# CATTLEMEN'S DAY 2025

## BEEF CATTLE RESEARCH

K-STATE Research and Extension

KANSAS STATE UNIVERSITY AGRICULTURAL EXPERIMENT STATION AND COOPERATIVE EXTENSION SERVICE

# Table of Contents

## *Meat Science*

# Assessment of Nutrient Content of Kansas Grasslands Enrolled in the Conservation Reserve Program

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

## Abstract

Kansas had 1.9 million acres enrolled in the Conservation Reserve Program (CRP) for the year 2023. The objective of this ongoing study was to evaluate the forage quality of standing CRP for grazing beef cattle to assist producers and advisors in making supplementation decisions. Monthly forage samples were collected from cooperator producers' locations across 19 counties in Kansas to determine nutrient quality throughout the year. Samples were classified as east or west Kansas based on the location of the tract from which they were collected. The samples were analyzed for nutrient content based on the region of the state, as precipitation and soil type are likely influencing factors. While variation exists between regions, data suggest CRP forage quality generally follows a pattern typical of warm-season grasses.

## Introduction

The Conservation Reserve Program (CRP) was established in the 1985 Farm Bill through the Farm Service Agency (FSA) that places environmentally sensitive land out of agricultural production and into conservation. Kansas had 1.9 million acres enrolled in CRP during 2023, which can be released for grazing or haying depending on specific local conditions each year. There are limited data on the quality of CRP forages harvested for hay, but even less information is available on nutrient content levels regarding standing CRP forages for grazing beef cattle.

Information on standing forage quality is necessary for accurate supplementation and feeding recommendations for producers, thereby allowing for more efficient and economical use of resources. Previous data (Harmoney et al., 2002) indicated that crude protein content of both tall grasses and short grasses increases during early- to mid-summer and then decreases as dormancy approaches. Soil type, years of enrollment in CRP, average annual precipitation, and management history may all impact forage quality. While emergency haying and grazing of CRP lands can be done during drought, programs may allow for use by the producer under non-drought conditions. The objective of this collaborative field study was to evaluate the quality of standing CRP forages throughout the year and compare samples collected from different regions across the state.

## Experimental Procedures

This project was a collaborative initiative among K-State Research and Extension (KSRE) Extension Agents and Specialists who are part of the Livestock Program Focus Team. Agents and specialists identified cooperating producers within local Extension units and collected monthly forage samples beginning winter 2023. A prearranged set of dates was determined to limit the variation of times that samples were collected within months. Samples were taken at cooperating producer locations in 19 counties across the state, and locations were classified as either western or eastern Kansas. Random locations within the specific tracts were selected, and samples were collected

by hand clipping forage to a height of approximately 1-in above the ground in 10.8 $ft^2$ quadrats. Samples were dried for 48 hours at 131°F using a forced air oven, then ground and sent to a single laboratory for analysis (SDK Laboratories, Hutchinson, KS). Data from a total of 206 forage samples ranging from February 2023 to July 2024 were analyzed using SAS 9.4 (SAS, Cary, NC), with relatively equal proportions between east (n = 102) and west (n = 104) regions. Probability values less than or equal to 0.05 were considered significantly different.

## Results and Discussion

Crude protein (CP) and fiber component content data are reported in Table 1. Crude protein did not differ between regions within a sampling month. Acid detergent fiber was different for the month of July ($P \leq 0.05$) and December ($P \leq 0.05$) for the two regions. Neutral detergent fiber was treated with amylase to remove any starch interference with the sample and did not differ between months or regions. Total digestible nutrients were different for February ($P \leq 0.05$), March ($P \leq 0.05$), and July ($P \leq 0.05$) for the two regions.

Forage sample mineral data are reported in Table 2. Calcium was different for the month of December ($P \leq 0.05$), and phosphorus was different for May ($P \leq 0.05$). Potassium was different for the months of May ($P \leq 0.05$) and October ($P \leq 0.05$). Magnesium was different for samples collected in February ($P \leq 0.05$), August ($P \leq 0.05$), September ($P \leq 0.05$), October ($P \leq 0.05$) and December ($P \leq 0.05$). This is an ongoing study of which additional data will be added to account for year-to-year variation in forage quality.

## Implications

Understanding the nutrient quality of CRP lands that are released for haying or grazing is critical for making informed supplementation and feeding decisions with producers. These data will contribute and add to the existing body of research of nutrient content of forages for grazing.

## Acknowledgments

The authors extend appreciation to all K-State Research and Extension Agents who participated in this project for their assistance with tract identification and sample collection. Appreciation is greatly expressed to all cooperating producers for allowing access to their property for sample collection. This project is a result of efforts from the KSRE Livestock Program Focus Team.

## References

Harmoney, K., S. Johnson, R. Cochran, E. Vanzant, T. Jones, J. Wilson, D. Yauk, M. Ploger, G. McGlure, M. Holder, B. Allen, W. Bell, and H. Jansonius. 2002. Seasonal forage quality of rangelands across. Kansas Agricultural Research Center-Hays Roundup.

**Table 1. Protein and fiber content of forage samples (dry matter basis) by month[1] and region**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Crude protein, % | | | | | | | | | | | | |
| East | 3.52 | 2.93 | 4.28 | 5.78 | 8.68 | 6.61 | 5.31 | 5.26 | 5.11 | 4.24 | 5.12 | 3.77 |
| West | --- | 2.99 | 4.85 | 4.69 | 5.25 | 10.8 | 4.53 | 4.64 | 3.79 | 3.55 | 3.35 | 3.19 |
| SEM[2] | --- | .050 | 1.69 | 1.58 | 1.82 | 2.56 | 0.67 | 0.86 | 1.73 | 0.57 | 0.92 | 0.40 |
| *P*-value | --- | 0.91 | 0.74 | 0.49 | 0.08 | 0.16 | 0.26 | 0.50 | 0.47 | 0.26 | 0.09 | 0.18 |
| Acid detergent fiber, % | | | | | | | | | | | | |
| East | 48.92 | 48.10 | 49.26 | 44.92 | 39.26 | 38.41 | 39.28 | 44.47 | 43.80 | 47.41 | 47.77 | 45.84 |
| West | --- | 50.91 | 50.63 | 47.90 | 44.40 | 34.71 | 45.78 | 43.59 | 44.37 | 46.84 | 47.48 | 51.46 |
| SEM | --- | 1.34 | 0.99 | 3.87 | 3.54 | 6.69 | 1.85 | 1.65 | 2.64 | 1.34 | 3.16 | 2.37 |
| *P*-value | --- | 0.08 | 0.19 | 0.45 | 0.17 | 0.60 | 0.01 | 0.61 | 0.83 | 0.68 | 0.93 | 0.05 |
| Neutral detergent fiber, % | | | | | | | | | | | | |
| East | 72.21 | 66.86 | 66.48 | 65.54 | 61.72 | 61.82 | 63.17 | 62.94 | 63.94 | 67.99 | 66.51 | 65.46 |
| West | --- | 70.30 | 67.68 | 67.72 | 65.31 | 51.78 | 66.24 | 64.71 | 65.48 | 66.79 | 67.94 | 70.44 |
| SEM | --- | 2.46 | 2.37 | 3.54 | 3.31 | 6.14 | 1.91 | 1.78 | 1.64 | 1.15 | 3.78 | 6.66 |
| *P*-value | --- | 0.21 | 0.62 | 0.56 | 0.29 | 0.15 | 0.13 | 0.35 | 0.37 | 0.32 | 0.71 | 0.48 |
| Total digestible nutrients, % | | | | | | | | | | | | |
| East | 36.51 | 42.15 | 40.15 | 41.85 | 51.22 | 50.70 | 50.13 | 42.46 | 41.69 | 38.54 | 35.55 | 36.71 |
| West | --- | 33.82 | 36.10 | 38.20 | 43.83 | 55.69 | 44.81 | 46.44 | 42.06 | 39.31 | 37.86 | 33.08 |
| SEM | --- | 1.74 | 1.91 | 5.12 | 4.05 | 9.04 | 2.19 | 3.08 | 2.64 | 1.81 | 4.23 | 3.57 |
| *P*-value | --- | 0.01 | 0.05 | 0.49 | 0.09 | 0.60 | 0.03 | 0.23 | 0.89 | 0.67 | 0.60 | 0.34 |

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

**Table 2. Mineral content of forage samples (dry matter basis) by month[1] and region**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Calcium, % | | | | | | | | | | | | |
| East | 0.64 | 0.07 | 0.81 | 0.59 | 0.44 | 0.63 | 0.53 | 0.50 | 0.51 | 0.61 | 0.59 | 0.51 |
| West | --- | 0.29 | 0.51 | 0.48 | 0.46 | 0.87 | 0.41 | 0.42 | 0.44 | 0.46 | 0.48 | 0.39 |
| SEM[2] | --- | 0.23 | 0.19 | 0.14 | 0.11 | 0.25 | 0.13 | 0.06 | 0.06 | 0.08 | 0.10 | 0.05 |
| *P*-value | --- | 0.17 | 0.13 | 0.45 | 0.86 | 0.39 | 0.37 | 0.22 | 0.29 | 0.07 | 0.34 | 0.03 |
| Phosphorus, % | | | | | | | | | | | | |
| East | 0.06 | 0.05 | 0.07 | 0.12 | 0.20 | 0.16 | 0.13 | 0.15 | 0.12 | 0.09 | 0.08 | 0.08 |
| West | --- | 0.04 | 0.06 | 0.06 | 0.08 | 0.29 | 0.11 | 0.14 | 0.08 | 0.11 | 0.08 | 0.05 |
| SEM | --- | 0.01 | 0.02 | 0.05 | 0.05 | 0.09 | 0.03 | 0.05 | 0.04 | 0.02 | 0.03 | 0.02 |
| *P*-value | --- | 0.86 | 0.70 | 0.31 | 0.02 | 0.20 | 0.44 | 0.84 | 0.28 | 0.42 | 0.83 | 0.28 |
| Potassium, % | | | | | | | | | | | | |
| East | 0.15 | 0.11 | 0.16 | 0.72 | 1.45 | 1.46 | 1.07 | 0.98 | 0.61 | 0.43 | 0.34 | 0.19 |
| West | --- | 0.22 | 0.27 | 0.49 | 0.38 | 2.69 | 0.87 | 1.04 | 0.80 | 0.78 | 0.59 | 0.32 |
| SEM | --- | 0.06 | 0.11 | 0.41 | 0.33 | 1.17 | 0.19 | 0.20 | 0.17 | 0.12 | 0.21 | 0.08 |
| *P*-value | --- | 0.11 | 0.36 | 0.58 | 0.01 | 0.34 | 0.28 | 0.74 | 0.27 | 0.02 | 0.28 | 0.13 |
| Magnesium, % | | | | | | | | | | | | |
| East | 0.09 | 0.09 | 0.12 | 0.09 | 0.13 | 0.17 | 0.15 | 0.15 | 0.16 | 0.16 | 0.12 | 0.11 |
| West | --- | 0.05 | 0.07 | 0.11 | 0.09 | 0.35 | 0.10 | 0.10 | 0.09 | 0.10 | 0.09 | 0.07 |
| SEM | --- | 0.01 | 0.04 | 0.04 | 0.03 | 0.13 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 |
| *P*-value | --- | 0.01 | 0.19 | 0.69 | 0.13 | 0.23 | 0.06 | 0.03 | 0.01 | 0.01 | 0.21 | 0.01 |

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

# Effects of Late-Summer Prescribed Fire on Botanical Composition, Soil Cover, and Forage Production in Caucasian Bluestem-Infested Rangeland in the Kansas Smoky Hills: Final Report

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## Abstract

The old world bluestem species yellow bluestem (*Bothriochloa ischaemum*) and Caucasian bluestem (*Bothriochloa bladhii*) have been spreading rapidly through the Great Plains since their introduction in Texas for soil conservation purposes. While nonselective herbicides have been successfully employed to control the grass, the high cost of the treatment, as well as the negative effect on native species, make the advantages of herbicide use questionable. Traditional spring prescribed fire has not been a successful management tool; however, following promising results of late-summer fire application to yellow bluestem, a similar experiment was undertaken with Caucasian bluestem in the native mixed-grass prairie of Ellsworth County, Kansas. A grazed Caucasian bluestem-infested pasture was broken into 18 one-acre plots and assigned to one of three treatments: no burn (control), one burn (August 14, 2019), or two burns (August 14, 2019, and August 11, 2021). Soil cover, botanical composition, and forage biomass were recorded annually in each plot. Prescribed fire was associated with decreased old world bluestem cover ($P < 0.01$) and bare soil ($P < 0.01$), both of which may have contributed to increases in native forb cover ($P < 0.04$) and grass species richness ($P = 0.01$). Warm-season midgrasses, which include old world bluestems, had less basal cover in burned plots following fire treatment ($P = 0.04$) while fire treatment did not affect C4 tall or shortgrass cover ($P \geq 0.13$). Frequency of old world bluestem was less in plots burned twice compared with nonburned plots in year four ($P = 0.03$); however, this difference was lost in year five ($P = 0.15$), suggesting repeated fire application may be necessary to maintain low presence of the invasive species. These results suggest late-summer prescribed fire may be an effective, low-cost means of controlling old world bluestem while having positive to neutral effects on native species.

## Introduction

Introduced for forage and soil-conservation properties, old world bluestems began establishing and spreading through the Great Plains to the great detriment of native flora populations. While they are grazable grasses early in the growing season, rapid rates of maturation lead to unpalatability and decreased nutrient profiles much earlier than native warm-season grasses. Grazing, mowing, and spring burning seem to promote old world bluestem populations. When decreased cover of yellow bluestem was reported following late-summer prescribed fire treatment, our objective was to determine if similar effects could be found in Caucasian bluestem.

## Experimental Procedures

The experiment took place in Ellsworth County, Kansas, on a privately owned grazed pasture with overwhelming Caucasian bluestem presence. Eighteen one-acre plots were arranged in a 9 × 2 block with each set of two plots randomly assigned to one of three treatments: no burn, one burn (August 14, 2019), or two burns (August 14, 2019, and August 11, 2021). Initial evaluation of soil cover, botanical composition, and forage biomass was made in July 2019, while post-fire assessments were conducted annually in July of each following year.

The ground cover and botanical composition along permanent 162-ft transects were evaluated using a modified step-point approach, while forage biomass was estimated using three randomly placed 19.7 × 19.7-in. clipping frames per plot. Litter was removed from the frame and discarded. Live vegetation was clipped at a height of 0.4 in. and dried in a forced-air oven for 96 hours at 131°F. Overall forage biomass was estimated from the dry weights of the clipped material. Finally, Caucasian bluestem aerial frequency was evaluated with a 12 × 12-in. frame placed at 50 points along each transect.

## Results and Discussion

As expected, litter cover decreased ($P < 0.01$) following each application of fire leaving more bare soil exposed ($P < 0.01$). Litter removal allowed for increased grazing activity, lesser forage biomass, and shorter forage height in burned plots compared with nonburned plots following fire treatment ($P < 0.01$). In each year after preliminary data collection, basal plant cover did not differ between treatments ($P < 0.01$).

Total grass cover tended to differ between treatments ($P = 0.07$). Although C4 grass cover was less for burned plots each year following fire application ($P \leq 0.04$), this difference was no longer evident two or more years post-fire for either burn treatment ($P \geq 0.15$). Treatment had no effect on C4 tallgrass ($P = 0.13$) or shortgrass ($P = 0.48$) cover, but C4 midgrass cover tended to be less in plots burned twice compared to nonburned plots in both years following the second burn ($P \leq 0.06$; Figure 1). This was associated with less old world bluestem cover and frequency in year four ($P \leq 0.03$; Figures 2 and 3, respectively). Conversely, frequency and cover of Caucasian bluestem was no longer different in year five ($P \geq 0.15$; i.e., two years post-treatment), suggesting repeated application of late-summer prescribed fire may be required for management of Caucasian bluestem. Cool-season grass cover increased in fire-treated plots only in the first year following fire but was no longer different two or more years post-fire ($P < 0.01$). Treatment had no effect on native or introduced grass cover ($P \geq 0.27$). Overall, these results suggest late-summer prescribed fire has the potential to temporarily control Caucasian bluestem while not negatively affecting native vegetation.

In burned plots, total forb cover increased to exceed that of nonburned plots in years two and three; interestingly, this difference was no longer present in year four, but in year five there was greater forb cover in plots burned twice compared to nonburned plots ($P = 0.03$). There was no treatment effect among leguminous forbs ($P = 0.80$), but the trend among all other forb sub-groups (annual, perennial, nectar-producing, introduced, and native) in burned plots was to increase drastically in year two then decrease to nonsignificant levels from control plots by year three or four ($P \leq 0.06$). Contributing to the difference in total forb cover in year five, cover of annual and native forbs

was greater ($P \leq 0.04$) in plots burned twice compared to nonburned plots, and perennial forb cover tended to be greater ($P = 0.07$) in these plots, as well.

Due to fire's tendency to eliminate presence of woody species, total shrub cover decreased with fire treatment ($P < 0.01$). Basal cover was less in both burn treatments until year five when cover in plots burned once no longer differed from nonburned plots ($P = 0.35$). The same relationship was noted in increaser shrub (shrubs that increase in abundance) cover (Figure 4). There was no difference in leguminous shrub cover between treatments ($P = 0.39$).

Total species richness was positively affected by fire treatment and, after a drastic increase in burned plots following the first fire treatment, continued to remain greater for these plots throughout the experiment ($P < 0.01$). The initial spike in species richness can likely be attributed to a sizable increase in forb species richness among burned plots in year two ($P < 0.01$), while continued high values can be attributed to improved grass species richness ($P = 0.01$; Figure 5). Loss of Caucasian bluestem cover and canopy removal may have allowed more species to establish in the newly exposed soil. Fast-growing forbs likely filled in the open soil spaces until grasses were able to establish. Unsurprisingly, due to the general loss of shrub cover with fire treatment, shrub species richness decreased in burned plots following fire ($P < 0.01$).

## Implications

These data are interpreted to suggest that late-summer prescribed fire application may reduce Caucasian bluestem frequency in an effective, low-cost manner while improving native grass species richness and having no overall detrimental effects on forage cover.

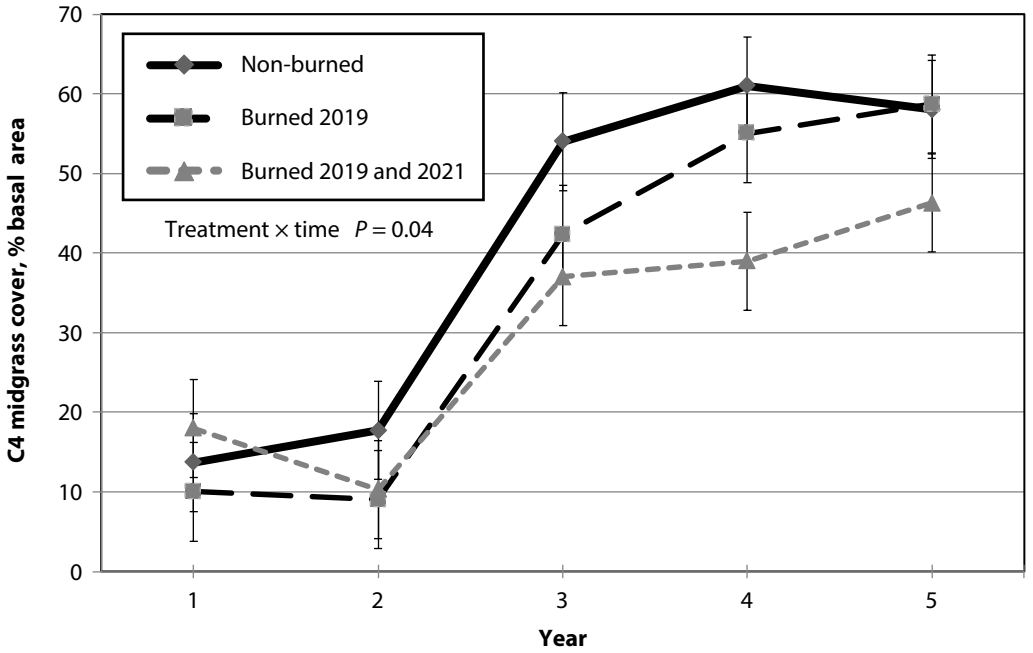


**Figure 1. Effects of late summer prescribed fire on percent C4 midgrass cover**

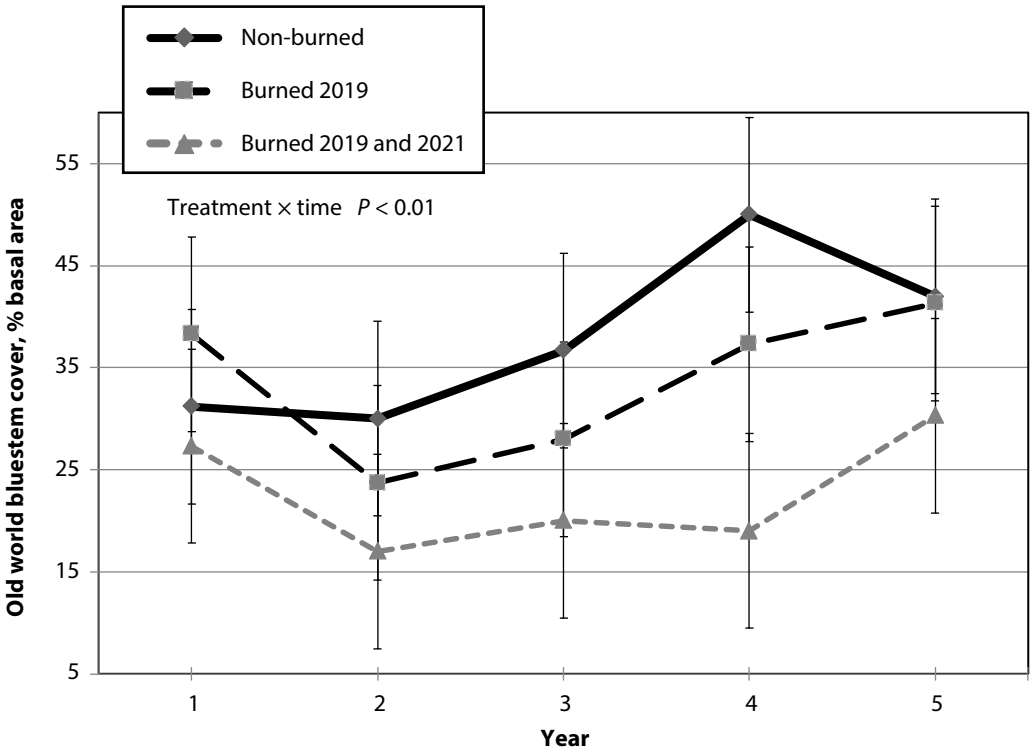


**Figure 2. Effects of late summer prescribed fire on percent Caucasian bluestem cover**

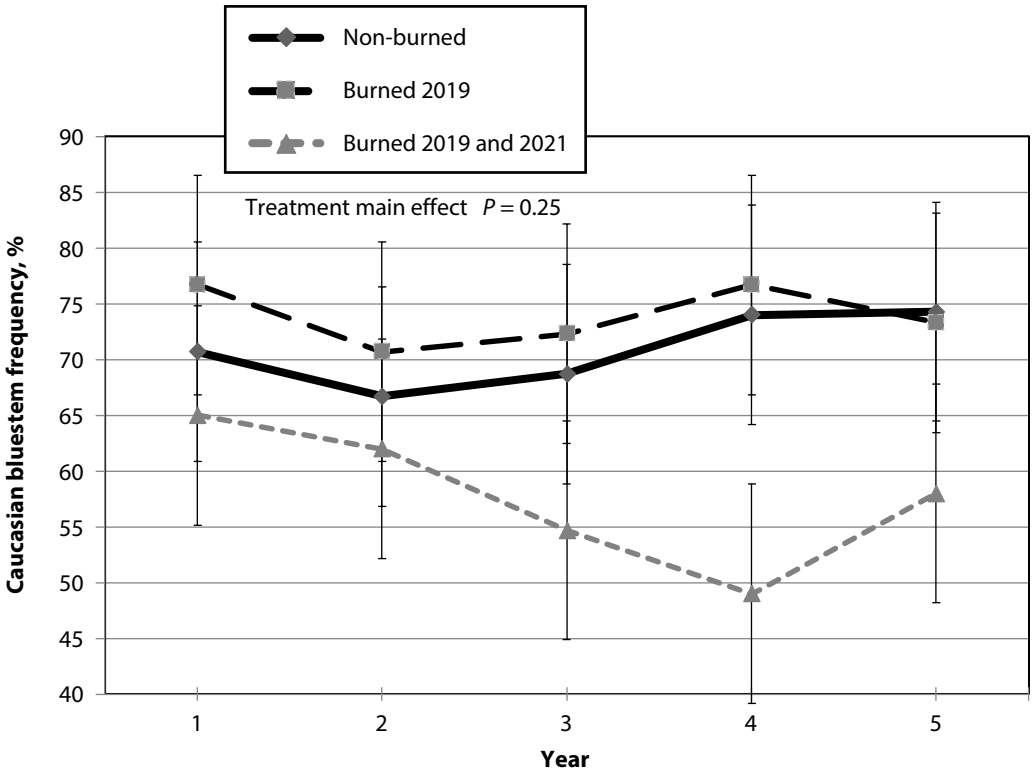


**Figure 3. Effects of late summer prescribed fire on percent Caucasian bluestem frequency**

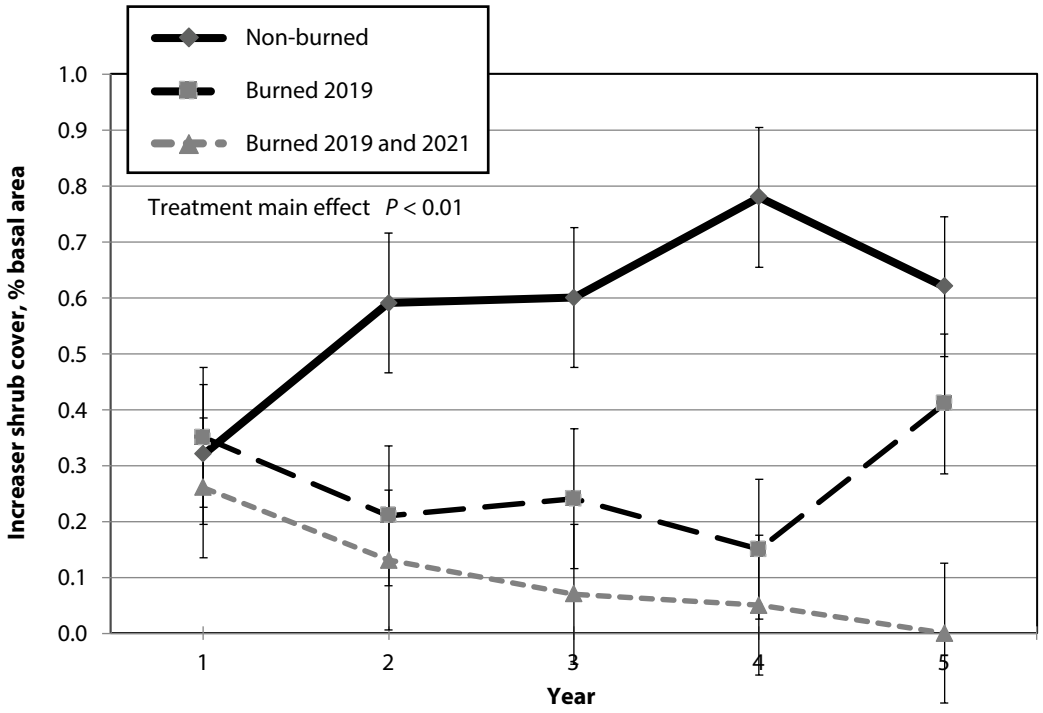


**Figure 4. Effects of late summer prescribed fire on percent increaser shrub cover**

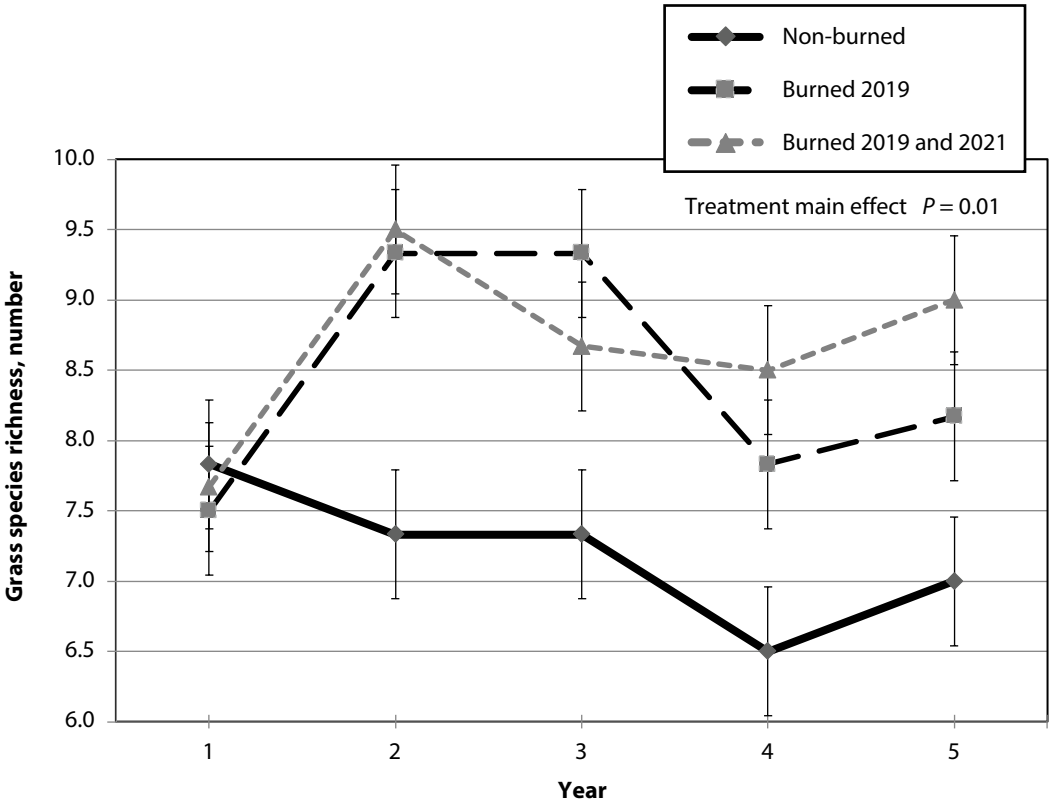


**Figure 5. Effects of late summer prescribed fire on grass species richness**

# Impact of Limit Feeding Finishing Beef Steers on Enteric Methane Production and Animal Performance

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## Abstract

The impact ruminants have on environmental sustainability has been a growing concern in recent decades. Many cattle in the northern Great Plains are fed on family-owned farms and feedlots, highlighting the need for producer-friendly mitigation strategies, such as the established, but not widely adopted, management strategy of controlled or limit feeding. The objective of this experiment was to determine the impact of limit feeding on enteric methane ($CH_4$) production and subsequent animal performance. Angus-cross steers (n = 48, body weight [BW] = 985 ± 9.7 lb) were blocked by BW and assigned to one of three treatment groups. Treatments consisted of a 1) control (CON) where steers were fed *ad libitum*; 2) Treatment 1 (TRT1) where steers were fed 96% of *ad libitum*; and 3) treatment 2 (TRT2) where steers were fed 92% of *ad libitum*. Once weekly, TRT1 and TRT2 were adjusted based on the CON steers' average intakes from the previous week. The BW was measured monthly and dry matter intake (DMI; lb/day) was measured using an Insentec Roughage Intake Control System (Insentec, Markenesse, The Netherlands). Enteric $CH_4$ and carbon dioxide ($CO_2$) production were determined utilizing two GreenFeed emission measurement systems (Automated Head-Chamber System; C-Lock Inc., Rapid City, SD). Only visits greater than 3 minutes in duration were used for analysis. Average daily gain and gain to feed did not differ among treatments ($P = 0.15$ and $P = 0.75$, respectively). The DMI was greatest for CON and least for TRT2 ($P \leq 0.01$). The $CH_4$ (g/day) output differed between treatments ($P \leq 0.007$). There was a tendency for a quadratic relationship for methane yield (g/lb DMI) among treatments ($P = 0.06$). Emission intensity (g $CH_4$/lb gain) was not different across treatments ($P = 0.78$). These results suggest precision feeding may have a positive impact on methane emissions and methane yield.

## Introduction

Over recent decades, the impact of human-induced climate change and the role of ruminant agriculture has been of growing concern for both the general public and the scientific community. Of particular interest is methane ($CH_4$) produced as a byproduct of reticulo-rumen fermentation, which is a potent greenhouse gas with a global warming potential of 28 times that of carbon dioxide ($CO_2$) over a 100-year time horizon and is responsible for 30% of the $CH_4$ budget in the U.S. (EPA, 2021). The production of this gas and its mitigation is an old energetics question that, in recent decades, has taken a new dimension because of its potent energy-trapping potential in the atmosphere (Hristov et al., 2022). Mitigation strategies are needed that ideally reduce emissions from all sources, or at a minimum, do not increase other emission sources through their respective mode of action. Additionally, strategies need to be producer-friendly by being easy to adopt and ideally increase their economic returns via improvements in efficiency/animal performance (Thompson and Rowntree, 2020). The concept of restricting feed intake is a long-established management strategy in the literature and comes in various forms including restricted feeding (where intake is

restricted based on the amount of anticipated intake), programmed feeding (based on net energy equations to calculate intake levels), and also limit feeding (Plegge, 1986; Galyean et al., 1999). Although generally, as animals increase energy consumption feed efficiency is improved, previous research indicates that maximum feed intake does not equal maximum feed efficiency (Gill et al., 1986). The objective of this experiment was to determine the impact of increasing feeding amounts on enteric $CH_4$ emissions and subsequent animal performance in finishing beef steers.

## Experimental Procedures

Prior the experiment, 70 steers were shipped from an auction house in southern Missouri to the Kansas State University Beef Cattle Research Center. On arrival, animals were held overnight with fresh water, fed a 50 net energy for gain receiving ration, and underwent initial processing the following morning. Animals were acclimated to an Automated Head-Chamber System (AHCS) for approximately 30 days and then acclimated to a pen and acclimated to 14 Insentech Roughage Intake Control feeders (Insentec, Markenesse, The Netherlands) for an additional 28 days. After the additional acclimation period, 48 steers were selected (body weight [BW] = 985 ± 9.7 lb) based on equipment acclimation, weighed, and were blocked by weight into one of three treatment groups, for a total of 16 animals per treatment. On day 0, all steers were weighed and implanted with Synovex Plus (200 mg trenbolone acetate plus 28 mg estradiol). During the experiment, three steers were removed from the study due to refusal to use the Insentec system.

Treatments consisted of a 1) control (CON) where steers were fed *ad libitum*; 2) Treatment 1 (TRT1) where steers were fed 96% of *ad libitum*; and 3) treatment 2 (TRT2) where steers were fed 92% of *ad libitum*. Once weekly, TRT1 and TRT2 were adjusted based on the CON steers' average intakes from the previous week. To minimize animal-to-animal variation, steers were ranked into high, medium, and low intake groups within each treatment, and intake restrictions for TRT1 and TRT2 were made with respect to each ranking. Steer BW were collected every 28 days for the duration of the experiment to determine animal performance via linear regression.

All steers were stepped up to a final finishing ration prior to the experiment and remained on this ration for the duration of the experiment (Table 1). The TRT1 and TRT2 intake restrictions occurred from day 0 through day 84 of the experiment. On day 84, these treatments were stepped up to *ad libitum* intake for the remainder of the experiment (day 134).

Enteric $CH_4$ and $CO_2$ production was determined utilizing two AHCS with a panel alleyway to ensure only one animal can access the systems at one time. Visits were set for a maximum of 6 drops per visit (approximately 36 g per drop) with 30-second intervals between each drop and a minimum of 4 hours between each visit to encourage animals to space visits throughout the day. This is of particular importance for meal-fed cattle where diurnal enteric $CH_4$ emission rates drastically change across the day (Gunter and Beck, 2018). Only visits greater than 3 minutes in duration were used for subsequent analyses as recommended by Velazco et al. (2016). Enteric $CH_4$ results were analyzed as g $CH_4$/day, g of $CH_4$/lb of BW gain, and g of $CH_4$/lb of dry matter intake (DMI).

## Results and Discussion

All results (Table 2) presented here encompass the entirety of the 134-day finishing period. There was no difference in initial BW between the three treatments, but there was a tendency for a linear reduction in BW at the end of the trial ($P = 0.08$). There was a reduction in DMI between the treatments ($P < 0.01$), but no difference in average daily gain (ADG) or gain:feed ($P \geq 0.15$). At the end of the intake restriction period on day 84, there was a tendency for a linear reduction in BW ($P = 0.10$) with TRT1 and TRT2 being similar at 1,200 and 1,204 lb compared to 1,265 lb for the CON. While the *ad libitum* intake period at the end of the finishing period did result in marginal increases in ADG for TRT1 and TRT2, the changes were not large enough to allow the steers to reach a similar end weight as CON steers.

For enteric $CH_4$ production, there was a quadratic effect of $CH_4$ on a g/day basis ($P = 0.02$). Emissions were lowest for TRT1 (114 g/day), intermediate for TRT2 (123 g/day), and highest for the *ad libitum* CON treatment (137 g/day). There was a reduction in DMI as well, when enteric $CH_4$ was expressed per lb of dry matter consumed, known as methane yield, there was a similar tendency for a quadratic response. This relationship did not continue when expressing emissions per lb of gain, referred to as emission intensity (EI). There was no difference between the three treatments for EI, with values ranging from 43.4 to 46.3 g $CH_4$/lb of gain.

## Implications

These results indicate that limit feeding is a viable strategy to reduce enteric $CH_4$ emissions, as previous literature would indicate, due to the close association between intake over maintenance and enteric $CH_4$ production (Johnson and Johnson, 1995). Further, limit feeding did not negatively impact feed efficiency or animal performance, in part, due to the final *ad libitum* intake period for the restricted steers at the end of the study. However, this reduction in emissions will have to be balanced against the altered body composition and lighter final BW at finishing with limit fed steers. For the 17% reduction in absolute emissions to be worthwhile, economic incentives for producers would be needed to offset this less desirable endpoint.

## References

EPA. 2021. Inventory of U.S. greenhouse gas emissions and sinks. EPA 430-R-21-005. Environmental Protection Agency. Washington, D.C.

