CATTLEMEN'S DAY 2022

BEEF CATTLE RESEARCH

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KANSAS STATE UNIVERSITY AGRICULTURAL EXPERIMENT STATION AND COOPERATIVE EXTENSION SERVICE

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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 3 of 4

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Abstract

The spread of introduced old-world bluestem species (*Bothriochloa ischaemum* and *Bothriochloa bladhii*) across the central and southern Great Plains represents a growing threat to the preservation of native rangelands. While current control methods rely on non-selective herbicides, recent research indicates that late summer prescribed fire may reduce the presence of old-world bluestems while maintaining or improving native plant populations. Eighteen one-acre plots were established on native mixed-grass prairie that was heavily infested with Caucasian bluestem (*Bothriochloa bladhii*). Plots were assigned to one of two treatments: no burn (control) or burned (burned August 14, 2019). Soil cover, botanical composition, and forage biomass were measured annually within each plot. One and two years' post-treatment, bare soil was greater (treatment × time; $P < 0.01$) in burned plots compared with non-burned plots. In contrast, litter cover was greater ($P < 0.01$) in non-burned plots compared with burned plots in years one and two post-treatment. Basal vegetation cover did not differ ($P < 0.01$) between burned and non-burned plots in either post-treatment year. While there were no differences in basal cover of native ($P = 0.54$) or introduced grasses ($P = 0.10$) between treatments, total grass cover decreased (treatment main effect; $P < 0.01$) in burned plots while remaining unchanged in non-burned plots. In years one and two post-treatment, basal cover of Caucasian bluestem was reduced ($P < 0.01$) by approximately 48% and 52%, respectively, in burned plots compared with non-burned plots. This trend was associated with less (treatment main effect; $P < 0.01$) forage biomass post-treatment in burned plots compared with non-burned plots. Total basal cover of all forbs and perennial forbs was greater (treatment main effect; $P < 0.01$) in burned plots than in non-burned plots; moreover, grass-species richness was greater (treatment × time; $P < 0.01$) in burned plots compared with non-burned plots. Forb richness was greater ($P < 0.01$) in burned plots than in non-burned plots in year one post-treatment only. These data were interpreted to suggest that application of late-summer prescribed fire may be an effective means of control for Caucasian bluestem while increasing native plant diversity.

Introduction

Initially introduced to the southern Great Plains for livestock forage and soil conservation, old-world bluestems (*Bothriochloa ischaemum* and *Bothriochloa bladhii*) have spread beyond cultivation and now threaten prairie biodiversity and pastoral production systems in Kansas. Rangelands dominated by old-world bluestems produce inferior forage quality compared with native vegetation, while degrading wildlife habitat and

decreasing botanical diversity. While prescribed fire has been traditionally applied in the spring to control undesirable plant species, old-world bluestems are unaffected by burning in the dormant season.

Recent research suggested that prescribed burning late in the summer may result in significant control of yellow bluestem. With similar morphology and phenology, Caucasian bluestem may respond similarly to late summer fire. Therefore, the objective of our experiment was to document the effects of late-summer prescribed fire on soil cover, botanical composition, plant-species richness, and forage production in mixed-grass prairie with established Caucasian bluestem stands over a four-year period.

Experimental Procedures

This experiment was conducted on a private ranch in Ellsworth County, KS. The experimental site was native mixed-grass prairie which contained established stands of Caucasian bluestem. Eighteen plots of one square acre each were established and then assigned randomly to one of two treatments: no burn (n = 6 plots) or burn (burned August 14, 2019; n = 12 plots). Permanent 164-ft transects were established in each plot. Pre-fire soil cover, botanical composition, and forage biomass were measured in July 2019. The fire treatment was applied August 14, 2019; post-fire effects were assessed in July 2020 and July 2021.

Ground cover and botanical composition were evaluated along each transect using a modified step-point method. Forage biomass was estimated by clipping the vegetation inside three randomly placed 0.82^2-ft clipping frames per plot. Litter was removed from the frame and remaining plant matter was clipped to a height of 0.39-in. Clipped material was dried in a forced-air oven (131°F; 96 hours) and weighed to estimate forage biomass.

Results were analyzed using a mixed statistical model that contained treatment, year, and treatment × year as fixed effects and pasture within treatment as a random effect. When protected by a significant *F*-test ($P < 0.05$), least-squares means of treatment and treatment × year effects were separated using the method of least significant difference.

Results and Discussion

Litter cover was less (treatment × time; $P < 0.01$) in burned plots compared with non-burned plots. Conversely, bare soil was greater (treatment × time; $P < 0.01$) in burned plots compared with non-burned plots (Table 1). These trends can likely be attributed to the late season in which fire was applied. Prescribed burns during late summer consume accumulated litter and the short growing season between August and the first frost prevents dominant warm-season grasses from building up significant amounts of litter before the next growing season begins. One and two years' post-treatment, basal plant cover did not differ between treatments ($P < 0.01$).

Pre-fire total grass cover did not differ between treatments ($P = 0.47$; Table 2); subsequently, burned plots were associated with lesser total grass cover than non-burned plots (treatment main effect; $P < 0.01$). Despite the reduction in total grass cover within burned plots, there were no differences in native (treatment × time; $P \geq 0.10$) or introduced grass cover between treatments. Furthermore, warm-season (C4) tall grass and mid-grass cover were not influenced (treatment × time; $P \geq 0.06$) by treatment. Although the treatment × time effect for total cool-season grass cover was significant

($P < 0.01$), there were no treatment differences ($P \geq 0.06$) in basal cover of C3 grasses within year. These trends were associated with a reduction (treatment × time; $P < 0.01$) in basal cover of Caucasian bluestem in treated plots (Figure 1). Basal cover of Caucasian bluestem decreased by approximately 48% and 52%, respectively, in burned plots compared with non-burned plots. Based on these data, we concluded that Caucasian bluestem may be less tolerant of growing-season fires than native grasses.

Total forb cover was greater (treatment main effect; $P < 0.01$) in burned plots than in non-burned plots (14.2 and 8.5%, respectively; Table 3). There were no treatment differences ($P \geq 0.14$) in basal cover of native forbs. In contrast, burned plots were associated with greater (treatment main effect; $P = 0.01$) perennial forb cover than non-burned plots (13.3 and 8.3%, respectively). Basal cover of introduced forbs, annual forbs, and nectar-producing forbs was different ($P \leq 0.02$) between burned and non-burned plots during year one post-treatment only. Basal cover of leguminous forbs was not different ($P = 0.72$) between treatments at any time.

Grass-species richness was increased (treatment × time; $P < 0.01$) in burned plots while remaining unchanged in non-burned plots (Table 4). During this same period, forb-species richness increased (treatment × time; $P < 0.01$) in treated plots from the pre-treatment year to year one but no differences were detected two years post-treatment ($P = 0.67$; Table 4). Litter accumulation within stands of Caucasian bluestem may prevent light and water penetration to the soil. Removal of this litter with prescribed fire may have intermittently allowed greater numbers of native grasses and forbs an opportunity for growth.

Implications

These data were interpreted to suggest that late-summer prescribed fire has the potential to allow low-cost, low-impact control of Caucasian bluestem in mixed-grass native rangeland. In addition, prescribed fire during late summer was also associated with improvements in plant-species richness and with no change to basal cover of native grasses and forbs. We will continue to monitor these trends over the next two years. A second burn treatment was applied in August of 2021.

Table 1. Effects of late-summer prescribed fire on mixed-grass prairie soil cover and biomass accumulations in the Kansas Smoky Hills

			Year post-treatment					
	Pre-treatment		Year 1		Year 2			
Item	No burn	Burn	No burn	Burn	No burn	Burn	SEM[1]	*P*-value
Bare soil, %	8.7[a]	5.7[a]	5.7[a]	65.8[b]	4.7[a]	63.0[b]	4.67	<0.01
Litter cover, %	80.0[a]	72.3[a]	81.0[a]	23.2[b]	87.7[c]	29.2[d]	4.58	<0.01
Basal vegetation cover, %	11.3[ab]	18.5[c]	13.3[b]	11.0[ab]	7.7[a]	7.8[a]	2.03	<0.01
Forage biomass, lb/acre*	2616	2229	3162	1978	3580	2859	208.9	0.30

[1]Standard error of the mean.
[a-c]Within rows, means with unlike superscripts differ ($P < 0.01$).
*Treatment main effect $P < 0.01$.

Table 2. Effects of late-summer burning on mixed-grass prairie graminoid composition in the Kansas Smoky Hills

			Year post-treatment					
	Pre-treatment		Year 1		Year 2			
Item, % of total	No burn	Burn	No burn	Burn	No burn	Burn	SEM[1]	*P*-value
Total grass*	92.0	91.2	89.0	81.5	92.0	85.2	1.81	0.14
Native	42.3	43.8	39.0	39.3	36.3	42.8	5.08	0.54
Introduced	49.7	46.3	50.0	42.2	55.7	42.3	6.25	0.10
Total C4 grasses	63.0[bc]	65.7[c]	63.7[bc]	46.8[a]	62.3[bc]	55.8[b]	5.29	<0.01
C4 tall grasses	17.7	18.3	16.0	16.5	8.0	14.7	2.94	0.24
C4 mid-grasses*	13.7	14.0	17.7	9.7	54.0	39.7	2.41	0.06
Total C3 grasses	29.0[ab]	24.5[a]	25.3[ab]	34.7[b]	29.7[b]	29.3[b]	4.94	<0.01

[1]Standard error of the mean.
[a-c]Within rows, means with unlike superscripts differ ($P \leq 0.05$).
*Treatment main effect $P < 0.01$.

Table 3. Effects of late-summer prescribed fire on mixed-grass prairie forb composition in the Kansas Smoky Hills

	Pre-treatment		Year post-treatment					
			Year 1		Year 2			
Item, % of total	No burn	Burn	No burn	Burn	No burn	Burn	SEM[1]	*P*-value
Total forbs*	7.7	9.5	10.4	18.3	7.4	14.7	1.79	0.10
Native	7.6	9.4	10.3	16.8	7.4	14.5	1.78	0.14
Introduced	0.1[a]	0.2[a]	0.1[a]	1.6[b]	0.0[a]	0.2[a]	0.44	0.02
Perennial*	7.4	9.3	10.3	16.2	7.3	14.3	1.75	0.16
Annual	0.3[a]	0.3[a]	0.1[a]	2.1[b]	0.1[a]	0.4[a]	0.47	<0.01
Nectar-producing	3.5[a]	4.6[a]	5.0[a]	9.7[b]	0.7[c]	0.8[c]	1.12	<0.01
Legumes	0.5	0.7	0.8	0.9	0.0	0.1	0.18	0.72

[1]Standard error of the mean.
[a-c]Within rows, means with unlike superscripts differ ($P \leq 0.05$).
*Treatment main effect $P \leq 0.01$.

Table 4. Effects of late-summer prescribed fire on mixed-grass prairie grass and forb richness in the Kansas Smoky Hills

	Pre-treatment		Year post-treatment					
			Year 1		Year 2			
Item	No burn	Burn	No burn	Burn	No burn	Burn	SEM[1]	*P*-value
Grass-species richness, number	7.8[a]	7.6[a]	7.3[a]	9.4[b]	7.3[a]	9.0[b]	0.57	<0.01
Forb-species richness, number	13.3[ab]	11.4[ac]	9.7[c]	15.1[b]	9.8[c]	10.4[c]	1.59	<0.01

[1]Standard error of the mean.
[a-c]Within rows, means with unlike superscripts differ ($P \leq 0.05$).

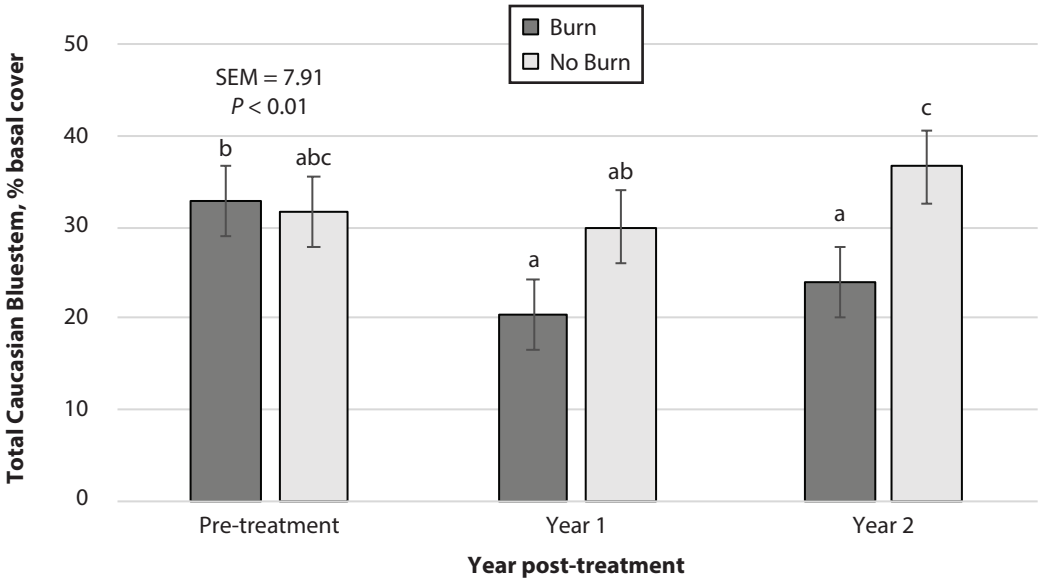

Figure 1. Effects of late-summer prescribed fire on Caucasian bluestem basal cover in the Kansas Smoky Hills

Effects of Prescribed Fire Timing on Stocker Cattle Performance and Native Plant Composition: Year 3 of 6

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Abstract

Mid- or late-summer prescribed fire can be utilized to reduce sericea lespedeza (*Lespedeza cuneata*) infestations and improve forb diversity; however, the effect of fire applied later in the year (i.e., August-October) on growth performance of yearling grazing cattle has not been evaluated. In this experiment, 18 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). Yearling cattle were grazed from May to August at a targeted stocking density of 250 lb of live-weight per acre for three consecutive grazing seasons. A permanent 328-ft transect was established in each pasture and was used to determine soil cover and plant composition using a modified step-point method. All fire treatments were applied prior to grazing. Total body weight (BW) gains and average daily gains did not differ ($P = 0.22$) between spring and summer prescribed-fire treatments. Final BW were greater ($P = 0.03$) for calves that grazed spring- and summer-burned pastures compared with those that grazed fall-burned pastures. No differences ($P \geq 0.14$) in basal cover of total grasses, native grass species, total forbs, and native forb species were observed between treatments. We interpreted these results to suggest that summer-season prescribed fire did not reduce stocker cattle performance or considerably alter native rangeland plant composition when compared with spring-season prescribed fire.

Introduction

Ranchers in the Kansas Flint Hills traditionally apply annual spring-season prescribed fire to improve stocker cattle body weight gains and improve warm season grass production. Recent research has demonstrated a reduction in sericea lespedeza (*Lespedeza cuneata*) infestations when the timing of prescribed fire application is shifted from spring to late summer or early fall. Additional benefits of late-summer or early-fall prescribed fire include increased forb diversity, improved air quality by distributing smoke throughout the year, and increased flexibility of burn dates. Despite optimistic reports, ranchers have voiced concerns that cattle growth performance and native warm-season grass populations may be negatively affected when fire is applied later in the year (i.e., August-October). At this time, no direct comparisons of yearling stocker cattle growth performance are available for cattle grazing spring-, summer-, and fall-burned rangelands; therefore, the objective of our experiment was to document the effects of prescribed-fire timing on stocker cattle performance, soil cover, and plant species composition over a six-year period.

Experimental Procedures

Our experiment was conducted at the Kansas State University Beef Stocker Unit. 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). A permanent 328-ft transect was established in each pasture. Pre-treatment plant species composition and soil cover were measured along each transect in June 2018 using a modified step-point method, and re-evaluated in 2019, 2020, and 2021. Prescribed-fire treatments were applied prior to grazing in 2019, 2020, and 2021.

A total of 1,060 yearling cattle were grazed over three consecutive growing seasons beginning in 2019. Pastures were stocked at a targeted density of 250 lb of live weight per acre for 90-days. Three-hundred-sixty heifers [initial body weight (BW) = 621 ± 85.7 lb] were grazed from May 2 to July 31 in year one; 315 steers (initial BW = 738 ± 123.3 lb) were grazed from May 11 to August 10 in year two; and 385 steers (initial BW = 616 ± 74.4 lb) were grazed from May 5 to August 3 in year three. All calves were purchased in Texas and transported to the Kansas State Beef Stocker Unit. Upon arrival, calves were individually weighed and randomly assigned to pasture and treatment. At the start of each grazing season, calves were individually weighed to determine initial BW, 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 year two and year three. Following the 90-day grazing period, calves were gathered and individual BW were measured.

Results and Discussion

After three consecutive grazing seasons, total BW gains (BWG) and average daily gains (ADG) did not differ ($P = 0.22$; Table 1) between calves that grazed spring- and summer-burned pastures; however, calves assigned to the fall prescribed-fire treatment had lower ($P \leq 0.01$) total BWG and ADG compared with calves assigned to the spring prescribed-fire treatment. Total BWG and ADG tended to be greater ($P = 0.09$) in the summer prescribed-fire treatment compared with the fall prescribed-fire treatment. As a result, final BW were greater ($P = 0.03$) for calves assigned to spring- and summer-burned pastures compared with those assigned to the fall-burned pastures. Final BW were 896, 894, and 872 lb for the spring, summer, and fall prescribed-fire treatments, respectively.

When soil cover was evaluated, proportions of bare soil were greater ($P \leq 0.01$; Table 2) in pastures burned in the spring compared with pastures burned in the summer and fall. Conversely, proportions of litter on the soil surface were greater ($P \leq 0.01$) in the summer and fall prescribed-fire treatments when compared with the spring prescribed-fire treatment. No differences ($P = 0.11$) in total basal vegetation cover were observed between treatments. In addition, basal cover of total grasses, native grass species, total forbs, and native forb species did not differ ($P \geq 0.14$) between spring-, summer-, or fall-burned pastures. Conversely, basal cover of total shrubs tended to be greater ($P = 0.07$) in the fall prescribed-fire treatment compared with the spring prescribed-fire treatment, whereas the summer prescribed-fire treatment was intermediate and not different ($P = 0.56$) from either spring or fall treatments; however, basal cover of increaser shrubs

(i.e., shrubs that tend to proliferate in response to grazing) did not differ ($P = 0.11$) between prescribed-fire treatments.

Implications

We interpreted these data to suggest that land managers could use summer-season prescribed fire to manage sericea lespedeza infestations without reducing grazing performance of yearling cattle or damaging the vigor of native warm-season plant populations.

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

	Prescribed-fire season				
Item	Spring	Summer	Fall	SEM[1]	*P*-value
Initial BW,[2] lb	658	662	653	8.6	0.56
Final BW, lb	896[a]	894[a]	872[b]	8.9	0.03
Total BWG,[3] lb	237[a]	230[ab]	219[b]	5.9	0.02
ADG,[4] lb/day	2.64[a]	2.56[ab]	2.44[b]	0.065	0.02

[1]Standard error of the mean.
[2]Body weight.
[3]Body weight gain.
[4]Average daily gain.
[ab] Within rows, means with unlike superscripts differ ($P \leq 0.05$).

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

	Prescribed-fire season				
Item	Spring	Summer	Fall	SEM[1]	*P*-value
Soil cover, % of total area					
Bare soil	66[a]	52[b]	55[b]	3.1	< 0.01
Litter cover	19[b]	35[a]	30[a]	3.0	< 0.01
Total basal vegetation cover	15	13	15	1.0	0.11
Basal cover, % of total basal vegetation cover					
Total grass cover	89	90	85	2.7	0.22
Native grass species	85	86	79	3.5	0.14
Total forb cover	10.2	8.9	13.2	2.65	0.29
Native forb species	10.1	8.8	13.2	2.53	0.24
Total shrub cover	0.5[y]	1.2[yz]	1.4[z]	0.41	0.07
Increaser shrubs[2]	0.02	0.12	0.23	0.100	0.11

[1]Standard error of the mean.
[2] Shrubs that tend to proliferate in response to grazing.
[ab] Within rows, means with unlike superscripts differ ($P \leq 0.05$).
[yz] Within rows, means with unlike superscripts tend to differ ($P \leq 0.10$).

