opportunities exist to capture added value by differentiating this grade, similar to USDA Choice. Therefore, the objective of this study was to evaluate consumer palatability preferences of strip loin steaks from upper 2/3 Prime (Super Prime), Low Prime, Top Choice, and Low Choice across three degrees of doneness (DOD): Rare, Medium, and Well-done. Beef strip loins (n = 15/grade) were collected from a commercial packing facility and fabricated into 1-in. steaks, aged for 28 days, and assigned to a DOD. Consumer panelists (n = 192) rated samples for juiciness, tenderness, flavor, and overall liking using 100-point line scales and indicated acceptability for each trait. There were no ($P > 0.05$) interactions between quality grade and DOD for any consumer-evaluated traits. Super Prime steaks were rated higher ($P < 0.05$) for all sensory traits evaluated by consumers compared to all other grades. Low Prime, Top Choice, and Low Choice did not differ ($P > 0.05$) for juiciness, flavor, or overall liking, although Low Prime was more tender ($P < 0.05$) than Low Choice. A higher percentage ($P < 0.05$) of Super Prime samples were rated as acceptable for juiciness, flavor, and overall liking than all other quality grades. Rare steaks were juicier and more tender ($P < 0.05$) than Medium and Well-done steaks, while Medium and Well-done samples were similar ($P > 0.05$) for those traits. These results indicate that consumers preferred the eating quality of upper 2/3 Prime steaks over the other grades evaluated and support the opportunity for a premium program within the Prime grade, offering the beef industry an opportunity to capture added value from this highest grade within beef.

Introduction

Over the past 25 years, the U.S. beef industry has experienced a steady improvement in carcass quality, most notably in the increased percentage of carcasses grading USDA Prime. During this time, the percentage of carcasses grading USDA Prime has increased by more than 7%, and the percentage of carcasses grading USDA Choice has risen by more than 17% (USDA-AMS, 2024). As a result, the percentage of carcasses grading USDA Select has decreased by more than 25% (USDA-AMS, 2024). Despite this shift, most differentiated value-based marketing programs continue to emphasize Choice carcasses, with Prime often treated as a single, undifferentiated category. As Prime availability grows, there is an opportunity to better characterize and capture added value from variations within the Prime grade. However, minimal research has been done to evaluate consumers' perceptions of upper 2/3 Prime steaks when compared to other quality grades. Therefore, the objective of this study was to evaluate consumer palatability preferences in strip loin steaks of upper 2/3 Prime when compared to Low Prime, upper 2/3 Choice, and Low Choice.

Experimental Procedures

An equal number (n = 15) of beef strip loins representing four marbling categories were collected from a commercial packing facility. The marbling categories represented were: Super Prime (moderately abundant and abundant); Low Prime (slightly abundant); Top Choice (modest and moderate), and Low Choice (small). Subprimals were fabricated into 1-in.-thick steaks and vacuum packaged. Additionally, steaks were designated to one of three degrees of doneness (DOD): Rare (140°F), Medium (160°F), and Well-done (170°F). Upon reaching the designated aging period of 28 days, steaks were frozen at -4°F until subsequent analyses.

Consumers (n = 192) evaluated samples for juiciness, tenderness, flavor, and overall liking on a 100-point continuous line scale. Anchors were designated on both ends as well as at the midway point with descriptive terms for each, with 0 being extremely dry, tough, and dislike extremely, and 100 being extremely juicy, tender, and like extremely. Consumers were then asked an additional question to determine if the sample was acceptable or unacceptable for each of the sensory traits evaluated. Responses were recorded using a digital survey on an electronic tablet. Steaks designated for consumer panels were thawed at 34-39°F for 24 hours before testing. Steaks were then cooked to their respective assigned DOD on an electric flat top grill utilizing a weighted (4.56 lb) steak press. Temperatures were monitored using a Type K thermocouple. Rare steaks were flipped at 80°F and pulled at 127°F for a peak temperature of 140°F. For a Medium DOD, steaks were flipped at 86°F and pulled from the grill at 154°F for a peak temperature of 160°F. Well-done steaks were flipped at 90°F and pulled at 165°F for a peak temperature of 170°F. Consumers were served two 0.5 × 0.5 × 1.0 in. cubes per sample. All final peak temperatures were collected. Data were analyzed using a split-plot design in SAS, with quality grade as the whole plot factor and DOD as the subplot factor. Alpha was set at 0.05.