Galyean, M.L, E.E. Hatfield, and T.L. Stanton. 1999. Review: Restricted and programmed feeding of beef cattle – definitions, application, and research results. The Professional Animal Scientist 15:1-6. doi:10.15232/S1080-7446(15)31715-0

Gill, D.R., F.N. Owens, and R.B. Hicks. 1986. Impact of feed intake on performance of grazing and feedlot cattle. In: Symposium Proceedings: Feed Intake by Beef Cattle. MP 121. page 360. Oklahoma Agricultural Experiment Station, Stillwater, OK.

Gunter, S. A., and M. R. Beck. 2018. Measuring the respiratory gas exchange by grazing cattle using an automated, open-circuit gas quantification system. Translational Animal Science 2:11–18. doi:10.1093/tas/txx009

Hristov, A.N., J. Oh, J. L. 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.2013-65834

Johnson, K.A. and D.E. Johnson. 1995. Methane emissions from cattle. Journal of Animal Science 73:2483–2492. doi:10.2527/1995.7382483x

Plegge, S.D. 1986. Restricting intake of feedlot cattle. In: Symposium Proceedings: Feed Intake by Beef Cattle. MP 121. Page 297. Oklahoma Agricultural Experiment Station, Stillwater, OK.

Thompson, L.R. and J.E. Rowntree. 2020. Invited review: Methane sources, quantification, and mitigation in grazing systems. Applied Animal. Science 36:556–573. 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 10:25–33. doi:10.1017/S1751731115001603

**Table 1. Experimental diet**

| Ingredient | Dry matter (%) |
|---|---|
| Rolled corn | 70.5 |
| Sweet Bran, wet | 15.1 |
| Corn silage | 6.1 |
| Supplement | 8.3 |
| Nutrient dry matter (%) composition | |
| Dry matter, as fed (%) | 76.3 |
| Crude protein | 11.3 |
| Acid detergent fiber | 7 |
| Total digestible nutrients | 15 |

**Table 2. Impact of limit feeding on animal performance and enteric methane emissions**

| | Treatment[1] | | | | *P*-value | |
|---|---|---|---|---|---|---|
| Item | CON | TRT1 | TRT2 | SEM[2] | Linear | Quadratic |
| Average daily gain, lb/day | 3.13 | 2.74 | 2.77 | 0.08 | 0.12 | 0.31 |
| Dry matter intake, lb/day | 23.9 | 21.9 | 21.5 | 0.56 | <0.01 | 0.21 |
| Gain:feed | 0.13 | 0.12 | 0.12 | 0.005 | 0.70 | 0.43 |
| Enteric methane (g/day) | 137 | 114 | 123 | 5.6 | 0.07 | 0.02 |
| Methane yield[3] | 5.7 | 5.2 | 5.7 | 0.2 | 0.87 | 0.06 |
| Emission intensity[4] | 45.2 | 43.4 | 46.34 | 3.0 | 0.79 | 0.52 |

[1]Treatments: CON = *ad libitum* intake; TRT1 = 96% *ad libitum* intake; TRT2 = 92% *ad libitum* intake.
[2]Standard error of the mean.
[3]Methane yield = g enteric $CH_4$/lb of dry matter consumed.
[4]Emission intensity = g enteric $CH_4$/lb of gain.

# Post-Weaning Feed Intake and Performance of Bulls Developed in an Automated Feed Intake Management System

*B.J. Fraser, J.W L. Banks, K.E. Fike, and J.M. Warner*

## Abstract

Three years of feed intake and performance data from spring-born growing bulls (n = 115) developed in an automated feed intake system were analyzed and compared to predicted values generated by the Beef Ration and Nutrition Decision Software (BRaNDS) feed formulation tool (Iowa State University, Ames, IA). Each year, bulls were weaned in the fall and entered the Kansas State University Precision Intake facility, where they were fed a total mixed ration during development prior to initial service. Feed intake data were recorded by the Insentec system for 64, 72, and 64 days in years one, two, and three, respectively. Across the three years, a moderate, statistically significant correlation (r = 0.61, $P < 0.01$) was observed between predicted and actual dry matter intake (DMI). A slightly stronger correlation (r = 0.65, $P < 0.01$) was found between predicted and actual average daily gain (ADG). However, actual ADG of bulls consistently exceeded the predicted values. These findings suggest that while the BRaNDS program appears to reasonably predict DMI, it underestimates ADG, likely due to current established nutrient requirement models for bulls and energy balance prediction equations.

## Introduction

Post-weaning intake and its relationship to average daily gain (ADG) are critical given the significant impact feed costs have on developing virgin bulls. In typical production systems, bulls upon weaning are often managed in pen settings in which the overall intake of the contemporary group is measured, yet significant variation on an individual animal basis may occur. Individual feed consumption data can be recorded by existing systems, but much of the previous work in this area with growing beef cattle has been with steers. Likewise, the performance of growing cattle can be predicted from nutrient requirements if feed intake is measured and dietary composition is known, and research evaluating this with pre- and peri-pubertal bulls post-weaning is limited. The Beef Ration and Nutrition Decision Software (BRaNDS) formulation program is used by Kansas State University Research and Extension as well as by other Extension services, nutritionists, and veterinarians. Data sets using individual feed intake and performance data to validate performance predictions are limited and valuable for improving accuracy of the BRaNDS program. Our objectives were to: 1) report observed intake and performance data, and 2) compare expected and observed dry matter intake (DMI) and ADG of bulls in a multi-year analysis using modeled nutrient requirement equations in the BRaNDS program.

## Experimental Procedures

Feed intake and performance data from purebred Angus, Hereford, and Simmental bull calves across three calf crops (birth years 2021 [n = 40], 2022 [n = 37], and 2023 [n = 41]) were used for this ongoing multi-year analysis. The first two years of this

analysis were previously reported (Banks et al., 2024). All calves were born at the Kansas State University Purebred Beef Unit in the spring and raised at the dam's side, grazing native Flint Hills range until weaning in September each year. At weaning, bulls initially had access to native prairie hay and a commercial creep feed for *ad libitum* consumption for approximately 2 weeks before being transitioned to a total mixed ration, which was subsequently fed for 5-6 weeks. Following the weaning and diet transition period, bulls entered the Kansas State University Precision Feed Intake Facility in mid-November each year. Intake test periods were November 11, 2021, through February 2, 2022 (83 days), November 19, 2022, through January 30, 2023 (72 days), and December 2, 2023, through February 4, 2024 (64 days), for years 1, 2, and 3, respectively. During the 2021-2022 test year, feed intake data were recorded for 64 days. In all years, bulls were managed as a common group in earthen partially covered pens and fed using Insentec bunk module units allowing for individual feed intake data to be recorded while on test. The third-year bulls were divided into diet treatment groups consisting of a 0 lb (control), 0.5 lb, and 1.0 lb per head per day equivalent intake (as-is basis) of an omega 3-based fatty acid supplement top-dressed onto the basal diet. Treatment groups were randomly assigned to bunk module units throughout the pen and individual feed intake data were recorded, but bulls were managed in a single pen. Ingredient composition of diets fed differed among years (Table 1). Bulls were individually weighed without feed or water restriction at both the beginning and end of the test period to calculate ADG, with feed to gain ratio (F:G) subsequently calculated for each bull from average individual DMI. In year 3, bulls were weighed for three consecutive days at both the beginning and end of the test period and averaged to determine initial and ending weight.

Projected DMI and ADG were calculated for each group of bulls by year on an individual basis using the Growing Bull module of the Excel-based BRaNDS formulation program. Intake and performance equations incorporated into BRaNDS are from the Nutrient Requirements of Beef Cattle 7$^{th}$ and 8$^{th}$ editions. Using actual initial and ending body weight (BW) for each bull, actual DMI of individual feedstuffs based on diet composition, and assumed average feedstuff composition values, projected DMI and ADG were retrospectively calculated to determine the accuracy of the program in predicting performance. In the 2021-2022 test year, two different diets were fed but only one diet was used in the analysis as it was fed for the majority of the total days. All data were analyzed using SAS (SAS Institute Inc., Cary, NC), and correlation procedures were used to evaluate the relationship between observed and projected DMI and ADG. *P*-values less than or equal to 0.05 were declared significant.

## Results and Discussion

Initial BW averaged 793 lb with an ending weight of 1,056 lb across the three-year study (Table 2). Actual DMI was similar to predicted values, with a mean of 20.2 lb/day compared to the predicted 20.7 lb/day, and a standard deviation of 3.9 (Table 1). Actual ADG was consistently higher than predicted, with a mean ADG of 3.63 lb/day compared to the predicted 2.26 lb/day.

For the combined 2021-2023 dataset, a moderate positive correlation ($r = 0.61$, $P < 0.01$) was found between actual and predicted DMI, indicating that the BRaNDS formulation program accurately models DMI across varying diet compositions (Table 3). A stronger positive correlation ($r = 0.65$, $P < 0.01$) was observed between actual and predicted ADG, although the actual ADG consistently exceeded the

predicted values (Table 3). This consistent underestimation of ADG may reflect how BRaNDS handles metabolizable protein and energy balances in relation to different diets and suggests the current performance models underpredict performance of young growing bulls.

## Implications

These results indicate that while BRaNDS accurately predicts DMI, further refinement of energy equations with additional individual performance data is needed to improve its ability to predict ADG.

## Acknowledgments

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## References

Banks, J., L Wyatt, K.E. Fike, and J.M. Warner. 2024. Post-weaning feed intake and performance of bulls developed in an automated feed intake management system. Kansas Agricultural Experiment Station Research Reports 10(1).

**Table 1. Ingredient composition of diets by year, percent dry matter basis**

| Item | 2021-2022[1] | 2021-2022[2] | 2022-2023 | 2023-2024[3] | 2023-2024[4] | 2023-2024[5] |
|---|---|---|---|---|---|---|
| Corn silage | 43.50 | 35.70 | 60.00 | 30.50 | 31.10 | 30.80 |
| Wet corn gluten feed | 21.75 | 25.00 | 25.00 | 29.20 | 27.50 | 26.10 |
| Steam flaked corn | --- | --- | 7.98 | --- | --- | --- |
| Dry rolled corn | 23.00 | 10.00 | --- | 20.30 | 17.80 | 16.40 |
| Brome hay | 9.46 | 22.15 | --- | 12.50 | 14.10 | 14.70 |
| supplement | 2.29 | 2.15 | 1.74 | 7.50 | 7.30 | 7.60 |
| Omega 3 fatty acid supplement | --- | 5.00 | 5.28 | --- | 2.20 | 4.50 |

[1]Fed from November 11 to December 29, 2021.
[2]Fed from December 30, 2021, to February 2, 2022.
[3]Control diet.
[4]0.5 lb Omega 3 fatty acid supplement inclusion diet.
[5]1.0 lb Omega 3 fatty acid supplement inclusion diet.

**Table 2. Actual and predicted bull performance means**

| | 2021-2023 | | |
|---|---|---|---|
| **Item** | **Actual** | **SD[1]** | **Predicted** |
| Initial BW,[2] lb | 793 | 114 | --- |
| Ending BW,[2] lb | 1,056 | 137 | --- |
| DMI,[2] lb/day | 20.2 | 3.9 | 20.7 |
| ADG,[2] lb | 3.63 | 0.79 | 2.26 |
| F:G[2] | 5.76 | 1.28 | --- |

[1] Standard deviation.
[2] BW = body weight; DMI = dry matter intake; ADG = average daily gain; F:G = feed to gain ratio.

**Table 3. Correlation coefficients for actual and predicted intake and gain of bulls**

| | 2021-2023 | | | |
|---|---|---|---|---|
| **Item** | **Actual** | **Predicted** | **r** | ***P*-value** |
| DMI,[1] lb/day | 20.2 | 20.7 | 0.61 | < 0.01 |
| ADG,[1] lb | 3.63 | 2.26 | 0.65 | < 0.01 |

[1] DMI = dry matter intake; ADG = average daily gain.

# Effects of an Acclimation Protocol During the Handling Events of the 7-day CO-synch + CIDR Protocol on Temperament and Reproductive Performance of *Bos taurus* Commercial Beef Heifers

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## Abstract

Cattle temperament can have a significant effect on reproductive performance. Earlier studies reported that enrolling excitable heifers in an estrus synchronization (ES) protocol effectively improved temperament by the day of artificial insemination (AI). The objective of this study was to assess the effects of acclimation, during the handling events of an ES protocol, on temperament and reproductive performance of commercial beef heifers. Heifers were assessed for reproductive tract score (RTS), chute score (CS), and exit velocity (EV) before enrollment in the study (day -10). Those with immature tract scores were excluded. Angus-influenced commercial heifers (n = 361) were stratified by RTS and CS to either the treatment (TRT) or the control (CTRL) group, tagged accordingly, and then pastured together. Before ES protocol handling events (day 0, 7, and 10), TRT heifers were sorted and acclimated by running them through the chute without restraint and commingling them with their CTRL pasture mates. CS and EV were collected to measure temperament during ES days -10, 0, 7, and 10 for all individuals. Estrus detection patches were applied on day 7 and scored on day 10. Pregnancy status was determined approximately 40 days post-AI by rectal ultrasonography. RTS ($P = 0.777$), CS ($P = 0.990$), and EV ($P = 0.9607$) did not differ between groups on day -10. There was no difference in estrus detection patch scores ($P = 0.1906$), or the percent of heifers pregnant to the ES protocol between TRT (56.8%) and CTRL (52.7%) heifers ($P = 0.3563$). On day 7 ($P = 0.001$) and day 10 ($P = 0.0002$), CS was lesser for TRT heifers in comparison to CTRL heifers. Our findings suggest that acclimating heifers to the facility during the handling events of the 7-day CO-synch + CIDR ES protocol effectively improved heifer temperament by the time of artificial insemination, but it did not support better reproductive performance.

## Introduction

Commercial beef producers have been hesitant to adopt estrus synchronization (ES) protocols as a production management tool. After a survey of Virginian cattlemen, the greatest concerns were focused on cost, number of handling events, and conception rates to fixed-time artificial insemination (TAI). One factor to have a known negative effect on TAI conception rates is excitable temperament (Dias et al., 2022). Temperament is the behavioral response to human handling (Fordyce et al., 1988). It has previously been shown that acclimation to human handling can decrease excitability and increase reproductive performance of Brahman-influenced cows (Cooke et al., 2011).

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Earlier studies reported that the human handling of beef heifers that occurs during the events of an ES protocol was effective at improving temperament in Angus-influenced beef heifers by TAI (Dias et al., 2022). The objective of this study was to assess the effects of acclimation, during the handling events of an ES protocol, on temperament and reproductive performance of commercial beef heifers. We hypothesized that acclimating heifers to the facility during the handling events of the ES protocol would effectively decrease temperament excitability by TAI, and thus increase the percent of heifers pregnant to the ES protocol when compared to nonacclimated counterparts.

## Experimental Procedures

### *Temperament Evaluation*

Angus-influenced commercial beef heifers (n = 361) from five locations were enrolled in the experiment. Before enrollment (day -10), all heifers were evaluated for reproductive tract score (RTS), chute score (CS), and exit velocity (EV). Reproductive tracts were scored using the five-point scoring system (Holm et al., 2009). Heifers with an RTS of 1, having an immature tract and no palpable structures, were excluded from the study. For measures of temperament, we used the methods described by Cooke and others (Cooke et al., 2011). CS was evaluated on a five-point system upon entering the chute; 1 = calm, no movement; 2 = restless movement; 3 = frequent movement and vocalization; 4 = constant movement, vocalization, shaking of the chute; and 5 = violent, continuous struggling. One infrared beam was set just outside of the head catch of the chute, and another was placed 6.6 ft from the first. Once the heifer was released from the chute and crossed the start beam, the timer started. When she crossed the second beam, the timer stopped and the exit time at chute side was recorded. To compute EV, the distance between the two timers (6.6 ft) was divided by the heifer's exit time. Additionally, on day -10, heifers were stratified by RTS and CS into either the treatment (TRT) or the control (CTRL) group and tagged with a colored ear tag indicating their respective group. Heifers were pastured together.

### *ES Protocol*

The ES protocol used was the 7-day CO-synch + CIDR protocol for beef heifers (Lamb et al., 2006). On day 0 heifers were given an injection of gonadotropin releasing hormone (GnRH) intramuscularly (IM) and an EAZI-BREED CIDR device (Zoetis Animal Health, Parsippany, NJ) was inserted vaginally. On day 7, the CIDR was removed, heifers were given an injection of prostaglandin ($PGF_{2\alpha}$) IM, and an estrus detection patch was applied to the individual's tailhead. After 54 hours ± 2 hours later (day 10), TAI was performed, and an IM injection of GnRH was administered. On all days (0, 7, and 10), TRT heifers were acclimated prior to the ES event of the day by running them through the tub, alley, and chute without being caught. They were then commingled back with their pasture mates, and all heifers (TRT and CTRL) were brought through the facility for the ES event of that day. Additionally, on all days (0, 7, and 10), all heifers were evaluated for CS and EV. On day 10, the estrus detection patches were evaluated and scored based on the percentage of patch surface that was rubbed off. Patches were scored on a 5-point system; 0 = lost patch, 1 = less than 25% activated, 2 = less than 50% activated, 3 = less than 75% activated, and 4 = more than 75% activated. After TAI, heifers were returned to the pasture and exposed to bulls 14 days after TAI (experimental day 24). Pregnancy status was determined via rectal ultrasonography approximately 40 days post-TAI.

### *Statistical Analysis*

All data were analyzed using the SAS 9.4 software. For the percentage of heifers pregnant to the ES protocol parameter, GLIMMIX was used with heifer as the experimental unit. For all repeated measures, EV and CS, the MIXED procedure was used. The level of significance was set at $P < 0.05$ with tendency set at $0.05 \leq P \leq 0.10$.

## Results and Discussion

There was no difference in RTS ($P = 0.777$), CS ($P = 0.990$), and EV ($P = 0.9607$) between TRT or CTRL heifers on day -10 before enrollment in the ES protocol and acclimation. When looking at measurements of temperament, on day 7 ($P = 0.001$) and day 10 ($P = 0.0002$), CS was lesser for TRT heifers in comparison to CTRL heifers (Table 1). For EV, there were no between-group differences but there was an effect of day ($P < 0.05$). All heifers had slower ($P > 0.05$) velocities for days 7 and 10 compared to days -10 and 0. We concluded that it is likely that acclimation during the ES protocol was effective at improving temperament due to the difference in CS between TRT and CTRL heifers. To support this claim, blood samples were collected on a subset of heifers, and these will be analyzed for plasma cortisol concentrations. Circulating levels of cortisol are a biomarker of stress (Sapolsky et al., 2000). This analysis is a work in progress and will help discern the physiological effect of acclimation. There was no difference in estrus detection patch scores between groups ($P = 0.1906$). While there was a 4-percentage point difference in the percent of heifers that became pregnant to the ES protocol between TRT (56.8%) and CTRL (52.7%) heifers, this was not a statistically significant difference (Table 1). This was attributed to the lack of significance with a small sample size. In the future, more heifers will be enrolled in the study to increase the power of the test.

## Implications

Acclimation during an ES protocol is cost-conscious and effective at improving temperament of beef heifers, and more research is needed to discern the effects on reproductive performance.

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## References

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. *https://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). *https://doi.org/10.1093/tas/txac156*

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

Holm, D.E., P.N. Thompson, and P.C. Irons. 2009. The value of reproductive tract scoring as a predictor of fertility and production outcomes in beef heifers. Journal of Animal Science 87(6):1934–1940. *https://doi.org/10.2527/jas.2008-1579*

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 $F_{2\alpha}$, and progesterone. Journal of Animal Science 84(11):3000–3009. *https://doi.org/10.2527/jas.2006-220*

Sapolsky, R.M., L.M. Romero, and A.U. Munck. 2000. How do glucocorticoids influence stress responses? Integrating permissive, suppressive, stimulatory, and preparative actions. Endocrine Reviews 21(1):55–89. *https://doi.org/10.1210/edrv.21.1.0389*

**Table 1. Average chute score, exit velocity, estrus detection patch score, and percent of heifers pregnant to the protocol by treatment group**

| | Average chute score | | Average exit velocity (m/second) | | Average estrus detection patch score | | TAI conception rate (%) | |
|---|---|---|---|---|---|---|---|---|
| **Heifer group** | **CTRL** | **TRT** | **CTRL** | **TRT** | **CTRL** | **TRT** | **CTRL** | **TRT** |
| Day -10 | 2.3 | 2.3 | 2.0 | 1.9 | | | | |
| Day 0 | 2.3 | 2.1 | 2.1 | 2.0 | | | | |
| Day 7 | 2.1[b] | 1.7[a] | 1.7 | 1.6 | | | | |
| Day 10 (TAI) | 2.2[b] | 1.8[a] | 1.6 | 1.6 | 2.1 | 2.3 | | |
| Day 40 | | | | | | | 52.7 | 56.8 |
| *P*-value | TRT = 0.0003<br>Day < .0001<br>TRT × Day = 0.0011 | | TRT = 0.3848<br>Day < .0001<br>TRT × Day = 0.8934 | | TRT = 0.1906<br>Location < .0001<br>TRT × Location = 0.4629 | | TRT = 0.3563<br>Location = 0.5405<br>TRT × Location = 0.9801 | |

[ab]Means within rows with unlike superscripts differ ($P < 0.05$).

# Effects of *Bacillus subtilis* PB6 (CLOSTAT 500) Incorporation Into a Commercial Mineral Supplement on Growth Performance and Health of Beef Stocker Calves Grazing in the Kansas Flint Hills

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## Abstract

The objective of this experiment was to evaluate the effects of incorporating *Bacillus subtilis* PB6 (CLOSTAT; Kemin Industries, Inc., Des Moines, IA) into a commercial mineral supplement on growth performance and health of crossbred beef steers grazing in the Kansas Flint Hills. Eighteen pastures were randomly assigned to receive one of two free choice mineral supplements (n = 9): a commercial mineral supplement (CON) or a commercial mineral supplement formulated to provide 0.5 g/head/day CLOSTAT 500 (CLO). A total of 495 steers (initial body weight [BW]= 477 ± 5.7 lb) were purchased in Texas and transported to the Kansas State Beef Stocker Unit. On day -1, steers were individually weighed, treated for internal and external parasites, and randomly assigned to pasture. The following day (day 0), steers were reweighed individually, given a growth-promoting implant, and walked to their respective pastures. Steers were grazed for 90 days at a targeted stocking density of 250 lb of live weight per acre. At the completion of the grazing period, steers were gathered and individually weighed. Prior to grazing, a supplement feeder was placed in each pasture, and mineral was delivered twice weekly to provide 4 oz/head/day. Initial BW, final BW, and average daily gain did not differ ($P \geq 0.29$) between steers supplemented with CON or CLO. Similarly, mineral consumption and the proportion of steers treated for bovine keratoconjunctivitis did not differ ($P \geq 0.16$) between treatments. Overall, incorporating CLOSTAT into a commercial mineral supplement did not improve growth performance of beef cattle grazing in the Kansas Flint Hills.

## Introduction

Each year beef cattle from around the United States are sent to Kansas to graze the native warm-season pastures of the Flint Hills. Cattle are traditionally grazed at a high stocking density from May to August (i.e., intensive-early stocking) and are often provided with a mineral supplement to improve weight gains. CLOSTAT 500 (Kemin Industries, Inc., Des Moines, IA) is a direct-fed microbial that contains a proprietary strain of *Bacillus subtilis*, PB6. Previous research evaluating CLOSTAT supplementation to feedlot cattle has demonstrated improvements in health and growth performance (Ryan et al., 2023; Smock et al., 2020; Word et al., 2022); however, supplementing CLOSTAT to grazing cattle has not been evaluated. The objective of this experiment was to determine if incorporation of CLOSTAT 500 into a commercial mineral supplement would improve growth performance and health of stocker cattle grazing in the Kansas Flint Hills.

[1] Kemin Industries, Inc., Des Moines, IA

## Experimental Procedures

This experiment was conducted between May and August 2024 at the Kansas State Beef Stocker Unit. The Beef Stocker Unit includes approximately 1,100 acres of native tallgrass prairie and is divided into 18 pastures that range from 40 to 70 acres. Prior to the start of the experiment, a spring-season prescribed fire was applied to 11 pastures on April 20 and seven pastures on April 24. Pastures were randomly assigned to receive one of two mineral supplements (n = 9): a free choice commercial mineral supplement (CON; Table 1) or a free choice commercial mineral supplement that contained CLOSTAT 500 (CLO). Mineral supplements were delivered twice weekly (i.e., Monday and Friday) to provide 4 oz/head/day. For CLO, CLOSTAT 500 was included in the mineral supplement at 9 lb/ton as-fed (AF) to provide 0.5 g of CLOSTAT/head/day.

A total of 495 crossbred beef steers (initial body weight [BW]= 477 ± 5.7 lb) were purchased in Texas and transported to the Kansas State Beef Stocker Unit between April 29 and May 8, 2024. Upon arrival, steers received a visual identification ear tag and were fed a growing diet at 2.0% of body weight (BW; dry matter basis) until May 12, 2024 (day -1). On day -1, steers were weighed individually using a hydraulic squeeze chute (SILENCER, Moly Manufacturing, LLC, Lorraine, KS), treated for internal (SAFE-GUARD; Intervet International B.V., Madison, NJ) and external (Clean-Up II; Elanco Animal Health, Greenfield, IN) parasites, and were randomly assigned to pasture (20 to 34 head). The following day (day 0), steers were reweighed individually, given a pasture ear tag, and administered a growth-promoting implant (Revalor-G, Intervet International B.V., Madison, NJ). Following processing, steers were sorted and then walked to their respective pastures. Steers were grazed for 90 days at a targeted stocking density of 250 lb of live weight per acre. At the completion of the grazing period, steers were gathered and reweighed individually.

Prior to the start of the experiment, a supplement feeder (Bull Master; F&B Mann Products, Waterville, KS) was placed in each pasture. Feeders were placed near the water tank with their flaps up to allow steers to acclimate. If the mineral was consumed within 3 days of delivery, feeder flaps were lowered. Similarly, if the mineral was consumed within 3 days of delivery with the flaps lowered, feeders were moved approximately 1,000 to 1,500 ft away from the water tank. An individual salt block was placed in each pasture at the start of the experiment. Salt blocks were removed from all pastures on day 26.

Growth performance data were analyzed using the MIXED procedure of SAS (SAS 9.4, SAS Inst. Inc., Cary, NC). The model included treatment as a fixed effect. Mineral consumption data were analyzed using the MIXED procedure of SAS. The model included fixed effects of treatment, week, and treatment × week. No treatment × week interactions were observed ($P = 0.98$); therefore, main effects of treatment are discussed. Health data were analyzed as a binomial proportion of the pasture using the GLIMMIX procedure of SAS. The model included treatment as a fixed effect.

## Results and Discussion

A total of four steers were removed from the experiment due to lameness. Three steers were removed from CLO and one steer was removed from CON. In addition, one steer from CON died. All performance data from lame and dead animals were removed prior to analysis.

At the completion of the 90-day grazing period, final BW and average daily gain did not differ ($P \geq 0.57$; Table 2) between mineral treatments. Average daily gains were 2.03 and 1.99 lb/day for steers supplemented with CON and CLO, respectively. Previous research demonstrated improvements in cattle health and growth performance when CLOSTAT was supplemented to feedlot cattle (Ryan et al., 2023; Smock et al., 2020; Word et al., 2022). In this experiment, no steers were treated for bovine respiratory disease (BRD), which may have contributed to the lack of a treatment response. The incidence of bovine keratoconjunctivitis (i.e., pinkeye) was relatively high in our experiment. Despite this, the proportion of steers treated for pinkeye prior to grazing, treated once during the grazing season, or treated twice during the grazing season did not differ ($P \geq 0.16$; Table 3) between CON or CLO.

Overall mineral consumption was similar ($P = 0.54$; Table 2; Figure 1) between treatments and averaged 3.38 and 3.33 oz/head/day for steers supplemented with CON and CLO, respectively. Mineral consumption during the first two weeks averaged 1.71 and 1.29 oz/head/day, respectively. Low mineral consumption during this period may have been influenced by precipitation. The Beef Stocker Unit received approximately 4.5 in of rainfall during the first two weeks of the experiment (Figure 2). Mineral feeder flaps were placed down during periods of rainfall, which likely increased the amount of time steers took to acclimate to the feeders. Regardless, mineral consumption increased (week: $P < 0.01$; Figure1) from week 2 to 5, where it remained relatively constant throughout the remainder of the grazing season.

## Implications

Feeding a commercial mineral supplement that contained *Bacillus subtilis* PB6 (CLOSTAT 500) did not improve growth performance or health of crossbred beef steers grazing in the Kansas Flint Hills.

## Acknowledgments

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## References

Ryan, W.R., E.S. DeSocio, M.E. Youngers, C.G. Lockard, C.J. Richards, S.J. Trojan, J.E. Hergenreder, and B.K. Wilson. 2023. Effects of feeding CLOSTAT (*Bacillus subtilis* PB6) on the clinical health, performance, and carcass characteristics of feedlot steers. Translational Animal Science 7:1-8. doi: 10.1093/tas/txad047

Smock, T.M., K.L. Samuelson, J.E. Hergenreder, P.W. Rounds, and J T. Richeson. 2020. Effects of *Bacillus subtilis* PB6 and/or chromium propionate supplementation on clinical health, growth performance, and carcass traits of high-risk cattle during the feedlot receiving and finishing periods. Translational Animal Science 4:1-12. doi: 10.1093/tas/txaa163

Word A., P.R. Broadway, N. Burdick-Sanchez, J. Carrol, K. Hales, K. Karr, B. Holland, G. Ellis, C. Maxwell, L. Canterbury, J.T. Leonhard, D. LaFleur, J. Hergenreder, and S. Trojan. 2022. The effect of supplementing CLOSTAT 500 (*Bacillus subtilis* PB6) to yearling steers in a commercial feedyard on health, *Salmonella* spp. prevalence, feedlot growth performance, and carcass characteristics. Translational Animal Science 6:1-11. doi: 10.1093/tas/txac131

**Table 1. Composition of mineral treatments**

| | Treatment | |
|---|---|---|
| **Ingredient, % AF** | **Control** | **CLOSTAT** |
| Calcium carbonate | 31.03 | 30.58 |
| Salt | 25.13 | 25.13 |
| Distillers grains | 20.54 | 20.54 |
| Molasses, 5% fat | 17.99 | 17.99 |
| Dicalcium phosphate | 2.00 | 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 |
| Pur licorice/anise flavor | 0.03 | 0.03 |
| Magnesium oxide bulk | 0.03 | 0.03 |
| CLOSTAT 500[1] | --- | 0.45 |

[1]*Bacillus subtilis* PB6 (CLOSTAT 500; Kemin Industries, Inc., Des Moines, IA).

**Table 2. Effects of *Bacillus subtilis* PB6 incorporation into a free choice commercial mineral supplement on growth performance of beef stocker calves grazing in the Kansas Flint Hills**

| | Treatment[1] | | | |
|---|---|---|---|---|
| **Item** | **Control** | **CLOSTAT** | **SEM[2]** | ***P*-value[3]** |
| Number of pastures | 9 | 9 | | |
| Number of head[4] | 246 | 244 | | |
| Initial body weight, lb | 476.0 | 479.0 | 1.88 | 0.29 |
| Final body weight, lb | 658.8 | 657.8 | 5.30 | 0.90 |
| Average daily gain, lb/day | 2.03 | 1.99 | 0.053 | 0.57 |
| Mineral consumption, oz/head/day | 3.38 | 3.33 | 0.050 | 0.54 |

[1] Commercial mineral supplement (Control) or commercial mineral supplement + 0.5 g/head/day *Bacillus subtilis* PB6 (CLOSTAT 500, Kemin Industries, Inc., Des Moines, IA) provided at 4 oz/head/day.
[2] Largest standard error of the mean.
[3] Treatment main effect.
[4] Four steers were removed from the study due to lameness; CLOSTAT: three; Control: one. One steer from Control died. All data presented with dead and lame steers removed.

**Table 3. Effects of *Bacillus subtilis* PB6 incorporation into a commercial mineral supplement on bovine keratoconjunctivitis (pinkeye) prevalence in beef stocker calves grazing in the Kansas Flint Hills**

| | Treatment[1] | | | |
|---|---|---|---|---|
| Item, % treated | Control | CLOSTAT | SEM[2] | *P*-value[3] |
| Prior to grazing | 2.4 | 3.7 | 1.21 | 0.44 |
| Treated once | 26.8 | 22.5 | 2.83 | 0.29 |
| Treated twice | 1.2 | 3.3 | 1.14 | 0.16 |

[1] Commercial mineral supplement (Control) or commercial mineral supplement + 0.5 g/head/day *Bacillus subtilis* PB6 (CLOSTAT 500, Kemin Industries, Inc., Des Moines, IA) provided at 4 oz/head/day.
[2] Largest standard error of the mean.
[3] Treatment main effect.
[4] Four steers were removed from the study due to lameness; CLOSTAT: three; Control: one. One steer from Control died. All data are presented with dead and lame steers removed.

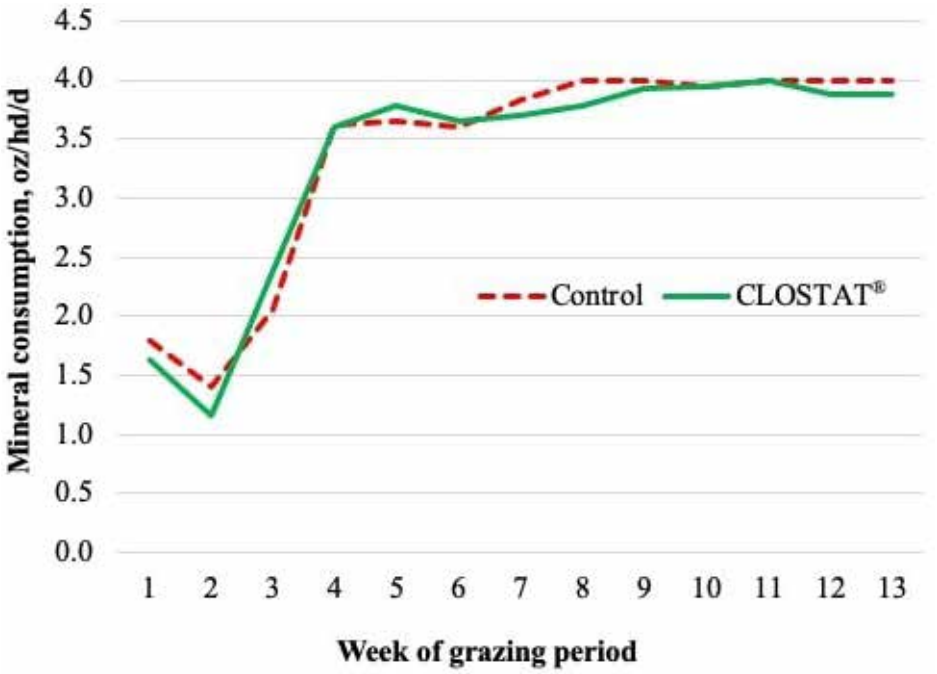


**Figure 1. Free choice mineral consumption of a commercial mineral supplement (Control) or a commercial mineral supplement + 0.5 g/hd/d *Bacillus subtilis* PB6 (CLOSTAT® 500) for beef stocker calves grazing in the Kansas Flint Hills. Treatment × week: *P* = 0.9730; Treatment: *P* = 0.54; Week: *P* < 0.01.**

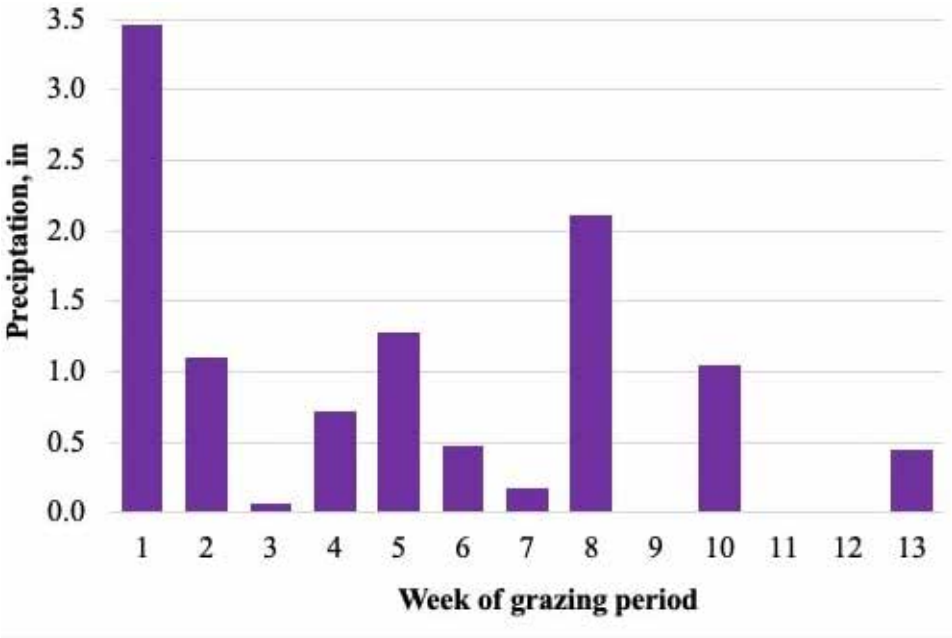


**Figure 2. Precipitation received near the Kansas State Beef Stocker Unit between May 13, 2024 and August 11, 2024. Data was obtained from the Kansas Mesonet database using the Rocky Ford weather station, located approximately 3 miles east of the Kansas State Beef Stocker Unit.**

# Effects of Omega-3 Fatty Acid Supplementation on Growth and Development of Bull Calves

*B.J. Fraser, A.G. Schwartz, and J.W. Warner*

## Abstract

An omega-3 fatty acid supplement was fed to spring-born purebred growing bulls (n = 42) developed in an automated feed intake system. Diets were generated using the Beef Ration and Nutrition Decision Software (BRaNDS) feed formulation package (Iowa State University, Ames, IA). The bulls were weaned in the fall and entered the Kansas State University Precision Feed Intake Facility, where they were fed a total mixed ration. Feed intake was recorded by the Insentec system for 64 days. The bulls were randomly assigned to three groups that included a control that did not receive the omega-3 supplement (n = 14), and calves that received 0.5 lb (n = 14) or 1.0 lb (n = 18) of the omega-3 supplement. No differences ($P = 0.64$) were found for dry matter intake (DMI) among treatment groups. However, bulls in the 1.0 lb treatment group had higher ($P = 0.04$) average daily gain (ADG) compared to the control group. Feed-to-gain ratios (F:G) were not different ($P = 0.72$) among groups. Scrotal circumference (SC) and final body weight also showed no differences ($P > 0.05$). The probability of passing the breeding soundness exam (BSE) was lower ($P = 0.0097$) in the 1.0 lb treatment group compared to the control group. These results suggest that while omega-3 supplementation at 1.0 lb/day improved weight gain, it may have negatively impacted reproductive soundness, as indicated by lower BSE pass rates.