Inclusion of Biuret With or Without Bovatec in a Commercial Mineral Supplement Did Not Improve Growth Performance of Yearling Calves Grazing Native Grass: Year 1 of 2

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Abstract

The addition of feed additives [rumen modifiers or non-protein nitrogen (NPN)] to mineral supplements may improve health and performance of grazing beef cattle. The objective of this experiment was to evaluate the inclusion of NPN (biuret) with and without Bovatec (Zoetis, Parsippany, NJ) in a commercial mineral mix on growth performance of yearling beef calves grazing in the Kansas Flint Hills. Three hundred ninety-five crossbred steers [initial body weight (BW) 612 ± 77.8 lb] were assigned to one of three mineral treatments (control, biuret, or biuret + Bovatec). Mineral treatments were randomly assigned to one of 18 pastures for a total of six pastures per treatment. Steers were grazed for 90 days from May to August. Individual BW were collected at the start and end of the grazing period. Mineral feeders were placed in each pasture and filled once weekly, and the respective mineral treatment amount was added to target a daily consumption of 4 oz per head. Feeders were weighed weekly and checked daily to estimate the number of days until an individual feeder was empty and in need of refilling (days-to-empty). Total BW gains, average daily gains, final BW, and mineral consumption did not differ ($P \geq 0.31$) between treatments. Conversely, there was an interaction ($P = 0.02$) between days-to-empty and week of the experiment; mineral consumption appeared to be influenced by temporal environmental conditions.

Introduction

Providing a mineral supplement to cattle grazing during summer months in the Kansas Flint Hills can improve growth rate, overall profitability, and provide an opportunity to add nutrients or growth-promoting feed additives to the diets of grazing cattle. The addition of non-protein nitrogen (NPN) or ruminal modifiers to a mineral supplement may be an effective way to improve overall productivity during the grazing season. The objective of this experiment was to measure the effects of NPN (biuret) or NPN + ruminal modifier (biuret + lasalocid) inclusion in a commercial mineral mix on growth performance of yearling beef calves grazing in the Kansas Flint Hills.

Experimental Procedures

Three hundred ninety-five crossbred steers (initial BW 612 ± 77.8 lb) of Texas origin previously backgrounded at the Kansas State University Beef Stocker Unit were used in this experiment. Steers were stratified by BW and then randomly allocated to 18 pastures. Steers were grazed for 90 days from May to August at a targeted stocking density of 250 lb of live-weight per acre. Mineral treatments were randomly assigned

to one of 18 pastures for a total of six pastures per treatment. Three mineral treatments consisted of basal supplement (control), basal supplement with biuret (biuret; 0.6 oz/head daily), and basal supplement with biuret and Bovatec (Zoetis, Parsippany, NJ; 180 mg/head/day). Biuret was included in the supplement at 300 lb/ton dry matter (DM) basis to provide 0.6 oz of biuret when mineral was consumed in an intended 4 oz per head daily. Bovatec was included in the supplement at 15.5 lb/ton DM basis to allow a daily consumption of 180 mg/head/day lasalocid when mineral was consumed at 4 oz per head daily. Identical supplement feeders (Bullmaster; Mann Enterprises, Inc., Waterville, KS) were placed in each pasture.

Prior to turnout, steers were individually weighed, assigned a pasture tag, treated for internal (Valbazen, Zoetis, Parsippany, NJ) and external (Standguard, Elanco, Greenfield, IN) parasites, and implanted (Revalor-G, Merck, Kenilworth, NJ). Following initial processing, cattle were sorted and allocated to pastures over a three-day period.

Initially, mineral feeder flaps were folded up for approximately two weeks to help cattle locate mineral. In the event of inclement weather, flaps were unfolded to prevent rain from getting into the mineral. Once mineral consumption increased, flaps were left down for the remainder of the grazing period. Each week mineral tubs were weighed to determine weekly mineral consumption. After the mineral tub was weighed, mineral was added to allow for a daily consumption of 4 oz/head for the following 7 days. Mineral tubs were checked daily for cleanliness, to monitor rate of consumption, and visually estimate the number of days until each mineral feeder was empty (days-to-empty). Mineral tubs were refilled the same day each week. At the completion of the 90-day grazing period, calves were gathered and individually weighed to determine final BW, total BW, and average daily gains (ADG).

Results and Discussion

At the conclusion of the grazing period, final BW, total BW, ADG, and mineral consumption did not differ ($P \geq 0.31$; Table 1) between mineral treatments; however, there was an interaction between days-to-empty and week of the experiment ($P = 0.02$; Figure 1). At the initiation of the experiment, mineral consumption was low. However, it increased rapidly such that days-to-empty for all treatments reached 2 to 4 days by week 3 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

The data from this first year suggest that the addition of biuret or biuret and Bovatec to a commercial mineral supplement did not affect growth performance of yearling beef cattle grazing in the Kansas Flint Hills. A second year of this study will be conducted to fully evaluate the impact of these mineral supplementation strategies.

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]

	Mineral treatment		
Item	**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	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
Vit 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 on stocker cattle performance grazing native grass

	Mineral treatments				
Item	**Control**	**Biuret**	**Biuret + Bovatec**	**SEM[1]**	***P*-value**
Initial BW,[2] lb	610	613	623	11.1	0.48
Final BW, lb	816	829	830	11.1	0.40
Total BWG,[3] lb	206	216	206	7.8	0.32
ADG,[4] lb/day	2.29	2.41	2.29	0.090	0.32
Daily mineral intake, oz/head	3.96	3.96	3.85	0.081	0.31

[1]Standard error of the mean.
[2]Body weight.
[3]Body weight gain.
[4]Average daily gain.

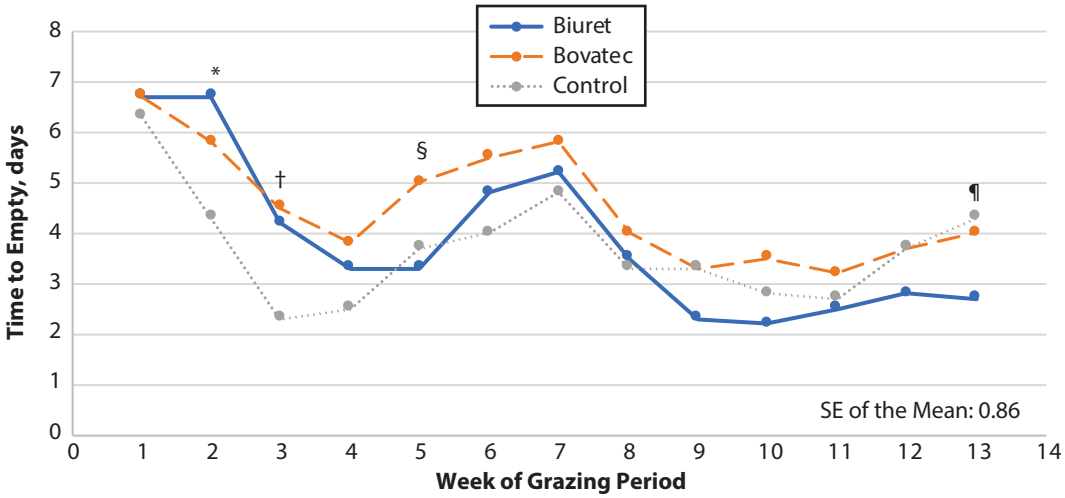

Figure 1. Effects of biuret and Bovatec on weekly mineral consumption rate of yearling cattle grazing native grass pasture, mixed model standard error of the mean associated with comparison of treatment × week interaction effect means ($P = 0.02$).

*Week 2 Biuret > Control ($P = 0.007$), Biuret = Bovatec ($P = 0.33$), Bovatec vs. Control ($P = 0.08$).

†Week 3 Biuret = Bovatec > Control ($P \leq 0.05$).

§Week 5 Bovatec > Biuret ($P = 0.05$), Biuret = Control, Bovatec = Control ($P \geq 0.12$).

¶Week 13 Control > Biuret ($P = 0.05$), Biuret = Bovatec, Bovatec = Control ($P \geq 0.12$).

Evaluation of Differing Genetic Potentials on Beef Cattle Resource Use in the Great Plains

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Abstract

Natural resource management is one of the keys to improving the sustainability of the beef industry. The objective of this project was to simulate 444 various cow-calf operations with differences in genetic potential, regional feedstuff availability, and climate to contrast land and water requirements, as well as methane emissions. The simulations replicated 74 different land regions in the Great Plains and six varying genetic potentials for cow mature size (large, moderate, and small) and milk production (high and low) within those regions. Weaning weight was also estimated to calculate the natural resource efficiency of each genetic potential.

Animals with greater energy demands (larger mature weight and/or higher lactation potential) required more natural resources. For example, heavier animals required more grazing land than lighter animals and emitted more methane per year. Interestingly, lactation potential influenced water requirements more than body size. High lactation animals had a larger irrigation footprint than low lactation animals of the same size as the high lactation animals required more supplementation (usually a hay and/or grain ration). This was because the model parameters prevented the animals from consuming more than 2.7% of their body weight in feed per day and high lactation animals could not meet their energy needs through forage alone. When natural resource use was scaled by estimated pounds of weaned calf produced, smaller animals were more efficient than larger animals. Small, high lactation cattle required the least total land and emitted the fewest pounds of methane per pound of weaned calf; while small, low lactation animals were the most efficient users of water.

Introduction

Sustainability in beef production has recently received a great deal of attention. In particular, environmental sustainability has received the most scrutiny from the public. The most discussed aspect of environmental sustainability is the greenhouse gas (GHG) footprint of the beef industry; however, environmental sustainability also encompasses land and water resources used in beef production.

Properly accounting for the environmental impact of beef cattle in the U.S. is a difficult task. This is partly because the resources used and the GHGs emitted are difficult to track and accurately measure. Further compounding the problem is the large scale of the U.S. beef industry and the variety of management and climatic conditions. Thus, one of the most robust and effective methods available to the scientific community to investigate the beef industry's environmental footprint is simulation. Simulation also allows for mitigation assessment, by comparing how changing one or a few factors affects sustainability metrics. In this study, mature cow body size and pounds of milk

produced at peak lactation were altered to examine the impact genetic potentials have on natural resource use while still accounting for regional differences in production practices.

Experimental Procedures

A stochastic simulation model was utilized to simulate a 100-head cow-calf operation over a 25-year period (Aherin, 2020). The program simulated six herds with differing combinations of genetic potential within 74 land use regions in the Great Plains resulting in 444 unique scenarios. Body size (large, moderate, and small) was parameterized for each herd using data from regional surveys of cattle producers (Asem-Hiablie et al., 2015; Asem-Hiablie et al., 2016). Low lactation potential was designated 17.6 lb milk per day at peak lactation while high lactation potential was 24.2 lb milk per day at peak lactation (NRC, 2016). Cattle were assumed to be grazing from May 1 to October 31 with supplement fed per cow as needed to maintain a body condition score of 5. Stocking rate for each scenario was based on observed stocking rates and scaled to match mature body weight (BW; Asem-Hiablie et al., 2015; Asem-Hiablie et al., 2016). From November 1 to April 30, the cattle were assumed to have received enough ration of hay and grain to maintain a body condition score of 5. Supplemental and delivered rations were formulated to be representative of common feedstuffs in each region.

Average yield for each feedstuff was found for a representative county located in each land region. The as-fed weight of the feedstuffs was divided by the yield of the feedstuff in that region to calculate the acres of land required to grow feedstuffs. For by-product feedstuffs, land and water used to grow the original crop was scaled by the percent mass of the by-product compared to the mass of the original crop. Grazing land was found by multiplying the number of animals of each class (replacement heifers, bred heifers, and mature cows) by the stocking rate of each class. Total land was the sum of land required to grow feedstuffs and grazing land.

Irrigation water needs were found by subtracting rainfall measurements from average crop water needs as determined by the Blaney-Criddle method (Blaney and Criddle, 1950; Brouwer and Heibloem, 1986). Total irrigation water was found by multiplying irrigation needs by the area of crop land allocated to growing feedstuffs. Drinking water was estimated for the herd each month by adjusting a baseline water intake by BW, peak lactation, and monthly temperature in each scenario and multiplying by the number of cattle in the herd (Spencer et al., 2017). Total water use was calculated as the sum of irrigation water and drinking water.

The gross energy of each diet was multiplied by dry matter intake of each diet. The gross energy intake was inserted into the IPCC Tier 2 methane estimation model to find the pounds of methane produced in each scenario in the average year (IPCC, 2019).

Weaning weight was estimated by taking the national average weaning weight of all calves from herds with 50–199 head (roughly 542 lb; USDA, 2020), and adding/subtracting 0.1476 lb in weaning weight for every 1 lb increase/decrease from 1208 lb in maternal weight (Ziegler, 2020). Weaning weight was then adjusted for milking potential by adding/subtracting 6.6 lb of weaned calf for every 1 lb increase/decrease from 22 lb of milk per day at peak lactation (King et al., 2020; Fraga et al., 2013).

Results and Discussion

Large animals required more total land than small animals regardless of lactation potential primarily because large animals were allocated more grazing land (Table 1). Grazing land comprised anywhere from 70–98% of the total land required. High lactation animals required the most supplement. This was because the model parameters prevented the animals from consuming more than 2.7% of their BW in feed per day, and high lactation animals could not meet their energy needs through forage alone.

Total water required was driven more by lactation potential than mature weight (Table 1). Animals with high milk yields required more total water than animals with low milk yields because of the additional need for crop land and the fact irrigation comprised between 75–99% of the total water required. Within lactation potential, large animals required more total water than smaller animals. In terms of drinking water, large animals drank more than small animals, and animals that produced greater amounts of milk drank more than low milking animals of the same size.

Methane production in this study was primarily driven by feed intake (Table 1). Animals with greater feed intake generally have greater methane emissions. Therefore, larger cattle produced more methane than smaller cattle. Higher milking cattle also produced more methane than lower milking cattle of the same weight.

When environmental footprint was scaled by weaning weight, it was shown that small, high milking cattle were the most efficient users of grazing land, total land, drinking water, and produced the least methane per pound of weaned calf (Table 2). In addition, small, low milking animals used the least crop land and irrigation water per pound of weaned calf. Conversely, large animals with low lactation potential generally had the greatest environmental impact per pound of calf weaned.

Although the results are a summary of average trends across the Great Plains, the genetic potential that is the most efficient on average may not be the genetic potential that is the most efficient in every location because weaning weights of different genetic potentials may vary from region to region. Further, environmental sustainability needs to be balanced with social and economic considerations.

Implications

Animals with greater energy requirements have larger environmental footprints. However, small, high lactation cattle required the least total land and emitted the fewest pounds of methane per pound of weaned calf, while small, low lactation animals were the most efficient users of water.

Acknowledgments

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Table 1. Average annual environmental impact of a 100 head cow-calf herd with differing genetic potentials in the Great Plains

Genetic potential[1]	Grazing land (ac)	Crop land (ac)	Total land (ac)	Drinking water (1000 gal)	Irrigation water (1000 gal)	Total water (1000 gal)	Methane (tons)
Large weight							
High milk	1757	156	1913	462	8299	8761	10.49
Low milk	1757	141	1898	446	7601	8047	10.17
Moderate weight							
High milk	1613	151	1764	443	7998	8441	10.00
Low milk	1613	137	1750	427	7294	7721	9.61
Small weight							
High milk	1472	146	1618	424	7680	8104	9.48
Low milk	1472	132	1604	408	7001	7409	9.06

[1]Weight (large, moderate, and small) was parameterized for each herd using data from regional surveys of cattle producers. Low lactation potential was designated 17.6 lb milk/day at peak lactation; high lactation potential was 24.2 lb milk/day at peak lactation.

Table 2. Average annual environmental impact per pound of weaning weight (WW) of a 100 head cow-calf herd with differing genetic potentials in the Great Plains

Genetic potential[1]	Grazing land (ac/lb WW)	Crop land (ac/lb WW)	Total land (ac/lb WW)	Drinking water (1000 gal/lb WW)	Irrigation water (1000 gal/lb WW)	Total water (1000 gal/lb WW)	Methane (lb/lb WW)
Large weight							
High milk	0.0252	0.0022	0.0275	0.0066	0.1192	0.1258	0.3013
Low milk	0.0269	0.0022	0.0291	0.0068	0.1165	0.1233	0.3117
Moderate weight							
High milk	0.0237	0.0022	0.0259	0.0065	0.1175	0.124	0.2939
Low milk	0.0253	0.0022	0.0275	0.0067	0.1145	0.1212	0.3017
Small weight							
High milk	0.0221	0.0022	0.0243	0.0064	0.1155	0.1219	0.2851
Low milk	0.0237	0.0021	0.0258	0.0066	0.1127	0.1193	0.2917

[1]Weight (large, moderate, and small) was parameterized for each herd using data from regional surveys of cattle producers. Low lactation potential was designated 17.6 lb milk/day at peak lactation; high lactation potential was 24.2 lb milk/day at peak lactation.

Bunk Space Requirements for Growing Beef Cattle Limit-Fed a High-Energy Corn and Corn Co-Product Diet

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

Abstract

Limit-fed diets with high-energy corn and corn co-product can improve feed efficiency and reduce manure production in growing cattle; however, bunk space allotments for limit-fed cattle have not been systematically determined. To ascertain bunk space requirements for limit-fed growing cattle, 385 crossbred steers [initial body weight (BW) 473 ± 56 lb] were blocked by arrival date and assigned to one of four bunk space treatments (i.e., 10, 15, 20, or 25 in of bunk per head). No differences ($P \geq 0.34$) in BW, dry matter intake, or gain-to-feed ratio were observed between treatments. During the first 29 days, average daily gain (ADG) increased linearly as bunk space increased ($P = 0.03$); however, no treatment effects were observed thereafter. At the completion of the 58-day receiving period, steers were blocked by bunk-space treatment, randomly assigned to one of eighteen pastures, and grazed for 90 days to investigate possible residual effects of bunk-space allotment on subsequent growth performance. Total BWG and ADG increased linearly ($P \leq 0.01$) as bunk space decreased; however, final BW did not differ ($P = 0.53$) between treatments.

Introduction

Recent research demonstrated an improvement in feed efficiency when growing cattle were limit-fed a high-energy corn and corn co-product diet, when compared with traditional high-roughage diets fed *ad libitum.* One concern associated with limit feeding is that bunk-space allotments required per calf have not been systematically evaluated. The current recommendation for growing beef cattle fed *ad libitum* (i.e., 500–700 lb) is 18 in of bunk per head. Cattle fed *ad libitum* have access to feed throughout the day; whereas, limit-fed cattle generally consume feed offered within six hours after feed delivery. Under limit-fed conditions, inadequate bunk space could result in over-consumption by aggressive calves which could potentially cause digestive disorders. In addition, less aggressive calves could potentially have limited access to feed which could result in reduced performance. Therefore, the objective of our experiment was to evaluate the effects of bunk allotment on performance of growing beef calves limit-fed a high-energy corn and corn co-product diet. An additional objective was to determine if bunk allotment during the receiving period impacted subsequent growth performance during a 90-day grazing season.

Experimental Procedures

A total of 385 crossbred steers [initial body weight (BW) 473 ± 56 lb] were purchased in Texas and transported to the Kansas State University Beef Stocker Unit. The first two truckloads of cattle were received on February 2, 2021, and the second two truckloads were received on March 2, 2021. Calves were blocked by arrival date (2), stratified by individual arrival weight within block, and assigned to earth-floor pens (n = 14

calves per pen). Within block, pens were randomly assigned to one of four treatments which resulted in seven pens per treatment for a total of 28 pens. Pens were equal in size (30 × 50 ft) and contained fenceline feed bunks and 12-ft concrete aprons. Bunk length was adjusted to allow 10, 15, 20, or 25 in of bunk space per calf. Due to arrival dates, steers in block one were fed for 84 days and steers in block two were fed for 58 days; therefore, calves received at the earlier date were slightly heavier at grazing turnout then calves received at the later date.

Upon arrival, steers were individually weighed and a visual identification tag was applied. The following morning (day 0), steers were vaccinated for respiratory and clostridial pathogens and treated for internal and external parasites. Individual BW were measured on days 0, 29, and 58. In addition, pen weights were collected weekly (days 0, 14, 21, 28, 35, 42, 49, and 56) and were used to calculate feed delivered for the following week. Steers were fed once daily at 7:00 a.m. using a Roto-Mix feed wagon. The experimental diet (Table 1) was offered at 1.8% of BW daily (dry matter basis) from February 2 to March 13, 2021; thereafter, the daily feed allotment was increased to 2.0% of BW.

At the completion of the receiving period, steers were individually weighed, blocked by treatment, and randomly assigned to one of eighteen native pastures. Steers were stocked at a targeted density of 250 lb of live weight per acre and grazed for 90 days. Individual BW were measured at the beginning (May) and end (August) of the grazing period to determine total body weight gains (BWG) and average daily gains (ADG).