Results and Discussion

Table 1 shows consumer sensory ratings. There were no ($P > 0.05$) interactions between quality grade and DOD for any consumer-evaluated traits. When evaluating the main effect of quality grade, Super Prime steaks were juicier, more tender, and rated higher for flavor and overall liking ($P < 0.05$) than all other grades (Table 1). Super Prime samples were rated 19% higher than Low Prime samples for juiciness, 15% higher for tenderness, 13% higher for flavor liking, and 14% higher for overall liking. No differences ($P > 0.05$) were observed among Low Prime, Top Choice, and Low Choice for juiciness, flavor, and overall liking (Table 1). Tenderness ratings were similar ($P > 0.05$) between Low Prime and Top Choice and between Top Choice and Low Choice. However, Low Prime steaks rated higher ($P < 0.05$) compared to Low Choice steaks for tenderness (Table 1).

Table 2 shows the percentage of samples identified as acceptable for each palatability trait. A higher percentage of Super Prime steaks were rated as acceptable ($P < 0.05$) for juiciness, tenderness, flavor, and overall liking than all lower grades (Table 2). Super Prime had more than 93% of all samples rated acceptable for all traits evaluated by consumers. No differences ($P > 0.05$) were found in the percentage of samples rated acceptable for tenderness between Low Prime and Top Choice steaks and Top Choice and Low Choice steaks (Table 2). However, a higher percentage ($P < 0.05$) of consumers rated Low Prime steaks as acceptable for tenderness than Low Choice steaks (Table 2).

When evaluating the main effect of DOD, Rare steaks were juicier, more tender, and rated higher overall ($P < 0.05$) than Medium and Well-done steaks (Table 1). However, Medium and Well-done steaks rated similarly ($P > 0.05$) for juiciness, tenderness, and overall liking. No differences ($P > 0.05$) were found between Rare and Medium steaks, and Medium and Well-done steaks for flavor liking. However, Rare steaks were rated higher ($P < 0.05$) than Well-done steaks for flavor liking (Table 1). Additionally, a higher percentage ($P < 0.05$) of Rare steaks were rated as acceptable for juiciness than Medium steaks, and a higher ($P < 0.05$) percentage of Medium steaks were rated as acceptable for juiciness than Well-done steaks (Table 2). A higher percentage ($P < 0.05$) of Rare steaks were rated as acceptable for tenderness than Medium and Well-done steaks. However, there was no difference ($P > 0.05$) in the percentage of Medium and Well-done steaks that were rated acceptable for tenderness (Table 2). For overall acceptability, no differences ($P > 0.05$) were found in the percentage of samples rated acceptable between Rare and Well-done steaks or between Well-done and Medium. However, a higher percentage ($P < 0.05$) of Well-done steaks were rated as acceptable than Medium for overall acceptability (Table 2). The DOD had no effect ($P > 0.05$) on the percentage of samples rated acceptable for flavor liking.

Implications

These results indicate that consumers preferred the eating quality of upper 2/3 Prime steaks over the other grades evaluated and support the need for a premium program within the Prime grade, offering the beef industry a valuable opportunity to capture added value from this highest grade within beef.