## Introduction

The post-weaning period is a critical developmental phase for beef bulls, during which nutrition plays a vital role in their growth and reproductive performance. After weaning, typically around 7 months of age, bulls experience rapid growth and development before their introduction to females for breeding at approximately 15 months. This developmental window is essential for ensuring long-term reproductive success and the overall viability of the animal. Much research has focused on the post-weaning nutrition of beef heifers; comparatively less attention has been given to beef bulls, particularly regarding how nutritional supplementation may influence growth, feed intake, efficiency, and sexual development characteristics.

Understanding the impact of dietary fatty acids on bulls during this period could have substantial implications for the beef industry. The objective of this study was to evaluate the effect of supplemental omega-3 fatty acids on post-weaning beef bulls. Specifically, this study aimed to assess the influence of dietary fatty acids on growth performance, including average daily gain (ADG), feed intake, and feed efficiency, and reproductive development, including scrotal circumference (SC) and breeding soundness exam (BSE) outcomes. Given the lack of extensive research in this area, especially concerning bull development, this study seeks to contribute valuable insights that can be applied to improve the management and nutrition of growing beef bulls in production systems.

## Experimental Procedures

Spring born purebred Angus, Hereford, and Simmental bull calves from the 2023 calf crop (n = 42) were utilized in this trial. All calves were born at the Kansas State University Purebred Beef Unit in the spring and raised at dam's side grazing native Flint Hills range until weaning in September each year. At weaning, bulls initially had access to native prairie hay and a commercial creep feed for *ad libitum* consumption for approximately 2 weeks before being transitioned to a total mixed ration, which was subsequently fed for 4 to 5 weeks. Following the weaning and diet transition period, bulls entered the Kansas State University Precision Feed Intake Facility in mid-November. Once at a stable intake level, bulls were randomly assigned to diet treatment groups consisting of a 0 lb (control, n = 14), 0.5 lb (n = 14), or 1.0 lb (n = 18) per head per day equivalent intake (as-is basis) of an omega 3-based fatty acid supplement top-dressed onto the basal diet. Bulls were weighed for three consecutive days at the beginning and end of the test period and averaged to determine initial and ending weight. Initial day of age and the average initial body weight (BW) were used to stratify the bulls. Treatment groups were randomly assigned to Insentec bunk module units throughout the pen and individual feed intake data were recorded. The ADG was calculated using the initial and ending weights with feed to gain ratio (F:G) subsequently calculated for each bull from average individual dry matter intake (DMI).

Each treatment group diet was created using the Growing Bull module of the Excel-based Beef Ration and Nutrition Decision Software (BRaNDS) formulation program used by Kansas State University Research and Extension as well as by other Extension services, nutritionists, and veterinarians. Ingredient composition of diets fed differed between treatment groups (Table 1). Intake and performance equations incorporated into BRaNDS were from the Nutrient Requirements of Beef Cattle 7$^{th}$ and 8$^{th}$ editions. Data were analyzed using SAS (SAS Institute Inc., Cary, NC) using the PROC GLIMMIX procedure. A *P*-value less than or equal to 0.05 was declared significant.

## Results and Discussion

Initial BW averaged 776 lb across the three treatment groups, with no differences ($P = 0.98$) observed (Table 2). By the end of the study, final BW were 1,003 lb for the control group, 1,023 lb for the 0.5 lb treatment group, and 1,035 lb for the 1.0 lb group, and were not different ($P = 0.77$) between groups. Despite the lack of significance, there was a trend toward higher final weights in the 1.0 lb group, suggesting a potential effect of omega-3 supplementation on growth.

No differences ($P = 0.64$) were found in DMI between the treatment groups. Average daily DMI was similar across the control (20.6 lb), 0.5 lb (21.4 lb), and 1.0 lb (21.9 lb) groups (Table 2), indicating that the omega-3 supplementation had no effect on overall feed consumption. In terms of ADG, however, an effect ($P = 0.03$) of omega-3 supplementation was observed. Bulls in the 1.0 lb group showed higher ($P = 0.04$) ADG compared to the control group (Table 2), with mean ADG values of 3.60 lb/day for the control group, 3.89 lb/day for the 0.5 lb group, and 4.25 lb/day for the 1.0 lb group. This suggests that while omega-3 supplementation did not impact feed intake, it may have enhanced feed efficiency, leading to greater weight gain. The F:G were similar across all treatment groups ($P = 0.72$), with no significant improvement in feed conversion efficiency observed between groups. This aligns with the observed lack of difference in DMI and suggests that the increase in ADG in the 1.0 lb group may be attributed to factors beyond simple feed efficiency. The SC was not affected ($P = 0.67$) by omega-3

supplementation. Mean SC ranged from 13.7-in in the control group to 13.6-in in the 0.5 lb group, and 13.8-in in the 1.0 lb group. This indicates that the omega-3 supplement did not affect reproductive development as measured by SC. Interestingly, the probability of passing a BSE was lower ($P = 0.03$) in the 1.0 lb treatment group compared to the control group (Table 2). While 85.46% of bulls in the control group passed the BSE, only 22.89% of bulls in the 1.0 lb group passed this exam. This finding suggests a potential negative impact of high omega-3 supplementation on reproductive health, despite the observed gains in BW. These results suggest that while omega-3 supplementation at 1.0 lb/day may enhance weight gain, it could have detrimental effects on reproductive soundness. The reduction in reproductive soundness may be attributed to disruptions in hormonal balance or other metabolic processes influenced by high omega-3 intake. The lack of significant differences in feed intake and SC further emphasizes that the reproductive outcomes may not be linked to changes in feed intake or growth traits but rather specific physiological effects of the omega-3 supplementation. Future studies should investigate the underlying mechanisms driving this trade-off between growth performance and reproductive health to better inform supplementation strategies in bull development programs.

## Implications

These results suggest that while omega-3 supplementation at 1.0 lb/day improved weight gain, it may have negatively affected reproductive soundness, as indicated by lower BSE pass rates.

## Acknowledgments

The authors extend appreciation to the employees of the Purebred Beef and Beef Cattle Research units for their daily management and care of the cattle represented in this report. Special thanks are offered to Shane Werk, Purebred Beef Unit Manager, and Nate Moore, undergraduate employee, for their assistance with data collection and management.

**Table 1. Ingredient composition of diets by treatment, percent dry matter basis**

| | Amount of omega-3 supplementation | | |
|---|---|---|---|
| **Item** | **Control** | **0.5 lb** | **1.0 lb** |
| Corn silage | 30.50 | 33.10 | 30.80 |
| Wet corn gluten feed | 29.20 | 27.50 | 26.10 |
| Dry rolled corn | 20.30 | 17.80 | 16.40 |
| Brome hay | 12.50 | 14.10 | 14.70 |
| Supplement | 7.50 | 7.30 | 7.60 |
| Omega-3 fatty acid supplement | --- | 2.20 | 4.50 |

**Table 2. Effects of omega-3 supplementation on growth, feed intake, and reproductive parameters in post-weaning beef bulls**

| | Amount of omega-3 supplementation | | | | |
|---|---|---|---|---|---|
| **Item** | **0 lb** | **0.5 lb** | **1.0 lb** | **SE[1]** | ***P*-value** |
| Initial age | 292 | 292 | 291 | 6.25 | 0.99 |
| Initial BW,[2] lb | 773 | 774 | 767 | 42.18 | 0.98 |
| End BW,[2] lb | 1,003 | 1,024 | 1,035 | 55.04 | 0.77 |
| DMI,[2] lb/day | 20.6 | 21.4 | 21.9 | 2.14 | 0.64 |
| ADG,[2] lb | 3.60[a] | 3.89[a] | 4.25[b] | 0.307 | 0.04 |
| F:G[2] | 5.89 | 5.65 | 5.51 | 0.3295 | 0.72 |
| SC,[2] in | 13.7 | 13.6 | 13.8 | 1.14 | 0.67 |
| BSE[2] % Pass | 85.46[a] | 67.76[ab] | 22.89[b] | 0.183 | 0.03 |

[1] Standard deviation.
[2] BW = body weight; DMI = dry matter intake; ADG = average daily gain; F:G = feed to gain ratio; SC = Scrotal circumference; BSE = Breeding soundness exam.
[a-b] Within rows, means with unlike superscripts differ ($P \leq 0.05$).

# Evaluation of Calcidol (25(OH)$D_3$) or Combination of Calcidol and Beta-Carotene on Feed Intake, Growth Performance, and Health in High-Risk, Newly Received Beef Heifers

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## Abstract

Calcidol supplementation can improve immune function in transitioning dairy cattle. The objective was to determine if supplemental calcidol [25(OH)$D_3$] at varying levels would affect feed intake, growth performance, and health of high-risk, newly received beef cattle. A total of 480 crossbred heifers were assembled around Dickson, TN, and shipped to Manhattan, KS. Heifers were weighed individually upon arrival. On the day following arrival, heifers were stratified within block by arrival weight to one of eight pens containing 12 heifers each. Cattle were limit-fed at 2.2% of body weight (BW) for 56 days. Pens were assigned one of four treatments: 1) 3,000 IU/head/day added vitamin $D_3$ (Control); 2) 0.5 mg/head/day calcidol; (HyD, DSM Nutritional Products, Plainsboro, NJ; HyD Low); 3) 1.0 mg/head/day calcidol (HyD High); or 4) 1.0 mg/head/day calcidol and 100 mg beta-carotene (Victus Transition; DSM Nutritional Products, Plainsboro, NJ; HyD + BC). Treatments were top-dressed daily. Pen weights were measured every 14 days to adjust feed offered the following 14 days. Individual BW were measured on days 0, 14, 28, and 56. Final BW, average daily gain, gain:feed, and dry matter intake did not differ ($P \geq 0.36$) among treatments. Overall prevalence of respiratory morbidity and mortality was 56.25% and 1.46%. No treatment differences were detected for first, second, or third respiratory morbidity or mortality ($P \geq 0.16$). Heifers fed HyD High had greater ($P < 0.001$) serum 25(OH)$D_3$ concentrations compared with heifers fed HyD Low at days 14, 28, and 56. At days 14, 28, and 56, all heifers supplemented with HyD (HyD Low, HyD High, HyD + BC) had greater ($P < 0.001$) serum 25(OH)$D_3$ concentrations compared with heifers fed Control. Overall, supplementation with calcidol or a combination of calcidol and beta-carotene did not affect feed intake, growth performance, or health of high-risk, newly received heifers.

## Introduction

Vitamin D is critical to the normal development and growth of all cattle. Recent reports have shown a positive role for vitamin D in immune function of dairy cattle. Calcidol is a metabolite of vitamin D metabolism. It can be used to prevent and treat vitamin D deficiency. Calcidol supplementation improves health and immune function in transition dairy cows, and beta-carotene (antioxidant) helps to improve immune function in dairy calves. High-risk receiving cattle are subjected to a wide variety of stressors, such as commingling, transportation, disease exposure, and low feed intake. Because calcidol and beta-carotene supplementation help to mitigate stress-induced immune responses in dairy cattle at different phases, we hypothesized it would provide similar benefits

[1] DSM Nutritional Products, Plainsboro, NJ

to receiving beef cattle. The objective of this study was to evaluate the effects of feed intake, growth performance, and health when calcidol [25(OH)$D_3$] or a combination of calcidol and beta-carotene is supplemented in newly received growing beef heifers.

## Experimental Procedures

A total of 480 crossbred heifers (BW = 500 ± 35 lb) were purchased at auction markets around Tennessee, assembled at an order buyer's facility in Dickson, TN, and then shipped 674 miles to the Kansas State University (KSU) Beef Stocker Unit over a 9-day period from October 4 to October 12, 2023. Cattle were weighed immediately upon arrival at KSU, individually identified with a visual and electronic identification tag, and an ear notch sample was taken for testing of persistent infection with bovine viral diarrhea virus. Four animals tested positive (two - HyD Low and two - HyD High) and were removed from the experiment.

Following initial processing, heifers were offered prairie hay at 1% of BW (dry matter (DM) basis), had *ad libitum* access to water, and were allowed to stand overnight. The following day (day 0), calves were individually weighed, treated for internal (Safeguard; Merck Animal Health, Madison, NJ) and external (Clean-Up II; Elanco, Greenfield, IN) parasites, vaccinated for respiratory (Titanium 5; Elanco, Des Moines, IA) and clostridial (Bovilus Vison 7 with somnus; Merck Animal Health, De Soto, KS) disease, given metaphylaxis treatment (Tulieve; Norbrook, Newry, IRE), and assigned a pen tag.

When processing was complete, heifers were allocated to their respective treatment pens. Treatments included: 1) 3,000 IU/head/day added vitamin $D_3$ (Control); 2) 0.5 mg/head/day calcidol; (HyD, DSM Nutritional Products, Plainboro, NJ; HyD Low); 3) 1.0 mg/head/day calcidol (HyD High); or 4) 1.0 mg/head/day calcidol and 100 mg beta-carotene (Victus Transition; DSM Nutritional Products, Plainsboro, NJ; HyD + BC). A common limit-fed experimental diet (Table 1) was offered at 2.2% of BW daily (DM basis). Treatments were top-dressed at feeding daily.

Throughout the trial, heifers were observed once daily for clinical signs of respiratory illness. Respiratory illness was treated as follows: first treatment was florfenicol, second treatment was enrofloxacin, and third treatment was oxytetracycline. Heifers requiring a third treatment were declared as chronic and removed from the experiment. During the trial, seven total animals were found dead in the pen from bronchopneumonia (one – Control; two - HyD Low; two - HyD High; and two - HyD + BC). Additionally, three heifers were removed for lameness injury (one - Control; one- HyD High; and one - HyD + BC) and 34 chronic pneumonias were removed from the study (seven - Control; seven - HyD Low; nine - HyD High; and eleven - HyD + BC). Data from these heifers were excluded from the analysis.

Blood samples were taken via jugular vein with 18-gauge needles from heifers on arrival (day 0) and on days 14, 28, and 56. Blood was collected into an 8.5 mL serum separator blood tube for analysis of serum 25(OH)$D_3$ concentrations. Samples were frozen at -4°F until analysis by High Performance Liquid Chromatography coupled with tandem mass spectrometry (DSM Nutritional Products, Belvidere, NJ). Data were analyzed as a randomized complete block design using the MIXED procedure of SAS (version 9.3; SAS Institute, Cary, NC). Pen was the experimental unit. In the statistical model, treatment was a fixed effect, and block was a random effect. Treatment differences were considered significant at *P*-value less than 0.05 and tendencies at *P*-value less than 0.10.

## Results and Discussion

Performance data are presented in Table 2. Final BW, average daily gain, gain:feed, and dry matter intake did not differ ($P \geq 0.36$) among treatments. Serum data are presented in Table 3. Heifers fed HyD High had greater ($P < 0.001$) serum 25(OH)$D_3$ concentrations than calves fed HyD Low at days 14, 28, and 56. At days 14, 28, and 56, all calves supplemented with HyD (HyD Low, HyD High, and HyD + BC) had greater ($P < 0.001$) serum 25(OH)$D_3$ concentrations compared with calves fed Control. Overall prevalence of respiratory morbidity and mortality were 54.6% and 1.45%, respectively. No treatment differences ($P \geq 0.16$) were detected for first, second, or third respiratory morbidity or mortality; however, many heifers were treated in the first 14 days of the trial. High respiratory morbidity early in the feeding period coupled with low concentrations of circulating 25-hydroxyvitamin $D_3$ could explain why there was no statistical significance in performance and health. Future research is needed in evaluating calcidol supplementation early in the receiving period to elevate circulating 25-hydroxyvitamin $D_3$. Overall, supplementation with calcidol or a combination of calcidol and beta-carotene did not affect feed intake, growth performance, or health of high-risk, newly received heifers.

## Implications

Overall, this study showed that the supplementation of calcidol [25(OH)$D_3$] or calcidol and beta-carotene did not improve feed intake, growth performance, or health in high-risk, newly receiving beef cattle; however, calcidol [25(OH)$D_3$] supplementation in the diet increased serum concentrations of 25(OH)$D_3$.

**Table 1. Composition of experimental diets fed to high-risk beef heifers**

| | Dietary Treatment[1] | | | |
|---|---|---|---|---|
| **Item** | **Control** | **HyD Low** | **HyD High** | **HyD + BC** |
| Ingredient, % dry matter | | | | |
| Whole corn | 39.5 | 39.5 | 39.5 | 39.5 |
| Supplement[2] | 7.5 | - | - | - |
| Supplement[3] | - | 7.5 | 7.5 | 7.5 |
| Wet corn gluten feed[4] | 40.0 | 40.0 | 40.0 | 40.0 |
| Prairie hay | 13.0 | 13.0 | 13.0 | 13.0 |
| Nutrient composition, % dry matter | | | | |
| Dry matter | 77.9 | 77.9 | 77.9 | 77.9 |
| Crude protein | 13.6 | 13.6 | 13.6 | 13.6 |
| Organic matter | 94.5 | 94.6 | 94.6 | 94.6 |
| Neutral detergent fiber | 25.2 | 25.3 | 25.3 | 25.3 |
| Acid detergent fiber | 14.0 | 13.7 | 13.7 | 13.7 |

[1] Control = 3,000 IU/head/day added vitamin $D_3$; HyD Low = 0.5 mg/head/day calcidol; HyD High = 1.0 mg/head/day calcidol; HyD + BC = 1.0 mg/head/day calcidol and 100 mg beta-carotene.
[2] Supplement pellet formulated to contain (dry matter basis) 7.5% calcium, 4.7% salt, 6,000,000 IU vitamin $D_3$/ton, and 10.8 oz/ton monensin (Rumensin 90; Elanco, Greenfield, IN).
[3] Supplement pellet formulated to contain (dry matter basis) 7.5% calcium, 4.7% salt, and 10.8 oz/ton monensin (Rumensin 90; Elanco, Greenfield, IN).
[4] Sweet Bran, Cargill Corn Milling, Blair, NE.

**Table 2. Effects of calcidol (25-OH-$D_3$) supplementation on feed intake and growth performance of limit-fed growing heifers**

| | Dietary Treatment[1] | | | | | |
|---|---|---|---|---|---|---|
| Item | Control | HyD Low | HyD High | HyD + BC | SEM[2] | *P*-value |
| Number of pens | 10 | 10 | 10 | 10 | -- | -- |
| Number of animals[3] | 111 | 109 | 106 | 106 | -- | -- |
| Body weight, lb | | | | | | |
| Day 0 | 498 | 498 | 501 | 498 | 2.7 | 0.88 |
| Day 56 | 650 | 642 | 637 | 639 | 7.3 | 0.54 |
| Average daily gain, lb/day | | | | | | |
| Day 0 to 56 | 2.71 | 2.58 | 2.47 | 2.51 | 0.059 | 0.40 |
| Dry matter intake, lb/day | | | | | | |
| Day 0 to 56 | 12.08 | 11.84 | 11.86 | 11.82 | 0.113 | 0.36 |
| Gain:feed, lb/lb | | | | | | |
| Day 0 to 56 | 0.225 | 0.212 | 0.209 | 0.212 | 0.0043 | 0.53 |
| Morbidity, % | | | | | | |
| Treated once | 50.00 | 58.33 | 53.33 | 63.33 | 0.276 | 0.17 |
| Treated twice | 13.33 | 16.67 | 15.83 | 25.83 | 0.408 | 0.34 |
| Treated thrice | 5.83 | 5.83 | 7.50 | 9.17 | 0.625 | 0.83 |
| Mortality, % | 0.83 | 1.67 | 1.67 | 1.67 | 1.045 | 1.00 |

[1] Control = 3,000 IU/head/day added vitamin $D_3$; HyD Low = 0.5 mg/head/day calcidol; HyD High = 1.0 mg/head/day calcidol; HyD + BC = 1.0 mg/head/day calcidol and 100 mg beta-carotene.
[2]Standard error of the mean.
[3]Performance data from dead and chronic heifers were removed from analysis.

**Table 3. Serum 25-hydroxyvitamin $D_3$ concentrations and beta-carotene of crossbred growing heifers relative to dietary treatment**

| | Dietary Treatment[1] | | | | | *P*-value | | |
|---|---|---|---|---|---|---|---|---|
| Item | Control | HyD Low | HyD High | HyD + BC | SEM[2] | Treatment | Day | Treatment × Day |
| Number of pens | 10 | 10 | 10 | 10 | --- | --- | --- | --- |
| Number of animals[3] | 113 | 109 | 106 | 104 | --- | --- | --- | --- |
| Serum 25-hydroxyvitamin $D_3$, ng/mL | | | | | | | | |
| Day 0 | 21.57 | 26.45 | 24.09 | 23.00 | 7.41 | <0.001 | <0.001 | 0.586 |
| Day 14 | 23.35 | 105.79 | 183.76 | 167.30 | 7.41 | <0.001 | <0.001 | <0.001 |
| Day 28 | 40.11 | 118.85 | 184.62 | 185.08 | 7.41 | <0.001 | <0.001 | <0.001 |
| Day 56 | 38.36 | 134.82 | 191.48 | 196.22 | 7.41 | <0.001 | <0.001 | <0.001 |
| Beta-carotene, mg/L | | | | | | | | |
| Day 0 | 4.944 | --- | --- | 4.420 | 0.189 | <0.001 | <0.001 | 0.042 |
| Day 14 | 1.018 | --- | --- | 1.470 | 0.189 | <0.001 | <0.001 | 0.078 |
| Day 28 | 0.667 | --- | --- | 1.525 | 0.189 | <0.001 | <0.001 | 0.001 |
| Day 56 | 0.516 | --- | --- | 1.874 | 0.189 | <0.001 | <0.001 | <0.001 |

[1] Control = 3,000 IU/head/day added vitamin $D_3$; HyD Low = 0.5 mg/head/day calcidol; HyD High = 1.0 mg/head/day calcidol; HyD + BC = 1.0 mg/head/day calcidol and 100 mg beta-carotene.
[2]Standard error of the mean.
[3]Serum data from dead and chronic heifers were removed from analysis.

# Nutrikinetic Evaluation and Modeling of 25-Hydroxyvitamin $D_3$ in Beef Cattle

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## Abstract

Two studies were designed to evaluate serum 25-hydroxyvitamin $D_3$ [25(OH)$D_3$] status in beef cattle when 1) fed diets with supplemental 25(OH)$D_3$ or calcidol (Hy-D, DSM Nutritional Products, Plainsboro, NJ) and 2) administered as a single dose of calcidol solution (Hy-D, DSM Nutritional Products) to cannulated heifers for nutrikinetic evaluation and predictive modeling simulations. In experiment one, high-risk heifer calves were assembled in Dickson, TN, for transport to Manhattan, KS. One of four dietary treatments was used for each pen in the trial: 1) no supplemental vitamin $D_3$ or calcidol (CON); 2) 3,000 IU supplemental vitamin $D_3$/head/day (D3); 3) 0.5 mg calcidol/head/day (HyD Low); or 4) 1.0 mg calcidol/head/day (HyD High) for 60 days. Blood samples were collected from each heifer prior to transport (day -1), on arrival (day 0), and on days 14, 31, and 60 of the dietary treatment period. Data were analyzed using the GLIMMIX procedure of SAS using animal as experimental unit and treatment as a fixed effect. On days 14, 31, and 60, calves fed the HyD High or the HyD Low had greater ($P < 0.001$) serum 25(OH)$D_3$ concentrations than calves fed the CON or D3 treatments. In experiment two, eight cannulated crossbred heifers were randomly assigned to one of two treatments: 1) 3 mg/600 lb body weight (BW) calcidol; or 2) 5 mg/600 lb BW calcidol in a single dose administered via rumen cannula at hour 0. Serial blood samples were collected at baseline through to 70 days. The elimination half-life ($t_{1/2}$) of calcidol was determined to be an average of 7.1 days and the area under the change in the concentration time curve from time 0 to last time point that measured above the baseline concentration post-dose ($AUC_{0\text{-last}}$) averaged 33 days. Non-parametric dosing simulations using nutrikinetic parameters suggest that administration of two 5 mg oral doses of calcidol with daily feeding of 1 mg would result in a rapid and sustained increase in serum 25(OH)$D_3$. However, simulations should be confirmed *in vivo* before implementation.

## Introduction

Vitamin D is critical to the normal development and growth of all cattle. Recent reports have shown a positive role for vitamin D in immune function of dairy cattle. Despite the role of vitamin D in growth and health, it has been largely ignored in beef cattle because it is commonly assumed that cattle on pasture or in a feedyard receive adequate vitamin D either from photoconversion of 7-dehydrocholesterol to vitamin $D_3$ in the skin or ingestion of vitamin $D_2$ from forages. The 25-hydroxyvitamin $D_3$ (25(OH)$D_3$) is the best indicator of vitamin D status in cattle. Serum 25(OH)$D_3$ concentrations above 20 ng/mL have generally been considered adequate for beef cattle; whereas concentrations less than 10 ng/mL are representative of deficiency and put cattle at risk for rickets and weak bones. Two experiments were conducted to evaluate serum 25-hydroxyvitamin $D_3$ [25(OH)$D_3$] status in beef cattle where heifers received supplemental calcidol through different administrations. Heifers in experiment one were fed diets with supplemental calcidol (HyD; DSM Nutritional Products, Plainsboro, NJ) as

[1] DSM Nutritional Products, Plainsboro, NJ

a top dress. Heifers in experiment two received a single dose of calcidol solution (HyD; DSM Nutritional Products, Plainsboro, NJ) through rumen cannula to evaluate nutrikinetics of calcidol to be used for predictive modeling simulations.

## Experimental Procedure

### *Experiment 1*

Ninety-six high-risk receiving heifer calves (489 ± 37.4 lb) were assembled from auction markets near Dickson, TN, and transported (~12 hours) to Manhattan, KS. Blood samples were taken via jugular vein with an 18 g needle from heifer calves at pre-transport (day -1), on arrival (day 0), and on days 14, 31, and 60 of the treatment period. Blood was collected into an 8.5 mL serum separator blood tube for analysis of serum 25(OH)$D_3$ concentrations. Calves were fed a corn-based receiving diet (Table 1) and administered one of four dietary treatments: 1) no supplemental vitamin $D_3$ or calcidol (CON, n = 24); 2) 3,000 IU supplemental vitamin $D_3$/head/day (D3, n = 24); 3) 0.5 mg calcidol/head/day (HyD Low, n = 24); or 4) 1.0 mg calcidol/head/day (HyD High, n = 24) for 60 days.

### *Experiment 2*

Eight cannulated, crossbred beef heifer calves (initial body weight (BW) 637 ± 98 lb) were used for the evaluation of a calcidol solution (HyD, DSM Nutritional Products, Plainsboro, NJ). Heifers were weighed on day 0 of the trial to calculate the dose to be administered. Heifers were bled via jugular vein with an 18 g needle and blood was collected into an 8.5 mL serum separator blood tube for baseline analysis of circulating 25(OH)$D_3$. Following the initial blood draw, calcidol dose was administered via ruminal cannula through a syringe and line of 12 g plastic tubing. Following the dose administration, the line was flushed with 35 mL of distilled water and 35 mL of air. Heifers were randomly assigned to one of two treatments: 1) 3 mg/600 lb kg BW of calcidol (n = 4); and 2) 5 mg/600 lb BW of calcidol (n = 4). All eight heifers were used in the nutrikinetics trial. Remaining blood samples were taken at hours 2, 4, 6, 8, 12, and 24, and on days 2, 3, 5, 7, 10, 14, 21, 28, 35, 42, 49, 56, 63, and 70 post initial pulse dose. Serum was separated by centrifugation at 3,000 rpm for 12 minutes and placed into 2 ml cryovials. Samples were frozen at -4°F until analysis by High Performance Liquid Chromatography coupled with tandem mass spectrometry (DSM Nutritional Products, Belvidere, NJ).

## Results and Discussion

### *Experiment 1*

Serum 25(OH)$D_3$ concentrations in heifers on arrival averaged 12 ± 3.1 ng/mL and were considered suboptimum. Heifer calves fed HyD Low or HyD High had increased serum 25(OH)$D_3$ levels ($P < 0.001$) from day 14 to 60 compared with heifer calves fed CON or D3 dietary treatments (Figure 1).

### *Experiment 2*

The maximum concentration from calcidol pulse dose was reached in 48 hours (Figure 2). The half-life ($t_{1/2}$) ofcalcidol was determined to be an average of 7.1 days. Calcidol pulse dose remained circulating in the serum for approximately 33 days. Modeling simulations were used to predict circulating 25(OH)$D_3$ concentrations in various scenarios. Non-parametric superposition was used from applying non-compartmental analysis from the single dose of 5 mg/600 lb BW of calcidol on nutrikinetics

evaluation in cannulated beef heifers (Table 2, n = 4) using the assumptions of linearity, independent calcidol dosing response, and rate of absorption, and the average systemic clearance are consistent for each calcidol dosing interval (Figure 3A, 3B, and 3C), but these results should be confirmed *in vivo* in animals prior to implementation.

## Implications

Calcidol can effectively elevate circulating 25(OH)$D_3$ concentrations in the serum of beef cattle. Greater circulating levels of 25(OH)$D_3$ would allow the calves to have a better chance at activating the vitamin D receptor in the body that would allow for a response in performance, immune function, and potentials in total carcass weight.

## Acknowledgments

This research was funded by DSM Nutritional Products. The authors would like to thank all the undergraduate student staff and DSM employees for their help in data collection.

**Table 1. Composition of experimental diets for experiment one**

| | Treatment[1] | | | |
|---|---|---|---|---|
| **Item** | **CON** | **D3** | **HyD Low** | **HyD High** |
| Ingredient, % dry matter | | | | |
| Dry rolled corn | 39.5 | 39.5 | 39.5 | 39.5 |
| Supplement[2] | --- | 7.5 | --- | --- |
| Supplement[3] | 7.5 | --- | 7.5 | 7.5 |
| Wet corn gluten feed[4] | 40.0 | 40.0 | 40.0 | 40.0 |
| Prairie hay | 13.0 | 13.0 | 13.0 | 13.0 |

[1] CON = no supplemental vitamin $D_3$ or calcidol (n = 24); $D_3$ = 3,000 IU supplemental vitamin $D_3$/head/day (n = 24); HyD Low = 0.5 mg calcidol/head/day (n = 24); HyD High = 1.0 mg calcidol/head/day (n = 24).
[2] Supplement pellet formulated to contain (dry matter basis) 7.5% calcium, 4.7% salt, 5,992,800 IU vitamin $D_3$/ton and 10.8 oz/ton monensin (Rumensin 90; Elanco, Greenfield, IN).
[3] Supplement pellet formulated to contain (dry matter basis) 7.5% calcium, 4.7% salt, and 10.8 oz/ton monensin (Rumensin 90; Elanco, Greenfield, IN).
[4] Sweet Bran, Cargill Corn Milling, Blair, NE.

**Table 2. Mean (range) of nutrikinetic parameters from non-compartmental analysis for change in serum 25-hydroxyvitamin $D_3$ concentrations in experiment two.**

| | Dietary 25-hydroxyvitamin $D_3$ supplementation | |
|---|---|---|
| | 3 mg | 5 mg |
| **Parameters** | **Mean (range)[1]** | **Mean (range)** |
| Dose[2], mg | 3.83 (3.37-4.39) | 5.52 (3.9-6.40) |
| $C_{baseline}$ [3] | 52.4 (45.1-67.3) | 56.6 (47.1-63.7) |
| $C_{max}$ [4] | 31.6 (28.5-36.8) | 40.3 (33.8-49.6) |
| Dose-normalized $C_{max}$ [b,5] | 2.87 (2.59-3.35) | 2.19 (1.8-2.7) |
| $T_{max}$ [a,6], hour | 60 (24-120) | 48 (48-72) |
| $t_{½}$ [7], hour | 177 (108-497) | 164.3 (74.6-247) |
| $AUC_{0\text{-last}}$ [8] | 10,224 (8,876-12,181) | 13,028 (8,786-19,037) |
| Dose-normalized $AUC_{0\text{-last}}$ [b,9] | 856 (581-1,107) | 709 (479-1,036) |

[1] Mean = geometric mean.
[2] Dose = oral dose of 25(OH)$D_3$ in mg administered to achieve target dose.
[3] $C_{baseline}$ = baseline serum concentration of 25-hydroxyvitamin $D_3$ prior to dosing.
[4] $C_{max}$ = maximum observed change in serum concentration from baseline reached.
[5] Dose-normalized $C_{max}$ = $C_{max}$ normalized to a dose of 1 mcg/kg.
[6] $T_{max}$ [a] = time to reach maximum observed change in serum concentration.
[7] $t_{½}$ = terminal half-life.
[8] $AUC_{0\text{-last}}$ = area under change in concentration-time curve from time 0 to the last time point that measured above baseline concentration, post dose.
[9] Dose-normalized $AUC_{0\text{-last}}$ = $AUC_{0\text{-last}}$ normalized to a dose of 1 mcg/kg.
[a] Tmax is expressed as median with minimum and maximum.
[b] *P* values were > 0.05 proving linearity between two treatments; (Dose-normalized $C_{max}$ = 0.06) (Dose-normalized $AUC_{0\text{-last}}$ = 0.49).

# Individual Sweet Bran Components in High-Forage Rations Fed to Holstein Steers Contribute to Changes in Nutrient Digestibility

*L.S. Monteiro and J.S. Drouillard*

## Abstract

Sweet Bran (SB), a wet corn gluten feed product (Cargill Corn Milling, Blair, NE), is widely used in cattle diets. Sweet Bran consists of a proprietary blend of corn bran, corn germ meal, and corn steep liquor, all of which are byproducts of the corn wet milling process. This study evaluated the impact of individual SB components on digestibility, ruminal fermentation, and feeding behavior of Holstein steers fed high-forage diets. Twelve steers with rumen and duodenal cannulas were assigned to one of four dietary treatments: no SB components (control), corn germ meal (germ), bran (bran), or steep liquor (steep). Diets containing SB components led to greater dry matter intake compared to steers fed the control diet ($P < 0.01$). The steep diet also enhanced the digestibility of dry matter, protein, and starch ($P < 0.01$, $P = 0.08$, and $P = 0.03$, respectively). Germ and bran, which were similar, improved neutral detergent fiber digestibility ($P < 0.01$) compared to the control diet. Steep notably increased ammonia concentration ($P < 0.01$) and achieved the highest butyrate levels ($P < 0.01$), indicating more vigorous fermentation. In terms of feeding behavior, the steep diet resulted in more frequent, shorter, and faster feeding sessions ($P < 0.01$), whereas the germ, bran, and control diets were associated with slower intake rates. Diets containing SB components, particularly steep, enhanced nutrient digestibility and fermentation in Holstein steers compared to control.

## Introduction

Sweet Bran (SB; Cargill Corn Milling, Blair, NE) is a wet corn gluten feed used in cattle diets. It consists of a mixture of three byproducts of the corn wet milling process: solvent-extracted germ meal, bran, and steep liquor. It is used to partially replace corn grain and soybean meal in cattle diets, and is an excellent source of energy and ruminally degradable protein. However, each of its components has a different nutrient profile. This research was done to compare and determine the digestibility, ruminal fermentation profile, and feed intake behavior of Holstein steers fed high-forage diets containing individual components of SB.

## Experimental Procedures

This study involved 12 Holstein steers that had cannulas in both their rumen and duodenum. They were housed at the Kansas State University Intake Facility and randomly assigned to one of four diets in a 4 × 4 Latin square design, balanced to avoid carryover effects and blocked by weight. The four diets (Table 1) were: 1) without any Sweet Bran components (control), 2) with corn germ meal (germ), 3) with corn bran (bran), and 4) with corn steep liquor (steep). The study lasted four periods, each 23 days long. The first 18 days were for the steers to adjust to their diets, and samples were collected from days 19 to 23. The diets were mixed daily in the morning and fed twice a

day at 9 a.m. and 3 p.m. The Roughage Intake Control system (Hokofarm Group, The Netherlands) monitored dry matter intake (DMI) and feeding behavior.

Titanium dioxide ($TiO_2$) was used as a marker to track digesta flow, and it was dosed twice daily (10 g/dose) into the rumen from days 7 through 21. Ruminal, duodenal, and fecal samples were taken every 2 hours over a 24-hour period from days 19 to 21. Ruminal fluid was analyzed for pH and then acidified 1:3 with 25% m-phosphoric acid (weight/volume) for later analysis of ammonia nitrogen ($N\text{-}NH_3$) and volatile fatty acids (VFA). Ammonia nitrogen levels were measured colorimetrically with a spectrophotometer, and VFA concentrations were determined by gas chromatography. Duodenal contents and fecal samples were combined for each steer within each period, and $TiO_2$ concentrations in these composites were measured colorimetrically to calculate apparent digestibility.

Data were analyzed using the MIXED model procedure of the Statistical Analysis System (SAS version SAS Studio; SAS Inst. Inc., Cary, NC). One steer was excluded from the analysis because it consumed alternative treatment diets. Fixed effects included treatment and period, and animal was utilized as a random effect. Ammonia, VFA, pH, and feeding behavior were analyzed using hour as repeated measures and animal within sequence as subject. Statistical significance was declared at $P < 0.05$, and tendency for significance at $P < 0.10$.

## Results and Discussion

For DMI (Table 2), cattle fed the control had less feed intake compared to other treatments ($P < 0.01$), indicating that including corn byproducts, especially steep, might enhance digestibility, leading to greater intake. Dry matter digestibility of the diet containing steep was greater than that of other treatments for both ruminal ($P < 0.01$) and total tract digestion ($P = 0.08$), and protein ($P < 0.01$) compared to other treatments, suggesting it is beneficial for protein utilization. Additionally, steep had higher total tract digestibility of starch ($P = 0.03$), suggesting it may offer an advantage in energy provision from starch. Germ and bran exhibited higher neutral detergent fiber digestibility than other treatments ($P < 0.01$), with an advantage in energy from fiber, and similar overall nutrient digestibility, while the control had the lowest digestibility percentages. The pattern of ruminal digestibility generally matched total tract digestibility, except for starch, where the control had numerically higher ruminal digestibility but not higher total tract digestibility.

The diets with SB components decreased ruminal pH (Table 3), indicating greater fermentation activity ($P < 0.01$). The steep diet notably increased $N\text{-}NH_3$ concentration by three to six times that of other treatments ($P < 0.01$), reflecting its high protein content and extensive ruminal degradation. It also led to the highest butyrate levels ($P < 0.01$), which likely was derived from the conversion of lactate within steep liquor to butyrate by lactic acid consuming bacteria. Though not statistically different, the highest total VFA concentrations were observed when cattle were fed the diet containing steep, suggesting more intense fermentation than other diets. Acetate levels were consistent across all diets, while steep had slightly higher propionate levels ($P > 0.10$).