Results and Discussion

Following the 58-day feeding period, final BW did not differ ($P = 0.15$) between treatments (Table 2). Average daily gains increased linearly ($P = 0.03$) with increased bunk space for the first 29 days; however, no trends were observed thereafter. In addition, no differences in dry matter intake ($P = 0.34$), gain-to-feed ratio ($P = 0.39$), or feed-to-gain ratio ($P = 0.96$) were observed between bunk space treatments. When evaluating subsequent growth performance during the grazing season, BW did not differ ($P = 0.25$) between bunk space treatments at the beginning or the completion of the grazing period (Table 3); however, total BWG and ADG increased linearly ($P \leq 0.01$) with decreased bunk space. It appeared that reduced bunk allotments had minimal impact on growth performance during the receiving period but were associated with improved BWG throughout the grazing season. Conversely, overall total BWG and ADG were not different ($P = 0.29$) between treatments at the completion of the study.

Implications

We interpreted our data to suggest that bunk allotments of 10, 15, 20, or 25 in per calf had minimal impact on growth performance during a 58-day receiving period and did not affect final BW at the completion of a 90-day grazing season.

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Table 1. Experimental diet

Ingredient	DM[1] %
Prairie hay	13.0
Dry-rolled corn	39.5
Sweet bran[2]	40.0
Supplement[3]	7.5

[1]Dry matter.
[2]Cargill Corn Milling (Blair, NE).
[3]Supplement pellet formulated to contain (DM basis) 11.5% crude protein, 0.60% phosphorus, 4.7% salt, 0.80% potassium, 2.5% fat, and 307.2 g/ton monensin (Rumensin; Elanco, Greenfield, IN).

Table 2. Effects of bunk allotment on performance of growing calves limit-fed a high-energy corn, corn co-product diet during the receiving period

	Treatment, in					*P*-value		
Item	10	15	20	25	SEM[1]	Lin	Quad	Cubic
BW,[2] lb								
Day 0	472	475	473	475	7.6	0.77	0.94	0.69
Day 29	524	531	536	535	8.4	0.15	0.49	0.92
Day 58	566	572	580	572	9.6	0.37	0.29	0.58
ADG,[3] lb/day								
0 to 58	1.61	1.67	1.85	1.68	0.100	0.23	0.10	0.13
0 to 29	1.79	1.94	2.17	2.06	0.148	0.03	0.23	0.38
29 to 58	1.44	1.41	1.54	1.30	0.104	0.40	0.15	0.10
DMI,[4] lb/day								
0 to 58	9.74	9.73	9.83	9.76	0.054	0.54	0.49	0.12
Gain:Feed, lb/lb								
0 to 58	0.17	0.17	0.19	0.17	0.012	0.34	0.31	0.30
Feed:Gain, lb/lb								
0 to 58	6.37	6.32	6.20	6.03	0.677	0.60	0.90	0.99

[1]Standard error of the mean.
[2]Body weight.
[3]Average daily gain.
[4]Dry matter intake.

Table 3. Effects of bunk allotment during the receiving period on subsequent growth performance throughout a 90-day grazing season in the Kansas Flint Hills

	Treatment, in					*P*-value		
Item,	**10**	**15**	**20**	**25**	**SEM[1]**	**Lin**	**Quad**	**Cubic**
BW,[2] lb								
Day 0 of grazing	601	611	615	612	10.5	0.25	0.38	1.00
Day 90 of grazing	823	829	825	822	10.3	0.80	0.53	0.73
Total BWG,[3] lb	219	216	206	202	5.5	≤ 0.01	1.00	0.40
ADG,[4] lb/day	2.44	2.40	2.29	2.25	0.062	≤ 0.01	0.99	0.40
Overall performance								
Total BWG, lb	351	353	351	345	7.1	0.33	0.37	0.98
ADG, lb/day	2.12	2.13	2.12	2.07	0.043	0.29	0.36	0.96

[1]Standard error of the mean.
[2]Body weight.
[3]Body weight gain.
[4]Average daily gain.

Feed Efficiency is Better and Activity is Greater in Growing Cattle Limit-Fed a High-Energy Diet During the Growing Phase Compared to a Traditional Roughage-Based Diet Fed for *Ad Libitum* Intake

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Abstract

Three hundred seventy crossbred heifers [initial body weight (BW) = 496 ± 44 lb] were used in a complete randomized block design receiving and growing study at the Kansas State University Beef Stocker Unit. Two dietary treatments included: (1) 45 Mcal of net energy for gain (NE_g) per 100 lb of dry matter (DM) fed for *ad libitum* intake (45AL), or (2) 60 Mcal NE_g per 100 lb of DM limit-fed at 2.2% of BW daily on a DM basis (60LF2.2). Both diets contained 40% of DM as Sweet Bran (Cargill Animal Nutrition, Blair, NE). Feed efficiency in the growing phase was greater ($P < 0.01$) by 35% for 60LF2.2 heifers compared to 45AL heifers. Average daily gain was lower for 60LF2.2 heifers than 45AL heifers ($P < 0.01$). Rumination time was greater ($P < 0.01$) for 45AL heifers compared to 60LF2.2 heifers, whereas activity was greater ($P < 0.01$) for 60LF2.2 heifers than 45AL heifers. These results suggest growing cattle fed a high-energy diet at a restricted intake level of 2.2% of BW daily on a DM basis have better feed efficiency and greater activity levels compared to growing cattle full-fed traditional roughage-based diets.

Introduction

Recent research suggests limit feeding a high-energy diet to growing cattle improves feed efficiency and reduces time spent ruminating during the growing phase prior to feedlot entry compared to roughage-based diets fed for *ad libitum* intakes on a dry matter (DM) basis. Intake restrictions were often applied based on a percentage of full-fed (*ad libitum*) intake. The objective of this experiment was to compare performance impacts of a high-energy diet limit-fed at 2.2% of body weight to a traditional roughage-based diet fed *ad libitum* during the growing phase.

Experimental Procedures

Three hundred seventy crossbred heifers [initial body weight (BW) = 496 ± 44 lb] were received at the Kansas State University Beef Stocker Unit on four separate days in mid-March 2020. The experimental design was a randomized complete block, and the experimental unit was pen. Heifers were blocked by truckload and were assigned to pens based on day-1 BW. There were 16 soil-surfaced pens, with four pens per block. Twenty to twenty-five heifers were allocated to each experimental pen. Experimental diets were formulated to contain 40% of DM as Sweet Bran (Cargill Animal Nutrition, Blair, NE), and heifers were assigned to one of two dietary treatments: 45 Mcal of net

[1] Corn Belt Livestock Services, Papillion, NE.

energy for gain (NE_g) per 100 lb of DM fed for *ad libitum* intake (45AL) or 60 Mcal of NE_g per 100 lb of DM limit-fed at 2.2% of BW daily on a DM basis (60LF2.2). Animals were fed once daily at 7:00 a.m. using a Roto-Mix feed wagon (Model 414-14B, Dodge City, KS). Bunks were visually observed, and feed refused was estimated at 6:30 a.m. the following morning. Treatment 45AL feed refusal was targeted at 20 lb. A scale (Rice Lake Weighing Systems, Rice Lake, WI) was used to record weekly pen BW, adjust feed offerings, and to calculate pen performance. During the final 14 days of the study, all cattle were offered a gastrointestinal tract fill equilibration diet, which was formulated to contain 53 Mcal NE_g per 100 lb of DM, limit-fed at 2.5% of BW daily on a DM basis. Individual BW were measured on arrival, at revaccination (day 14), and at the conclusion of the study. Feed samples were collected weekly and frozen at -4°F. At the conclusion of the study, feed samples were thawed, mixed, subsampled, refrozen, and taken to a commercial laboratory for nutrient analysis (SDK Labs, Hutchinson, KS).

On arrival (day -1) cattle were individually weighed, received a visual number ear tag, and any pre-assigned ear tags or markings were recorded. Additionally, all cattle were ear-notched to mark cattle persistently infected with bovine respiratory disease. Cattle had *ad libitum* access to long-stem prairie hay and water via automatic waterers (Lil' Spring 3000; Miraco Livestock Water Systems, Grinnell, IA) prior to allocation to experimental pens on day 0. Twenty-four hours after arrival (day 0), cattle were individually weighed and were assigned an electronic identification ear tag. Each heifer was also outfitted with a 3-axial accelerometer ear tag (Allflex Livestock Intelligence, Madison, WI) to measure rumination and activity in 2-hour increments throughout the day, summarized in minutes per day. Cattle received a 7-way clostridial vaccine (Caliber 7, Boehringer Ingelheim Animal Health, Duluth, GA); and Titanium 5 (Elanco Animal Health, Greenfield, IN), a modified-live vaccine for protecting against infectious bovine rhinotracheitis, bovine viral diarrhea types 1 and 2, and parainfluenza. Additionally, cattle received Nuplura PH (Elanco Animal Health, Greenfield, IN) for protection against *Mannheimia haemolytica*; and tulathromycin (Draxxin; Zoetis, Parsippany, NJ), a macrolide antibiotic. Cattle were revaccinated on day 14 using Titanium 5.

Results and Discussion

Composition of study diets are presented in Table 1, and growing phase growth performance is presented in Table 2. Average daily gain for 60LF2.2 heifers was, on average, 15% lower ($P < 0.01$) than 45AL heifers, and feed to gain ratio was 35% greater ($P < 0.01$) for 60LF2.2 heifers than for heifers receiving 45AL. More DM was consumed by 45AL heifers than 60LF2.2 heifers ($P < 0.01$), except during gastrointestinal tract fill equilibration, by design ($P = 0.23$). The 45AL heifers lost BW during the first 7 days of the equilibration period. Concentration of NE_g calculated based on animal performance was greater for 60LF2.2 heifers than 45AL heifers ($P < 0.01$), but calculated net energy (NE) was lower relative to diet formulation. Our results indicate cattle performed worse than would have been predicted by NE_g, which may be due to environmental factors, including pen conditions, heat stress, or cold stress. Calculated 45AL NE concentration was 18.2% lower than diet formulation, whereas calculated 60LF2.2 NE concentration was only 3.8% lower than diet formulation.

The 60LF2.2 heifers spent, on average, 154 fewer minutes per day ruminating than 45AL heifers ($P < 0.01$; Table 2). An effect of diet was detected for rumination ($P < 0.01$, Figure 1), which was expected due to differences in DM intake between diets.

A diet × day interaction was detected for rumination ($P = 0.04$; Figure 1), when the time 60LF2.2 heifers spent ruminating increased on day 56, increased between day 56 and day 75, and increased again on day 77. A diet × hour interaction was detected for rumination ($P < 0.01$; Figure 2); 45AL heifers spent more time ruminating overnight than 60LF2.2 cattle (8:00 p.m. to 6:00 a.m.; $P < 0.05$), but no differences ($P > 0.10$) were observed between treatments at 10:00 a.m. when rumination time for both groups reached a nadir. An effect of diet was detected for daily activity ($P < 0.01$; Figure 1), but no diet × day interaction for daily activity was detected ($P = 0.93$). A diet × hour interaction was detected for activity ($P < 0.01$; Figure 2), when 60LF2.2 heifers were more active 1 hour before feeding at 6:00 a.m., and again 3 to 7 hours after feeding between 10:00 a.m. and 2:00 p.m. ($P < 0.01$). The 60LF2.2 heifers were more active than 45AL heifers in this experiment, most likely due to increased appetite from meal-eating behavior and treatment design differences.

Implications

We interpret our results to suggest that growing cattle limit-fed a high-energy diet based on Sweet Bran and corn to have better feed to gain ratio, greater activity, and shorter rumination times compared to cattle fed traditional roughage-based diets *ad libitum*, which could enable more efficient observation of morbid cattle.

Acknowledgments

National Cattlemen's Beef Association
Kansas Corn Commission

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Table 1. Composition and nutrient analysis of study diets

	Diet[1]		
Ingredient, % of dry matter	**45AL**	**60LF2.2**	**GFE[2]**
Corn[3]	8.6	38.8	23.8
Wet corn gluten feed[4]	40.0	40.0	40.7
Long-stem alfalfa	22.5	6.5	14.2
Chopped prairie hay	22.5	6.5	14.4
Supplement[5]	6.4	8.2	6.9
Nutrient, % of DM			
DM, % of as fed	74.7	74.2	74.5
Organic matter	85.3	93.7	92.9
Crude protein	15.8	15.1	16.3
Starch	10.0	29.3	19.1
Neutral detergent fiber	40.8	25.7	33.6
Acid detergent fiber	20.8	9.9	15.9
Calcium	1.2	1.1	1.0
Phosphorus	0.5	0.6	0.6

[1]45AL = 45 Mcal of net energy for gain (NE_g) per 100 lb of dry matter (DM) offered for *ad libitum* DM intake. 60LF2.2 = 60 Mcal of NE_g per 100 lb of DM limit-fed at 2.2% of body weight (BW) daily on a DM basis.
[2]GFE = Gastrointestinal tract fill equilibration diet. Fed during last 14 days of the study (depending on block), it contained 53 Mcal of NE_g per 100 lb of DM limit-fed at 2.5% of BW daily on a DM basis.
[3]Dry-rolled yellow #2 corn.
[4]Sweet Bran, Cargill Animal Nutrition, Blair, NE.
[5]Supplement pellet (Cargill Animal Nutrition, Minneapolis, MN) was formulated to contain (DM basis) 9.2% crude protein, 1.53% crude fat, 17.0% crude fiber, 7.4% calcium, 0.22% phosphorus, 4.62% salt, 0.50% potassium, 331 mg/kg monensin, and 60.1 mg/kg diflubenzuron.

Table 2. Effect of limit-fed high-energy or traditional roughage-based diets in the growing phase on performance and behavior

	Diet[1]			
Item	**45AL**	**60LF2.2**	**SE[2]**	***P*-value**
Number of pens	8	8		
Number of animals	186	184		
BW,[3] lb				
Day 0	500.9	503.8	2.65	0.43
Treatment end[4]	757.7	721.6	5.91	< 0.01
GIT equilibration, day 7[5]	751.3	739.9	3.75	0.05
GIT equilibration, day 14[5]	780.7	770.1	3.70	0.07
ADG,[6] lb/day				
Day 0 – treatment end[4]	2.93	2.49	0.07	< 0.01
GIT equilibration, day 0 – 7[5]	-0.90	2.58	0.40	< 0.01
GIT equilibration, day 7 – 14[5]	4.19	4.34	0.20	0.59
GIT equilibration, day 0 – 14[5]	1.65	3.53	0.22	< 0.01
DM intake, lb/day	21.50	13.29	0.73	< 0.01
Daily intake, % of BW daily	3.42	2.17	0.11	< 0.01
Gain to feed ratio, lb/lb	0.139	0.188	0.01	< 0.01
NE_m, Mcal/lb DM[7]	0.63	0.87	0.02	< 0.01
NE_g, Mcal/lb DM[7]	0.37	0.58	0.01	< 0.01
Rumination, minutes/day[8]	455.7	302.8	12.01	< 0.01
Activity, minutes/day[8]	346.2	369.5	3.12	< 0.01

[1]45AL = 45 Mcal of net energy for gain (NE_g) per 100 lb of dry matter (DM) offered for *ad libitum* DM intake. 60LF2.2 = 60 Mcal of NE_g per 100 lb of DM limit-fed at 2.2% of BW daily on a DM basis.
[2]Standard error; largest standard error of the means is reported.
[3]Body weight.
[4]Treatment-end date was day 84 for 2 blocks, and day 91 for 2 blocks.
[5] Gastrointestinal tract equilibration diet. Fed for 14 days, it was formulated to provide 53 Mcal of NE_g per 100 lb of DM limit-fed at 2.5% of BW daily on a DM basis.
[6]Average daily gain.
[7]Net energy calculations from day 0 through GIT fill equilibration phase: Galyean (2021) using NRC (1996) equations.
[8]Measured using 3-axial accelerometer ear tags (Allflex Livestock Intelligence, Madison, WI).

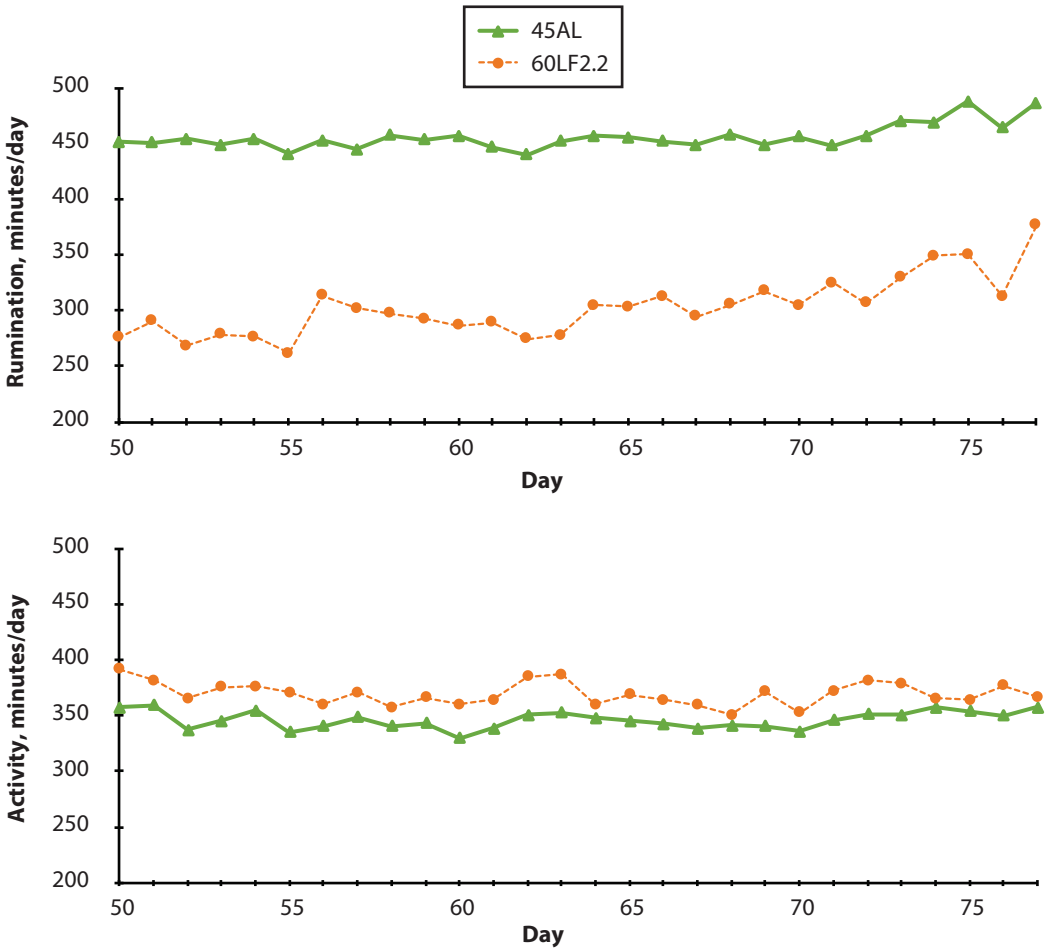

Figure 1. Effect of limit-fed high-energy or *ad libitum* roughage-based diets fed in the backgrounding phase on daily rumination and activity. Top graph: 45AL (▲) = 45 Mcal of net energy for gain (NE_g)per 100 lb of dry matter (DM) offered for *ad libitum* DMI, n = 186; 60LF2.2 (●) = 60 Mcal of NE_g per 100 lb of DM limit-fed at 2.2% of body weight (BW) daily on a DM basis, n = 184. Diet effect: $P < 0.0001$. Day effect: $P < 0.0001$. Diet × day effect: $P = 0.04$. Standard error of the mean (SEM) = 15.94. Bottom graph: 45AL (▲) = 45 Mcal of NE_g per 100 lb of DM offered for *ad libitum* DMI, n = 186; 60LF2.2 (●) = 60 Mcal of NE_g per 100 lb of DM limit-fed at 2.2% of BW daily on a DM basis, n = 184. Diet effect: $P < 0.001$. Day effect: $P = 0.01$. Diet × day effect: $P = 0.93$. SEM = 9.55.

