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Contents

Effects of Late-Summer Prescribed Fire on Botanical Composition, Soil Cover, and Forage Production in Caucasian Bluestem-Infested Rangeland in the Kansas Smoky Hills: Year 4 of 5

H.P. Giefer, K.R. Harmoney, M.P. Ramirez, A.J. Tajchman, Z.M. Duncan, J. Lemmon, and K.C. Olson

Abstract

The rapid spread of the old world bluestem species *Bothriochloa ischaemum* (yellow bluestem) and *Bothriochloa bladhii* (Caucasian bluestem) is becoming a threat to the natural landscapes of the central and southern Great Plains. While use of non-selective herbicides has been the primary means of controlling these species, this method is costly, and its lethal effects are not limited to old world bluestems. Recent research has shown late-summer prescribed fire has potential for reducing old world bluestem cover without harming native vegetation. Eighteen one-acre plots were studied in a grazed pasture composed of native mixed-grass prairie and containing large amounts of Caucasian bluestem. Plots were randomly assigned to one of three treatments: no burn (control), one burn (August 14, 2019), or two burns (August 14, 2019, and August 11, 2021). In each plot, soil cover, botanical composition, and forage biomass were measured annually. Bare soil increased ($P < 0.01$) in both fire-treated plots. Consequently, after the first burn the litter decreased ($P < 0.01$) in single and double burn plots. Basal plant area did not differ ($P \geq 0.31$) among treatments. Total grass cover tended to differ ($P = 0.07$) between treatments; however, Caucasian bluestem frequency decreased ($P < 0.01$) following application of a second fire treatment. Biomass in the plots burned twice was less ($P < 0.01$) than in non-burned plots and plots burned once. Grass species richness increased (treatment main effect; $P = 0.01$) in all fire-treated plots. Forb species richness increased ($P = 0.02$) in burned plots after the first burn only, with no differences noted among any plots between treatments in years three and four of data collection ($P \geq 0.54$). These data suggest that regular application of late-summer prescribed fire may be an effective method for reducing Caucasian bluestem frequency while improving overall grass-species richness.

Introduction

Originally viewed as valuable resources for forage and soil-conservation properties, old world bluestems (*Bothriochloa ischaemum* and *Bothriochloa bladhii*) promptly demonstrated chemical and physical abilities of reducing native vegetation and spreading beyond areas of intended cultivation. Due to their tendency to mature more quickly than other grasses, nutrient quality of old world bluestems rapidly declines, rendering the forage highly unpalatable to grazing animals relatively early in the growing season. Further adding to the complications of containment, these species display great resiliency when grazed, mowed, or burned in a traditional spring season prescribed fire.

Based on promising research reporting a decrease in yellow bluestem (*B. ischaemum*) cover following a late-summer prescribed fire, the objective of this study was to record the effects of similarly timed fires on a pasture infested with Caucasian bluestem (*B. bladhii*), a phenotypically similar species.

Experimental Procedures

The location of the experiment was Ellsworth County, Kansas, in a privately owned grazed pasture heavily infested with Caucasian bluestem. The pasture was divided into 18 plots, each one acre in size and arranged in a 9 × 2 block fashion with every set of two plots randomly assigned to one of three treatments: no burn, one burn, or two burns. Preliminary assessment of soil cover, botanical composition, and forage biomass was undertaken in July 2019; fire treatments were applied August 14, 2019, and August 11, 2021. Post-fire evaluations were conducted in July each year beginning in 2020.

A modified step point approach was used to measure ground cover and botanical composition along permanent 162-ft transects in each plot. Forage biomass was estimated by clipping vegetation to a height of 0.39-in inside three randomly placed 19.7 × 19.7-in clipping frames in each plot. Litter was manually removed before clipping, and the remaining live vegetation was placed in a forced-air oven for 96 hours at 131°F. The dry material was weighed and used to estimate overall forage biomass. Aerial frequency of Caucasian bluestem was assessed using a 12 × 12-in frame at 50 points along each transect.

Results and Discussion

Bare soil increased ($P < 0.01$) with each application of fire on burn-treated plots while litter decreased ($P < 0.01$) after each fire treatment (Figures 1 and 2, respectively). This can be attributed to litter consumption by fire. Litter accumulates over the growing season and a late summer fire will eliminate it without leaving time for buildup before growth ceases for the year. In all years after the first burn, basal plant cover did not differ ($P \geq 0.31$) among plots (Figure 3).

In year four, total grass cover did not differ ($P \geq 0.83$; Figure 4) between treatments, Caucasian bluestem frequency was less ($P \leq 0.03$) in plots burned twice compared to non-burned plots and plots burned once (Figure 5). Concurrently, total warm season (C4) grass cover decreased ($P < 0.01$) in both burn treatments after the first burn and was still less ($P = 0.04$) in plots burned twice than in non-burned plots by year four (data not shown). Midgrasses, including Caucasian bluestem, were the only subgroup of the C4 grasses to decline ($P = 0.03$) in plots treated twice (Figure 6). Total cool season (C3) grass basal cover increased ($P < 0.01$) after each burn in fire-treated plots (data not shown). No differences were detected in native or introduced grasses ($P \geq 0.24$) between plots at any time (data not shown). These data were interpreted to suggest late-summer prescribed fire may be an effective means to reduce Caucasian bluestem frequency without negatively affecting populations of desirable grass species. A drop in biomass ($P < 0.01$) in both burn treatments following the first burn and a subsequent drop in biomass in plots burned twice following the second burn can likely be attributed to lower frequency of Caucasian bluestem (Figure 7). Grasses, including Caucasian bluestem, noticeably received more grazing pressure in plots burned twice than in other treatments, implying that removal of litter and dead plant material may have resulted in more desirable grazing.

Grass species richness increased (treatment main effect; $P = 0.01$) in both burn treatments after the first burn and continued to be different ($P < 0.01$) between plots burned twice and non-burned plots by year four (Figure 8). Conversely, a drop after year three in plots burned once resulted in only a tendency for difference ($P = 0.07$) from non-burned plots by year four. Decreases in frequency of Caucasian bluestem, along with canopy elimination following fire, may have allowed greater grass germination and tillering in the newly exposed soil.

Total forb cover was greater (treatment main effect; $P < 0.02$) in plots burned twice compared with non-burned plots, whereas forb cover in plots burned once was intermediate to and not different from non-burned plots and plots burned twice (data not shown). Annual forb cover increased ($P < 0.01$) following the first burn in both burn treatments while perennial forb cover was not different ($P = 0.08$) between treatments (data not shown). Nectar-producing forbs similarly increased ($P \leq 0.04$) in burned plots after the first burn only (data not shown). No difference was detected in native ($P = 0.07$) or leguminous ($P = 0.79$) forb populations (data not shown). Corresponding with overall cover, forb species richness increased ($P = 0.02$) in all fire-treated plots following the first burn, while no differences ($P \geq 0.54$) were detected between plots in years three and four (data not shown). This is likely due to the increase in annual forb cover following the first burn and the subsequent decrease to initial levels.

Shrub cover decreased (treatment main effect; $P = 0.01$) in all burned plots after the first burn but did not decrease significantly ($P = 0.91$) in plots burned twice following the second burn application (data not shown). Low levels of shrub cover persisted in fire-treated plots and shrubs were still significantly less ($P < 0.01$) than in non-burned plots by year four. Basal cover of leguminous shrubs was not different ($P = 0.39$) between treatments over time (data not shown). Many woody plants are intolerant to fire, so only resistant shrubs would have remained after the first fire, leaving fewer susceptible species at the time of the second burn. In close association with the decreases in shrub cover, species richness also decreased (treatment main effect; $P = 0.04$) following the first burn in fire-treated plots (data not shown). Unlike trends in shrub cover, richness once again increased in plots burned once in years three and four and was not significantly different ($P = 0.58$) from non-burned plots by year four. This can likely be attributed to post-burn re-infiltration of shrubs not resistant to fire. Richness in plots burned twice, however, did still differ ($P = 0.03$) from non-burned plots.

Implications
These data suggest application of late-summer prescribed fire may be an effective, low-cost method of reducing old world bluestem frequency while subsequently improving native grass species richness. The project will be concluded following one more year of data collection in July 2023.
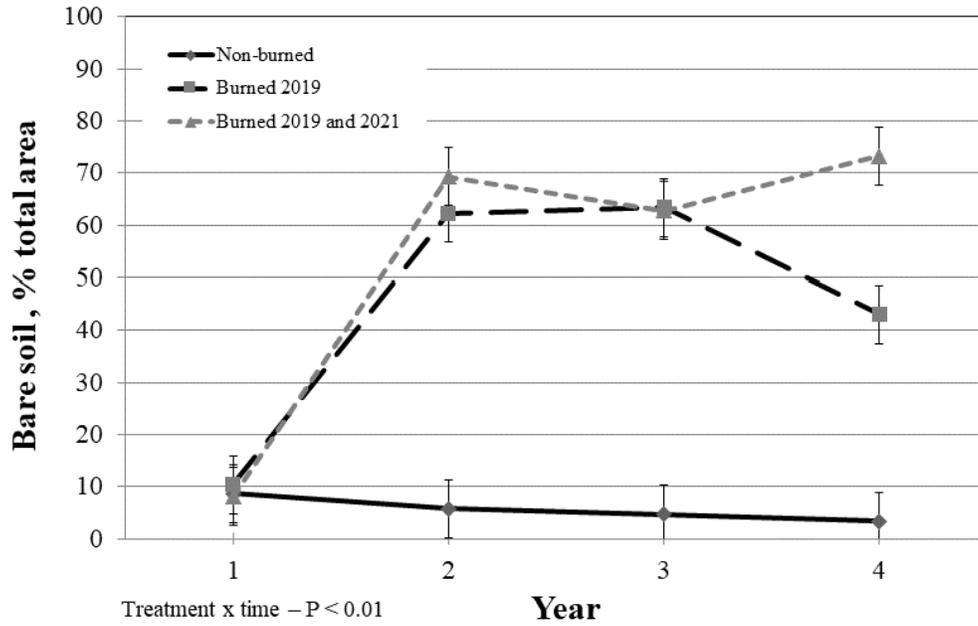
Figure 1. Effects of late summer prescribed fire on percent bare soil.

Figure 2. Effects of late summer prescribed fire on percent litter cover.

Treatment x time – P < 0.01

Figure 3. Effects of late summer prescribed fire on percent basal cover.

Treatment x time – P = 0.07

Figure 4. Effects of late summer prescribed fire on percent total grass cover.

Figure 5. Effects of late summer prescribed fire on percent Caucasian bluestem frequency.

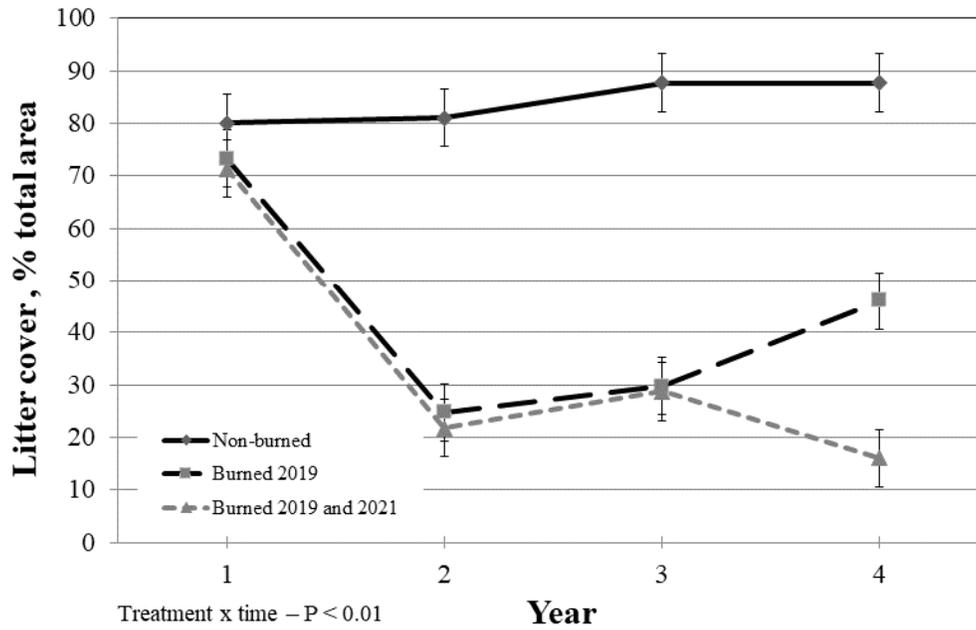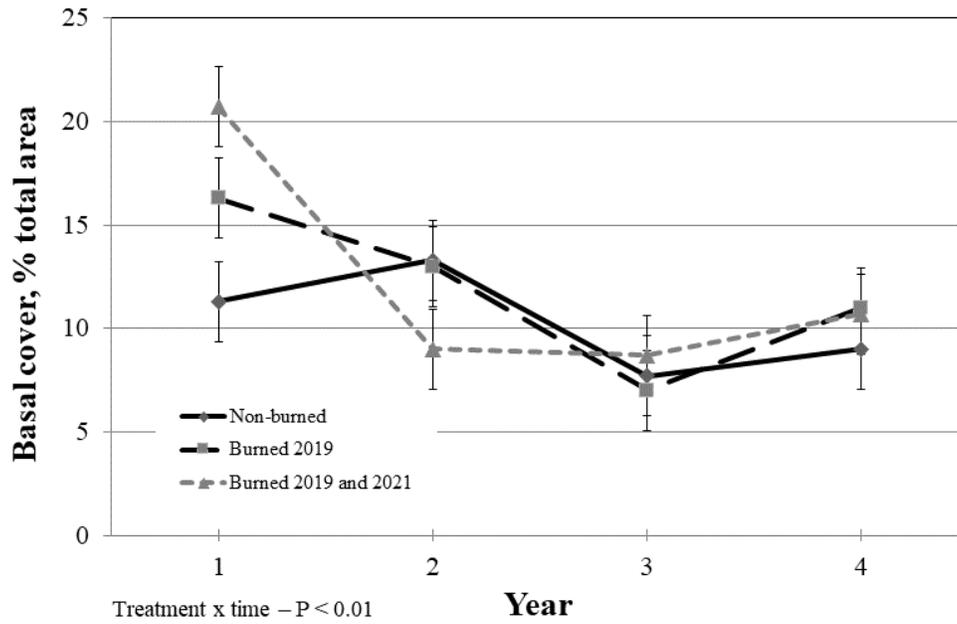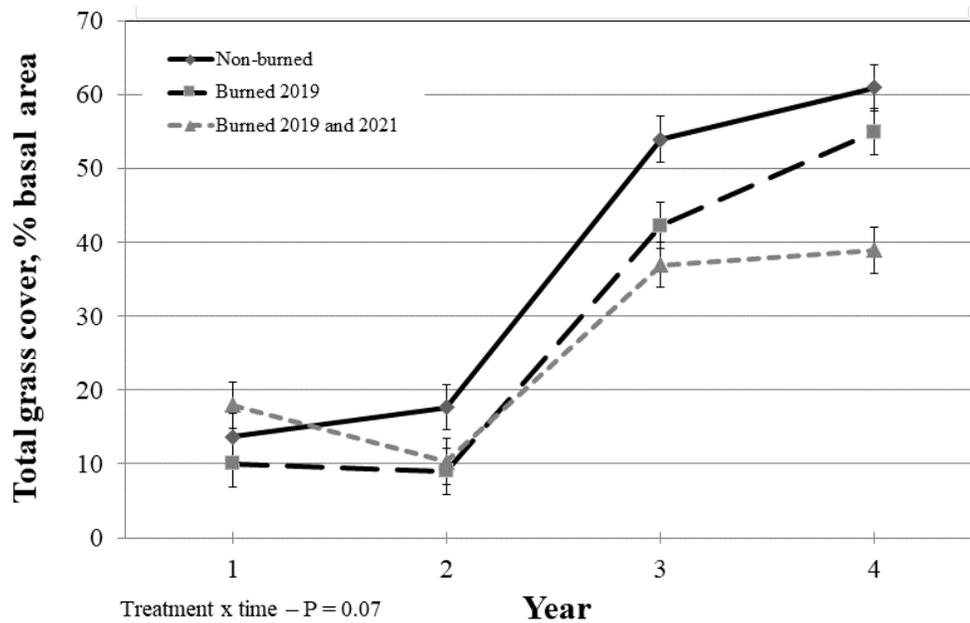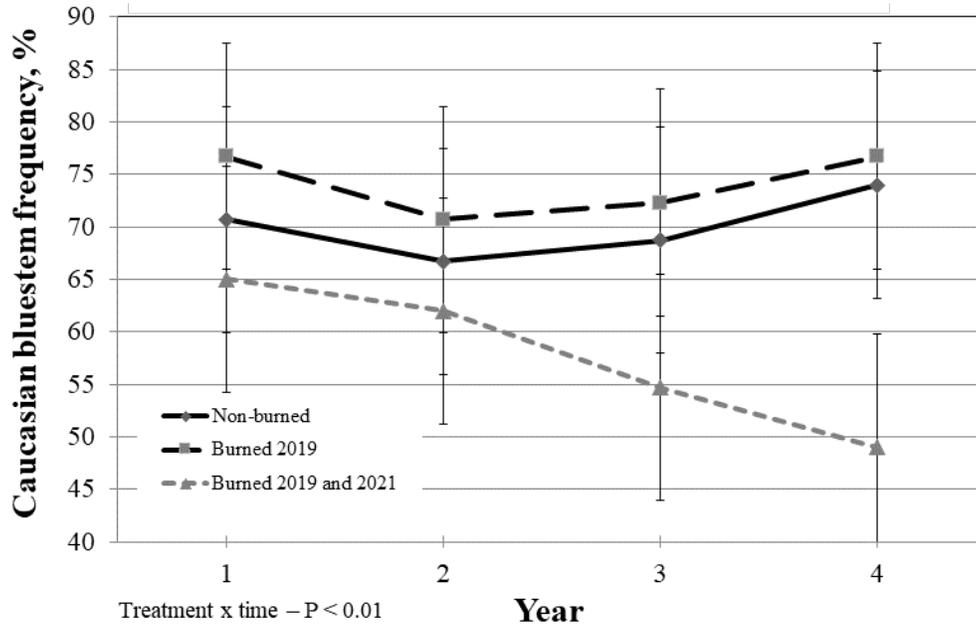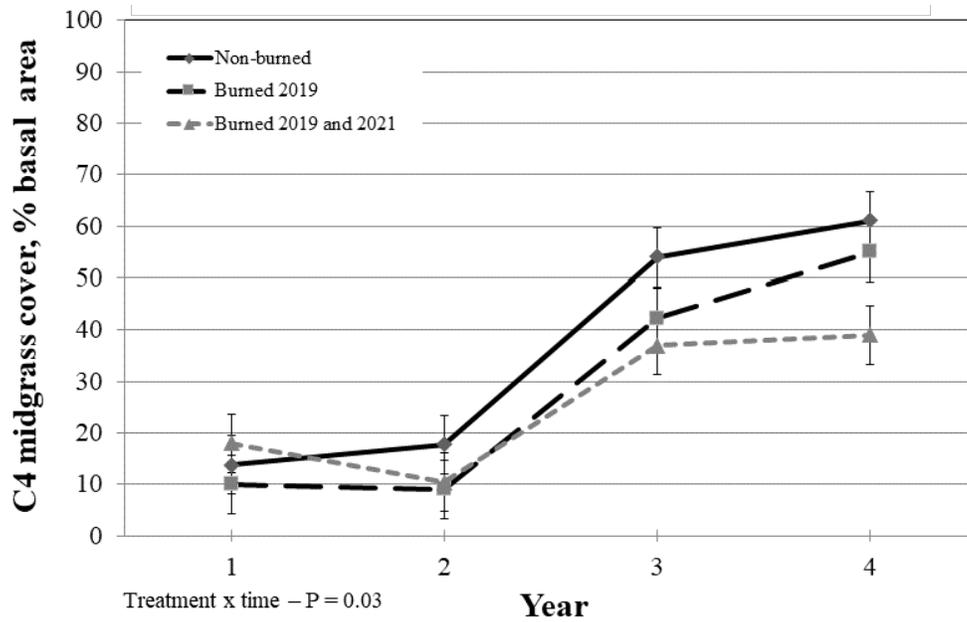**Figure 6. Effects of late summer prescribed fire on percent C4 midgrass cover.**
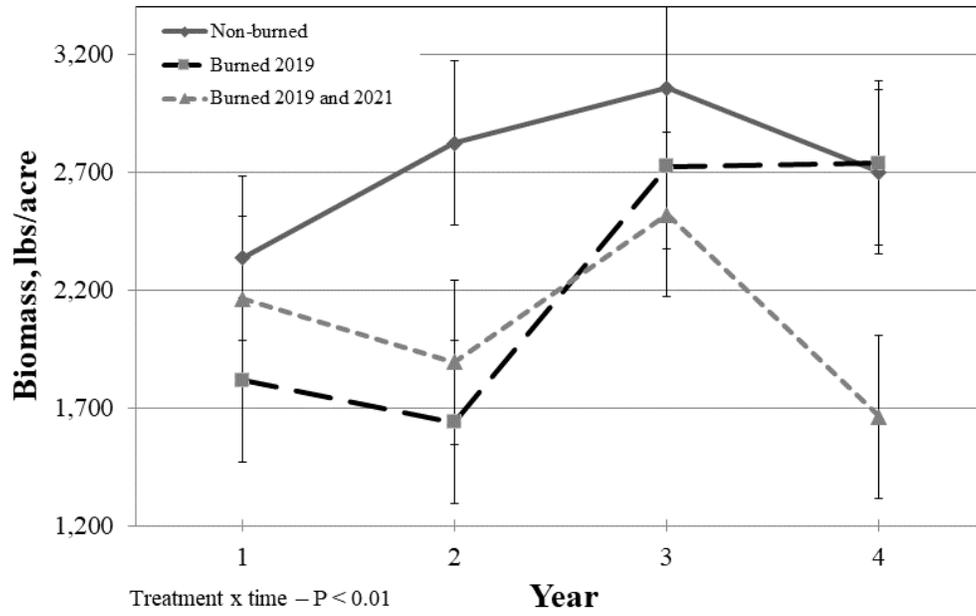
Figure 7. Effects of late summer prescribed fire on forage biomass.
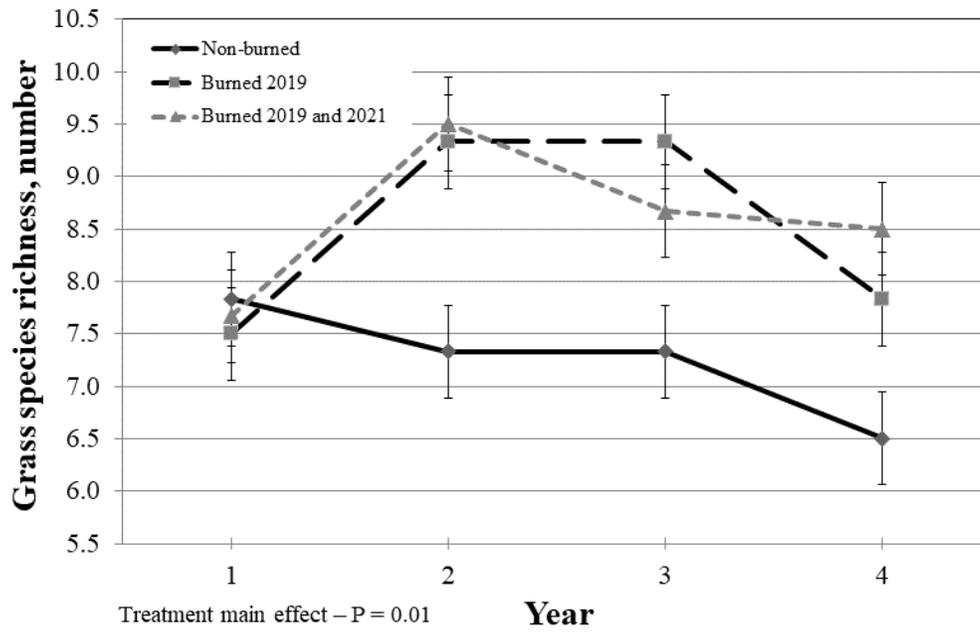
Figure 8. Effects of late summer prescribed fire on grass species richness.

Effects of Prescribed-Fire Timing on Stocker Cattle Performance, Forage Biomass Accumulation, and Native Plant Species Composition

Z.M. Duncan, A.J. Tajchman, J. Lemmon, W.R. Hollenbeck, D.A. Blasi, and K.C. Olson

Abstract

Shifting the timing of prescribed fire application from spring (i.e., April) to late summer (i.e., August) or early fall (September) can reduce sericea lespedeza (*Lespedeza cuneata*) infestation and improve native forb diversity. Currently, information evaluating effects of late-summer or early-fall prescribed fire on yearling stocker cattle growth performance is limited. Eighteen pastures were grouped by watershed and each watershed was assigned to one of three prescribed-fire treatments (n = 6 pastures per treatment): spring (April 9 ± 5.1 days), summer (August 23 ± 4.9 days), or fall (September 29 ± 8.7 days). Burn treatments were applied in years 1, 2, and 3 but were not applied in year 4 due to unfavorable burn conditions. A total of 1,416 yearling stocker calves were grazed from May to August at a stocking density of 250 lb of live weight per acre over four consecutive grazing seasons. A permanent 328-ft transect was established in each pasture and was used to determine plant species composition and soil cover using a modified step-point method. Total body weight (BW) gains tended to be greater ($P = 0.06$) for spring-burned pastures compared with fall-burned pastures, whereas total BW gains for summer-burned pastures were intermediate. Spring-season prescribed fire resulted in greater ($P < 0.01$) proportions of bare soil compared with summer- and fall-season prescribed fire. Proportions of litter on the soil surface were greatest ($P \leq 0.05$) in the summer, intermediate ($P \leq 0.05$) in the fall, and least ($P < 0.01$) in the spring. Total grass, native grass, total forb, and native forb basal cover did not differ ($P \geq 0.13$) among treatments; however, basal cover of nectar-producing forbs was greater ($P \leq 0.05$) in fall-burned pastures compared with spring- and summer-burned pastures. Overall, shifting prescribed-fire timing from spring to summer resulted in similar stocker cattle growth performance and native rangeland plant composition.

Introduction

Annual spring-season prescribed fires are traditionally applied in the Kansas Flint Hills to improve yearling stocker cattle growth performance and promote native warm-season plant growth. Although spring-season prescribed fire has become a standard management tool for Flint Hills ranchers, shifting the timing of fire from spring to late summer (i.e., August) or early fall (i.e., September/October) may be beneficial. Our research group has demonstrated late-summer (i.e., August) or early-fall (i.e., September) prescribed fires can be employed to manage sericea lespedeza (*Lespedeza cuneata*) infestations while subsequently improving native forb diversity. Sericea lespedeza is a noxious weed that has degraded more than 600,000 acres of native tallgrass prairie. In addition, shifting the timing of prescribed fire from spring to late summer or early fall may improve air quality by distributing smoke produced from burning the

Flint Hills throughout the year. Despite optimistic reports, the effects of late-summer or early-fall prescribed fire on yearling stocker growth performance has not been documented. The objective of this experiment was to evaluate the effects of prescribed-fire timing on stocker cattle growth performance, soil cover, forage biomass accumulation, and plant species composition in the Kansas Flint Hills.

Experimental Procedures

This experiment was conducted at the Kansas State University Beef Stocker Unit from June 2018 to August 2022. Eighteen pastures were grouped by watershed, and each watershed was assigned to one of three prescribed-fire treatments (n = 6 pastures per treatment): spring (April 9 ± 5.1 days), summer (August 23 ± 4.9 days), or fall (September 29 ± 8.7 days). Burn treatments were applied in years 1, 2, and 3 of the experiment. Due to unfavorable burn conditions, burn treatments were not applied in year 4. Within each pasture, a permanent 328-ft transect was established. In June 2018, pre-treatment soil cover and plant species composition were measured using a modified step-point method and measured annually in June thereafter. Standing forage biomass was determined in 2018, 2020, and 2022 by clipping vegetation within ten 0.82^2-ft frames randomly placed at 33-ft intervals along each transect. Plant material was clipped at a height of 0.39-in above the soil and dried in a forced-air oven (122°F, 96 hours).

A total of 1,416 yearling cattle were grazed over four consecutive growing seasons beginning in 2019. Calves were grazed for 90 days at a targeted density of 250 lb of live weight per acre. Three-hundred-sixty heifers [initial body weight (BW) = 621 ± 86 lb] were grazed from May 2 to July 31 in year 1; 315 steers (initial BW = 738 ± 123 lb) were grazed from May 11 to August 10 in year 2; 385 steers (initial BW = 616 ± 74 lb) were grazed from May 5 to August 3 in year 3; and 356 steers (initial BW = 722 ± 85 lb) were grazed from May 5 to August 3 in year 4. In years 1, 2, and 3 calves were purchased in Texas, whereas calves were from Texas and Nebraska in year 4. Following purchase, calves were transported to the Kansas State University Beef Stocker Unit. Upon arrival, calves were held in earth-floor pens and limit-fed a growing diet until the start of the grazing season. Prior to grazing, calves were individually weighed and randomly assigned to one of 18 pastures. On the day grazing began, calves were individually weighed, vaccinated for viral respiratory and clostridial pathogens, treated for internal and external parasites, and allocated to their assigned pasture. In addition, a growth-promoting implant was given to steers in years 2, 3, and 4. Following the 90-day grazing period, calves were gathered, and individual BW were immediately measured.

Results and Discussion

Total BW gains and average daily gains (ADG) following the fourth consecutive grazing season tended to be greater ($P \leq 0.07$; Table 1) for calves grazing spring-burned pastures compared with calves grazing fall-burned pastures, whereas total BW gains and ADG for calves grazing summer-burned pastures were intermediate and not different from spring- and fall-burned pastures. Average daily gains were 2.38, 2.27, and 2.24 lb per day for spring, summer, and fall prescribed-fire treatments, respectively. Overall, spring and summer prescribed-fire treatments resulted in similar growth performance, whereas fall prescribed fire slightly reduced BW gains when compared to spring burning. When considering fall prescribed fire for sericea lespedeza control, ranchers are encouraged to compare the costs associated with herbicide application versus the costs of reduced performance.

Forage biomass accumulation was not affected ($P = 0.58$; Table 2) by prescribed-fire treatments. Conversely, proportions of bare soil were greater ($P < 0.01$) in spring-burned pastures compared with summer- and fall-burned pastures. In addition, proportions of litter on the soil surface were greatest ($P \leq 0.05$) in the summer prescribed-fire treatment, intermediate ($P \leq 0.05$) in the fall prescribed-fire treatment, and least ($P < 0.01$) in the spring prescribed-fire treatment. Differences in proportions of bare soil and litter on the soil surface may be related to the length of time between fire application and soil cover measurements. Soil cover was determined in June of each year; therefore, as the length of time between fire application and sampling increased, proportions of bare soil decreased and proportions of litter on the soil surface increased. Conversely, basal vegetation cover did not differ ($P = 0.25$) among treatments.