References

USDA-AMS. 2024. Historical Beef Grading Data. *https://www.ams.usda.gov/reports/meat-grading*

Table 1. Least squares means of consumer (n = 64/degree of doneness) panel palatability ratings[1] for strip loin steaks across four marbling categories and three degrees of doneness

Treatment	Juiciness	Tenderness	Flavor liking	Overall liking
Quality grade[2]				
Super Prime	74.3[a]	75.6[a]	70.6[a]	73.6[a]
Low Prime	62.5[b]	65.6[b]	62.5[b]	64.4[b]
Top Choice	60.0[b]	60.5[bc]	60.9[b]	61.8[b]
Low Choice	59.4[b]	59.5[c]	59.9[b]	60.9[b]
SEM[4]	2.0	2.1	1.6	1.8
P-value	< 0.01	< 0.01	< 0.01	< 0.01
Degree of doneness[3]				
Rare	69.0[a]	69.3[a]	66.9	69.4[a]
Medium	63.6[b]	63.3[b]	60.9	62.8[b]
Well-done	59.5[b]	63.3[b]	62.7	63.3[b]
SEM[4]	2.4	1.8	1.9	1.7
P-value	< 0.01	0.02	0.08	< 0.01

[abc] Least squares means within the same section of the same column without a common superscript differ ($P < 0.05$).
[1] Sensory scores: 0 = extremely dry/tough/dislike extremely, 50 = neither dry nor juicy, neither tough nor tender, neither like nor dislike, 100 = extremely juicy/tender/like extremely.
[2] Marbling scores: Super Prime - Moderately Abundant, Abundant, and Very Abundant ; Low Prime - Slightly Abundant ; Top Choice - Moderate and Modest ; Low Choice - Small.
[3] Degrees of doneness: Rare - 140°F, Medium - 160°F, and Well-done - 170°F.
[4] Standard error (largest) of the least square means.

Table 2. Least-squares means (n = 64/degree of doneness) of the percentage of samples rated as acceptable[1] for each palatability trait evaluated by consumers for strip loin steaks across four marbling categories and three degrees of doneness

Treatment	Juiciness acceptability	Tenderness acceptability	Flavor acceptability	Overall liking acceptability
Quality grade[2]				
Super Prime	95.8[a]	95.2[a]	93.2[a]	95.5[a]
Low Prime	86.6[b]	90.7[ab]	84.4[b]	87.5[b]
Top Choice	84.8[b]	86.8[b]	86.1[b]	85.1[b]
Low Choice	81.3[b]	85.3[b]	84.2[b]	84.7[b]
SEM[4]	3.4	2.8	2.3	2.4
P-value	< 0.01	< 0.01	< 0.01	< 0.01
Degree of doneness[3]				
Rare	93.9[a]	93.6[a]	89.4	92.4[a]
Medium	87.7[b]	87.1[b]	84.7	85.6[b]
Well-done	80.9[c]	89.0[b]	88.2	88.8[ab]
SEM[4]	2.4	1.9	1.8	1.9
P-value	< 0.01	< 0.01	0.10	< 0.01

[abc] Least squares means within the same section of the same column without a common superscript differ ($P < 0.05$).
[1] Percentage of samples rated acceptable for the palatability trait by consumer sensory panelists.
[2] Marbling scores: Super Prime - Moderately Abundant, Abundant, and Very Abundant ; Low Prime - Slightly Abundant ; Top Choice - Moderate and Modest ; Low Choice - Small.
[3] Degrees of doneness: Rare - 140°F, Medium - 160°F, and Well-done - 170°F.
[4] Standard error (largest) of the least square means.