Regarding feeding behavior (Table 4), steers on the steep diet had the most frequent bunk visits, with the shortest duration per visit, and the fastest intake rate ($P < 0.01$). In contrast, steers on the control diet had the fewest visits and the slowest intake rate.

When consuming the germ diet, steers had the longest total meal duration, while on the bran diet, they fell between germ and steep in most metrics. On the control diet, steers exhibited the least feeding activity, while the germ diet promoted prolonged eating.

## Implications

Adding corn steep liquor to the diet increased ruminal fermentation and diet digestion compared to other components of wet corn gluten feed.

## Acknowledgments

This project was sponsored by the Cargill Starches, Sweeteners & Texturizers division. The conduct of the field trial and laboratory analyses were made possible with the help of graduate and undergraduate students of the K-State Beef Cattle Research Center, Intake Facility, and Preharvest Food Safety Laboratory.

**Table 1. Composition of high-forage diets containing individual components of Sweet Bran fed to Holstein steers**

| | Treatments[1] | | | |
|---|---|---|---|---|
| **Percent on dry matter basis** | **Control** | **Germ** | **Bran** | **Steep** |
| Ingredients | | | | |
| Corn silage | 70.00 | 35.00 | 35.00 | 35.00 |
| Alfalfa hay | 15.00 | 15.00 | 15.00 | 15.00 |
| Corn, fine ground | 13.06 | 13.84 | 13.07 | 12.43 |
| Urea | 1.00 | --- | 0.76 | --- |
| Vitamin and mineral supplement | 0.94 | 1.16 | 1.17 | 2.56 |
| Solvent-extracted germ meal | --- | 35.00 | --- | --- |
| Corn bran | --- | --- | 35.00 | --- |
| Corn steep liquor | --- | --- | --- | 35.00 |
| Analyzed nutrients | | | | |
| Crude protein | 12.07 | 13.57 | 13.51 | 17.03 |
| Neutral detergent fiber | 32.99 | 37.04 | 43.19 | 21.82 |
| Starch | 32.80 | 29.00 | 25.00 | 24.20 |

[1]Germ = corn solvent-extracted germ meal; Bran = corn bran; Steep = corn steep liquor.

**Table 2. Apparent digestibility of nutrients in the rumen and the total tract of Holstein steers fed individual components of Sweet Bran**

| | Treatments[1] | | | | | |
|---|---|---|---|---|---|---|
| Item | Control | Germ | Bran | Steep | SEM[2] | *P*-value |
| Dry matter intake, lb/day | 19.4[b] | 24.6[a] | 24.8[a] | 26.4[a] | 1.5 | <0.01 |
| Ruminal digestibility, % | | | | | | |
| Dry matter | 83.2 | 84.4 | 84.3 | 86.4 | 1.1 | 0.08 |
| Protein | 73.6[b] | 72.0[b] | 75.1[b] | 80.1[a] | 1.5 | <0.01 |
| Neutral detergent fiber | 81.1[b] | 86.9[a] | 87.4[a] | 82.8[b] | 1.4 | <0.01 |
| Starch | 95.4 | 94.7 | 93.9 | 94.9 | 0.7 | 0.44 |
| Total tract digestibility, % | | | | | | |
| Dry matter | 89.6[c] | 90.9[b] | 90.0[bc] | 93.2[a] | 0.6 | <0.01 |
| Protein | 87.7[c] | 88.3[bc] | 89.3[b] | 93.0[a] | 0.6 | <0.01 |
| Neutral detergent fiber | 84.3[c] | 88.7[a] | 87.5[ab] | 87.0[b] | 0.7 | <0.01 |
| Starch | 99.4[b] | 99.4[b] | 99.3[b] | 99.7[a] | 0.1 | 0.03 |

[1]Germ = corn solvent-extracted germ meal; Bran = corn bran; Steep = corn steep liquor.
[2]Standard error of the mean.
[a,b,c]Values in a row with a common superscript letter are not different ($P > 0.05$).

**Table 3. Ruminal fermentation parameters for Holstein steers fed individual components of Sweet Bran**

| | Treatments[1] | | | | | |
|---|---|---|---|---|---|---|
| Item | Control | Germ | Bran | Steep | SEM[2] | *P*-value |
| pH | 6.4[a] | 6.2[b] | 6.2[b] | 6.2[b] | 0.1 | <0.01 |
| Ammonia-nitrogen, mM | 9.2[b] | 5.0[c] | 8.7[d] | 29.3[a] | 1.3 | <0.01 |
| Acetate, mM | 60.3 | 58.2 | 61.2 | 59.5 | 1.5 | 0.49 |
| Propionate, mM | 18.7 | 20.3 | 20.4 | 21.7 | 0.8 | 0.12 |
| Butyrate, mM | 11.3[b] | 11.7[b] | 11.1[b] | 14.3[a] | 0.6 | <0.01 |
| Total volatile fatty acids, mM | 93.3 | 93.2 | 95.2 | 100.5 | 2.8 | 0.21 |

[1]Germ = corn solvent-extracted germ meal; Bran = corn bran; Steep = corn steep liquor.
[2]Standard error of the mean.
[a,b,c]Values within a row with a common superscript letter are not different ($P > 0.05$).

**Table 4. Feed intake behavior of Holstein steers fed individual components of Sweet Bran**

| | Treatments[1] | | | | | |
|---|---|---|---|---|---|---|
| Item | Control | Germ | Bran | Steep | SEM[2] | *P*-value |
| Number of visits to bunk/day | 23.4[c] | 26.2[bc] | 29.1[ab] | 30.5[a] | 1.4 | <0.01 |
| Meal duration, minutes/day | 96.7[c] | 119.5[a] | 110.3[ab] | 100.8[bc] | 4.6 | <0.01 |
| Visit duration, minutes | 5.1[a] | 5.1[a] | 4.6[a] | 3.6[b] | 0.3 | <0.01 |
| Intake rate, oz/minute | 7.4[b] | 7.4[b] | 8.0[b] | 9.6[a] | 0.3 | <0.01 |

[1]Germ = corn solvent-extracted germ meal; Bran = corn bran; Steep = corn steep liquor.
[2]Standard error of the mean.
[a,b,c]Values within a row with a common superscript letter are not different ($P > 0.05$).

# Evaluating Ground Grain Sorghum as an Alternative to Dry-Rolled Corn in Finishing Cattle Diets

*H.A. Johnson, S.A. Sexton-Bowser, J.K. Farney, and J.S. Drouillard*

## Abstract

Grain sorghum has limited adoption in cattle finishing diets due to the perception of inferior performance relative to corn in cattle finishing diets. However, with the rapid decline of the Ogallala Aquifer there is a need to adopt feed grains like grain sorghum, which grow reliably under water stress. This study evaluated ground sorghum (unknown variety) as a substitute for dry-rolled corn in finishing beef cattle fed for 182 days. Metabolizable energy content of sorghum was determined to be 94% that of corn, with values of 1.39 Mcal/lb and 1.42 Mcal/lb, respectively. Dry matter intakes of cattle fed sorghum were greater than those of cattle fed corn, but average daily gains were less, leading to a reduced feed conversion for cattle fed sorghum. Carcasses of steers fed corn were 32 lb heavier than those of steers fed sorghum, and percentages of Prime and premium Choice carcasses favored cattle fed corn resulting in a carcass value premium for corn fed cattle of $112 relative to sorghum fed cattle (based on average U.S. Department of Agriculture pricing for the week of harvest). This study supports that dry processed sorghum is inferior to dry processed corn as a feedstuff for finishing cattle. Future efforts need to focus on superior hybrids and alternative methods of grain processing, such as steam flaking, to improve the competitiveness of sorghum as a feedstuff for finishing cattle.

## Introduction

Crop production in the semi-arid climate of the Southern Great Plains is heavily dependent on irrigation water provided by the Ogallala aquifer. The High Plains region, from Nebraska to Texas, utilizes this groundwater to grow crops such as corn, wheat, alfalfa, and sorghum. Over-withdrawal of irrigation water from the aquifer threatens to leave farmers without sufficient water for future production of irrigated crops. It is estimated that by 2100, 24% of irrigated lands utilizing water from the aquifer will be unable to support irrigated crops, and 13% of those affected areas will be unsuitable even for dryland crops. To sustain production capacity for future generations, farmers in this region need to adopt cropping systems that require less water.

Corn has long been the industry-preferred energy source in cattle finishing diets because of its wide availability and suitable effects on animal growth. The High Plains region has one of the highest concentrations of feedlot cattle in the world, with approximately 2.32 million cattle on feed in Kansas as of June 2024, with the vast majority feeding on corn as the primary energy source. Kansas is also the leading producer of grain sorghum (*Sorghum bicolor* L.) in the United States, with a total planted acreage of 3.3 million acres. Grain sorghum is more drought tolerant and hardy than corn, thus presenting as an alternative feed crop that could effectively reduce a farmer's water usage. There is a significant geographical overlap of feedlot cattle and grain sorghum production in the High Plains, yet sorghum is seldom utilized in feedlot operations.

Sorghum generally is regarded as being inferior to corn as cattle feed, but variations in grain processing methods and improved genetics may help overcome these differences, leading to increased use of grain sorghum and less overall water use for feed grain production. The variability in grain sorghum, including kernel size, genetic variety, and nutrient composition, requires research to evaluate these cumulative effects on beef cattle growth and carcass merit when compared to corn. Demonstrating the viability of grain sorghum as an alternative energy source for finishing cattle may increase acceptance and use by cattle feeders.

## Experimental Procedures

A randomized complete block design (15 blocks of two treatments) study was conducted at the Kansas State University Southeast Research and Extension Center between March and September of 2024. Black-hided, yearling steers (n = 300; 763.5 ± 14.3 lb initial body weight) were procured from a rye grazing operation in Lyons, Kansas, and transported 201 miles to the research center. At induction, cattle were identified using their existing ranch tags as well as individually numbered radio frequency identification ear tags, treated for internal and external parasites, implanted with long-acting steroidal implants, and weighed. Cattle were randomly allocated to feedlot pens (10 animals/pen) based on order of processing, such that the first 20 animals processed were allocated to block one, the second twenty animals to block two, and so on until all 15 blocks were complete. Cattle were housed in open, earthen-surfaced feedlot pens measuring 50 × 100 ft. Pens within block were then allocated randomly to treatments of diets containing either corn or grain sorghum (Table 1). Both diets were balanced to similar crude protein and starch content. Cattle were fed once daily, *ad libitum*. Feed bunks were scored daily, and dry matter content of ingredients was determined using weekly composites of each ingredient. Unconsumed feed was removed from feed bunks every Monday and Thursday and dried, making it possible to determine actual dry matter intake (DMI) for each 3- or 4-day interval.

Interim pen weights were recorded at 28-day intervals for DMI, average daily gain (ADG), and feed efficiency calculations. The energy content of diets was calculated using performance measurements and values from the Nutrient Requirements of Beef Cattle (National Academies of Sciences, Engineering, and Medicine, 2016). Feed and fecal samples collected from each pen were analyzed for total digestible nutrients. After 182 days on feed, the cattle were shipped and harvested for carcass data collection. Hot carcass weight and the incidence and severity of abscessed livers were recorded on the day of harvest. After approximately 72 hours of refrigeration, 12$^{th}$ rib subcutaneous fat thickness, marbling score, percent kidney, pelvic, and heart fat (KPH), ribeye area (REA), and U.S. Department of Agriculture (USDA) quality and yield grades were acquired via a camera imaging system.

Data were analyzed as mixed models (SAS, version 9.4) with diet as the fixed effect and initial weight block as the random effect. Incidence and severity of abscessed livers, USDA quality grade, and USDA yield grade were analyzed as multinomial distributions. Least-squares means were separated using the predicted difference function of SAS.

## Results and Discussion

The effect of grain sorghum finishing diets on growth performance and carcass characteristics, as well as diet digestibility are shown in Tables 2 and 3, and Figure 1, respectively. Cattle in the sorghum treatment ate more and gained less, leading to poor

efficiency of feed conversion ($P < 0.01$). Incidence of abscessed livers did not differ ($P > 0.30$). Percentages of cattle grading Prime and premium Choice were greater ($P < 0.01$) for cattle fed corn compared to those fed sorghum, and percentages of low Choice and Select cattle were greater for cattle fed sorghum. Overall carcass value was calculated using weekly average discounts and premiums reported by USDA and was $112 more for cattle fed corn than for cattle fed sorghum ($P < 0.01$). Metabolizable energy value was calculated from performance data and was 1.42 and 1.39 Mcal/lb for corn and sorghum, respectively ($P < 0.01$).

## Implications

The energy value of ground sorghum grain was approximately 94% that of dry-rolled corn, which is higher than previously perceived, but its inferiority is reflected in carcass quality. Future efforts should focus on development of superior sorghum hybrids and processing methods that enhance nutritional value of sorghum.

## Acknowledgments

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## References

National Academies of Sciences, Engineering, and Medicine. 2016. Nutrient requirements of beef cattle: Eighth revised edition. Washington, DC: The National Academies Press. *https://doi.org/10.17226/19014*

**Table 1. Composition of diets (dry matter basis)**

| Item | Control | Sorghum |
|---|---|---|
| Corn silage | 12.00 | 12.00 |
| Dry-rolled corn | 79.37 | --- |
| Ground grain sorghum | --- | 79.37 |
| Supplement[1] | 8.63 | 8.63 |
| | | |
| Nutrient composition, analyzed | | |
| Crude protein, % | 11.6 | 11.5 |
| Neutral detergent fiber, % | 13.8 | 12.5 |
| Starch, % | 68.9 | 68.5 |

[1]Supplement contained soybean meal, urea, minerals, vitamins, and feed additives and was formulated to provide (total diet dry matter basis) 0.7% calcium, 0.7% potassium, 0.3% salt, 33 g/ton monensin, 8 g/ton tylosin, and the following added amounts of trace elements and vitamins: 1,000 IU/lb vitamin A, 15 IU/lb vitamin E, 0.1 ppm cobalt, 10 ppm copper, 0.5 ppm iodine, 40 ppm manganese, 0.1 ppm selenium, and 40 ppm zinc. Ractopamine hydrochloride was included at 25 g/ton of the diet dry matter for the final 42 days on feed.

**Table 2. Performance of steers fed diets containing dry-rolled corn or ground grain sorghum throughout a 182-day finishing period**

| Item | Control | Sorghum | SEM[1] | *P*-value |
|---|---|---|---|---|
| Average daily gain, lb | 3.57 | 3.21 | 0.07 | <0.01 |
| Feed intake, lb/day | 24.14 | 25.25 | 0.36 | <0.01 |
| Feed:gain | 6.77 | 7.87 | 0.002 | <0.01 |
| Metabolizable energy (calculated from animal performance), Mcal/lb | 1.42 | 1.39 | --- | --- |

[1]Standard error of the mean.

**Table 3. Carcass characteristics of steers fed diets containing dry-rolled corn or ground grain sorghum throughout a 182-day finishing period**

| Item | Control | Sorghum | SEM[1] | *P*-value |
|---|---|---|---|---|
| Hot carcass weight, lb | 877.8 | 845.54 | 7.11 | <0.01 |
| Marbling score[2] | 519 | 467 | 8.0 | <0.01 |
| 12th rib fat thickness, in | 0.56 | 0.54 | 0.019 | 0.188 |
| Ribeye area, in$^2$ | 13.2 | 12.9 | 0.10 | <0.01 |
| Kidney, pelvic, and heart fat, % | 1.8[8] | 1.87 | 0.02 | 0.677 |
| | | | | |
| Prime, % | 5.33 | 0.67 | 2.25 | 0.057 |
| Premium Choice, % | 47.63 | 29.33 | 5.49 | <0.01 |
| Low Choice, % | 35.55 | 47.33 | 5.79 | 0.061 |
| Select, % | 11.48 | 21.33 | 4.19 | 0.034 |
| Sub-Select, % | 0.0 | 0.67 | 0.67 | 0.334 |
| Yield Grade 1 | 1.41 | 0 | 0.96 | 0.165 |
| Yield Grade 2 | 24.37 | 30.00 | 5.64 | 0.335 |
| Yield Grade 3 | 52.81 | 51.00 | 6.94 | 0.867 |
| Yield Grade 4 | 20.07 | 15.33 | 4.22 | 0.280 |
| Yield Grade 5 | 1.33 | 0.67 | 1.13 | 0.564 |
| Abscessed livers, % | 8.74 | 6.00 | 2.62 | 0.31 |
| Total carcass value, $[3] | 2491.55 | 2379.11 | 22.11 | <0.01 |

[1]Standard error of the mean.
[2]Slight amount of marbling, 300-399; Small amount of marbling, 400-499; Modest amount of marbling, 500-599; Moderate amount of marbling, 600-699.
[3]Based on average price premiums and discounts reported by USDA on Sept 13, 2024.

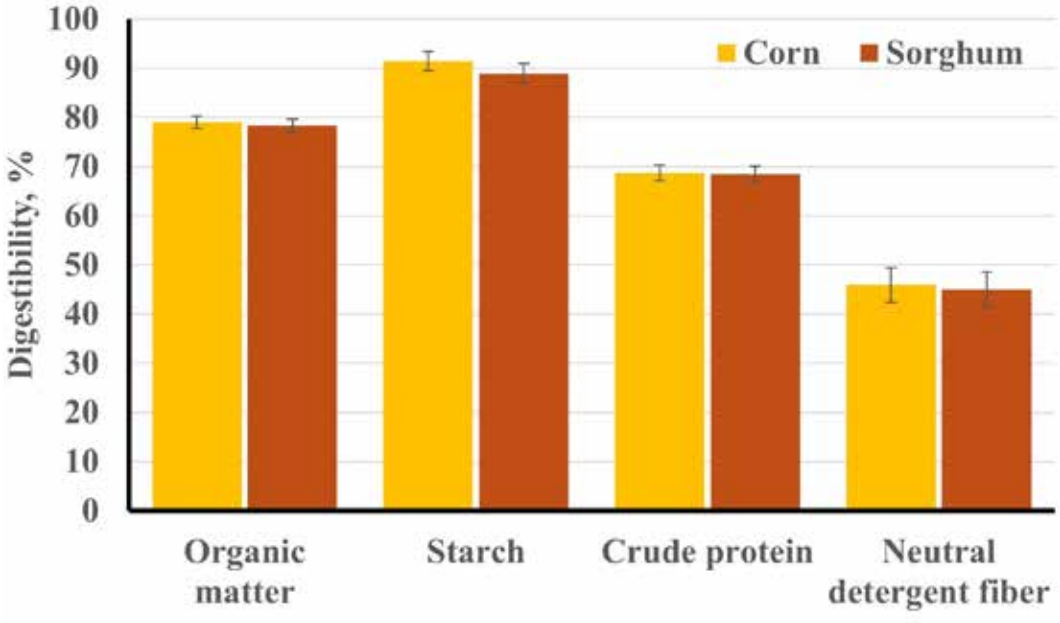


**Figure 1. Digestibility of diet components**

# *greatOplus* (Extruded Blend of Flaxseed and *Nannochloropsis oculata* Biomass) Improves Finishing Cattle Performance and Carcass Characteristics

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## Abstract

Omega-3 fatty acid supplements such as flaxseed and microalgae in beef cattle diets have shown promising results for increasing the omega-3 fat content of beef, particularly alpha-linolenic acid (ALA) and eicosapentaenoic acid (EPA). This study investigated the effect of supplementing an extruded blend of flaxseed and *Nannochloropsis oculata* microalgae (*greatOplus,* GOP) as a source of omega-3 fatty acids to determine the impact on animal performance and carcass characteristics of finishing steers. Cattle fed GOP had greater ($P < 0.05$) dry matter intake (DMI) and average daily gain (ADG) compared to cattle fed the control diet (CON), but gain: feed (G:F) was not affected by treatment ($P > 0.10$). Cattle fed GOP had greater hot carcass weight (HCW) compared to those fed CON (932.1 versus 902.8 lb; $P < 0.01$) and tended to produce more Prime and Choice carcasses (87.4 versus 83.0%; $P = 0.11$) with greater 12$^{th}$ rib backfat (0.61 versus 0.59 in; $P < 0.02$) and greater U.S. Department of Agriculture (USDA) yield grades (2.91 versus 2.75; $P < 0.01$). Marbling score (488 versus 491), longissimus muscle area (14.6 versus 14.5 in$^2$), and liver abscess incidence (12 versus 16% for CON and GOP, respectively) were unaffected by treatment ($P > 0.10$). Carcass values were calculated using base prices, premiums, and discounts published by the USDA during the week of harvest, and were greater for cattle fed GOP compared to cattle fed the control diet ($2,122 versus $2,059; $P < 0.01$). Including *greatOplus* at 10% of the diet dry matter improved cattle performance, largely as the result of its impact on DMI and ADG.

## Introduction

Replacing saturated fats with polyunsaturated fats has been shown to reduce cardiovascular disease (CVD) risk in humans, and is recommended by the American Heart Association as a preventative for CVD. Cattle diets can be altered to favor deposition of desirable omega-3 polyunsaturated fatty acids in beef, providing an opportunity to address concerns over contributions of beef to overall saturated fatty acid consumption by consumers. Additionally, omega-3 fatty acids are essential for cattle, and providing these fats in balanced amounts can contribute to overall health and productivity of cattle.

Flaxseed contains a relatively high proportion of alpha-linolenic acid, which is an essential omega-3 fatty acid, and has been used successfully to promote health and performance of cattle in previous research. Alpha linolenic acid is a precursor for formation of the longer chain polyunsaturated fat, eicosapentaenoic acid (EPA), which in turn serves as a precursor for the formation of several important reproductive hormones and immune compounds that regulate inflammatory responses in animals. Rate of conversion of linolenic acid to EPA is limited, however. Some species of marine algae,

including *Nannochloropsis* species, are known to produce substantial amounts of EPA. This study investigated the effect of supplementing an extruded blend of flaxseed and *Nannochloropsis oculata* microalgae biomass (*greatOplus*) as a source of omega-3 fatty acids on animal performance and carcass characteristics of finishing steers.

## Experimental Procedures

Yearling steers (n = 700; 825 ± 18.07 lb initial body weight (BW)) were blocked by initial BW and assigned randomly, within block, to 28 feedlot pens containing 25 animals/pen. Cattle were vaccinated against viral and clostridial pathogens and treated for internal and external parasites (Bovishield Gold 5, Ultrabac 7 Somubac, and Dectomax injectable; Zoetis Animal Health), and implanted with a combination implant (Component TE-200; Elanco USA). The control diet (CON) consisted of 58.3% steam-flaked corn, 20% wet corn gluten feed, 2.56% soybean meal, and 4.17% vitamin/mineral/feed additive premix. For the *greatOplus* (GOP; an extruded blend of flaxseed and *Nannochloropsis oculata* microalgae) diet, a portion of the corn and all the soybean meal were replaced with 10% GOP (dry basis) to create isonitrogenous diets (Table 1). Cattle were fed once daily, *ad libitum*. After 175 days on feed, animals were weighed and transported to a commercial abattoir for harvest. Animal performance measurements included average daily gain (ADG), dry matter intake (DMI), and gain: feed (G:F). Hot carcass weight (HCW) and incidence of abscessed livers were assessed on the day of harvest, and marbling score, 12$^{th}$ rib fat thickness, longissimus muscle area, and U.S. Department of Agriculture (USDA) yield and quality grades were determined following 48 hours of refrigeration. Data were analyzed as a mixed model using diets as the fixed effect, block as the random effect, and feedlot pen as the experimental unit.

## Results and Discussion

Animal performance is summarized in Table 2. Cattle fed GOP had greater DMI and ADG ($P < 0.05$) compared to cattle fed CON, but G:F was not affected by treatment ($P > 0.10$). Carcass characteristics and USDA carcass quality grade, and liver abscess incidence are presented in Table 3, Table 4, and Table 5, respectively. Cattle fed GOP had greater HCW compared to those fed CON (932.11 versus 902.79 lb; $P < 0.01$) and tended to produce more Prime and Choice carcasses (87.4 versus 83.0%; $P = 0.11$) with greater 12$^{th}$ rib backfat (0.61 versus 0.59 in; $P < 0.02$) and greater yield grades (2.91 versus 2.75; $P < 0.01$). Marbling score (488 versus 491), longissimus muscle area (14.6 versus 14.5 in$^2$) and liver abscess incidence (12 versus 16% for CON and GOP, respectively) were unaffected by treatment ($P > 0.10$). Carcass values were calculated using base prices, premiums, and discounts published by USDA, and were greater for cattle fed GOP compared to cattle fed the control diet ($2,122 versus $2,059; $P < 0.01$).

## Implications

Including *greatOPlus* at 10% of the diet dry matter improved cattle performance, largely as the result of its impact on DMI and ADG.

**Table 1. Ingredients and nutritional composition of control diet (CON)[1] and diet supplemented with *greatOplus* (GOP)[2]**

| Item | CON[1] | GOP[2] |
|---|---|---|
| Diets, % dry matter | | |
| Steam-flaked corn | 58.27 | 50.84 |
| Corn silage | 15.00 | 15.00 |
| Sweet bran | 20.00 | 20.00 |
| Dehulled soybean meal | 2.57 | --- |
| *greatOplus*[3] | --- | 10.00 |
| Supplement[4] | 4.17 | 4.17 |
| Nutrients, % | | |
| Dry matter | 65.41 | 66.1 |
| Crude protein | 14.00 | 14.00 |
| NDF | 16.05 | 16.28 |
| ADF | 8.15 | 8.36 |
| Ether extract | 3.18 | 5.19 |
| Calcium | 0.68 | 0.70 |
| Phosphorus | 0.38 | 0.42 |

[1] Control diet.
[2] *greatOplus* diet.
[3] Extruded flaxseed-algae blend supplement.
[4] Supplement was formulated to provide 2,205 IU/kg of vitamin A; 10 mg/kg of copper; 30 mg/kg of zinc; 20 mg/kg of manganese; 0.50 mg/kg iodine; 0.1 mg/kg of selenium; and 0.15 mg/kg of cobalt.

**Table 2. Effect of *greatOplus* treatment on animal performance**

| Item | CON[1] | GOP[2] | SEM[3] | *P*-value |
|---|---|---|---|---|
| Average daily gain, lb | 3.92[a] | 4.07[b] | 0.03 | <0.01 |
| Dry matter intake, lb/day | 22.95 | 24.07 | 0.36 | 0.03 |
| Gain:feed | 5.85 | 5.91 | 0.07 | 0.53 |

[1] Control diet.
[2] *greatOplus* diet.
[3] Standard error of the least square mean.
[a,b] Means in the same row without a common superscript are different ($P < 0.01$).

**Table 3. Effect of *greatOplus* treatment on carcass characteristics**

| Item | CON[1] | GOP[2] | SEM[3] | *P*-value |
|---|---|---|---|---|
| Carcass weight, lb | 902.8[a] | 931.9[b] | 12.27 | <0.01 |
| Rib eye area, in$^2$ | 12.6 | 12.5 | 0.22 | 0.27 |
| Marbling score | 488 | 491 | 7.01 | 0.61 |
| 12$^{th}$ rib fat thickness, in | 0.58 | 0.61 | 0.02 | 0.02 |

[1] Control diet.
[2] *greatOplus* diet.
[3] Standard error of the least square mean.
[a,b] means in the same row without a common superscript are different ($P < 0.01$).

**Table 4. Effect of *greatOplus* treatment on USDA carcass quality and yield grades**

| Item | CON[1] | GOP[2] | SEM[3] | *P*-value |
|---|---|---|---|---|
| Prime, % | 2.63[a] | 3.74[b] | 0.97 | <0.01 |
| Choice, % | 80.41 | 83.62 | 2.13 | 0.27 |
| Select, % | 14.62 | 11.50 | 1.91 | 0.22 |
| Sub-select, % | 1.47 | 0.86 | 0.62 | 0.46 |
| Final yield grade | 3.26[a] | 3.40[b] | 0.66 | <0.01 |

[1] Control diet.
[2] *greatOplus* diet.
[3] Standard error of the least square mean.
[a,b] means in the same row without a common superscript are different ($P < 0.01$)

**Table 5. Effect of *greatOplus* treatment on liver abscess incidence**

| Abscess severity | CON[1] | GOP[2] | SEM[3] | *P*-value |
|---|---|---|---|---|
| A$^-$ | 1.8 | 3.4 | 0.99 | 0.16 |
| A$^0$ | 5.8 | 6.6 | 1.30 | 0.68 |
| A$^+$ | 6.3 | 6.3 | 1.25 | 0.26 |

[1] Control diet.
[2] *greatOplus* diet.
[3] Standard error of the least square mean.

# Effects on Stocker Steer Performance While Consuming Essential Oil or Ionophore Minerals

*T.M. Jones and J.K. Farney*

## Abstract

This study evaluated an alternative to antibiotics for growth performance in grazing stocker steers. Steers (n = 281 head; 641 ± 10.3 lb) were assigned to one of two mineral treatments and grazed on tallgrass native range. Treatments consisted of the "positive" control of ionophore (lasalocid at 3.6 lb/ton) and essential oil (garlic oil at 3 lb/ton and essential oil blend at 6 lb/ton) in free-choice mineral. Steers were weighed at the beginning and end of the 92-day grazing period. Pasture biomass production and mineral intake were monitored weekly. There was no difference in total gains ($P = 0.92$) nor average daily gain ($P = 0.92$) between the two minerals fed to the steers. Mineral intake was the same for both treatments ($P = 0.58$) and was slightly higher than formulated intake (5.2 oz/head/day as compared to 4.0 oz/head/day). Available forage was not different between treatment pastures ($P = 0.67$). Overall, there was no difference between feeding ionophore or essential oils in mineral. The results of this study could provide operations that implement natural marketing systems an option to have cattle gains equivalent to traditional systems and may reduce cost of gain for a more profitable feeding system.

## Introduction

Alternative methods to reduce the use of synthetic products in cattle production, as well as reduction in feeding antibiotics to cattle, have been a growing preference in consumer opinions. Essential oils/spices have been found to alter rumen microbial population (Elcoso et al., 2019) and replace feed antibiotics in feedlot diets (Araujo et al., 2019), all of which may increase cattle gains. There have been varying responses to cattle gains based on types of essential oil within feedlot diets, with a greater majority reporting similar gains as control diets. Limited other studies have reported cattle gains while grazing pastures, thus clarifying the importance of evaluating essential oils on stocker cattle gains. In studies where growing cattle grazed tallgrass native range or bromegrass pastures, these calves gained on average, 0.10 lb/day more with an essential oil mineral than control minerals (range 0.08-0.25 lb/day depending on year and animal type; Farney et al., 2020; Farney et al., 2021; Farney et al., 2022; Farney et al., 2023; Farney et al., 2024).

Ionophores are antibiotics that alter rumen microbial populations to increase efficiency in cattle production systems. This treatment alters the ratio of volatile fatty acids to more propionate, which is more energy dense than acetate. In general, the gains are greater when grazing a higher energy diet than grass alone. Studies have shown monensin and lasalocid have been proven to improve stocker cattle gains but including them in a mineral package has been less consistent (Brazle et al, 1990). Outside of one grazing study directly comparing essential oils to ionophore, there is limited information about the differences in performance between the two. Therefore, this study compared cattle performance and mineral intakes between essential oils and ionophores.

## Experimental Procedures

The study was conducted at the Bressner Research unit in Yates Center, KS. The unit consists of eight pastures on 625 acres of tallgrass native range. Treatments consisted of two minerals offered free choice to the steers. The positive-control mineral was a stocker mineral that contained 3.6 lb/ton of lasalocid (ionophore; Table 1; Bovatec 91; Zoetis, Kalamazoo, MI). The treatment mineral was the same base mineral with 3 lb/ton of garlic oil and 6 lb/ton of Solace (essential oil; Table 1; Wildcat Feeds LLC, Topeka, KS). There were four pastures of each mineral offered to the steers in AmeriAg mineral feeders (Burlington, NC). Mineral was offered weekly at 125% of the formulated intake, and the amount placed in feeders was weighed, as well as the amount remaining after consumption for the week. This was used to calculate average daily mineral intake for each week while on grass.

Two hundred eighty-one predominantly black-hided steers (641 ± 10.3 lbs) were weighed individually and randomly assigned to pasture based on order through the chute. The steers were weighed on April 30, 2024, and placed on pasture May 1, 2024. Steers grazed until removal from pasture on August 1, 2024.

Pasture biomass was determined weekly in the areas that the cattle grazed to determine the amount of available forage. To determine pasture biomass, three sections within each pasture were clipped to 1-in height in 1-ft × 1-ft squares. The samples were weighed, then dried in a 131°F forced air oven until completely dry. Then the weighed amounts were converted to dry matter/acre. The weekly biomass clippings were averaged by month to determine the total average available biomass by month. To determine forage accumulation there were exclusion cages in the pastures. At the end of grazing, the exclusion cages were clipped, weighed, dried, and calculated to determine dry matter/acre. The difference between the amount of forage in the exclusion cage and the pre-grazing biomass measurement is forage accumulation for the 92-day window of May 1, 2024, to August 2, 2024.

## Results and Discussion

### *Cattle gains*

There was no difference ($P = 0.92$; Table 1) in steer gains based on the two minerals offered. In studies by Farney et al. (2020, 2021, 2022, 2023, 2024) comparing the same essential oil blend used in this study to non-additive mineral, the authors found on average a 0.10 lb/day increase in average daily gain with essential oils. Initial weight of the steers was not significantly different, even though numerically those steers randomly assigned to essential oil treatment started out averaging about 20 lb heavier than ionophore steers. This was also observed at the final grazing weight where those steers were still at an actual numerical weight about 20 lb heavier. Thus, the gain difference was the same for the feeding period. In a grazing study by Beck et al. (2017), no improvements in gains were observed when handfeeding or offering as free choice a cinnamon and garlic essential oil product as compared to ionophore.

### *Mineral consumption*

There was no difference ($P = 0.58$; Table 2) in mineral consumption between the two minerals offered. The cattle consumed an average of 5.41 oz/head/day. Consumption of mineral averaged greater than formulated intake except in one week. Week four consumption of mineral dropped below 4 oz/head/day. This amount was different than

what had been seen in previous studies where consumption decreased below formulated consumption amounts at the end of the grazing period, (Farney et al., 2020; Farney et al., 2021; Farney et al., 2022).

### *Forage production*

There were no differences in available forage between the two treatments and both averaged 1,205 lb dry matter/acre. As summarized in Lyons et al. (1999), forage standing crop levels above 2,250 to 3,000 lb/acre do not limit intake by most livestock species. However, as standing crop levels decline from 2,250 to 1,000 lb/acre, a 15% decline in forage intake can be expected. The steers in this study gained an acceptable amount; however, due to some dry weather conditions during growing season, intake might have been restricted. Although available forage might have been limiting voluntary intake, forage accumulation over the grazing period was 3,895 lb dry matter/acre, and not different ($P = 0.89$) between treatments. Based on animal unit month calculations, the amount of forage available to the steers was sufficient to meet forage intake demands.

## Implications

These data demonstrate that offering essential oil mineral *ad libitum* has similar effects to feeding ionophore mineral. In the case of natural and organic producers, this treatment could provide a feed supplement option that could help increase production rates, proficiency, and profitability.

## Acknowledgments

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## References

Araujo. R.C., D.R. Daley, S.R. Goodall, S. Jalali, O.A. Guimarães Bisneto, A.M. Budde, J.J. Wagner, and T.E. Engle. 2019. Effects of a microencapsulated blend of essential oils supplemented alone or in combination with monensin on performance and carcass characteristics of growing and finishing beef steers. Applied Animal Science 35(2):177-184. doi.org/10.15232/aas.2018-01822

Beck, P.A., M.S. Gadberry, C.B. Stewart, H C. Gray, T.J. Wistuba, M.D. Cravey, and S.A. Gunter. 2017. Effects of a blended garlic and cinnamon essential oil extract with and without monensin sodium on the performance of grazing steers. The Professional Animal Scientist 33(2): 176–185. doi:10.15232/pas.2016-01572

Brazle, F.K., G. Kuhl, , D.L Harmon, W.M. Larson, and K.S. Lusby. 1990. The effect of antibiotics and ionophores on the gain of stocker cattle grazing native grass pasture. The Professional Animal Scientist 6(3):19–23. doi:10.15232/s1080-7446(15)32268-3

Elcoso, G., B. Zweifel, and A. Bach. 2019. Effects of a blend of essential oils on milk yield and feed efficiency of lactating dairy cows. Applied Animal Science 35(3):304–311. doi:10.15232/aas.2018-01825

Farney, J. K., K. Rash, H. Gillespie, E. Black, and N. Collins. 2024. Stocker steer gains and fly numbers as impacted by burn date and type of mineral on tallgrass native range – Year 5. Kansas Agricultural Experiment Station Research Reports 10(2). doi: 10.4148/2378-5977.8574

Farney, J.K., H. Allen, and L. Muniz. 2023. Stocker steer gains and fly numbers as impacted by burn date and type of mineral on tallgrass native range – Year 4, Kansas Agricultural Experiment Station Research Reports 9(2). doi: 10.4148/2378-5977.8434

Farney, J.K. and M. Frahm. 2022. Stocker steer gains and fly numbers as impacted by burn date and type of mineral on tallgrass native range – Year 3. Kansas Agricultural Experiment Station Research Reports 8(3). doi: 10.4148/2378-5977.8289

Farney, J.K., and M.E. Reeb. 2021. Stocker steer gains and fly numbers as impacted by burn date and type of mineral on tallgrass native range. Kansas Agricultural Experiment Station Research Reports 7(2). doi:10.4148/2378-5977.8043

Farney, J.K. 2020. Evaluating stocker steer gains on tallgrass native range with two burn dates and spices in mineral, Kansas Agricultural Experiment Station Research Reports 6(2). doi: 10.4148/2378-5977.7885

Lyons, R. K., R. Machen, and T.D.A. Forbes. 1999. Understanding forage intake in range animals. Texas Agricultural Extension Services L-5152:1–6.