Prescribed-fire timing did not affect ($P \geq 0.13$) basal cover of total grass species, native grass species, total forb species, or native forb species. In contrast, fall-burned pastures contained greater ($P \leq 0.01$) proportions of nectar-producing forbs compared with spring- and summer-burned pastures. Increased basal cover of nectar-producing forbs was interpreted to suggest prescribed fire applied later in the year (i.e., October) may benefit native birds or grassland-obligate invertebrates. In addition, fall-burned pastures tended to contain greater ($P \leq 0.08$) proportions total shrubs and increaser shrubs compared with spring-burned pastures, whereas proportions of total shrubs and increaser shrubs in summer-burned pastures were intermediate and not different ($P \geq 0.11$) from spring- and fall-burned pastures.

Implications
Data following four consecutive grazing seasons were interpreted to suggest that Flint Hills ranchers can employ summer-season prescribed fires to manage sericea lespedeza infestations without negatively impacting grazing yearling stocker growth performance, forage biomass accumulation, or native rangeland plant species composition.

Acknowledgments

Table 1. Effects of prescribed-fire timing on stocker cattle performance in the Kansas Flint Hills

Item	Prescribed fire season			SEM[1]	P-value
	Spring	Summer	Fall		
Initial BW,[2] lb	672	680	667	7.7	0.26
Final BW, lb	887[a]	886[a]	868[b]	6.8	0.03
Total BW gain, lb	214[y]	204[yz]	201[z]	5.4	0.06
ADG,[3] lb/day	2.38[y]	2.27[yz]	2.24[z]	0.060	0.07

[a,b] Within rows, means with unlike superscripts differ ($P \le 0.05$).
[y,z] Within rows, means with unlike superscripts tend to differ ($P \le 0.10$).
[1] Standard error of the mean.
[2] Body weight.
[3] Average daily gain.

Table 2. Effects of prescribed-fire timing on forage biomass accumulation, soil cover, and plant species composition in the Kansas Flint Hills

Item,	Prescribed fire season			SEM[1]	P-value
	Spring	Summer	Fall		
Forage biomass, lb/acre	1756	1919	1972	221	0.58
Soil cover, % of total area					
Bare soil	64.2[a]	50.4[b]	54.0[b]	2.60	< 0.01
Litter cover	22.1[c]	37.0[a]	31.5[b]	2.55	< 0.01
Total basal vegetation cover	13.8	12.6	14.1	0.90	0.25
Basal cover, % of total basal vegetation cover					
Total grass cover	89.6	89.4	85.5	2.60	0.24
Native grass species	85.1	85.7	79.3	3.32	0.13
Total forb cover	9.9	9.4	13.0	2.57	0.34
Native forb species	9.8	9.3	13.0	2.44	0.29
Nectar-producing forbs	1.5[b]	1.7[b]	2.9[a]	0.44	0.01
Total shrub cover	0.5[z]	1.2[yz]	1.5[y]	0.44	0.07
Increaser shrubs[2]	0.02[z]	0.11[yz]	0.24[y]	0.093	0.08

[a,b,c] Within rows, means with unlike superscripts differ ($P \le 0.05$).
[y,z] Within rows, means with unlike superscripts tend to differ ($P \le 0.10$).
[1] Standard error of the mean.
[2] Shrubs that tend to proliferate in response to grazing.

Effects of Limit Feeding and Shade Allocation on Growing Calf Performance, Water Usage, and Animal Comfort

Z.L. DeBord, Z.M. Duncan, M.G. Pflughoeft, K.J. Suhr, W.C. Ellis, W.R. Hollenbeck, S.P. Montgomery, T.J. Spore, E.C. Titgemeyer, D.A. Blasi, and A.J. Tarpoff

Abstract

A group of 852 heifers (553 ± 62 lb) were used in growing studies during the summers of 2021 and 2022 to determine the effects of diet type and shade allocation on growth performance and animal comfort. Heifers were assigned to one of four treatments: high-roughage diet fed for *ad libitum* intake or limit-fed high-energy diet offered at 2.2% of body weight (BW) daily [dry matter (DM) basis] in shaded or non-shaded pens. Pen weights were measured weekly from day 14 to 84 and individual BW were measured on days 0, 90, and 97. Pen weights were used to adjust weekly intakes of limit-fed diets. All calves were fed a single diet at 2.5% of BW daily (DM basis) between days 90 and 97 to equilibrate gut-fill among treatments. Average daily gain was greater ($P < 0.01$) for shaded calves compared with non-shaded calves. Dry matter intake was greater ($P < 0.01$) for calves fed for *ad libitum* intake compared with limit-fed calves. Gain-to-feed ratio was better ($P < 0.01$) for limit-fed calves compared with calves fed for *ad libitum* intake and was also better ($P < 0.01$) for shaded calves compared with non-shaded calves. Limit-fed heifers spent less ($P < 0.01$) time ruminating and more ($P < 0.01$) time active compared with heifers fed diets for *ad libitum* intake. Time spent ruminating was greater ($P = 0.02$) for shaded calves compared with non-shaded calves. Water usage was less ($P < 0.01$) for calves provided shade compared with calves not provided shade and was less ($P < 0.01$) for limit-fed calves compared with calves fed for *ad libitum* intake. Panting scores were lower ($P < 0.01$) for shaded calves compared with non-shaded calves. Overall, limit feeding and provision of shade both improved calf growth and feed efficiency, decreased water usage, and improved animal comfort.

Introduction

Limit feeding high-energy diets can improve feed efficiency in growing calves compared with traditional high-roughage diets fed for *ad libitum* intake. Due to incidence of heat stress across the Central Plains region, the use of shade has been evaluated as a mitigation strategy to improve animal comfort and growth performance of finishing beef cattle. To our knowledge, limited information is available about effects of limit-fed high-energy diets in conjunction with shade on growth performance of growing beef cattle. The objective of this experiment was to evaluate the impacts of limit feeding and shade access as possible strategies to improve cattle efficiency, reduce water usage, and improve animal comfort in growing cattle.

Experimental Procedures

A group of 852 predominately black-hided heifers (553 ± 62 lb) were received at the Kansas State University Beef Stocker Unit during May and June of 2021 and 2022. Heifers were blocked by truckload (eight), stratified by individual arrival weight within

block, and assigned to pens containing nine to twelve heifers. Within block, pens were assigned to one of four treatments for a total of 40 pens and 10 replications per treatment per year. The experimental design was a randomized block design with pen serving as the experimental unit.

On arrival, cattle were individually weighed, assigned a visual identification ear tag and an electronic identification ear tag, then provided 5 lb of prairie hay per animal [dry matter (DM) basis] and *ad libitum* access to water. On day 0 in 2021 (year 1), heifers were administered a 3-axial accelerometer ear tag (Allflex Livestock Intelligence Madison, WI) to measure rumination and activity. For both years, the heifers received a 7-way clostridial vaccine (Vision 7 with SPUR, Merck Animal Health, Madison, NJ), a modified-live vaccine to protect against infectious bovine rhinotracheitis, parainfluenza, and bovine viral diarrhea (Vista Once SQ, Merck, Madison, NJ), and an anti-parasitic drench (Valbazen, Zoetis Animal Health).

Prior to arrival, two shade structures (40 × 40 ft) per block were randomly assigned to cover two pens per structure; for the two pens under a common shade structure, one pen was fed each of the two dietary treatments. Shade structures provided 77 ± 6.3 ft^2 of shade per animal (Strobel Manufacturing Inc., Clarks, NE). Diets (Table 1) included a high-energy diet formulated to provide 60 Mcal of net energy for gain (NE$_g$) per 100 lb of DM fed at 2.2% of body weight (BW) daily and a high-roughage diet formulated to provide 45 Mcal of NE$_g$ per 100 lb of DM fed for *ad libitum* intake. Animals were fed once daily beginning at 7:00 a.m. using a Roto-Mix feed wagon (Model 414-14B, Dodge City, KS). Bunks were observed prior to feeding to estimate *ad libitum* intake. Refusals for *ad libitum* diets were targeted at 5% of DM fed the previous day. Using a pen scale (Rice Lake Weighing Systems, Rice Lake, WI) pen BW were measured weekly from day 14 to 84 as well as on days 0, 90, and 97. Pen weights were used to adjust feed delivery and calculate animal performance. A gut-fill equilibration period was used to account for gastrointestinal tract fill differences between treatments by providing a diet at 2.5% of BW daily (DM basis) formulated to contain 53 Mcal of NE$_g$ per 100 lb of DM to all treatment groups.

Feed ingredient samples were collected weekly. A portion of the sample was used to determine diet DM and the remaining feed sample was immediately frozen. Diet DM weights were used weekly to adjust feed offerings.

To determine the effects of shade on animal comfort, animals were evaluated at 9:30 a.m., 1:30 p.m., and 5:30 p.m. on days when the temperature humidity index (THI) was estimated to be greater than 74 (US MARC Animal Comfort Index). Using a method adapted from Guaghan et al. (2008; Table 2), individual panting score was determined using respiration rate and breathing conditions. Three animals per pen were selected randomly at each time point to represent each pen. The three values were averaged to obtain a mean panting score for each pen. Water usage was measured via iPERL water meters (SENSUS, Morrisville, NC) connected to individual automatic waterers (Lil' Spring 3000; Miraco Livestock Water Systems, Grinnell, IA) for each pen. The presented water usage and panting scores are only from year one.

Results and Discussion

Effects of diet

On day 0, BW did not differ ($P = 0.90$; Table 3) between dietary treatments; however, on day 90 BW were greater ($P < 0.01$) for calves fed for *ad libitum* intake compared with limit-fed calves. After the gut-fill equilibration period, limit-fed calves had greater ($P < 0.01$) BW compared with calves previously fed for *ad libitum* intake. This demonstrates how the diet affects gut fill and subsequently BW; it is important to equalize gut fill to obtain the best possible estimates of true BW gain. Average daily gains (ADG) from day 0 to 97 were greater ($P < 0.01$) for limit-fed heifers compared with heifers fed for *ad libitum* intake. A diet effect ($P < 0.01$; Table 3) was observed through day 97 where calves fed for *ad libitum* intake had greater DM intake compared with limit-fed calves. Dry matter intake did not differ ($P = 0.69$) between treatments during the gut-fill equilibration period, which was expected because all cattle were limit fed during this time. A diet effect was observed through day 97 for gain-to-feed where calves fed for *ad libitum* intake had worse feed efficiency than limit-fed calves; this is associated with a lower DM intake of limit-fed calves compared with calves fed for *ad libitum* intake, while ADG were greater ($P < 0.01$) for limit-fed calves compared with calves fed for *ad libitum* intake.

Heifers fed for *ad libitum* intake spent more time ruminating than limit-fed heifers ($P < 0.01$; Table 3), and the greater time spent ruminating was associated with greater DM intake and greater dietary forage concentration of the diets fed for *ad libitum* intake. Limit-fed heifers were more active ($P < 0.01$) compared with heifers fed for *ad libitum* intake.

Dietary treatments did not affect the mean panting scores. Limit-fed calves used 9% less ($P < 0.01$) water when compared with calves fed for *ad libitum* intake. Differences in water usage between diets may be attributed to differences in DM intake.

Effects of shade

On day 0, BW did not differ ($P = 0.22$; Table 3) between shaded and non-shaded calves. Heifers provided with shade had heavier ($P < 0.01$) day 90 and day 97 BW compared to heifers without access to shade. Average daily gains from day 0 to 97 were greater ($P < 0.01$) for shaded heifers compared with non-shaded heifers. Calves fed for *ad libitum* intake in shaded pens had greater ($P < 0.01$) DM intake compared with calves in non-shaded pens fed for *ad libitum* intake, whereas limit-fed calves in non-shaded pens and shaded pens did not differ in DM intake. Gain-to-feed was better ($P < 0.01$) for calves in shaded pens compared with calves in non-shaded pens.

Limit-fed heifers in shaded pens spent less time ruminating ($P < 0.01$) compared with limit-fed heifers in non-shaded pens; however, rumination time of calves fed for *ad libitum* intake was not affected by provision of shade. Heifers in shaded pens tended to be more active ($P = 0.10$) compared with heifers in non-shaded pens.

Calves in non-shaded pens had greater ($P < 0.01$; Figure 1) mean panting scores than calves in shaded pens. We attribute this difference to an increase in animal comfort due to reduced solar radiation exposure in shaded pens leading to lower heat load during the summer.

Water usage was 11% less ($P < 0.01$; Table 3) for shaded calves compared with non-shaded calves. This can be attributed to a decrease in heat load of calves in shaded pens compared with calves in non-shaded pens.

Implications

These data demonstrate that limit feeding a high-energy diet during the receiving period can improve feed efficiency and reduce water usage when compared to a higher forage diet fed for *ad libitum* intake. During periods of heat stress, shade can improve animal performance, reduce water usage, and improve animal comfort.

Acknowledgments

References

Gaughan J. B., T. L. Mader, S. M. Holt, A. Lisle. 2008. A new heat load index for feedlot cattle. J. Anim. Sci. 86:226–234. doi: 10.2527/jas.2007-0305.

Table 1. Composition of experimental diets

Ingredient, % DM	Diet[1]		
	45	60	53
Dry-rolled corn	8.6	38.8	23.8
Supplement[2]	6.4	8.2	6.9
Sweet bran[3]	40.0	40.0	40.7
Alfalfa hay	22.5	6.5	14.2
Prairie hay	22.5	6.5	14.4

[1]45 = diet containing 45 Mcal of net energy for gain (NE_g) per 100 lb of dry matter (DM) offered for *ad libitum* intake; 60 = diet containing 60 Mcal of NE_g per 100 lb of DM limit-fed at 2.2% of body weight (BW) daily (DM basis); 53 = diet containing 53 Mcal of NE_g per 100 lb of DM limit-fed at 2.5% of BW daily (DM basis).
[2]Supplement pellet formulated to contain (DM basis) 8.5% calcium, 0.64% phosphorus, 0.76% potassium, 5.0% salt, and 307 g/ton monensin (Rumensin; Elanco, Greenfield, IN).
[3]Cargill Corn Milling (Blair, NE).

Table 2. Panting score evaluation[1]

Panting score	Breathing conditions
0	No panting. Respiration <60 breaths per minute
1.0	Slight panting, mouth closed, no drool, easy to see chest movement. Respiration ~60 to 90 breaths per minute.
1.5	Moderate panting, no drool present, easy to see chest movement, mouth closed. Respiration ~60 to 90 breaths per minute.
2.0	Fast panting, drool present, mouth closed. Respiration ~90 to 120 breaths per min
2.5	Fast panting, drool present, occasional mouth panting. Respiration ~90 to 120 breaths per minute.
3.0	Occasional open mouth panting, excessive drooling, neck extended, head held up. Respiration ~120 to 150 breaths per minute.
3.5	Open mouth panting, excessive drooling, tongue slightly extended or occasionally extended for short periods. Respiration ~120 to 150 breaths per minute.
4.0	Open mouth with extended tongue for a prolonged period, excessive drooling, neck extended, and head up. Respiration may decrease. Respiration ~120 to 150 breaths per minute.
4.5	Open mouth with extended tongue for a prolonged period, excessive drooling, neck extended, head up, visible breaths from the flank, drooling may be ceased. Respiration may decrease. Respiration ~120 to 150 breaths per minute.

[1]Panting score evaluation was adapted from Guaghan et al. (2008).

Table 3. Effects of shade and diet type on growth performance, feed efficiency, rumination, activity, and water usage

| | Treatment[1] | | | | | P-value | | |
| | No shade | | Shade | | | | | |
Item	45	60	45	60	SEM	Diet	Shade	D × S
Number of pens	20	20	20	20				
Number of animals	214	213	215	210				
Body weight, lb								
Day 0	551	551	548	549	3.0	0.90	0.22	0.76
Day 90	784	772	801	787	6.2	<0.01	<0.01	0.80
Day 97	785	799	802	811	6.3	<0.01	<0.01	0.58
Average daily gain, lb/day								
Days 0 to 97	2.25	2.39	2.44	2.53	0.056	<0.01	<0.01	0.47
DM intake, lb/day								
Days 0 to 90	20.14	14.84	21.45	14.92	0.274	<0.01	<0.01	<0.01
Days 90 to 97	20.78	20.75	21.00	20.94	0.164	0.69	0.07	0.90
Gain to feed, lb/lb								
Days 0 to 97	0.112	0.158	0.114	0.165	0.003	<0.01	<0.01	0.15
Feed to gain, lb/lb								
Days 0 to 97	9.04	6.37	8.82	6.09	0.157	<0.01	0.03	0.76
Rumination,[2,3] minutes/day	473.5	423.5	476.4	399.0	6.53	<0.01	0.02	<0.01
Activity,[2,3] minutes/day	312.7	316.7	313.0	322.7	2.76	<0.01	0.10	0.14
Water usage,[3,4] gallons/day per heifer	11.9	10.8	10.6	9.8	0.28	<0.01	<0.01	0.13

[1] 45 = diet containing 45 Mcal of net energy for gain (NE_g) per 100 lb of dry matter (DM) offered for *ad libitum* intake; 60 = diet containing 60 Mcal of NE_g per 100 lb of DM limit-fed at 2.2% of body weight (DM basis) daily.

[2] Measured using 3-axial accelerometer ear tags (Allflex Livestock Intelligence, Madison, WI).

[3] Analysis of year one data only: non-shaded 45 = 105 animals; shaded 45 = 106 animals; non-shaded 60 = 100 animals; shaded 60 = 102 animals. Treatments in year one comprised 10 pens each.

[4] Measured using iPERL water meters (SENSUS, Morrisville, NC).
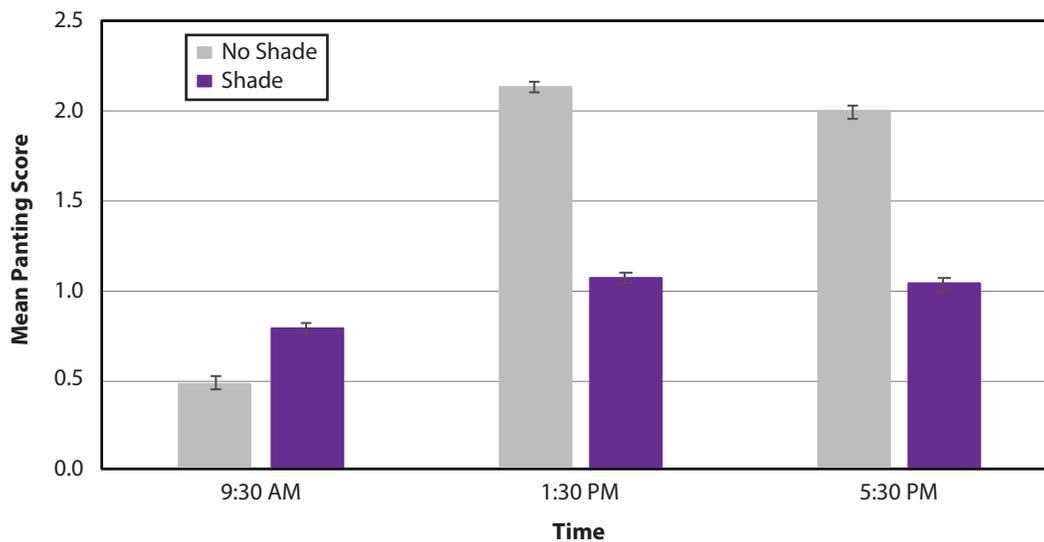
Figure 1. Effect of shade allotment on mean panting scores. Shade effect: $P < 0.01$. Standard error of the mean = 0.033. Panting score evaluation adapted from Guaghan et al. (2008).

Effects of Biuret and Lasalocid (Bovatec) Inclusion into a Commercial Mineral Supplement on Growth Performance of Yearling Calves Grazing in the Kansas Flint Hills

M.G. Pflughoeft, Z.M. Duncan, Z.L. DeBord, W.R. Hollenbeck, F.K. Brazle, E.C. Titgemeyer K.C. Olson, and D.A. Blasi

Abstract

Inclusion of feed additives (i.e., ruminal modifiers or non-protein nitrogen) to mineral supplements may improve health and performance of grazing cattle. The objective of this experiment was to evaluate the inclusion of biuret with or without Bovatec (Zoetis, Parsippany, NJ) in a commercial mineral supplement on growth performance of yearling beef calves grazing in the Kansas Flint Hills. Over a 2-year period, 742 crossbred steers [initial body weight (BW): 655 ± 52.2 lb] were randomly assigned to one of three mineral treatments (i.e., control, biuret, biuret + Bovatec). Mineral treatments were randomized into one of 18 pastures, with six pastures per mineral treatment. Steers grazed from May to August for a total of 90 days. Mineral tubs were weighed weekly to determine mineral consumption and refilled with respective mineral treatments to target a daily consumption of 4 oz per head per day. Mineral feeders were checked daily to estimate the number of days until an individual feeder was empty (days-to-empty). Total BW gains, average daily gains (ADG), and mineral consumption did not differ ($P \geq 0.15$) among mineral treatments; however, final BW were greater ($P \leq 0.03$) for biuret and biuret + Bovatec mineral treatments compared with the control mineral treatment. Initially, biuret and biuret + Bovatec led to more days-to-empty than the control ($P \leq 0.05$), but these differences disappeared by week 8.

Introduction

Mineral supplementation to cattle grazing in the Kansas Flint Hills may improve growth performance and overall profitability. A possible way to improve overall productivity of grazing cattle is through the addition of ruminal modifiers (lasalocid) or non-protein nitrogen (NPN) in mineral supplements. The objective of this experiment was to measure the effects of NPN (biuret) or NPN + ruminal modifier (biuret + lasalocid) inclusion in a commercial mineral supplement on growth performance of yearling beef calves grazing in the Kansas Flint Hills.

Experimental Procedures

Over a 2-year period, 742 crossbred steers (initial BW 655 ± 52.2 lb) previously backgrounded at the Kansas State Beef Stocker Unit were used to evaluate the effects of three mineral supplementation strategies on growth performance of yearling grazing cattle. Steers were purchased in Texas and Nebraska and randomly assigned to one of 18 pastures. Pastures were randomly assigned to one of three mineral treatments consisting of a basal supplement (control), a basal supplement with biuret and a basal

supplement with biuret and Bovatec (Zoetis, Parsippany, NJ). Biuret was included in the supplement at 300 lb/ton dry matter (DM) basis to provide 0.6 oz per day of biuret when mineral was consumed at 4 oz per head daily. Bovatec was included in the supplement at 15.50 lb/ton DM basis to provide 180 mg/head/day lasalocid when mineral was consumed at 4 oz per head daily. An identical supplement feeder (Bullmaster; Mann Enterprises, Inc., Waterville, KS) was placed in each pasture.

Prior to grazing, steers were individually assigned a pasture tag, and treated for external (Standguard; Elanco, Greenfield, IN) and internal (Valbazen; Zoetis, Parsippany, NJ) parasites. In addition, steers were administered a growth promoting implant (Ralgro; Zoetis, Parsippany, NJ). Steers were grazed for 90 days from May to August at a targeted stocking density of 250 lb of live weight per acre. Immediately prior to turn out, pasture weights were measured using a pen scale. Following initial processing, steers were sorted and allocated to pastures over a 3-day period. At the completion of the grazing period, cattle were gathered, and pasture weights were immediately measured to determine average final BW, total BW gains, and ADG.

Mineral feeder flaps were initially folded up for approximately 2 weeks to allow cattle to locate the mineral. Flaps were unfolded, in the event of inclement weather, to prevent rain from getting into the mineral tubs. Following the two-week adaptation period, flaps were folded down for the remainder of the grazing season. Tubs were checked daily to monitor mineral consumption and determine days-to-empty. Mineral tubs were weighed each week to determine weekly mineral consumption. Mineral feeders were then refilled to target a mineral consumption of 4 oz/head/day for the following 7 days.

Results and Discussion
At the conclusion of the grazing period, total BW gains, ADG, and mineral consumption did not differ among treatments ($P \geq 0.15$; Table 2). Final BW were greater ($P \leq 0.03$; Table 2) for biuret and biuret + Bovatec mineral treatments compared with the control mineral treatment. Mineral feeders were monitored for mineral consumption daily and a visual estimate was made on the number of days until each mineral feeder was empty, this was expressed as days-to-empty. In weeks two and three of the grazing period, rate of mineral consumption (i.e., days-to-empty) was greater ($P \leq 0.01$; Figure 1) for steers consuming the control mineral treatment compared with steers consuming the biuret or biuret + Bovatec mineral treatments. In addition, rate of mineral consumption during weeks 4, 5, 6, and 7 of the grazing period was greater ($P \leq 0.01$; Figure 1) for the control compared with biuret + Bovatec. Overall, mineral consumption during the beginning of the grazing period was low; however, consumption increased so days-to-empty were 2 to 4 days by week 4 of the experiment. In late June, mineral consumption decreased, coinciding with elevated ambient temperatures. After the elevated ambient temperatures, normal mineral consumption resumed, and all treatments were consistently between 2 to 4 days-to-empty at each observation.

Implications
These data were interpreted to suggest that the addition of biuret or biuret + Bovatec to commercial mineral supplement may improve growth performance of yearling beef cattle grazing in the Kansas Flint Hills.

Brand names appearing in this publication are for product identification purposes only. No endorsement is intended, nor is criticism implied of similar products not mentioned. Persons using such products assume responsibility for their use in accordance with current label directions of the manufacturer.

Table 1. Mineral ingredients and nutrient composition[1]

Item	Mineral treatment		
	Control	Biuret	Biuret + Bovatec
Ingredient, lb/ton			
Salt	485	485	485
Monocalcium phosphate 21%	385	385	385
Calcium carbonate	350	300	300.25
Dried distillers grains	310	310	310
Microlite	200	15.75	---
Dried molasses	120	120	120
Soy hulls	85	---	---
Soy oil	20	20	20
Magnesium oxide	15	30	30
Zinc oxide	15	15	15
Copper sulfate	8	8	8
Sulfur flour	---	4.25	4.25
Vitamin A 60,000	6	6	6
Ethylenediamine dihydroiodide	1	1	1
Biuret	---	300	300
Bovatec[2]	---	---	15.5
Total	2000	2000	2000

continued

Table 1. Mineral ingredients and nutrient composition[1]

	Mineral treatment		
Item	Control	Biuret	Biuret + Bovatec
Calculated nutrient composition			
DM,[3] %	96.46	97.14	97.14
Crude protein, %	5.4	42.9	42.9
Crude fat, %	2.27	2.18	2.18
Crude protein, NPN,[4] %	---	37.95	37.95
Total digestible nutrients, %	21.03	18.05	18.05
Calcium, %	10.35	9.28	9.27
Phosphorus total, %	4.24	4.2	4.2
Salt, %	24.23	24.23	24.23
Sodium, %	9.71	9.66	9.66
Chloride, %	14.74	14.74	14.74
Potassium, %	0.66	0.43	0.41
Magnesium. %	1.38	1.06	1
Sulfur, %	0.33	0.542	0.542
Manganese, ppm	197.8	137.9	132.8
Zinc, ppm	5485.6	5439.6	5435.6
Iron, ppm	1061.2	1024.3	1021.2
Copper, ppm	1019.3	1013.7	1013.3
Cobalt, ppm	52	5.93	2
Iodine, ppm	495.1	495.1	495.1
Selenium, ppm	0.056	0.056	0.056
Vitamin A, total KIU/lb	81.65	81.65	81.65
Bovatec,[2] mg/lb	---	---	705.3

[1]Designed for 4 oz intake per day, Dr. Frank Brazle, 2021, personal communication.
[2]Zoetis, Parsippany, NJ.
[3]Dry matter.
[4]Nonprotein nitrogen.

Table 2. Inclusion of biuret with or without Bovatec[1] on stocker cattle performance when grazing native grass

| Item | Mineral treatments | | | | |
	Control	Biuret	Biuret + Bovatec	SEM[2]	*P*-value
Initial, lb	653	652	659	6.2	0.66
Final BW,[3] lb	816[b]	827[a]	834[a]	4.5	0.03
Total BW gain, lb/day	162	175	174	4.9	0.15
ADG,[4] lb/day	1.80	1.94	1.94	0.05	0.15
Daily mineral intake, oz/head	3.90	3.86	3.85	0.051	0.77

[ab]Within column, means with unlike superscripts differ ($P < 0.05$).
[1]Zoetis, Parsippany, NJ.
[2]Standard error of the mean.
[3]Body weight.
[4]Average daily gain.
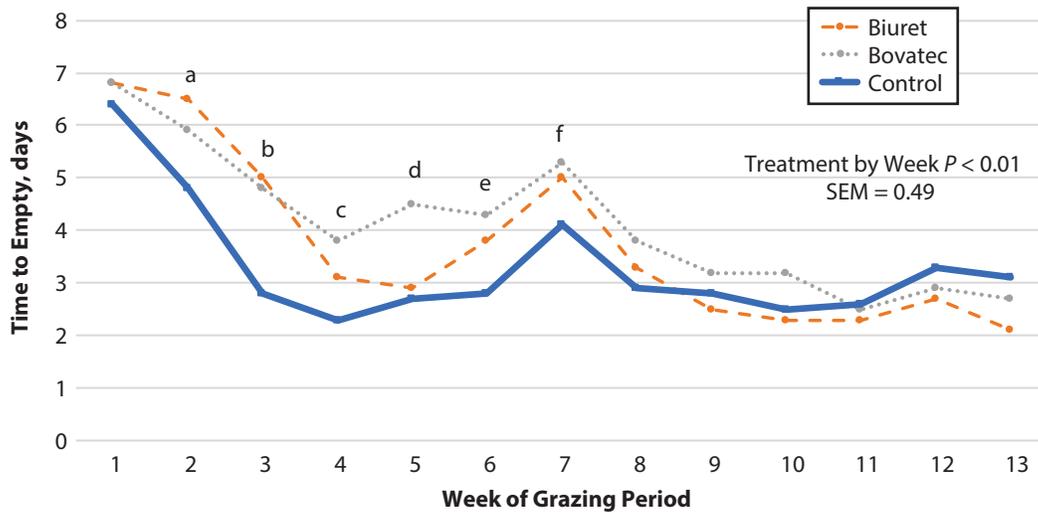
Figure 1. Effects of biuret and Bovatec (Zoetis, Parsippany, NJ) on weekly mineral consumption rate of yearling cattle grazing native grass pasture.
[a] Week 2 Biuret > Control ($P < 0.01$), Bovatec = Control ($P = 0.055$), Biuret = Bovatec ($P = 0.27$).
[b] Week 3 Biuret > Control ($P < 0.01$), Bovatec > Control ($P < 0.01$), Biuret = Bovatec ($P = 0.68$).
[c] Week 4 Bovatec > Control ($P < 0.01$), Biuret = Bovatec, Biuret = Control ($P = 0.22$).
[d] Week 5 Biuret > Bovatec ($P < 0.01$), Bovatec > Control ($P < 0.01$), Biuret = Control ($P = 0.68$).
[e] Week 6 Bovatec > Control ($P < 0.01$), Biuret = Bovatec, Biuret = Control ($P = 0.34$).
[f] Week 7 Bovatec > Control ($P = 0.04$), Biuret = Bovatec, Biuret = Control ($P = 0.58$).