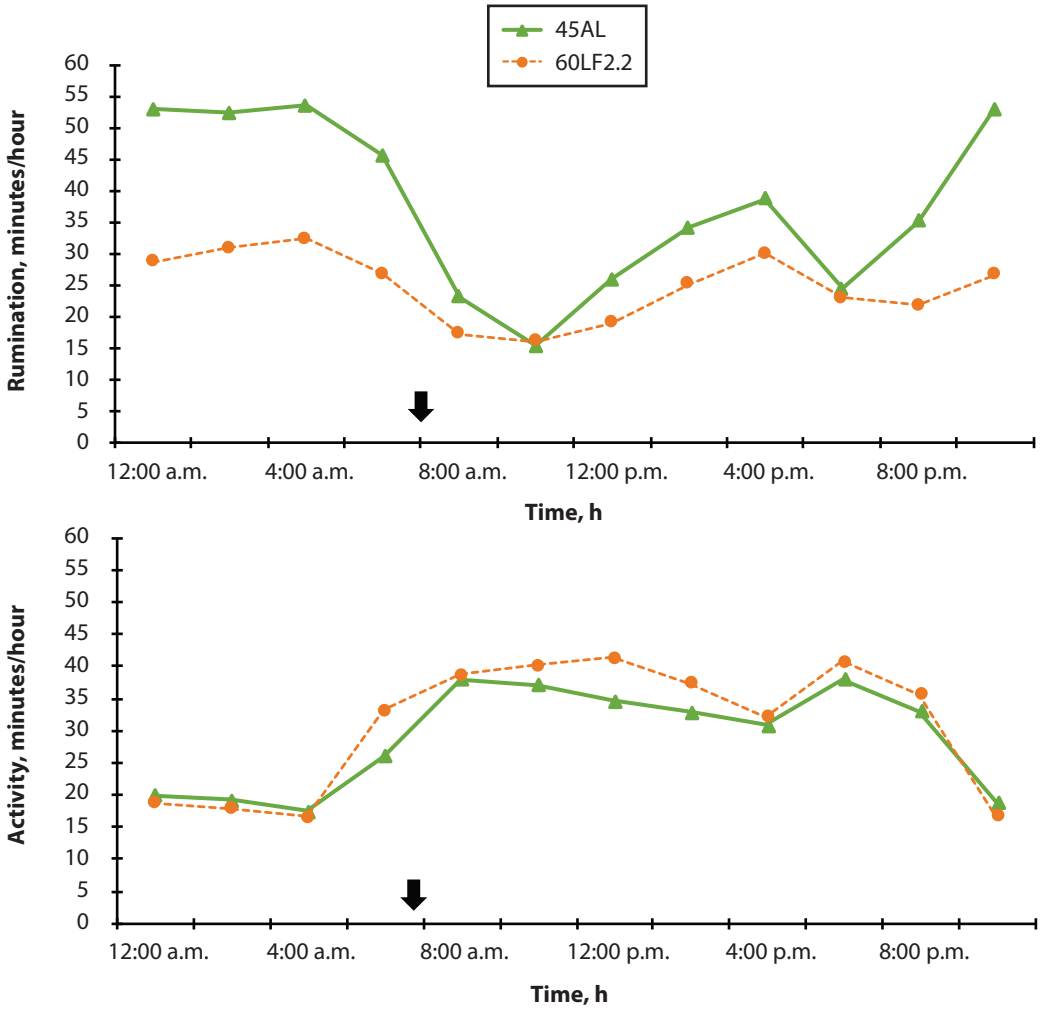

Figure 2. Effect of limit-fed high-energy or *ad libitum* roughage-based diets fed in the backgrounding phase on hourly rumination and activity. Top graph: 45AL (▲) = 45 Mcal of net energy for gain (NE_g) per 100 lb of dry matter (DM) offered for *ad libitum* intake, n = 186; 60LF2.2 (●) = 60 Mcal of NE_g per 100 lb of DM limit-fed at 2.2% of body weight (BW) daily on a DM basis, n = 184. The arrow represents time of feeding (7:00 a.m.). Diet effect: $P < 0.0001$. Hour effect: $P < 0.0001$. Diet × hour effect: $P < 0.0001$. Standard error of the mean (SEM) = 1.18. Bottom graph: 45AL (▲) = 45 Mcal of NE_g per 100 lb of DM offered for *ad libitum* DMI, n = 186; 60LF2.2 (●) = 60 Mcal of NE_g per 100 lb of DM limit-fed at 2.2% of BW daily on a DM basis, n = 184. The arrow represents time of feeding (7:00 a.m.). Diet effect: $P < 0.0001$. Hour effect: $P < 0.0001$. Diet × hour effect: $P < 0.0001$. SEM = 0.65.

A Limit-Fed, High-Energy Diet Fed During the Growing Phase Does Not Negatively Affect Subsequent Feedlot Growth Performance or Carcass Merit Compared to Feeding a Traditional Roughage-Based Diet *Ad Libitum* During the Growing Phase

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Abstract

Three hundred seventy crossbred heifers [initial body weight (BW) = 496 ± 44 lb] previously used in a 90-day growing and receiving study at the Kansas State University Beef Stocker Unit were transported to a commercial feedlot (Pratt Feeders, Pratt, KS) for finishing where cattle were fed a common diet. The two backgrounding diets included: (1) 45 Mcal of net energy for gain (NEg) per 100 lb of dry matter (DM) fed for *ad libitum* intake (45AL), or (2) 60 Mcal NEg per 100 lb of DM limit-fed at 2.2% of BW daily on a DM basis (60LF2.2). Both diets contained 40% of DM as Sweet Bran (Cargill Animal Nutrition, Blair, NE). Cattle were sorted by weight group (light or heavy) and backgrounding diet (45AL or 60LF2.2) and placed in one of four pens. Finishing growth performance and carcass characteristics were measured. Feedlot morbidity was 15.5% greater for 60LF2.2 heifers than 45AL heifers. Light-sort heifers had greater ($P = 0.01$) morbidity than heavy-sort heifers. Feedlot mortality was greater ($P < 0.01$) for 60LF2.2 heifers in the light-sort group than the heavy-sort group. No effect of backgrounding diet was observed for days on feed, average daily gain, or final out-weight. Although heavy-sort carcasses had greater backfat ($P = 0.02$) and greater U.S. Department of Agriculture yield grade scores ($P = 0.01$), light-sort carcasses had less backfat and lower yield grade scores, previous growing phase diet had little to no carryover effect on carcass characteristics.

Introduction

Previous research suggests limit feeding a high-energy diet to growing cattle during the growing phase may have carryover effects on both finishing growth performance and carcass characteristics. The objective of this experiment was to compare the subsequent growth performance and carcass impacts of a high-energy diet limit-fed at 2.2% of body weight to a traditional roughage-based diet fed *ad libitum* during the growing phase and weight sort group in the finishing phase.

Experimental Procedures

Three hundred seventy crossbred heifers [initial body weight (BW) = 496 ± 44 lb] previously used in a 90-day growing and receiving study at the Kansas State Univer-

[1] Corn Belt Livestock Services, Papillion, NE.

[2] Pratt Feeders, Pratt, KS.

sity Beef Stocker Unit were transported to a commercial feedlot (Pratt Feeders, Pratt, KS) for finishing where cattle were fed a common diet. The two backgrounding diets included: (1) 45 Mcal of net energy for gain (NEg) per 100 lb of dry matter (DM) fed for *ad libitum* intake (45AL), or (2) 60 Mcal NEg per 100 lb of DM limit-fed at 2.2% of BW daily on a DM basis (60LF2.2). Both diets contained 40% of DM as Sweet Bran (Cargill Animal Nutrition, Blair, NE). At the end of the growing trial, cattle were sorted into a heavy-sort or light-sort based on final individual weights measured on day 98 or 105 of the backgrounding phase study, depending on block. Sort group weight thresholds were established for each treatment diet group (45AL: BW = 800 lb; 60LF2.2: BW = 790 lb).

To maintain treatment diet integrity, cattle were transported by backgrounding phase diet (45AL or 60LF2.2) and weight-sort group (light or heavy) to a commercial feedlot (Pratt Feeders, Pratt, KS) and fed a common diet in four separate pens containing a similar number of heifers per pen. At the end of the finishing phase, cattle were marketed and transported by backgrounding treatment/weight sort group pen to a commercial abattoir (National Beef, Dodge City, KS) on November 17, 2020 (heavy-sort) and January 12, 2021 (light-sort), and carcass characteristics were measured. Finishing growth performance was calculated as deads-out by using the individual shrunk weights collected after the gastrointestinal tract fill equilibration period at the end of the growing phase trial as beginning BW (beginning weight). Ending live weight (ending weight) was calculated by dividing hot carcass weight by average dressing percentage collected at the abattoir.

Results and Discussion

Finishing growth performance is presented in Table 1. A significant ($P = 0.03$) interaction between backgrounding diet and sort group was observed for mortality, as 60LF2.2 cattle had greater ($P = 0.01$) mortality in the light-sort group than the heavy-sort group, and the 60LF2.2 cattle had greater ($P = 0.04$) mortality than 45AL cattle in the light-sort group. No other significant interactions between backgrounding diet or sort group were observed. A main effect of backgrounding diet was observed for morbidity; it was 15.5% greater for 60LF2.2 cattle compared to 45AL cattle. Beginning weight tended ($P = 0.06$) to be greater for 60LF2.2 cattle than for 45AL cattle. No effect between backgrounding diets was observed for days on feed, ending weight, average daily gain (ADG), or mortality. A main effect between sort groups was observed for morbidity, because light-sort cattle had greater ($P = 0.01$) morbidity than heavy-sort cattle. Heavy-sort cattle had a higher ($P < 0.01$) beginning weight, lower ($P < 0.01$) number of days on feed, and better ($P < 0.01$) ADG than light-sort cattle. No effect between sort groups was observed for ending weight or mortality.

Carcass characteristics are presented in Table 2. Live weight ($P = 0.59$) and hot carcass weight ($P = 0.84$) was similar between backgrounding diet/sort groups. No main effects between backgrounding diets were observed, but there were main effects observed between sort groups. Light-sort cattle had greater backfat ($P = 0.02$) and greater United States Department of Agriculture (USDA) yield grade scores ($P = 0.01$), whereas the heavy-sort cattle had less backfat and lower USDA scores. Heavy-sort cattle tended ($P = 0.09$) to have greater ribeye areas than light-sort cattle. No effects ($P \geq 0.39$) between sort groups were observed for marbling score or USDA quality grades. This suggests that although sort group in the finishing phase appears to affect finishing

growth performance and carcass characteristics to some degree, previous backgrounding diet (energy level confounded by intake restriction) had little to no carryover effect on finishing growth performance and carcass characteristics after a long finishing period in which cattle are offered high-energy diets *ad libitum*.

Implications

A limit-fed, high-energy diet based on corn and Sweet Bran fed during the growing phase had little to no carryover effect on feedlot growth performance or carcass characteristics, but feedlot morbidity may increase in cattle previously limit-fed a high-energy diet compared to a traditional roughage-based diet fed *ad libitum*.

Acknowledgments

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Table 1. Effect of a limit-fed high-energy or traditional roughage-based diet in the backgrounding phase or weight sort group in the finishing phase on finishing growth performance

	Sort group[1]							
	Heavy		Light					
	Backgrounding diet[2]					*P*-value[4]		
Item	45AL	60LF2.2	45AL	60LF2.2	SEM[3]	S	B	S × B
Number of pens	1	1	1	1				
Number of animals	94	91	92	92				
Days on feed, days	144	144	200	200	0.5	< 0.01	0.99	0.99
Beginning weight, lb	853.0	841.5	742.5	733.7	5.7	< 0.01	0.06	0.78
Ending weight,[5] lb	1329.6	1326.5	1328.3	1312.6	14.1	0.51	0.53	0.59
ADG,[6] lb/day	3.33	3.37	2.93	2.89	0.07	< 0.01	0.90	0.43
DMI,[7] lb/day	21.98	20.81	19.09	19.16	–	–	–	–
Gain to feed ratio, lb/lb	0.151	0.162	0.154	0.151	–	–	–	–
Morbidity, %	5.3	16.0	10.4	30.6	4.5	0.01	< 0.01	0.19
Mortality, %	2[ab]	0[a]	1[a]	5[b]	1.3	0.14	0.46	0.03

[ab]Least square means in the same row with different superscripts are significantly different ($P < 0.05$).

[1]Sort groups for each treatment were created prior to finishing phase. Heavy and light sort groups were finished in four separate pens at a commercial feed yard (Pratt Feeders, Pratt, KS), then sent to a commercial abattoir (National Beef, Dodge City, KS) on November 17, 2020 and January 12, 2021, respectively.

[2] Diets offered during the backgrounding phase prior to the finishing phase. 45AL = 45 Mcal of net energy for gain (NEg) per 100 lb of dry matter (DM) fed for *ad libitum* intake. 60LF2.2 = 60 Mcal NEg per 100 lb of DM limit-fed at 2.2% of BW daily on a DM basis.

[3]Largest standard error of the mean is reported.

[4]S = sort group; B = backgrounding diet; S × B = sort group × backgrounding diet interaction.

[5]Ending weight is calculated from hot carcass weight multiplied by dressing percentage, both collected at the abattoir (National Beef, Dodge City, KS).

[6]Average daily gain.

[7]Dry matter intake.

Table 2. Effect of a limit-fed high-energy or traditional roughage-based diet in the backgrounding phase or weight sort group in the finishing phase on carcass characteristics

	Sort group[1]							
	Heavy		Light					
	Backgrounding diet[2]					*P*-value[4]		
Item	45AL	60LF2.2	45AL	60LF2.2	SEM[3]	S	B	S × B
Number of pens	1	1	1	1				
Number of animals	92	88	88	83				
Carcass traits[5]								
Live weight, lb	1329.6	1326.5	1328.3	1312.6	14.1	0.51	0.53	0.59
Hot carcass weight, lb	850.3	849.9	847.2	849.9	8.8	0.83	0.91	0.84
Dressing percentage, %	63.95	64.07	63.78	64.74	---	---	---	---
Backfat, in	0.70	0.70	0.75	0.74	0.02	0.02	0.97	0.74
USDA[6] yield grade	2.58	2.65	2.83	2.85	0.10	0.01	0.62	0.80
Marbling score[7]	540	531	523	528	17.4	0.39	0.84	0.56
Ribeye area, sq. in	15.0	14.7	14.5	14.6	0.2	0.09	0.52	0.32
USDA[6] quality grade, %								
Select	4.8	6.4	8.8	5.1	3.1	0.57	0.65	0.26
Choice	86.4	83.7	81.9	87.5	3.5	0.92	0.67	0.24
Prime	8.9	8.8	9.4	6.5	3.4	0.74	0.59	0.62

[1]Sort groups for each treatment were created prior to finishing phase. Heavy and light sort groups were finished in separate pens at a feed yard (Pratt Feeders, Pratt, KS), then sent to a commercial abattoir (National Beef, Dodge City, KS) on November 17, 2020 and January 12, 2021, respectively.
[2]Diets offered during the backgrounding phase prior to the finishing phase. 45AL = 45 Mcal of net energy for gain (NEg) per 100 lb of dry matter (DM) fed for *ad libitum* intake. 60LF2.2 = 60 Mcal NEg per 100 lb of DM limit-fed at 2.2% of BW daily on a DM basis.
[3]Largest standard error of the mean is reported.
[4]S = sort group; B = backgrounding diet; S × B = sort group × backgrounding diet interaction.
[5]Carcass traits collected at the National Beef abattoir in Dodge City, KS.
[6]U.S. Department of Agriculture.
[7]Score ranges are as follows: < 400 = select. 400 to 499 = low choice. 500 to 599 = average choice. 600 to 699 = high choice.

Digestibility of Dry Matter is Better and Manure Output is Lower in Growing Cattle Limit-Fed a High-Energy Diet During the Growing Phase Compared to a Traditional Roughage-Based Diet Fed for *Ad Libitum* Intake

M.A. Scilacci, E.C. Titgemeyer, S.P. Montgomery,[1] T.J. Spore, A.J. Tarpoff, T.G. O'Quinn, W.R. Hollenbeck, and D.A. Blasi

Abstract

Eight ruminally cannulated crossbred Angus heifers [body weight (BW) = 450 ± 24 lb] were used in a cross-over design with two consecutive 15-day periods at the Kansas State University Beef Stocker Unit. Experimental unit was animal within period. Two dietary treatments were fed: (1) 45 Mcal of net energy for gain (NE_g) per 100 lb of dry matter (DM) fed for *ad libitum* DM intake (45AL), or (2) 60 Mcal NE_g per 100 lb of DM limit-fed at 85% of 45AL diet intake on a DM basis (60LF85%). Both diets contained 40% of DM as Sweet Bran (Cargill Animal Nutrition, Blair, NE). Apparent total-tract diet digestibilities of DM and organic matter were 5.2% and 6.4% greater ($P < 0.01$) than roughage-based diets fed *ad libitum*, respectively, but fiber digestibility was not affected by diet ($P \geq 0.59$). Heifers fed 60LF85% had 35% lower ($P < 0.01$) apparent fecal output than heifers fed 45AL. There was a diet × hour interaction, such that ruminal pH was greater ($P < 0.01$) from 10:00 p.m. to 10:00 a.m. for heifers fed 60LF85% compared to heifers fed 45AL. There was a diet × hour interaction for ammonia concentration ($P < 0.01$), with heifers fed 45AL having a greater concentration of ammonia 2 hours after feeding and again from 8 to 18 hours after feeding compared to 60LF85% heifers. Acetate:propionate ratio was lower ($P < 0.01$) in heifers fed 60LF85% than heifers fed 45AL. Better diet digestibility and reduced production of manure was observed in heifers limit-fed a high-energy diet than heifers fed a traditional roughage-based diet.

Introduction

Recent research conducted at the K-State Beef Stocker Unit suggests limit feeding a high-energy diet based on corn and Sweet Bran to growing cattle improves diet digestibility of dry matter without affecting fiber digestibility compared to a roughage-based diet. The objective of this experiment was to evaluate the impact on intake and digestion of a high-energy diet limit-fed at 85% of the *ad libitum* daily consumption of a roughage-based diet on a dry matter basis compared to a traditional roughage-based growing diet in growing cattle.

[1] Corn Belt Livestock Services, Papillion, NE.

Experimental Procedures

Eight ruminally cannulated crossbred Angus heifers [body weight (BW) = 450 ± 24 lb] were used in a cross-over design with two consecutive 15-day periods. Experimental unit was animal within period.

Eight, soil-surfaced 20 × 40 ft pens were constructed in a large outdoor holding facility. Each pen had access to a manually filled water tank, and cattle were fed once daily at 10:00 a.m. Each 15-day period included 10 days for diet adaption, 4 days for fecal sampling, and 1 day for ruminal sampling. All cattle were offered the 45AL treatment diet for 7 days prior to starting the study to acclimate and determine *ad libitum* DM intakes. Feed refusal for 45AL was targeted at 4 lb/day during diet adaption and sampling. Cattle receiving the 60LF85% diet were restricted to 85% of their own reference 45AL DM intake determined prior to study initiation.

Indwelling rumen pH boli (smaXtec, Graz, Austria) inserted through the ruminal cannula continuously monitored pH throughout the study in 10-minute intervals. On days 4 to 14, chromic oxide (Cr_2O_3) marker was top dressed and hand mixed into each total mixed ration to calculate apparent total-tract diet digestibility of DM, organic matter, fiber, and starch. Feed samples were collected on days 10–14. Feed refusals were collected on days 11–14 for each animal. Fecal samples were collected from the rectum of each animal on days 11–14 at 8-hour intervals after feeding. Fecal sampling time advanced by 2 hours each day, so each 2-hour interval after feeding was represented. Immediately following collection, all samples were frozen at -4°F. Following study completion all samples were thawed, mixed, subsampled, and refrozen by animal within period.

On day 15 of each period, four locations in the rumen were sampled prior to feeding, and at 2, 4, 6, 8, 12, 18, and 24 hours after feeding to determine ruminal volatile fatty acid profile and ammonia concentration. A small amount of ruminal fluid was strained through eight layers of cheesecloth. One cc of strained ruminal fluid was transferred into four, 2-cc microcentrifuge tubes each containing 250 µL of 25% (wt/vol) *m*-phosphoric acid, then frozen at -4°F. Following collection of samples prior to feeding, cobalt edetate (Co-EDTA) dissolved into 200 cc of distilled water was dosed through the ruminal cannula. At 2, 4, 6, 8, 12, 18, and 24 hours after feeding, 15 cc of ruminal fluid was transferred into scintillation vials to measure cobalt concentration and estimate liquid passage rate and ruminal liquid volume. Following collection all ruminal fluid samples were frozen at -4°F pending analysis.