Trained Panel Evaluation of Upper 2/3 Prime Beef Strip Loin Steaks

K.E. Wallace, C.A. Effling, L.M. Frink, M.J. Prester, S.L. Witberler, G.E. Huber, S F. Stickley, E.S. Beyer, M.D. Zumbaugh, J.L. Vipham, and T.G. O'Quinn

Abstract

The objective of this study was to evaluate trained sensory panel perceptions of beef strip loin steaks representing four marbling categories: Super Prime (moderately abundant and abundant), Low Prime (slightly abundant), Top Choice (modest and moderate), and Low Choice (small). Strip loins (n = 15/grade) were collected from a commercial packing facility, fabricated into approximately 1-in. steaks, and aged 28 days before analysis. Steaks were assigned to one of three degrees of doneness ([DOD]; Rare = 140°F, Medium = 160°F, and Well-done = 170°F) and evaluated by trained panelists for initial juiciness, sustained juiciness, myofibrillar tenderness, connective tissue amount, overall tenderness, and beef flavor intensity using a 100-point line scale. Data were analyzed using a split-plot design with quality grade as a whole-plot factor and DOD as the subplot factor. There were no interactions ($P > 0.05$) between quality grade and DOD for any trained panel-evaluated traits. Quality grade influenced ($P < 0.05$) all sensory attributes. Super Prime steaks received higher ($P < 0.05$) ratings for juiciness, tenderness, and flavor traits than Low Prime, Top Choice, and Low Choice steaks. For DOD, Rare and Medium samples were rated similar ($P > 0.05$) for initial juiciness, myofibrillar tenderness, and overall tenderness. Rare samples scored higher ($P < 0.05$) than Medium for sustained juiciness. Well-done steaks, regardless of grade, received the lowest ($P < 0.05$) scores. However, there was an interaction ($P < 0.05$) between quality grade and DOD for objective measurements, providing additional evidence of the negative effect of increased doneness on palatability and the positive effect of higher marbling scores. These results suggest that both marbling level and DOD are critical to the eating quality of beef strip loin steaks.

Introduction

In the past quarter century, the U.S. beef industry has experienced a steady and measurable improvement in carcass quality, with one of the most notable shifts being the increased prevalence of USDA Prime carcasses. According to the National Beef Quality Audit, only 2.0% of carcasses graded Prime in 2000; however, by 2021, this percentage had increased to nearly 7.8% (Mayer et al., 2025). This improvement reflects industrywide advancements in genetics, nutrition, and management practices. At the same time, heightened consumer demand for high-quality beef has reinforced incentives for producers to pursue carcass traits associated with tenderness, juiciness, and flavor (Gonzalez et al., 2024). Despite these gains, most value-based marketing programs continue to focus on upper 2/3 USDA Choice carcasses, often treating USDA Prime as a single, undifferentiated category. This suggests that the beef industry may be failing to fully capture the added value potential of carcasses within the upper 2/3 of the USDA Prime grade, which contains substantially more marbling than those at the lower threshold of Prime. As USDA Prime availability grows, there is a unique opportunity to evaluate whether consumers can discern differences in eating quality within the USDA Prime grade. Previous research has clearly established that marbling is a strong predictor

of palatability, particularly tenderness, juiciness, and flavor (O'Quinn et al., 2012). However, little work has been done to determine whether the sensory improvements associated with increasing marbling extend beyond the current USDA Prime threshold. The lack of such information has limited the development of branded beef programs that could differentiate and market "Super Prime" products as a premium tier within USDA Prime. The objective of this study was to evaluate palatability characteristics of strip loin steaks from the upper 2/3 USDA Prime (Super Prime), USDA Low Prime, upper 2/3 USDA Choice (Top Choice), and USDA Low Choice grades by trained sensory panelists.