Effects of Almond Hull Inclusion on Growth Performance of Limit-Fed Growing Cattle

Z.M. Duncan, Z.L. DeBord, M.G. Pflughoeft, K.J. Suhr, W.R. Hollenbeck, F.K. Brazle, E.C. Titgemeyer, K.C. Olson, and D.A. Blasi

Abstract

Almond hulls contain soluble sugars and could potentially be used as a feed ingredient in beef cattle diets. Three-hundred sixty-four steers [initial body weight (BW) 567 ± 45.7 lb] were blocked by source (4) and assigned to one of four treatments to determine the effects of almond hull inclusion on growth performance of limit-fed beef cattle. The control diet (CON) contained [dry matter (DM) basis] 39.5% dry-rolled corn, 7.5% supplement, 40% wet-corn gluten feed, and 13% prairie day. Non-processed almond hulls replaced prairie hay and were fed at 13% of dietary DM (13AH) or replaced prairie hay and a proportion of dry-rolled corn and were fed at 26% of dietary DM (26AH). In addition, a subset of almond hulls was processed using a grinder mixer with no screen. Processed almond hulls replaced prairie hay and were fed at 13% of dietary DM (13PAH). Steers were limit-fed at 2.2% of BW daily (DM basis) for a 56-day growing period. Individual BW were measured on days 0, 14, and 56. Body weights following the 56-day feeding period were greater ($P < 0.01$) in 13AH and 13PAH compared with 26AH. In addition, BW on day 56 tended ($P = 0.10$) to be greater in 13PAH compared with CON. Average daily gains and DM intakes from days 0 to 56 were greater ($P \leq 0.05$) in 13PAH, 13AH, and CON compared with 26AH. As a result, gain-to-feed ratio from days 0 to 56 was greater ($P \leq 0.02$) in 13PAH and 13AH compared with 26AH and tended to be greater ($P = 0.10$) in CON compared with 26AH. Overall, replacing proportions of dry-rolled corn with almond hulls reduced growth performance; however, final BW were similar among steers fed prairie hay or almond hulls at 13% of dietary DM.

Introduction

The California almond crop was estimated to produce 2.8 billion pounds of almonds in 2022. Almond hulls are by-product of almond production and contain soluble sugars that make them a suitable ingredient in livestock diets. Currently, almond hulls are primarily marketed to local California dairies. Unfortunately, increased regulations have resulted in a decline in the California dairy inventory. Almond hulls could potentially be incorporated as a feed ingredient in beef cattle diets; however, the current bulk density of almond hulls make transporting them long distances to cattle-feeding areas difficult. In addition, research evaluating almond hull inclusion in beef cattle diets is limited. The objective of this experiment was to evaluate the effects of almond hull inclusion and almond hull processing on growth performance of limit-fed growing beef cattle.

Experimental Procedures

Three-hundred sixty-four steers [initial body weight (BW) 567 ± 45.7 lb] were purchased in Nebraska and Texas and transported to the Kansas State Beef Stocker Unit. Four truckloads were received between February 17, 2022 and February 21,

2022. Upon arrival, steers were held in earth floor pens and fed the control diet at 2.2% of BW daily [dry matter (DM) basis]. A randomized block design was used to determine the effects of almond hull inclusion in limit-fed growing beef cattle diets. Steers were blocked by source (4), stratified by day -1 BW, and randomly assigned to pens containing 7 to 11 steers. Blocks 1 and 2 contained 12 pens per block and blocks 3 and 4 contained 8 pens per block. Within block, pens were randomly assigned to one of four treatments for a total of 40 pens and 10 replications per treatment.

Composition of experimental diets is presented in Table 1. The control diet (CON) contained (DM basis) 39.5% dry-rolled corn, 7.5% supplement, 40% wet-corn gluten feed, and 13% prairie hay. Non-processed almond hulls replaced prairie hay and were fed at 13% of dietary DM (13AH) or prairie hay and dry-rolled corn and were fed at 26% (26AH) of dietary DM. In addition, a subset of almond hulls was processed using a grinder mixer (Gehl 100 Mix-All, Gehl, West Bend, WI) with no screen. Processed almond hulls replaced prairie hay and were fed at 13% of DM (13PAH).

On March 6, 2022 steers were individually weighed and a visual identification tag was applied. The following morning (day 0), steers were weighed individually, vaccinated against viral respiratory and clostridial pathogens, and treated for external parasites. On day 14, calves were revaccinated against viral respiratory pathogens. Beginning on day 0, steers were limit-fed their respective treatment diets at 2.2% of BW daily (DM basis) for a 56-day period. Feed was mixed and delivered once daily beginning at 7:00 a.m. using a using a Roto-Mix feed wagon. Individual BW were measured on days 0, 14, and 56 and pen weights were measured weekly to determine feed offered the following week.

Results and Discussion

Body weights on day 0 did not differ ($P = 0.22$; Table 2) among treatments; however, BW on day 14 tended ($P = 0.09$) to be greater in 13PAH compared with 26AH. Body weights at the completion of the 56-day period were greater ($P <0.01$) in steers fed 13PAH and 13AH compared with calves fed 26AH. In addition, day 56 BW tended to be greater ($P = 0.10$) in 13PAH compared with CON and tended to be greater ($P = 0.06$) in CON compared with 26AH. Average daily gains (ADG) from day 0 to 56 were greater ($P ≤ 0.05$) in 13PAH, 13AH, and CON compared with 26AH. Although overall ADG were similar for steers fed 13PAH, 13AH, and CON, differences in ADG from days 14 to 56 were observed. Average daily gains from days 14 to 56 were greater ($P = 0.03$) in 13PAH compared with CON and tended to be greater ($P = 0.09$) in 13AH compared with CON. These data were interpreted to suggest that once steers were adapted to almond hulls in the diet, ADG were improved when almond hulls replaced prairie hay at 13% of dietary DM. The adaptation in the initial 14 days likely reflected differences among treatments in gut fill.

Dry matter intakes from days 14 to 56 and days 0 to 56 were greater ($P ≤ 0.05$) in 13PAH, 13AH, and CON compared with 26AH. Differences in DM intake were associated with improved weight gains in steers fed 13PAH, 13AH, and 26AH. Feed delivery was calculated each week by multiplying weekly average pen weight by 2.2% of BW (DM basis); therefore, greater ADG in steers fed 13PAH, 13AH, and CON resulted in greater average pen weights and ultimately more feed delivered compared with steers fed 26AH. Similarly, gain-to-feed ratio from days 0 to 56 was greater

($P \leq 0.02$) in steers fed 13PAH and 13AH compared with steers fed 26AH. In addition, gain-to-feed ratio from days 0 to 56 tended to be greater ($P = 0.10$) in CON compared with 26AH.

Replacing prairie hay with almond hulls at 13% of dietary DM resulted in similar final BW in limit-fed growing calves; however, improved ADG from days 14 to 56 in calves fed 13AH and 13PAH were interpreted to suggest almond hull inclusion may result in improved growth performance compared with prairie hay inclusion when cattle have adapted to almond hulls in the diet. Conversely, replacing proportions of dry-rolled corn with almond hulls reduced BW gains and feed efficiency.

Implications
These data were interpreted to suggest almond hulls can be utilized as an alternative to prairie hay in limit-fed growing beef cattle diets while maintaining or slightly improving growth performance.

Acknowledgments
Appreciation is expressed to the Almond Board of California for financial support of this study.

Table 1. Composition of experimental diets

Ingredient, % dry matter	Diet			
	Control	13AH	13PAH	26AH
Dry-rolled corn	39.5	39.5	39.5	26.5
Supplement[1]	7.5	7.5	7.5	7.5
Sweet Bran[2]	40.0	40.0	40.0	40.0
Prairie hay	13.0	---	---	---
Almond hulls	---	13.0	---	26.0
Processed almond hulls	---	---	13.0	---

[1] Supplement pellet formulated to contain (DM basis) 8.5% calcium, 0.64% phosphorus, 0.76% potassium, 5.0% salt, and 307 g/ton monensin (Rumensin; Elanco, Greenfield, IN).
[2] Cargill Corn Milling (Blair, NE).

Table 2. Effects of almond hull inclusion on growth performance of limit-fed growing steers

Item	Diet[1] CON	13AH	13PAH	26AH	SEM[2]	Treatment P-value
Number of pens	10	10	10	10		
Number of animals	91	91	91	91		
Body weight, lb						
Day 0	573	578	577	572	3.9	0.22
Day 14	595[yz]	595[yz]	598[y]	586[z]	4.9	0.09
Day 56	720[aby]	729[a]	734[ax]	703[bz]	8.4	< 0.01
Average daily gain, lb/day						
Days 14 to 56	2.97[bcz]	3.18[aby]	3.24[a]	2.80[c]	0.115	< 0.01
Days 0 to 56	2.63[a]	2.69[a]	2.80[a]	2.36[b]	0.133	0.02
Dry matter intake, lb/day						
Days 14 to 56	14.64[a]	14.59[a]	14.69[a]	14.25[b]	0.159	0.04
Days 0 to 56	13.88[a]	13.82[a]	13.93[a]	13.55[b]	0.131	0.03
Gain-to-feed, lb/lb						
Days 14 to 56	0.205[b]	0.222[a]	0.222[a]	0.205[b]	0.008	< 0.01
Days 0 to 56	0.191[aby]	0.198[a]	0.202[a]	0.176[bz]	0.010	0.04
Feed-to-gain, lb/lb						
Days 14 to 56	5.05[b]	4.65[a]	4.64[a]	5.23[b]	0.188	< 0.01
Days 0 to 56	5.44[aby]	5.18[a]	5.15[a]	5.93[bz]	0.275	0.03

[1]CON = prairie hay fed at 13% of dietary dry matter (DM); 13AH = almond hulls fed at 13% of dietary DM; 13PAH = processed almond hulls fed at 13% of dietary DM; 26AH = almond hulls fed at 26% of dietary DM.
[2]Standard error of the mean.
[a,b,c] Within row, means with unlike superscripts differ ($P \leq 0.05$).
[x,y,z] Within row, means with unlike superscripts tended to differ ($P \leq 0.10$).

Assessment of Novel Semen Evaluation Technologies and Breed Comparisons in Yearling Beef Bulls

A.R. Hartman, I.E. Batey, D.M. Grieger, and K.E. Fike

Abstract

The objective of this study was to evaluate correlations of sperm quality assessments and breed comparisons as observed during yearling beef bull breeding soundness exams (BSE). Ejaculates were collected via electroejaculation from yearling Charolais (n = 23) and Angus (n = 23) bulls as part of BSE. One veterinarian conducted BSE, and one technician conducted sperm quality assessments. Additional sperm motility analysis was conducted with the iSperm. Ejaculates meeting minimum thresholds for passing a BSE were subjected to flow cytometry. Pearson's correlation coefficients were determined, and breed comparisons were made using GLIMMIX in SAS. The iSperm analyzer gross and progressive motilities were correlated ($r = 0.30$; 0.38; $P < 0.001$) with the progressive motility assessed by the technician. Neither iSperm ($P = 0.26$) nor visual assessment ($P = 0.66$) of sperm motility differed between breeds. Bull breed did not influence total percentage of viable cells ($P = 0.83$), percentage of viable cells with intact acrosomes ($P = 0.83$), or percentage of live sperm cells with positive reactive oxygen species (ROS) status ($P = 0.92$). Sperm from Charolais bulls ($31.1\% \pm 3.35$) tended ($P = 0.10$) to have greater percentage of positive mitochondrial energy potential as compared with Angus bulls ($17.6\% \pm 3.35$). Percentage of live spermatozoa with negative ROS status was moderately correlated with the percentage of spermatozoa exhibiting secondary abnormalities ($r = 0.33$; $P = 0.02$). Percentage of live spermatozoa with disrupted acrosomes was strongly correlated ($r = 0.66$; $P < 0.001$) with percentage of live spermatozoa with negative ROS. Percentage of live spermatozoa with positive ROS status was correlated ($r = 0.58$; $P < 0.001$) with percentage of spermatozoa with active mitochondrial membranes. Sperm motility data assessed by the technician and iSperm data are positively correlated, offering producers an on-farm evaluation tool. Though the bull breed had little influence on sperm quality assessments, negative ROS status appears to impair sperm health and function.

Introduction

There is currently no definitive test that evaluates a bull's fertility. Current semen evaluation techniques include evaluation of motility and morphology, and although these are insightful tools for bull fertility, they are not definitive fertility tests and are highly subjective. In recent years many new fertility markers have been identified that provide an objective analysis of spermatozoa and an insight into identifying sub-fertile bulls. The use of flow cytometry is a method of analysis that works through excitation and emissions spectra and aids in the detection of fertility markers. Specific colors bind to sperm based on the functional status of the individual cells. In recent years development of assays that target components known to be essential to bull fertility has advanced our knowledge of sperm functional statuses (Bucher et al., 2019). Reactive oxygen species are endogenous, highly reactive, oxygen- and nitrogen-bearing molecules that can be found throughout the body (Krumova and Gonzalo, 2016). In semen, ROS affects sper-

matozoa characteristics, including mitochondrial membrane potential, acrosomal integrity, and structural abnormalities that can influence spermatozoa function. In bulls, the presence of ROS in semen has been shown to have a direct impact on the function of spermatozoa as well as a relationship to bull fertility (Kumaresan et al., 2017; Leite et al., 2022).

Use of on-farm technologies for semen evaluation in cattle is limited; however, a product called the iSperm offers hope that these technologies may become more accessible. The iSperm works through the camera on an iPad Mini and is a relatively easy-to-use, affordable, and portable semen analysis device. This device has been validated in equines and canines but not in the bovine (Moraes et al., 2019; Dini et al., 2019; Domain et al., 2022).

Bull breed influences bull fertility. Barth and Waldner (2002) found that Angus bulls were more likely to pass a BSE than Charolais bulls, and Brito et al. (2002) found differences in motility and ejaculate concentrations among *Bos taurus* bulls when compared to *Bos indicus* but proposed no suggested explanation for these differences. Others have shown that breed influences motility, morphology, concentration, and volume of ejaculates (Hartman, 2021). As the need for a better understanding of bull fertility grows, the influence of breed has been largely understudied.

Experimental Procedures

Ejaculates were collected via electroejaculation on one of three consecutive days from Angus and Charolais yearling bulls (403 ± 11 days of age; n = 46) as part of a BSE. One veterinarian conducted all BSE, and ejaculates were evaluated by one technician. Ejaculates were diluted in BoviFree to accomplish a 1:5 dilution based on manufacturer recommendations, and an additional sperm motility and concentration analysis was conducted with the iSperm analyzer. Ejaculates meeting minimum thresholds for passing a BSE were diluted to 70 million cells/mL using BoviFree and sent overnight for flow cytometry evaluation. Flow cytometry assays included acrosome and cell membrane integrity, mitochondrial energy potential, and oxidation status.

Data for analysis comparisons were assessed using Pearson's correlation coefficients in SAS. The GLIMMIX procedure of SAS with bull as experimental unit, bull breed as the main effect, and collection date as a random variable was used to assess potential differences in sperm quality variables between breeds.

Results and Discussion

Percentage of live spermatozoa with positive ROS status was correlated ($r = 0.53$; $P < 0.001$) with percentage progressive motility (Table 1). Percentage of live spermatozoa with negative ROS status was moderately correlated with percentage spermatozoa exhibiting secondary abnormalities ($r = 0.33$; $P = 0.02$) and tended to be lowly correlated ($r = 0.28$; $P = 0.06$) with percentage spermatozoa exhibiting primary abnormalities. Percentage of live spermatozoa that had disrupted acrosomes was strongly correlated ($r = 0.66$; $P < 0.001$) with percentage live spermatozoa with negative ROS and moderately negatively correlated ($r = -0.31$; $P = 0.04$) with percentage live spermatozoa with positive ROS. These results for the relationship between ROS and acrosome integrity are similar to those observed by Kumaresan et al. (2017). The percentage of live spermatozoa with positive ROS status was correlated ($r = 0.58$; $P < 0.001$) with the

percentage of spermatozoa with active mitochondrial membranes. Leite et al. (2022) found that when there were increased levels of ROS and impaired mitochondrial membranes, this often resulted in lower fertility in bulls, which supports our findings of this relationship. Live spermatozoa with positive ROS were strongly correlated ($P < 0.001$) with live spermatozoa ($r = 0.94$) and live spermatozoa with intact acrosomes ($r = 0.92$). Bucher et al. (2019) found that evaluation of the viability, acrosomal status, and mitochondrial function of cryopreserved bovine sperm could be predictive of sperm functional status. Thus, our data confirm previous research showing detrimental effects of ROS on spermatozoa function.

Both gross and progressive motilities were significantly correlated ($r = 0.30$; 0.38; $P < 0.001$) to the technician's assessment of progressive motility. These results are similar to previous research comparing assessments by technicians to the iSperm when evaluating stallion semen (Moraes et al., 2019; Dini et al., 2019). Our results are comparable to previous results when validating the iSperm for canine use (Domain et al., 2022).

Neither iSperm ($P = 0.26$) nor visual assessment ($P = 0.66$) of sperm motility differed among breeds (Table 2). Bull breed did not influence the total percentage of viable cells ($P = 0.83$) or viable cells with intact acrosomes ($P = 0.83$). When evaluating oxidation status by measuring reactive oxygen species, the bull breed did not influence ($P = 0.92$) the percentage of live sperm cells with positive reactive oxygen species status. There was a tendency ($P = 0.10$) for a greater percentage of sperm from Charolais bulls (31.1% ± 3.35) to have positive mitochondrial energy potential as compared with Angus bulls (17.6% ± 3.35). These results differ from those found by Barth and Waldner (2002), who saw differences in motility in relation to BSE between Angus and Charolais bulls. In our study, the bull breed appears to have little influence on sperm quality assessments among yearling bulls meeting the threshold requirements for passing BSE.

Implications

Technician and iSperm assessment of sperm motility data are positively correlated, offering producers an on-farm evaluation tool. Though the bull breed has little influence on sperm quality assessments, negative ROS status in sperm appears to impair sperm health and function.

Acknowledgments

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Table 1. Pearson's correlation coefficients of sperm attributes from ejaculates collected following breeding soundness exams

Item	% Live negative ROS spermatozoa[1]	% Live positive ROS spermatozoa[2]
	r (*P*-value)	
% Primary abnormalities[3]	0.28 (0.06)	-0.15 (0.33)
% Secondary abnormalities[4]	0.33 (0.02)	-0.23 (0.12)
% Progressive motility[5]	-0.27 (0.10)	0.53 (<0.001)
% Live with intact acrosome[6]	-0.16 (0.29)	0.92 (<0.001)
% Live with disrupted acrosome[7]	0.66 (<0.001)	-0.31 (0.04)
% Live[8]	-0.19 (0.22)	0.94 (<0.001)
% Polarized[9]	0.03 (0.84)	0.58 (<0.001)

[1]Percentages of spermatozoa from ejaculate with an intact cell membrane that have negative reactive oxygen species (ROS).
[2]Percentages of spermatozoa from ejaculate with an intact cell membrane that have positive ROS.
[3]Percentage of spermatozoa from ejaculate exhibiting primary abnormalities.
[4]Percentage of spermatozoa from ejaculate exhibiting secondary abnormalities.
[5]Percentages of spermatozoa from ejaculate that are progressively motile.
[6]Percentage of spermatozoa from ejaculate with an intact cell membrane and acrosome.
[7]Percentage of spermatozoa from ejaculate with an intact cell membrane and disrupted acrosome.
[8]Percentage of spermatozoa from ejaculate with an intact cell membrane.
[9]Percentage of spermatozoa from ejaculate with polarized mitochondrial membranes.

Table 2. Sperm quality assessments using visual analysis and flow cytometry on ejaculates from Angus and Charolais breeds of yearling bulls meeting BSE threshold requirements

Factor	Least squares mean ± Standard error of mean		
	Angus n = 23	Charolais n = 23	*P*-value of factor
Bull age, days	402.9 ± 2.36	403.3 ± 2.36	0.90
Semen characteristic			
Technician progressive motility,[1] %	43.7% ± 1.69	47.39 ± 1.69	0.26
iSperm progressive motility,[2] %	50.1 ± 2.26	47.8 ± 3.18	0.66
iSperm gross motility,[2] %	71.6 ± 2.78	70.5 ± 2.78	0.82
Cells live and viable,[3] %	42.3 ± 3.95	43.6 ± 3.95	0.83
Cells live with intact acrosome,[4] %	41.5 ± 3.40	42.6 ± 3.40	0.83
Cells viable with positive reactive oxygen species,[5] %	29.1 ± 3.52	28.5 ± 3.52	0.92
Active mitochondrial potential,[6] %	17.6 ± 3.35	31.1 ± 3.35	0.10

[1]Ejaculate gross motility was analyzed by a single veterinarian as a part of a breeding soundness exam.
[2]Progressive and gross motility of each ejaculate were analyzed using the iSperm software and manufacturer recommendations.
[3]Percentages of live and viable cells were determined by flow cytometry using the Invitrogen Live/Dead sperm viability kit.
[4]Percentages of live cells with intact acrosomes and sperm membrane integrity were determined by flow cytometry using the IMV Technologies acrosome and sperm membrane integrity assay.
[5]Percentages of viable cells with a positive reactive oxygen species were determined by flow cytometry using the IMV Technologies Easy Kit 3: Oxidation molecule D assay.
[6]Percentages of spermatozoa with active mitochondrial potential were determined by flow cytometry using IMV Technologies Easy Kit 2: Mitochondrial activity assay.

Delayed Timing of Insemination Relative to Estrus Improves Pregnancy to Artificial Insemination With Sex-Sorted Semen in Beef Heifers

K. Aubuchon, J.A. Odde,[1] A.R. Hartman, K.E. Fike, and K.G. Odde

Abstract

The objective was to evaluate the effect of timing of insemination relative to the onset of estrus when using sex-sorted semen in beef heifers. Estrous cycles of beef heifers were synchronized using the melengestrol acetate with prostaglandin (MGA-PG) protocol and were visually observed for signs of estrus every four hours for five days following injection of $PGF_{2\alpha}$. Following visual detection of estrus, heifers were inseminated with semen sorted to contain X-chromosome bearing sperm cells from either an Angus or Simmental sire (packaged at 4.0×10^6 live cells per 0.25 mL straw of SexedULTRA 4M). Heifers were retrospectively categorized into one of the three following intervals from time of estrus onset to insemination: 1) 12.5–15.9 hours; 2) 16.5–21.0 hours; and 3) 21.4–27.5 hours. Heifers with the shortest interval (12.5–15.9 hours) from estrus onset to insemination had a similar ($P > 0.10$) AI pregnancy rate (51.4%) as compared with heifers with the estrus onset to insemination interval of 16.5 to 21 hours (56.3%). Heifers inseminated 21.4 to 27.5 hours following estrus onset achieved a greater ($P \leq 0.05$) artificial insemination pregnancy rate (75.9%) than heifers inseminated 12.5 to 15.9 hours following estrus onset (51.4%).

Introduction

The ability to determine gender at conception has been a widely desired technology that has been available commercially for less than 20 years (Garner and Seidel, 2008; Seidel and DeJarnette, 2021). A beef producer can potentially benefit from use of sex-sorted semen in decreasing incidence of dystocia or in targeting production of replacement females, seedstock bulls, or male calves to be fed for harvest. Sex-sorted semen use in fixed-time artificial insemination programs for beef females, however, has been shown to result in pregnancy rates that are 75–85% of those observed with conventional semen (Oosthuizen, et al., 2021; Perry et al., 2020; Thomas et al., 2019). The sorting process affects function and life span of sex-sorted sperm (Carvalho et al., 2013, Moce et al., 2006) and fewer sperm cells are packaged in a dose of sex-sorted semen, contributing to decreased pregnancy rates. It has been suggested that semen deposition of sex-sorted semen nearer time of expected ovulation in beef females may improve pregnancy outcomes (Thomas et al., 2014; Oosthuizen et al., 2021). Chebel and Cunha (2020) did not observe an improvement in pregnancy outcomes to artificial insemination (AI) in dairy heifers with delayed insemination. These studies were conducted using fixed-time AI programs and thus actual onset of estrus and timing from estrus onset to insemination were not necessarily known. The objective of this study was to evaluate the effect of timing of insemination relative to the onset of estrus on pregnancy outcome when using sex-sorted semen in beef heifers.

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[1] Odde Ranch, Pollock, SD.

Experimental Procedures

This trial was conducted on a commercial beef ranch in north-central South Dakota. Ninety-eight crossbred beef heifers housed in a drylot setting were subjected to the MGA-PG estrous synchronization protocol. Heifers were fed MGA for 14 days in an amount of 0.5 mg/head/day. Eighteen days after the last feeding of MGA, heifers were injected with 5 mL of $PGF_{2\alpha}$ (Lutalyse; Zoetis, Madison, NJ). Estrous detection aids (Estrotect, Rockway Inc., Spring Valley, WI) were applied at the time of $PGF_{2\alpha}$ injection. Following injection of $PGF_{2\alpha}$ heifers were visually observed for estrus every 4 hours for the next 5 days. Heifers were determined to have exhibited estrus when they were seen standing to be mounted, when >50% of the Estrotect patch coating was removed, or the Estrotect patch was missing. After the earliest observation of estrus, heifers were inseminated 12.5–27.5 hours later (retrospectively determined) with semen sorted to contain X-chromosome bearing sperm cells from either an Angus or Simmental sire (packaged at 4.0×10^6 live cells per 0.25 mL straw of SexedULTRA 4M, STgenetics, Navasota, TX). Ninety-eight heifers were visually observed in estrus and retrospectively divided into one of the three following intervals from time of estrus onset to insemination: 1) 12.5–15.9 hours (n = 37); 2) 16.5–21.0 hours (n = 33); and 3) 21.4–27.5 hours (n = 28) for this analysis.

Pregnancy diagnosis was conducted 65–70 days post-insemination via transrectal ultrasonography (ReproScan XTC equipped with a 4.0 MHz 60mm convex rectal probe; ReproScan, Winterset, IA). Fetal size was used to differentiate AI pregnancies from natural service pregnancies.

Results and Discussion

The results of this study support the suggestion that delayed insemination following estrus may be advantageous for increasing AI pregnancy rates when using sex-sorted semen in beef heifers. A 24.5 percentage point improvement in AI pregnancy rate was observed among heifers inseminated 21.4 to 27.5 hours after observed estrus (75.9%) as compared with insemination 12.5 to 15.9 hours after observed estrus (51.4%; Table 1).

The timing from the onset of estrus to ovulation in cattle has been found to range from 24 to 32 hours (Senger, 2012). Research by White et al. (2002) showed that the average time of ovulation relative to the onset of estrus was 31.1 hours. Oosthuizen et al. (2021) have recently demonstrated improved pregnancy outcomes with delayed insemination and use of strategies that synchronize ovulation timing when using sexed semen in fixed-time AI protocols in beef heifers. Extent of synchrony of estrus among heifers and whether estrus is expressed at all before insemination in a fixed-time AI system could be affecting pregnancy outcomes which were relatively unknown. In the present study, with frequent observation of estrus, we were able to definitively categorize heifers into three time intervals to more precisely evaluate effect of interval from estrus to insemination alone.

Based on previous research, we speculate that the functional changes imposed on sperm from the sorting process may explain the benefit of delayed insemination on pregnancy outcomes. Sex-sorted sperm display altered motility and reduced capacity to fertilize oocytes (Steele et al., 2020). Embryos resulting from fertilization with sex-sorted sperm have impaired development as well. Deposition of sperm into the female reproductive tract at a later time following observation of estrus (and nearer time of ovulation)

likely improves opportunity for these altered sex-sorted sperm to successfully reach and fertilize the oocytes. Additional research investigating more multiple estrus to insemination intervals, with greater numbers of females and across multiple herds, is warranted to further our understanding.

Implications

We interpret the results of this study to indicate an advantage to delaying insemination of beef heifers from the traditional 12 hours following observation of estrus to 21 to 27 hours after onset of estrus when using sex-sorted semen.

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Table 1. Effect of interval from observed estrus to insemination on AI[1] pregnancy rate using sex-sorted semen in crossbred beef heifers

Estrus onset to insemination interval range[2]	Number	AI pregnancy rate
Overall	98	60.2%
12.5–15.9 hours[3]	37	51.4%[a]
16.5–21.0 hours[4]	33	56.3%[ab]
21.4–27.5 hours[5]	28	75.9%[b]

[ab] Values within a column without a common superscript are different ($P \leq 0.05$).
[1] Artificial insemination.
[2] Interval of time from when heifers were detected in estrus (with observation occurring every 3 to 4 hours) to the time of insemination. Average interval from estrus to insemination was 18.5 hours (range: 12.5–27.5 hours).
[3] Average interval from estrus to insemination was 14.7 hours.
[4] Average interval from estrus to insemination was 17.9 hours.
[5] Average interval from estrus to insemination was 24.3 hours.

Sire Distribution of Calves in a Beef Herd with Use of Fixed Time Artificial Insemination Followed by Immediate Bull Exposure for Natural Service in Cows and Heifers

A.R. Hartman, E.D. McCabe, D.R. Jacobs, K.E. Fike, and D.M. Grieger

Abstract

Use of fixed time (FT) artificial insemination (AI) followed by immediate exposure of females to bulls for natural service can be a useful management strategy for commercial cow-calf producers to limit labor and time related to bull turnout and increase pregnancy rates earlier in the breeding season. Considering influence of bull fertility and time to and length of estrus in females, expectations for outcomes in natural service sire versus AI sire parentage is relatively unknown. Our objective was to determine the relative percentages of calves sired by either a natural service or FTAI sire within the same estrous period. In two consecutive years, heifers and cows were synchronized and inseminated using the 7-day CO-Synch + controlled internal drug release (CIDR) FTAI protocol. All females were inseminated by one AI technician using one sire for heifers and a different sire for cows. Females were exposed to natural service bulls immediately after insemination. After calving, DNA was collected from a random subset of calves born in the first 21 days of the calving season for parentage analysis (calves born from heifers in Year 1 = 59 and in Year 2 = 82; calves born from cows in Year 1 = 89, Year 2 = 102). The percentage of calves sired by AI and natural service was determined following parentage verification. In Year 1, for calves born from heifers in the first 21 days of the calving season, 5.1% (n = 3/59) were sired by natural service. For calves born from cows, 14.6% (n = 13/89) were sired by natural service. In Year 2, for calves born from heifers, 9.8% (n = 8/82) were sired by natural service, whereas 20.6% of calves born from cows (n = 21/102) were sired by natural service. If commercial producers use FTAI followed by immediate bull exposure the proportion of calves sired by natural service bulls may be greater in cows than heifers.