**Table 1. Mineral composition**

| Item (dry matter basis) | Ionophore | Essential oil |
|---|---|---|
| Crude protein, % | 5.48 | 5.50 |
| Calcium, % | 16.11 | 16.17 |
| Phosphorus, % | 3.44 | 3.44 |
| Salt, % | 22.53 | 22.53 |
| Magnesium, % | 2.48 | 2.48 |
| Potassium, % | 0.88 | 0.88 |
| Iron, ppm | 5529 | 5529 |
| Copper, ppm | 1153 | 1153 |
| Zinc, ppm | 3471 | 3471 |
| Manganese, ppm | 1818 | 1818 |
| Selenium, ppm | 22 | 22 |
| Iodine, ppm | 333 | 333 |
| Cobalt, ppm | 13 | 13 |
| Vitamin A, IU | 141,667 | 141,667 |
| Vitamin D, IU | 14,167 | 14,167 |
| Vitamin E, IU | 172 | 172 |

**Table 2. Effects of mineral types on growth performance, average daily gain, average daily mineral intake, and pasture biomass**

| Item | Ionophore[1] | Essential oil[2] | SEM[3] | *P*-value |
|---|---|---|---|---|
| Initial weight, lb | 629 | 653 | 10 | 0.16 |
| Final weight, lb | 833 | 856 | 9 | 0.12 |
| Total gain, lb | 204 | 203 | 8.8 | 0.92 |
| Average daily gain, lb/day | 2.15 | 2.13 | 0.09 | 0.92 |
| Pasture biomass, lb dry matter/acre | 1180 | 1229 | 79 | 0.67 |
| Average mineral intake, oz/head/day | 5.18 | 5.63 | 0.54 | 0.58 |

[1]Ionophore mineral (Bovatec 91 included at 18 lb/ton to provide 3.6 lb/ton lasalocid; Zoetis, Kalamazoo, MI).
[2]Essential oil mineral (3 lb/ton garlic oil and 6 lb/ton Solace; Wildcat Feeds LLC, Topeka, KS).
[3]Standard error of means.

# The Effects of Aging Time on Eating Quality of *Semimembranosus* Steaks

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## Abstract

The objective of this study was to evaluate palatability, objective tenderness, and raw and cooked color of *semimembranosus* (SM) steaks aged 14 to 70 days. Beef top round subprimals (n = 10 / aging period) were collected and aged for 14, 28, 35, 42, 49, 56, 63, and 70 days. One steak from each aging period was used to evaluate Warner-Bratzler Shear Force (WBSF), and color measurements while one steak was used for consumer sensory evaluation. Steaks were cooked to an internal peak temperature of 160°F, following the American Meat Science Association Sensory Guidelines. Consumers (n = 96) were asked to evaluate each sample for overall liking, flavor, juiciness, and tenderness liking, and determine if the sample was acceptable for each attribute. One steak per treatment combination was used to evaluate cooked $L^*$ (lightness), $a^*$ (redness), and $b^*$ (yellowness) values, then refrigerated for 24 hours before conducting WBSF. Consumer sensory results showed steaks aged 28, 56, and 70 day rated higher ($P < 0.05$) for tenderness and overall liking scores compared to 14 day steaks. There was also a higher ($P < 0.05$) percentage of 70 day steaks rated as acceptable for tenderness compared to 14 day steaks. There were no other sensory differences ($P > 0.05$) found for flavor liking and juiciness liking. The WBSF values for 14 and 35 day steaks were higher ($P < 0.05$) than all other treatments. No differences ($P > 0.05$) were found in all cooked color data. Conversely, 49, 56, and 63 day steaks had higher ($P < 0.05$) raw $L^*$ values than 14 and 28-day steaks. Furthermore, 14, 28, 35, and 49 day steaks resulted in higher $a^*$ values ($P < 0.05$) compared to the 70 day treatment. Therefore, extended aging can be used as an effective tool to improve tenderness without negatively impacting flavor or overall liking.

## Introduction

Understanding how to add value to the cuts outside of the middle meats has been a priority over the past decade within the industry and scientific communities. The National Cattlemen's Beef Association (NCBA) Innovation Cuts were developed to educate consumers on lesser-known muscles to promote carcass utilization. One of these NCBA Innovation Cuts is the Tucson Cut, deriving from the *semimembranosus* (SM), or top round subprimal (Institutional Meat Purchase Specifications #169, NAMP, 2014). However, whole muscle cuts derived from the round are typically known to be less tender and less desirable to consumers (Gruber et al., 2006). Gruber et al. (2006) also found the SM, specifically, to be one of the least tender cuts. Increasing tenderness in cuts outside the middle meats provides an opportunity for greater marketing emphasis at retail for lean, affordable beef (Miller et al., 2001).

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Aging is a common practice in the meat industry to improve overall palatability. The 2010/2011 National Beef Tenderness Survey showed food service aging times ranged from 9 to 67 days, with the most common aging period in the industry being 28 days (Guelker et al., 2013). Aging has been shown to positively affect tenderness, while also causing changes to beef flavor compounds (Barker et al., 2023, Hernandez et al., 2023). Beef palatability is characterized by flavor, juiciness, and tenderness, with flavor being recognized as the most critical quality attribute of beef products (Lucherk et al., 2016, O'Quinn et al., 2018). While tenderness is easily the most variable and therefore the most researched palatability trait, flavor has moved to the forefront of research due to its importance for consumers.

Previous research has shown differing results with the effect of extended aging periods on flavor. Colle et al., (2015) found consumer sensory panel flavor scores in strip loin and top sirloin steaks aged 63 days did not change over time. Conversely, recent studies with trained panelists were able to identify negative beef flavor attributes (liver-like, oxidized, metallic, fishy, earthy/musty, and sour) as aging time increased for the same steaks (Barker et al., 2023, Hernandez et al., 2023). However, little research has been done to understand the effects of extended aging (>35 d) on consumer palatability of SM steaks. Continued research around less utilized muscles is imperative to understanding how to improve palatability of these muscles and therefore carcass utilization. The objective of this study was to evaluate consumer palatability, instrumental tenderness, and objective color of *semimembranosus* steaks aged from 14 to 70 days.

## Experimental Procedures

Beef top round subprimals (n = 10 cuts / aging time) were collected at a commercial beef processing plant and brought to Kansas State University. Subprimal cuts were aged for 14, 28, 35, 42, 49, 56, 63, and 70 days at 35 to 38°F. Following aging, cuts were fabricated into 1-in. thick steaks, frozen, and stored at -4°F. One steak from each subprimal was allocated for tenderness and color evaluations, while another was designated for consumer sensory evaluation. Steaks were removed from storage, then thawed between 35 and 38°F. After thawing, packages were opened and steaks were allowed a 30-minute bloom period before measuring $L^*$ (lightness), $a^*$ (redness), $b^*$ (yellowness), using a HunterLab MiniScan Spectrophotometer (A/10 illuminate). These readings were used to calculate hue angle, chroma, and percentage of oxymyoglobin (OMb), deoxymyoglobin (DMb), and metmyoglobin (MMb) on the surface of the steak according to the American Meat Science Association Color Guidelines (AMSA; King et al., 2023). A flat top griddle was used to cook steaks at 375°F to an internal peak temperature of 160°F, measured with a temperature probe inserted at the geometric center of the steak. Steaks were divided into equal thirds for consumer sensory analysis. Consumers (n = 96) were given samples, which they evaluated for overall liking, flavor liking, juiciness liking, and tenderness liking, and asked to determine if samples were acceptable for each attribute. Samples were rated on a 10-point scale, with 0 indicating extremely dry, tough, or extremely dislike, and 10 indicating extremely juicy, tender, or extremely like. Immediately following cooking of the steaks to be tested for color and shear force, the steaks were sliced at a 45° angle exposing a 1-in. internal surface used for cooked color readings. Cooked $L^*$, $a^*$, and $b^*$ readings were taken after a 3-minute bloom period using a HunterLab MiniScan Spectrophotometer. Cook loss was calculated from the weight of the steaks prior to and after cooking. Steaks were refrigerated at 35-38°F for 24 hours before conducting Warner-Bratzler Shear Force tests (WBSF). The WBSF steaks were cooked using the same protocol as described above, and

followed the AMSA Sensory Guidelines (AMSA, 2015). All data were analyzed using SAS PROC GLIMMIX (v. 9.4, SAS Institute, Inc., Cary, NC) as a completely randomized design, with aging period as a fixed effect, and the level of significance set at 0.05.

## Results and Discussion

Results of consumer sensory evaluation indicated there were no differences ($P > 0.05$) among aging periods for flavor and juiciness liking (Table 1), or for the percentage of samples consumers rated as acceptable for flavor and overall acceptability (Table 2). Consumer sensory results showed 28, 56, and 70 day steaks rated higher ($P < 0.05$) for tenderness and overall liking scores compared to 14 day steaks. There was also a higher ($P < 0.05$) percentage of 70 day steaks rated as acceptable for tenderness compared to 14 day steaks. These results align with previous studies that also found increased tenderness in cuts aged for extended periods (Colle et al., 2015, Dixon et al., 2012; Gruber et al., 2006). The consumer sensory results show consumer panelists were unable to detect negative flavor changes associated with extended aging periods, but still found them to be more tender, resulting in a better eating experience.

Supporting the consumer data, WBSF results showed 14 and 35 day steaks had higher ($P < 0.05$) shear values than all other aging periods, indicating they were tougher than the other aging periods (Table 3). Raw $L^*$ values for 14 and 28 day steaks were lower ($P < 0.05$) than 56 day steaks showing steaks were darker at a shorter aging period. Furthermore, 14, 28, 35, and 49 day steaks resulted in higher $a^*$ values ($P < 0.05$) compared to the 70 day treatment. This indicates the less aged steaks were more red than 70 day steaks. Furthermore, 70 day steaks had a higher ($P < 0.05$) raw MMb percentage than 28 day steaks, as well as a higher ($P < 0.05$) raw OMb percentage than 49 and 56 day steaks. Additionally, 28 day steaks had a higher ($P < 0.05$) raw DMb percentage than 70 day steaks. Having a higher percentage of OMb shows the treatment should remain at a bright, cherry-red color for a longer period, potentially impacting shelf life. Surprisingly, no differences ($P > 0.05$) were observed in cooked color ($L^*$, $a^*$, $b^*$ values, OMb, DMb, MMb percentages, chroma and hue angle) readings.

## Implications

This research indicates extended aging improves tenderness and overall liking while not decreasing flavor for consumers, which supports using extended aging periods for historically tough muscles.

## References

American Meat Science Association. 2015. Research guidelines for cookery, sensory evaluation, and instrumental tenderness measurements of meat. 2nd ed. American Meat Science Association. Champaign, IL.

Barker, S.N., J.C. Brooks, J.T. Bachler, D.R. Woerner, and J.F. Legako. 2023. Flavor development of individually vacuum-packaged beef steaks during extended wet aging. Meat and Muscle Biology 7.

Colle, M., R. Richard, K. Killinger, J. Bohlscheid, A. Gray, W. Loucks, R. Day, A. Cochran, J. Nasados, and M. Doumit. 2015. Influence of extended aging on beef quality characteristics and sensory perception of steaks from the gluteus medius and longissimus lumborum. Meat Science 110:32-39.

Dixon, C.L., D. Woerner, R. Tokach, P. Chapman, T. Engle, J. Tatum, and K. Belk. 2012. Quantifying the aging response and nutrient composition for muscles of the beef round. Journal of Animal Science 90:996-1007.

Gruber, S., J. Tatum, J. Scanga, P. Chapman, G. Smith, and K. Belk. 2006. Effects of postmortem aging and USDA quality grade on Warner-Bratzler shear force values of seventeen individual beef muscles. Journal of Animal Science 84:3387-3396.

Guelker, M., A. Haneklaus, J. Brooks, C. Carr, R. Delmore Jr, D. Griffin, D. Hale, K. Harris, G. Mafi, and D. Johnson. 2013. National Beef Tenderness Survey–2010: Warner-Bratzler shear force values and sensory panel ratings for beef steaks from United States retail and food service establishments. Journal of Animal Science 91:1005-1014.

Hernandez, M.S., D.R. Woerner, J.C. Brooks, T.L. Wheeler, and J.F. Legako. 2023. Influence of aging temperature and duration on flavor and tenderness development of vacuum-packaged beef longissimus. Meat and Muscle Biology 7.

King, D. A., M.C. Hunt, S. Barbut, J.R. Claus, D.P. Cornforth, P. Joseph, Y.H.B. 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. doi:10.22175/mmb.12473.

Miller, M.F., M. Carr, C. Ramsey, K. Crockett, and L. Hoover. 2001. Consumer thresholds for establishing the value of beef tenderness. Journal of Animal Science 79:3062-3068.

**Table 1. Consumer panel palatability ratings for *semimembranosus* steaks across aging treatments**

| Aging period | Overall liking | Flavor liking | Juiciness liking | Tenderness liking |
|---|---|---|---|---|
| 14 | 4.7[c] | 4.7 | 4.6 | 3.7[c] |
| 28 | 6.0[ab] | 5.7 | 5.9 | 5.2[ab] |
| 35 | 5.3[bc] | 4.8 | 4.9 | 4.5[bc] |
| 42 | 5.2[bc] | 4.9 | 5.2 | 4.8[bc] |
| 49 | 5.7[abc] | 5.3 | 5.2 | 5.0[abc] |
| 56 | 6.4[a] | 5.9 | 6.5 | 6.2[a] |
| 63 | 5.7[abc] | 5.4 | 5.7 | 5.5[ab] |
| 70 | 6.1[ab] | 5.8 | 5.6 | 5.7[ab] |
| SEM[1] | 0.39 | 0.37 | 0.44 | 0.50 |
| *P*-value | 0.04 | 0.07 | 0.06 | 0.02 |

[abc]Means within the same column without a common superscript differ ($P < 0.05$).
[1]Standard error of the mean (largest) of the least square means.

**Table 2. Percentage of consumers who rated each palatability trait as acceptable for *semimembranosus* steaks**

| Aging period | Overall acceptability | Flavor acceptability | Juiciness acceptability | Tenderness acceptability |
|---|---|---|---|---|
| 14 | 61.3 | 69.9 | 60.6$^{b}$ | 50.7$^{d}$ |
| 28 | 85.4 | 83.9 | 84.4$^{a}$ | 67.2$^{bcd}$ |
| 35 | 79.9 | 74.2 | 62.8b | 66.7$^{bcd}$ |
| 42 | 71.5 | 67.6 | 72.5$^{ab}$ | 60.8$^{cd}$ |
| 49 | 82.5 | 80.5 | 74.9$^{ab}$ | 69.5$^{abcd}$ |
| 56 | 91.4 | 79.6 | 86.8$^{a}$ | 81.1$^{ab}$ |
| 63 | 77.4 | 76.6 | 82.9$^{a}$ | 72.9$^{abc}$ |
| 70 | 76.3 | 76.5 | 76.5$^{ab}$ | 83.8$^{a}$ |
| SEM[1] | 4.8 | 3.7 | 4.2 | 3.0 |
| *P*-value | 0.2 | 0.51 | 0.02 | 0.01 |

$^{abc}$Means within the same column without a common superscript differ ($P < 0.05$).
[1]Standard error of the mean (largest) of the least square means.

**Table 3. Warner-Bratzler Shear Force (WBSF), raw *L**, *a**, *b**, percentage of myoglobin content, chroma, and hue angle for *semimembranosus* steaks**

| Aging period | WBSF | *L**[1] | *a**[2] | *b**[3] | Metmyoglobin (%)[4] | Oxymyoglobin (%)[4] | Deoxymyoglobin (%)[4] | Chroma[4] | Hue angle[4] |
|---|---|---|---|---|---|---|---|---|---|
| 14 | 4.77$^{a}$ | 41.23$^{c}$ | 19.16$^{a}$ | 17.94$^{a}$ | 6.58$^{ab}$ | 42.81$^{bc}$ | 50.61$^{a}$ | 26.30$^{a}$ | 0.76 |
| 28 | 3.61$^{c}$ | 40.14$^{c}$ | 18.02$^{ab}$ | 17.88$^{a}$ | 4.43$^{c}$ | 46.74$^{abc}$ | 48.84$^{ab}$ | 25.40$^{a}$ | 0.78 |
| 35 | 4.47$^{ab}$ | 42.04$^{bc}$ | 17.89$^{ab}$ | 16.36$^{bc}$ | 6.13$^{bc}$ | 44.65$^{abc}$ | 49.23$^{ab}$ | 24.29$^{ab}$ | 0.75 |
| 42 | 3.89$^{bc}$ | 41.97$^{bc}$ | 17.76$^{abc}$ | 16.18$^{bc}$ | 6.95$^{ab}$ | 43.21$^{bc}$ | 49.84$^{ab}$ | 24.07$^{abc}$ | 0.74 |
| 49 | 3.68$^{bc}$ | 43.67$^{ab}$ | 18.71$^{a}$ | 16.84$^{ab}$ | 6.59$^{ab}$ | 40.64$^{c}$ | 52.78$^{a}$ | 25.21$^{a}$ | 0.74 |
| 56 | 3.33$^{c}$ | 45.03$^{a}$ | 17.57$^{abc}$ | 16.20$^{bc}$ | 7.73$^{ab}$ | 42.60$^{c}$ | 49.67$^{ab}$ | 23.91$^{abc}$ | 0.75 |
| 63 | 3.34$^{c}$ | 43.57$^{ab}$ | 15.74$^{bc}$ | 15.76$^{bc}$ | 7.23$^{ab}$ | 49.03$^{ab}$ | 43.75$^{bc}$ | 22.35$^{bc}$ | 0.80 |
| 70 | 3.80$^{bc}$ | 42.21$^{bc}$ | 15.27$^{c}$ | 15.21$^{c}$ | 8.21$^{a}$ | 50.68$^{a}$ | 41.11$^{c}$ | 21.60$^{c}$ | 0.79 |
| SEM[5] | 0.29 | 0.81 | 0.90 | 0.50 | 0.72 | 2.28 | 2.23 | 0.91 | 0.02 |
| *P*-value | 0.01 | <0.01 | 0.04 | <0.01 | 0.02 | 0.03 | <0.01 | 0.01 | 0.29 |

$^{abc}$Means within the same column without a common superscript differ ($P < 0.05$).
[1]*L**: 0 = black, 100 = white.
[2]*a**: -60 = green, 60 = red.
[3]*b**: -60 = blue, 60 = yellow.
[4]Calculated following the AMSA Color Guidelines.
[5]Standard error of the mean (largest) of the least square means.

# The Effects of Aging Time on the Eating Quality of *Biceps Femoris* Steaks

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## Abstract

This study evaluated the sensory, instrumental color, and tenderness characteristics of *biceps femoris* steaks aged over eight periods ranging from 14 to 70 days. Eighty beef sirloin top butt sub-primal cuts were collected from a commercial processing facility and aged at 35.6° and 39.2°F throughout the duration of their aging periods. After aging, the *biceps femoris* and *gluteus medius* muscles were separated, and 1-in thick steaks were fabricated, packaged, frozen at -4°F, and stored for subsequent analysis. The steaks underwent instrumental evaluations for raw and cooked color traits, tenderness, and consumer sensory preferences. Key objective measurements included $L^*$ (lightness), $a^*$ (redness), and $b^*$ (yellowness) color, hue angle, chroma, and the percentages of oxymyoglobin (OMb) and metmyoglobin (MMb) on the steak surface. Steaks were cooked to an internal temperature of 159.8°F and analyzed for cook loss and Warner-Bratzler Shear Force (WBSF) values. Additionally, sensory evaluation was conducted with 96 consumers who assessed the steaks for tenderness, flavor, and juiciness using a 10-point scale, and evaluated the steaks for the acceptability of each trait. There were no differences ($P > 0.05$) in the percentage of samples rated acceptable for flavor, juiciness, tenderness, or overall. Moreover, there were no differences ($P > 0.05$) in flavor, juiciness, tenderness, or overall liking among the different aging periods. Furthermore, no differences ($P > 0.05$) were observed in the percentage of cook loss, WBSF, or cooked color readings among aging treatments. However, raw steaks aged 14 and 28 days had higher ($P < 0.05$) $a^*$ and $b^*$ values than steaks aged 42, 49, or 70 days. Despite these minor differences in raw color, the aging period had minimal impact on overall eating quality, indicating that within the studied range, the aging process has only a minimal effect on the quality traits of *biceps femoris* steaks.

## Introduction

The consumer beef-eating experience is primarily reliant on three factors: tenderness, juiciness, and flavor. All three are factors in the overall eating experience for consumers, but the failure of even one of these factors can increase the likelihood of the overall experience being unacceptable to the consumer (O'Quinn et al., 2018). One factor influencing the consumer beef-eating experience is aging and its effect on beef (O'Quinn et al., 2024). Although aging is commonly undergone to improve the tenderness of beef, a recent review of factors that can influence beef flavor concluded that wet-aging beef past 35 days can have negative effects on the consumer with off-flavors, odors, and volatile compounds (O'Quinn et al., 2024). Aging has been widely studied across numerous conditions and with multiple muscles. However, few studies have evaluated aging's impact on the *biceps femoris* (Colle et al., 2016). One previous study reported extended aging periods resulted in reduced color characteristics for *biceps*

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*femoris* steaks across five different aging periods, but resulted in improved tenderness although that study only evaluated steaks across a comparatively short aging period (Colle et al., 2016).

The current study evaluated the sensory, instrumental color, and tenderness characteristics of *biceps femoris* steaks aged from 14 to 70 days. Understanding the impact of extended aging will provide valuable insights into optimal management practices for *biceps femoris* steaks and help identify the point at which palatability is maximized as well as when any potential negative flavor traits arise for steaks from the *biceps femoris*.

## Experimental Procedures

Beef sirloin top butt sub-primal cuts (n = 80) were collected from a commercial beef processing facility. Subprimal cuts were then aged for eight aging periods: 14, 28, 35, 42, 49, 56, 63, or 70 days at 35.6°F and 39.2°F. Once the aging period concluded, the *biceps femoris* and *gluteus medius* were separated, and 1-in thick steaks were fabricated, packaged, frozen at -4°F, and stored for further analysis. Steaks were analyzed for instrumental raw and cooked color traits, tenderness, and consumer sensory taste panels. Steaks assigned for instrumental tenderness and raw and cooked color traits were thawed for 24 hours at 33.8 - 39.2°F. Once packages were opened, steaks underwent a 30-minute bloom period at ambient temperature prior to color evaluation using a Hunter Lab Miniscan Spectrum photometer (Illuminant A, 2.54 cm aperture, 10° observer, Hunter Lab Associates Laboratory, Reston, VA). $L^*$(lightness), $a^*$ (redness), and $b^*$ (yellowness) readings and spectral data were used to calculate hue angle, chroma, and percentage of oxymyoglobin (OMb) and metmyoglobin (MMb) according to the American Meat Science Association Meat Color Measurement Guidelines (King et al., 2023). Steaks were cooked to an internal temperature of 154.4°F on a flat top griddle with a surface temperature of 375.8°F, then pulled and allowed to rise to a peak temperature of 159.4°F, with temperatures monitored using a thermocouple connected to a Doric MiniTrend 205. Once steaks reached peak temperature, they were sliced at a 45° angle, perpendicular to the outer cooked surface, in the medial section of the steak, and after a 3-minute bloom period, $L^*$, $a^*$, $b^*$ readings, spectral, and cook loss data were collected as a measure of cooked color. After chilling steaks at 33.8 – 39.2°F for 24 hours, Warner Bratzler Shear Force (WBSF) was measured using an Instron. For sensory analysis, steaks assigned for consumer sensory taste panels were divided into equal thirds, and consumers were provided an approximately 2-in$^2$ sample for evaluation. Consumers evaluated five samples representing different aging periods. Consumers (n = 96) evaluated overall tenderness, flavor, and juiciness liking on 10-point line scales and determined if the sample was acceptable for each trait (yes/no). Data were analyzed using a completely randomized design with an aging period as a fixed effect.

## Results and Discussion

Consumers found no differences ($P > 0.05$) among aging treatments for overall liking, flavor liking, juiciness liking, or tenderness liking (Table 1). Moreover, the percentage of samples rated acceptable for *biceps femoris* steaks did not differ ($P > 0.05$) among the aging treatments, with more than 90% of samples from each aging period rated acceptable overall (Table 2). However, instrumental color readings for raw steaks changed throughout aging with $a^*$ and $b^*$ values decreasing (Table 3). The 14- and 28-day-aged steaks had the highest ($P < 0.05$) values for $a^*$ and $b^*$ measures, and the 42- and 49-day-aged steaks had the lowest ($P < 0.05$). Similarly, 14- and 28-day aged steaks had

the lowest ($P < 0.05$) OMb percentage of all aging periods, while 70-day aged steaks had the highest ($P < 0.05$) OMb percentage following blooming. Additionally, there was no difference ($P > 0.05$) in cooking loss, WBSF, and cooked color among the evaluated aging periods (Table 4).

## Implications

The aging period, ranging from 14 to 70 days, has minimal impact on the overall quality traits of *biceps femoris* steaks, with over 90% of samples rated as acceptable overall by consumers regardless of the aging duration. This indicates that key sensory attributes like flavor, tenderness, juiciness, and instrumental measurements of cooked color and tenderness remain consistent across aging periods. For industry and consumers, aging within this range does not significantly affect eating quality, allowing for more flexible and potentially cost-effective aging practices without compromising consumer satisfaction.

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## References

Colle, M.J., R.P. Richard, K.M. Killinger, J.C. Bohlscheid, A.R. Gray, W.I. Loucks, R.N. Day, A.S. Cochran, J.A. Nasados, and M.E. Doumit. 2016. Influence of extended aging on beef quality characteristics and sensory perception of steaks from the biceps femoris and semimembranosus. Meat Science 119:110-117. doi:10.1016/j.meatsci.2016.04.028

King, D.A., M.C. Hunt, S. Barbut, J.R. Claus, D.P. Cornforth, P. Joseph, Y.H.B. 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. doi:10.22175/mmb.12473

O'Quinn, T.G., J.F. Legako, D.R. Woerner, C.R. Kerth, M.N. Nair, J.C. Brooks, J.M. Lancaster, and R.K. Miller. 2024. A current review of U.S. beef flavor II: Managing beef flavor. Meat Science 209:109403. doi:10.1016/j.meatsci.2023.109403

O'Quinn, T.G., J.F. Legako, J.C. Brooks, and M.F. Miller. 2018. Evaluation of the contribution of tenderness, juiciness, and flavor to the overall consumer beef eating experience. Translational. Animal Sciences 2:26-36. doi:10.1093/tas/txx008

**Table 1. Least-squares means for consumer (n = 96) panel palatability ratings[1] for *biceps femoris* steaks across eight aging treatments**

| Aging period (days) | Overall liking | Flavor liking | Juiciness liking | Tenderness liking |
|---|---|---|---|---|
| 14 | 6.6 | 6.0 | 6.6 | 6.2 |
| 28 | 6.7 | 6.5 | 6.8 | 7.0 |
| 35 | 6.8 | 6.3 | 6.7 | 6.4 |
| 42 | 6.9 | 6.3 | 7.3 | 7.1 |
| 49 | 6.0 | 5.7 | 6.6 | 6.1 |
| 56 | 7.0 | 6.6 | 7.5 | 7.2 |
| 63 | 6.5 | 5.9 | 6.7 | 6.6 |
| 70 | 6.3 | 5.4 | 6.4 | 6.1 |
| SEM[2] | 0.30 | 0.33 | 0.35 | 0.35 |
| *P*-value | 0.21 | 0.09 | 0.36 | 0.14 |

[1]Sensory score: 1 = extremely dislike; 5 = neither like nor dislike; 10 = extremely like.
[2]Standard error of the mean (largest) of the least square means.

**Table 2. Least-squares means (n = 10/aging treatment) for the percentage of consumers who rated each palatability trait as acceptable (yes/no) for *biceps femoris* steaks**

| Aging period (days) | Overall acceptability | Flavor acceptability | Juiciness acceptability | Tenderness acceptability |
|---|---|---|---|---|
| 14 | 93.8 | 94.2 | 96.1 | 89.5 |
| 28 | 95.2 | 95.1 | 89.1 | 95.2 |
| 35 | 92.6 | 89.9 | 92.7 | 91.6 |
| 42 | 95.6 | 93.6 | 98.8 | 91.1 |
| 49 | 92.5 | 87.5 | 89.7 | 86.0 |
| 56 | 95.1 | 96.8 | 96.3 | 95.4 |
| 63 | 91.0 | 90.6 | 92.5 | 91.0 |
| 70 | 93.3 | 84.2 | 94.4 | 92.2 |
| SEM[1] | 3.8 | 5.2 | 4.7 | 5.0 |
| *P*-value | 0.98 | 0.36 | 0.36 | 0.71 |

[1]Standard error of the mean (largest) of the least square means.

**Table 3. Least-squares means for *L**, *a**, and *b**, percentage of myoglobin content, chroma, hue angle for raw *biceps femoris* steaks**

| Aging period (days) | L* | a* | b* | MMb[1] | OMb[2] | Chroma | Hue angle |
|---|---|---|---|---|---|---|---|
| 14 | 38.99[d] | 26.79[a] | 20.59[a] | 7.14 | 23.52[d] | 38.79[a] | 0.65[ab] |
| 28 | 41.40[cd] | 26.36[a] | 20.01[a] | 6.55 | 24.32[d] | 33.10[ab] | 0.65[abc] |
| 35 | 41.89[bcd] | 24.93[ab] | 18.82[ab] | 7.72 | 25.39[cd] | 31.25[ab] | 0.64[bc] |
| 42 | 44.53[ab] | 21.54[c] | 15.67[c] | 9.26 | 28.80[bc] | 26.66[c] | 0.62[c] |
| 49 | 45.65[a] | 21.48[c] | 15.52[c] | 7.66 | 28.48[bc] | 26.50[c] | 0.62[c] |
| 56 | 41.92[bc] | 25.47[ab] | 19.71[a] | 7.30 | 25.49[cd] | 32.22[ab] | 0.66[ab] |
| 63 | 40.95[cd] | 23.44[bc] | 18.40[ab] | 9.49 | 30.54[b] | 29.82[bc] | 0.67[ab] |
| 70 | 40.32[cd] | 21.37[c] | 17.04[bc] | 8.42 | 34.84[a] | 27.35[c] | 0.67[a] |
| SEM[3] | 1.04 | 0.91 | 0.82 | 0.72 | 1.45 | 1.20 | 0.01 |
| *P*-value | <0.01 | <0.01 | <0.01 | 0.06 | <0.01 | <0.01 | <0.01 |

[abcd] Least square means within the same column lacking a common superscript differ ($P < 0.05$).
[1]Metmyoglobin.
[2]Oxymyoglobin.
[3]Standard error of the mean (largest) of the least square means.

**Table 4. Least-squares means for *L**, *a**, and *b**, percentage of myoglobin content, chroma, hue angle, cook loss, and Warner-Bratzler Shear Force (WBSF) for cooked *biceps femoris* steaks**

| Aging period (days) | Cook loss | WBSF | L* | a* | b* | MMb[1] | OMb[2] | Chroma | Hue angle |
|---|---|---|---|---|---|---|---|---|---|
| 14 | 25.74 | 3.85 | 48.56 | 19.17 | 28.17 | 1.01 | 39.69 | 26.98 | 0.78 |
| 28 | 23.96 | 3.13 | 47.31 | 20.73 | 23.98 | 1.50 | 37.50 | 29.01 | 0.78 |
| 35 | 23.01 | 3.35 | 49.95 | 19.48 | 23.03 | 1.16 | 37.85 | 26.85 | 0.75 |
| 42 | 22.26 | 3.35 | 48.67 | 20.51 | 22.21 | 0.57 | 38.18 | 28.01 | 0.75 |
| 49 | 25.21 | 3.31 | 48.81 | 19.07 | 25.27 | 0.20 | 40.99 | 26.80 | 0.78 |
| 56 | 21.93 | 3.33 | 49.53 | 17.81 | 24.98 | 0.19 | 40.13 | 24.68 | 0.77 |
| 63 | 23.18 | 3.53 | 47.62 | 19.19 | 23.24 | 1.35 | 38.64 | 27.20 | 0.78 |
| 70 | 24.18 | 3.68 | 48.25 | 17.55 | 27.26 | 0.58 | 40.27 | 25.01 | 0.80 |
| SEM[3] | 1.38 | 0.25 | 0.96 | 1.13 | 2.23 | 0.53 | 1.67 | 1.42 | 0.02 |
| *P*-value | 0.46 | 0.52 | 0.54 | 0.44 | 0.53 | 0.50 | 0.75 | 0.43 | 0.48 |

[1]Metmyoglobin.
[2]Oxymyoglobin.
[3]Standard error of the mean (largest) of the least square means.

# The Effects of Aging Time on the Eating Quality of *Gluteus Medius* Steaks

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## Abstract

The objective of this study was to determine the palatability characteristics and color traits of *gluteus medius* steaks aged 14, 28, 35, 42, 49, 56, 63, and 70 days. Beef top sirloin butt subprimals were collected and designated to one of the eight aging time periods. Once the subprimals reached their respective aging period, the *gluteus medius* was fabricated into 1-in thick steaks and frozen. The steaks were designated to consumer sensory panels, Warner-Bratzler Shear Force (WBSF), raw color evaluation, or cooked color evaluation. Raw steaks bloomed for 30 minutes before color data were collected. Steaks were cooked to 160°F, sliced at a 45° angle, and bloomed for 3 minutes before internal cooked temperature readings were taken. Samples were cooled for 24 hours before WBSF evaluation. For consumer sensory panels, steaks were cooked to an internal temperature of 160°F before being served. Consumers evaluated samples for overall liking, juiciness liking, tenderness liking, and flavor liking. Results showed that consumers found no difference ($P > 0.05$) among aging treatments for juiciness, tenderness, flavor, or overall liking. Although there were no differences ($P > 0.05$) in the percentage of samples rated acceptable for juiciness, tenderness, flavor, or overall liking, all treatments had, at minimum, 83% of samples rated overall acceptable by the consumers. Additionally, there were no differences ($P > 0.05$) in cooking loss, cooked $L^*$ (lightness), $a^*$ (redness), $b^*$ (yellowness), deoxymyoglobin, oxymyoglobin, metmyoglobin, chroma, or hue angle among all treatments. Steaks that were aged for 14 days had a higher ($P < 0.05$) WBSF value than all other treatments. Steaks aged 63 and 70 days were more tender ($P < 0.05$) than samples aged for 42 days or less. Therefore, these results indicate that extending the aging time of *gluteus medius* steaks has limited impact on the palatability and color characteristics of the steaks.

## Introduction

Beef palatability is often conceptualized as a three-legged stool consisting of tenderness, flavor, and juiciness. All of these attributes are important to the overall eating experience for consumers. Studies have shown that flavor significantly influences consumer satisfaction and is often prioritized over tenderness and juiciness when evaluating beef quality (Lucherk et al., 2016, O'Quinn et al., 2018).

Steaks consisting of the *longissimus dorsi* muscle, such as the ribeye and strip steak, have historically been viewed as higher quality and sold for a premium. However, as the cost of meat products continues to rise, consumers are looking for cheaper alternatives with the same eating experience. Previous work has shown top loin steaks and top sirloin steaks have similar customer ratings across most consumer attributes, including overall likeability (Miller et al., 2018). Other studies have reported similar results for top loin

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and sirloin steaks (Glascock, 2014, Luckemeyer, 2015, and Laird, 2015). Postmortem aging of beef is a common practice to enhance beef eating quality, specifically as it relates to tenderness. However, few studies have evaluated the effects of aging on the palatability of the *gluteus medius*. Therefore, the objective of this study was to determine the palatability characteristics and color traits of *gluteus medius* steaks aged 14, 28, 35, 42, 49, 56, 63, and 70 days.

## Experimental Procedures

Beef top sirloin butt subprimals (n = 80) were collected from a commercial packing facility 48 hours postmortem and aged for 14, 28, 35, 42, 49, 56, 63, and 70 days at 35.6-39.2°F in vacuum packaging as whole subprimals. Once the subprimals reached their designated age time, the *gluteus medius* and *biceps femorus* were separated and fabricated into 1-in thick steaks. The steaks were then vacuum packaged and frozen. All steaks were designated for either consumer sensory panels, Warner-Bratzler Shear Force (WBSF), raw color evaluation, or cooked color evaluation. Steaks were thawed for 24 hours at 34-39°F prior to all analyses and assays. Steaks used for WBSF were removed from the package and allowed approximately 30 minutes to bloom. After the 30-minute bloom time, raw $L^*$ (lightness), $a^*$ (redness), $b^*$ (yellowness), and spectra data were collected using a Hunter Lab MiniScan spectrophotometer (Illuminant A, 10° observer, 1-in aperture). The data collected from these readings were used to calculate the percent deoxymyoglobin (DMb), oxymyoglobin (OMb), and metmyoglobin (MMb), chroma, and hue angle according to the AMSA Guidelines for Meat Color Measurement. All steaks were cooked on a flat top griddle to an internal temperature of 160°F. In preparation for WBSF and color evaluation, the steaks were sliced at a 45° angle parallel to the muscle fiber orientation and allowed to bloom for an additional 3 minutes post-cooking before measuring internal cooked color, using the same technique that was used for raw color. Samples were cooled at 33.8-39.2°F for 24 hours before WBSF evaluation. Steaks were weighed prior to cooking and after cooking to calculate the percentage of cook loss. Steaks designated for consumer sensory panels were cooked to an internal temperature of 160°F, sliced into 3 pieces approximately 2-in × 2-in in size, and served to consumers. Consumers (n = 96) evaluated five samples of varying age times for overall liking, juiciness liking, tenderness liking, and flavor liking. These traits were evaluated on a 10-point line scale with 1 being dislike extremely, and 10 being like extremely. Additionally, each sample was evaluated for acceptability of each trait (acceptable/unacceptable).

## Results and Discussion

Table 1 shows that consumers found no difference ($P > 0.05$) among aging treatments for juiciness, tenderness, flavor, or overall liking. Although there were no differences ($P > 0.05$) in the percentage of samples rated acceptable for juiciness, tenderness, flavor, or overall liking, all treatments had, at minimum, 83% of samples rated overall acceptable by the consumers as shown in Table 2. Additionally, Table 3 shows there were no differences ($P > 0.05$) in cooking loss, cooked $L^*$, $a^*$, $b^*$, DMb, OMb, MMb, chroma, or hue angle among all treatments. Steaks that were aged for 14 days had a higher ($P < 0.05$) WBSF value than all other treatments. Steaks aged 63 and 70 days were more tender ($P < 0.05$) than samples aged for 42 days or less. Although there were differences found in raw color, there were few evident trends. Steaks that were aged 14, 49, and 56 days were redder ($P < 0.05$) than those aged for 63 and 70 days. Steaks aged for 14 days were darker ($P < 0.05$) than steaks aged for 49 days or more. Although

there were no differences ($P > 0.05$) in raw calculated MMb, there were differences ($P < 0.05$) in DMb, with values being higher in 14, 35, 49, and 56 days than 63 and 70 days. Furthermore, OMb was higher ($P < 0.05$) at 63 days than at 14, 35, 42, and 56 days.

## Implications

There was no impact on palatability traits evaluated by consumers through aging *gluteus medius* steaks from 14 to 70 days. However, increased aging time was associated with improved shear force values and steaks lighter in color. Therefore, these results indicate that extending the aging time of *gluteus medius* steaks has limited impact on the palatability and color characteristics of the steaks.