Experimental Procedures

Beef strip loins (n = 15/grade) representing four marbling categories were collected from a commercial packing facility. Marbling categories included: Super Prime (moderately abundant and abundant), Low Prime (slightly abundant), Top Choice (modest and moderate), and Low Choice (small). Subprimals were fabricated into approximately 1-in.-thick steaks, vacuum-packaged, and aged for 28 days. Also, steaks were designated to be one of the three degrees of doneness ([DOD]; Rare = 140°F, Medium = 160°F, or Well-done = 170°F). Following aging, steaks were frozen at -4°F until later analytical testing. Trained sensory panelists (n = 8) evaluated samples for initial juiciness, sustained juiciness, myofibrillar tenderness, connective tissue amount, overall tenderness, and beef flavor intensity using a 100-point line scale. Anchors were provided with 0 being extremely dry/tough/bland and 100 being extremely juicy/tender/intense, and 50 being neutral. For off-flavor, there was a "not applicable" option. If there was an off-flavor present, panelists had the option to describe the type of off-flavor. Responses were collected using a digital survey platform on electronic tablets. Steaks designated for trained panels were thawed for 24 hours at 35-39°F before cooking. Samples were cooked on a flat-top electric grill using a weighed steak press to maintain consistent surface contact. Internal temperatures were monitored using a Type K thermocouple. Rare steaks were flipped at 80.6°F and removed from the grill at 127.4°F to achieve a peak temperature of 140°F. Medium steaks were flipped at 86°F and removed at 154.4°F for a peak of 160°F, while Well-done steaks were flipped at 89.6°F and removed at 165.2°F for a peak of 170°F. After cooking, each sample was portioned into two cubes (0.51 × 0.51 × 1 in.) and served to panelists. Final internal peak temperatures were recorded for all samples. Data were analyzed as a split-plot design using SAS with quality grade as a whole-plot factor and DOD as the subplot factor. Statistical significance was declared at $\alpha = 0.05$.

Results and Discussion

Table 1 shows there was no quality grade × DOD interaction for all sensory attributes evaluated by trained sensory panelists. Super Prime steaks received the highest ($P < 0.05$) scores for initial and sustained juiciness, myofibrillar tenderness, overall tenderness, and beef flavor intensity. Low Prime samples were rated higher ($P < 0.05$) for both initial and sustained juiciness when compared to Low Choice. However, for initial and sustained juiciness, there were no differences ($P > 0.05$) between Low Prime and Top Choice, or between Top Choice and Low Choice. There were also no differences ($P > 0.05$) among Low Prime, Top Choice, and Low Choice for myofibrillar tenderness, connective tissue amount, and overall tenderness. Super Prime scored the lowest ($P < 0.05$) for connective tissue amount compared to all other quality grades. Low Prime and Top Choice steaks scored similar ($P > 0.05$) for beef flavor intensity,

while Low Choice was rated the lowest ($P < 0.05$) for beef flavor intensity. For DOD, Rare and Medium samples were rated similar ($P > 0.05$) for initial juiciness, myofibrillar tenderness, and overall tenderness. Rare samples scored higher ($P < 0.05$) than Medium for sustained juiciness. Well-done samples were rated the lowest ($P < 0.05$) for initial and sustained juiciness, myofibrillar tenderness, and overall tenderness. There were no differences ($P > 0.05$) among all DOD for connective tissue and beef flavor intensity.

Table 2 shows an interaction ($P < 0.05$) between quality grade and DOD for Warner-Bratzler Shear Force (WBSF), slice shear force (SSF), pressed juice percentage (PJP), and cook loss. In all DOD categories, Super Prime had the lowest ($P < 0.05$) WBSF values. Rare Low Prime and Top Choice were similar ($P < 0.05$) for WBSF, and Low Choice was the highest ($P > 0.05$). Within Medium and Well-done, Top Choice and Low Choice samples had similar ($P > 0.05$) WBSF but were higher ($P < 0.05$) than Low Prime. For SSF, there were no differences ($P > 0.05$) among quality grade treatments cooked to Rare. Within Medium, Low Prime, Top Choice, and Low Choice all were similar ($P > 0.05$) for SSF, but Super Prime and Low Prime were similar ($P > 0.05$). Within the Well-done DOD, Super Prime had the lowest ($P < 0.05$) SSF values. Low Prime and Top Choice had similar ($P > 0.05$) SSF values but were lower ($P < 0.05$) than Low Choice. For PJP, there were no differences ($P > 0.05$) among treatments when cooked to Rare. Within Medium, Super Prime had the highest ($P > 0.05$) PJP values, when compared to all the lower grades, which were similar ($P > 0.05$). Within Well-done samples, Super Prime samples had a higher ($P < 0.05$) PJP value than Top Choice. There were no differences ($P > 0.05$) among the other quality grades. For cook loss in Rare, there were no differences ($P > 0.05$) among the quality grades. In Medium, Super Prime had the lowest ($P < 0.05$) cook loss value, when compared to Low Prime, Top Choice, and Low Choice, which had no differences ($P > 0.05$). Within Well-Done, Top Choice samples had a higher ($P < 0.05$) cook loss compared to Super Prime. There were no differences ($P > 0.05$) among the other quality grades.