Results and Discussion

Composition of study diets are presented in Table 1, and results for intake and digestibility are presented in Table 2. By design, intake of DM, organic matter, and fiber was lower ($P < 0.01$) for 60LF85% heifers compared to 45AL heifers. Conversely, also by design, intake of starch was greater ($P < 0.01$) for 60LF85% heifers than 45AL heifers. By restricting intake of a high-energy diet, apparent total-tract diet digestibilities of DM and organic matter were 5.2% and 6.4% greater ($P < 0.01$) than roughage-based diets fed *ad libitum*, respectively, but fiber digestibility was not affected ($P \geq 0.59$) by diet. Starch digestibility was also unaffected ($P > 0.32$) by diet. The 60LF85% heifers had a slower liquid dilution rate ($P < 0.01$) than 45AL heifers, but ruminal liquid volume was greater ($P < 0.01$) in 60LF85% heifers than 45AL heifers.

Ruminal pH data are presented in Figure 1 and concentration of ammonia over time is presented in Figure 2. Although ruminal pH in 60LF85% heifers rapidly declined after feeding, results showed no effect of diet on ruminal pH over the course of the experiment ($P < 0.93$; Figure 1), but there was an interaction of diet across time detected for ruminal pH. Ruminal pH was greater ($P < 0.01$) from 10:00 p.m. to 10:00 a.m. just before feeding for heifers fed 60LF85%. Ammonia concentration was greater in 45AL heifers than 60LF85% heifers ($P = 0.03$; Figure 2). There was a diet × hour interaction for ammonia concentration ($P < 0.01$; Figure 2), with 45AL cattle having a greater concentration of ammonia 2 hours after feeding and again from 8 to 18 hours after feeding compared to 60LF85% cattle. The heifers fed 45AL had greater concentrations of total ruminal volatile fatty acids than did cattle eating 60LF85%, and thus was largely a result of greater concentrations of acetate ($P < 0.01$). Butyrate was also greater ($P < 0.01$) for heifers fed 45AL than heifers fed 60LF85%. Propionate, isovalerate, and valerate were not affected ($P > 0.10$) by diet. There was a diet × hour interaction for straight-chain volatile fatty acids including propionate, butyrate, and valerate ($P < 0.01$), which resembles meal-eating behavior. Volatile fatty acids concentration peaked twice for heifers fed 45AL at 2 hours and 12 hours after feeding, while heifers fed 60LF85% peaked only once 4 to 6 hours after feeding. There was a diet × hour interaction ($P < 0.01$) for branched chain volatile fatty acids, including isobutyrate and isovalerate, with a greater decrease in concentration 2 hours after feeding in 60LF85% heifers than 45AL heifers. Acetate:propionate ratio was lower ($P < 0.01$) in heifers fed 60LF85% than heifers fed 45AL. Molar proportions of acetate were greater ($P < 0.01$) for 45AL heifers, whereas proportions of propionate, isobutyrate, isovalerate, and valerate were greater ($P < 0.01$) for 60LF85% heifers. These results suggest that apparent diet digestibility was better and apparent fecal output was reduced by 35% when heifers were limit-fed a high energy diet compared to a roughage-based diet fed *ad libitum*.

Implications

Apparent diet digestibility was 5.2% better and fecal output was 35% lower in growing cattle limit-fed a high-energy diet based on corn and Sweet Bran compared to cattle full-fed a traditional roughage-based diet, which could help reduce manure removal costs and improve producer sustainability.

Acknowledgments

National Cattlemen's Beef Association
Kansas Corn Commission

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Table 1. Composition and nutrient analysis of study diets

	Diet[1]	
Ingredient, % of dry matter	**45AL**	**60LF85%**
Corn[2]	8.6	38.8
Wet corn gluten feed[3]	40.0	40.0
Long-stem alfalfa	22.5	6.5
Chopped prairie hay	22.5	6.5
Supplement[4]	6.4	8.2
Nutrient, % of dry matter		
Dry matter, % of as fed	73.1	72.7
Organic matter	91.3	94.5
Crude protein	17.0	15.5
Starch	11.9	33.0
Neutral detergent fiber	36.4	24.6
Acid detergent fiber	18.3	9.9
Calcium	0.8	0.6
Phosphorus	0.6	0.7

[1] 45AL = 45 megacalories of net energy for gain per 100 lb of dry matter offered for *ad libitum* dry matter intake. 60LF85% = 60 megacalories of net energy for gain per 100 lb of dry matter limit-fed at 85% of 45AL diet intake on a dry matter basis.
[2] Dry-rolled yellow #2 corn.
[3] Sweet Bran, Cargill Animal Nutrition, Blair, NE.
[4] Supplement pellet (Cargill Animal Nutrition, Minneapolis, MN) was formulated to contain (dry matter basis) 9.2% crude protein, 1.53% crude fat, 17.0% crude fiber, 7.4% calcium, 0.22% phosphorus, 4.62% salt, 0.50% potassium, 331 mg/kg monensin, and 60.1 mg/kg diflubenzuron.

Table 2. Effect of a limit-fed high-energy or traditional roughage-based diet in the growing phase on diet digestibility and ruminal characteristics

	Diet[1]			
Item	**45AL**	**60LF85%**	**SEM[2]**	***P*-value**
Number of observations	8	8		
Intake, lb/day				
Dry matter	17.77	13.73	0.82	< 0.01
Organic matter	16.23	12.96	0.77	< 0.01
Neutral detergent fiber	6.44	3.40	0.24	< 0.01
Acid detergent fiber	3.24	1.37	0.11	< 0.01
Starch	2.09	4.52	0.18	< 0.01
Ruminal[3]				
Ammonia, m*M*	5.22	3.89	0.49	0.03
Acetate:propionate ratio	2.80	1.98	0.15	< 0.01
Total volatile fatty acid, m*M*	109.37	82.81	5.02	< 0.01
Acetate, m*M*	66.90	44.18	2.48	< 0.01
Propionate, m*M*	23.77	24.63	2.20	0.63
Butyrate, m*M*	13.78	9.05	0.53	< 0.01
Valerate, m*M*	2.24	2.62	0.38	0.42
Isobutyrate, m*M*	0.89	0.67	0.04	< 0.01
Isovalerate, m*M*	1.66	1.65	0.24	0.98
Ruminal volatile fatty acid, molar % of total[3]				
Acetate	61.3	54.0	0.73	< 0.01
Propionate	21.8	29.0	1.15	< 0.01
Butyrate	12.49	11.11	0.54	0.02
Valerate	1.99	2.95	0.31	0.02
Isobutyrate	0.79	0.87	0.06	0.02
Isovalerate	1.51	2.12	0.32	0.06
Liquid passage rate,[4] %/hour	11.3	5.7	1.04	< 0.01
Ruminal liquid volume, gal	8.6	12.7	1.02	< 0.01
Apparent total tract digestibility, %				
Dry matter	74.8	78.7	0.77	0.01
Organic matter	77.1	82.0	0.62	< 0.01
Neutral detergent fiber	73.4	73.5	1.45	0.94
Acid detergent fiber	67.6	66.4	1.54	0.59
Starch	94.4	96.2	1.16	0.32
Fecal dry matter output, lb/day	4.52	2.92	0.24	< 0.01

[1]45AL = 45 megacalories of net energy for gain per 100 lb of dry matter fed for *ad libitum* intake daily. 60LF85% = 60 megacalories of net energy for gain per 100 lb of dry matter limit-fed at 85% of 45AL diet intake.
[2]Largest standard error of the mean is reported.
[3]Average of values collected at 0, 2, 4, 6, 8, 12, 18, and 24 hours after feeding.
[4]Calculated from samples collected at 0, 2, 4, 6, 8, 12, and 18 hours after dosing of cobalt edetate (Co-EDTA) at time of feeding.

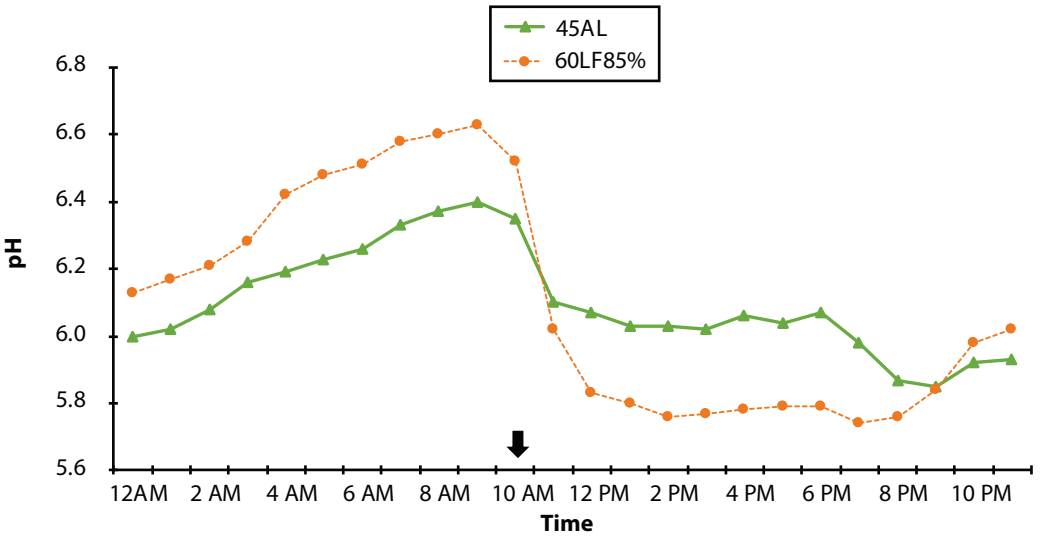

Figure 1. Effect of a limit-fed high-energy or traditional roughage-based diet in the growing phase on hourly pH . 45AL (▲) = 45 megacalories of net energy for gain per 100 lb of dry matter offered for *ad libitum* intake, n = 7; 60LF85% (●) = 60 megacalories of net energy for gain per 100 lb of dry matter limit-fed at 85% of 45AL intake, n = 8. The arrow represents time of feeding (10:00 a.m.). Diet effect: $P = 0.93$. Hour effect: $P < 0.0001$. Diet × hour effect: $P < 0.0001$. Standard error of the mean = 0.11.

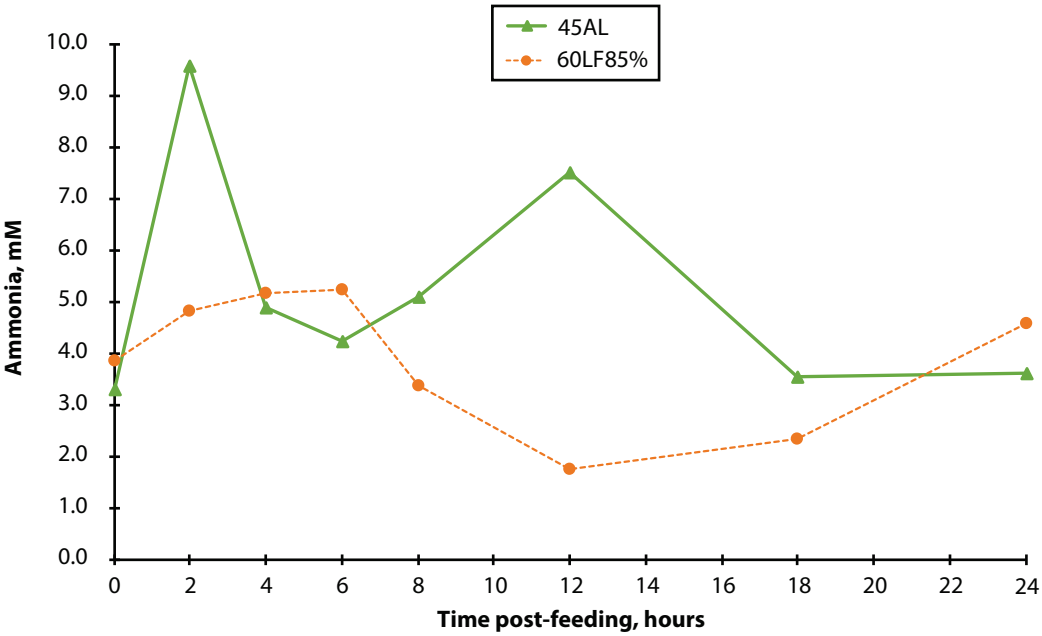

Figure 2. Effect of a limit-fed high-energy or a traditional roughage-based diet in the growing phase on ruminal ammonia concentration over 24 hours. 45AL (▲) = 45 megacalories of net energy for gain per 100 lb of dry matter offered for *ad libitum* intake, n = 7; 60LF85% (●) = 60 megacalories of net energy for gain per 100 lb of dry matter limit-fed at 85% of 45AL intake, n = 8. Diet effect: $P = 0.03$. Hour effect: $P < 0.0001$. Diet × hour effect: $P < 0.0001$. Standard error of the mean = 0.73.

Syngenta Enogen Corn Fed as Corn Grain and Corn Silage in Diets Containing Corn Coproducts Did Not Enhance Growth Performance of Growing Heifers

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Abstract

Three hundred eighty-four crossbred heifers [initial body weight (BW) = 582 ± 42 lb] were used in a completely randomized design, 81-day receiving and growing study, with a 2 × 2 factorial arrangement of four dietary treatments. The objective was to evaluate the effect of feeding corn grain and corn silage from Enogen corn hybrids (EC; Syngenta Seeds, LLC., Downers Grove, IL) or conventional corn hybrids (CON) in diets containing either wet distillers grain (WDG; ICM Biofuels, St. Joseph, MO) or Sweet Bran [proprietary wet corn gluten feed (WCGF); Cargill Animal Nutrition, Blair, NE]. Experimental unit was pen. There were eight pens per treatment, with 12 heifers stratified by weight to each pen. Experimental diets were formulated to contain 30% WDG or 30% WCGF on a dry matter (DM) basis and provide 51 megacalories of net energy for gain per 100 lb of DM daily. All diets were fed once daily for *ad libitum* consumption. No corn source × coproduct interactions ($P > 0.10$) were observed for performance or fecal starch analysis, with the exceptions of DM intake ($P < 0.01$) and gain to feed ratio ($P = 0.01$) at day 14. An effect of coproduct was observed at day 64, with heifers fed WDG having greater ($P < 0.03$) average daily gain (ADG) than heifers fed WCGF. Effect of coproduct on DM intake or gain to feed ratio was not different ($P > 0.05$) after day 14. Heifers fed EC had greater ($P < 0.01$) ADG at days 28 and 56 than heifers fed CON, but gain to feed ratio was not different ($P > 0.13$) between corn sources after day 28. Starch concentration of fecal DM was greater ($P < 0.02$) in CON heifers than EC heifers. Results indicate EC when fed with WCGF or WDG did not enhance growth performance of growing heifers, possibly due to similar dietary net energy densities fed in all diets.

Introduction

Recent research conducted at the Kansas State University Beef Stocker Unit suggested average daily gain (ADG) of growing cattle was 5% better by feeding diets containing Enogen corn as corn silage compared to silage with conventional corn hybrids. Growing cattle eating Enogen corn as dry rolled corn had a 2.4% better gain to feed ratio than growing cattle eating conventional corn hybrids as whole corn. Corn coproducts are widely used in the cattle feeding industry, but an evaluation of Enogen corn hybrids fed as dry rolled corn and corn silage in diets containing corn coproducts fed to growing cattle has not been conducted.

[1] Corn Belt Livestock Services, Papillion, NE.
[2] Syngenta Crop Protection, Greensboro, NC.

Experimental Procedures

Five hundred twenty-two crossbred heifers [initial body weight (BW) = 582 ± 67 lb] of Wyoming and Nebraska origin were loaded on trucks at a ranch 5 miles north of Stapleton, NE, and shipped 360 miles to the Kansas State University Beef Stocker Unit. Of these cattle, 384 heifers (initial BW = 582 ± 42) were used in a completely randomized design, with a 2 × 2 factorial arrangement of four dietary treatments. Experimental unit was pen. Cattle were fed in an outdoor receiving facility containing 32 soil-surfaced pens, each with an adjoining 30-ft concrete bunk attached to a 11.8-ft apron. All pens were equipped with automatic tank waterers (Lil' Spring 3000; Miraco Livestock Water Systems, Grinnell, IA), and daily total mixed rations were delivered using a Roto-Mix feed wagon (model 414-14B, Dodge City, KS). On arrival (day -2), cattle were individually weighed and assigned a visual ear tag, while being assessed for pre-existing tags, physical injuries, or morbidity. Before processing and allocation to experimental pens on day 0, cattle were allowed *ad libitum* access to long-stem prairie hay and water. Because heifers had an extensive preconditioning and vaccination history, they were not vaccinated on arrival. The preconditioning program from previous ownership included an initial vaccination and booster with each of the following: Bovishield Gold FP5, One Shot, and UltraBac 8 (Zoetis, Parsippany, NJ). On day 0, heifers were individually weighed (model T20, Te Pari Products, Burnsville, MN), identified with visual and electronic identification ear tags, and drenched with an oral dewormer (Synanthic, Boehringer Ingelheim Animal Health, Duluth, GA). Heifers were stratified by day -2 body weight to one of 32 pens, with eight pens per dietary treatment and 12 heifers per pen. Pen weights were recorded on day 0 and used for initial BW weight in performance calculations.

Dietary treatments (Table 1) were formulated to contain 30% wet distillers grain (WDG; ICM Biofuels, St. Joseph, MO) or 30% wet corn gluten feed (WCGF; Sweet Bran, Cargill Animal Nutrition, Blair, NE) on a dry matter (DM) basis and provide 51 megacalories (Mcal) of net energy for gain (NE_g) per 100 lb of DM daily. Main effects were corn source that included conventional corn, dry rolled (CON) or Enogen corn, dry rolled (EC; Syngenta Seeds, LLC, Downers Grove, IL) and coproduct that included WCGF or WDG. All corn grain was dry rolled by a commercial feed mill (Key Feeds, Clay Center, KS). All pens had *ad libitum* access to diets throughout the study. Bunks were visually assessed, and feed refusals were estimated each morning at 7:00 a.m. Daily feed refusals were targeted at 20 lb per pen. A scale (Rice Lake Weighing Systems, Rice Lake, WI) was used to record pen weights on day 0, 14, 28, 42, 56, 64, and 81. Individual BW were measured and a fecal grab sample for starch determination was collected on day 42. Final growth performance was calculated for each period from day 0 to 81. Treatment diets were provided from day 0 through day 64. Then, to minimize differences in gastrointestinal-tract fill all pens were limit-fed the CON/WCGF diet at 2.2% of day 64 body weight daily from day 64 to 81. Feed samples were collected on a weekly basis throughout the study and frozen at -4°F. Upon study completion, samples were thawed, composited, refrozen, and taken to a commercial laboratory (SDK Laboratories, Hutchinson, KS) for nutrient analysis.

Results and Discussion

Composition and nutrient analysis of experimental diets are presented in Table 1, and analysis of corn silages and corn coproducts are presented in Table 2. Growth performance data are reported in Table 3. With the exceptions of minor interactions for DM

intake and gain to feed ratio between days 0 and 14, no interactions between main effects of corn source and coproduct were noted for this study. In our 81-day growing trial there were significant corn source × coproduct interactions detected from days 0 through 14 for DM intake ($P < 0.01$) and gain to feed ratio ($P = 0.05$). While heifers consuming CON/WCGF had lower ($P < 0.01$) DM intake than EC heifers, heifers consuming CON/WDG had greater ($P < 0.01$) DM intake than EC heifers. There was a tendency ($P = 0.054$) for CON/WCGF heifers to have a greater gain to feed ratio compared to EC heifers.

There were main effects ($P \leq 0.03$) of coproduct for BW and ADG at the time provision of treatment diets concluded (day 64) as well as after the gastrointestinal tract fill equilibration period (day 81); heifers fed WDG had greater BW and ADG than heifers fed WCGF. Because DM intake was not markedly affected by coproduct, heifers consuming WDG also tended to have a better gain to feed ratio at day 64 ($P = 0.06$) as well as a numerically better gain to feed ratio at day 81 than heifers fed WCGF. At day 14, heifers fed WCGF had a greater ($P < 0.05$) gain to feed ratio than those fed WDG, which resulted from greater DM intake for heifers fed WDG. Heifers consuming EC had greater ($P \leq 0.03$) BW and ADG gain at day 28 and day 56 compared to heifers fed CON. At day 28, heifers fed EC also had a better ($P < 0.01$) gain to feed ratio than those fed CON, with a similar tendency ($P = 0.06$) observed for DM intake. No differences between corn sources were observed for gain to feed ratio or DM intake after day 28. Main effect of corn source for net energy concentration was not observed in this study, but WDG diets had numerically greater net energy concentration calculated from animal performance than WCGF diets. The EC heifers had less starch in the feces ($P < 0.02$) than CON heifers, but there was no main effect detected for coproduct.

Implications

Our results revealed no effect of replacing conventional corn grain and silage with Enogen corn grain and silage on the growth performance of growing cattle, but diets containing WDG resulted in better gain to feed ratio and ADG in growing heifers compared to diets containing WCGF.