## Acknowledgments

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## References

Glascock, R. A. 2014. Beef flavor attributes and consumer perception. M.S. thesis, Texas A&M University, College Station, TX.

Lucherk, L. W., T.G. O'Quinn, J.F. Legako, R.J. Rathmann, J.C. Brooks, and M.F. Miller. 2016. Consumer and trained panel evaluation of beef strip steaks of varying marbling and enhancement levels cooked to three degrees of doneness. Meat Science 122:145–154. doi:10.1016/j.meatsci.2016.08.005

Luckemeyer, T. J. 2015. Beef flavor attributes and consumer perception of light beef eaters. M.S. thesis, Texas A&M University, College Station, TX.

Laird, H. L. 2015. Millennial's perception of beef flavor. M.S. thesis, Texas A&M University, College Station, TX.

Miller, R. K., Pena, C. A., Legako, J. F., Woerner, D. R., Brooks, C., Schilling, B., Nair, M. N., Cramer, T., Smith, P., Wall, K. R. & Kerth, C. R. 2022. 2018 National Beef Flavor Audit: Consumer and Descriptive Sensory Attributes. Meat and Muscle Biology 6(1): 13017. 1-20. doi: *https://doi.org/10.22175/mmb.13017*

O'Quinn, T. G., J. F. Legako, J. C. Brooks, and M. F. Miller. 2018. Evaluation of the contribution of tenderness, juiciness, and flavor to the overall consumer beef eating experience. Translational Animal Science 2:26-36. doi:10.1093/tas/txx008

**Table 1. Least-square means for consumer (n = 96) panel palatability ratings for *gluteus medius* steaks across eight aging treatments**

| Aging period | Overall liking[1] | Flavor liking[1] | Juiciness liking[1] | Tenderness liking[1] |
|---|---|---|---|---|
| 14 | 5.9 | 5.9 | 5.8 | 5.7 |
| 28 | 6.0 | 5.6 | 5.4 | 5.6 |
| 35 | 6.3 | 6.2 | 5.8 | 5.8 |
| 42 | 6.7 | 6.2 | 6.4 | 6.4 |
| 49 | 6.2 | 5.9 | 5.9 | 6.3 |
| 56 | 6.7 | 6.5 | 6.4 | 6.7 |
| 63 | 6.5 | 6.1 | 5.7 | 6.4 |
| 70 | 6.2 | 5.9 | 5.5 | 6.4 |
| SEM[2] | 0.35 | 0.41 | 0.36 | 0.44 |
| *P*-value | 0.29 | 0.59 | 0.30 | 0.32 |

[1]Sensory scores: 1 = dislike extremely, 5 = neither like nor dislike, 10 = like extremely.
[2]Standard error of the mean (largest) of the least square means.

**Table 2. Least-squares means (n = 12/aging treatment) for the percentage of consumers who rated each palatability trait as acceptable[1] for *gluteus medius* steaks**

| Aging period (days) | Overall acceptability[2] | Flavor acceptability[2] | Juiciness acceptability[2] | Tenderness acceptability[2] |
|---|---|---|---|---|
| 14 | 83.0 | 87.1 | 78.8 | 84.3 |
| 28 | 86.9 | 76.5 | 70.7 | 84.6 |
| 35 | 87.6 | 88.2 | 85.9 | 75.4 |
| 42 | 89.6 | 91.4 | 81.8 | 87.3 |
| 49 | 83.2 | 82.0 | 76.2 | 83.1 |
| 56 | 92.6 | 88.3 | 90.3 | 92.5 |
| 63 | 93.6 | 89.4 | 82.7 | 91.8 |
| 70 | 90.7 | 85.3 | 79.2 | 83.3 |
| SEM[3] | 5.3 | 4.9 | 4.4 | 5.5 |
| *P*-value | 0.51 | 0.41 | 0.31 | 0.33 |

[1]Acceptability asked as a yes/no question with yes being acceptable and no being unacceptable.
[2]Percentage of samples rated acceptable for that particular trait by consumer sensory panelists.
[3]Standard error of the mean (largest) of the least square means.

**Table 3. Least-square means for *L** (lightness), *a** (redness), and *b** (yellowness) values, percentage of myoglobin content, chroma, hue angle, cooking loss, and Warner-Bratzler Shear Force (WBSF) for raw and cooked *gluteus medius* steaks**

| Aging period (days) | Cook loss | WBSF | *L**[1] | *a**[2] | *b**[3] | Metmyo-globin | Oxymyo-globin | Deoxymyo-globin | Chroma | Hue angle |
|---|---|---|---|---|---|---|---|---|---|---|
| Raw | | | | | | | | | | |
| 14 | | | 40.64$^{d}$ | 21.53$^{a}$ | 19.16$^{a}$ | 5.33 | 39.95$^{bcd}$ | 54.76$^{a}$ | 28.83$^{a}$ | 0.73$^{abc}$ |
| 28 | | | 41.30$^{cd}$ | 19.97$^{ab}$ | 18.06$^{ab}$ | 5.61 | 40.84$^{abc}$ | 53.54$^{ab}$ | 26.93$^{a}$ | 0.74$^{abc}$ |
| 35 | | | 42.85$^{bcd}$ | 20.21$^{a}$ | 17.01$^{bcd}$ | 6.03 | 36.87$^{cd}$ | 57.10$^{a}$ | 26.43$^{ab}$ | 0.70$^{c}$ |
| 42 | | | 42.60$^{bcd}$ | 19.77$^{ab}$ | 17.81$^{ab}$ | 5.69 | 39.94$^{bcd}$ | 54.37$^{ab}$ | 26.63$^{ab}$ | 0.73$^{abc}$ |
| 49 | | | 44.57$^{ab}$ | 21.23$^{a}$ | 17.68$^{abc}$ | 5.71 | 35.17$^{d}$ | 59.17$^{a}$ | 27.66$^{a}$ | 0.70$^{c}$ |
| 56 | | | 46.30$^{a}$ | 20.78$^{a}$ | 18.10$^{ab}$ | 5.33 | 35.79$^{cd}$ | 58.91$^{a}$ | 27.58$^{a}$ | 0.72$^{bc}$ |
| 63 | | | 44.81$^{ab}$ | 16.11$^{c}$ | 15.55$^{d}$ | 7.48 | 46.17$^{a}$ | 46.35$^{c}$ | 22.48$^{c}$ | 0.77$^{a}$ |
| 70 | | | 43.36$^{bc}$ | 17.01$^{bc}$ | 15.69$^{cd}$ | 7.16 | 44.60$^{ab}$ | 48.23$^{bc}$ | 23.15$^{bc}$ | 0.75$^{ab}$ |
| SEM[4] | | | 0.87 | 1.12 | 0.74 | 0.70 | 1.97 | 2.26 | 1.28 | 0.02 |
| *P*- value | | | <0.01 | 0.01 | 0.01 | 0.22 | <0.01 | <0.01 | 0.01 | 0.02 |
| Cooked | | | | | | | | | | |
| 14 | 29.21 | 4.25$^{a}$ | 48.30 | 20.10 | 32.87 | 1.69 | 29.79 | 64.32 | 28.91 | 0.81 |
| 28 | 29.71 | 3.57$^{bc}$ | 50.51 | 19.50 | 29.35 | 0.51 | 39.19 | 66.19 | 28.08 | 0.82 |
| 35 | 28.32 | 3.69$^{b}$ | 50.03 | 20.74 | 28.17 | 0.02 | 38.69 | 68.41 | 29.86 | 0.81 |
| 42 | 27.85 | 3.43$^{bc}$ | 50.96 | 18.37 | 27.51 | 0.23 | 42.72 | 68.06 | 27.58 | 0.86 |
| 49 | 30.12 | 3.28$^{cbd}$ | 50.90 | 17.92 | 30.11 | 0.44 | 41.61 | 63.66 | 27.06 | 0.85 |
| 56 | 26.00 | 2.89$^{d}$ | 50.38 | 18.70 | 26.96 | 0.43 | 42.70 | 68.45 | 28.68 | 0.84 |
| 63 | 26.97 | 3.09$^{cd}$ | 51.36 | 18.11 | 29.27 | 0.05 | 42.88 | 67.82 | 26.99 | 0.86 |
| 70 | 26.97 | 2.86$^{d}$ | 49.21 | 18.64 | 29.62 | 0.11 | 42.11 | 66.11 | 28.60 | 0.83 |
| SEM[4] | 1.70 | 0.18 | 0.9 | 0.99 | 2.48 | 0.58 | 1.84 | 1.88 | 1.09 | 0.02 |
| *P*- value | 0.58 | <0.01 | 0.26 | 0.4 | 0.78 | 0.50 | 0.51 | 0.42 | 0.58 | 0.60 |

$^{abc}$Means within the same section of the same column lacking a common superscript differ ($P < 0.05$).

[1]L*: 0 = black, 100 = white.

[2]a*: -60 = green, 60 = red.

[3]b*: -60 = blue, 60 = yellow.

[4]Standard error of the mean (largest) of the least square means.

# The Effects of Aging Period and Freezing Sequence on Consumer Palatability Ratings, Tenderness, and Color Stability of *Longissimus Dorsi, Semitendinosus,* and *Biceps Femoris* Steaks

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## Abstract

The objective of this study was to examine the effect that freezing and aging sequence has on palatability, overall tenderness, and color readings of three different beef muscles and two aging periods. The *longissimus dorsi* (LD), *semitendinosus* (ST), and *biceps femoris* (BF) were fabricated, sliced into 1-in steaks and assigned to one of the following treatment combinations: age (21 days) then freeze, freeze then age (21 days), age (28 days) then freeze, or freeze then age (28 days). For all assays, samples were cooked to a peak internal temperature of 160˚F. The consumers (n = 192) evaluated samples for flavor, juiciness, tenderness, and overall liking, as well as acceptability for each sensory trait. The next day, steaks were cooked for Warner-Bratzler shear force and color evaluation. Before steaks were cooked, each sample was allowed 20 minutes to bloom for raw color evaluation. Cooked and raw color readings were taken using a spectrophotometer. The freezing treatment did not affect ($P > 0.05$) consumer sensory rating of tenderness, flavor, or overall liking. There was a three-way interaction in juiciness between muscle, age, and freezing treatment ($P < 0.05$). As expected, the LD resulted in the highest ($P < 0.05$) tenderness rating for the consumer. The LD resulted in the lowest ($P < 0.05$) shear force values, indicating it was the most tender. There was a two-way interaction between aging period and muscle ($P < 0.05$). For raw and cooked color, the $L^*$ (lightness) values differed ($P < 0.05$) among all main effects including freezing treatments (Age Freeze > Freeze Age), aging periods (21 days > 28 days), and muscle (ST > LD > BF). These results showed that freezing and then aging or aging and then freezing does not impact palatability or shear force values. This indicates that reversing the freezing order is not an effective way to improve tenderness of historically tough muscles.

## Introduction

In 2022, the United States produced 28.2 billion lb of beef. To maintain quality and extend shelf life, beef is often frozen across the meat industry (Kim et al., 2015). Post-mortem aging of beef enhances proteolytic systems, which improves its palatability. Numerous studies have explored how post-mortem freezing affects consumer perceptions of various beef cuts. Most of the beef industry ages meat after harvest and before freezing, but this process can lead to ice crystal formation which is linked to increased purge loss (Beyer et al., 2024, Setyabrata et al., 2019). Research has shown that the freezing process influences the shape and distribution of ice crystals within the muscle, resulting in variations in the gaps between muscle fibers and increased extracellular drip channels leading to increased tenderness (Setyabrata et al., 2019). In previous studies,

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it has been shown that calcium-dependent protease inhibitors lose their activity rapidly through the freezing process, thus increasing the tenderness of post-mortem muscles (Koohmaraie 1990). However, there has been little research done since to determine if the freezing sequence affects consumer ratings, instrumental tenderness, or objective color readings of muscles. This study aimed to assess how freezing and aging sequences influence consumer perception, tenderness, and objective color readings of three different beef muscles.

## Experimental Procedures

Beef carcasses (n = 12) were selected from a midwestern beef plant and graded U.S. Department of Agriculture Choice and A maturity. The trimmed strip loins (Institutional Meat Purchase Specifications [IMPS] #180) and goosenecks (IMPS #170) were collected from the right side of the carcasses (NAMI, 2014). The strip loins and goosenecks were transported to North Dakota State University (NDSU) and were fabricated the day after the collection. The *semitendinosus* (ST) and *biceps femoris* (BF) were separated from the rest of the gooseneck. The strip loins (LD), ST, and BF were denuded and sliced into 1-in steaks. Each steak was randomly assigned a 4-digit code with a tag and assigned to either age and then freeze (AF) for 21 or 28 days or freeze and then age (FA) for 21 or 28 days. Each steak was assigned to one of the following assays: consumer sensory panels, shear force, or lab assays. All steaks were aged at 34-40°F in the absence of light. After treatment, steaks were blast frozen and held at -4°F for 91 days before being placed in a refrigerator to thaw for 24 hours before the time of use (if applicable).

Consumers (n = 96 per aging period, n = 192 total) were fed all treatment combinations within a single aging period. Samples were presented to consumers for tasting one aging period at a time due to the freezing logistics and consumer panel capability. Samples were cooked to a peak temperature of 160°F as outlined by the American Meat Science Association sensory guidelines (AMSA 2015) on a Cuisinart Clamshell griddle and monitored using a Thermapen temperature probe. The consumers evaluated each sample for flavor, juiciness, tenderness, and overall liking. Each trait was ranked on a line scale of 0 to 100, with anchors set at 0, 50, and 100 with 0 being undesirable and 100 being the most desirable.

Consumers also rated each sample as acceptable or unacceptable for each sensory trait. The consumer panel data were collected on electronic tablets using Qualtrics software. The day after the samples from specific aging periods were evaluated by the consumer panels, one steak from each muscle and treatment combination was evaluated for Warner-Bratzler shear force. Before the steaks were cooked, each sample was allowed 20 minutes to bloom, and raw $L^*$ (lightness), $a^*$ (redness), and $b^*$ (yellowness) color readings were taken using a HunterLab Miniscan spectrophotometer (Illuminant A/10, 1 in aperture). Steaks were cooked following the procedures described above. After the peak temperatures were recorded, each steak was sliced to expose a 1-in internal surface, and a cooked color reading was taken after a 3-minute bloom time. After 24 hours of chilling, six cores were taken parallel to the muscle fiber according to AMSA sensory guidelines (AMSA, 2015). The six cores were sheared perpendicular to the muscle fibers on the Warner-Bratzler shear force machine, and the six readings were recorded as average lb.

## Results and Discussion

Overall, the freezing treatment and aging period did not affect the consumer's juiciness, tenderness, flavor, or overall liking scores. The consumers rated the LD as the juiciest ($P < 0.05$) compared to the ST and BF. As expected, the tenderness scores were significant for muscle as the LD was rated as the most tender ($P < 0.05$) followed by the ST and BF. Within flavor, the consumers rated the LD as the most flavorful ($P < 0.05$) followed by the ST, and then the BF. Supporting the consumer data, the shear force analysis found the LD to have the lowest shear force ($P < 0.05$) value compared to BF (Table 1).

The raw color readings (Table 1) indicated that all three main effects were influenced ($P < 0.05$) for $L^*$ values including the freezing treatment (AF > FA), aging period (21 days > 28 days), and muscle (ST > BF > LD). There was also a two-way interaction in $a^*$ between the freezing treatment and the different muscles ($P < 0.05$), with the frozen then aged ST having the highest $a^*$ value, resulting in being the brightest, most cherry red in appearance. For cooked color, all three main effects impacted ($P < 0.05$) $L^*$ values including among the freezing treatments (AF > FA), aging periods (21 days > 28 days), and muscles (ST > LD > BF). There were no differences in $a^*$ values ($P > 0.05$) for cooked color. Finally, only the aging period was significant ($P < 0.05$) for $b^*$ values as the 21-day aged steaks had higher ($P < 0.05$) $b^*$ values.

## Implications

The results indicate reversing the typical age and freezing order does not improve tenderness and therefore is not a valid way to improve palatability of historically tough muscles.

## Acknowledgments

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## References

AMSA. 2015. Research guidelines for cookery, sensory evaluation, and instrumental tenderness measurements of meat. 2 ed. American Meat Science Association, Champaign, IL.

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. doi: https://doi.org/10.22175/mmb.16903

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

Kim, Y.H., D. Ma, D. Setyabrata, M.M. Farouk, S.M. Lonergan, E. Huff-Lonergan, and M.C. Hunt. 2018. Understanding postmortem biochemical processes and post-harvest aging factors to develop novel Smart-Aging Strategies. Meat Science 144:74–90. https://doi.org/10.1016/j.meatsci.2018.04.031

Kim, H.W., J.H. Kim, J.K. Seo, D. Setyabrata, and Y.H.B. Kim. 2018. Effects of aging/freezing sequence and freezing rate on meat quality and oxidative stability of pork loins. Meat Science 139:162-170.

Koohmaraie, M. 1990. Quantification of Ca2+-dependent protease activities by hydrophobic and ion-exchange chromatography. Journal of Animal Science 68:659-665.

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

Setyabrata, D., and Y.H. 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

USDA ERS. n.d. Statistics & Information. https://www.ers.usda.gov/topics/animal-products/cattle-beef/statistics-information/

**Table 1. Warner-Bratzler shear force (WBSF) and objective raw color readings of two freezing treatments, two aging periods and three muscles**

| Parameter | WBSF[1], lb | *L**[2] | *a**[3] | *b**[4] |
|---|---|---|---|---|
| Freezing treatment | | | | |
| Age then freeze | 8.33 | 45.79[a] | 19.82 | 16.66 |
| Freeze then age | 9.11 | 44.59[b] | 19.95 | 16.63 |
| SEM[5] | 0.35 | 0.37 | 0.34 | 0.18 |
| *P*-value | 0.48 | 0.02 | 0.79 | 0.92 |
| Aging period | | | | |
| 21 Days | 8.25 | 45.79[a] | 19.58 | 16.46 |
| 28 Days | 9.19 | 44.59[b] | 20.20 | 16.84 |
| SEM[5] | 0.35 | 0.37 | 0.34 | 0.18 |
| *P*-value | 0.37 | 0.02 | 0.79 | 0.92 |
| Muscle[6] | | | | |
| LD[6] | 6.31[b] | 43.62[c] | 19.28[b] | 15.86[b] |
| ST[6] | 8.69[ab] | 46.23[a] | 21.88[a] | 18.02[a] |
| BF[6] | 11.16[a] | 45.31[b] | 18.51[b] | 16.05[b] |
| SEM[5] | 0.42 | 0.45 | 0.42 | 0.22 |
| *P*-value | 0.0016 | <0.0001 | <0.0001 | <0.001 |

[abc] Means within the same column without a common superscript differ ($P < 0.05$).
[1]Warner-Bratzler shear force; lb.
[2]$L^*$ (lightness): 0 = black, 100 = white.
[3]$a^*$ (redness): -60 = green, 60 = red.
[4]$b^*$ (yellowness): -60 = blue, 60 = yellow.
[5]Standard error of the mean (largest) of the least squares means.
[6]LD: *longissimus dorsi, ST: semitendinosus,* BF: *biceps femoris*.

**Table 2. Objective cooked color readings of two freezing treatments, two aging periods and three muscles**

| Parameter | *L**[1] | *a**[2] | *b**[3] |
|---|---|---|---|
| Freezing Treatment | | | |
| Age then freeze | 56.32[a] | 19.69 | 19.01 |
| Freeze then age | 55.48[b] | 19.43 | 18.80 |
| SEM[4] | 0.29 | 0.39 | 0.19 |
| *P*-value | 0.04 | 0.65 | 0.44 |
| Aging Period | | | |
| 21 Days | 56.25 | 19.63 | 19.17 |
| 28 Days | 55.55 | 19.49 | 18.64 |
| SEM[4] | 0.29 | 0.39 | 0.19 |
| *P*-value | 0.09 | 0.79 | 0.05 |
| Muscle[5] | | | |
| LD[5] | 55.97[b] | 19.91 | 19.16 |
| ST[5] | 58.05[a] | 18.98 | 18.82 |
| BF[5] | 53.69[c] | 189.79 | 18.74 |
| SEM[4] | 0.35 | 0.47 | 0.33 |
| *P*-value | <0.0001 | 0.33 | 0.24 |

[abc] Means within the same column without a common superscript differ ($P < 0.05$).
[1]*L**: 0 = black, 100 = white.
[2]*a**: -60 = green, 60 = red.
[3]*b**: -60 = blue, 60 = yellow.
[4]SE (largest) of the least squares means.
[5]LD: *longissimus dorsi, ST: semitendinosus,* BF: *biceps femoris*.

**Table 3. Consumer rankings of two freezing treatments, two aging periods and three muscles**

| Parameter | Juiciness | Tenderness | Flavor | Overall Liking |
|---|---|---|---|---|
| Freezing Treatment | | | | |
| Age then Freeze | 62.33 | 58.30 | 64.22 | 62.62 |
| Freeze then Age | 61.98 | 61.01 | 65.21 | 64.62 |
| SEM[4] | 1.12 | 1.50 | 0.85 | 1.01 |
| *P*-value | 0.82 | 0.11 | 0.37 | 0.23 |
| Aging Period | | | | |
| 21 Days | 61.22 | 59.27 | 63.60 | 63.31 |
| 28 Days | 63.08 | 60.03 | 65.60 | 63.74 |
| SEM[4] | 1.12 | 1.22 | 0.78 | 1.08 |
| *P*-value | 0.24 | 0.66 | 0.11 | 0.77 |
| Muscle[5] | | | | |
| LD[5] | 70.16[a] | 76.39[a] | 73.39[a] | 75.26[a] |
| ST[5] | 60.01[b] | 57.66[b] | 61.53[b] | 61.69[b] |
| BF[5] | 56.29[b] | 44.91[c] | 59.23[c] | 53.62[c] |
| SEM[4] | 1.37 | 1.49 | 0.96 | 1.32 |
| *P*-value | <0.0001 | <0.0001 | <0.001 | <0.001 |

[abc] Means within the same column without a common superscript differ ($P < 0.05$).
[4]SE (largest) of the least squares means.
[5]LD: *longissimus dorsi, ST: semitendinosus,* BF: *biceps femoris.*

# Determination of Consumer Purchase Thresholds for Discoloration of Beef Strip Steaks in Retail Display

*S.L. Witberler, L.M. Frink, M.J. Prester, C.A. Effling, M.D. Chao, M.D. Zumbaugh, J.L. Vipham, E.S. Beyer, and T.G. O'Quinn*

## Abstract

The objectives of this study were to determine the consumer purchase threshold for discoloration of beef steaks in simulated retail display and to determine the best objective measurement to predict consumer purchase intent. Beef strip steaks were evaluated by trained sensory panelists and consumer panelists, and objective color data were collected. Trained panelists determined percent discoloration, redness score, and fat color score, while consumer sensory panelists were asked to rate the sample appearance, and then asked if they would purchase the sample, with a follow-up question of if they would purchase the sample at a discounted rate, or if they said they would not purchase at full price. Objective $L^*$ (lightness), $a^*$ (redness), and $b^*$ (yellowness), and spectral data were collected using a HunterLab MiniScan Spectrophotometer (Illuminant A, 10° observer, 1-in aperture). Objective color data were then used to calculate hue angle, chroma, and percent deoxymyoglobin, metmyoglobin, and oxymyoglobin according to the Guidelines for Meat Color Measurement. The $a^*$ values were a good objective predictor of purchase intent ($R^2 = 0.64$ full-priced and $R^2 = 0.56$ for discounted; $P < 0.05$). Trained sensory panel percent discoloration scores were also a good predictor of consumer purchase intent ($R^2 = 0.61$ full-priced and $R^2 = 0.47$ discounted; $P < 0.05$).

## Introduction

Meat color is one of the most important purchasing motivators for beef consumers (Olson et al., 2019; Farmer et al., 2022; Harr et al., 2022). Annually, 2.2 billion pounds of beef are discarded due to discoloration at retail (Ramanathan, 2022). Discoloration alone accounts for about a $3.73 billion economic loss yearly in addition to other wasted resources such as water and energy. Previous studies have been conducted to try to establish a consumer purchase threshold for discoloration of steaks. However, previous work has been conducted with an online survey, which does not ensure uniform evaluation by consumers (Holman et al., 2016; Holman et al., 2017). Other work had been completed over 50 years ago and did not account for the full range of discoloration (Hood and Riordan, 1973).

A study conducted at Kansas State University worked to determine consumer purchase thresholds for discoloration of ground beef in retail display and established highly predictive models. (Lybarger et al., 2023). While Lybarger's study followed a very similar design to the current study, it has been established that steaks discolor differently than ground beef. Ground beef discolors in an "all at once" manner (Lybarger et al., 2023), whereas steaks develop brown spots that expand. While Lybarger's models were very predictive for ground beef, consumer purchase thresholds for discoloration of steaks have not been explored widely in this manner.

## Experimental Procedures

Samples were acquired from Cargill Meat Solutions (Wichita, KS) and transported to Kansas State University under refrigeration conditions (36-40°F). Samples were delivered in mother bags of six packages. Mother bags were kept in the absence of light under refrigeration until the designated display day. Five of the six packages per mother bag were allocated randomly to one of five retail case sections. One steak per package was covered with a piece of black tape so only one steak was visible. If one of the steaks had the *gluteus medius* present, that steak was covered, otherwise the steak for display was randomly selected. The last package in the mother bag was allocated to pH and proximate analysis. Three mother bags were opened every other day to allow for variation in sample discoloration. Packages were placed in their respective case sections on the morning of their designated display day. Samples were placed in three coffin style cases (model DMF8; Tyler Refrigeration, Niles, MI) at 36°F to 40°F under continuous fluorescent lighting (32 W Del-Warm White 3,000 K; Philips Lighting Company, Somerset, NJ).

Trained panelists (n= 12-20) were required to attend at least three training sessions to become familiar with the scales being used. Trained panelists evaluated all samples daily on 100-point line scales for percent discoloration (0% - 100%), redness score with 0 being extremely dark red and 100 being bright cherry-red, and fat color score with 0 being brownish-white and 100 being bright white. Objective $L^*$ (lightness), $a^*$ (redness), and $b^*$ (yellowness), and spectral data were collected using a HunterLab MiniScan Spectrophotometer (Illuminant A, 10° observer, 1-in aperture). Three readings were collected, averaged, and used to calculate chroma, hue angle, and percent metmyoglobin, deoxymyoglobin, and oxymyoglobin according to the Guidelines for Meat Color Measurement (King et al., 2023). Consumer panelists (n = 200) evaluated 24 samples varying from 0% to 100% discoloration. Consumers were asked to designate an overall appearance score on a 100-point continuous line scale with 0 being extremely undesirable and 100 being extremely desirable. They also were asked if they would purchase the sample at retail. If they selected yes, they would move on to the next sample; however, if they selected no, they would be shown an additional question asking if they would purchase the sample if it was discounted.

## Results and Discussion

Logistic regression equations calculated for the prediction of purchase intent by the consumer sensory panel of beef strip steaks are presented in Table 1. All models were predictive of consumer purchase intent ($P < 0.05$). Using the logistic regression models, thresholds (50%, 75%, 90%, and 95%) for consumer purchase intent were identified for full-price and at discount. The $a^*$ values were a good objective predictor of purchase intent ($R^2 = 0.64$ full-priced and $R^2 = 0.56$ for discounted; $P < 0.05$). At full price, $a^*$ values of 25.3, 29.9, 34.4, and 37.6 corresponded to a 50%, 75%, 90%, and 95% likelihood for consumers to purchase the sample (Figure 1); whereas if the product was discounted, $a^*$ values of 20.3, 25.8, 31.3, and 35.0 corresponded to those same thresholds. Trained sensory panel percent discoloration scores were also a good predictor of consumer purchase intent ($R^2 = 0.61$ full-priced and $R^2 = 0.47$ discounted; $P < 0.05$). At full price, trained discoloration scores of 12% corresponded to a 50% likelihood of consumers purchasing the samples (Figure 2); whereas, if the product was discounted, trained discoloration scores of 35.8% and 8.3% corresponded to 50% and 75% thresholds.

## Implications

The *a** value and trained panel redness score are good indicators of consumer purchase intent showing that consumers highly value redness when choosing steaks.

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## References

Farmer, K.J., E.S. Beyer, S.G. Davis, K.M. Harr, K.R. Lybarger, L.A. Egger, M.D. Chao, J.L. Vipham, M.D. Zumbaugh, and T.G. O'Quinn. 2022. Evaluation of the impact of bone-in versus boneless cuts on beef palatability. Meat and Muscle Biology 6:1-13. doi:10.22175/mmb.15488

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. doi:10.22175/mmb.15482

Holman, B.W.B., Y. Mao, C.E.O. Coombs, R.J. van de Ven, and D.L. Hopkins. 2016. Relationship between colorimetric (instrumental) evaluation and consumer-defined beef colour acceptability. Meat Science 121:104-106. doi:10.1016/j.meatsci.2016.05.002

Holman, B.W.B., R.J. van de Ven, Y. Mao, C.E.O. Coombs, and D.L. Hopkins. 2017. Using instrumental (CIE and reflectance) measures to predict consumers' acceptance of beef colour. Meat Science 127:57-62. doi:10.1016/j.meatsci.2017.01.005

Hood, D.E., and E.B. Riordan. 1973. Discolouration in pre-packaged beef: measurement by reflectance spectrophotometry and shopper discrimination. International Journal of Food Science & Technology 8:333-343. doi:10.1111/j.1365-2621.1973.tb01721.x

King, D.A., M.C. Hunt, S. Barbut, J.R. Claus, D.P. Cornforth, P. Joseph, Y.H.B. 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. doi: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. doi:10.22175/mmb.16757

Olson, B.A., E.A. Rice, L.L. Prill, L.N. Drey, J.M. Gonzalez, J.L. Vipham, M.D. Chao, and T.G. O'Quinn. 2019. Evaluation of beef top sirloin steaks of four quality grades cooked to three degrees of doneness. Meat and Muscle Biology 3:399-410. doi:10.22175/mmb2019.07.0022

Ramanathan, R., L.H. Lambert, N.N. Mahesh, B. Morgan, R. Feuz, G. Mafi, and M. Pfeiffer. 2022. Economic Loss, amount of beef discarded, natural resources wastage, and environmental impact due to beef discoloration. Meat and Muscle Biology 6. doi:10.22175/mmb.13218

**Table 1. Logistic regression equations for predicting consumer sensory panel purchase intent of beef strip steaks**

| Measurement | Intercept | Slope | Adjusted $R^2$ | $P$ – value | $C$ – statistic[1] | % Correct[2] |
|---|---|---|---|---|---|---|
| Product sold at full price | | | | | | |
| $L^*$ | -12.97 | 0.29 | 0.30 | < 0.01 | 0.75 | 73.2 |
| $a^*$ | -6.07 | 0.24 | 0.64 | < 0.01 | 0.87 | 83.5 |
| $b^*$ | -8.69 | 0.41 | 0.60 | < 0.01 | 0.85 | 82.6 |
| Metmyoglobin[3] | 3.70 | -0.13 | 0.51 | < 0.01 | 0.85 | 79.4 |
| Oxymyoglobin[3] | -5.63 | 0.09 | 0.56 | < 0.01 | 0.86 | 81.9 |
| Chroma[3] | -7.11 | 0.21 | 0.64 | < 0.01 | 0.87 | 83.6 |
| Hue angle[3] | 8.27 | -0.22 | 0.33 | < 0.01 | 0.79 | 75.1 |
| Trained sensory panel redness score[4] | -4.08 | 0.06 | 0.64 | < 0.01 | 0.88 | 82.9 |
| Trained sensory panel discoloration score[5] | 0.84 | -0.07 | 0.56 | < 0.01 | 0.88 | 82.3 |
| Trained sensory fat score[6] | -4.10 | 0.06 | 0.61 | <0.01 | 0.86 | 82.4 |
| Consumer appearance score[7] | -4.62 | 0.08 | 0.78 | < 0.01 | 0.91 | 86.2 |
| | | | | | | |
| Product sold at discounted price | | | | | | |
| $L^*$ | -10.49 | 0.25 | 0.27 | < 0.01 | 0.72 | 66.4 |
| $a^*$ | -4.06 | 0.20 | 0.56 | < 0.01 | 0.82 | 75.0 |
| $b^*$ | -6.60 | 0.36 | 0.53 | < 0.01 | 0.81 | 74.8 |
| Metmyoglobin[3] | 3.36 | -0.09 | 0.41 | < 0.01 | 0.80 | 70.8 |
| Oxymyoglobin[3] | -3.45 | 0.07 | 0.49 | < 0.01 | 0.81 | 74.6 |
| Chroma[3] | -5.27 | 0.19 | 0.58 | < 0.01 | 0.82 | 76.0 |
| Hue angle[3] | 6.39 | -0.15 | 0.27 | < 0.01 | 0.74 | 69.7 |
| Trained sensory panel redness score[4] | -2.34 | 0.05 | 0.59 | < 0.01 | 0.84 | 76.2 |
| Trained sensory panel discoloration score[5] | 1.43 | -0.04 | 0.47 | < 0.01 | 0.83 | 73.0 |
| Trained sensory fat score[6] | -2.15 | 0.05 | 0.48 | <0.01 | 0.80 | 72.1 |
| Consumer appearance score[7] | -3.03 | 0.08 | 0.72 | < 0.01 | 0.87 | 78.4 |

[1]Measure of goodness of fit for binary outcomes in a logistic regression model, ranging from 0 – 1.
[2]Percentage of correctly classified events and nonevents by the model.
[3]Calculated utilizing the equations presented in the American Meat Science Association Guidelines for Meat Color Measurement (King et al., 2023).
[4]Sensory scores: 0 = extremely dark red, 100 = bright cherry red.
[5]Sensory scores: 0 = no visible discoloration, 100 = complete discoloration.
[6]Sensory scores: 0 = brownish-white, 100 = bright white.
[7]Sensory scores: 0 = extremely undesirable, 100 = extremely desirable.

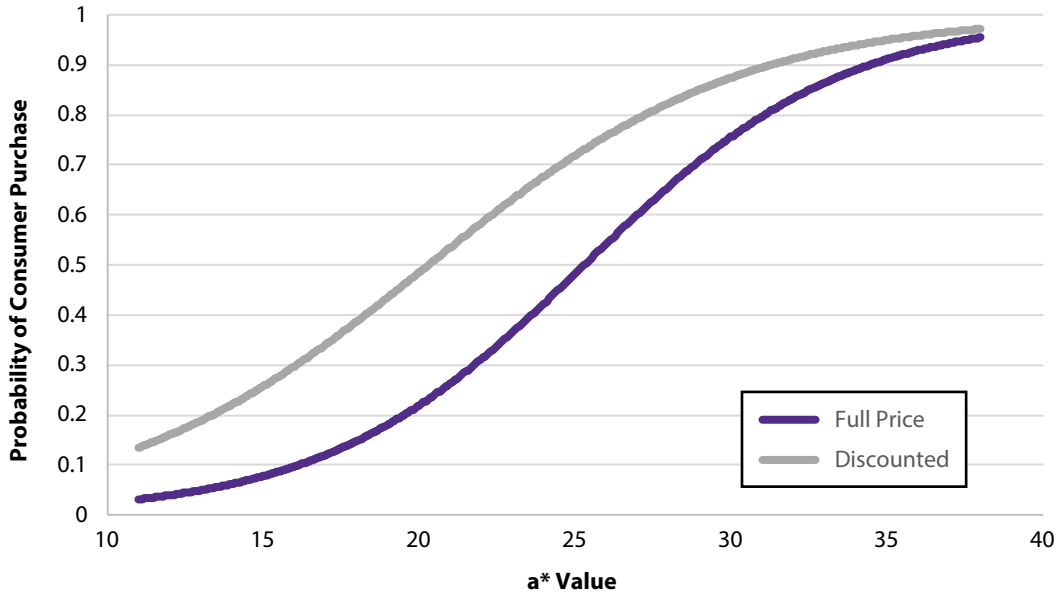


**Figure 1. Probability of a consumer purchasing a steak based on a* value**

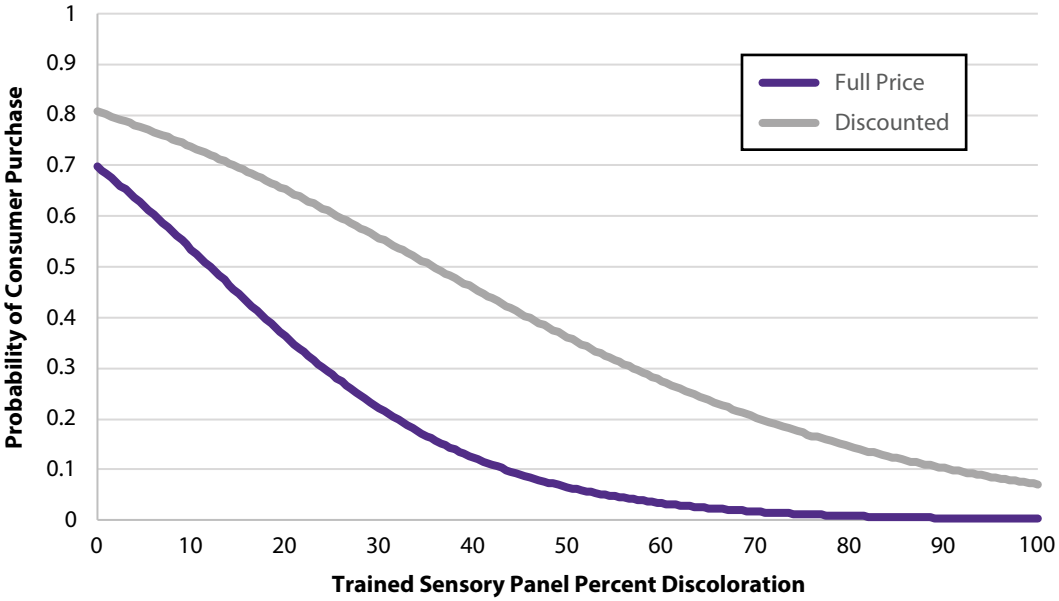


**Figure 2. Probability of a consumer purchasing a steak based on trained sensory panel discoloration score and pricing: sensory discoloration scores: 0 = 0% discoloration, 100 = 100% discoloration.**

# The Impact of Degree of Doneness, Muscle Source, and Bloom Time on Cooked Color and Cooked Color Stability

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## Abstract

This study examined differences in color stability between three muscles with varying raw color stability cooked to three degrees of doneness (DOD). Steaks from the *longissimus lumborum* (LL), *psoas major* (PM), and *semitendinosus* (ST) were assigned to medium rare (MR), medium (MED), and well-done (WD) DOD. They were aged for 28 days in the absence of light at 34-38°F, then frozen at -4°F until evaluated. Steaks were thawed for 24 hours and then cooked to their designated DOD monitored with a Thermapen. The steaks were sliced to take objective $L^*$ (lightness), $a^*$ (redness), and $b^*$ (yellowness) color readings measured at 0, 3, 6, and 9 minutes to observe how color stability changed. Spectral data were recorded and used to determine the percent oxymyoglobin (OMb) remaining in the muscle. There was an interaction ($P < 0.05$) between DOD and muscle for $L^*$ and $a^*$ readings. The ST had the highest $L^*$ reading within the MR and MED DOD followed by the LL; however, there were no differences between muscles ($P > 0.05$) within the WD DOD. Within the MED DOD, the ST had the highest ($P < 0.05$) $a^*$ reading followed by the LL while the LL had the highest ($P < 0.05$) $a^*$ reading within the MR and WD DOD. There was an interaction ($P < 0.05$) between DOD and muscle and DOD and time for percent OMb. Within the MR samples, the LL and ST muscles resulted in similar ($P > 0.05$) percent OMb. The MR DOD had the highest ($P < 0.05$) percent OMb for 3, 6, and 9 minutes while the 0-minute readings for MR and MED were similar ($P > 0.05$) and higher ($P < 0.05$) than all time points for the WD DOD. These results indicate muscle, bloom time, and DOD impact the final internal pigment.