Introduction

Development of fixed time artificial insemination (FTAI) protocols has provided beef producers with tools to harness genetic improvement benefits from the use of AI sires, economic benefits from cows calving earlier in the subsequent calving season, while eliminating the need for estrus detection (Lamb et al., 2016; Lamb and Mercadante, 2016).

Fixed time AI followed by immediate exposure of females to bulls for natural service can be a beneficial management strategy for cow-calf producers. It has the potential to limit labor and time related to bull turnout, as well as to increase proportion of females becoming pregnant early in the breeding season. When natural service sires are exposed to females immediately after FTAI, potential variations in bull fertility, time to estrus onset, and length of estrus in females likely will influence whether the female conceives

to the AI sire or natural service sire. Expectations for outcomes in natural service sire versus AI sire parentage are relatively unknown. Our objective was to determine the relative percentages of calves sired by either natural service sires or FTAI sires within the same estrous period when natural service sires are exposed to females immediately after FTAI.

Experimental Procedures

During the spring breeding seasons in two consecutive years at a ranch in Kansas, commercial Angus cows and heifers from a single producer were part of an FTAI program then immediately were exposed to bulls for natural service. In Year 1, cows ranged from two to five years of age and averaged 2.6 years. In Year 2, cows ranged from two to six years of age and averaged 3.2 years of age. Heifers were approximately 15 months of age at insemination in both years.

In both years, cows and heifers were synchronized using the 7-day CO-Synch + CIDR FTAI protocol. Heifers were artificially inseminated approximately 52-56 hours, and cows approximately 60-66 hours, following the removal of the CIDR and prosta-glandin injections. The same AI technician inseminated all females in both years. The FTAI procedure used a single Angus sire for heifers and a different single Angus sire for cows. Different Angus AI sires were used in Year 1 and Year 2, but a single sire was used within a single year for both heifers and cows. All females were exposed to natural service sires immediately following insemination.

All natural service sires passed a breeding soundness exam before exposure to females. Natural service sires ranged in age from one to five years. Bull to female ratios were kept between 1:30 and 1:15 based on sire ages. Natural service bulls remained with the females for the 90-day breeding season. Pregnancy detection was performed via rectal palpation 60 days after bull removal, and all open cows and heifers were culled.

At calving, all calves born in the first 21 days of the calving season were weighed, tagged, and any color markings recorded. Calves born in these first 21 days received a tag with a different color for ease of identification at DNA collection.

To determine the proportion of calves sired by the FTAI sire and natural service sires, blood was collected from a subset of calves born in the first 21 days of the calving season (Year 1: calves born from heifers n = 59; calves born from cows n = 89. Year 2: calves born from heifers n = 82; calves born from cows n = 102). SeekSire (Neogen) parentage testing was used to determine percentage of calves from this subset born in the first 21 days of the calving season that were sired by AI or natural service bulls.

Results and Discussion

In Year 1, among calves born from heifers, the actual percentage sired by natural service was 5.1% (n = 3/59). Among calves born from cows, the actual percentage sired by natural service was 14.6% (n = 13/89). In Year 2, among calves born from heifers, the actual percentage sired by natural service was 9.8% (n = 8/82). Among calves born from cows, the actual percentage sired by natural service was 20.6% (n = 21/102). The percentage of calves born from natural service sires in Year 1 was less than in Year 2 for both cows and heifers, see Figure 1 and Figure 2. Although natural service sires sired varying percentages of calves, it is unknown if those calves were additional pregnancies

early in the breeding season or if other factors influenced fertilization and resulted in fewer AI-sired calves. Other literature has shown increased pregnancy rates with FTAI along with immediate exposure to natural service sires in heifers when compared to natural service alone (Kasimanickam et al., 2021), and increases in conception rate with AI compared to natural service in indigenous cows (Washaya et al., 2019). These studies, however, did not assess parentage of calves to determine if they were sired by an AI sire or natural service sire. Similarly, Gutierrez et al. (2014) demonstrated increased breeding season pregnancy rates in heifers when using AI and natural service sires compared to natural service sires alone, and Sa Filho et al. (2013) demonstrated this same concept in cows.

Implications

If commercial producers use FTAI followed by immediate bull exposure in heifers, natural service sires may sire 5 to 10% of calves born early in the calving season. In cows, producers may expect 15 to 20% of calves born early in the calving season to be sired by natural service. These data provide estimates of the parentage of calves from AI and natural service sires with use of FTAI followed by immediate bull exposure. This strategy can reduce time and additional steps related to bull turnout and increase pregnancies earlier in the breeding season.

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Figure 1. Percentage of calves born to heifers in the first 21 days of the calving season sired by AI and natural service sires[1]

[1]Comparison of percentage of calves sired by AI sires compared to those sired by natural service sires born to heifers bred following a 7-day CO-Synch + CIDR fixed time AI protocol and immediate bull exposure in a two-year study.
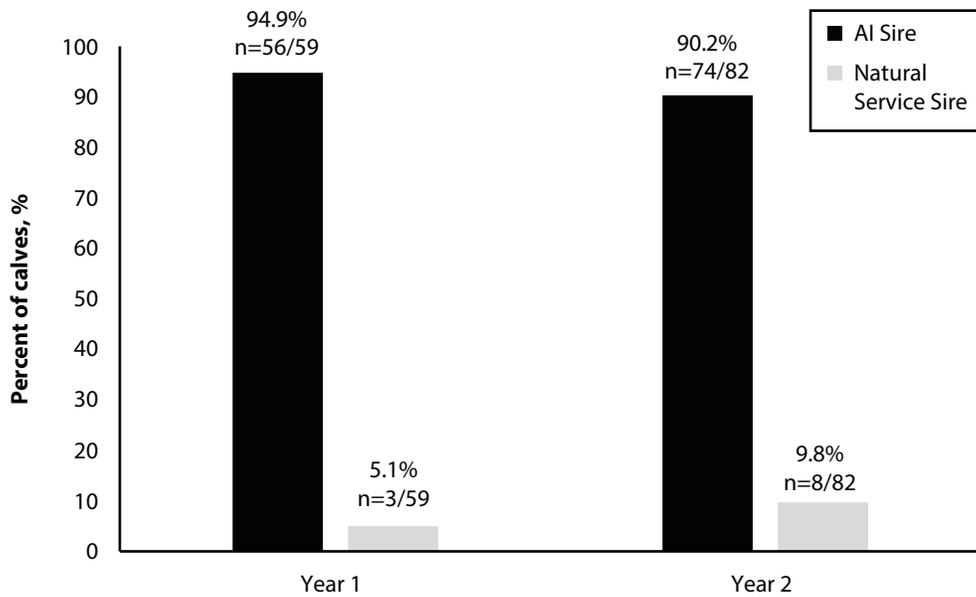

Figure 2. Percentage of calves born to cows in the first 21 days of the calving season sired by AI and natural service sires[1]

[1]Comparison of percentage of calves sired by AI sires compared to those sired by natural service sires born to cows bred following a 7-day CO-Synch + CIDR fixed time AI protocol and immediate bull exposure in a two-year study.
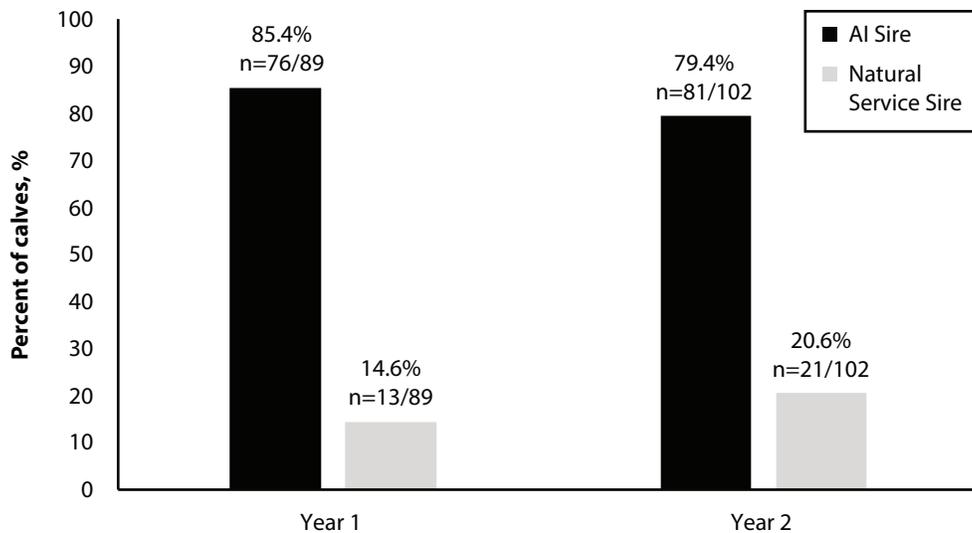
Assessment of Kansas Beef Producers' Perception and Knowledge Level of Business-to-Consumer Marketing

K.R. Lybarger, J. Kwon,[1] G. Ibendahl, Y. Teng-Vaughan, D. Kehler, and T.G. O'Quinn

Abstract

The objective of this study was to assess the perception and knowledge level of Kansas beef producers regarding business-to-consumer (B2C) marketing. A digital survey (Qualtrics Software, Provo, UT) was created to assess the perception and knowledge level of B2C marketing of Kansas beef producers. The survey was disseminated to Kansas beef producers utilizing the Shop Kansas Farms online social networking group. Finished beef cattle sales consisted of 20 or fewer head for 50.0% of respondents, with 43.9% selling 100% of their beef to individual consumers. An increase in sales to individual consumers in 2020 compared to previous years was reported by 61.0% of respondents. The use of B2C marketing associated with an increase in individual consumer sales was identified as "very desirable" by 73.0% of respondents. Producers noted challenges due to consumer concerns or complaints (38.9%) and indicated an increase in state extension resources would be "moderately" or "very" effective in improving the knowledge of both consumers (46.9%) and producers (33.3%). The results from this study confirm the need for more state extension resources to support B2C marketing for beef producers in Kansas and set the foundation for future research priorities.

Introduction

The COVID-19 pandemic that reached the United States in 2020 severely disrupted the beef supply chain (Thilmany et al., 2021), leaving grocery store shelves empty and consumers uncertain about how they would obtain their food. These events led to an increase in the demand for local beef (McKay et al., 2019; Atkins, 2020), and an opportunity for small- and medium-sized beef producers to capitalize on the growing interest of consumers to purchase beef products directly from beef producers. However, many producers faced concerns or complaints from consumers as they worked to expand the business-to-consumer (B2C) marketing channel. Therefore, it was the objective of this study to assess the perception and knowledge level of Kansas beef producers regarding B2C marketing of beef products.

Experimental Procedures

To accomplish the study objectives, a digital survey (Qualtrics Software, Provo, UT) was created to assess the perception and knowledge level of B2C marketing of Kansas beef producers. The survey was disseminated to Kansas beef producers utilizing the Shop Kansas Farms online social networking group. This group has a membership of over 130 Kansas beef producers, many of whom participate directly in B2C marketing channels. A total of 43 producers completed the survey. All responses were self-reported digitally by the participating producers.

[1] Department of Retail, Hospitality, and Tourism Management, University of Tennessee – Knoxville, Knoxville, TN.

Results and Discussion

Results from this study showed that 25.5% of beef producer respondents (n = 41) raise another species in addition to beef. It was found that 50.0% of survey respondents sold 20 or fewer head of finished beef cattle in 2020, with 43.9% selling 100% of their beef to individual consumers. Furthermore, 61.0% of respondents reported an increase in sales to individual consumers in 2020 compared to previous years, with 75.0% indicating sales to large beef processors were about the same. An increase in individual consumer sales was considered "very desirable" by 73.0% of respondents, and 87.1% believe sales to individual consumers are the most profitable marketing channel. There were 72.2% of respondents selling beef in a B2C market for 1–10 years, with 47.2% reporting that repeat customers make up 75% of their sales (Table 1). Word of mouth was the most common method of product marketing, as indicated by 91.6% of producers (Table 1). Concerns or complaints from consumers were noted by 38.9% (Table 1). It was believed by 47.1% of respondents that an improvement in consumer knowledge would be "very effective" to prevent future complaints or concerns (Table 2). Moreover, 31.0% of respondents believed that an increase in producer knowledge would be "extremely effective" in preventing future complaints or concerns (Table 2). Finally, it was believed that an increase in state extension resources would be "moderately" or "very" effective in improving consumer and producer knowledge by 46.9% and 33.3% of respondents, respectively (Table 2).

Implications

Producers self-reported that B2C was the most profitable marketing channel within their operation. However, many are not utilizing this channel to its full potential, and many have experienced consumer concerns or complaints. This study confirms the need for more state extension resources to support B2C marketing for beef producers in Kansas and sets the foundation for future research priorities.

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Table 1. Summary of responses from producers who reported beef production within their operation regarding sales to individual consumers and concerns or complaints (n = 41)

Characteristic	Response	Percentage of consumers
Estimate number of years selling to individual consumers (n = 36)	0	5.6%
	1 – 5	44.4%
	6 – 10	27.8%
	11 – 15	2.8%
	16 – 20	5.6%
	> 20	13.9%
Percentage of customers being repeat customers (n = 36)	0%	13.9%
	25%	22.2%
	50%	8.3%
	75%	47.2%
	100%	8.3%
Form of sales (n = 35)	Half beef	5.7%
	Half beef, portion cuts	2.9%
	Half beef, quarter beef	8.6%
	Portion cuts	5.7%
	Portion cuts, butcher bag	2.9%
	Whole beef	8.6%
	Whole beef, half beef	8.6%
	Whole beef, half beef, quarter beef	34.3%
	Whole beef, half beef, quarter beef, portion cuts	14.3%
	Whole beef, half beef, quarter beef, portion cuts, butcher bag	5.7%
	Whole beef, portion cuts	2.9%
Method of product marketing (n = 35)	Farmer's market, social media, other marketplace[1]	2.9%
	Other marketplace[1]	2.9%
	Social media	2.9%
	Word of mouth	22.9%
	Word of mouth, stand-alone website, farmer's market, other marketplace[1]	2.9%
	Word of mouth, stand-alone website, farmer's market, social media, other marketplace[1]	5.7%
	Word of mouth, stand-alone website, social media, other marketplace[1]	8.6%
	Word of mouth, farmer's market, social media, other marketplace[1]	2.9%
	Word of mouth, other marketplace[1]	2.9%
	Word of mouth, social media	17.1%
	Word of mouth, social media, other marketplace[1]	28.6%

continued

Table 1. Summary of responses from producers who reported beef production within their operation regarding sales to individual consumers and concerns or complaints (n = 41)

Characteristic	Response	Percentage of consumers
Experienced trouble (n = 36)	Yes	38.9%
	No	61.1%
Concern or complaint[2] (n = 14)	Unsatisfied portions	7.1%
	Unsatisfied portions, other	7.1%
	Low take-home weight	7.1%
	Low take-home weight, unsatisfied portions	7.1%
	Low take-home weight, unsatisfied portions, high price	7.1%
	Low take-home weight, unsatisfied portions, high price, other	7.1%
	Low take-home weight, unsatisfied portions, unexpected costs[3]	7.1%
	Low take-home weight, unexpected costs[3]	7.1%
	Unsatisfied quality	7.1%
	High price	14.3%
	High price, unexpected costs[3]	7.1%
	Other	14.3%
Other concern or complaint[2] (n = 5)	Lack of knowledge regarding buying process	20.0%
	Order cancellations	40.0%
	Poor workmanship	20.0%
	Customer didn't believe product met USDA inspection standards	20.0%
Attempted to resolve issue[2] (n = 14)	Yes	92.9%
	No	7.1%
Description of attempt made[3] (n = 12)	Provided a discount	25.0%
	Provided additional beef or other products	8.3%
	Other	66.7%
Other attempts made[4] (n = 6)	Provided an explanation or education	100.0%
Consumer satisfaction with attempt made[4] (n = 12)	Yes	75.0%
	No	25.0%

[1]Including Shop Kansas Farms and Facebook Marketplace.
[2]Question appeared only to producers who responded yes to experiencing trouble.
[3]Including processing fees and disposal fees.
[4]Question appeared only to producers who responded yes to attempted to resolve issue.

Table 2. Summary of responses from producers who reported beef production within their operation regarding complaints or concerns regarding options to prevent future complaints and concerns (n = 41)

Characteristic	Response	Percentage of consumers
Effectiveness of improved consumer knowledge (n = 34)	Extremely effective	32.4%
	Very effective	47.1%
	Moderately effective	20.6%
	Slightly effective	0.0%
	Not effective at all	0.0%
Effectiveness of improved producer knowledge (n = 32)	Extremely effective	31.3%
	Very effective	28.1%
	Moderately effective	25.0%
	Slightly effective	12.5%
	Not effective at all	3.1%
Effectiveness of improved locker knowledge (n = 32)	Extremely effective	34.4%
	Very effective	31.3%
	Moderately effective	21.9%
	Slightly effective	6.3%
	Not effective at all	6.3%
Effectiveness of improved communication between consumers and producers (n = 33)	Extremely effective	36.4%
	Very effective	42.4%
	Moderately effective	21.2%
	Slightly effective	0.0%
	Not effective at all	0.0%
Effectiveness of improved communication between consumers and lockers (n = 33)	Extremely effective	36.4%
	Very effective	33.3%
	Moderately effective	18.2%
	Slightly effective	12.1%
	Not effective at all	0.0%
Effectiveness of increased state extension resources to improve consumer knowledge[1] (n = 32)	Extremely effective	12.5%
	Very effective	18.8%
	Moderately effective	46.9%
	Slightly effective	12.5%
	Not effective at all	9.4%
Effectiveness of increased USDA[2] or KDA[3] resources to improve consumer knowledge[1] (n = 31)	Extremely effective	12.9%
	Very effective	25.8%
	Moderately effective	38.7%
	Slightly effective	16.1%
	Not effective at all	6.5%
Effectiveness of non-government advocates to improve consumer knowledge[1,4] (n = 31)	Extremely effective	12.9%
	Very effective	32.3%
	Moderately effective	35.5%
	Slightly effective	12.9%
	Not effective at all	6.5%

continued

Table 2. Summary of responses from producers who reported beef production within their operation regarding complaints or concerns regarding options to prevent future complaints and concerns (n = 41)

Characteristic	Response	Percentage of consumers
Effectiveness of consumer testimonials to improve consumer knowledge [1] (n = 31)	Extremely effective	45.2%
	Very effective	32.3%
	Moderately effective	19.4%
	Slightly effective	0.0%
	Not effective at all	3.2%
Effectiveness of producer or locker testimonials to improve consumer knowledge [1] (n = 31)	Extremely effective	29.0%
	Very effective	29.0%
	Moderately effective	25.8%
	Slightly effective	12.9%
	Not effective at all	3.2%
Effectiveness of increased state extension resources to improve producer and locker knowledge [5] (n = 27)	Extremely effective	18.5%
	Very effective	33.3%
	Moderately effective	22.2%
	Slightly effective	22.2%
	Not effective at all	3.7%
Effectiveness of increased USDA [2] or KDA [3] resources to improve producer and locker knowledge [5] (n = 27)	Extremely effective	14.8%
	Very effective	40.7%
	Moderately effective	25.9%
	Slightly effective	18.5%
	Not effective at all	0.0%
Effectiveness of non-government advocates to improve producer and locker knowledge [5,4] (n = 26)	Extremely effective	15.4%
	Very effective	38.5%
	Moderately effective	34.6%
	Slightly effective	7.7%
	Not effective at all	3.8%
Effectiveness of consumer testimonials to improve producer and locker knowledge [5] (n = 27)	Extremely effective	25.9%
	Very effective	40.7%
	Moderately effective	25.9%
	Slightly effective	3.7%
	Not effective at all	3.7%
Effectiveness of producer or locker testimonials to improve producer and locker knowledge [5] (n = 27)	Extremely effective	29.6%
	Very effective	29.6%
	Moderately effective	37.0%
	Slightly effective	3.7%
	Not effective at all	0.0%

[1]Question appeared only to producers who responded extremely effective and very effective to improved consumer knowledge.
[2]United States Department of Agriculture.
[3]Kansas Department of Agriculture.
[4]Including National Cattlemen's Beef Association and Kansas Beef Council.
[5]Question appeared only to producers who responded extremely effective and very effective to improved producer knowledge and improved locker knowledge.

Evaluation of Kansas Beef Consumers' Awareness and Understanding of Business-to-Consumer Marketing

L.K. Decker, K.R. Lybarger, J. Kwon,[1] G. Ibendahl, Y. Teng-Vaughan, D. Kehler, and T.G. O'Quinn

Abstract

The objective of this study was to determine the understanding and knowledge level of consumers purchasing beef in the business-to-consumer (B2C) format within the state of Kansas and identify their purchasing perceptions, concerns, and areas perceived to require additional support. Consumers (n = 174) were recruited from an online social site of Shop Kansas Farms, where members were invited to participate in a survey during a two-week period in March of 2021. Consumers, though some were new to the B2C method of buying beef, had high levels of previous experiences. It was found that 93% of consumers surveyed had purchased local beef previously. Only 5.7% of those who had purchased B2C beef previously had challenges during their experience. Of the consumers who had trouble during their experience, consumers listed "unsatisfied quality," "unsatisfied portions," "limited variety," and "low take-home weight" as areas of concern or complaint. Moreover, 63.1% of consumers reported that their latest purchase was also their first purchase, indicating that the demand for beef in a B2C format is increasing, due largely in part to the COVID-19 pandemic. Therefore, while Kansas consumers have an overall positive experience purchasing beef through B2C channels, there is an opportunity for improvement in consumer-focused resources and education.

Introduction

Consumer demand for local beef has increased over the past few decades and has been further heightened by the COVID-19 pandemic (Hobbs, 2020). While research has been conducted to determine the distance consumers are willing to consider "local beef" and the premium price consumers are willing to pay (Ridley et al., 2014), little information is available as to consumers' awareness and perceptions of business-to-consumer (B2C) type programs within Kansas. Moreover, a lack of information available to consumers about B2C opportunities has created challenges for producers and consumers navigating the current B2C market. Therefore, the objective of the current study was to evaluate the current consumer views of buying beef in the B2C model within the state of Kansas.

Experimental Procedures

An online survey (Qualtrics Software, Provo, UT) was created to assess the understanding and knowledge level of consumers purchasing beef in a B2C format within Kansas. Consumers were recruited from an online social media group called Shop Kansas Farms, which has 158,732 members, of which 174 participated in the survey.

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[1] Department of Retail, Hospitality, and Tourism Management, University of Tennessee – Knoxville, Knoxville, TN.

Members were invited to participate in a survey during a two-week period in March 2021 and all responses were self-reported via the digital survey.

Results and Discussion

Results of the survey showed 93% of consumers (n = 174) reported having previously purchased beef products from a local producer or locker. Of these, 63.1% reported that their most recent purchase was their first time purchasing in a B2C format and the same percentage of consumers had been purchasing beef in a B2C format for less than five years. The most common methods of purchasing beef in a B2C format were "portion cuts" (24.5%), followed by "quarter beef" (17.0%) and "half beef" (15.1%), or a combination of at least two of these methods (20.7%). Only 5.7% of consumers experienced challenges while purchasing beef in a B2C format, yet 100% of those consumers still intended to continue purchasing beef in this format. When consumers were given options that would be useful to prevent future complaints, the most selected response was "improved consumer knowledge." The consumers (n = 82) who rated this response as "very effective" or "extremely effective" indicated that "increased state extension resources" would be at least "moderately effective" (82.9%). This indicates that increased state extension resources would be an effective way to improve consumer knowledge. Consumers (n = 12) who had not purchased beef in a B2C format had considered purchasing B2C beef 91.7% of the time, while the most common barriers were "lack of freezer space" (25%), "quantity too large" (16.7%), or a combination of freezer space and quantity (16.7%).

Implications

Consumers within the state of Kansas are interested in and have positive experiences with purchasing beef in the B2C format. Moreover, most consumers are new consumers to buying beef in the B2C format, indicating that there is increasing demand for beef available for purchase in this format. Results of this study also show an opportunity for growth within consumer understanding of purchasing beef in a B2C format, leaving room for improvement in extension and other resources for consumers.

Acknowledgments

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Table 1. Summary of responses from consumers who previously purchased beef in a B2C[1] format regarding most recent purchase and complaints or concerns (n = 174)

Characteristic	Response	Percentage of consumers
Most recent purchase was first purchase (n = 157)	Yes	63.1
	No	36.9
Method of finding product (n = 154)	Stand-alone website	0.6
	Stand-alone website, other marketplace[2]	0.6
	Stand-alone website, social media	1.3
	Farmer's market	3.2
	Farmer's market, social media	0.6
	Farmer's market, social media, other marketplace[2]	0.6
	Other marketplace[2]	23.4
	Other	11.7
	Recommendations	31.8
	Recommendations, farmer's market	0.6
	Recommendations, other marketplace[2]	2.6
	Recommendations, other	0.6
	Recommendations, social media	0.6
	Social media	15.6
	Social media, other marketplace[2]	3.9
	Social media, other	1.9
Other method of finding product (n = 22)	4-H animal	4.5
	Personal relationship	54.5
	Local locker/butcher	18.2
	KC Food Circle	4.5
	Shop Kansas Farms	18.2
Experienced trouble (n = 157)	Yes	5.7
	No	94.3
Concern or complaint[3] (n = 9)	Unsatisfied portions	11.1
	Low take-home weight, other	11.1
	Low take-home weight, unsatisfied portions	11.1
	Unsatisfied quality, unsatisfied portions, other	11.1
	Unsatisfied quality, unsatisfied portions, limited variety, other	11.1
	Unsatisfied quality, low take-home weight, unsatisfied portions, other	11.1
	Limited variety	11.1
	Other	22.2

Table 1. Summary of responses from consumers who previously purchased beef in a B2C[1] format regarding most recent purchase and complaints or concerns (n = 174)

Characteristic	Response	Percentage of consumers
Other concern or complaint[3] (n = 6)	Lack of knowledge regarding cut order	33.3
	Poor workmanship	16.7
	Bad experience	16.7
	Tough meat	16.7
	Issue with locker	16.7
Requested bones and organs[4] (n = 9)	Yes	33.3
	No	66.7
Requested boneless steaks[4] (n = 9)	Yes	66.7
	No	33.3
Producer or locker attempted to resolve issue[3] (n = 9)	Yes	44.4
	No	55.6
Description of attempt made[5] (n = 4)	Provided additional beef or other products	50.0
	Provided an explanation	50.0
Consumer satisfaction with attempt made[5] (n = 4)	Extremely satisfied	50.0
	Somewhat satisfied	25.0
	Neither satisfied nor dissatisfied	25.0
Intention to continue purchasing B2C beef[3] (n = 9)	Yes	100.0
Reason for continued purchase[6] (n = 7)	Pleased with quality	42.9
	Intend to switch producer/locker	28.6
	Support local economy	14.3
	Access to specialty cuts	14.3

[1]Business-to-consumer (B2C) is a business model in which consumers purchase products directly from a business.
[2]Including Shop Kansas Farms and Facebook Marketplace.
[3]Question appeared only to consumers who responded yes to experiencing trouble.
[4]Question appeared only to consumers who responded low take home weight to concern or complaint.
[5]Question appeared only to consumers who responded yes to attempted to resolve issue.
[6]Question appeared only to consumers who responded yes to intention to continue purchasing.

Consumer Color and Discoloration Thresholds for Purchase of Retail Ground Beef When Evaluating Packages of a Single Day of Display

K.R. Lybarger, E.S. Beyer, K.J. Farmer, L.A. Egger, L.N. Drey,[1] J.L. Vipham, M.D. Zumbaugh, M.D. Chao, and T.G. O'Quinn

Abstract

This study utilized a simulated retail display to investigate the impact of ground beef color and discoloration on consumer purchase intent, while identifying the best objective measurements to predict consumer preferences of ground beef on the same day of retail display. Ground beef loaves (80% lean/20% fat) were obtained and assigned to a specific day of retail display (day 0–9). Consumers (n = 318) assessed ground beef samples at each day of display, with a single day of display evaluated per consumer group. Results of these models showed that the objective measurements assessed were indicators ($P < 0.05$) of consumer purchase intent. Logistic regression equations which predicted consumer purchase intent were significant ($P < 0.01$) for all objective measures and had R^2 values of 0.26–0.65. The logistic regression models accurately classified 70.5–84.0% of samples as would/would not purchase. Linear regression equations that predicted consumer overall liking of appearance scores were significant ($P < 0.01$), with R^2 values of 0.35–0.54. The a^* (redness) values of 20.7, 26.2, 31.7, and 35.4 correspond with consumers being 50, 75, 90, and 95% likely to purchase the product at full price. However, if the product was discounted, the values were 17.7, 22.7, 27.7, and 31.1. The percentage of metmyoglobin values of 37.8, 28.7, 19.5, and 13.3 correspond with consumers being 50, 75, 90, and 95% likely to purchase the product at full price and 45.2, 36.0, 26.9, and 20.6 if the product was discounted. Overall, these models showed that each of the objective measures evaluated were predictors of consumer purchasing intent and can be utilized by ground beef producers to predict consumer purchasing behaviors and willingness to purchase.

Introduction

The consumer discrimination of ground beef results in 2.55% of beef being discarded at the retail level, which is equivalent to 780,000 head of cattle going to waste in the United States alone (Ramanathan, 2022). Consumers often use discoloration as an indicator of meat freshness and wholesomeness when making meat purchasing decisions (Mancini and Hunt, 2005), but knowledge surrounding consumer perceptions of meat color is limited. Therefore, the objective of this study was to investigate the impact of ground beef color and discoloration on consumer purchase intent, while identifying the best objective measures to predict consumer preferences of ground beef on the same day of retail display.

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[1] Cargill, Wichita, KS.

Experimental Procedures

A commercial processor provided 180 1-lb 80% lean ground beef loaves for this study. Each loaf was assigned to a specific day of retail display (day 0–9) and placed under fluorescent lights in coffin-style cooler cases. Consumers (n = 318) assessed ground beef samples at each day of display, with a single day of display evaluated per consumer group. Consumers used 100-point continuous line scales to indicate overall appearance for each sample and indicated their willingness to purchase the loaves at full price and discounted prices with yes/no questions. A trained descriptive panel assessed redness and percentage discoloration values. A HunterLab Miniscan spectrophotometer (Model 2500L, Hunter Associates Laboratory Inc, Reston, VA) collected $L*$ (lightness), $a*$ (redness), and $b*$ (yellowness) values and hue angle, chroma, percent oxymyoglobin and percent metmyoglobin were calculated. Simple linear regressions were calculated for consumer overall appearance ratings, while logistic regression models were calculated for the probability of each sample being classified as "would purchase" for full and discounted price responses from consumers. Lastly, Pearson correlation coefficients were calculated for relationships among sensory and objective measurements.