Acknowledgments

Syngenta Seeds, LLC, Downers Grove, IL.

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NRC. 1996. Nutrient requirements of beef cattle. 7th ed. The National Academies Press, Washington, D.C.

Table 1. Composition and nutrient analysis of study diets

		Corn source[1]			
		CON		EC	
		Coproduct[2]			
Ingredient, % of total DM[3]	GFE[4]	WCGF	WDG	WCGF	WDG
Conventional corn hybrids	21.0	21.0	19.0	0.0	0.0
Enogen corn hybrids	0.0	0.0	0.0	21.0	19.0
Conventional corn silage	20.0	20.0	20.0	0.0	0.0
Enogen corn silage	0.0	0.0	0.0	20.0	20.0
WCGF	30.0	30.0	0.0	30.0	0.0
WDG	0.0	0.0	30.0	0.0	30.0
Long-stem alfalfa hay	12.0	12.0	13.0	12.0	13.0
Chopped prairie hay	12.0	12.0	13.0	12.0	13.0
Supplement	5.0	5.0	5.0	5.0	5.0
Nutrient composition					
DM, % as fed	72.48	55.56	48.55	58.12	50.30
Crude protein	14.38	14.06	16.48	14.01	15.40
Starch	28.15	23.31	19.23	23.16	20.77
Neutral detergent fiber	27.75	31.27	32.49	31.25	32.33
Acid detergent fiber	11.56	15.20	15.86	15.07	15.72
Calcium	0.83	0.75	0.86	0.76	0.83
Phosphorus	0.57	0.50	0.56	0.50	0.53

[1] CON = Conventional corn hybrids, dry rolled. EC = Enogen corn hybrids, dry rolled (Syngenta Seeds, LLC, Downers Grove, IL).
[2] WCGF = wet corn gluten feed (Sweet Bran, Cargill Animal Nutrition, Blair, NE). WDG = wet distillers grain (ICM Biofuels, St. Joseph, MO).
[3] DM = dry matter.
[4] GFE = gastrointestinal tract fill equilibration diet fed from days 64 to 81 to all cattle.

Table 2. Analysis of nutrients in corn silages and corn coproducts fed

	Ingredient[1]			
Item, % of total DM[2]	CS	ES	WCGF	WDG
Nutrient composition				
DM,[2] % as fed	27.2 ± 2.0	31.6 ± 2.6	61.1 ± 2.5	37.5 ± 1.2
Crude protein	9.5 ± 0.9	8.7 ± 0.5	22.4 ± 0.5	28.1 ± 1.0
Starch	23.5 ± 4.2	27.5 ± 3.6	---	---
Acid detergent fiber	21.7 ± 2.3	20.4 ± 1.5	8.5 ± 0.6	9.7 ± 2.1
Neutral detergent fiber	38.4 ± 3.5	36.2 ± 2.1	30.5 ± 1.8	33.1 ± 5.1
Calcium	0.27 ± 0.03	0.23 ± 0.03	0.05 ± 0.02	0.09 ± 0.03
Phosphorus	0.21 ± 0.03	0.19 ± 0.01	1.06 ± 0.07	1.15 ± 0.14

[1] CS = conventional corn hybrid silage. ES = Enogen corn hybrid silage (Syngenta Seeds, LLC., Downers Grove, IL). WCGF = wet corn gluten feed (Sweet Bran, Cargill Animal Nutrition, Blair, NE). WDG = wet distillers grain (ICM Biofuels, St. Joseph, MO).
[2]DM = dry matter.

Table 3. Effect of Enogen corn hybrids or conventional corn hybrids in diets containing corn coproducts on growth performance and fecal starch output

	Corn source[1]							
	CON		EC					
	Coproduct[2]					*P*-value[4]		
Item	WCGF	WDG	WCGF	WDG	SE[3]	S	CP	S × CP
Number of pens	8	8	8	8				
Number of animals	96	96	96	96				
BW,[5] lb								
Day 0	549.0	551.4	548.7	546.7	1.94	0.21	0.95	0.26
Day 81, after GFE[6]	798.1	815.0	806.2	813.9	5.71	0.49	0.03	0.48
ADG,[7] lb/d	3.06	3.26	3.17	3.31	0.07	0.25	0.03	0.72
DM intake, lb/d	20.02	20.11	20.26	20.53	0.31	0.30	0.55	0.78
Gain to feed ratio, lb/lb	0.154	0.162	0.157	0.161	0.01	0.78	0.12	0.68
NE_m, Mcal/lb DM[8]	0.71	0.73	0.72	0.73	0.01	0.96	0.16	0.54
NE_g, Mcal/lb DM[8]	0.44	0.46	0.44	0.45	0.01	0.86	0.17	0.49
Fecal starch, % of total DM	15.2	17.1	13.5	11.4	1.35	0.02	0.91	0.15

[1] CON = Conventional corn hybrids, dry rolled. EC = Enogen corn hybrids, dry rolled (Syngenta Seeds, LLC, Downers Grove, IL). The diets were formulated to contain 51 megacalories of net energy for gain per 100 lb of dry matter daily.
[2] WCGF = wet corn gluten feed (Sweet Bran, Cargill Animal Nutrition, Blair, NE). WDG = wet distillers grain (ICM Biofuels, St. Joseph, MO).
[3] Standard error.
[4] S = corn source. CP = coproduct.
[5] BW = body weight.
[6] GFE = Gastrointestinal tract fill equilibration period. GFE diet was limit-fed at 2.2% of day 64 body weight daily on a dry matter basis from days 64 to 81.
[7] ADG = average daily gain.
[8] NE_m = megacalories (Mcal) of net energy for maintenance per lb of DM. NE_g = Mcal of net energy for gain per lb of DM. Net energy calculations of day 0 to 81 from (Galyean, 2021) based on NRC (1996) requirements.

Syngenta Enogen Corn Fed as Corn Grain and Corn Silage in Diets Containing Corn Coproducts Did Not Enhance Diet Digestibility in Growing Heifers

M.A. Scilacci, M.A. Johnson, E.C. Titgemeyer, S.P. Montgomery,[1] A.J. Tarpoff, E.D. Watson,[2] W.R. Hollenbeck, and D.A. Blasi

Abstract

Eight ruminally cannulated crossbred heifers [initial body weight (BW) = 816 ± 94 lb] were used in an intake and digestibility study designed as a replicated 4 × 4 Latin square. The objective was to evaluate the effect of feeding corn grain and corn silage from Enogen corn hybrids (EC; Syngenta Seeds, LLC., Downers Grove, IL) or conventional corn hybrids (CON) in diets containing either wet distillers grain (WDG; ICM Biofuels, St. Joseph, MO) or Sweet Bran [proprietary wet corn gluten feed (WCGF); Cargill Animal Nutrition, Blair, NE]. Four consecutive, 15-day periods consisted of 10 days for diet adaptation, 4 days of fecal sampling, and 1 day of ruminal sampling. Experimental unit was animal within period. Corn source × coproduct interactions were not observed ($P > 0.16$) in this study. A main effect ($P < 0.05$) of coproduct occurred for molar percentage of isobutyrate, and there was a tendency ($P < 0.07$) for greater digestibility of starch in EC diets than CON diets, but neither dry matter nor fiber digestibility were affected ($P > 0.34$) by corn source or coproduct. There were coproduct × hour interactions detected for concentration of ruminal ammonia ($P < 0.01$) and two branched chain fatty acids, isobutyrate ($P < 0.01$) and isovalerate ($P < 0.01$). Although diets containing EC hybrids tended to have better starch digestibility, Enogen corn hybrids fed as dry rolled corn and corn silage in diets containing corn coproducts did not result in better diet digestibility compared to conventional corn hybrids.

Introduction

Recent research conducted at the Kansas State University Beef Stocker Unit suggested dietary dry matter (DM) digestibility was better for diets containing Enogen corn hybrids compared to conventional corn hybrids. Growing cattle eating Enogen corn as dry rolled or whole shelled corn had lower fecal starch concentrations than cattle fed similarly processed conventional corn hybrids. Corn coproducts are widely used in the cattle feeding industry, but the impacts to nutrient intake and digestion by feeding Enogen corn hybrids as dry rolled corn and corn silage in diets containing corn coproducts to growing cattle have not been determined.

Experimental Procedures

Eight ruminally cannulated crossbred Angus heifers [initial body weight (BW) = 816 ± 94 lb] were used in a replicated 4 × 4 Latin square design with four consecutive 15-day periods. Experimental unit was animal within period. Heifers were housed in

[1] Corn Belt Livestock Services, Papillion, NE.
[2] Syngenta Crop Protection, Greensboro, NC.

8 soil-surfaced 20 × 40 ft pens in a large outdoor holding facility. Each heifer had access to a manually filled water tank, and cattle were fed once daily at 10:00 a.m. Heifers were fed (Table 1) corn grain and corn silage from Enogen corn hybrids (EC; Syngenta Seeds, LLC., Downers Grove, IL) or conventional corn hybrids (CON) in diets containing either wet distillers grain (WDG; ICM Biofuels, St. Joseph, MO) or Sweet Bran [proprietary wet corn gluten feed (WCGF); Cargill Animal Nutrition, Blair, NE]. Each 15-day period included 10 days for diet adaption, 4 days for fecal sampling, and 1 day for ruminal sampling. Feed refusals were collected each morning and weighed using a portable scale (model iGB; Ishida, Kyoto, Japan). Additionally, feed refusals were targeted at 4 lb/day during diet adaptation and sampling to ensure *ad libitum* consumption of diets. On days 4 to 14, chromic oxide (Cr_2O_3) as an external digestion marker was top dressed and hand mixed into each daily ration to allow calculation of apparent total-tract diet digestibility. Feed samples were collected, and fecal samples were collected from the rectum of each animal on days 11 to 14 at 8-hour intervals after feeding. Fecal sampling time advanced by 2 hours each day, thus, 2-hour intervals were represented for 24 hours after feeding. Following collection, feed and fecal samples were frozen at -4°F. Following study completion, feed and fecal samples were thawed, subsampled, and composited by animal within period, then refrozen and taken to a commercial laboratory for nutrient analysis (SDK Laboratories, Hutchinson, KS).

On day 15 of each period, four locations in the rumen were sampled prior to feeding, and at 2, 4, 6, 8, 12, 18, and 24 hours after feeding to determine ruminal volatile fatty acid profile and ammonia concentration. The pH of each sample was measured using a calibrated pH meter (Pinpoint; American Marine Inc., Ridgefield, CT). Approximately 100 cc of ruminal contents were strained through 8 layers of cheesecloth. One cc of strained ruminal fluid was transferred into each of four 2-cc microcentrifuge tubes containing 250 µL of 25 % (wt/vol) *m*-phosphoric acid. Following collection of 0-hour samples, cobalt-ethylenediamine tetraacetic acid (Co-EDTA) dissolved into 200 cc of distilled water was immediately dosed through the ruminal cannula. At 2, 4, 6, 8, 12, 18, and 24-hour sampling times, 15 cc of ruminal fluid was transferred into 20-cc scintillation vials for use in measuring concentration of cobalt and calculating liquid passage rate and ruminal liquid volume. Immediately after collection, all ruminal fluid samples were frozen at -4°F pending analysis.

Results and Discussion

Experimental diet composition and nutrient analysis are presented in Table 1. Intake and nutrient digestibilities are presented in Table 2. No significant ($P \leq 0.16$) corn source × coproduct interactions were observed in this study, thus only main effects are discussed. No main effect differences ($P \geq 0.21$) between corn sources were observed for DM intake, fiber intake, or starch intake. The EC heifers tended to have greater ($P = 0.07$) starch digestibility than those fed CON. No other detectable differences ($P > 0.34$) in DM or fiber digestibilities were observed between corn sources. Differences between corn sources were also not detected for ruminal pH, ammonia concentration, total volatile fatty acid concentration, liquid passage rate, and ruminal liquid volume. Heifers fed CON had a greater ($P < 0.01$) molar percentage of acetate compared to EC heifers. Conversely, heifers fed EC had a greater molar percentage of butyrate ($P < 0.05$) than those fed CON. Heifers fed EC also tended to have greater molar percentages of propionate and isovalerate ($P < 0.10$) than heifers fed CON.

Heifers consuming WCGF had lower ($P < 0.05$) intake of neutral detergent fiber and acid detergent fiber than those fed WDG, and this was associated with a tendency ($P = 0.07$) for lower DM intake for heifers fed WCGF. No main effects ($P = 0.30$) between coproducts were detected for starch intake. No other detectable differences ($P > 0.29$) in DM, fiber, or starch digestibilities were observed for main effect of coproduct. Main effect differences between coproducts were also not observed for ruminal pH, ammonia concentration, total volatile fatty acid concentration, liquid passage rate, and ruminal liquid volume, but heifers fed WCGF had numerically greater ruminal liquid volume than those fed WDG. Heifers fed WDG had a greater ($P < 0.05$) molar proportion of isobutyrate than heifers fed WCGF, whereas heifers fed WCGF had a greater ($P < 0.01$) molar percentage of valerate than those fed WDG. Heifers fed WDG had a greater ($P < 0.05$) molar percentage of butyrate than those fed WCGF. No main effect between coproducts was observed for molar proportions of acetate ($P < 0.19$), propionate ($P > 0.75$), or isovalerate ($P > 0.35$).

There were no corn source × coproduct × hour interactions for any ruminal parameters, and no corn source × hour interactions were observed ($P > 0.05$). However, there were coproduct × hour interactions for concentration of ruminal ammonia ($P < 0.01$) and two branched chain fatty acids, isobutyrate ($P < 0.01$) and isovalerate ($P < 0.01$). In heifers fed WCGF, isobutyrate and isovalerate concentrations reached a peak at 2 hours after feeding, then declined between 2 and 24 hours after feeding. Heifers fed WDG isobutyrate and isovalerate concentrations were greatest at 0 hours after feeding, then declined between 0 hours through 24 hours after feeding. Concentration of isobutyrate and isovalerate in heifers fed WDG increased above concentrations of isobutyrate and isovalerate in heifers fed WCGF between 12 hours and 24 hours after feeding.

Differences between concentrations of isobutyrate, isovalerate, and ammonia can be explained by differences in protein digestibility of WCGF and WDG. Rumen undegradable protein comprises a greater proportion of crude protein in WDG compared to WCGF or Sweet Bran (National Academies of Science, 2016). Thus, protein in WCGF is more extensively catabolized in the rumen. More degradable protein in WCGF diets can explain a more rapid response in ruminal ammonia production post-feeding, compared to WDG diets.

Implications

Although diets containing Enogen corn hybrids tended to have better starch digestibility, Enogen corn hybrids fed as dry rolled corn and corn silage in diets containing corn coproducts did not result in better diet digestibility compared to conventional corn hybrids. However, diets containing WDG may offer better growth performance (Scilacci et al., 2022) for growing cattle due to more ruminally undegradable protein than diets containing WCGF.

Acknowledgments

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Table 1. Composition and nutrient analysis of study diets

	Corn source[1]			
	CON		EC	
	Coproduct[2]			
Ingredient, % of total DM[3]	WCGF	WDG	WCGF	WDG
Conventional corn hybrids	21.0	19.0	0.0	0.0
Enogen corn hybrids	0.0	0.0	21.0	19.0
Conventional corn silage	20.0	20.0	0.0	0.0
Enogen corn silage	0.0	0.0	20.0	20.0
WCGF	30.0	0.0	30.0	0.0
WDG	0.0	30.0	0.0	30.0
Long-stem alfalfa hay	12.0	13.0	12.0	13.0
Chopped prairie hay	12.0	13.0	12.0	13.0
Supplement[4]	5.0	5.0	5.0	5.0
Nutrient composition				
DM, % as fed	56.45	50.78	52.93	48.24
Crude protein	14.31	15.47	14.28	15.87
Starch	24.93	23.23	25.00	22.88
Neutral detergent fiber	29.31	29.64	30.94	31.88
Acid detergent fiber	14.02	14.32	15.24	15.75
Calcium	0.69	0.73	0.76	0.85
Phosphorus	0.41	0.46	0.39	0.46

[1]CON = Conventional corn hybrids, dry rolled. EC = Enogen corn hybrids, dry rolled (Syngenta Seeds, LLC, Downers Grove, IL).
[2]WCGF = wet corn gluten feed (Sweet Bran, Cargill Animal Nutrition, Blair, NE). WDG = wet distillers grain (ICM Biofuels, St. Joseph, MO).
[3]DM = dry matter.
[4]Supplement pellet (Cargill Animal Nutrition, Minneapolis, MN) was formulated to contain (DM basis) 9.2% crude protein, 1.53% crude fat, 17.0% crude fiber, 7.4% calcium, 0.22% phosphorus, 4.62% salt, 0.50% potassium, 331 mg/kg monensin, and 60.10 mg/kg diflubenzuron.

Table 2. Effect of Enogen corn hybrids or conventional hybrids in diets containing corn coproducts on intake and digestibility

	Corn source[1]							
	CON		EC					
	Coproduct[2]					*P*-value[4]		
Item	WCGF	WDG	WCGF	WDG	SE[3]	S	CP	S × CP
Number of observations	8	8	8	8				
Intake, lb/day								
Dry matter	26.54	27.54	27.09	28.90	1.23	0.21	0.07	0.58
Neutral detergent fiber	8.20	8.80	7.94	8.58	0.42	0.40	0.05	0.90
Acid detergent fiber	4.01	4.34	3.79	4.14	0.20	0.22	0.04	0.95
Starch	6.64	6.35	6.79	6.75	0.35	0.30	0.53	0.66
Ruminal[5]								
pH	6.11	6.10	6.04	6.16	0.07	0.99	0.34	0.28
Ammonia, m*M*	3.48	3.26	3.25	3.33	0.31	0.77	0.80	0.58
Total volatile fatty acid, m*M*	79.83	77.59	78.04	76.88	1.82	0.39	0.25	0.71
Ruminal,[6] molar %								
Acetate	62.77	62.08	61.25	60.81	0.47	< 0.01	0.19	0.76
Propionate	20.66	21.05	21.63	21.50	0.46	0.09	0.75	0.53
Butyrate	12.10	12.56	12.57	13.01	0.31	0.05	0.05	0.96
Valerate	1.81	1.65	1.86	1.69	0.05	0.28	< 0.01	0.95
Isobutyrate	0.86	0.90	0.87	0.93	0.03	0.45	0.04	0.82
Isovalerate	1.79	1.75	1.82	2.06	0.12	0.09	0.35	0.16
Liquid passage rate,[7] %/hour	10.5	10.5	10.8	11.0	0.01	0.44	0.80	0.79
Ruminal liquid volume,[7] gal	17.0	15.3	16.7	15.9	1.20	0.88	0.16	0.61

[1] CON = Conventional corn hybrids, dry-rolled. EC = Enogen corn hybrids, dry-rolled (Syngenta Seeds, LLC., Downers Grove, IL).
[2] WCGF = wet corn gluten feed (Sweet Bran, Cargill Animal Nutrition, Blair, NE). WDG = wet distillers grain (ICM Biofuels, St. Joseph, MO).
[3] Largest standard error of least square mean is reported.
[4] S = Corn source. CP = coproduct.
[5] Average of values collected at 0, 2, 4, 6, 8, 12, 18, and 24 hours after feeding.
[6] Individual volatile fatty acid expressed as a molar percentage of total ruminal volatile fatty acid concentration.
[7] Calculated from samples collected at 0, 2, 4, 6, 8, 12, and 18 hours after dosing of Co-EDTA at time of feeding.

Impacts of a Post-Transport/Pre-Processing Rest Period on the Growth Performance and Serum Metabolites of Cattle Entering a Feedlot

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Abstract

A total of 80 crossbred, high-risk heifers [initial body weight (BW) = 551 ± 9.3 lb] were transported from an Oklahoma City, OK, sale barn to the Kansas State University Beef Cattle Research Center. Upon arrival, heifers were placed into one of four pens in a completely randomized design. Each pen of heifers was then randomly assigned to one of four rest times before processing: 1) immediately upon arrival (0); 2) after a 6-hour rest period (6); 3) after a 24-hour rest period (24); and 4) after a 48-hour period (48). Heifers were weighed individually on days 0, 7, 14, 21, 28, and 35 to calculate average daily gain (ADG). Feed added and refusals were measured daily to determine dry matter intake (DMI). Blood samples were analyzed for infectious bovine rhinotracheitis (IBR) titer and serum chemistry. Processing time did not impact ($P > 0.05$) heifer BW or ADG. Overall, DMI decreased linearly ($P = 0.027$) as rest time increased. The number of days for heifers to reach a targeted DMI of 2.5% BW was linearly increased ($P = 0.023$) as rest time increased. Serum IBR titer for heifers processed at either 0 or 6 hours upon arrival was higher ($P < 0.01$) on day 35 compared to day 0. In summary, rest time prior to processing did not impact receiving calf growth performance; however, a 6-hour rest period upon arrival appeared to be most beneficial to DMI.