## Introduction

Meat color is one of the most important attributes for consumers from purchase to consumption (Beyer et al., 2024a, Prill et al., 2019a). While raw color has been heavily researched, cooked color of whole muscles has remained relatively unexplored. Cooked color is the visual internal and external appearance of a steak (Beyer et al., 2024a). Cooked color impacts the eating experience for the consumer as it gives the consumer an expectation of quality (Prill et al., 2019b). However, the initial internal color is not nearly as important as the final pigment before consumption (Garber et al., 2000). Cooked color stability is how well meat maintains its color after being sliced. Cooked color plays a pivotal role in the eating experience and the consumer's perception of the quality of the product, therefore warranting further research.

Cooked color represents a spectrum of varying degrees of doneness (DOD), each with its own set of expectations from a consumer (Prill et al., 2019b). DOD were created to establish consistency when a consumer is ordering or cooking a steak (Prill et al., 2019a). DOD are the range of internal peak temperatures from rare to well-done that

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typically correlate to expected internal colors (Prill et al., 2019a). These are important to cater to personal preferences of flavor, texture, juiciness, and color.

Since cooked color of whole muscles is a relatively under-researched topic, the factors that impact it are also unknown. Salim et al. (2020) found myoglobin undergoes a series of post-translational changes during the cooking process that impact thermal stability and could impact cooked color stability. Based on research done by Beyer et al. (2024b), muscles could impact the final cooked color. Biochemical properties of muscles vary within the same carcass. Muscles have different fiber types and metabolic mechanisms, which can affect color, color stability, and potentially cooked color (Ramanathan et al., 2020). Understanding how these variables interact is essential for optimizing cooking processes and ensuring that the resulting color aligns with consumer expectations and standards. Therefore, the objective was to explore and analyze differences in cooked color and cooked color stability among three different muscles when cooked to three different degrees of doneness.

## Experimental Procedures

Beef strip loins (n = 6; Institutional Meat Purchase Specification [IMPS] #180), tenderloins (n = 6; IMPS #189), and eye of rounds (n = 6; IMPS #171C) were selected based on varying raw color stability (USDA-AMS, 2020; North American Meat Institute, 2014). All carcasses were selected in a commercial Midwest beef processing plant (USDA Choice, A Maturity). The primals were collected and then brought back to North Dakota State University for further processing. The strip loins, tenderloins, and the eye of rounds were denuded into the *longissimus lumborum* (LL), *psoas major* (PM), and *semitendinosus* (ST). These subprimals were sliced into 1-in steaks and were randomly assigned a four-digit code and tag indicating their treatment designation including: raw, medium rare (MR), medium (MED), or well-done (WD). The steaks were vacuum sealed and then aged 28 d in the absence of light at 38-40°F before being frozen at -4°F until the time of use. Steaks were then thawed for 24 hours before being cooked to their designated degree of doneness (DOD). The samples were cooked on a Cuisinart Gridler Deluxe clamshell grill set to 350°F. Steaks were cooked to an internal peak temperature of 145°F (MR), 160°F (MED), or 170°F (WD), monitored with a Thermapen probe that was inserted in the geometric center of each steak. Immediately after peak temperatures were recorded, the steaks were sliced using a slice shear box to expose a 1-in internal surface used to determine color readings. Using the exposed internal surface, $L^*$, $a^*$, and $b^*$ readings were taken using a HunterLab Miniscan Spectrophotometer (Illuminant A/10, aperture 1-in) after blooming for 0, 3, 6, and 9 minutes measured with a timer. The change between time points in the objective color readings was used to determine cooked color stability. Spectral data were recorded and used to determine the percent oxymyoglobin (OMb) remaining in the cooked steak, using the American Meat Science Association Color Guidelines (King et al., 2024). The data were analyzed as a split split plot design using SAS PROC GLIMMIX with an alpha set at 0.05.

## Results and Discussion

There was an interaction ($P < 0.05$) between the degree of doneness (DOD) and muscle for lightness ($L^*$ readings; Table 1). Specifically, within the MED and MR DOD, the ST muscle had the highest ($P < 0.05$) $L^*$ reading, followed by the LL. However, there were no significant differences ($P > 0.05$) in $L^*$ readings between muscles at the well-done (WD) level. This means there was a different relationship between different

muscles and degrees of doneness that influenced lightness. Beyer et al. (2024) found a similar relationship between the *biceps femoris,* LL, and *gluteus medias* and $L^*$ values. The 0-, 3-, and 6-minute readings were all similar ($P > 0.05$) for $L^*$ readings but the 9-minute reading resulted in the lightest ($P < 0.05$) $L^*$ value. This indicates the final lightness was not developed until 9 minutes after slicing.

Like the $L^*$ readings, there was an interaction ($P < 0.05$) between DOD and muscle for redness ($a^*$ readings; Table 1). The $a^*$ values are considered to be the most important factor when evaluating meat color (King et al., 2024). Within the MED doneness level, the ST muscle had the highest $a^*$ reading, followed by the LL. However, within the MR and WD doneness levels, the LL had the highest $a^*$ reading. This indicates that the LL keeps its redness throughout the cooking process better than the ST. These results support that muscle does impact the final color, consistent with findings from Beyer et al. (2024a). Therefore, other muscles should be evaluated in the future to fully understand the impact.

The OMb percentage was used as another measure to indicate color stability. There was an interaction ($P < 0.05$) between DOD and muscle and DOD and time for the OMb percentage (Figure 1). Within the MR samples, the LL and ST muscles resulted in higher OMb percentage readings compared to the PM. The MR DOD had the highest OMb percentage at 3, 6, and 9 minutes. The 0-minute readings for MR and MED were similar ($P > 0.05$) and higher when compared to all time points for WD DOD.

The color measurements were influenced by muscle, DOD, and time. This indicated that meat's final cooked color depends on multiple factors. Investigating these factors could help explain how raw color stability correlates to cooked color stability. The increase in OMb percentage after 0 minutes suggests that the remaining active myoglobin can retain its color stability over time. These results indicate that cooked color is complex and should be investigated further to understand if muscle should be included in cooking instructions or educational materials to consumers. Factors such as additional muscles and cooking methods should be investigated to evaluate their impact on cooked color.

## Implications

Muscle influences cooked color and its stability, so if there are significant differences among muscles, it might be necessary to provide consumers with specific cooking instructions for each muscle.

## 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. 2024a. Change in myoglobin denaturation and physiochemical properties among three degrees of doneness and three beef whole muscles. Meat and Muscle Biology 8(1):1-12. doi : *https://doi.org/10.22175/mmb.16919*

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. 2024b. Evaluation of fresh and frozen beef strip loins of equal aging periods for palatability traits. Meat and Muscle Biology 8(1):1-13. doi: *https://doi.org/10.22175/mmb.16903*

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

King, D. A., M. C. Hunt, S. Barbut, J. R. Claus, D. P. Cornforth, P. Joseph, Y. H. 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):1-81. doi: *https://doi.org/10.22175/mmb.12473*

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*

Ramanathan R**,** S.P., Suman, and C. Faustman. 2020. Biomolecular interactions governing fresh meat color in post-mortem skeletal muscle: A review. Journal of Agricultural and Food Chemistry 68(46). doi: *https://doi.org/10.1021/acs.jafc.9b08098*

Salim, A. A., Y. Wang, S. Li, C. A. Conte-Junior, J. Chen, H. Zhu, G. Rentfrow, and S. P. Suman. 2020. Sarcoplasmic proteome profile and internal color of beef longissimus lumborum steaks cooked to different endpoint temperatures. Meat and Muscle Biology 4(1). doi: *https://doi.org/10.22175/mmb.9470*

USDA-AMS. 2020. National daily boxed beef cutout and boxed beef cuts - negotiated sales - PM. *https://usda.library.cornell.edu/concern/publications/9880vq97f?locale=en*

**Table 1. Objective cooked color readings of three muscles within raw, medium rare, medium, and well-done degrees of doneness**

| Degree of doneness | Muscle[1] | *L**[2] | *a**[3] | *b**[4] | OMb[5] % |
|---|---|---|---|---|---|
| Medium rare | LL | 55.54$^{c}$ | 26.48$^{a}$ | 21.74$^{a}$ | 66.21$^{a}$ |
| | PM | 51.81$^{e}$ | 24.36$^{b}$ | 18.66$^{cd}$ | |
| | ST | 57.36$^{b}$ | 21.88$^{b}$ | 20.88$^{a}$ | 65.65$^{a}$ |
| Medium | LL | 55.84$^{c}$ | 20.50$^{c}$ | 19.66$^{bc}$ | 61.21$^{b}$ |
| | PM | 53.41$^{d}$ | 20.75$^{c}$ | 18.56$^{d}$ | 61.24$^{b}$ |
| | ST | 59.30$^{a}$ | 21.88$^{c}$ | 20.70$^{ab}$ | 64.22$^{ab}$ |
| Well-done | LL | 55.49$^{c}$ | 16.59$^{d}$ | 17.87$^{d}$ | 52.20$^{c}$ |
| | PM | 53.59$^{d}$ | 14.52$^{e}$ | 15.96$^{e}$ | 52.20$^{c}$ |
| | ST | 55.10$^{c}$ | 13.47$^{e}$ | 16.61$^{e}$ | 48.84$^{c}$ |
| SEM[6] | | 0.48 | 0.59 | 0.41 | 1.49 |
| *P* - value | | < 0.01 | < 0.01 | < 0.01 | < 0.01 |

$^{abcde}$ Means within the same column without a common superscript differ ($P < 0.05$).
[1]LL: *longissimus lumborum,* PM: *psoas major*, ST: *semitendinosus.*
[2]*L**: 0 = black, 100 = white.
[3]*a**: -60 = green, 60 = red.
[4]*b**: -60 = blue, 60 = yellow.
[5]Oxymyoglobin (OMb) calculated from the AMSA Color Guidelines.
[6]Standard error of the mean (largest) of the least squares means.

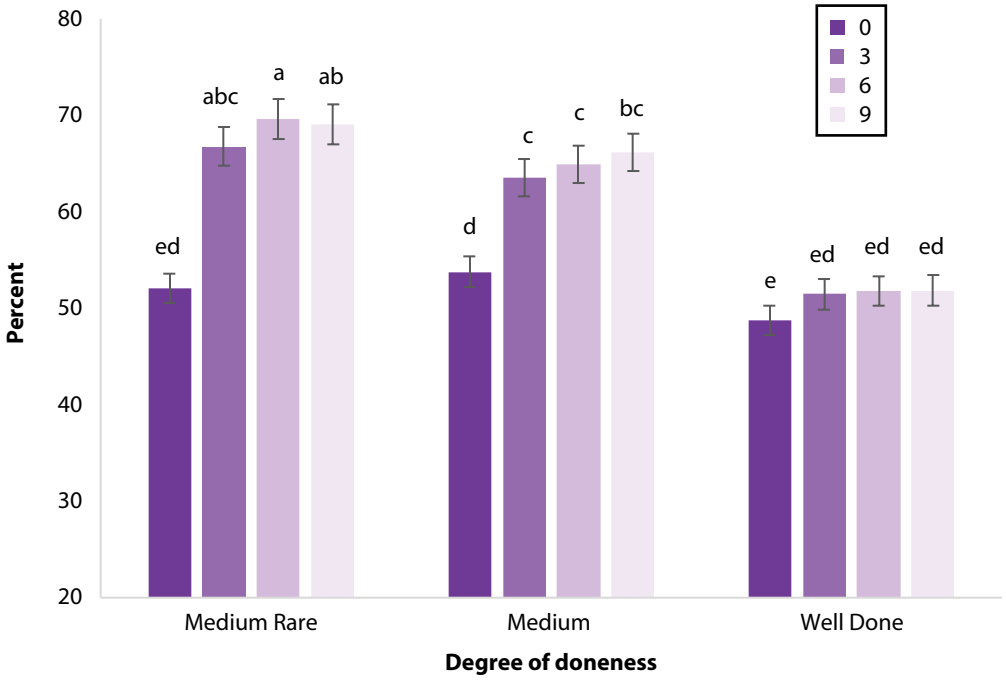


**Figure 1. Degree of doneness and time (minutes) interaction on oxymyoglobin percentage.**
$^{abcde}$ Means within the same column without a common superscript differ (P < 0.05).

# Influence of Degree of Doneness on the Alpha-Gal Content of Striploins and its Relationship with Red Meat Allergy

***S.R. Hene, J.R. Kress, J.T. Looper, E.S. Beyer, T.G. O'Quinn, and M.D. Chao***

## Abstract

Alpha-Gal Syndrome (AGS) is an acquired sensitivity to galactose-alpha-1, 3-galactose (α-Gal) after exposure to a bite from the Lone Star Tick (*Amblyomma americanum*). Affected individuals can experience a range of symptoms from mild itching to potentially fatal anaphylaxis after consuming products containing α-Gal from mammalian tissues. However, little research has been done to examine the α-Gal content of different products nor how it relates to the severity of a reaction. Thus, the objective of this study was to establish the α-Gal content of striploin steaks cooked to varying degrees of doneness to evaluate if heat treatment reduces the α-Gal content of red meat. Ten beef striploins were collected, cut into steaks, and cooked to either medium rare (MR; 130°F), medium (MED; 140°F), or well done (WD; 160°F). Whole muscle proteins from each sample were extracted and measured for α-Gal content. Notably, α-Gal content increased as the degree of doneness increased, with WD steaks having the highest concentration and raw steaks having the lowest α-Gal concentration ($P < 0.01$). The results of this study indicated that heating is not a viable method to decrease the α-Gal content of red meat products.

## Introduction

Alpha-Gal Syndrome (AGS), commonly known as red meat allergy or mammalian meat allergy, is an immunoglobulin mediated hypersensitivity to galactose-alpha-1, 3-galactose (α-Gal), an oligosaccharide found in all mammalian tissues except humans and Old World monkeys. Following a tick bite, the body produces a specific α-Gal IgE antibody and binds to the α-Gal epitope presented on glycoproteins and glycoproteins of the mammalian product, subsequently eliciting an allergic response. Patients that have been sensitized to α-Gal can experience a wide spectrum of responses from mild symptoms like itching and gastrointestinal discomfort to a severe and potentially fatal anaphylactic reaction. In many ways, AGS differs from typical food allergies in many ways, and as a result, the variation from patient to patient makes the diagnosis and management of AGS more difficult.

Despite the implication of red meat to AGS, there is no research that investigated quantifying the amount of α-Gal in different meat products and the impact of different processing methods on α-Gal content in these products. Knowing the baseline α-Gal content in various products is essential for proper diagnosis and the construction of appropriate management plans for patients. Thus, our objective was to determine the α-Gal content of striploin steaks cooked to varying degrees of doneness to understand the effect of heating as a potential intervention to reduce the α-Gal antigen in beef.

## Experimental Procedures

Ten beef striploins were collected from a Midwest beef processing plant and transported under refrigeration to the Kansas State University Meat Laboratory (n = 10). Striploins were cut into four steaks each and either left raw or cooked to medium rare (MR; 130°F), medium (MED; 140°F), or well done (WD; 160°F). Whole muscle proteins were extracted, and protein concentration was adjusted. Proteins were separated by gel electrophoresis, transferred to a polyvinylidene difluoride membrane, and tested by immunoblot against a primary anti-α-Gal antibody. Each gel contained a reference sample of α-Gal conjugated human serum albumin (HSA) with a known α-Gal content of 59.2 pmol. The concentration of α-Gal was determined as a ratio of the lane densities of the sample and the HSA reference multiplied by the known α-Gal content of the HSA reference. The α-Gal concentration is expressed as pmol/μg of protein of the striploin.

## Results and Discussion

A representative image of the western blot is depicted in Figure 1. Striploins that were cooked to WD had the greatest α-Gal concentration of 16.32 pmol/μg ($P < 0.01$; Figure 2). Steaks cooked to MR and MED did not differ from each other and had the second greatest α-Gal concentration of 13.86 pmol/μg and 13.57 pmol/μg, respectively ($P < 0.01$). Finally, steaks that were left raw had the lowest α-Gal concentration at 10.30 pmol/μg ($P < 0.01$).

Our results are consistent with previous research, which also found that cooking pork and beef meat extracts by roasting or boiling increased the binding of anti-α-Gal antibodies as compared to raw samples. During the cooking process, proteins undergo considerable modification that leads to tissue shrinkage and hardening. Muscle fiber shrinkage during cooking results in the loss of water and water-soluble proteins in the form of purge, further concentrating the α-Gal content in WD steaks on a per protein basis. Furthermore, the linearization of proteins during denaturation from heating may expose more α-Gal epitopes, allowing for more efficient binding of IgE antibody and may elicit a greater immune response.

## Implications

The increase in α-Gal concentration in beef after cooking suggested another unique characteristic of AGS as compared to other traditional food protein allergies—heat stability of the α-Gal epitope. While there are other potential methods of α-Gal epitope modifications that should be explored, cooking beef to a higher degree of doneness does not seem to be a viable solution to make meat consumption safe for AGS patients. Further research is needed to evaluate the efficacy of other interventions to improve the care and management of AGS patients.

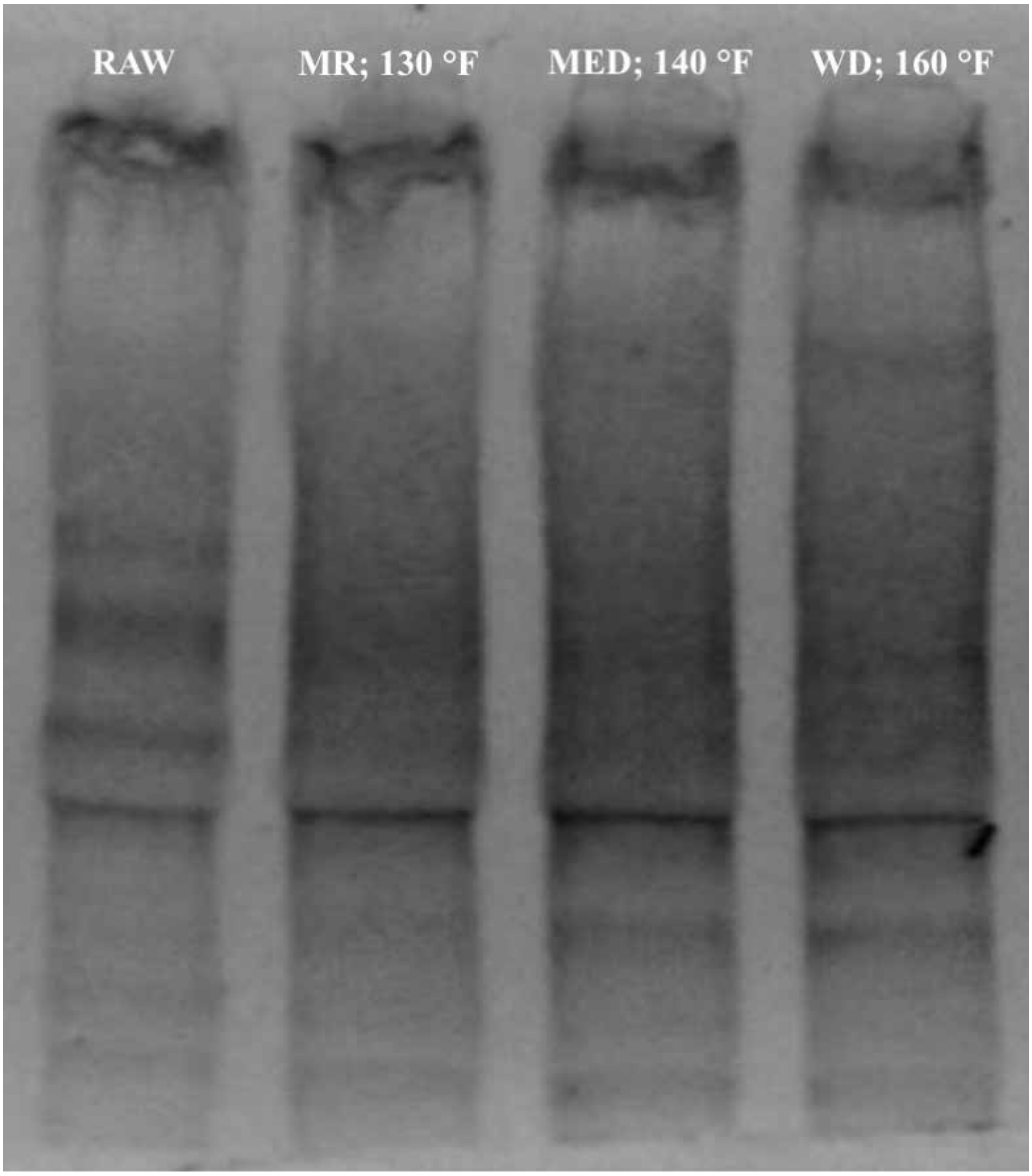


**Figure 1. Representative western blot of α-Gal content of striploins steaks cooked to varying degrees of doneness.**

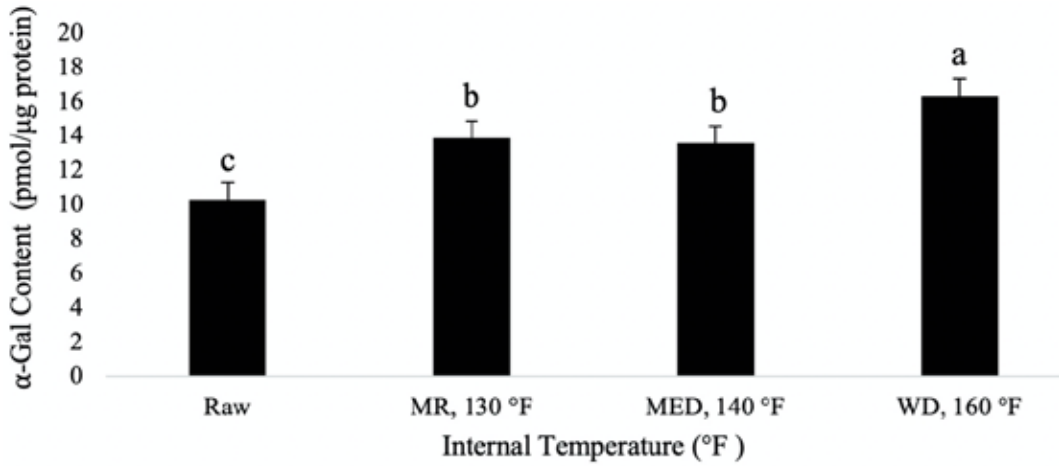


**Figure 2. α-Gal content of striploins at varying degrees of doneness.**

# Determining the Spoilage Threshold for Ground Beef Using Multiple Objective Measures

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## Abstract

The objective of this study was to determine the point at which ground beef reaches spoilage as determined by consumers. Retail ground beef packages were procured from a case-ready ground beef facility and randomly assigned to a storage duration (0 – 14 days) for simulated retail display. Packages were stored in mother bags at 36 – 40°F in the absence of light until placed in the retail case under fluorescent lights on the designated display date. Samples were displayed in three coffin-style cases at 36 – 40°F for 8 different display periods (0, 2, 4, 6, 8, 10, 12, and 14 days). Consumer sensory panelists evaluated eight samples for visual appearance, odor, and touch. For each measure, consumers were asked if they would purchase the sample and if they considered the sample spoiled. Trained sensory panelists evaluated the same samples on the same day of display and were asked to evaluate redness, percent discoloration, odor, and touch characteristics. Consumers were less *($P < 0.05$)* likely to purchase and more ($P < 0.05$) likely to rate samples spoiled once samples reached 8 days of display for visual appearance, touch, and odor. Consumer evaluation of the visual appearance score of the samples showed the strongest relationship to spoilage, having a high $R^2$ of 0.89 ($P < 0.05$). Threshold values of 50%, 75%, 90%, and 95% were identified for consumer purchase intent likelihood using multiple objective measures. With an $R^2$ of 0.86 ($P < 0.05$), trained panel redness scores of 60.15, 73.9, 87.6, and 96.95 corresponded to 50%, 75%, 90%, and 95% likelihood of a consumer purchasing the product. The likelihood of consumers classifying a sample as spoiled ($R^2 = 0.76$) 5, 10, 25, and 50% of the time corresponded with a trained sensory panel redness score of 74.8, 64.1, 48.4, and 32.7, respectively. Overall, consumers' opinion towards the appearance of the product plays the biggest role in their purchase intent and assessment of spoilage as opposed to touch and odor.

## Introduction

The global population is projected to increase by approximately 10% by the year 2031 (Dohlman et al., 2022). With this impending increase, safeguarding food products within the supply chain has a heightened significance. An overwhelming 23% of the world's produced meat goes to waste, with spoilage standing out as a primary culprit (Karwowska et al., 2021). Food waste is responsible for an annual cost of 780,000 animals in the beef industry alone, coupled with financial losses exceeding $3.73 billion due to discoloration (Ramanathan, 2022). Notably, much of the meat removed from shelves remains consumable, falling short only of consumer preferences. Consequently, a significant portion of beef product is prematurely withdrawn from retail shelves before reaching its full shelf-life potential. By recognizing that consumers are deterred by the oxidized metmyoglobin brown color replacing the bright cherry-red color of fresh meat, it's essential to revisit the benchmarks of spoilage (Harr, 2021). Therefore, the purpose of this study was to establish spoilage thresholds for ground beef

using multiple measures to offer the meat industry valuable insights for better product management, ultimately increasing the shelf-life of ground beef by aligning with the consumer's expectations of freshness and quality.

## Experimental Procedures

This study utilized 1-pound ground beef (80% lean) packages obtained from a commercial case-ready ground beef facility. Packages were stored at 36 – 40°F in gas-flushed mother bags in the absence of light at the Kansas State University Meat Laboratory. Four individual packages were stored in one mother bag (Tri gas, 69.6% nitrogen, 30% carbon dioxide, 0.4% carbon monoxide). Packages within a mother bag (2 pair per mother bag) were randomly assigned a display day (0, 2, 4, 6, 8, 10, 12, and 14 days). One paired sample was assigned to color and visual analysis while the other paired sample was utilized for smell and touch sensory analysis. Samples were placed in three coffin-style cases (model DMF8; Tyler Refrigeration Corp., Niles, MI) at 36 – 40°F under continuous fluorescent lighting (32 W Del-Warm White 3,000 K; Phillips Lighting Company, Somerset, NJ) for the duration of their assigned display period. Samples (n = 128) were placed in the case every other day from 14 days prior to evaluation until day 0 samples were displayed. Samples were placed in the case at the same time every day and rotated daily. To avoid fogging of packages during evaluation, the display cases were set to defrost once per day in the morning, prior to new samples being added. Each display case was divided into three sections (A - I) with distinct barriers. In addition to consumer sensory panels, objective measurements such as trained sensory panels, $L^*$ (lightness), $a^*$(redness), and $b^*$ (yellowness) readings using a Hunter Lab Miniscan spectrophotometer (Illuminant A, 2.54 cm aperture, 10° observer, Hunter Lab Associates Laboratory, Reston, VA), and spectral data were collected to calculate percent myoglobin present using the methods outlined in the American Meat Science Association (AMSA) color guidelines (AMSA, 2012).

Consumer sensory panelists (n = 128) were asked to evaluate one section of the display case that included 8 samples (one from each display period) and rate the visual appearance. Additionally, consumers were asked to evaluate the touch and odor of the samples under low-intensity red lights to avoid any bias toward the color of the product. For all attributes the consumers rated their overall liking of the sample on continuous 0 – 100-point line scales. They were also asked if they would purchase the sample (yes/no) or consider it spoiled (yes/no) based upon the attribute they were observing.

Trained sensory panelists also evaluated the samples for visual appearance, touch, and odor. During the weeks leading up to trained panels, panelists were trained with numerous samples of varying characteristics anchored to the scales. For color evaluation, panelists were trained according to the AMSA meat color measurement guidelines (AMSA, 2012). Panelists were asked to evaluate discoloration and redness of the samples using 100-point continuous line scales with anchors at 0 (0% discoloration and extremely dark red) and 100 (100% discoloration and bright, cherry-red color). Furthermore, panelists evaluated the texture of the samples by touch using a continuous 100-point line scale with anchors at 0 (characteristic beef texture) and 100 (non-characteristic beef texture). The odor of the samples was also evaluated on a continuous 100-point line scale with anchors at 0 (no odor present) and 100 (extreme off odor present). Trained panelists evaluated both touch and odor under the same red lights as consumers to avoid any bias toward the sample color. Both trained and consumer panelists recorded their answers using electronic tablets (Model 5709 HP Stream 7,

Hewlett – Packard, Palo Alto, CA) utilizing a digital survey (Qualtrics Software, Provo, UT). Data were analyzed using logistic regression models to identify the points at which consumers determined a product to be spoiled based on visual, touch, and odor characteristics.

## Results and Discussion

Overall, consumers rated samples that had been in the case for less time higher ($P < 0.05$) for visual appearance, touch, and odor liking. Consumer likeliness to purchase thresholds for visual appearance were generated from logistic regression equations and common threshold values of (50%, 75%, 90%, and 95% likely) that were identified using the values of independent variables measured represented in Table 1. Consumer visual appearance scores explained 89% of the variation of consumer purchase intent. A model with an $R^2$ of 0.79 ($P < 0.05$) for $a^*$ values of 21.5, 24.8, 28, and 30.2, corresponded to 50%, 75%, 90%, and 95% likelihood of consumers purchasing the product as shown in Figure 1. Logistic models of consumer likeliness to purchase based on percent metmyoglobin present were also calculated ($R^2 = 0.81$; $P < 0.05$) with values of 37.5, 30.8, 24.35, and 19.95% associated with 50%, 75%, 90%, and 95% likelihood of consumer purchasing intent as shown in Figure 2. Additionally, as shown in Figure 3, consumer purchasing thresholds were generated from trained discoloration scores ($R^2 = 0.83$; $P < 0.05$) identifying 38.7%, 23.0%, and 7.3% discoloration associated with 50%, 75%, and 90% likelihood of purchase intent. Trained redness score models ($R^2 = 0.86$; $P < 0.05$) showed values of 60.2, 73.9, 87.6, and 97 corresponded to 50%, 75%, 90%, and 95% likelihood of purchase intent. Furthermore, logistic regression equations were used to identify at what point consumers determined the product to be spoiled, shown in Table 2. The equation ($R^2 = 0.80$; $P < 0.05$) for $a^*$ identified values of 30.1, 27.2, 22.8, and 18.4 corresponding with a 5%, 10%, 25%, and 50% chance that a consumer would classify the sample as spoiled. For the percent metmyoglobin present ($R^2 = 0.72$; $P < 0.05$), values of 20.6%, 26.8%, 36%, and 45.1% were associated with a 5%, 10%, 25%, and 50% likelihood of being classified as spoiled. Consumer spoilage classification was also predicted with trained sensory panel discoloration and redness scores. Both trained redness and discoloration scores generated significant models representing about 75% of the variation of consumer spoilage classification.

Significant ($P < 0.05$) logistic regression models were also generated for odor liking to predict consumer likeliness to purchase thresholds but only described less than 8% of the variation within the model. Trained touch score logistic models for predicting spoilage classification were significant ($P < 0.05$) but only explained 3% of the variation. Overall, measures related to the visual characteristics were much better predictors of consumer likelihood to purchase and identification of spoilage than measures related to changes in odor and touch characteristics.

## Implications

Though many changes were identified throughout the retail display period, the change in color from a bright, cherry-red to brown was shown to be the most important factor considered by consumers when they identified whether or not samples were spoiled; therefore, maintaining beef in a bright, cherry-red state is crucial to maximize value.

## References

Dohlman, E., J. Hansen, and D. Boussios. 2022. USDA agricultural projections to 2031. USDA Office of the Chief Economist Long-Term Projections Report OCE-2022-1. 10.22004/ag.econ.323859

AMSA. 2012. Meat color measurement guidelines. 2 ed. American Meat Science Association, Champaign, IL.

Harr, K. M. 2021. Impact of providing information about the fat content, primal source, price, and labeling terms on consumer sensory evaluation of ground beef from the same source. Master's Thesis, Kansas State University. *https://krex.k-state.edu/dspace/handle/2097/41700*

Karwowska, M., S. Łaba, and K. Szczepański. 2021. Food loss and waste in meat sector—Why the consumption stage generates the most losses? Sustainability 13(11):6227. doi:10.3390/su13116227.

Ramanathan, R., L.H. Lambert, N. N. Mahesh, B. Morgan, R. Feuz, G. Mafi, and M. Pfeiffer. 2022. Economic loss, amount of beef discarded, natural resources wastage, and environmental impact due to beef discoloration. Meat and Muscle Biology 6(1):13218. doi:10.22175/mmb.13218

**Table 1. 50, 75, 90, and 95% likeliness thresholds for various quality measures for consumer purchase intent of 80% lean ground beef**

| Measurement | 50% | 75% | 90% | 95% |
|---|---|---|---|---|
| *L** | 54.4 | 55.9 | | |
| *a** | 21.5 | 24.7 | 28.0 | 30.2 |
| *b** | 20.7 | 22.3 | 23.8 | 24.9 |
| Metmyoglobin[1] | 37.3 | 30.8 | 24.4 | 19.0 |
| Oxymyoglobin[1] | 59.5 | 65.7 | 71.8 | 75.9 |
| TBARS[2] | 0.3 | | | |
| Trained sensory redness score[3] | 60.2 | 73.9 | 87.6 | 96.0 |
| Trained sensory discoloration score[4] | 38.7 | 23.0 | 7.3 | |
| Trained odor score[5] | 22.5 | | | |
| Trained touch score[6] | 51.6 | 15.0 | | |
| Consumer appearance score[7] | 48.5 | 59.5 | 70.5 | 77.0 |
| Consumer odor score[7] | 45.6 | 61.3 | 77.0 | 87.7 |
| Consumer touch score[7] | 43.15 | 56.9 | 70.6 | 80.0 |

[1]Calculated utilizing the equations presented in the AMSA Meat Color Measurement Guidelines (AMSA, 2012).
[2]Thiobarbituric acid reactive substances.
[3]Sensory scores: 0 = extremely dark red, 100 = bright cherry-red.
[4]Sensory Scored: 0 = no visible discoloration, 100 = complete discoloration.
[5]Sensory scores: 0 = no off odor, 100 = extreme off odor.
[6]Sensory scores: 0 = characteristic beef texture, 100 = non-characteristic beef texture.
[7]Sensory scores: 0 = extremely dislike, 100 = extremely like.

**Table 2. 5, 10, 25 and 50% likeliness thresholds for various quality measures for consumer spoilage classification of 80% lean ground beef**

| Measurement | 5% | 10% | 25% | 50% |
|---|---|---|---|---|
| *L** | | | 55.4 | 53.2 |
| *a** | 30.1 | 27.2 | 22.3 | 18.4 |
| *b** | 24.9 | 23.9 | 21.6 | 19.6 |
| Metmyoglobin[1] | 20.6 | 26.8 | 36.0 | 45.1 |
| Oxymyoglobin[1] | 77.0 | 71.5 | 62.3 | 53.2 |
| TBARS[2] | | | | 0.5 |
| Trained sensory redness score[3] | 74.8 | 64.1 | 48.4 | 32.7 |
| Trained sensory discoloration score[4] | 1.6 | 16.5 | 38.5 | 60.4 |
| Trained odor score[5] | | | 9.6 | 64.5 |
| Trained touch score[6] | | | 34.1 | |
| Consumer appearance score[7] | 74.7 | 65.3 | 51.6 | 37.9 |
| Consumer odor score[7] | 79.1 | 68.4 | 52.7 | 37.0 |
| Consumer touch score[7] | 84.6 | 72.1 | 53.8 | 35.5 |

[1]Calculated utilizing the equations presented in the AMSA Meat Color Measurement Guidelines (AMSA, 2012).
[2]Thiobarbituric acid reactive substances.
[3]Sensory scores: 0 = extremely dark red, 100 = bright cherry-red.
[4] Sensory scores: 0 = no visible discoloration, 100 = complete discoloration.
[5] Sensory scores: 0 = no off odor, 100 = extreme off odor.
[6] Sensory scores: 0 = characteristic beef texture, 100 = non-characteristic beef texture.
[7] Sensory scores: 0 = extremely dislike, 100 = extremely like.