Results and Discussion

Results of these models showed that the objective measurements assessed were indicators of consumer purchase intent. Logistic regression equations that predicted consumer purchase intent were significant ($P < 0.01$) for all objective measures and had R^2 values of 0.26–0.65. The logistic regression models accurately classified 70.5–84.0% of samples as would/would not purchase. Linear regression equations that predicted consumer overall liking of appearance scores were also significant ($P < 0.01$), with R^2 values of 0.35–0.54. Calculated Pearson correlation coefficients were significant ($P < 0.01$) among all variables with r values of 0.10–0.99. Threshold values for consumer willingness to purchase for $a*$ were 20.7, 26.2, 31.7 and 35.4, which aligned with consumers being 50, 75, 90 and 95% likely to purchase the ground beef at full price (Figures 1 and 2); whereas packages sold at a discounted price saw reduced $a*$ values to 17.7, 22.7, 27.7, and 31.1, respectively (Table 1). Notably, thresholds for calculated percentage metmyoglobin were 37.8, 28.7, 19.5, and 13.3, which coincided with consumers being 50, 75, 90, and 95% likely to purchase ground beef at full price (Figures 3 and 4). These scores shifted to 45.2, 36.0, 26.9, and 20.6 for discounted packages, indicating consumer willingness to purchase ground beef with greater discoloration when offered at a lower price (Table 1).

Implications

Consumer intent to purchase ground beef at varying days of retail display can be predicted by the objective measures used in this study. Several measures including $a*$ and calculated percentage metmyoglobin were good predictors of consumer likelihood to purchase. Moving forward, these models can provide ground beef producers and retailers with an indication of potential consumer purchasing behaviors for ground beef at varying levels of discoloration.

Acknowledgments

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Table 1. The 50, 75, 90, and 95% likeliness thresholds for various objective quality measures for consumer purchase intent of 80% lean/20% fat ground beef

Measurement	50%	75%	90%	95%
Product sold at full price				
L^*	52.2	54.7	57.3	59.0
a^*	20.7	26.2	31.7	35.4
b^*	20.2	22.8	25.3	27.1
Metmyoglobin[1]	37.8	28.7	19.5	13.3
Oxymyoglobin[1]	57.9	67.9	77.9	84.7
Chroma[1]	29.7	35.5	41.3	45.2
Hue angle[1]	0.79	0.72	0.66	0.61
Trained sensory panel redness score[2]	60.6	82.6	-	-
Trained sensory panel discoloration score[3]	40.3	12.8	-	-
Consumer appearance score[4]	48.4	60.7	72.9	81.2
Product sold at discounted price				
L^*	50.0	52.5	55.1	56.8
a^*	17.7	22.7	27.7	31.1
b^*	19.1	21.4	23.7	25.3
Metmyoglobin[1]	45.2	36.0	26.9	20.6
Oxymyoglobin[1]	48.8	57.9	67.1	73.3
Chroma[1]	25.8	30.8	35.8	39.2
Hue angle[1]	0.84	0.77	0.70	0.66
Trained sensory panel redness score[2]	45.6	67.6	89.6	---
Trained sensory panel discoloration score[3]	79.0	42.4	5.8	---
Consumer appearance score[4]	38.8	51.0	63.2	71.5

[1]Calculated utilizing the equations presented in the AMSA Meat Color Measurement Guidelines (AMSA, 2012).
[2]Sensory scores: 0 = extremely dark red, 100 = bright cherry red.
[3]Sensory scores: 0 = no visible discoloration, 100 = complete discoloration.
[4]Sensory scores: 0 = extremely undesirable, 100 = extremely desirable.
L^* (lightness), a^* (redness), and b^* (yellowness).
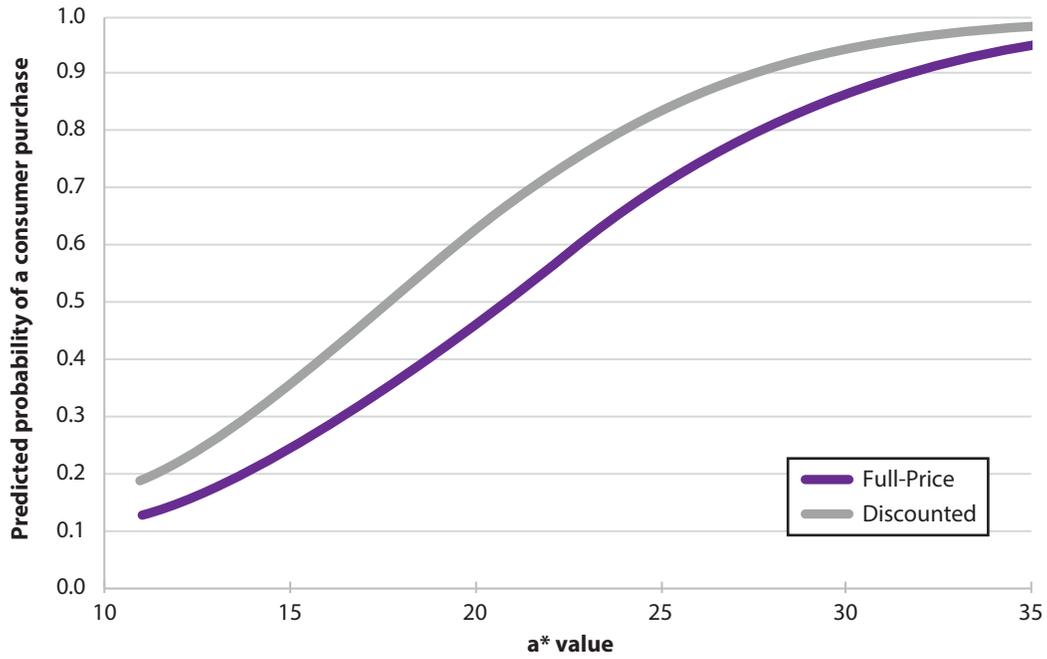
Figure 1. Probability of a consumer purchasing an 80% lean/20% fat ground beef package based on *a** (redness) value and pricing.

Day of Display: 0
a* Value: 35.314

Day of Display: 5
a* Value: 26.039

Day of Display: 9
a* Value: 18.131
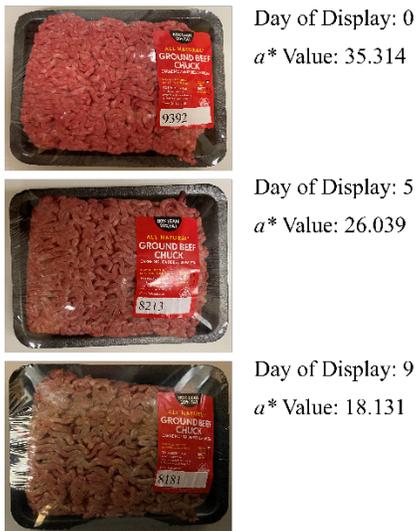
Figure 2. Sample photos with corresponding *a** (redness) values.

Figure 3. Probability of a consumer purchasing an 80% lean/20% fat ground beef package based on calculated metmyoglobin percentage and pricing.

Day of Display: 0

Calculated Percentage
Metmyoglobin: 20.78

Day of Display: 5

Calculated Percentage
Metmyoglobin: 27.03

Day of Display: 9

Calculated Percentage
Metmyoglobin: 48.28

Figure 4. Sample photos with corresponding calculated percentage metmyoglobin values.

Determination of Consumer Color and Discoloration Thresholds for Purchase of Retail Ground Beef When Evaluating Multiple Days of Display Simultaneously

K.R. Lybarger, E.S. Beyer, K.J. Farmer, L.A. Egger, L.N. Drey,[1] J.L. Vipham, M.D. Zumbaugh, M.D. Chao, and T.G. O'Quinn

Abstract

The objective of this study was to identify the threshold for color and discoloration for consumers to purchase ground beef in a simulated retail display and to determine the best objective measurement to predict consumer purcha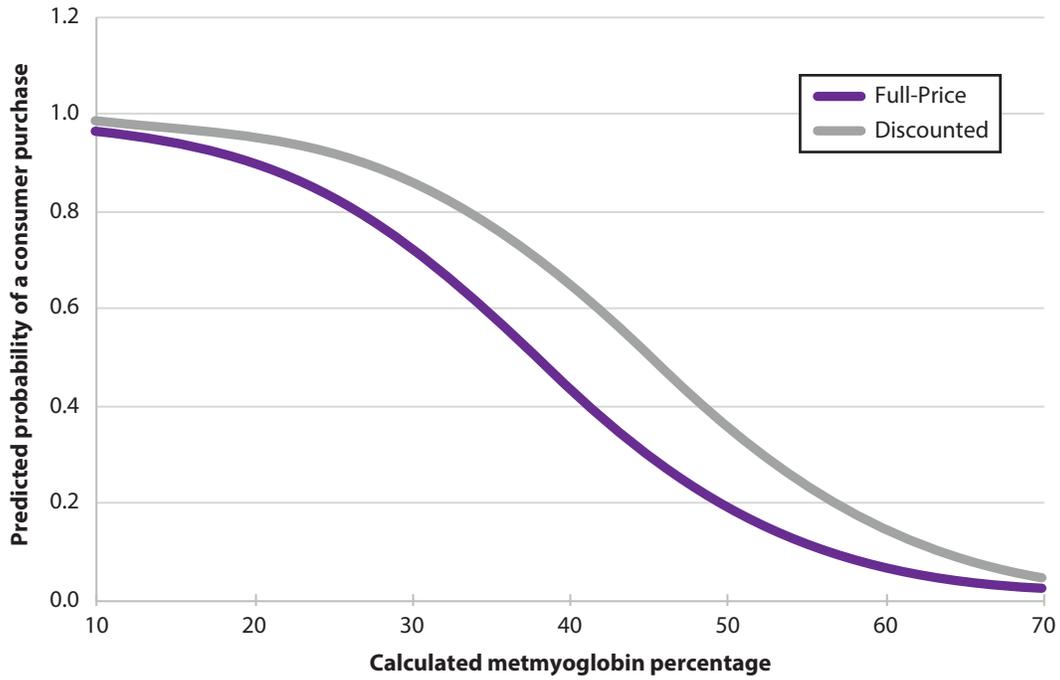se intent. One-lb ground beef packages containing 80% lean/20% fat were obtained and assigned to a day of retail display (day 0–9). Consumers (n = 216) evaluated ground beef samples from each day of display simultaneously. The models showed that each of the objective measures evaluated were predictors ($P < 0.05$) of consumer purchasing intent. All logistic regression equations ($P < 0.01$) had high R^2 values of 0.48–0.86, and correctly classified 78.1–90.1% of samples as would/would not purchase. Linear regression equations predicting consumer overall appearance ratings with objective measures also resulted in significant ($P < 0.01$) models, with R^2 values of 0.57–0.93. The a^* (redness) values of 21.6, 24.6, 28.3, and 30.5 correspond with consumers being 50, 75, 90, and 95% likely to purchase the product at full price. However, if the product was discounted, the values were 17.9, 21.4, 25.0, and 27.4. The percentage of metmyoglobin values of 40.1, 33.6, 27.1, and 22.7 correspond with consumers being 50, 75, 90, and 95% likely to purchase the product at full price and 47.8, 40.5, 33.2, and 28.2 if the product was discounted. The models generated from this study provide the ability to predict consumer willingness to purchase ground beef and provide ground beef producers an indication of potential consumer purchasing behaviors based upon objective values that are easy to measure.

Introduction

Recent increases in ground beef demand have shifted ground beef from an industry by-product to an increasingly valuable segment of the meat industry (Speer et al., 2015). Although the United States has transitioned to a "ground beef nation" (Close, 2014), there are many unknowns regarding consumer purchasing intent of ground beef products in the retail setting. Meat color is an extensively researched area, but only limited research exists that evaluates consumer perceptions. Ground beef discoloration leads to an estimated loss of $3.73 billion to the beef industry annually (Ramanathan, 2022). Therefore, the objective of this study was to identify the threshold for color and discoloration for consumers to purchase ground beef in a simulated retail display and to determine the best objective measurement to predict consumer purchase intent.

Experimental Procedures

For this study, 180 1-lb 80% lean/20% fat ground beef packages were obtained from a commercial processor in Kansas and transported to the Kansas State University Meat

[1] Cargill, Wichita, KS.

Laboratory. Packages were assigned to a day of retail display (day 0–9). Ground beef packages from each day of display were displayed in coffin-style cooler cases under fluorescent lights. Consumers (n = 216) evaluated ground beef samples from each day of display simultaneously. Consumers were asked to assess the overall appearance and desirability of each sample on a 100-point continuous line scale. Additionally, consumers answered yes/no questions related to whether they would purchase the package if it was full-priced at retail, and if it was discounted at retail. A trained descriptive panel evaluated the samples for redness and percentage discoloration using 100-point continuous line scales. Instrumental L^* (lightness)$,$ a^* (redness)$,$ and b^* (yellowness) values were collected utilizing a Hunter Lab Miniscan (Model 2500L, Hunter Associates Laboratory Inc, Reston, VA) spectrophotometer, and spectral data were recorded for the calculation of hue angle, chroma, percent oxymyoglobin, and percent metmyoglobin. Logistic regression models were calculated for the probability of a sample being identified as "would purchase" for both full-price and discounted responses by consumer sensory panelists. Simple linear regressions were calculated for consumer overall appearance ratings. Pearson correlation coefficients were calculated for sensory and objective measurements.

Results and Discussion

Overall, the models showed that each of the objective measures evaluated were predictors of consumer purchasing intent. All logistic regression equations ($P < 0.01$) had high R^2 values of 0.48–0.86, and correctly classified 78.1–90.1% of samples as would/would not purchase. Linear regression equations predicting consumer overall appearance ratings with objective measures also resulted in significant ($P < 0.01$) models, with R^2 values of 0.57–0.93. Pearson correlation coefficients showed strong relationships ($P < 0.01$) between consumer appearance score and all other variables ($r > 0.92$), except for L^* ($r = 0.76$). The a^* values of 21.6, 24.6, 28.3, and 30.5 correspond with consumers being 50, 75, 90, and 95% likely to purchase the product at full price (Figures 1 and 2). However, if the product was discounted, these numbers were 17.9, 21.4, 25.0, and 27.4 (Table 1). The percentage of metmyoglobin values of 40.1, 33.6, 27.1, and 22.7 correspond with consumers being 50, 75, 90, and 95% likely to purchase the product at full price (Figures 3 and 4). However, if the product was discounted, these numbers shifted substantially to 47.8, 40.5, 33.2, and 28.2 (Table 1).

Implications

All objective measurements were predictors of consumer purchasing intent of 80% lean/20% fat ground beef. Objective measurements shown to be the best included the a^* value and calculated percent metmyoglobin. The models generated from this study provide the ability to predict consumer willingness to purchase ground beef of varying days of retail display and provide ground beef producers an indication of potential consumer purchasing behaviors based upon objective values that are easy to measure.

Acknowledgments

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Speer, N., T. Brink, and M. McCully. 2015. Changes in the Ground Beef Market and What it Means for Cattle Producers. The Angus Foundation, St. Joseph, MO.

Table 1. The 50, 75, 90, and 95% likeliness thresholds for various objective quality measures for consumer purchase intent of 80% lean/20% fat ground beef

Measurement	50%	75%	90%	95%
Product sold at full price				
L^*	50.6	51.7	52.8	53.6
a^*	21.6	24.9	28.3	30.5
b^*	20.4	21.8	23.2	24.2
Metmyoglobin[1]	40.1	33.6	27.1	22.7
Oxymyoglobin[1]	58.5	64.9	71.4	75.8
Chroma[1]	30.5	33.9	37.4	39.7
Hue angle[1]	0.77	0.73	0.68	0.65
Trained sensory panel redness score[2]	53.6	67.4	81.1	90.4
Trained sensory panel discoloration score[3]	37.8	19.5	1.1	-
Consumer appearance score[4]	49.8	60.8	71.8	79.3
Product sold at discounted price				
L^*	49.5	50.8	52.2	53.2
a^*	17.9	21.4	25.0	27.4
b^*	18.9	20.3	21.8	22.8
Metmyoglobin[1]	47.8	40.5	33.2	28.2
Oxymyoglobin[1]	50.1	57.4	64.7	69.7
Chroma[1]	25.8	29.2	32.7	35.0
Hue angle[1]	0.84	0.78	0.72	0.68
Trained sensory panel redness score[2]	40.9	56.6	72.3	82.9
Trained sensory panel discoloration score[3]	64.0	42.0	20.1	5.2
Consumer appearance score[4]	36.9	49.1	61.3	69.6

[1]Calculated utilizing the equations presented in the AMSA Meat Color Measurement Guidelines (AMSA, 2012).
[2]Sensory scores: 0 = extremely dark red, 100 = bright cherry red.
[3]Sensory scores: 0 = no visible discoloration, 100 = complete discoloration.
[4]Sensory scores: 0 = extremely undesirable, 100 = extremely desirable.
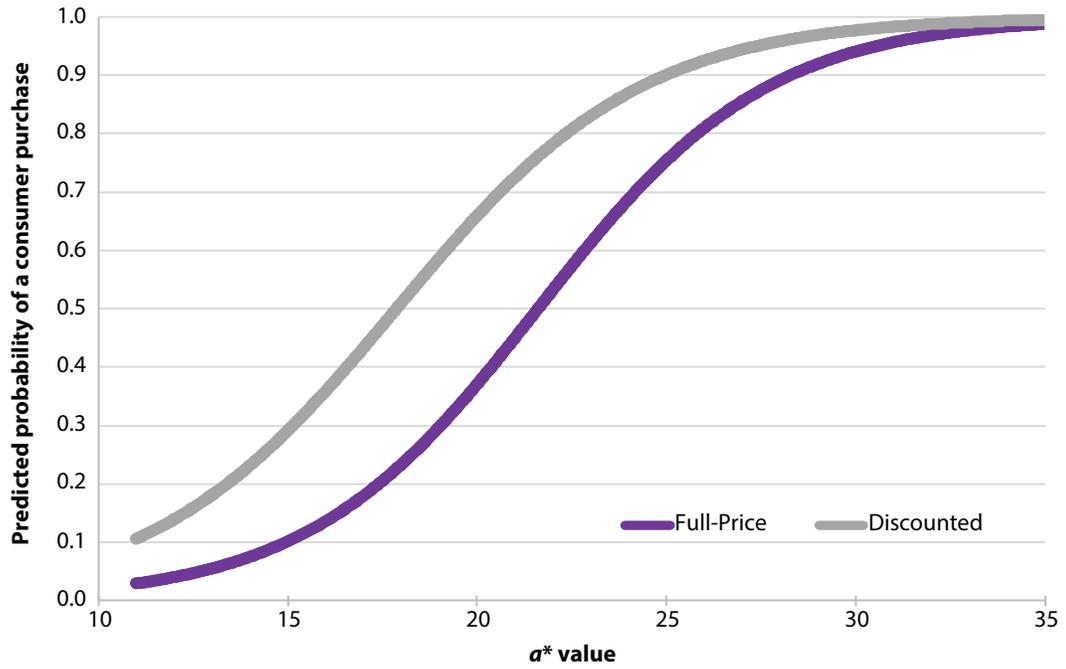
Figure 1. Probability of a consumer purchasing an 80% lean/20% fat ground beef package based on *a** (redness) value and pricing.

Day of Display: 0
a* Value: 36.07

Day of Display: 5
a* Value: 25.27

Day of Display: 9
a* Value: 14.47

Figure 2. Sample photos with corresponding *a** (redness) values.

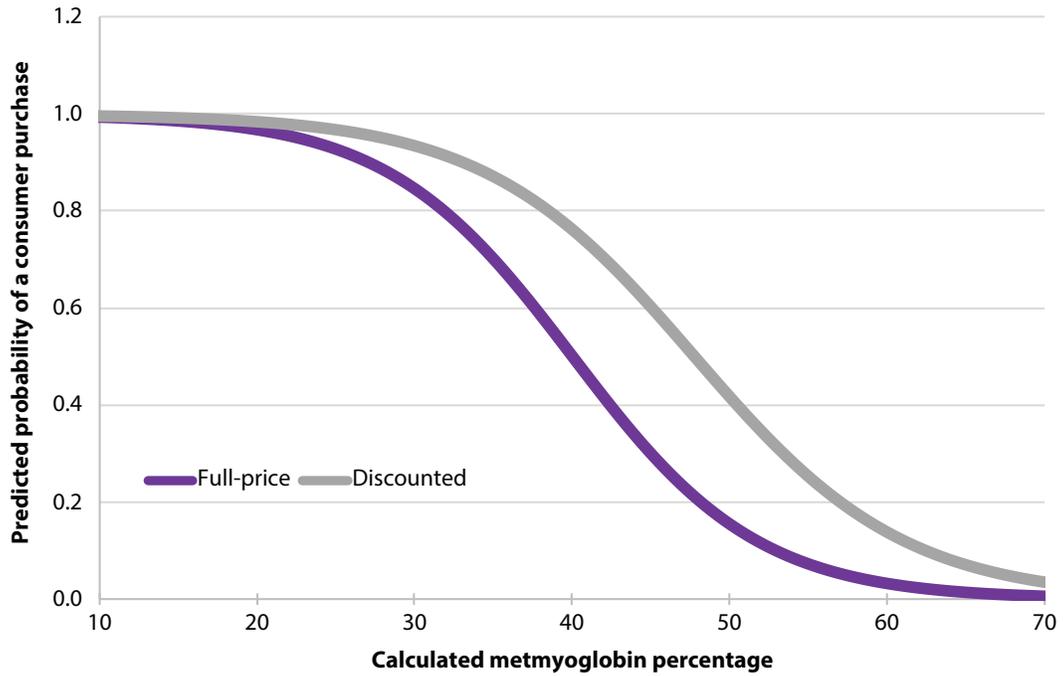**Figure 3. Probability of a consumer purchasing an 80% lean/20% fat ground beef package based on calculated metmyoglobin percentage and pricing.**

Day of Display: 0

Calculated Percentage Metmyoglobin: 22.73

Day of Display: 5

Calculated Percentage Metmyoglobin: 29.92

Day of Display: 9

Calculated Percentage Metmyoglobin: 54.23

Figure 4. Sample photos with corresponding calculated percentage metmyoglobin values.

Effects of Adding Egg Powder from Hens Immunized Against Phospholipase α2 on Ground Striploin Shelf Life

C. Velasco Ayala, L.A. Koulicoff, C.K. Chun, T.G. O'Quinn, E. Boyle, M. Richards,[1] C.K. Jones, and M.D. Chao

Abstract

The present study investigated the effect of incorporating three levels (0.4%, 0.8%, and 1.6%) of dried egg powder (EP) containing anti-phospholipase α2 (aPLA2) in ground striploin for its potential to extend ground striploin shelf life. Ten U.S. Department of Agriculture choice striploins were ground, formed into patties and over-wrapped for retail display. Impacts on beef discoloration, L* (lightness), a* (redness), and b* (yellowness) parameters, and lipid oxidation over a 7-day retail display period were studied, and the fatty acid profile of the patties was examined. Throughout the 7 days of retail display, a* and b* values decreased ($P < 0.05$) and visual discoloration increased ($P < 0.05$) independently from egg powder inclusions. Lipid oxidation increased ($P < 0.05$) for all treatments throughout the 7-day display period, and beef patties containing 1.6% EP had higher ($P < 0.05$) lipid oxidation than the rest of the treatments. Furthermore, the addition of 1.6% EP to ground striploin increased the relative percentage of C11-18:1 trans, C18:2, C18:3, C20:1, and C22:6 fatty acids, but decreased the relative percentage of C17:0 and C17:1 when compared to other treatments ($P < 0.05$). There was also a decrease ($P < 0.05$) in the relative percentage of phosphatidylethanolamine and an increase ($P < 0.05$) in phosphatidylcholine with the 1.6% EP treatment when compared to the control. These results indicated that the inclusion of aPLA2 EP may be able to preserve phospholipid integrity in beef but was unsuccessful in inhibiting lipid oxidation.

Introduction

Beef is a nutritious food product with a relatively short shelf life because of its susceptibility to attack by free radicals resulting in lipid oxidation. Lipid oxidation in beef produces undesirable off-flavors, discoloration, and loss of nutrients. A previous study demonstrated that lipid oxidation is enhanced by the hydrolysis of phospholipids by phospholipase α2 (PLA2) in beef. Anti-phospholipase α2 (aPLA2) is an antibody that has been shown to inhibit PLA2 activity, and aPLA2 can be mass-produced in eggs from hens immunized against PLA2. The resulting eggs can be spray- or freeze-dried into egg powder (EP) to preserve the antibody activity. This study aimed to investigate the effect of incorporating three levels of aPLA2 egg powder on ground striploin shelf life.

Experimental Procedures

Vacuum packaged U.S. Department of Agriculture (USDA) choice striploins from ten different beef carcasses were obtained from a USDA facility at 2 days postmortem. The next day, each loin was ground, divided into four equal batches, hand mixed with 0, 0.4, 0.8, or 1.6% of dried EP containing aPLA2 (w/w), vacuum packaged, and stored at 36°F for 14 days. After the storage period, each batch of ground striploin was

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[1] Department of Animal and Dairy Sciences, University of Wisconsin-Madison, Madison, WI.

formed into four 0.25-lb patties, overwrapped and randomly assigned to one of the three retail display periods (day 0, 4, and 7) at 35.6°F. Percent visual discoloration was determined using a trained panel (n = 7). Additionally, L*, a*, and b* were measured using a colorimeter each day of display on the day 7 patties. At the end of each sample's designated display period, patties were removed from the overwrapped packaging, repackaged in vacuum packaging, and stored at -112°F until analysis. Enzymatic activity of aPLA2 from EP was assessed using an enzyme-linked immunosorbent assay (ELISA). Lipid oxidation status was measured on samples from all three retail display periods. The fatty acid and phospholipid profiles were determined on the day 0 samples.

Results and Discussion

The aPLA2 activity was confirmed for the egg powder used on the patties. As expected, a* and b* values decreased ($P < 0.05$), and visual discoloration increased ($P < 0.05$) for all treatments throughout the 7 days of retail display (Figures 1, 2, and 3). However, the inclusion of EP had no effect on beef patty visual discoloration, a*, or b* ($P > 0.05$). The L* value was not altered ($P > 0.05$) due to EP concentration nor display day (Figure 4). Lipid oxidation increased ($P < 0.05$) for all treatments throughout the 7-day display period (Figure 5). Beef patties containing 1.6% EP had higher ($P < 0.05$) lipid oxidation than the rest of the treatments (Figure 6). The addition of 1.6% EP to ground striploin increased the relative percentage of C11-18:1 trans, C18:2, C18:3, C20:1, and C22:6 fatty acids, but decreased the relative percentage of C17:0, and C17:1 when compared to the other treatments ($P < 0.05$, Table 1). Adding more than 0.8% of EP containing aPLA2 in ground beef altered the fatty acid profile by increasing the content of some polyunsaturated fatty acids, particularly 18:2, which likely led to the enhanced lipid oxidation in ground striploin patties. The PC relative percentage was higher for the 1.6% EP treatment compared to the control, which is possibly due to the inhibition of PLA2 by aPLA2 in the EP ($P < 0.05$; Table 2).

Implications

Inclusion of EP containing active aPLA2 in beef patties did not demonstrate any direct effect in extending beef shelf life, possibly due to the alteration of fatty acid profile introduced by the egg powder.

Acknowledgments

Table 1. Comparison of fatty acid profiles of beef patties with the addition of 0%, 0.4%, 0.8%, and 1.6% of egg powder containing antiphospholipase α2

Fatty acid	Treatment				SEM[1]	P-value
	0%	0.40%	0.80%	1.60%		
14:0	2.60	2.38	2.31	2.36	0.15	0.12
14:1	0.62	0.55	0.54	0.54	0.05	0.14
16:0	29.24	29.12	29.26	29.20	0.39	0.94
16:1	3.44	3.37	3.07	3.04	0.22	0.24
17:0	1.01[a]	0.98[b]	0.96[bc]	0.94[c]	0.06	<0.01
17:1	0.77[a]	0.74[ab]	0.73[bc]	0.71[c]	0.05	<0.01
18:0	13.22	13.17	13.22	13.10	0.29	0.54
18:1	37.91	37.98	38.16	37.75	0.72	0.79
9-18:1 trans	1.89	1.83	1.78	1.77	0.13	0.11
11-18:1 trans	1.34[b]	1.37[ab]	1.39[a]	1.38[a]	0.03	0.03
18:2	4.93[b]	5.38[ab]	5.52[ab]	6.05[a]	0.45	0.02
18:3	0.20	0.20	0.21	0.21	0.01	0.18
20:1	0.15[b]	0.16[a]	0.16[a]	0.16[a]	0.01	0.03
20:3	0.43	0.43	0.41	0.40	0.05	0.72
20:4	1.53	1.59	1.56	1.62	0.20	0.93
20:5	0.11	0.11	0.11	0.11	0.02	0.93
22:4	0.24	0.25	0.24	0.23	0.03	0.92
22:5	0.33	0.32	0.30	0.30	0.04	0.60
22:6	0.03[d]	0.05[c]	0.08[b]	0.11[a]	0.01	<0.01
SFA[2]	46.07	45.65	45.75	45.61	0.53	0.52
MUFA[3]	46.12	46.00	45.82	45.36	0.77	0.43
PUFA[4]	7.81	8.35	8.43	9.03	0.77	0.23

[abcd] Values with different superscripts indicate a difference within each row.
[1]Standard error of the mean.
[2]Saturated fatty acids
[3]Monounsaturated fatty acids.
[4]Polyunsaturated fatty acids.