Introduction

Stress from transportation and processing is unavoidable in the beef industry; however, management of cattle upon receiving to a feedlot plays an integral role in their health and performance thereafter. Appropriately vaccinating, deworming, and treatment with antibiotics is part of a successful receiving protocol. Additionally, rest time during long transport of cattle has been studied, but data are variable regarding its benefits to animal stress levels and performance upon receiving (Melendez et al., 2021; Cooke et al., 2013; Marti et al., 2017). Delaying processing upon arrival to a feedlot is an area of interest to counteract the stress associated with transport. A general rule of thumb is that cattle should receive one hour of rest for every hour they were transported; however, few studies have evaluated different rest times under controlled conditions. Thus, our objectives were to evaluate the impact a post-transport rest period had on calf growth performance. Additionally, we also aimed to determine any effects on calf blood serum metabolites as indicators of immune function.

Experimental Procedures

A total of 80 crossbred heifers [initial body weight (BW) = 551 ± 9.4 lb] were transported from an Oklahoma City, OK, sale barn to the Kansas State University Beef

Cattle Research Center. Heifers were considered high-risk and originated from a geographic area high in parasites. Upon arrival, heifers were unloaded and placed into one of four receiving pens. Each pen of heifers (n = 20) was then randomly assigned to one of four treatments of varying rest times before processing: 1) immediately upon arrival (0); 2) after a 6-hour rest period (6); 3) after a 24-hour rest period (24); and 4) after a 48-hour period (48). At processing, all heifers were tagged, weighed, and subcutaneously injected with moxidectin and orally dosed with oxfendazole. Heifers were also subcutaneously injected with tulathromycin, a recombinant *Mannheimia haemolytica* leukotoxoid vaccine, and a modified-live virus vaccine containing infectious bovine rhinotracheitis (IBR), bovine viral diarrhea (types 1 and 2), bovine respiratory syncytial virus, and parainfluenza 3. After processing, cattle were returned to their receiving pen until all cattle had been processed at 48-hour after arrival to the facility. Heifers were then placed into individual pens, each containing an automatic waterer and feed bunk to provide *ad libitum* access to feed and water. Heifers were weighed individually on days 0, 7, 14, 21, 28, and 35 to calculate average daily gain (ADG). Feed was individually weighed and delivered to each heifer daily, with refusals collected and weighed daily to determine dry matter intake (DMI). On days 0 and 35, blood samples were collected via the coccygeal vein from each heifer and submitted to the Kansas State University Veterinary Diagnostic Laboratory for analysis of IBR titer and serum chemistries. All data were analyzed as a completely randomized design using the GLIMMIX procedure of SAS (v. 9.4, SAS Inst., Cary, NC) with individual animal as the experimental unit. The statistical model included the random effects of 'barn' and 'location within barn'. For blood metabolite data, the model included the main effects of treatment and sampling day, as well as their interaction. Results were considered significant if $P < 0.05$ and marginally significant if $0.05 < P < 0.10$.

Results and Discussion

Growth performance data are presented in Table 1. Processing time did not impact ($P > 0.05$) heifer ADG. Overall, DMI decreased linearly ($P = 0.027$) as the rest time increased. The number of days for heifers to reach a targeted DMI of 2.5% BW was linearly increased ($P = 0.023$) as time of rest increased. The main effect of rest time impacted ($P = 0.038$) the percentage of heifers that reached a DMI of 2.5% BW by day 14 of the experiment, where 25.0, 60.0, 52.6, and 23.5% of cattle reached this parameter after 0, 6, 24, and 48 hours of rest prior to processing, respectively. While morbidity did not differ between treatments ($P > 0.10$), mortality increased linearly ($P = 0.026$) as the time of rest increased.

Serum metabolite data are presented in Table 2. While a significant processing time × day interaction was observed for nearly all parameters ($P < 0.05$), only a few differences were biologically significant. Serum IBR titer for heifers processed at either 0 or 6 hours upon arrival was significantly higher ($P < 0.01$) on day 35 compared to day 0. This response was expected, as these cattle were vaccinated immediately or shortly after arrival. Interestingly, no difference in IBR titer was observed ($P > 0.05$) between day 0 and day 35 for heifers processed at either 24 or 48 hours upon arrival, indicating that these cattle may have been exposed to virus during transport or the rest period and had time to seroconvert antibodies to the virus before vaccination.

Implications

These results indicate that rest time after arrival and prior to processing may not affect calf growth performance, but there is evidence that a 6-hour rest period could maximize DMI upon arrival to a feedlot. Additional research with greater replication and more industry-standard experimental conditions should be conducted to further evaluate these parameters.

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Table 1. Impact of time of processing on feedlot heifer growth performance, mortality, and morbidity[1]

	Processing time after arrival, hour[2]					*P* =		
Item	**0**	**6**	**24**	**48**	**SEM[3]**	**Treatment**	**Linear**	**Quadratic**
Weight, lb								
Day 0	551	556	542	556	3.70	0.858	0.980	0.473
Day 14	593	595	586	597	3.02	0.949	0.896	0.654
Day 35	664	675	661	668	2.91	0.902	0.992	0.835
ADG,[4] lb/day								
Days 0 to 14	2.9	2.9	3.3	2.9	0.33	0.879	0.750	0.493
Days 14 to 35	3.3	3.7	3.5	3.3	0.33	0.624	0.693	0.509
Days 0 to 35	3.3	3.3	3.3	3.3	0.18	0.678	0.945	0.311
DMI,[5] lb/day								
Days 0 to 14	11.5[ab]	11.9[a]	11.2[ab]	10.8[b]	1.4	0.031	0.012	0.635
Days 14 to 35	19.8	20.7	19.2	18.7	3.1	0.150	0.072	0.937
Days 0 to 35	16.3	17.2	15.4	15.4	2.1	0.057	0.027	0.956
DMI, % of BW[6]								
Days 0 to 14	2.11	2.16	2.09	1.93	0.15	0.091	0.020	0.344
Days 14 to 35	3.37	3.50	3.29	3.15	0.28	0.239	0.075	0.782
Days 0 to 35	2.98	3.10	2.97	2.80	0.22	0.183	0.061	0.426
Gain:feed								
Days 0 to 14	0.25	0.24	0.29	0.26	0.030	0.645	0.507	0.368
Days 14 to 35	0.17	0.18	0.18	0.18	0.015	0.891	0.626	0.936
Days 0 to 35	0.20	0.20	0.21	0.21	0.010	0.703	0.375	0.471
Days to 2.5% BW DMI	18[ab]	15[b]	18[ab]	20[a]	1.3	0.030	0.023	0.393
Prevalence, %								
Mortality	0.0	0.0	0.0	10.5	3.57	0.096	0.026	0.236
Morbidity	0.0	0.0	5.3	0.0	2.60	0.382	0.806	0.113
Cattle to 2.5% BW by day 14	25.0	60.0	52.6	23.5	11.56	0.038	0.354	0.025

[ab]Means within a row that do not share a common superscript differ $P < 0.05$.

[1]A total of 80 mixed-breed, high-risk heifers were used in a 35-day experiment with one heifer per pen and 20 replicates per treatment.

[2]Cattle were processed at either 0, 6, 24, or 48 hours after their arrival to the research facility.

[3]SEM = standard error of the mean.

[4]ADG = average daily gain.

[5]DMI = dry matter intake.

[6]BW = body weight.

Table 2. Impact of processing time after arrival on IBR titer and serum biochemical parameters[1]

	Processing time after arrival, hour[2]					Treatment
Blood parameter	**0**	**6**	**24**	**48**	**SEM**	**× day, *P* =**
IBR titer, 1:X[3]					15.2	0.0006
Day 0	8[b]	1[b]	54[ab]	54[ab]		
Day 35	64[a]	70[a]	47[ab]	31[ab]		
Glucose, mg/dL					7.3	0.0002
Day 0	82[bc]	76[bc]	68[c]	108[a]		
Day 35	83[bc]	85[abc]	83[abc]	96[ab]		
Urea nitrogen, mg/dL					0.9	< 0.0001
Day 0	12[b]	18[a]	16[a]	17[a]		
Day 35	9[b]	10[b]	10[b]	9[b]		
Creatinine, mg/dL					0.10	0.0008
Day 0	1.2[ab]	1.2[ab]	1.2[ab]	1.3[a]		
Day 35	0.9[b]	0.9[b]	1.0[b]	1.1[ab]		
Total protein, g/dL					0.15	< 0.0001
Day 0	7.4[a]	7.4[a]	7.3[ab]	7.3[ab]		
Day 35	6.7[c]	6.7[c]	6.8[bc]	6.8[bc]		
Globulin, g/dL					0.15	< 0.0001
Day 0	4.1[a]	4.1[a]	4.0[ab]	3.9[abc]		
Day 35	3.4[cd]	3.4[d]	3.6[bcd]	3.6[bcd]		
Bicarbonate, mmol/L					1.1	0.0008
Day 0	19[b]	22[ab]	22[ab]	18[b]		
Day 35	22[ab]	23[a]	23[a]	22[ab]		
Anion gap, mmol/L					1.2	< 0.0001
Day 0	29[bc]	27[c]	32[b]	37[a]		
Day 35	30[bc]	29[bc]	30[bc]	30[bc]		
Sodium:potassium ratio					0.7	< 0.0001
Day 0	26[a]	26[a]	23[b]	25[ab]		
Day 35	26[a]	27[a]	26[a]	26[ab]		
Alkaline phosphatase, U/L					17.5	< 0.0001
Day 0	112[c]	120[c]	142[bc]	119[c]		
Day 35	208[a]	204[ab]	199[ab]	201[ab]		
Sorbitol dehydrogenase, U/L					2.18	< 0.0001
Day 0	6.5[b]	10.2[b]	3.6[b]	4.5[b]		
Day 35	20.9[a]	18.7[a]	18.2[a]	19.5[a]		

[a-c]Means within the same row that do not share a common superscript differ, $P < 0.05$.

[1]A total of 80 mixed-breed, high-risk heifers were used in a 35-day experiment with one heifer per pen and 20 replicates per treatment.

[2]Cattle were processed at either 0, 6, 24, or 48 hours after their arrival to the research facility.

[3]Serum samples were analyzed for infectious bovine rhinotracheitis (IBR) titer via serum neutralization antibody test with the means displayed as the ratio of serum:dilutant where no antibodies remained detectable within the sample.

Effect of Holstein and Beef-Dairy Cross Breed Description on the Sale Price of Feeder and Weaned Calf Lots Sold Through Video Auctions

E.D. McCabe, M.E. King, K.E. Fike, and K.G. Odde

Abstract

Objectives were to determine: 1) value of Holstein feeder steer lots compared with steer lots of other breed descriptions, 2) value of beef-dairy cross weaned steer calves compared with Holstein weaned calves or weaned calves of other breed descriptions, and 3) value of beef-dairy cross weaned calves compared with weaned calves of other beef breed descriptions sold through video auctions. Data on 14,075 feeder steer lots sold in 211 auctions from 2010 through 2018; 763 weaned steer calf lots, and 1,125 weaned steer and heifer calf lots sold via seven auctions in 2020 and 2021 were used. Separate multiple regression models using backwards selection to quantify effects of various factors on sale price were developed for feeder cattle, weaned steer, and weaned steer and heifer calf lots. Breed group categories used to assess potential differences in sale price included: English-English crossed, English-Continental crossed, Brahman-influenced, Holstein, and beef-dairy crossed (weaned calves). Breed description of feeder steer, weaned steer calf, and weaned steer and heifer calf lots affected sale price ($P < 0.0001$). Among feeder steer lots, Holsteins sold for the lowest ($P < 0.05$) sale price ($110.56/cwt) compared with all other breed groups. Among weaned steer calves, beef-dairy crossed lots sold for the second lowest ($P < 0.05$) price ($147.62/cwt), though greater than Holsteins. Among weaned steer and heifer calves, beef-dairy crosses sold for less than ($P < 0.05$; $136.39/cwt) all other breed groups. Beef-dairy crosses have improved value prospect compared to Holstein steers in the beef supply chain, potentially contributing to increased use of beef semen in dairy females.

Introduction

Improvements in and greater availability of sex-sorted semen technologies in the beef and dairy industries have been instrumental to the growth in number of beef-dairy cross calves in the beef supply chain today. Some dairy producers use beef semen to mate a portion of their breeding females, creating beef-dairy crosses, in attempt to add value to calves entering the beef supply chain (Scanavez and Mendonça, 2018; Penhorwood, 2019; Berry, 2020).

Bovine semen companies, breed associations, and allied industry stakeholders have and are continuing to work to identify ideal beef bull genetics, management protocols, and marketing strategies to improve efficiency and profitability of beef-dairy cross calf production. As beef-dairy calf production increases, opportunities to measure beef-dairy cross calf value exists. Data available on feeder and weaned calves sold through video auctions enabled evaluation of three distinct but related research questions on dairy feeder steer and beef-dairy cross calf values relative to other breed categories. Questions addressed include: 1) What is the relative value of Holstein feeder steers compared with steers of other breed descriptions? 2) What is the relative value of beef-

dairy cross weaned steer calves compared with Holstein weaned calves or weaned calves of other breed descriptions? and 3) What is the value of beef-dairy cross weaned calves compared with weaned calves of other beef breed descriptions?

Experimental Procedures

Information describing factors about lots of feeder steers and weaned steer and heifer calf lots sold through a livestock video auction service (Superior Livestock Auction, Fort Worth, TX) was obtained from the auction service in an electronic format. Data were collected for lots of feeder steers sold from 2010 through 2018 and for lots of weaned steer and heifer calves in 2020 and 2021. Units of study were a lot of feeder steers, lot of weaned steer calves, and lot of weaned steer and heifer calves.

Data available on the lots varied with each analysis, but included some combination of the following variables:

- Auction year
- Auction date
- Gender of the lot
- Lot size (linear and quadratic)
- Base weight (linear and quadratic)
- Mixed gender lot
- Breed description
- Health protocol administration
- Region of United States lot originated from
- Number of days between auction and forecasted delivery dates
- Slide and weight stop combination
- Weight variation
- Presence of horns
- Implant status
- Freight adjustment status
- Frame score
- Flesh score
- Sale price of lot ($/cwt)
- Whether the lot qualified for one or more of these programs: Bovine Viral Diarrhea Persistently Infected free, Source and Age verified, Beef Quality Assurance, Superior Progressive Genetics, GainSmart, Verified Grassfed, IGS Feeder Profit Calculator, Non-GMO, Black Angus Verified Beef, BeefCare, Top Dollar Angus, AngusLink, Charolais Advantage, Balancer Edge, VitaFerm Raised, Non-Hormone Treated Cattle program, Global Animal Partnership GAP 1 or 4 program, or Certified Natural program

Separate multiple-regression models for each analysis to address each of the three posed research questions were developed using a backwards selection procedure to quantify effects of independent factors on the sale price of beef calves. Where appropriate,

models were adjusted for the random effect of auction date nested within auction year. The multiple regression models included 16, 22, and 21 variables potentially affecting sale price, respectively, in analysis of relative value of Holstein feeder steers, beef-dairy cross, and Holstein weaned steer calf value, and beef-dairy cross weaned calf (steers and heifers) value research questions. The variable of interest in addressing these research questions was breed description of the lot.

Only lots of feeder steers were included in analyses comparing value of Holsteins to feeder steers of other breed descriptions. By nature of structure of the dairy industry, few, if any Holstein feeder heifer lots are sold via this video auction platform. Additionally, it has only been in recent years that weaned calves marketed via this video auction have been described as "beef-dairy cross" within the lot descriptions for sale, and beef-dairy cross calves of both genders were available for sale. Therefore, those comparisons were made in data available from 2020 and 2021 sales that weren't available in earlier years.

Results and Discussion

In addressing the question, "What is the relative value of beef-dairy cross weaned steer calves compared with either Holstein weaned calves or weaned calves of other breed descriptions?", data were analyzed from 763 lots of weaned steer calves sold via seven video auctions through Superior Livestock Auction in 2020 and 2021. Mean weight and number of steer calves in the lots analyzed were 614.9 ± 130.3 lb body weight (BW) and 124.7 ± 75.4 head, respectively. Of the 22 fixed effects, nine were considered significant and included in the final model for lots of weaned steer calves. Breed description of the lot affected ($P < 0.05$) calf sale price, with English-English cross weaned steer calves having sold for the greatest sale price at $165.18/cwt, while Holstein weaned steer calves sold for the lowest sale price at $113.04/cwt (Table 1). Beef-dairy cross weaned steer calf lots sold for $34.58/cwt more ($P < 0.05$) than Holstein weaned steer calves.

In addressing the question, "What is the value of beef-dairy cross weaned calves compared with weaned calves of other beef breed descriptions?" data were analyzed from 1,125 lots of weaned steer and heifer calves sold via seven video auctions through Superior Livestock Auction 2020 and 2021. Mean weight and number of steer and heifer calves in lots analyzed were 618.4 ± 98.8 lb BW and 123.4 ± 75.4 head, respectively. Of the 21 fixed effects, 11 were considered significant and included in the final model for lots of weaned steer and heifer calves. Again, breed description of the lot affected ($P < 0.05$) weaned steer and calf sale price, with Brahman-influenced, English-Continental cross, and English-English cross lots selling for more ($P < 0.05$) than beef-dairy cross weaned steer and heifer calves (Table 2).

To address the question, "What is the relative value of Holstein feeder steers compared with steers of other breed descriptions?", data were analyzed from 14,075 lots of feeder steers sold via 211 video auctions through Superior Livestock Auction from 2010 through 2018. Mean weight and number of steers in lots analyzed were 800.7 ± 111.6 lb BW and 121.1 ± 110.3 head, respectively. Of the 16 fixed effects, 15 were significant and included in the final model for lots of feeder steers sold from 2010 through 2018, as only the presence of horns did not affect sale price ($P = 0.43$). To determine potential change in relative value of Holstein feeder steer lots from

2010 through 2018, data were analyzed in three-year increments. A separate analysis was performed for each three-year increment (Table 3). In all three-year increments, Holstein feeder lots sold for the lowest ($P < 0.05$) sale price compared to the other breed descriptions of beef feeder steer lots. The mean discount of Holstein feeder steer lots relative to other breed descriptions was $33.19/cwt in 2010 through 2012, $42.96/cwt in 2013 through 2015, and was the greatest in 2016 through 2018 at a mean discount of $46.24/cwt. The greater relative percentage discount in sale price of Holstein feeder steers as compared with beef breed categories from 2016 to 2018 (33.2% discount) compared with earlier years (26.9% and 24.3% discount in 2010 to 2012 and 2013 to 2015, respectively) was likely partially in response to key events in the beef value chain. In December 2016, a major packer announced a decision to no longer harvest Holstein steers. It has been well documented that Holstein feeder cattle are less feed efficient and have a lower dressing percentage than beef feeder cattle. Perhaps, though, in this time of growth of beef-on-dairy production there is also opportunity for segments of the beef value chain to capitalize on what some may deem as a more consistent and predictable Holstein feeder steer while knowledge gaps about growth performance and carcass quality and consistency of beef-dairy cross cattle are being filled.

Implications

Holstein and beef-dairy cross calves are discounted relative to other beef breed descriptions, though industry stakeholders are continuing to gain insight about performance characteristics of beef-dairy cross animals through all segments of modern beef production. This study, however, also found that lots of beef-dairy cross feeder steers not only had greater value than lots of Holstein steers, but were much closer in value to the traditional beef breed descriptions, likely further driving use of beef semen in dairy females.

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Table 1. Effect of breed description on the sale price of weaned steer calf lots sold through seven Superior Livestock Auction video sales in 2020 and 2021

Breed description	Number of lots	Least squares mean of sale price, $/cwt	Regression coefficient
English-English cross	270	165.18[a]	52.14
English-Continental cross	197	160.38[b]	47.34
Brahman influenced	111	155.54[c]	42.50
Beef-dairy cross	94	147.62[d]	34.58
Holstein	91	113.04[e]	0.00

[a-e]Means within a factor without a common superscript differ ($P < 0.05$).

Table 2. Effect of breed description on the sale price of weaned steer and heifer calf lots sold through seven Superior Livestock Auction video sales in 2020 and 2021

Breed description	Number of lots	Least squares mean of sale price, $/cwt	Regression coefficient
English-English cross	441	155.15[a]	18.79
English-Continental cross	321	151.09[b]	14.70
Brahman influenced	181	146.20[c]	9.81
Beef-dairy cross	182	139.39[d]	0.00

[a-d]Means within a factor without a common superscript differ ($P < 0.05$).