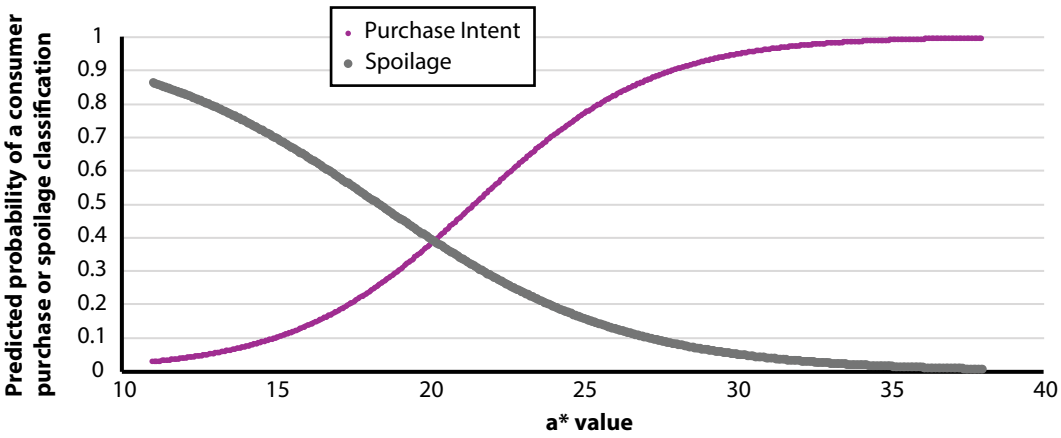


**Figure 1. Threshold values for consumer likeliness to purchase 80% lean ground beef or classifying as spoiled according to a* value.**

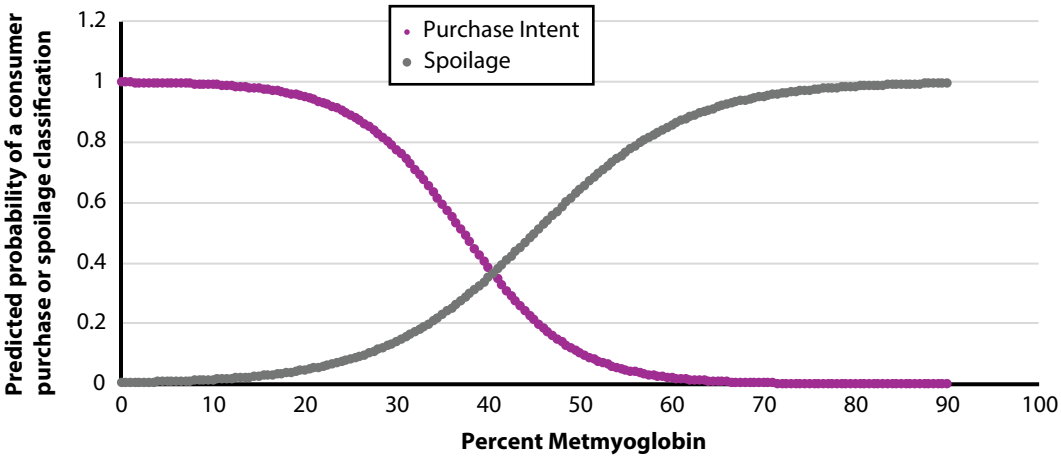


**Figure 2. Threshold values for consumer likeliness to purchase 80% lean ground beef or classifying as spoiled according to metmyoglobin percentage.**

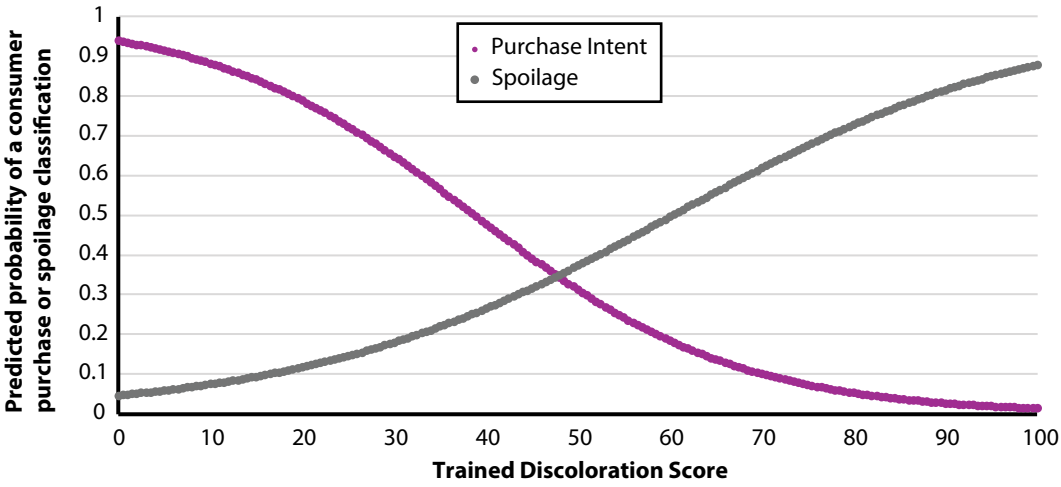


**Figure 3. Threshold values for consumer likeliness to purchase 80% lean ground beef or classifying as spoiled according to trained discoloration scores where 0 = no visible discoloration, 100= complete discoloration.**

# Determining the Spoilage Threshold for Ground Beef Using Microbial, Color, and Oxidation Measures

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## Abstract

The objective of this study was to determine the point at which ground beef becomes spoiled relative to microbiological, lipid oxidation, and color measurements. One lb ground beef packages from a case-ready facility were stored at 36 – 40°F in the absence of light until displayed in three coffin-style cases under fluorescent lighting. The packages were assigned to one of eight display periods (0, 2, 4, 6, 8, 10, 12, and 14 days). Samples were evaluated by consumers for visual appearance, touch, and odor liking; as well as evaluated for discoloration, redness, off-odor presence, and characteristic beef texture by trained sensory panelists. Additionally, objective measurements of aerobic plate counts (APC), *Enterobacteriaceae* plate counts (EB), and *Escherichia coli* (*E. coli*) coliform plate counts (ECC) for microbiology were obtained along with thiobarbituric acid reactive substances (TBARS) for lipid oxidation and $L^*$ (lightness), $a^*$ (redness), and $b^*$ (yellowness) values for color. Logistic regression models were generated to identify purchase intent thresholds and consumer spoilage classification based on the objective measures. As expected, consumer appearance liking was the strongest predictor compared to the microbiological assays, explaining 81% of the variation when predicting consumer purchase intent. Logistic models for APC ($R^2 = 0.59$; $P < 0.05$) identified values of 7.3, 6.7, 6.1, and 5.8 log colony forming units (CFU)/g representing 50, 75, 90, and 95% likelihood a consumer would purchase the product. Additionally, APC values ($R^2 = 0.46$; $P < 0.05$) of 5.3, 5.9, 6.8, and 7.7 log CFU/g relating to 5, 10, 25, and 50% likelihood a consumer would consider a product spoiled. The EB and ECC models also showed the strongest relationships corresponded to appearance liking, but not as strong as the APC predictors.

## Introduction

Spoilage can be defined and measured in a number of ways. Assays to evaluate microbial growth, lipid oxidation, and color can all be used to determine spoilage. However, spoilage is ultimately defined as the end of the product shelf-life and "the perception of a state of spoilage is, therefore, essentially a subjective evaluation which will vary with consumer expectations" (Gill, 1983). It's essential to study the effects of spoilage relevant to industry due to the millions of pounds of product discarded on an annual basis. Approximately 23% of the meat produced in the world is wasted, with spoilage playing a large role (Karwowska et al., 2021). Nonetheless, the annual loss for animals wasted in the beef industry is 780,000 animals in conjunction with $3.73 billion lost due to discoloration that makes beef fall short of consumer expectations. The purpose of this study was to establish thresholds of spoilage for ground beef using multiple objective measures of color, microbial growth, and lipid oxidation to gain valuable insight for the beef industry for better product management. The goal is to increase the shelf-life of ground beef by identifying consumer expectations of freshness and quality.

## Experimental Procedures

This study used one lb ground beef packages (80% lean) sourced from a commercial case-ready ground beef facility. The packages were stored at 36 to 40°F in gas-flushed mother bags (Tri gas composition: 69.6% nitrogen, 30% carbon dioxide, and 0.4% carbon monoxide) without exposure to light at the Kansas State University Meat Laboratory. Each mother bag contained four individual packages. Within each mother bag, two pairs of packages were randomly assigned to specific display days (0, 2, 4, 6, 8, 10, 12, and 14 days). One package per pair was designated for color and visual analysis, while the other was used for sensory evaluation of smell and touch. In addition to consumer sensory panels, objective measurements were taken, including trained sensory panel assessments, as well as microbiological, lipid oxidation, and $L^*$ (lightness), $a^*$ (redness), and $b^*$ (yellowness) values using a Hunter Lab Miniscan spectrophotometer (Illuminant A, 2.54 cm aperture, 10° observer; Hunter Lab Associates Laboratory, Reston, VA). Spectral data were collected to determine the percentage of myoglobin present, following the methods outlined in the American Meat Science Association (AMSA) color guidelines (AMSA, 2012). Microbiological analysis was conducted using aerobic plate counts (APC), *Enterobacteriaceae* plate counts (EB), and *Escherichia coli* (*E. coli*) coliform plate counts (ECC). From each ground beef sample, a 0.9 oz portion was combined with 7.6 oz of peptone water (PW) and stomached for 60 seconds (Stomacher 400, Seward, Bohemia, NY). On duplicate 3M Petrifilm for each APC, EB, and ECC, serial dilutions of 1 ml were plated using PW. Petrifilms were incubated for their respective times and colonies were counted for data collection. Additionally, lipid oxidation was measured using the thiobarbituric acid reactive substances (TBARS) assay following procedures outlined in Ahn et al. (1998) and similar procedures followed in other Kansas State University studies (Beyer et al., 2024). The samples (n = 128) were placed in three coffin-style display cases (model DMF8; Tyler Refrigeration Corp., Niles, MI) maintained at 36 to 40°F under continuous fluorescent lighting (32 W Del-Warm White 3,000 K; Phillips Lighting Company, Somerset, NJ) for their entire assigned display period. Samples were introduced to the display cases every other day, starting 14 days before evaluation, with day 0 samples placed on display last. The samples were added at the same time daily and rotated within the cases, which were set to defrost once each morning to prevent package fogging during evaluations.

Consumer sensory panelists (n = 128) were asked to rate the visual appearance of eight samples (one from each display period) using a 100-point continuous line scale. Additionally, they were asked (yes/no) if they would purchase the sample and (yes/no) if they thought the sample was spoiled. Consumers were also asked to rate the touch and odor of samples on 100-point continuous line scales with the same (yes/no) questions above after evaluating each trait.

Similar to the consumers, trained sensory panelists were asked to evaluate percent discoloration, redness, touch, and odor. Panelists were trained with multiple samples of varying characteristics anchored to the scales. Additionally, panelists were trained according to the AMSA meat color measurement guidelines (AMSA, 2012). Discoloration and redness of the samples were evaluated with a 100-continuous line scale with anchors at 0 (0% discoloration and extremely dark red) and 100 (100% discoloration and bright, cherry-red). On similar 100-point continuous line scales, sensory panelists evaluated touch and odor with anchors at 0 (characteristic beef texture and no odor present) and 100 (non-characteristic beef texture and extreme off odor present). Both

consumer and trained sensory panelists evaluated touch and odor samples under red lights to avoid bias toward the color of the sample. All panelists recorded their answers using electronic tablets (Model 5709 HP Stream 7, Hewlett-Packard, Palo Alto, CA) using a digital survey (Qualtrics Software, Provo, UT). Data were analyzed using logistic regression models to identify the points at which consumers determined the product to be spoiled based on visual, touch, and odor characteristics.

## Results and Discussion

Overall, consumer sensory panelists rated samples in the case for 0 and 2 days higher ($P < 0.05$) for all three attributes evaluated (color, touch, and odor liking) than any samples in the case for 8, 10, 12 and 14 days.

### *Logistic regressions predicting consumer purchase intent*

Predictors of consumer purchase intent were generated utilizing logistic regression models, and common threshold values (50, 75, 90, and 95%) were identified in regard to the objective measurements. Different models were generated for all microbiological measurements (APC, EB, and ECC) corresponding to the consumer visual appearance liking as shown in Figure 1. A model with an $R^2$ of 0.59 ($P < 0.05$) was generated for APC, with values of 7.3, 6.7, 6.1, and 5.8 log colony forming units (CFU)/g corresponding to 50, 75, 90, and 95% likelihood of the consumer purchasing the product. Additionally, values for EB of 4.4, 3.5, 2.6, and 2.0 log CFU/g were associated with 50, 75, 90, and 95% likelihood of purchase intent, with the model ($P < 0.05$) explaining 49% of the variation in purchase intent. An ECC level of 2.2 log CFU/g corresponded to a 50% chance a consumer would purchase the product ($R^2 = 0.17$; $P < 0.05$). The same logistic techniques were used to generate predictor models for consumer purchase intent in regard to the consumer odor liking as shown in Figure 2. When evaluating the odor of the product, APC values of 7.5 and 5.3 log CFU/g corresponded to a 50 and 75% chance a consumer would purchase the product ($R^2 = 0.17$; $P < 0.05$). The EB and ECC models were significant ($P < 0.05$), but only explained 12 and 8% of the variation in purchase intent. Logistic regression models for TBARS were also significant ($P < 0.05$), but again only explained a low (6%) amount of variation in consumer purchase intent. Likewise, models were created to predict purchase intent based on consumer touch liking as shown in Figure 3. Although models were significant ($P < 0.05$), the strongest predictor variable was APC, but again that only explained 11% of the variation for consumer purchase intent.

### *Logistic regressions predicting consumer likeliness to classify a sample as spoiled*

Common thresholds (5, 10, 25, and 50%) were generated using logistic regression models to predict the likelihood of consumers classifying a sample as spoiled based on the objective measurements evaluated. Shown in Figures 4, 5, and 6, three models were generated from all microbial assays (APC, EB, and ECC) for consumer appearance ratings to predict spoilage classification. The APC model ($R^2 = 0.46$; $P < 0.05$) generated values of 5.3, 5.9, 6.8, and 7.7 log CFU/g corresponding to a 5, 10, 25, and 50% likelihood consumers would classify a sample as spoiled. The EB and ECC assays also had significant ($P < 0.05$) models; however, they only accounted for 46 and 12% of the variation when predicting consumer spoilage classification. In addition, thresholds were determined for spoilage classification with consumer odor liking and touch liking scores. Although models for APC, EB, ECC, and TBARS were significant ($P < 0.05$),

APC explained the most variation, but still only a relatively small (17%) amount when predicting spoilage. Similarly, APC regression models explained the most variation in consumer spoilage assessment based on touch but only explained 10% of the variation.

## Implications

Overall, logistic regression models demonstrated relationships between the objective and microbial measures evaluated and consumer willingness to purchase and assessment of spoilage; however, many of the measures explained only a minimal amount of variation in the consumer responses, providing evidence that spoilage determination is likely not dependent upon these variables.

## References

Ahn, D. U., D. Olson, C. Jo, X. Chen, C. Wu, and J. Lee. 1998. Effect of muscle type, packaging, and irradiation on lipid oxidation, volatile production, and color in raw pork patties. Meat Science 49:27-39.

AMSA. 2012. Meat color measurement guidelines. 2 ed. American Meat Science Association, Champaign, IL.

Beyer, E. S., L. K. Decker, E. G. Kidwell, A. L. McGinn, M. D. Chao, M. D. Zumbaugh, J. L. Vipham, and Travis G. O'Quinn. 2024. Evaluation of fresh and frozen beef strip loins of equal aging periods for palatability traits. Meat and Muscle Biology 8.

Gill, C. O. 1983. Meat Spoilage and Evaluation of the Potential Storage Life of Fresh Meat. Journal of Food Protection 46:444-452. doi:*https://doi.org/10.4315/0362-028X-46.5.444*

Karwowska, M., S. Łaba, and K. Szczepański. 2021. Food Loss and Waste in Meat Sector—Why the Consumption Stage Generates the Most Losses? Sustainability 13 doi:10.3390/su13116227.

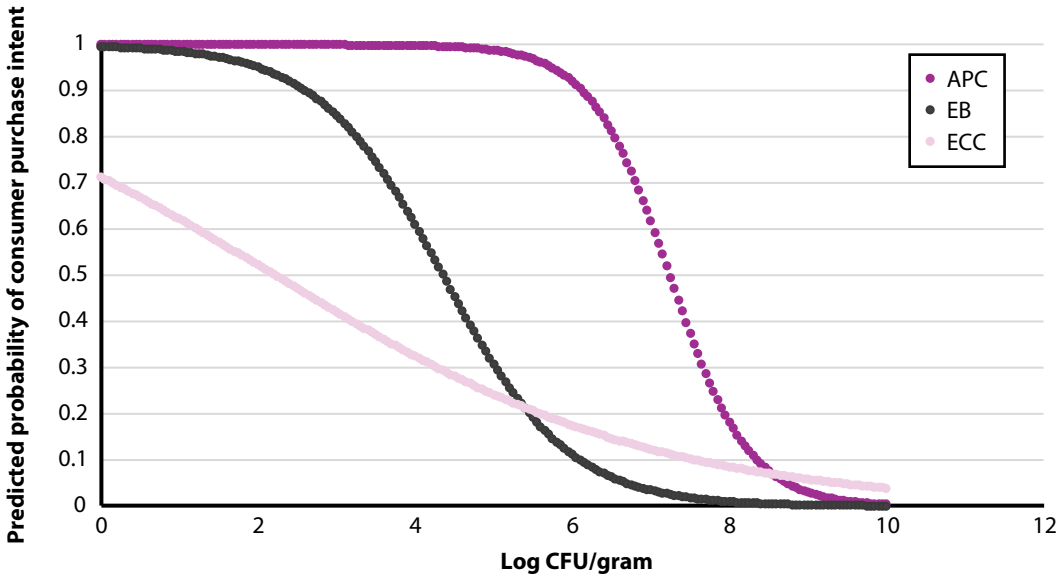


**Figure 1. Threshold values for consumer likeliness to purchase 80% lean ground beef according to aerobic plate counts (APC), *Enterobacteriaceae* plate counts (EB), and *Escherichia coli* coliform plate counts (ECC) based on appearance.**

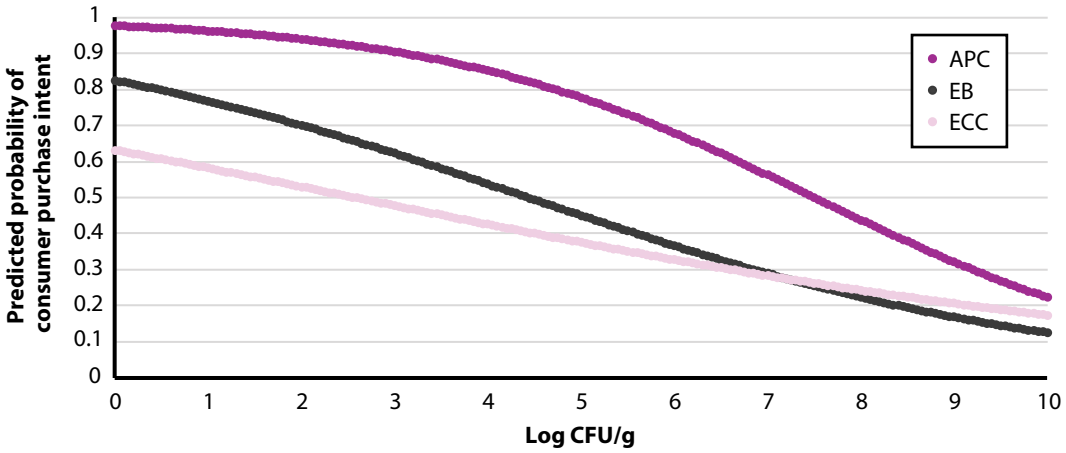


**Figure 2. Threshold values for consumer likeliness to purchase 80% lean ground beef according to APC, EB, and ECC based on odor.**

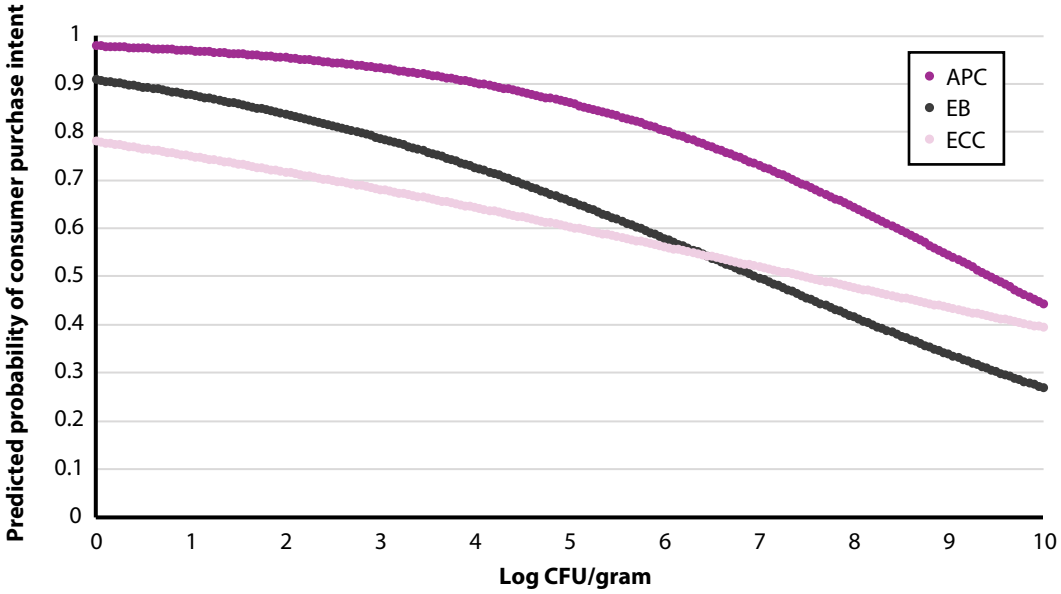


**Figure 3. Threshold values for consumer likeliness to purchase 80% lean ground beef according to APC, EB, ECC based on touch.**

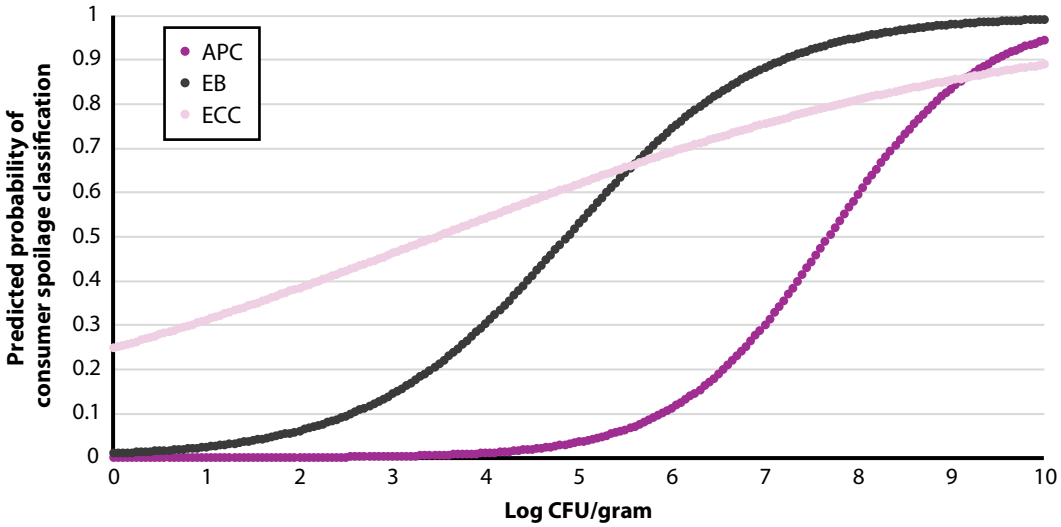


**Figure 4. Threshold values for consumer likeliness to classify 80% lean ground beef spoiled according APC, EB, and ECC based on appearance.**

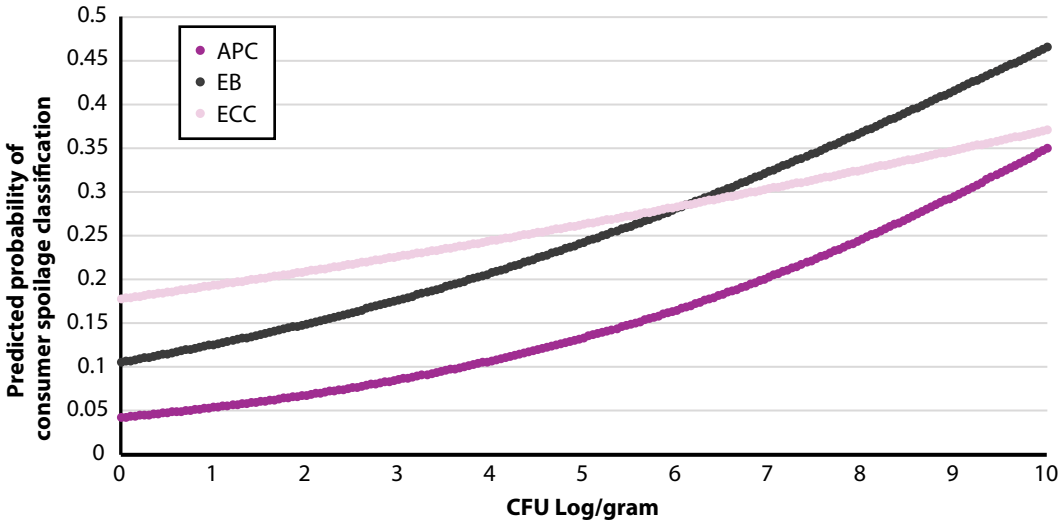


**Figure 5. Threshold values for consumer likeliness to classify 80% lean ground beef spoiled according APC, EB, and ECC based on touch.**

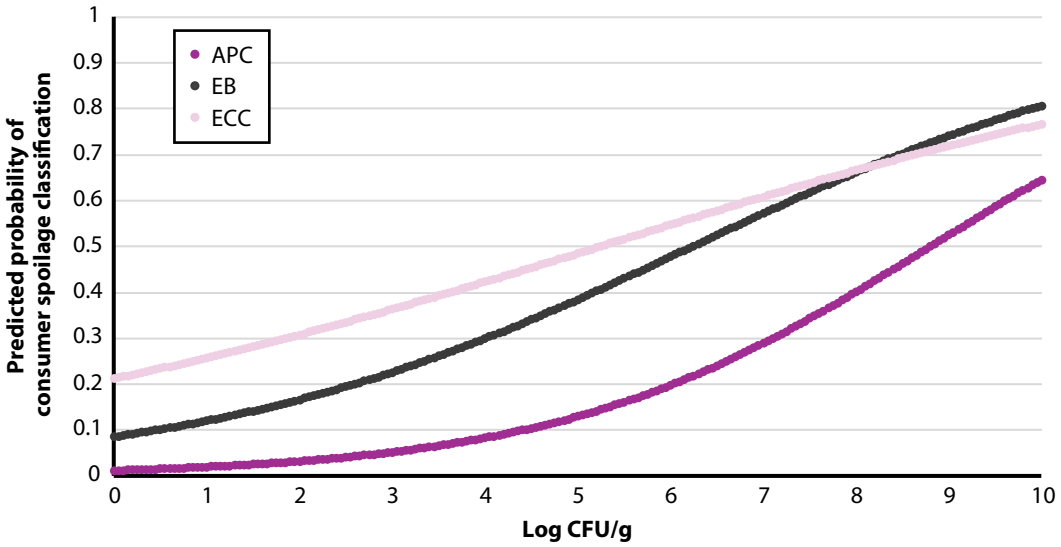


**Figure 6. Threshold values for consumer likeliness to classify 80% lean ground beef spoiled according to APC, EB, and ECC based on odor.**

# Quality and Sensory Attributes of Tumbled or Marinated Beef Jerky

*A.L. McGinn, D.L. Boyle, T.G. O'Quinn, and E.A.E. Boyle*

## Abstract

Twelve USDA Select beef inside top rounds (*semimembranosus*) were held at 36°F for 10 - 14 days prior to processing. Trimmed rounds were cut in half and each half was allocated to a tumbled or marinated treatment group. Before the treatments were applied, the beef round halves were sliced and weighed. Pieces from each half were held for moisture, fat, and protein determination, with separate samples allocated for transmission electron microscopy (TEM) and light microscopy (LM) to evaluate structural changes, sarcomere length (SL), and myofiber diameter (MD). After tumbling or marination, percent pickup was measured, and a piece from each half of tumbled or marinated rounds was held for sodium chloride content (SCC) analysis. Additionally, structural changes, SL, and MD were measured. Vacuum-packaged jerky was stored at 68°F and evaluated after 3 and 6 months of storage for color, sensory evaluation, water activity ($a_w$), shear force (SF), SCC, moisture, structural changes, SL, and MD. There were similar ($P > 0.05$) results for the percent cook yield while the percent pickup was higher ($P < 0.05$) for the tumbling process versus the marination process. Analysis of the moisture, fat, and protein content showed no differences ($P > 0.05$) among treatment methods within raw top-round samples. After the tumbling and marinating process, there was no difference ($P > 0.05$) in the SCC among the raw top round slice samples. After the beef jerky was thermally processed, there were no differences ($P > 0.05$) for pH, $a_w$, protein content, moisture protein ration (MPR), or SCC. However, the moisture content was higher ($P < 0.05$) in tumbled jerky than in marinated jerky, which could be related to the increase in percent pickup during the tumbling process. The instrumental color values showed that tumbled beef jerky was lighter ($P < 0.05$) in color and redder ($P < 0.05$) than marinated jerky. Overall, jerky became darker ($P < 0.05$) in color and redder ($P < 0.05$) during storage. Shear force values were lower ($P < 0.05$) in tumbled jerky with no change ($P > 0.05$) over time. Sensory panelists found tumbled jerky to be less brittle, less chewy, and more flavorful ($P < 0.05$) at day 0 and up to 6 months of storage compared to marinated jerky. Changes in structural integrity were observed due to processing methods and storage time. However, there was no difference between treatments or storage time for SL and MD. During storage, there was a decrease ($P < 0.05$) in SCC over time and an interaction ($P < 0.05$) with process treatment and storage time for $b^*$ (yellowness). All the other variables of $a_w$, SF, moisture, and MPR were similar ($P > 0.05$) for processing method and storage time. Overall, tumbling produced a jerky product that was more tender, less brittle, and more flavorful during 6 months of storage compared to marination as a processing method. Although tumbling yielded a higher percent pickup and jerky was darker in color than marinated jerky, the processing method did not influence SCC, $a_w$, or MPR of beef jerky.

## Introduction

Meat processors use a variety of methods to produce whole muscle or ground and formed beef jerky (Lonnecker et al., 2010). Tumbling and marination are production methods used singly or in combination with dry or wet ingredients to add flavor and

uniqueness to jerky products. A survey by Lonnecker et al. (2010) of 37 Midwestern small plants that produced beef, pork, turkey, or buffalo jerky found that 56% of the respondents made whole muscle jerky and 44% of the respondents made ground and formed jerky. Additionally, the marinade incorporation ranged from 1-85% and percent pickup ranged from 3-100%. Vacuum packaging was used to package beef jerky by 78% of respondents with the rest using no vacuum or gas-flushed plastic bags. For storage of the packages, 32% refrigerated the jerky, 38% kept jerky at 68°F and 3% froze their jerky. The overall conclusion from this survey was that processors exhibited diversity in the processing of products, which caused variability in production. This presented the need for understanding what differences looked like in terms of quality and sensory attributes when different processing methods such as tumbling or marinating were used with a lethality step to produce jerky. Skaar and Boyle (2011) analyzed whole-muscle beef jerky produced using tumbling or marination. Beef strips were marinated for 24 hours or vacuum-tumbled for 20 minutes. They found that the tumbling process was able to increase the flavor intensity of the product, and tumbled jerky had a lower protein content and a lower water activity ($a_w$) than jerky produced using marination. The objective of this research was to evaluate the quality and sensory characteristics of vacuum-packaged shelf-stable beef jerky produced using tumbling or marination.

## Experimental Procedures

This study used 12 USDA Select beef inside top rounds (*semimembranosus*) that were stored in a non-barrier shrink bag held at 36°F for 10 to 14 days before processing. On each processing day, whole rounds were trimmed, pH was measured, and the weights were obtained before and after trimming. Trimmed rounds were cut in half, and each half was allocated to a tumbled or marinated treatment. Before the processing treatments were applied, each beef round half was sliced using a slicer (Treif Puma Slicer, Shelton, CT) into 3 mm slices and then weighed. Pieces from each half were collected for determination of structural analysis, sarcomere length (SL), and myofiber diameter (MD) using transmission electron microscopy (TEM) and light microscopy (LM) and for proximate analysis. After tumbling or marinating, percent pickup was measured following a 5-minute rest period, and a sample from each half of tumbled or marinated rounds was held to measure sodium chloride content (SCC), structural analysis, SL, and MD.

After thermal processing, samples from each treatment were vacuum-packaged and sampled initially on day 0 and after 3 and 6 months at 68°F. Cook yield was determined after thermal processing. On day 0, the pH, moisture, and protein content, $a_w$, instrumental color, shear force (SF), sensory evaluation, SCC, structural analysis, SL, and MD were measured. After 3 and 6 months of storage, instrumental color, sensory evaluation, $a_w$, SF, SCC, moisture, structural analysis, SL, and MD were measured.

## Results and Discussion

Physical and chemical characteristics of vacuum-packaged beef jerky produced using tumbling or marination are shown in Table 1. Percent cook yield was similar ($P > 0.05$) among processing methods, while the percent pickup was higher ($P < 0.05$) for the tumbling process versus the marination process. Analysis of the moisture, fat, and protein content showed no differences ($P > 0.05$) among processing methods within raw top round samples. After the tumbling and marinating process, there was no difference ($P > 0.05$) in the SCC among the raw top round slice samples. After the jerky was thermally processed, there were no differences ($P > 0.05$) for pH, $a_w$, protein content,

moisture protein ratio (MPR), or SCC. However, the moisture content was higher ($P < 0.05$) in tumbled jerky than in marinated jerky, which could be related to the increase in percent pickup during the tumbling process. The instrumental color values showed that tumbled beef jerky was lighter and redder ($P < 0.05$) than marinated jerky.

Physical and chemical characteristics during storage of vacuum-packaged beef jerky produced using tumbling or marination are shown in Table 2. Overall, jerky became darker and redder ($P < 0.05$) during storage. Shear force values were lower ($P < 0.05$) in tumbled jerky with no change ($P > 0.05$) over time. Sensory panelists found tumbled jerky to be less brittle and chewy ($P < 0.05$), and more flavorful ($P < 0.05$) at day 0 and up to 6 months of storage at 68°F compared to marinated jerky. Changes in structural integrity were observed due to processing methods and storage time. However, there was no difference between treatments or storage time for SL and MD. During storage, there was a decrease ($P < 0.05$) in SCC over time and an interaction ($P < 0.05$) with process treatment and storage time for $b^*$ (yellowness). All the other variables of $a_w$, SF, moisture, and MPR were similar ($P > 0.05$) for processing method and storage time. Overall, tumbling produced a jerky product that was more tender, less brittle, and more flavorful during 6 months of storage compared to marination as a processing method. Although tumbling yielded a higher percent pickup and jerky was darker in color than marinated jerky, the processing method did not influence the SCC, $a_w$, or MPR of beef jerky.

## Implications

Tumbling produced a jerky product that was more tender, less brittle, and more flavorful during 6 months of storage compared to marination as a processing method.

## References

Lonnecker, S.M., E.A.E., Boyle, K.J.K., Getty, D.R., Buege, S.C., Ingham, G. Searls, and N.M. Harper. 2010. Production methods and product characteristics of jerky produced by small and very small meat processing businesses. Journal of Muscle Foods 21(4):826-833. doi.org/10.1111/j.1745-4573.2010.00222.x

Skaar, G.R. and E.A.E. Boyle, 2011. Marination technique influences whole muscle beef jerky salt content and flavor intensity. Kansas Agricultural Experiment Station Research Report. doi.org/10.4148/2378-5977.2922

**Table 1. Least square means (LSmeans) of physical and chemical characteristics of vacuum-packaged beef jerky produced using tumbling or marination**

| Process Treatment | $L^*$[1] | $a^*$[2] | Shear force (lbf) | Water activity | Pickup % | Cook yield % | Tender-ness[3] | Texture[4] | Flavor[5] | Sodium chloride (%) | pH | MPR[6] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Marinade | 24.30[b] | 3.32[b] | 84.3[a] | 0.74 | 17.3[b] | 32.6 | 25.66[b] | 74.78[a] | 34.60[b] | 3.410 | 5.56 | 0.13 |
| Tumble | 25.93[a] | 4.11[a] | 71.3[b] | 0.76 | 27.4[a] | 31.4 | 35.96[a] | 61.16[b] | 37.17[a] | 3.336 | 5.45 | 0.14 |
| *P*-value | 0.0032 | 0.0017 | 0.0039 | 0.2385 | 0.0004 | 0.1181 | <.0001 | <.0001 | 0.0455 | 0.527 | 0.0529 | 0.6425 |
| SEM[7] | 0.6738 | 0.2325 | 4.8 | 0.01 | 0.0170 | 0.0052 | 1.8668 | 2.2130 | 1.0461 | 0.009 | 0.0522 | 0.0202 |

[ab]Means within a column without a common superscript differ ($P < 0.05$).
[1]$L^*$ = 0 = black, 100 = white.
[2]$a^*$ = - 60 = green, 60 = red.
[3]Tenderness: 0 = extremely tough/chewy, 50 = neither tough/chewy nor tender/non chewy, 100 = extremely tender/non chewy.
[4]Texture: 0 = extremely soft, 50 = neither soft nor brittle/hard, 100 = extremely brittle/hard.
[5]Flavor: 0 = extremely bland, 100 = extremely intense.
[6]Moisture protein ratio.
[7]Standard error of the least square means.

**Table 2. Least square means (LSmeans) of physical and chemical characteristics of vacuum-packaged beef jerky produced using tumbling or marination during storage at 68°F for up to six months**

| Storage Time | $L^*$[1] | $a^*$[2] | Shear Force (lbf) | Water activity | Tenderness[3] | Texture[4] | Flavor[5] | Sodium Chloride (%) |
|---|---|---|---|---|---|---|---|---|
| Day 0 | 26.47[a] | 3.30[b] | 79.9 | 0.74 | 33.00[a] | 63.45[b] | 39.05[a] | 3.695[a] |
| 3 Months | 25.17[a] | 3.61[b] | 76.0 | 0.75 | 32.10[ab] | 67.30[b] | 34.53[b] | 3.519[a] |
| 6 Months | 23.70[b] | 4.24[a] | 77.6 | 0.76 | 27.33[b] | 73.16[a] | 34.07[b] | 2.906[b] |
| *P*-value | 0.0004 | 0.0073 | 0.3744 | 0.3196 | 0.0485 | 0.0057 | 0.0032 | <.0001 |
| SEM[6] | 0.7243 | 0.2614 | 5.2 | 0.01 | 2.1067 | 2.5063 | 1.2207 | 0.0143 |

[ab]Means within a column without a common superscript differ ($P < 0.05$).
[1]$L^*$ = 0 = black, 100 = white.
[2]$a^*$ = - 60 = green, 60 = red.
[3]Tenderness: 0 = extremely tough/chewy, 50 = neither tough/chewy nor tender/non chewy, 100 = extremely tender/non chewy.
[4]Texture: 0 = extremely soft, 50 = neither soft nor brittle/hard, 100 = extremely brittle/hard.
[5]Flavor: 0 = extremely bland, 100 = extremely intense.
[6]Standard error of the least square means.

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