Table 2. Phospholipid profile of beef patties with the addition of 0%, 0.4%, 0.8%, and 1.6% of egg powder containing antiphospholipase α2

Phospholipid (%)	Treatment				SEM[1]	P-value
	0%	0.4%	0.8%	1.6%		
PE[2]	29.35[a]	30.16[a]	24.86[ab]	18.73[b]	2.83	<0.05
PC[3]	54.98[b]	58.35[b]	63.60[ab]	70.59[a]	2.62	<0.05
SM[4]	15.01	11.49	11.11	10.38	3.01	0.52

[ab]Values with different superscripts indicate a difference within each row.
[1]Standard error of the mean.
[2]Phosphatidylethanolamine.
[3]Phosphatidylcholine.
[4]Sphingomyelin.
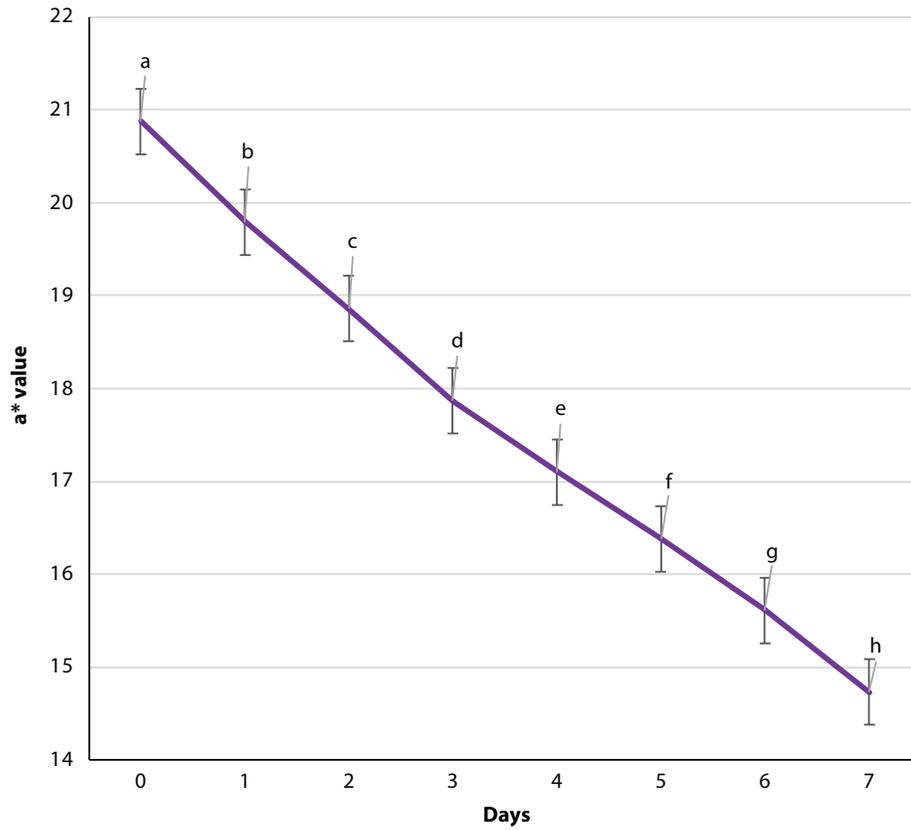
Figure 1. The a* values pooled across treatment for 7-day patties (*P* < 0.05).
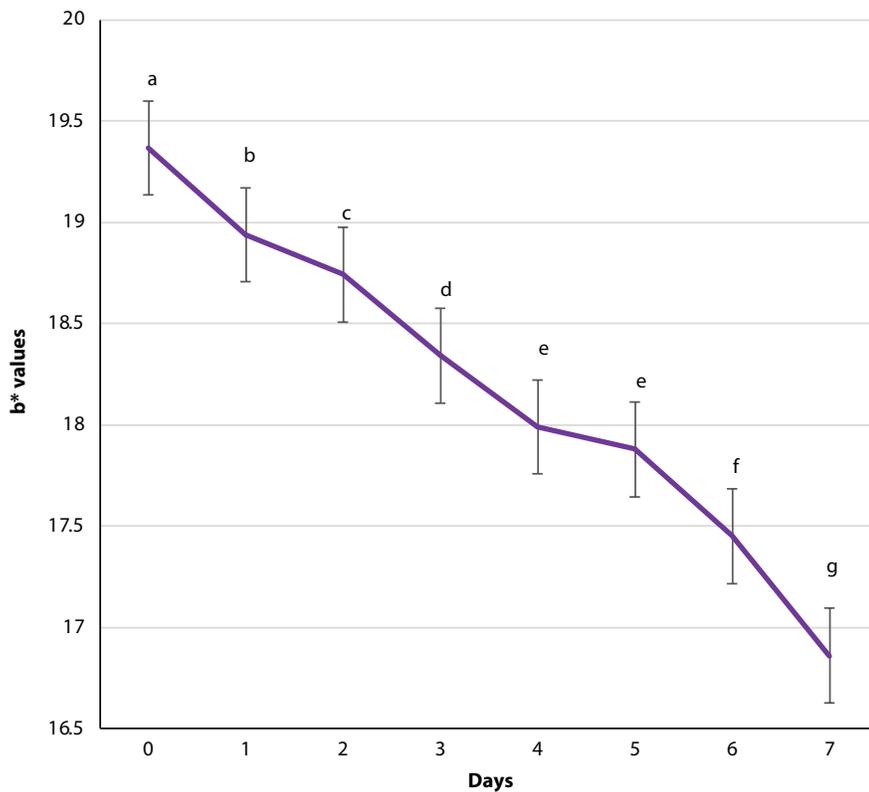
Figure 2. The b* values pooled across treatment for 7-day patties (*P* < 0.05).
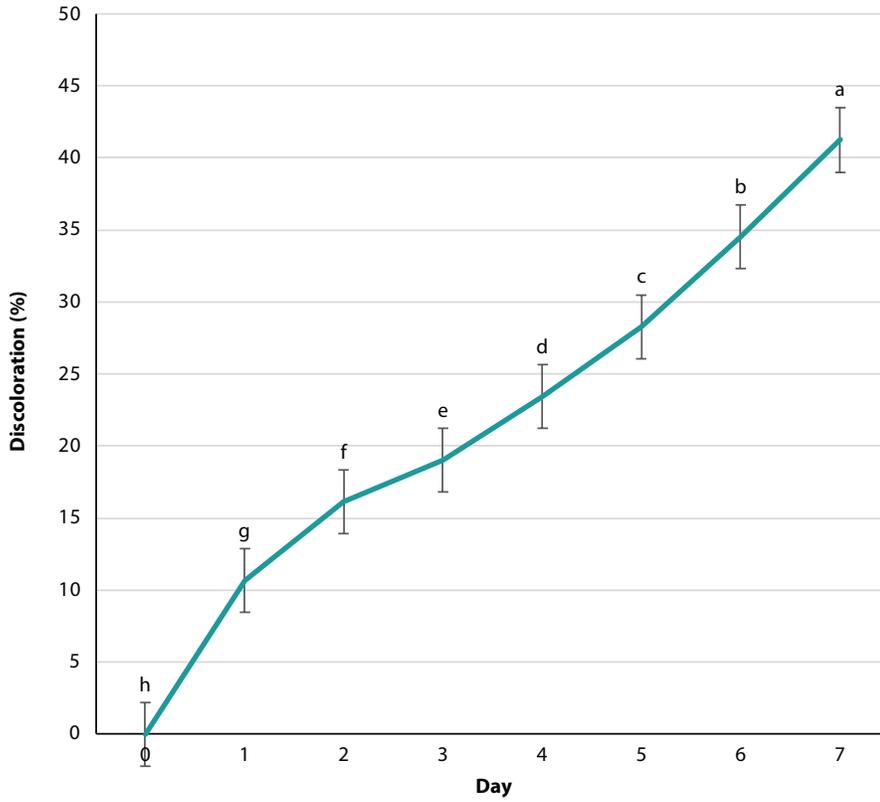
Figure 3. Visual discoloration pooled across treatments during 7 days of refrigerated display (*P* < 0.05).
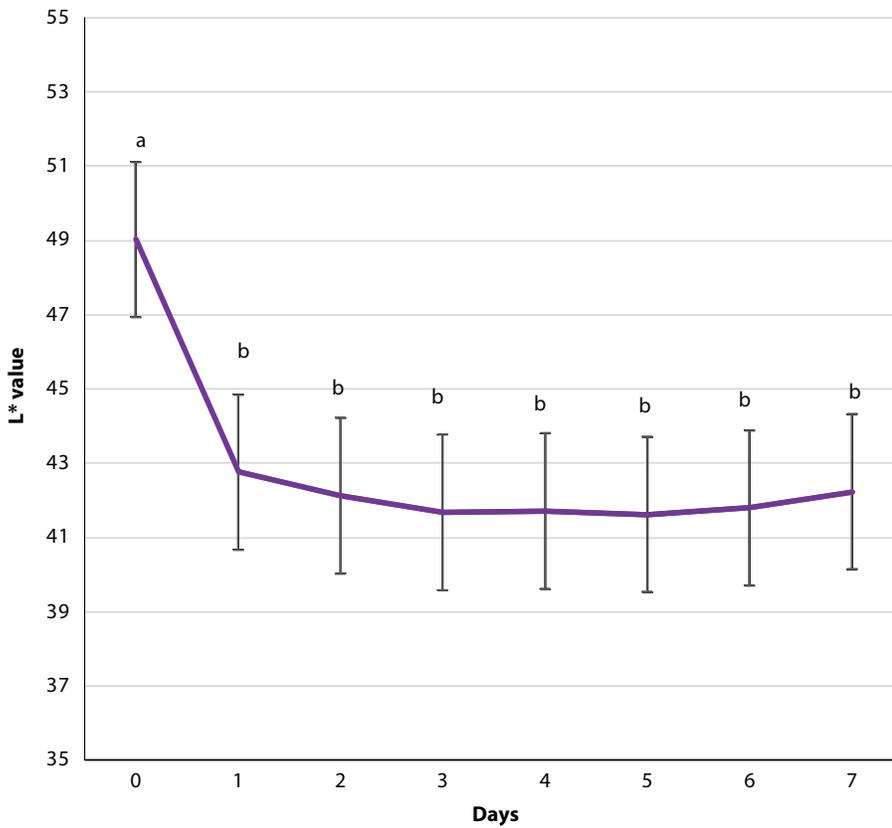
Figure 4. The L* values pooled across treatment for 7-day patties (*P* < 0.05).

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Figure 5. Pooled results across treatment for lipid oxidation for different display periods ($P < 0.05$).

Figure 6. Pooled results across display days for lipid oxidation for different treatments ($P < 0.05$).

Establishing Spoilage Thresholds of Ground Beef in a Traditional Retail Case Scenario

G.E. Corrette, E.S. Beyer, E.A. Mendez, V. Hay, T.G. O'Quinn, M.D. Chao, and J.L. Vipham

Abstract

The objective of this study was to determine spoilage in fresh ground beef and the perception of consumers regarding changes in sensory characteristics, as well as the desirability at different days of shelf-life. Ground beef loaves (n = 84) of 80% lean, 20% fat composition and 2.25 lb were utilized. Ground beef loaves in plastic overwrap foam trays were placed in a retail refrigerated case for 0–6 days. Consumers (n = 96) were asked to evaluate samples independently for visual color, odor, touch, and flavor to rate overall desirability, purchase intent, and identification of spoilage. Colorimeter data, thiobarbituric acid reactive substances (TBA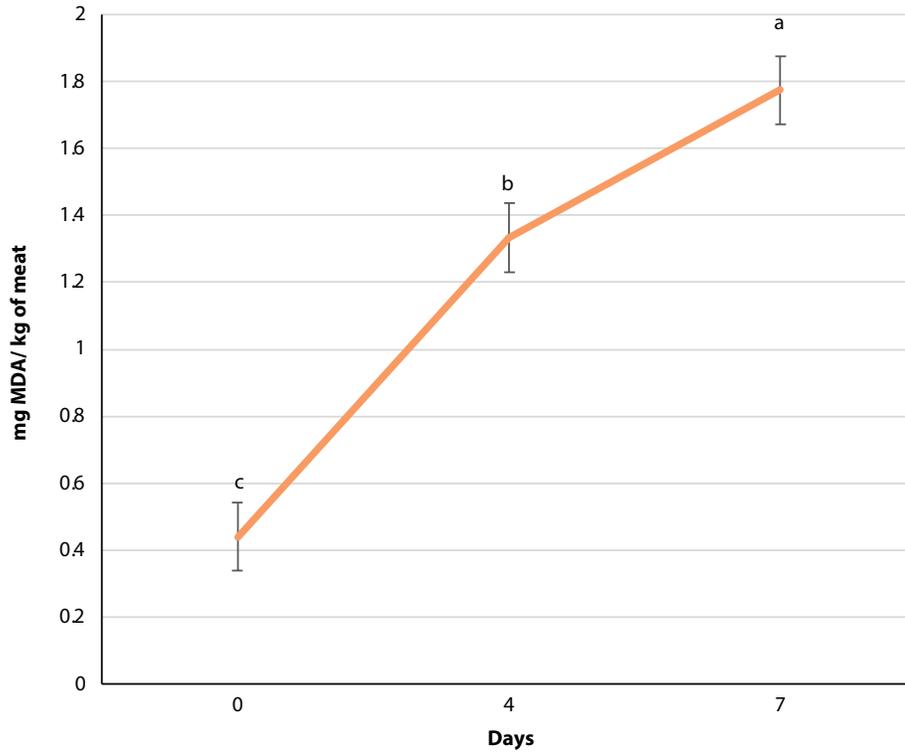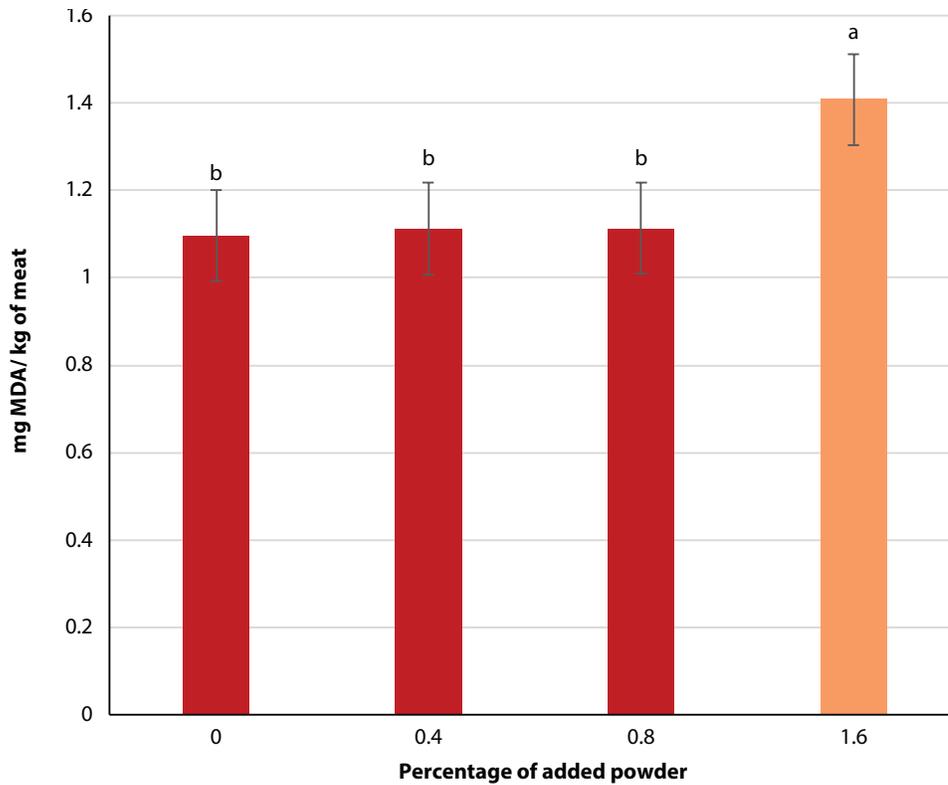RS), lipid oxidation, and aerobic plate count (APC; log CFU/g) and *Enterobacteriaceae* (EB) count plate were collected after consumer evaluation. On day 3, consumers reported decreased ($P < 0.05$) purchase intent, desirability, and identified spoilage for visual color. The L* (lightness), a* (redness), and b* (yellowness) decreased ($P < 0.05$) from day 0 to 4. Odor identification of spoilage by consumers increased ($P < 0.05$) across different shelf-life days, with the highest ($P < 0.05$) spoilage identification at day 6. Touch showed the largest decrease ($P < 0.05$) in purchase intent and increase ($P < 0.05$) in spoilage identification on days 5 and 6. Microbial analysis revealed a steady increase in log CFU/g for each consecutive display day for APC and EB ($P > 0.05$), with EB having the largest increase ($P < 0.05$) in log CFU/g from day 0–6. Flavor did not show differences in consumer perception for all days of shelf-life ($P > 0.05$). The TBARS did not show differences between treatment days ($P > 0.05$). Results of this study reveal that previously established values of spoilage used as a threshold in the industry for fresh meat products does not translate to negative consumer perceptions or consumer-identified points of spoilage. Consumers relied most on visual color to assess spoilage. Most of the other variables evaluated, including microbial counts, were not reliable indicators of ground beef spoilage.

Introduction

Understanding meat spoilage and the perception of consumers related to meat spoilage characteristics enables the meat industry to accurately assess shelf-life and establish a correct threshold of microbial growth. Meat spoilage can be defined as the negative alteration of a meat product because of a chemical, environmental, or bacterial process that compromises the quality or safety of the product (Nychas et al., 2007). The resulting economic loss from spoiled meat products is considerable for the meat industry (Odeyemi et al., 2020). A value of 10^7 log CFU/g has been used by the industry as a standard for spoilage for years (Ellis et al., 2002). However, consumer-focused studies validating this threshold are lacking. Therefore, the objective of this study was to determine an accurate shelf-life of fresh ground beef and perceptions of consumers to various sensory characteristics regarding spoilage.

Experimental Procedures

Ground beef samples (n = 84) of 80% lean, 20% fat composition were collected from a commercial meat processor in the Midwest region. Ground beef loaves that were 2.25 lb packaged in plastic overwrap foam trays were assigned as pairs, and randomly placed into a coffin-style cooler retail case scenario under fluorescent lights with constant 24-hour intensity. As the ground beef loaves were assigned as pairs, one package from each pair was designated for visual and spectral color, consumer panel, microbial plating, and lipid oxidation. The paired sample was utilized in the following consumer panels: odor, texture, and flavor. All samples were identified by a random 4-digit code. Consumers (n = 96) were placed in panels of eight, and seven samples were evaluated by each panel where all display days were represented. Consumers were asked to assess each sample independently for visual color, odor, touch, and flavor. For visual color, odor, and touch, consumers were asked to rate overall desirability, purchasing intent, and identification of spoilage. Consumers rated desirability on a sliding scale of 0–100 using an electronic ballot in Qualtrics (Version 2417833; Provo, UT) using an electronic tablet. For purchasing intent and identification of spoilage, consumers answered yes or no questions in the same electronic ballot.

For flavor assessment, ground beef was collected and made into 0.25-lb patties, vacuum sealed, and stored at -4°F until used for panels. Samples were thawed 24 hours prior to use, cooked to 165°F peak internal temperature, and served to panelists with palate cleansers. For flavor assessment, panelists answered yes or no regarding the desirability of the flavor, the likelihood of purchase, if the panelist considered the sample spoiled, and if the panelist liked the sample overall based upon flavor. All surveys contained a demographic questionnaire and questions regarding handling practices, storage practices, use-by-date understanding, and spoilage perception that was completed prior to evaluation of samples.

For instrumental color measurement, L* (lightness), a* (redness), and b* (yellowness) were measured on each ground beef loaf using a Hunter Lab Miniscan EZ spectrophotometer (Hunter Associates Laboratory, Reston, VA). Three scans were collected from various locations on the top of the ground beef loaf and averaged to yield a single value for each loaf. The extent of lipid oxidation during simulated retail display was assessed using the thiobarbituric acid reactive substances (TBARS) assay. A ground beef aliquot was frozen in liquid nitrogen, pulverized, and stored at -112°F in a Whirl Pak bag until analysis. The TBARS procedure was performed, and samples were read in a spectrophotometer at a wavelength of 532 nm (BioTek Eon; BioTek Instruments Inc., Winooski, VT) to determine malondialdehyde (MDA) concentration, and MDA concentration was recorded as mg of MDA/kg of muscle tissue.

Microbial analysis was conducted after the visual color consumer panel was concluded. Ground beef loaves were collected from the retail case and the plastic overwrap was removed. Using aseptic technique, serial dilutions were performed, and appropriate dilutions were plated onto aerobic count plate (APC) petrifilm and *Enterobacteriaceae* (EB) count plate petrifilm for each sample, incubated, and counted.

Results and Discussion

For instrumental color measurements, L* decreased ($P < 0.05$) from day 0–2. There was no decline ($P > 0.05$) in L* from days 3–6, and day 6 ground beef was darker than day 1

ground beef (Table 1; $P < 0.05$). There was a decline in a* and b* values ($P < 0.05$) from day 0–3 (Table 1). Consumer assessment of visual color showed that purchase intent and overall desirability rating decreased most on day 3 ($P < 0.05$) and was lowest on day 6 ($P < 0.05$). Additionally, consumers did not consider the samples spoiled until day 3, with the largest increase occurring between days 3–4 (Figure 1; $P < 0.05$). When considering the instrumental color data with consumer perceptions in this study, it was determined that spoilage-affected color occurred between days 2–3. Consumers revealed the largest negative alteration of odor occurred between day 0 and 1 ($P < 0.05$). There were no differences ($P > 0.05$) in purchase intent, overall desirability, and spoilage perception between days 1–5. Day 6 demonstrated the lowest purchase intent and overall desirability with the highest number of samples considered spoiled ($P < 0.05$). The lack of a steady decrease in sensory assessment reveals that odor is not as large of a priority to consumers as visual color assessment. Additionally, consumers reported that samples were acceptable by touch until days 5 and 6 ($P < 0.05$).

When comparing day 0 to 6, the APC of ground beef increased 0.29 log CFU/g (Table 2; $P < 0.05$). The EB counts remained constant ($P > 0.05$) from day 0 to day 3, and there was no change in EB from day 3 to day 6 ($P > 0.05$). The increase of EB over display days was higher than for APC, increasing 0.60 log CFU/g from day 0 to day 6 ($P < 0.05$).

Panelists noted no differences ($P > 0.05$) in desirability of the flavor, the desirability of purchase, if the panelist considered the sample spoiled, and if the panelist liked the sample overall based upon flavor. In addition, there was no difference ($P > 0.05$) in TBARS between treatment days.

Implications

Understanding the role of spoilage and the interaction of spoilage with consumers' perception can allow market industry and retail establishments to accurately assess shelf-life. This can lead to decreasing waste from meat products that do not have sensory alterations. In this study, ground beef color appeared to be the most important product characteristic indicative of spoilage to consumers. Overall, based on this research, the industry threshold of 10^7 log CFU/g is not an accurate value to assess spoilage and the alteration of sensory characteristics that is detectable by consumers.

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Table 1. Least square means for instrumental measurements[1] for lightness (L*), redness (a*), and yellowness (b*) after retail display

Instrumental measurement	Day 0	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	SEM[2]	P-value
L*	57.60[a]	55.54[b]	53.56[c]	53.02[cd]	52.97[cd]	52.88[cd]	52.61[d]	0.36	< 0.01
a*	32.81[a]	28.28[b]	22.83[c]	18.01[d]	12.29[e]	11.29[e]	9.38[f]	0.57	< 0.01
b*	24.44[a]	22.30[b]	19.26[c]	17.28[d]	15.84[e]	15.56[e]	15.57[e]	0.26	< 0.01

[abcdef] Least square means within rows without common superscript differ ($P < 0.05$).
[1] Standard error of the least square mean.

Table 2. Least square means (log CFU/g) for aerobic plate count (APC) and *Enterobacteriaceae* (EB) counts on aerobically packaged ground beef displayed refrigerated for 6 days

Plate type	Day 0	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	SEM[1]	P-value
APC	7.73[d]	7.81[cd]	7.86[bcd]	7.88[abc]	7.89[abc]	7.97[ab]	8.02[a]	0.07	< 0.01
EB	4.76[c]	4.77[c]	4.95[bc]	5.09[abc]	5.12[ab]	5.35[a]	5.36[a]	0.18	< 0.01

[abcdef] Least square means within rows without common superscript differ ($P < 0.05$).
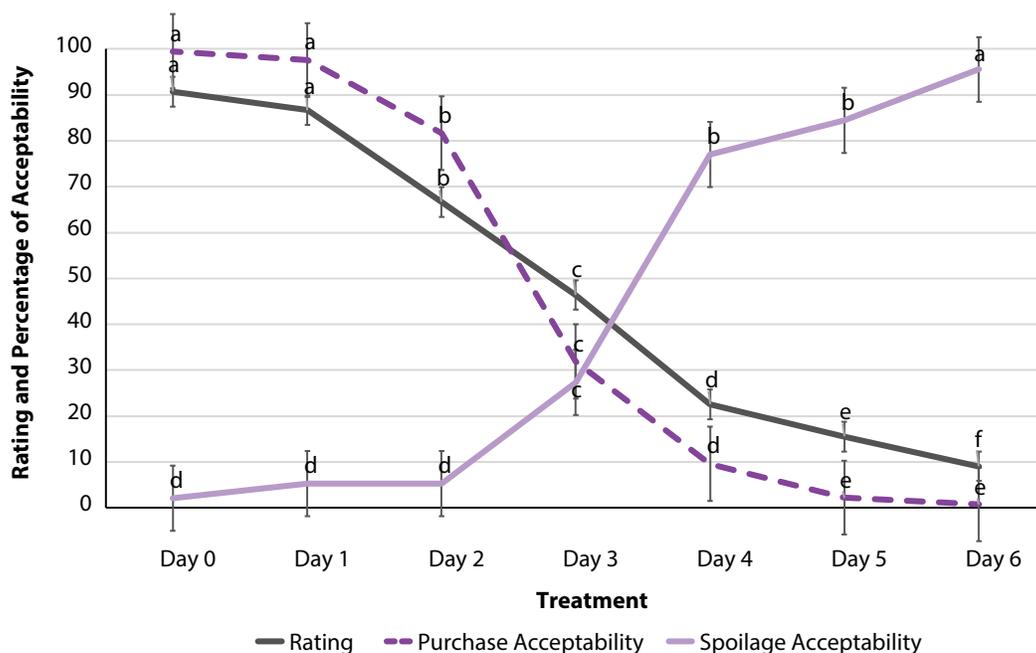[1] Standard error of the least square mean.

Figure 1. Least square means for consumers (n = 96) panel rating and percentage rated acceptable for purchase and spoilage based upon visual color. Least square means without common superscript differ ($P < 0.05$).

Consumer Sensory Evaluation of Ground Beef and Plant-Based Ground Beef Alternatives Used in a Hamburger Application

L.A. Egger, K.J. Farmer, E.S. Beyer, K.R. Lybarger, J.L. Vipham, M.D. Zumbaugh, M.D. Chao, and T.G. O'Quinn

Abstract

The objective of this study was to evaluate the palatability traits and consumer acceptance of three plant-based ground beef alternatives in comparison to ground beef in a foodservice-like hamburger application. One ground beef (80% lean/20% fat; 1 lb chubs) and three commercially available plant-based ground beef alternative (GBA) treatments (n = 20 production lots/treatment) were formed into 2.5 oz patties to be served to consumers on a bun with an opportunity to apply ketchup, mustard, cheese, lettuce, and pickles to samples. The GBAs were selected as representatives of GBAs well-known to be sold at foodservice (FGBA) and retail (RGBA). In addition, a popular "traditional" soy-based patty (TGBA) on the market was selected for use. Consumers (n = 120) evaluated samples for juiciness, tenderness, texture, flavor liking, beef-like flavor intensity, overall liking, and willingness to purchase. Panelists rated each of the samples as acceptable or unacceptable for these sensory traits. Furthermore, panelists assigned a purchase price they would be willing to pay for each sample if purchasing a similar product at foodservice. Overall, GB was preferred by consumers compared to all three GBAs. The GB treatment rated higher ($P < 0.05$) for juiciness and texture compared to all GBAs. The GB, FGBA, and RGBA tenderness ratings were similar ($P > 0.05$), but all three rated higher ($P < 0.05$) than the TGBA. Consumer ratings for overall flavor liking, beef-like flavor intensity, and overall liking showed GB was higher ($P < 0.05$) compared to all three GBAs. However, GB and FGBA were similar ($P > 0.05$) for the percentage of samples rated acceptable by consumers for juiciness and texture, but both had a higher ($P < 0.05$) percentage rated acceptable for these traits than RGBA and TGBA. Similar to the consumer ratings, the percentage of samples rated acceptable for tenderness for GB, FGBA, and RGBA were similar ($P > 0.05$), but all three had a higher ($P < 0.05$) percentage rated acceptable than the TGBA. The GB treatment had a higher ($P < 0.05$) percentage of samples rated acceptable for overall flavor liking, beef-like flavor intensity, and overall liking than all GBAs. Moreover, consumers rated GB higher ($P < 0.05$) for purchase intent than all GBAs and indicated they would be willing to pay a price more than 50% higher ($P < 0.05$) for the GB than all the GBAs. Subsequently, this research shows the use of ground beef and ground beef alternatives provide different eating experiences when consumed as a complete hamburger and should be marketed as such by the foodservice and retail sectors.

Introduction

During the past decade, modern plant-based ground beef alternatives have grown in market share in food markets. A push for healthy, environmentally friendly food production has sparked consumer interest in the trend to use plant-based meat alternatives. While research has been completed comparing ground beef alternatives and

ground beef directly, the research of these products in at-home or a foodservice environment is minimal (Davis et al., 2021). The addition of toppings is commonplace for American consumers in hamburger consumption and can affect palatability preferences among consumers. Thus, the objective of this study was to evaluate the palatability traits and consumer acceptance of three plant-based ground beef alternatives in comparison to ground beef in a foodservice-like hamburger application.

Experimental Procedures

One ground beef (80% lean, 20% fat; 1.0 lb chubs) and 3 commercially available plant-based ground beef alternative (GBA) treatments (n = 20 production lots/treatment) were purchased from five supermarkets in the Manhattan, KS, area over a 5-month period. The plant-based GBAs were selected as representatives of GBAs well-known to be sold at foodservice (FGBA) and retail (RGBA). In addition, a popular "traditional" soy-based patty (TGBA) on the market was selected for use. Ground beef (GB) and the 3 GBA packages were stored frozen at the Kansas State University Meat Laboratory in Manhattan, KS, for no more than 4 months prior to patty fabrication. All lots were formed into 2.5 oz patties to be served to consumers on a bun with an opportunity to apply ketchup, mustard, cheese, lettuce, and pickles to samples.

A total of 20 sensory panels were conducted at the Kansas State University Meat Science Sensory Lab. Consumers (n = 120) evaluated samples for juiciness, tenderness, texture, flavor liking, beef-like flavor intensity, and overall liking on 100-point continuous line scales anchored on both ends with descriptive terms. Panelists rated each of the samples as acceptable or unacceptable for each of the sensory traits. Furthermore, panelists rated each sample on their willingness to purchase on a 100-point continuous line scale, and assigned a purchase price they would be willing to pay for each sample if purchasing a similar product at foodservice.

Results and Discussion

Overall, GB was preferred by consumers compared to all three GBAs (Table 1). The GB treatment rated higher ($P < 0.05$) for juiciness and texture compared to all GBAs. The GB, FGBA, and RGBA tenderness ratings were similar ($P > 0.05$), but all three rated higher ($P < 0.05$) than the TGBA. Consumer ratings for overall flavor liking, beef-like flavor intensity, and overall liking showed GB was higher ($P < 0.05$) compared to all three GBAs. However, GB and FGBA were similar ($P > 0.05$) for the percentage of samples rated acceptable by consumers for juiciness and texture, but both had a higher ($P < 0.05$) percentage rated acceptable for these traits than RGBA and TGBA (Table 2). Similar to the consumer ratings, the percentage of samples rated acceptable for tenderness for GB, FGBA, and RGBA were similar ($P > 0.05$), but all three had a higher ($P < 0.05$) percentage rated acceptable than the TGBA. The GB treatment had a higher ($P < 0.05$) percentage of samples rated acceptable for overall flavor liking, beef-like flavor intensity, and overall liking than all GBAs. Moreover, consumers rated GB higher ($P < 0.05$) for purchase intent than all GBAs and indicated they would be willing to pay a price more than 50% higher ($P < 0.05$) for the GB than all the GBAs (Table 1).