Implications

Super Prime steaks consistently rated higher than the other grades in trained sensory evaluations, indicating that marketing them as a premium tier could boost value and ensure a more consistent, high-quality eating experience.

References

Gonzalez, A.A., E.P. Williams, T.E. Schwartz, A.N. Arnold, D.B. Griffin, R.K. Miller, K.B. Gehring, J.C. Brooks, J.F. Legako, C.C. Carr, G.G. Mafi, C.L. Lorenzen, R.J. Maddock, and J.W. Savell. 2024. National beef tenderness survey—2022: Consumer sensory panel evaluations and Warner-Bratzler shear force of beef steaks from retail and foodservice. Meat and Muscle Biology 8(1): 16997, 1-11. doi: https://doi.org/10.22175/mmb.16997

Mayer T.R., S.E. Borders, T.E. Schwartz, K.B. Gehring, D.B. Griffin, C.R. Kerth, K.E. Belk, J.A. Scanga, M.N. Nair, M.M. Pfeiffer, G.G. Mafi, K.M. Harr, T.E. Lawrence, T.C. Tennant, L.W. Lucherk, T.G. O'Quinn, E.S. Beyer, P.D. Bass, L.G. Garcia, B.M. Bohrer, J.A. Pempek, A.J. Garmyn, R.J. Maddock, C.C. Carr, T.D. Pringle, T.L. Scheffler, J.M. Scheffler, A.M. Stelzleni, J.M. Gonzalez, K.R. Underwood, B.N. Harsh, C.M. Waters, and J.W. Savell. 2025. National Beef Quality Audit - 2022: Instrument grading assessments of carcass characteristics of fed steers and heifers. Translational Animal Science 9. https://doi.org/10.1093/tas/txaf097

O'Quinn, T.G., J.C. Brooks, R.J. Polkinghorne, A.J. Garmyn, B.J. Johnson, J.D. Starkey, R.J. Rathmann, and M.F. Miller. 2012. Consumer assessment of beef strip loin steaks of varying fat levels. Journal of Animal Science 90(2):626–634. doi: https://doi.org/10.2527/jas.2011-4282

Table 1. Least square means (n = 8/panel) of trained panelist palatability ratings[1] for strip loin steaks across four marbling categories and three degrees of doneness

Treatment	Initial juiciness	Sustained juiciness	Myofibrillar tenderness	Connective tissue amount	Overall tenderness	Beef flavor intensity
Quality Grade[2]						
Super Prime	76.0[a]	70.2[a]	76.6[a]	3.4[b]	74.9[a]	57.7[a]
Low Prime	64.9[b]	58.0[b]	65.4[b]	5.0[a]	62.8[b]	49.4[b]
Top Choice	63.5[bc]	56.6[bc]	64.9[b]	4.5[a]	62.3[b]	47.5[b]
Low Choice	60.4[c]	52.8[c]	62.9[b]	5.3[a]	59.6[b]	43.7[c]
SEM[4]	1.5	1.6	1.3	0.3	1.5	1.4
P-value	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Degree of doneness[3]						
Rare	71.8[a]	65.5[a]	70.8[a]	4.8	68.3[a]	51.8
Medium	68.3[a]	61.8[b]	69.3[a]	4.8	66.6[a]	49.1
Well-done	58.6[b]	51.0[c]	62.2[b]	4.0	59.8[b]	47.9
SEM[4]	1.4	1.4	1.0	0.3	1.1	1.3
P-value	< 0.01	< 0.01	< 0.01	0.07	< 0.01	0.07