Implications

This research indicates that when ground beef and ground beef alternatives are used as an ingredient to make products such as a hamburger patty, ground beef provided a different eating experience preferred by consumers. Therefore, the use of ground beef and ground beef alternatives provide different eating experiences when consumed as a complete hamburger and should be marketed as such by the foodservice and retail sectors.

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Davis, S. G., K. M. Harr, K. J. Farmer, E. S. Beyer, S. B. Bigger, M. D. Chao, A. J. Tarpoff, D. U. Thomson, J. L. Vipham, M. D. Zumbaugh, and T. G. O'Quinn. 2021. Quality of Plant-Based Ground Beef Alternatives in Comparison with Ground Beef of Various Fat Levels. Meat and Muscle Biology 5(1): 38, p.1–15.

Table 1. Least squares means for consumer (n = 120) panel ratings for hamburgers with ground beef and plant-based ground beef alternatives (GBA)[1]

Trait[2]	Ground beef	Foodservice GBA	Retail GBA	Traditional GBA	SEM[3]	P-value
Hamburger panels[4]						
Juiciness	66.4[a]	55.3[b]	53.5[b]	39.1[c]	2.2	< 0.01
Tenderness	64.7[a]	61.4[a]	62.6[a]	48.8[b]	2.1	< 0.01
Texture	64.6[a]	55.0[b]	50.0[b]	40.5[c]	2.3	< 0.01
Overall flavor	67.7[a]	48.6[b]	43.4[bc]	37.4[c]	2.5	< 0.01
Beef flavor	66.1[a]	47.2[b]	41.0[c]	36.8[c]	2.7	< 0.01
Overall liking	67.5[a]	49.6[b]	42.3[b]	34.1[c]	2.6	< 0.01
Purchase intent[5]	63.3[a]	42.2[b]	34.5[c]	28.3[c]	2.7	< 0.01
Purchase price[6]	4.8[a]	3.2[b]	2.7[bc]	2.1[c]	0.2	< 0.01

[abc]Least squares means in the same row without a common superscript differ ($P < 0.05$).

[1]Foodservice GBA = plant-based ground beef alternative most commonly sold in foodservice establishments (restaurants).

Retail GBA = plant-based ground beef alternative most commonly sold in retail markets (grocery stores, supermarkets).

Traditional GBA = plant-based ground beef alternative most indicative of a traditional soy-based product.

[2]Sensory scores: 0 = extremely dry/tough, dislike texture/overall flavor/beef flavor/overall; 50 = neither dry nor juicy/neither tough nor tender, neither like nor dislike texture/overall flavor/beef flavor/overall; 100 = extremely juicy/tender, like texture/overall flavor/beef flavor/overall.

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

[4]Consumers were served a hamburger patty on a white bun with an option to add cheese, ketchup, lettuce, mustard, and pickle to their hamburger samples.

[5]If price were not a factor, likelihood of purchase; 1 = Not Likely, 100 = Extremely Likely.

[6]Price, in US dollars, willing to be paid at foodservice for comparable product.

Table 2. Least squares means for the percentage of ground beef and plant-based ground beef alternatives (GBA)[1] hamburger samples rated acceptable for each palatability trait by consumers (n = 120)

Trait	Ground beef	Foodservice GBA	Retail GBA	Traditional GBA	SEM[2]	*P*-value
Hamburger panels[3]						
Juiciness	89.7[a]	81.5[ab]	79.0[b]	50.0[c]	5.1	< 0.01
Tenderness	93.4[a]	92.5[a]	86.7[a]	70.1[b]	4.3	< 0.01
Texture	86.7[a]	82.5[ab]	72.5[b]	55.0[c]	4.5	< 0.01
Overall flavor	90.9[a]	67.6[b]	50.8[c]	45.0[c]	4.6	< 0.01
Beef flavor	89.4[a]	61.8[b]	52.5[bc]	39.9[c]	4.8	< 0.01
Overall liking	90.2[a]	69.4[b]	49.2[c]	49.9[c]	4.8	< 0.01

[abcd]Least squares means in the same row without a common superscript differ (*P* < 0.05).

[1]Foodservice GBA = plant-based ground beef alternative most commonly sold in foodservice establishments (restaurants).

Retail GBA = plant-based ground beef alternative most commonly sold in retail markets (grocery stores, supermarkets).

Traditional GBA = plant-based ground beef alternative most indicative of a traditional soy-based product.

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

[3]Consumers were served a hamburger patty on a white bun with an option to add cheese, ketchup, lettuce, mustard, and pickle to their hamburger samples.

Consumer Sensory Evaluation of Ground Beef and Plant-Based Ground Beef Alternatives Used in a Taco Application

L.A. Egger, K.J. Farmer, E.S. Beyer, K.R. Lybarger, J.L. Vipham, M.D. Zumbaugh, M.D. Chao, and T.G. O'Quinn

Abstract

The objective of this study was to evaluate consumer preferences for palatability traits and consumer acceptability of three plant-based protein alternatives and ground beef in a taco application. Three commercially available plant-based ground beef alternative (GBA) treatments (n = 20 production lots/treatment) were selected based upon industry availability. The GBAs were considered the most popular in the marketing sectors of foodservice (FGBA), retail (RGBA), and traditional (TGBA). One ground beef (80% lean/20% fat; 1.0-lb chubs) treatment was selected for use. After individual lots were cooked with taco seasoning, approximately 0.16-lb portions were served to panelists on a flour tortilla with the opportunity to add cheese, lettuce, and tomatoes to the samples. Consumers (n = 120) rated samples on a 100-point line scale for juiciness, tenderness, texture, flavor liking, beef-like flavor intensity, overall liking, and willingness to purchase. Additionally, consumers evaluated the sensory traits as acceptable or unacceptable. Furthermore, panelists identified a price of purchase for all samples as if purchasing a comparable product at a foodservice outlet. The GB treatment was preferred by consumers in nearly all categories. Consumer ratings for juiciness, texture, overall flavor liking, beef-like flavor intensity, and overall liking showed GB was higher ($P < 0.05$) compared to all three GBAs. However, GB, FGBA, and RGBA tenderness ratings were similar ($P > 0.05$), but all three rated higher ($P < 0.05$) than the TGBA. Moreover, GB, FGBA, and RGBA tenderness and juiciness were similar ($P > 0.05$) for the percentage of samples rated as acceptable by consumers, but all three had a higher ($P < 0.05$) percentage of samples rated acceptable than the TGBA. The GB treatment had a higher ($P < 0.05$) percentage of samples rated acceptable for texture, overall flavor liking, beef-like flavor intensity, and overall liking than all GBAs. Moreover, consumers rated GB higher ($P < 0.05$) for purchase intent than all GBAs and indicated they would be willing to pay a price nearly 50% higher ($P < 0.05$) for the GB than all the GBAs. Overall, GB was preferred by consumers when consumed as a crumbled product and GB should be marketed as a distinct eating experience at foodservice and retail when plant-based GBAs are available in similar crumbled products.

Introduction

The evolution of American consumer diet habits and growing concerns of environmental impacts from animal agricultural production is associated with the growth of plant-based proteins market (Church, 2022). Plant-based protein processors have marketed traditionally toward vegetarian markets. They now have expanded the marketing plan to meat consumers who are environmentally conscious and incorporating modern diets that minimize meat consumption (Anonymous, 2021). Despite growing market popularity, there has been a gap of consumer research for consumption preferences among plant-based proteins and ground beef in practical usages, such as

tacos and hamburgers (Anonymous, 2021). A recent consumer study conducted at Kansas State University directly compared ground beef and ground beef plant-based alternatives. Results showed consumers had a strong preference for ground beef (Davis et al., 2021). However, rarely do consumers consume ground beef or ground beef alternative products without the addition of toppings. Thus, the objective of this study was to evaluate consumer preferences for palatability traits and consumer acceptability of three plant-based protein alternatives and ground beef in a taco application.

Experimental Procedures

Three commercially available plant-based ground beef alternatives (GBA) treatments (n = 20 production lots/treatment) were selected based upon industry prevalence. The GBAs were identified as the most popular in the marketing sectors of foodservice (FGBA), retail (RGBA) and traditional (TGBA). One ground beef (80% lean/20% fat; 1-lb chubs) treatment (n = 20 production lots/treatment) was selected for use. All lots were purchased from multiple supermarkets in the Manhattan, KS, area over a four-month period. All samples were stored frozen at the Kansas State University Meat Laboratory in Manhattan, KS, for four months or less prior to consumer testing. Samples were thawed at 38°F for 24 hours prior to consumer panel analysis for identification and repackaging. Individual lots for GB and RGBA were unpackaged, hand mixed for 15 seconds, and immediately repackaged into 1-lb samples using a commercial rollstock packing machine (Model Bulldog 42a 300, Ultrasource, Kansas City, MO). The FGBA and TGBA treatments followed the same packaging procedure; however, two packages per production lot were combined from the same production lot to reach the 1-lb sample size.

Individual lots were crumbled in an Oster 12-in electric skillet (Boca Raton, FL) to a surface temperature of 180°F. Following cooking, a taco seasoning was added to the cooked treatments and allowed to simmer for 3 minutes following the manufacturer's instructions. Approximately 0.16-lb portions were served to panelists on a flour tortilla with the opportunity to add cheese, lettuce, and tomatoes to samples.

Consumer sensory panels (n = 20) were conducted at the Kansas State Meat Science Sensory Lab. Consumers (n = 120) rated samples on a 100-point continuous line scale for juiciness, tenderness, texture, flavor liking, beef-like flavor intensity, overall liking, and willingness to purchase. Line scales were anchored with descriptive terms at end and mid-points: 0 = extremely dry, tough, extremely dislike overall flavor/beef flavor/texture/overall, and extremely unlikely to purchase; 50 = neither juicy nor dry, tough nor tender, neither like or dislike overall flavor/beef flavor/texture/overall, or neither likely or unlikely to purchase; and 100 = extremely juicy, tender, extremely like overall flavor/beef flavor/texture/overall, and extremely likely to purchase. Additionally, consumers evaluated the palatability traits as acceptable or unacceptable. Furthermore, panelists designated a price of purchase for all samples as if purchasing a comparable product at a foodservice outlet.

Results and Discussion

The GB treatment was preferred by consumers in nearly all categories (Table 1). Consumer ratings for juiciness, texture, overall flavor liking, beef-like flavor intensity, and overall liking showed GB was higher ($P < 0.05$) compared to all three GBAs. However, GB, FGBA, and RGBA tenderness ratings were similar ($P > 0.05$), but all

three rated higher ($P < 0.05$) than the TGBA. Moreover, GB, FGBA, and RGBA tenderness and juiciness were rated similar ($P > 0.05$) for the percentage of samples rated as acceptable by consumers (Table 2), but all three had a higher ($P < 0.05$) percentage of samples rated acceptable than the TGBA. The GB treatment had a higher ($P < 0.05$) percentage of samples rated acceptable for texture, overall flavor liking, beef-like flavor intensity, and overall liking than all GBAs. Moreover, consumers rated GB higher ($P < 0.05$) for purchase intent and indicated they would be willing to pay a price nearly 50% higher ($P < 0.05$) for the GB than all the GBAs.

Implications

This research indicates consumers preferred ground beef to ground beef alternatives when used as a crumbled ingredient in tacos. Therefore, ground beef should be marketed as a distinct eating experience to consumers at foodservice and retail when plant-based ground beef alternatives are available in similar crumbled products.

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Table 1. Least squares means for consumer (n = 120) panel ratings for tacos made with ground beef and plant-based ground beef alternatives (GBA)[1]

Trait[2]	Ground beef	Foodservice GBA	Retail GBA	Traditional GBA	SEM[3]	P-value
Taco panels[4]						
Juiciness	74.3[a]	60.8[b]	66.6[b]	45.4[c]	2.4	< 0.01
Tenderness	68.6[a]	67.1[a]	65.4[a]	58.8[b]	2.2	< 0.01
Texture	70.9[a]	55.1[b]	53.7[b]	43.1[c]	2.9	< 0.01
Overall flavor	68.7[a]	51.3[b]	49.0[b]	36.0[c]	3.2	< 0.01
Beef flavor	68.3[a]	50.4[b]	46.4[b]	35.0[c]	3.1	< 0.01
Overall liking	69.7[a]	51.7[b]	47.4[b]	34.5[c]	3.3	< 0.01
Purchase intent[5]	63.7[a]	42.6[b]	39.6[b]	27.3[c]	3.4	< 0.01
Purchase price[6]	2.8[a]	1.9[b]	1.6[bc]	1.3[c]	0.2	< 0.01

[abc]Least squares means in the same row without a common superscript differ (P < 0.05).
[1]Foodservice GBA = plant-based ground beef alternative most commonly sold in foodservice establishments (restaurants).
Retail GBA = plant-based ground beef alternative most commonly sold in retail markets (grocery stores, supermarkets).
Traditional GBA = plant-based ground beef alternative most indicative of a traditional soy-based product.
[2]Sensory scores: 0 = extremely dry/tough, dislike texture/overall flavor/beef flavor/overall; 50 neither dry nor juicy/neither tough nor tender, neither like nor dislike texture/overall flavor/beef flavor/overall; 100 = extremely juicy/tender, like texture/overall flavor/beef flavor/overall
[3]Standard error (largest) of the least square means.
[4]Consumers were served samples seasoned with a taco seasoning blend on a flour tortilla with an option to add cheese, lettuce, and tomato to their taco samples.
[5]If price were not a factor, likelihood of purchase; 1 = Not Likely, 100 = Extremely Likely.
[6]Price, in U.S. dollars, willing to be paid at foodservice for comparable product.

Table 2. Least squares means for the percentage of ground beef and plant-based ground beef alternatives (GBA)[1] taco samples rated acceptable for each palatability trait by consumers (n = 120)

Trait	Ground beef	Foodservice GBA	Retail GBA	Traditional GBA	SEM[2]	P-value
Taco panels[3]						
Juiciness	94.1[a]	91.8[a]	90.3[a]	63.4[b]	5.4	< 0.01
Tenderness	98.0[a]	96.7[a]	96.7[a]	84.7[b]	4.2	< 0.01
Texture	94.6[a]	83.2[b]	76.5[bc]	67.7[c]	5.8	< 0.01
Overall flavor	94.2[a]	73.1[b]	62.6[b]	39.2[c]	5.6	< 0.01
Beef flavor	93.4[a]	71.2[b]	58.0[c]	41.9[d]	5.7	< 0.01
Overall liking	93.5[a]	71.5[b]	61.7[b]	46.4[c]	5.9	< 0.01

[abcd]Least squares means in the same row without a common superscript differ (P < 0.05).
[1]Foodservice GBA = plant-based ground beef alternative most commonly sold in foodservice establishments (restaurants).
Retail GBA = plant-based ground beef alternative most commonly sold in retail markets (grocery stores, supermarkets).
Traditional GBA = plant-based ground beef alternative most indicative of a traditional soy-based product.
[2]Standard error (largest) of the least square means.
[3]Consumers were served samples seasoned with a taco seasoning blend on a flour tortilla with an option to add cheese, lettuce, and tomato to their taco samples.

Consumer Sensory Evaluation of the Impact of Bone-In Versus Boneless Cuts on Beef Palatability

K.J. Farmer, E.S. Beyer, S.G. Davis, K.M. Harr, M.D. Chao, J.L. Vipham, M.D. Zumbaugh, and T.G. O'Quinn

Abstract

Palatability traits of ribeye, strip loin, and tenderloin steaks were evaluated in a bone-in versus boneless scenario. Eating quality of these cuts was also evaluated in a high quality (upper 2/3 U. S. Department of Agriculture Choice) and a lower quality (USDA Select) product to evaluate the interactions of marbling level and bone state. Subprimal cuts were collected from both sides of 12 beef carcasses per quality grade and aged for 28 days. Product was fabricated into 1-in thick steaks and randomly designated for consumer sensory analysis. Bone state had no impact ($P > 0.05$) on consumer tenderness and flavor ratings for any of the three cuts. However bone-in strip loin samples were rated juicier and higher ($P < 0.05$) overall than boneless strip loin steaks by consumers. Tenderloin steaks were juicier, more tender, more flavorful, and rated higher overall ($P < 0.05$) than ribeye steaks and boneless strip loin steaks by consumers. Furthermore, there were no differences ($P > 0.05$) between strip loins and ribeyes for flavor liking by consumers and no difference ($P > 0.05$) in overall liking rating between ribeyes and boneless strip loin steaks. Overall, bone status had a minimal impact on beef palatability traits, providing evidence that eating quality is not greatly impacted by bone status for any of the cuts evaluated.

Introduction

Millennials have coined the term "foodie" to describe those who have a passion for eating and learning about the overall eating experience (Ulver, 2019). As a result, these consumers prefer the aesthetic and visual stimulation that bone-in beef cuts offer in comparison to boneless alternatives (Bass, 2018). Moreover, bone-in cuts are believed to have a more flavorful eating experience for consumers (Chicago Steak Company, 2016; Lopez, 2018; Goldwyn, 2021).

Previous research evaluating bone-in versus boneless cuts is limited and has produced mixed results related to eating quality. Therefore, the objective of the current study was to evaluate palatability traits of beef cuts (ribeye, strip loin, tenderloin) in a bone-in versus boneless scenario and compare the palatability characteristics of these cuts in a high quality (upper 2/3 USDA Choice) and a lower quality (USDA Select) product to evaluate the interactions of marbling level and bone state.

Experimental Procedures

Left and right sides of 12 beef carcasses representing USDA Choice (upper 2/3) and USDA Select quality grades were selected by trained Kansas State University personnel at a commercial packing plant in the Midwest. Paired (n = 12 pairs; 24 total/cut/grade) beef short loins, bone-in ribeye rolls, and boneless ribeye rolls were vacuum packaged and transported to the Kansas State University Meat Laboratory. Short loins were

fabricated into either a boneless strip loin with a corresponding bone-in tenderloin or a bone-in strip loin with a paired boneless tenderloin at 3 days postmortem. Product was then vacuum-packaged and aged for 28 days at 32–39°F. Frozen subprimal cuts were then fabricated into 1-in thick steaks using a band saw. Steaks were cooked to a peak temperature of 160°F (medium) on clamshell style griddles and temperatures were monitored using a probe thermometer. Samples were cut into 1-in thick × 0.4-in × 0.4-in cuboids, and 2 pieces were served to untrained panelists. Consumer sensory panelists (n = 144) were recruited from Manhattan, KS, and the surrounding area and monetarily compensated for their participation in the study. Panels were conducted in a lecture-style classroom at Kansas State University. Testing followed procedures previously described McKillip et al. (2017), Nyquist et al. (2018), and Davis et al. (2021). Consumers evaluated samples for juiciness, tenderness, flavor liking, beef-like flavor intensity, and overall liking on 100-point continuous line scales anchored on both ends with descriptive terms. Additionally, panelists were asked to classify each sample as acceptable or unacceptable for each of the sensory traits previously listed and to assess the quality of the sample by identifying if the sample was unsatisfactory, everyday quality, better than everyday quality, or premium quality. Consumer sensory panelists recorded their responses using a digital survey (Qualtrics Software, Provo, UT) on an electronic tablet (Lenovo TB-8505F).

Results and Discussion

There were no ($P > 0.05$) interactions found between quality grade and cut/bone state for any of the traits evaluated by consumers. The means for the main effects of quality grade and cut/bone state are reported in Table 1. When evaluating the main effect of quality grade, all Choice steaks were rated higher ($P < 0.05$) than Select steaks for juiciness, tenderness, flavor, and overall liking. Bone state had no impact ($P > 0.05$) on consumer ratings of juiciness and overall liking for tenderloins and ribeyes, but in the strip loin, bone-in steaks were rated juicier ($P < 0.05$) and higher ($P < 0.05$) for overall liking when compared to boneless steaks. Moreover, bone state had no impact ($P > 0.05$) on consumer ratings of tenderness and flavor ratings for any of the three cuts. Regardless of bone state, tenderloin steaks were juicier, more tender, more flavorful, and rated higher overall ($P < 0.05$) than ribeyes and boneless strip loin steaks. However, bone-in strip loin steaks were similar ($P > 0.05$) in juiciness to bone-in tenderloins. There were no differences ($P > 0.05$) between strip loins and ribeyes for flavor liking. Additionally, boneless ribeye steaks were similar ($P > 0.05$) to bone-in and boneless strip loin samples for tenderness and similar ($P > 0.05$) to boneless strip loins for overall liking ratings.

Consumers were also asked to rate palatability traits as either acceptable or unacceptable as they were evaluating each sample (Table 1). No ($P > 0.05$) interactions were found between quality grade and cut/bone state. Choice steaks had a higher ($P < 0.05$) percentage of consumers that rated juiciness as acceptable when compared to Select steaks. But quality grade did not impact ($P > 0.05$) the percentage of samples rated acceptable by consumers for tenderness, flavor, and overall acceptability. Furthermore, bone state had no impact ($P > 0.05$) on the percentage of consumers that rated juiciness as acceptable for tenderloins and ribeyes, but in strip loins, bone-in steaks had a higher ($P < 0.05$) percentage of acceptable consumer responses than boneless cuts. The percentage of acceptable samples for tenderness and overall acceptability were not ($P > 0.05$) impacted by bone state in tenderloins and strip loins; however, in ribeyes,

the percentage of acceptable consumer ratings was higher ($P < 0.05$) for bone-in cuts for both traits. Tenderloins had a higher ($P < 0.05$) percentage of acceptable ratings for tenderness than strip loins and ribeyes. Likewise, tenderloins also had a higher ($P < 0.05$) percentage of acceptable ratings for juiciness and overall acceptability when compared to boneless strip loins and boneless ribeyes. Strip loin and ribeye steaks had similar ($P > 0.05$) percentages of acceptable juiciness ratings, except for boneless strip loins, which had lower ($P < 0.05$) percentages than either bone-in cut.

Additionally, consumer panelists were asked to identify the quality level at which they perceived each sample (Table 1). Once again, there were no ($P > 0.05$) interactions observed between quality grade and cut/bone state. Likewise, no ($P > 0.05$) quality grade effects were observed for the percentage of steaks rated as unsatisfactory, everyday, and premium quality. However, a greater ($P < 0.05$) percentage of Choice samples were rated as better than everyday quality compared to Select. Moreover, bone state did not ($P > 0.05$) impact quality perception on strip loin and tenderloin samples. Bone state also did not ($P > 0.05$) impact premium, better than everyday, and everyday quality perceptions among ribeyes; but the percentage of consumers rating ribeye samples unsatisfactory was higher ($P < 0.05$) for boneless ribeye steaks. Fewer ($P < 0.05$) samples from tenderloins were perceived as unsatisfactory quality when compared to boneless strip loin and ribeye steaks. Likewise, a greater ($P < 0.05$) percentage of consumer ratings for tenderloin samples were perceived as premium quality than either of the other cuts.

Implications

The results observed within palatability traits show that regardless of bone state, bone-in and boneless cuts of the same muscle are rated similarly by panelists. This indicates that a similar overall eating experience could be derived from a boneless or bone-in steak from the same cut and quality grade.

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Table 1. Least squares means for consumer sensory panel ratings, percentage of samples rated acceptable, and perceived quality level for strip loin, tenderloin, and ribeye steaks of varying bone states and USDA quality grade[1]

Trait	Strip loin Bone-In	Strip loin Boneless	Tenderloin Bone-In	Tenderloin Boneless	Ribeye Bone-In	Ribeye Boneless	SEM[2]	P-value	Choice	Select	SEM[2]	P-value
Palatability rating[3]												
Juiciness rating	58.5[bc]	51.1[d]	63.7[ab]	66.6[a]	57.2[cd]	52.7[cd]	2.5	< 0.01	66.7[a]	54.0[b]	1.8	< 0.01
Tenderness rating	53.1[bc]	49.7[c]	73.5[a]	78.4[a]	56.5[b]	51.2[bc]	2.6	< 0.01	64.9[a]	55.9[b]	1.9	< 0.01
Flavor rating	59.7[b]	55.6[b]	66.2[a]	64.7[a]	58.3[b]	56.0[b]	2.2	< 0.01	63.0[a]	57.1[b]	1.7	< 0.01
Overall like rating	60.0[b]	53.2[c]	69.0[a]	72.2[a]	58.2[bc]	54.5[c]	2.4	< 0.01	65.2[a]	57.2[b]	1.9	< 0.01
Acceptability rating[4]												
Juiciness acceptability	83.7[ab]	72.1[c]	87.5[a]	89.0[a]	81.7[ab]	76.1[bc]	0.04	< 0.01	87.3[a]	76.3[b]	0.03	< 0.01
Tenderness acceptability	77.3[bc]	74.2[c]	95.0[a]	96.9[a]	83.8[b]	70.1[c]	0.04	< 0.01	89.7	82.8	0.03	0.08
Flavor acceptability	86.1	79.2	87.2	85.6	82.9	79.1	0.03	0.20	85.4	81.7	0.02	0.20
Overall acceptability	84.6[abc]	78.1[cd]	91.2[a]	89.1[ab]	82.2[bc]	73.4[d]	0.04	< 0.01	86.7	80.7	0.03	0.08
Perceived quality level[5]												
Unsatisfactory	13.6[bc]	15.5[ab]	7.2[cd]	6.8[d]	15.0[b]	23.4[a]	0.04	< 0.01	9.9	16.0	0.03	0.07
Everyday	50.9[a]	55.8[a]	37.0[b]	34.2[b]	57.2[a]	47.4[a]	0.04	< 0.01	43.0	51.0	0.03	0.09
Better than everyday	28.2[abc]	20.9[c]	31.6[ab]	33.8[a]	19.4[c]	23.6[bc]	0.04	0.02	31.0[a]	21.3[b]	0.03	0.02
Premium	4.5[b]	2.0[b]	21.4[a]	23.0[a]	6.4[b]	3.8[b]	0.04	< 0.01	9.5	5.3	0.02	0.10

[abcd]Least squares means in the same section of the same row without a common superscript differ (P < 0.05).

[1]Quality grade: Choice = USDA Choice (upper 2/3) with marbling scores ranging from modest[00] to moderate[100]. Select = USDA Select with marbling scores ranging from slight[00] to slight[100].

[2]Standard error of the mean (largest) of the least square means in the same section of the same row.

[3]Sensory scores: 0 = extremely dry/tough/extremely bland; 50 = neither dry nor juicy/neither tough nor tender; 100 = extremely juicy/tender/extremely intense.

[4]Percentage of samples rated as acceptable (yes/no) by consumer sensory panelists.

[5]Percentage of samples classified at various quality levels by consumer sensory panelists.

Change in Myoglobin Denaturation Among Three Degrees of Doneness of Three Muscles

E.S. Beyer, K.J. Farmer, E.G. Kidwell, S.G. Davis, K.M. Harr, K.R. Lybarger, L.E. Egger, M.D. Chao, M.D. Zumbaugh, J.L. Vipham, M.C. Hunt, and T.G. O'Quinn

Abstract

The objective of this study was to determine the change in myoglobin denaturation through three degrees of doneness (medium rare, medium, and well-done) within the *longissimus dorsi, gluteus medius,* and *biceps femoris.* Strip loins (n = 12) and top butts (n = 12) were collected and fabricated into 1-in steaks, aged for 28 days, and held frozen at -10°F. Steaks were cooked to the assigned degree of doneness (DOD) and used for either lab assays or cook loss and Warner-Brazler shear force (WBSF). After cooking to the appropriate degree of doneness, the steaks were sliced in half, scanned internally for CIE L* (lightness), a* (redness), b* (yellowness), and powdered for lab assays. Myoglobin denaturation was determined using a modified protocol from the American Meat Science Association Color Measurement Guidelines and calculated as a percentage of deoxymyoglobin denaturation compared to the raw sample. Myoglobin was denatured 29.08%, 48.34%, or 70.17% at each degree of doneness, respectively. As expected, the a* values decreased ($P < 0.05$) with each different degree of doneness; however, the pH was not impacted ($P > 0.05$). Similarly, the cooking loss percentages increased ($P < 0.05$) with each degree of doneness and the WBSF force values were higher ($P < 0.05$) for well-done steaks in comparison to the other treatments. As expected, the myoglobin denaturation percentage increased with increasing DOD and behaved similarly to changes in the a* values. This research gives more insight to the impacts of cooking and the changes that proteins, especially myoglobin, undergo between different DOD.

Introduction

Myoglobin is a complex molecule mostly responsible for meat color. It undergoes a series of changes through the aging and cooking processes, altering the pigment (Hughes et al., 2020). Consumers are heavily motivated by raw meat color, both when evaluating the overall appearance and willingness to purchase; however, the impact and mechanisms of cooked color is less understood (Carpenter et al., 2001; Hughes et al., 2020). Salim et al. (2021) determined myoglobin undergoes post-translational changes through the cooking process, but the basic question of myoglobin denaturation has yet to be answered. Therefore, the objective of this study was to determine the changes in myoglobin denaturation through cooking three different muscles to medium rare, medium, or well-done degrees of doneness.

Experimental Procedures

Beef strip loins (n = 12) [Institutional Meat Purchase Specifications (IMPS) # 180, NAMP, 2010], and top butts (n = 12) (IMPS #184, NAMP, 2010) were collected at a Midwest beef processing plant and brought to Kansas State University for processing. The strip loins (LL) and the top butts were denuded, and the top butts were separated into the *biceps femoris* (BF) and *gluteus medius* (GM). The muscles were sliced into

1-in steaks and assigned to one of the following treatments: raw, medium rare (MR), medium (MED), or well-done (WD). All three muscles were aged for 28 days at 36°F, frozen and held at -10°F.

The steaks assigned for lab assays were cooked to the appropriate degree of doneness (DOD) to peak temperatures of 145°F, 160°F, or 170°F for each DOD. A thermopen (Thermopen Mk4, ThermoWorks, Salt Lake City, UT) was inserted into the geometric center of the steak to record the peak internal temperature. Color readings [CIE L* (lightness), a* (redness), b* (yellowness)] were taken using a Hunter Lab Miniscan (Model 2500L, Hunter Associates Laboratory Inc, Reston, VA), and then samples were powdered immediately for moisture, fat, pH, and myoglobin denaturation. Myoglobin denaturation was determined using a modified protocol provided in the American Meat Science Association Color Measurement Guidelines (AMSA, 2012). The samples were weighed, homogenized in a potassium phosphate buffer, centrifuged, and filtered. A 200 μL sample was plated on a 96-well plate in duplicate and 1% sodium hydrosulfite was added to reduce all forms of myoglobin to deoxymyoglobin. The plates were evaluated with a spectrophotometer at 433 nm and the absorbance was used to calculate the percent myoglobin denaturation of each sample.