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

[1] Sensory scores: 0 = extremely dry/tough/bland/none, 50 = neither juicy/dry/tough/tender, 100 = extremely juicy/tender/abundant/intense.

[2] Marbling scores: Super Prime-moderately abundant, abundant, and very abundant, Low Prime-slightly abundant, Top Choice-moderate and modest, and Low Choice-small.

[3] Degrees of doneness: Rare = 140°F, Medium = 160°F, and Well-done = 170°F.

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

Table 2. Least square means for the interaction ($P < 0.05$) between quality[1] treatment and degree of doneness[2] for Warner-Bratzler shear force (WBSF), slice shear force (SSF), pressed juice percentage (PJP), and cook loss

Degree of doneness/ quality treatment	WBSF, lb	SSF, lb	PJP, %	Cook loss, %
Rare				
Super Prime	4.6[c]	28.0	23.5	15.6
Low Prime	5.5[b]	30	21.1	14.6
Top Choice	5.7[b]	29.8	21.9	15.6
Low Choice	6.4[a]	33.1	21.7	14.4
SEM[3]	0.2	1.5	0.7	0.8
P-value	< 0.01	0.11	0.11	0.56
Medium				
Super Prime	4.4[c]	25.4[b]	20.3[a]	20.0[b]
Low Prime	6.0[b]	29.5[ab]	15.0[b]	24.6[a]
Top Choice	6.6[a]	32.4[a]	16.9[b]	23.4[a]
Low Choice	6.6[a]	32.4[a]	17.0[b]	23.1[a]
SEM[3]	0.2	1.5	0.7	0.8
P-value	< 0.01	< 0.01	< 0.01	< 0.01
Well-done				
Super Prime	4.4[c]	24.3[c]	16.8[a]	24.3[b]
Low Prime	6.4[b]	28.4[b]	14.9[ab]	26.2[ab]
Top Choice	7.1[a]	29.1[b]	13.3[b]	27.2[a]
Low Choice	7.3[a]	36.6[a]	14.8[ab]	25.3[ab]
SEM[3]	0.2	1.5	0.7	0.8
P-value	< 0.01	< 0.01	< 0.01	0.05

[abc] Least square means within the same section of the same column without a common superscript differ ($P < 0.05$).
[1] Marbling scores: Super Prime-moderately abundant, abundant, and very abundant, Low Prime-slightly abundant, Top Choice-moderate and modest, and Low Choice-small.
[2] Degrees of doneness: Rare = 140°F, Medium = 160°F, and Well-done = 170°F.
[3] SEM (largest) of the least square means.

Acknowledgments

Listed below are individuals, organizations, and firms that have contributed to the beef research program through financial support, product donations, or services. We appreciate your help!

Better Fed Foods, Wamego, Kansas

Bimeda Animal Health, Schaumburg, Illinois

Lee Borck, Larned, Kansas

Cargill Corn Milling, Blair, Nebraska

Cargill Protein, Wichita, Kansas

Cattlemen's Beef Board, Centennial, Colorado

Clark County Feeders, Minneola, Kansas

Cobalt Cattle Company LLC, Garden City, Kansas

Cornbelt Livestock Services, Rock Falls, Illinois

Downey Ranch, Wamego, Kansas

Fairleigh Feedyard, Scott City, Kansas

Finney County Feedyard, Garden City, Kansas

Huvepharma, Peachtree, Georgia

Hy-Plains Feedyard, LLC, Montezuma, Kansas

Innovative Livestock Services, LLC, Great Bend, Kansas

Irsik & Doll Feed Services, Inc., Cimarron, Kansas

Kansas Artificial Breeding Service Unit, Manhattan, Kansas

Kansas Beef Council, Topeka, Kansas

Kansas Grain Sorghum Commission, Manhattan, Kansas

Kansas Livestock Association, Topeka, Kansas

Livestock and Meat Industry Council (LMIC), Manhattan, Kansas

Merck Animal Health, Rahway, New Jersey

Micro Technologies, Amarillo, Texas

Midwest Feeders, Inc., Ingalls, Kansas

Midwest PMS LLC, Leawood, Kansas

National Cattlemen's Beef Association, Centennial, Colorado

NBO3, Manhattan, Kansas

Poky Feeders Inc., Scott City, Kansas

Pratt Feeders, Pratt, Kansas

Pyramid Feeds, Scott City, Kansas

Reeve Cattle Company Inc., Garden City, Kansas

Tiffany Cattle Company, Herington, Kansas

USDA National Institute of Food and Agriculture, Washington, DC

Zoetis, Parsippany, New Jersey

The Livestock and Meat Industry Council, Inc

The Livestock and Meat Industry Council, Inc (LMIC) is a non-profit charitable organization supporting animal agriculture research, teaching, and education. This is accomplished through the support of individuals and businesses that make LMIC a part of their charitable giving.

Tax-deductible contributions can be made through gifts of cash, appreciated securities, real estate, life insurance, charitable remainder trusts, and bequests as well as many other forms of planned giving. LMIC can also receive gifts of livestock, machinery, or equipment. These types of gifts, known as gifts-in-kind, allow the donor to be eligible for a tax benefit based on the appraised value of the gift.

Since its inception in 1970, LMIC has provided student scholarships, research assistance, capital improvements, land, buildings, and equipment to support students, faculty, and the industry of animal agriculture. If you would like to be a part of this mission or would like additional information, please contact the Livestock and Meat Industry Council/Animal Sciences and Industry, Weber Hall, Manhattan, Kansas 66506, or call 785-532-1259.

LMIC Board Members

Tera Barnhardt
Gene Barrett
Tracy Brunner
Doug Claassen
Larry Corah
Doug Deets
Todd Domer
Barb Downey
Jeff George
Chelsea Good
Mark Gratny
Kirk Gray
Kim Harms
Justin Janssen
Jerry Kuckelman
David Latta
Debbie Lyons-Blythe
Steve Mangan
Mary McCurry
Bill Miller
Greg Reno
Jerry Riemann
Hal Sankey
Randall Spare
Michael Springer
John Stika
Tom Toll
Scott Vander Hamm
Mark Young

Royal Board Members

Dell Allen
Kyle Bauer
Jerry Bohn
David Clawson
Galen Fink
Randy Fisher
Mark Gardiner
Craig Good
Lyle Gray
Ken Grecian
Sam Hands
Frank Harper
Bernie Hansen
Roy Henry
Patsy Houghton
Steven Hunt
Virgil Huseman
Larry Jones
Pat Koons
Kelly Lechtenberg
Jan Lyons
Gina Miller
Lisa Moser
Andrew Murphy
Stanton O'Neil
Tom Perrier
Rich Porter
Harland Priddle
Lee Reeve
Ken Stielow
Mikel Stout
Kathleen Strunk
Warren Weiber

CATTLEMEN'S DAY 2026

BEEF CATTLE RESEARCH

This publication is online at ***newprairiepress.org/kaesrr***

Publications from K-State Research and Extension are available at ***www.ksre.ksu.edu***

KANSAS STATE UNIVERSITY AGRICULTURAL EXPERIMENT STATION AND COOPERATIVE EXTENSION SERVICE

K-State Research and Extension is an equal opportunity provider and employer.

February 2026