Cook loss and Warner-Brazler shear force (WBSF) samples were cooked using the same procedures outlined above. For cook loss, the raw steak was weighed and recorded and then reweighed following cooking. The steaks were allowed to cool for a minimum of 12 hours to a temperature of 36°F before taking six 0.5-in cores parallel to the muscle fiber. Each core was sheared perpendicular to the muscle fiber orientation using an Instron testing machine (Model 5569, Instron Corp., Canton, MA) with a cross-head speed of 9.8 in/min and a load cell of 220 lb. The shear force measurements from all six cores were averaged for each sample and presented as average peak force (lb).

Moisture, fat, and pH were determined using the powdered meat samples. Moisture content was determined using the drying oven method (950.46 and 934.01; AOAC, 1995). The fat content was measured using the Folch method (Folch et al., 1957). The pH was measured by homogenizing a 0.17 oz sample in 1.69 oz of deionized water using a calibrated InLab Solids Pro-ISM probe (Part #51344155; Mettler-Toledo, Schwerzenbach, Switzerland) connected to a Seven Compact pH meter (Mettler-Toledo).

Results and Discussion

Cook loss increased ($P < 0.05$) with each DOD, while the LL had the lowest ($P < 0.05$) cook loss compared to the other muscles (Table 1). Similarly, moisture content decreased ($P < 0.05$) with each DOD while the LL resulted in the lowest ($P < 0.05$) moisture content (Table 1). Only the DOD impacted the WBSF values, with MR having the lowest ($P < 0.05$) value, being the most tender (Table 1). The L* values were not impacted ($P > 0.05$) by the different DOD; however, the LL resulted in the highest ($P < 0.05$) L* value followed by the GM and then the BF (Table 2). As expected, the a* values decreased ($P < 0.05$) with each different DOD. The MR and MED treatments had a higher ($P < 0.05$) b* value in comparison to the WD treatments. Even though color and pH are intimately related, only muscle impacted pH, with the BF having a higher ($P < 0.05$) pH value compared to the other muscles. Similar to the a* values, the myoglobin denaturation increased ($P < 0.05$) for each DOD, but muscle did not ($P > 0.05$) have an impact (Table 1). Myoglobin was denatured 29.08%, 48.34%, or

70.17% respectively at each DOD. Even though myoglobin undergoes post-translational changes through cooking to increase thermal stability as described by Salim et al. (2020), it still significantly denatures with each DOD to correspond to the visual changes associated with each DOD.

Implications

Myoglobin is a complicated molecule that has been shown to undergo post-translational changes in previous research, but the question of how much of myoglobin is denatured at certain DOD was not answered until this research. As expected, the myoglobin denaturation percentage increased with increasing DOD and behaved similarly to changes in the a* values. These changes were accompanied by expected changes in L*, a*, b*, moisture content, WBSF, and cook loss. This research gives more insight to the impacts of cooking and the changes that proteins, especially myoglobin, undergo between different DOD. Lastly, this research can act as a baseline for changes in myoglobin denaturation and cooked color for future research projects with other processing steps such as different aging periods, cooking methods, or freezing methods.

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Table 1. Fat, moisture, cook loss, WBSF, and myoglobin denaturation percentages of three degrees of doneness and three muscles

Degree of doneness	Fat, %	Moisture, %	Cook loss,[1] %	WBSF[2]	Myoglobin denaturation,[3] %
Raw	4.41[b]	72.69[a]	---	---	---
Medium rare, 145°F	4.69[ab]	66.52[b]	14.13[c]	7.47[b]	29.08[c]
Medium, 160°F	4.97[ab]	64.61[c]	20.00[b]	9.46[a]	48.34[b]
Well done, 170°F	5.25[a]	62.93[d]	24.71[a]	10.20[a]	70.17[a]
SEM[4]	0.30	0.25	1.46	0.18	2.08
P-value	0.04	<0.01	<0.01	<0.01	<0.01
Muscle[5]					
LL	5.23[a]	65.88[b]	16.64[b]	9.17	48.85
BF	5.32[a]	67.01[a]	21.86[a]	8.71	49.65
GM	3.94[b]	67.18[a]	20.34[a]	9.30	49.08
SEM[4]	0.53	0.41	1.74	0.22	3.17
P-value	0.02	<0.01	<0.01	0.44	0.97

[abcd] Means within the same column without a common superscript differ ($P < 0.05$).
[1] Cooking loss = 1 - (cooked weight / raw weight) × 100.
[2] Warner-Bratzler shear force; lb.
[3] Myoglobin denaturation, % = [1 - (raw - cooked) / raw] × 100.
[4] Standard error (largest) of the least squares means.
[5] LL = *longissimus dorsi*; BF = *biceps femoris*; GM = *gluteus medius*.

Table 2. CIE L*, a*, and b*, and pH of three degrees of doneness and three muscles

Degree of doneness	L*[1]	a*[2]	b*[3]	pH
Medium rare, 145°F	50.04	25.32[a]	20.69[a]	5.82
Medium, 160°F	50.90	21.90[b]	20.68[a]	5.83
Well done, 170°F	50.33	17.68[c]	19.49[b]	5.75
SEM[4]	0.36	0.59	0.34	0.06
P-value	0.06	<0.01	<0.01	0.09
Muscle[5]				
LL	53.03[a]	20.07	20.17	5.74[b]
BF	48.21[c]	21.89	20.40	5.87[a]
GM	50.03[b]	21.60	20.28	5.71[b]
SEM[4]	0.83	0.80	0.40	0.06
P-value	<0.01	0.05	0.84	0.01

[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] Standard error (largest) of the least squares means.
[5] LL = *longissimus dorsi*; BF = *biceps femoris*; GM = *gluteus medius*.

Evaluating the Effect of Accelerated Aging at Different Temperature and Time Points on Beef Quality and Enzyme Activity of Lower Quality Beef Cuts

H. Jeneske, C.K. Chun, S. Hene, L.A. Koulicoff, H. Aufdemberge, J.L. Vipham, T.G. O'Quinn, and M.D. Chao

Abstract

The objective of this study was to explore the effects of different time and temperature accelerated aging (AA) treatments on beef tenderness, yield, microbial quantity, and enzyme activity on lower quality beef cuts. The shoulder clod and top round muscles were collected from 10 U.S. Department of Agriculture choice beef carcasses, fabricated into steaks, and assigned to one of six treatments: 3 days postmortem (control), cooler aged for 21 days, AA 120°F for 2 h, AA 120°F for 3 h, AA 130°F for 2 h, and AA 130°F for 3 h. Yield calculation, aerobic plate counts, instrumental tenderness, cathepsin enzyme activity, and collagen analysis were performed. All AA treatments effectively decreased microbial loads on the steak surface and in purge ($P < 0.05$). The AA steaks exhibited lower yield compared to the cooler aged steaks or control ($P < 0.01$). All AA treatments improved tenderness of the samples compared to the control ($P < 0.01$) with most exhibiting similar tenderness as the 21-day cooler aged treatment. The amount of collagen present in the purge was greater in AA samples compared to the cooler aged samples ($P < 0.01$). Finally, it was interesting to point out that AA 120°F at 3 h seem to stimulate the most cathepsin enzyme activity among the treatments in beef ($P < 0.01$).

Introduction

As the prices for beef products continue to rise, consumers search for alternatives to the middle meat beef cuts. These lower priced cuts are often less tender than the middle meat, so there is a continued effort for the meat industry to develop technologies to increase the palatability of these "lower quality" beef cuts. A new tenderization method known as accelerated aging (AA) encompasses incubating vacuum packaged beef in a warm water bath to stimulate native enzymatic activity in beef and subsequently increase the rate of the tenderization process. To our knowledge, there is no research on the impact of AA on beef quality. Therefore, this study aimed to explore the effects of four AA methods at different temperature and time points on meat quality and enzymatic activity of two lower quality beef cuts.

Experimental Procedures

Shoulder clod and top round were collected from 10 U.S. Department of Agriculture choice beef carcasses, and each cut was fabricated into steaks and assigned to one of six treatments: 3 days postmortem (control), cooler aged for 21 days, AA 120°F for 2 h, AA 120°F for 3 h, AA 130°F for 2 h, and AA 130°F for 3 h. Yield was calculated based on loss during AA treatment and cooking loss. Warner-Bratzler shear force (WBSF) was measured for each sample, and the purge for microbial analysis was collected from

each primal bag as well as from each vacuum package after the AA treatment. The purge for collagen analysis was collected from all six treatments. The steak surface was swabbed on the anterior side prior to AA treatments and swabbed on the posterior side after the AA treatments. Aerobic plate counts (APC) were performed on the purge and swab samples. Cathepsin activity was determined through zymography. Soluble collagen content and total collagen in the purge was determined through hydroxyproline content.

Results and Discussion

As expected, all AA treatments decreased APC on steak surfaces ($P < 0.01$; Figure 1) and in the purge ($P < 0.05$; Table 1). After AA, the 130°F samples had a lower yield than the 120°F groups ($P < 0.05$; Table 1). The cooler aged samples had a lower cook yield than all of the AA samples ($P < 0.01$; Table 2), and shoulder clod displayed higher cooking yield than the top round muscle ($P < 0.01$; Table 1). On the other hand, the WBSF results showed that AA 120°F for 3 h samples and both AA 130°F samples displayed similar tenderness to the samples that were cooler aged for 21 days ($P < 0.01$; Table 2). The amount of collagen in the purge was highest in the shoulder clod ($P < 0.01$; Table 1), and all of the AA treatments had higher collagen in the purge than the control or cooler aged samples ($P < 0.01$; Table 2). The amount of soluble collagen was highest in the AA 130°F samples compared to the other treatments in the shoulder clod, while no difference was found for soluble collagen among treatments in the top round ($P < 0.01$; Table 1). Interestingly, there were three distinct bands in the cathepsin zymography data, which likely indicated that the tenderness improvement in beef samples was the result of a synergistic effect of multiple cathepsin enzymes. In general, the zymography data indicated there was heightened enzymatic activity during all of the treatments when compared to the control samples, and all 3 bands demonstrated that the AA at 120°F for 3 h treatment displayed the highest activity compared to other AA treatments ($P < 0.01$; Table 2).

Implications

Accelerated aging has shown to be a promising technique to increase value in lower price beef cuts through increasing enzymatic activity as well as tenderness without accelerating the growth of microorganisms. However, the accelerated aging process may also increase moisture loss during treatment. By thoroughly understanding the process of accelerated aging, the beef industry may be able to add value to lower-priced beef cuts in a speedy, convenient, and economical manner.

Acknowledgments

Table 1. Effects of six different accelerated aging (AA) treatments on band 3 of cathepsin zymography, collagen content in purge, cook yield, soluble collagen content, treatment yield, and microbial loads in purge on two different muscles

		Muscle			
Items	Treatment	Shoulder clod	Top round	SEM[1]	*P*-value
Cathepsin enzyme band 3		2.72[a]	2.23[b]	0.46	<0.05
Total collagen in purge (%)		0.05[a]	0.04[b]	0.002	<0.01
Cook yield (%)		80.08[a]	78.23[b]	0.29	<0.01
Soluble collagen (%)				0.04	<0.01
	Cooler aged 2 d	0.16[Ca]	0.07[Aa]		
	Cooler aged 21 d	0.12[Ca]	0.07[Aa]		
	AA 120°F for 2 h	0.13[Ca]	0.09[Aa]		
	AA 120°F for 3 h	0.11[Ca]	0.08[Aa]		
	AA 130°F for 2 h	0.38[Aa]	0.07[Ab]		
	AA 130°F for 3 h	0.26[Ba]	0.10[Ab]		
Treatment yield (%)				0.38	<0.05
	AA 120°F for 2 h	95.2[Aa]	90.59[Ab]		
	AA 120°F for 3 h	94.79[Aa]	91.4[Ab]		
	AA 130°F for 2 h	91.47[Ba]	89.07[Bb]		
	AA 130°F for 3 h	90.73[Ba]	87.14[Cb]		
Purge (log CFU/oz)				8.84	<0.05
	Before treatment	79.2[Aa]	27.6[Ab]		
	AA 120°F for 2 h	0.19[Ba]	0.17[Ba]		
	AA 120°F for 3 h	0.08[Ba]	0.19[Ba]		
	AA 130°F for 2 h	0.19[Ba]	0.07[Ba]		
	AA 130°F for 3 h	0.39[Ba]	0.07[Ba]		

[A-C]Values within a column of an item, with different superscripts differ significantly at *P* < 0.05.
[a-b]Values within a row with different superscripts differ significantly at *P* < 0.05.
[1]SEM = Standard error of the mean.

Table 2. Main effect of six different accelerated aging (AA) treatments on cathepsin activity, total collagen in purge, Warner-Bratzler shear force (WBSF) and cook yield (n = 120)

| | Treatment | | | | | | | |
Item	Cooler aged 3 days	Cooler aged 21 days	AA 120°F 2 h	AA 120°F 3 h	AA 130°F 2 h	AA 130°F 3 h	SEM[1]	*P*-value
Total collagen in purge (%)	0.03[d]	0.03[d]	0.04[c]	0.04[c]	0.05[b]	0.07[a]	0.003	<0.01
WBSF (lb)	9.8[a]	8.5[cd]	9.2[b]	8.9[bc]	8.5[cd]	8.2[d]	0.26	<0.01
Cook yield (%)	76.47[c]	77.52[c]	79.19[b]	79.64[b]	80.36[ab]	81.76[a]	0.5	<0.01
Cathepsin enzyme activity								
Band 1	1.33[b]	1.28[b]	2[a]	1.95[a]	1.45[b]	1.27[b]	0.3	<0.01
Band 2	1.09[bc]	1.07[bc]	1.23[ab]	1.46[a]	1.15[bc]	0.91[c]	0.25	<0.01
Band 3	1.41[c]	2.58[ab]	2.26[b]	3.19[a]	2.77[ab]	2.63[ab]	0.46	<0.01

[a-d]Values within a row with different superscripts differ significantly at *P* < 0.05.
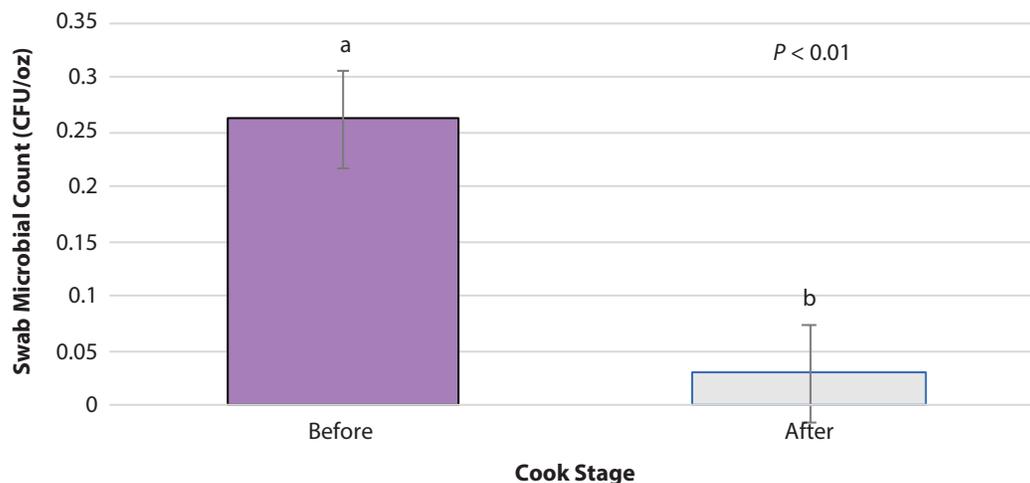[1]SEM = Standard error of the mean.

Figure 1. Main effect of cooking stage on six different treatments in microbial swabs (n = 80).

Evaluation of Bovine Myosin Heavy Chain Isoforms and Muscle Fiber Cross-Sectional Area on the Eating Quality of 11 Different Beef Muscles

S. Hene, H. Ness, E. Verrill, P. Hammond, C.K. Chun, T.G. O'Quinn, and M.D. Chao

Abstract

The objective of this study was to determine the impact of muscle fiber type, diameter, and cross-sectional area (CSA) on the eating quality of 11 different beef muscles. Ten U.S. Department of Agriculture choice shoulder clod (SC), flank (F), knuckle (K), mock tender (MT), top sirloin butt (TS), brisket (B), eye of round (ER), and ribeye (R) were collected in study 1 (n = 80). In study 2, strip loin (SL), tri-tip (TT), and heel (H) were collected from ten USDA low choice beef carcasses (n = 30). Muscle fiber types, CSA, and diameters were determined. Pearson correlation analysis was performed to determine the relationship between muscle fiber type, CSA, diameter, and the eating quality of beef from previously reported studies. Correlation analysis from both studies demonstrated positive correlations between type 1 fibers and many attributes of eating quality such as juiciness and lipid flavor intensity ($P < 0.05$). Negative correlations were found between type 2A fibers and those attributes ($P < 0.05$) and between type 2X fibers and tenderness measurements ($P < 0.05$). Interestingly, a negative correlation was found between muscle fiber CSA and diameter with connective tissue amount ($P < 0.05$), and a positive correlation was found between muscle fiber CSA and diameter with tenderness measurements ($P < 0.05$) in those same studies.

Introduction

Skeletal muscle is composed of heterogeneous muscle fiber types, and there are type 1, fast twitch fibers and type 2, slow twitch fibers. Each fiber type has a unique set of characteristics influencing key factors such as energy metabolism and contractile speed in the live animal, and these same unique characteristics influence eating quality of different beef cuts. However, the exact relationship among muscle fiber types and size on beef quality has yet to be fully established. The traditional immunohistochemical method to determine muscle fiber type is labor intensive and prone to a high degree of human error, so this research is difficult.. Therefore, the objective of this study was to investigate the contribution of muscle fiber type and size on the eating quality of 11 different beef muscles.

Experimental Procedures

Eleven different beef muscles were utilized from two separate studies. In study 1, shoulder clod (SC), flank (F), knuckle (K), mock tender (MT), top sirloin butt (TS), brisket (B), eye of round (ER), and ribeye (R) were collected from 10 U.S. Department of Agriculture choice carcasses (n = 80), and each muscle was fabricated into steaks at 2 days postmortem. In study 2, strip loin (SL), tri-tip (TT), and heel (H) were collected from 10 USDA low choice carcasses (n = 30), and each muscle was fabricated into

steaks at 5 days postmortem. For both studies, two cores were obtained from each sample parallel to the muscle fiber direction and frozen in a 2-methyl butane bath using liquid nitrogen immediately following fabrication.

Myofibrillar proteins were extracted from each sample and separated using sodium dodecyl-sulfate polyacrylamide gel electrophoresis with precast 6% polyacrylamide gels. Following gel electrophoresis, proteins were transferred from gels to polyvinylidene fluoride membranes. Membranes were then blocked using fluorescent blocking buffer overnight. After blocking, membranes were immunoblotted in two cocktails against 4 primary antibodies that recognize: 1) all myosin heavy chains (MyHC) isoforms; 2) type 1 only; 3) type 2X only; and 4) type 2A only. Following the primary antibody incubation, membranes were incubated with a fluorescent secondary antibody and imaged (Figure 1). The relative percentage of each fiber type was calculated by normalizing the intensity of each specific isoform against the intensity of all MyHC isoforms. A cryostat was used to collect two 10 μm cryosections per sample from the frozen cores. Slices were transferred to microscope slides and allowed to air dry. To determine cross-sectional area (CSA) and diameter, slides were incubated with primary (anti-dystrophin) and secondary antibody prior to imaging under the microscope. At 10X objective, five photomicrographs were captured. An average of 400 fibers per sample were analyzed to determine CSA and muscle fiber diameter (Figure 2). Pearson correlation analysis was conducted to determine the relationship between muscle fiber type, CSA, and diameter with the results for the eating quality of beef as determined by the trained panel that were previously reported in Chun et al. (2020) and Hammond et al. (2022).

Results and Discussion

In study 1, flank and mock tender had the greatest relative percent of type 1 fibers, followed by shoulder clod and top sirloin butt, with brisket, ribeye, knuckle, and eye of round having the lowest ($P < 0.01$; Table 1). On the other hand, ER, R, and K had the greatest relative percent of type 2A fibers, followed by TS, B, and SC, with MT and F having the least ($P < 0.01$). However, there was only a tendency for differences in relative percent of type 2X fibers among the muscles ($P = 0.08$). In study 1, F and MT were found to have the greatest CSA followed by R, ER, SC and TS with K and B having the smallest muscle fiber area ($P < 0.01$). In study 1, F was shown to have the greatest muscle fiber diameter, followed by MT, R, ER, TS, SC, K, with B having the smallest fiber diameter ($P < 0.01$; Table 1). In study 2, there was no difference between the relative percent of type 1 fibers ($P > 0.05$). The ER had a greater relative percent of type 2A fibers than TT and H ($P < 0.05$). Finally, TT had a greater relative percent of 2X fibers than SL ($P < 0.05$) with H not differing from any of them ($P > 0.10$). In study 2, SL was found to have the greatest CSA and diameter ($P < 0.01$) with H and TT not differing between them in either CSA or diameter. It was expected that muscles used for posture and stability are more densely comprised of type 1 fibers, while muscles used for locomotion that need quick bursts of energy and movement have a higher relative percentage of type 2 fibers.

In study 1, there was a positive correlation between fiber type 1 and initial juiciness ($r = 0.37$; $P < 0.05$; Table 2), sustained juiciness ($r = 0.39$; $P < 0.05$) and lipid flavor ($r = 0.41$; $P < 0.05$). Conversely, there was a negative correlation between fiber type 2A and initial juiciness ($r = -0.40$; $P < 0.05$) sustained juiciness ($r = -0.42$; $P < 0.05$), and lipid flavor ($r = -0.45$; $P < 0.01$). These relationships are likely due to type 1 oxidative

fibers utilizing lipids for energy in comparison to type 2 fibers utilizing glycogen as an energy source. Therefore, the high lipid content in type 1 fibers likely had a positive impact on beef quality characteristics like juiciness and flavor. Furthermore, a negative correlation was seen between muscle fiber diameter and connective tissue amount (r = -0.23; P < 0.05), but a positive correlation was seen to overall tenderness (r = 0.24; P < 0.05) for study 1. In study 2, a negative correlation was seen between type 2X fiber and myofibril tenderness (r = -0.52; P < 0.05), overall tenderness (r = -0.46; P < 0.05) and WBSF (r = -0.46; P < 0.05). Furthermore, study 2 saw negative correlations between CSA and muscle fiber diameter with connective tissue content (r = -0.45; P < 0.05) and WBSF (r = -0.60; P < 0.01), but a positive correlation was to overall tenderness (r = 0.39; P < 0.05). It is known that larger muscle fibers have thinner endomysium (connective tissue) surrounding the muscle fiber. Therefore, it is possible that as muscle fiber CSA and diameter increase, the collagen fibers making up the endomysium undergo both qualitative and quantitative changes, resulting in a more tender product.

Implications

This study shows that muscles predominated by type 1 fibers will likely deliver a higher eating quality experience for consumers, while muscles with more glycolytic fibers 2A and 2X will deliver a less favorable eating experience for consumers. On the other hand, these data also demonstrated that a larger muscle fiber CSA and diameter are not necessarily a marker of negative eating quality, as muscles with those characteristics had less connective tissue and had greater tenderness scores.

Acknowledgments

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Table 1. Relative muscle fiber type percentage, muscle fiber cross-sectional area (CSA), and diameter measurements of 11 beef muscles from 2 studies (n = 110)

Muscle[1]	Type 1, %	Type 2X, %	Type 2A, %	CSA, μm^2	Diameter, μm
Study 1					
TS	28.85[c]	34.52	36.64[ab]	2.02[bc]	1.57[bcd]
R	25.19[cd]	33.16	41.52[a]	2.25[ab]	1.65[abc]
B	25.43[cd]	38.15	36.42[ab]	1.37[d]	1.29[e]
F	48.87[a]	32.83	18.29[c]	2.38[a]	1.71[a]
K	21.94[d]	37.48	40.45[a]	1.84[c]	1.50[d]
MT	45.6[a]	33.98	20.43[c]	2.38[a]	1.68[ab]
ER	18.59[d]	39.20	42.08[a]	2.13[abc]	1.61[abcd]
SC	35.70[b]	33.82	30.48[b]	1.98[bc]	1.53[cd]
[2]SEM	3.30	2.90	3.00	0.13	0.04
P-value	<0.01	0.08	<0.01	<0.01	<0.01
Study 2					
H	21.93	31.93[ab]	46.69[b]	2.34[b]	1.67[b]
SL	18.19	25.45[b]	56.36[a]	3.88[a]	2.15[a]
TT	17.12	35.61[a]	47.27[b]	2.68[b]	1.82[b]
[2]SEM	3.50	3.10	3.60	0.20	0.07
P-value	0.5	<0.05	<0.05	<0.01	<0.01

[a-d] Values within a column without a common superscript differ significantly at *P* < 0.05.
[1]TS = Top sirloin butt; R = Ribeye; B = Brisket; F = Flank; K = Knuckle; MT = Mock tender; ER = Eye of round; SC = Shoulder clod.
[2]Standard error of the mean.

Table 2. Correlation coefficient (r) of muscle fiber types, muscle fiber cross-sectional area (CSA) and diameter with eating quality measurements evaluated by trained panels

|	Type 1	Type 2X	Type 2A	CSA (μm²)	Diameter (μm)
Study 1					
Initial juiciness	0.37**	-0.04	-0.39**	0.16	0.17
Sustained juiciness	0.39**	-0.05	-0.42**	0.17	0.18
Myofibrillar tenderness	0.27*	-0.24*	-0.24*	0.14	0.20
Connective tissue content	-0.03	0.05	0.00	-0.12	-0.23*
Lipid flavor intensity	0.41**	-0.03	-0.45**	0.06	0.09
Overall tenderness	0.15	-0.08	-0.12	0.18	0.24*
Warner-Bratzler shear force	-0.09	0.03	0.13	-0.03	-0.08
Study 2					
Initial juiciness	0.15	-0.06	-0.07	0.00	0.02
Sustained juiciness	0.14	0.01	-0.12	-0.04	-0.02
Myofibrillar tenderness	0.15	-0.52**	0.34	0.33	0.33
Connective tissue content	-0.10	0.44*	-0.31	-0.45*	-0.44*
Lipid flavor intensity	-0.16	0.22	-0.06	-0.22	-0.20
Overall tenderness	0.13	-0.46*	0.30	0.39*	0.39*
Warner-Bratzler shear force	-0.13	0.50*	-0.34	-0.60**	-0.61**

* $P < 0.05$.
** $P < 0.01$.
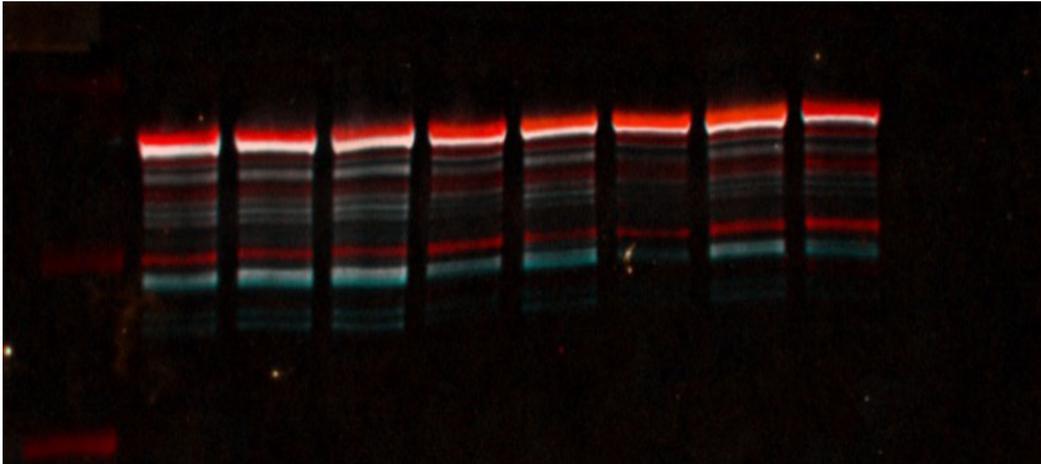
Figure 1. Cocktail 1 myosin heavy chain isoform immunoblot.
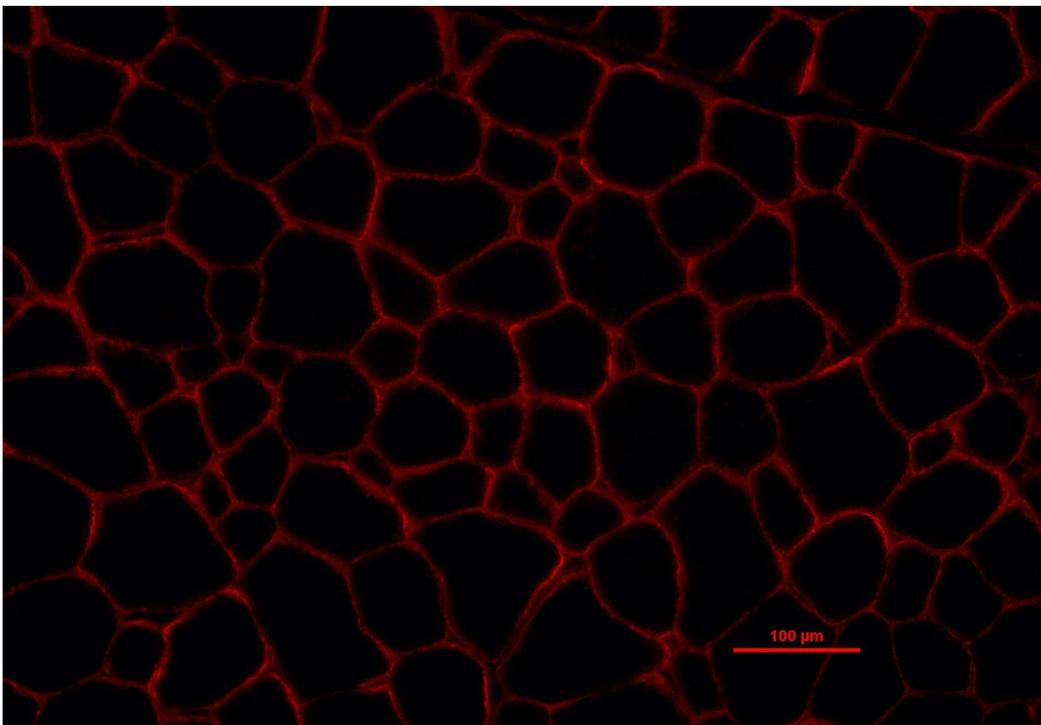

100 µm

Figure 2. Representative muscle fiber cross sectional area (CSA) and diameter.

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