Table 3. Sale price of Holstein feeder steer lots relative to other breed descriptions sold through 211 Superior Livestock Auction video sales from 2010 through 2018

Breed description	Number of lots	Least squares mean of sale price, $/cwt	Regression coefficient
2010 to 2018			
English-English cross	3,829	152.39[a]	41.83
English-Continental cross	4,310	150.61[b]	40.05
Brahman influenced	4,945	148.75[c]	38.19
Holstein	991	110.56[d]	0.00
2010 to 2012			
English-English cross	1,252	128.10[a]	34.47
English-Continental cross	1,562	126.81[b]	33.18
Brahman influenced	2,185	125.56[c]	31.93
Holstein	282	93.63[d]	0.00
2013 to 2015			
English-English cross	1,171	182.43[a]	44.82
English-Continental cross	1,485	180.46[b]	42.85
Brahman influenced	1,630	178.83[c]	41.22
Holstein	373	137.61[d]	0.00
2016 to 2018			
English-English cross	1,465	145.62[a]	47.84
English-Continental cross	1,359	144.47[b]	46.69
Brahman influenced	1,283	141.97[c]	44.19
Holstein	360	97.78[d]	0.00

Breed description affected sale price ($P < 0.0001$).

[a-d]Prices without a common superscript differ ($P < 0.05$) within years.

Within each analysis (2010 to 2018, 2010 to 2012, 2013 to 2015, and 2016 to 2018), each multiple regression model was adjusted for the random effect of auction date nested within auction year.

Challenges Associated with Semen Quality While Collecting Beef Bulls for Semen Freezing

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Abstract

The objective of this study was to evaluate the frequency of failure to freeze semen due to semen quality. Semen collection data from 2008 to 2018 were obtained from Kansas Artificial Breeding Services Unit. A single technician was responsible for all semen analysis. Ejaculates were required to meet quality standards for both progressive motility and morphology. Of the ejaculates collected, 21% met all requirements for freezing semen. Over the ten years, 11% of all ejaculates collected did not have a high enough motility to be considered satisfactory for a breeding soundness exam (BSE), and 63% of all ejaculates did not reach the motility threshold for freezing. Bulls ≤ 12 months of age produced ejaculates not satisfactory for a BSE 15% of the time. Bulls 13–18 months of age produced ejaculates unsatisfactory for progressive motility for a BSE 6% of the time. Ejaculates from bulls 13–18 months of age had a 58% failure rate while ejaculates from bulls ≥ 31 months of age failed 67% of the time with ejaculates from bulls ≤ 12 months of age or 19–30 months falling in between. When evaluating primary sperm abnormalities, 87% of ejaculates had less than 20% primary sperm abnormalities. Ejaculates from bulls ≤ 12 months failed to pass due to primary abnormalities 24% of the time, while ejaculates from bulls ≥ 31 months produced the least amount of primaries at 10%. When evaluating total sperm abnormalities per ejaculate, 77% of ejaculates met the threshold of less than 30% total abnormalities. Ejaculates from bulls ≤ 12 months of age failed to meet the total sperm abnormality threshold 28% of the time. These results highlight one of the main difficulties of collecting freezing-quality semen, in which semen meets the standards of normal spermatozoa but where most samples do not meet needs for progressive motility.

Introduction

Bull breeding soundness exams (BSE) are typically performed on yearling bulls and annually on herd bulls. Many producers have come to expect an industry average BSE failure rate of 20% in yearling bulls (Bagley and Burrell, 1997). What has not yet been well documented are the reasons and expectations as to why bulls in a collection facility do not produce semen to meet freezing standards. While most bulls in a collection facility may pass a BSE, this does not mean their semen will meet the more stringent qualifications for freezing semen. To better understand why bulls fail to produce better quality semen, the objective of this study was to evaluate the frequency of failure to freeze semen due to semen quality.

Experimental Procedures

Data were provided from Kansas Artificial Breeding Services Unit, and bulls were collected from January 2008 to December 2018. A total of 14,750 ejaculates from

[1] Kansas Artificial Breeding Service Unit, Manhattan, KS.

906 bulls were provided for analysis. Bull birth dates were provided, and bull age was calculated as months of age from birthdates supplied until the collection date of each ejaculate. Once bull age was determined, bulls were assigned to one of four age groups: ≤ 12 months, 13–18 months, 19–30 months, and > 60 months. Bulls were collected twice weekly on Mondays and Thursdays, with the preferred collection method, artificial vagina. Bulls at this facility, not receptive to the mount steers or the artificial vagina after 3 or 4 attempts, were subject to electro-ejaculation to ensure ejaculates were collected.

Once an ejaculate was collected, a single technician at Kansas Artificial Breeding Services Unit was responsible for all pre-freeze and post-thaw semen analysis. Ejaculates were required to meet quality standards which included pre-freeze progressive motility of equal to or greater than 50%. The ejaculates could not contain greater than 30% abnormal spermatozoa and must have had a progressive motility of at least 30% post-thaw to pass freezing quality standards. All ejaculates that passed the initial assessment were extended and frozen in half cubic centimeter straws. The descriptive information provided for each ejaculate was progressive motility prior to freezing, progressive motility post-freezing, and primary and secondary sperm abnormalities.

Although these samples were collected to freeze semen, for this project, we set secondary quality standards based on the bull BSEs from the Society of Theriogenology (Society of Theriogenology, 2018). The threshold to be considered a satisfactory breeder for progressive motility is 30% or greater, and with sperm abnormalities of less than 30% total morphological abnormal sperm, with less than 20% of those being head defects (Society of Theriogenology, 2018).

Collection characteristics were evaluated using multiple frequency models in Statistical Analysis System. The frequency models were utilized to assess the overall distribution of ejaculates' likeliness to pass a BSE and be acceptable for freezing semen. Age groups within each semen characteristic were then analyzed for their likeliness to meet these quality thresholds.

Results and Discussion

Over the ten years, 21% of all ejaculates collected met the freezing quality standards of 50% progressive motility pre-freeze, 30% progressive motility post-freezing, and the sperm morphology requirements of less than 30% abnormal spermatozoa, with less than 20% of those being from primary sperm abnormalities (Figure 1). When evaluating ejaculates for progressive motility, 11% of all ejaculates collected did not have a high enough progressive motility (≥ 30%) to be considered satisfactory for a BSE, and 63% of all ejaculates did not reach the initial progressive motility threshold for freezing (≥ 50%). Of ejaculates collected from bulls ≤ 12 months of age, 15% did not meet minimum progressive motility requirements of a BSE, which is 30% (Figure 2). Bulls 13–18 months of age produced unsatisfactory ejaculates for progressive motility for a BSE 6% of the time, and ejaculates from bulls 19–30 months of age did not meet the standard 10% of the time. Ejaculates collected from bulls ≥ 31 months of age failed to meet BSE progressive motility standards 14% of the time. When evaluating ejaculates' likeliness to be acceptable for freezing semen, the percentage of ejaculates that met the quality stands was much lower. Ejaculates collected from bulls ≤ 12 months of age failed to meet freezing quality progressive motility 64% of the time, while ejaculates from

bulls 13–18 months old failed 58% of the time, and ejaculates from 19- to 30-month old bulls failed 61% of the time. Ejaculates from bulls ≥ 31 months of age did not meet the progressive motility threshold 67% of the time. Failure of bulls to produce freezing-quality semen may be explained by several factors. It has been previously reported that as bulls age, they experience a reproductive decline in motility (Barth and Walder, 2002; Snoj et al., 2013). These results suggest that when collecting bulls ≤ 12 months and ≥ 31 months of age, progressive motility may be a challenge in collecting freeze quality semen.

For bulls whose ejaculates were of freezing quality for both pre-freeze and post-freeze progressive motility, those samples were evaluated for percentage of abnormal spermatozoa. When evaluating ejaculates for primary sperm abnormalities, 87% had less than 20% primary sperm abnormalities, which would be considered satisfactory for a BSE and for freezing semen (Figure 3). Unlike the results for motility as bulls aged, the percentage of primary abnormalities in the ejaculates decreased, suggesting an increase in ejaculate quality. Ejaculates from bulls ≤ 12 months of age had the greatest number of primary abnormalities with 24%, while ejaculates from bulls ≥ 31 months of age had the least percentage of primary abnormalities with 10%.

When evaluating total sperm abnormalities per ejaculate, 77% of ejaculates met the threshold of less than 30% total abnormalities (Figure 3). Ejaculates from bulls ≤ 12 months of age failed to meet the total sperm abnormality threshold 28% of the time. Ejaculates from bulls 13–18 and 19–30 months of age failed to meet the total abnormality threshold 25% of the time, and ejaculates from bulls ≥ 31 months of age only failed to meet the standard 20% of the time. The percentage of ejaculates failing to meet abnormality thresholds was comparable to research findings from others (Bruner et al., 1995). These results highlight one of the main difficulties of collecting freezing quality semen, in which semen meets the standards of normal spermatozoa but where most samples do not meet needs for progressive motility.

Implications

Of over 14,000 collections, only 21% met all requirements for freezing semen, approximately 63% did not meet progressive motility freezing standards, and 11% did not meet the satisfactory level of a BSE.

Acknowledgments

We appreciate the Kansas Artificial Breeding Services Unit's crew and customers for providing their data and insight to make this project possible.

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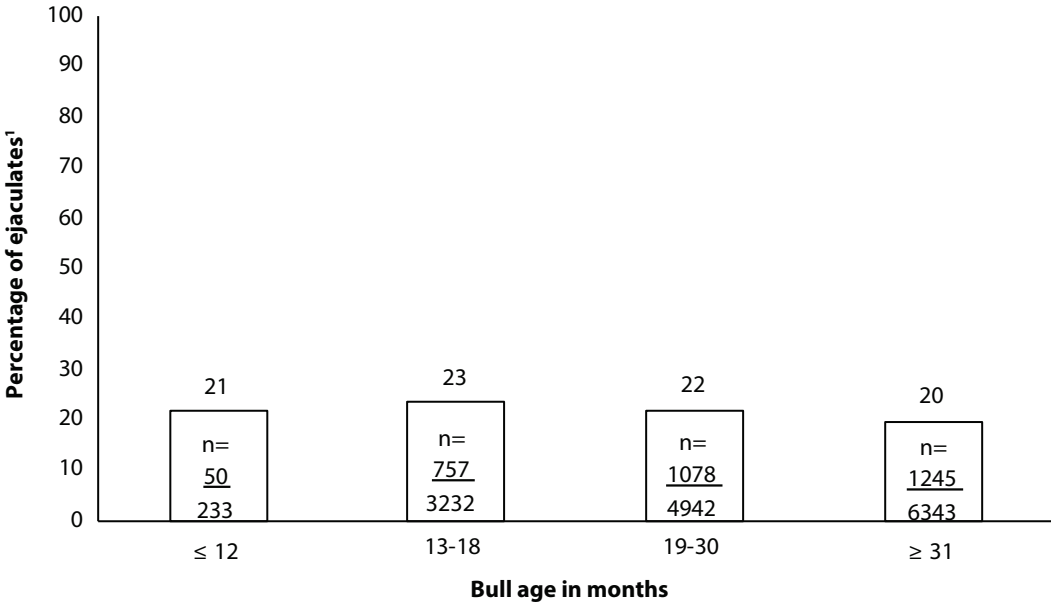

Figure 1. Percentage of all ejaculates meeting motility and morphology requirements for freezing. All ejaculates meeting freezing requirements were required to meet a pre-freeze progressive motility of 50%, a post-thaw progressive motility of 30%, have less than 20% primary sperm abnormalities, and less than 30% total sperm abnormalities. [1]Percentage of ejaculates is based on total ejaculates collected per age group divided by total of ejaculates passing the freezing quality standards.

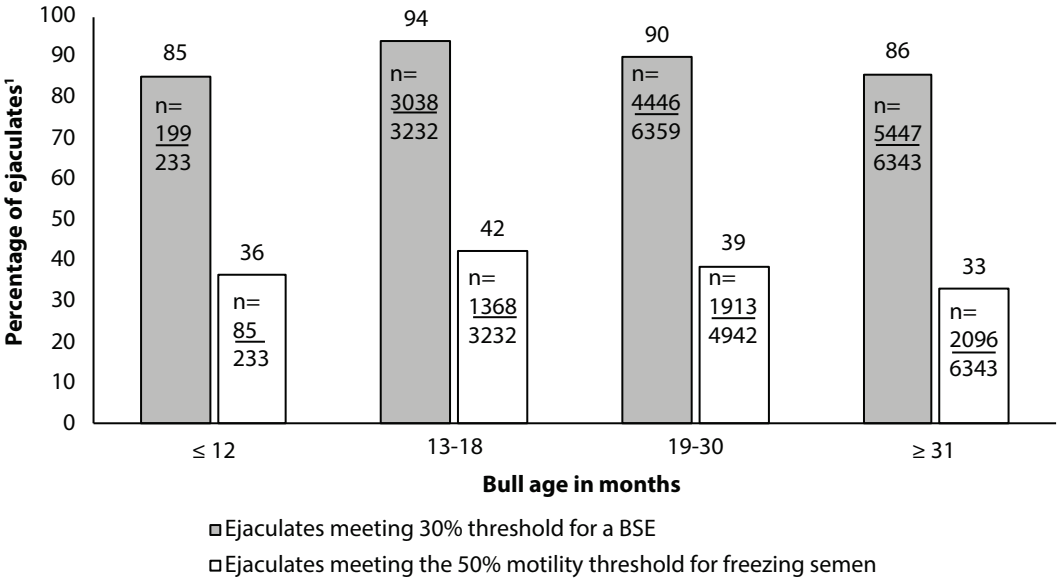

Figure 2. Percentage of ejaculates considered satisfactory for progressive motility during a breeding soundness exam or when freezing semen. Progressive motility must meet a minimum of 30% to be considered satisfactory for a BSE, and 50% to meet the standards for semen pre-freeze quality. [1]Percentage of ejaculates is based on total ejaculates collected per age group divided by total of ejaculates meeting the specific progressive motility requirements.

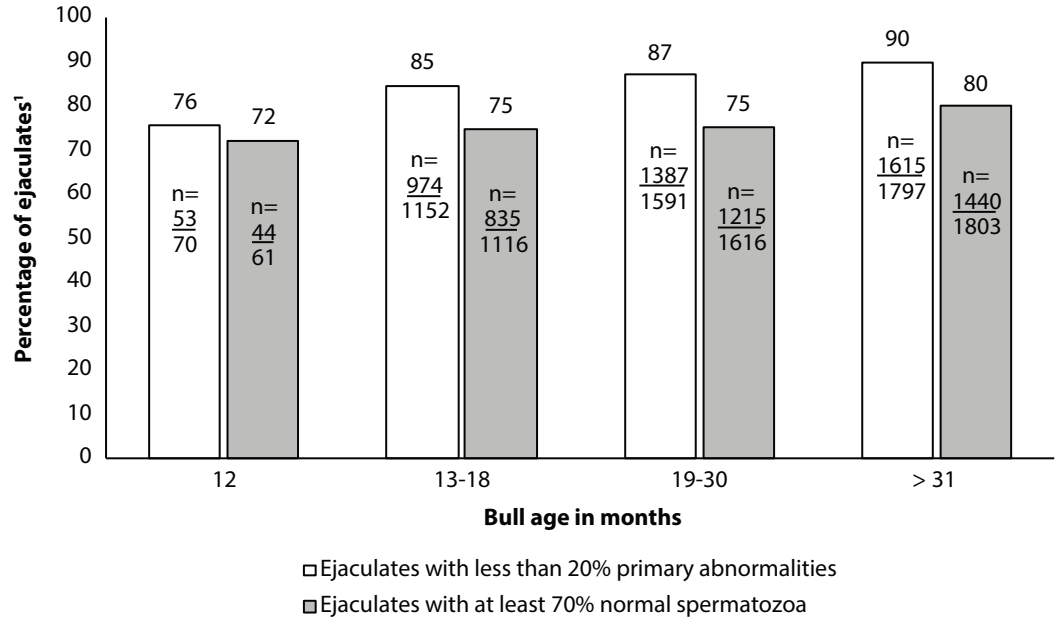

Figure 3. Percentage of ejaculates meeting primary and total abnormal spermatozoa requirements after ejaculates have previously met freezing progressive motility standards. All ejaculates in the analysis had met both the pre-freeze progressive motility standard of 50%, and the post-thaw progressive motility standard of 30%. [1]Percentage of ejaculates is based on total ejaculates that passed pre-freeze and post-thaw standards collected per age group divided by total of ejaculates meeting the specific sperm abnormality requirements.

Field Trial Assessing the Use of Sex-Sorted Semen in Beef Cattle

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Abstract

Sex-sorted semen utilization holds the potential to create a high percentage of either bull or heifer calves, but often comes with a reduction in fertility. The objective of this study was to evaluate the reproductive performance of sex-sorted semen (both X- and Y-sorted semen) in commercial beef cows and heifers. For this trial, 320 Angus and SimAngus cows and heifers from four groups were used. The groups were: yearling heifers (Group 1, n = 101); young cows (Group 2, n = 51) bred to an Angus sire sorted for >90% X-bearing sperm; and 168 mature cows (Group 3, n = 80; and Group 4, n = 88) bred to a Charolais sire sorted to contain >90% Y-bearing sperm. Heifers were synchronized using melengestrol acetate plus prostaglandin $F_{2\alpha}$ (MGA-$PGF_{2\alpha}$) and were bred based on visual estrus detection. The three cow groups were synchronized using the 7-Day CO-Synch plus CIDR protocol. Group 2 young cows and Group 3 mature cows were inseminated using a split-time artificial insemination (STAI) approach, while Group 4 mature cows were inseminated using a fixed-time AI (FTAI) approach. The estrus responses were: 95.1% (Group 1), 88.2% (Group 2), 75.0% (Group 3), and 69.3% (Group 4). The AI pregnancy rates were: 63.4% (Group 1), 47.1% (Group 2), 46.3% (Group 3), and 40.2% (Group 4). The Group 1 heifers had a high estrus response and AI pregnancy rate likely due to the inherent fertility of heifers and intensive estrus detection used. The AI pregnancy rates for the Group 2 young cows and Group 3 mature cows were similar to what is seen in the literature. Group 4 mature cows' decreased estrus response and AI pregnancy rate were lower than reported in other studies. Finally, the Charolais sired calves averaged around 100 lb heavier than their Angus sired counterparts. These results show the commercial potential of using "bull" sex-sorted semen in terminal sire programs.

Introduction

Sex-sorted semen utilization holds the potential to create a high percentage of either bull or heifer calves. Most of the research to date has investigated success rates utilizing "heifer" semen. The objective of this study was to evaluate the success of "bull" and "heifer" sex-sorted semen in a commercial cattle operation.

Experimental Procedures

This trial was conducted on the Odde Ranch in North Central South Dakota from the summer of 2019 through fall 2020. There was a total of 320 Angus and SimAngus cows and heifers from four separate groups utilized in this trial (Table 1). The groups were: yearling heifers housed in a dry lot system (Group 1, n = 101); young cows (nursing calves) on pasture (Group 2, n = 51); cows (nursing calves) on pasture (Group 3, n = 80); and cows (nursing calves) on pasture (Group 4, n = 88).

[1] Odde Ranch, Pollock, SD.

[2] Department of Animal Sciences; College of Agriculture, Food and Environmental Sciences; University of Wisconsin-River Falls; River Falls, WI.

The yearling heifers and young cows were inseminated to a commercially available Angus sire (Sire A) sorted to contain >90% X-chromosome bearing sperm cells. The mature cows were inseminated to a commercially available Charolais sire (Sire B) sorted to contain >90% Y-chromosome bearing sperm cells. All semen was packaged at a concentration of 4×10^6 sperm cells per 0.25 mL dose.

The Group 1 yearling heifers were estrus synchronized using the melengestrol acetate plus prostaglandin $F_{2\alpha}$ (MGA-$PGF_{2\alpha}$) protocol. Heifers were fed MGA for 14 days at a concentration of 0.5 mg/head/day. After feeding MGA for 14 days, MGA was removed from the ration for 19 days. On day 19 after the final day of MGA feeding, heifers received a 5 mL injection of $PGF_{2\alpha}$ (Lutalyse; Zoetis, Madison, NJ). Estrus was synchronized in Groups 2, 3, and 4 using the 7-day CO-Synch plus CIDR protocol. Cows received a progesterone insert (CIDR; Zoetis, Madison, NJ) along with a 2 mL injection of a gonadotropin-releasing hormone (GnRH) analog (Gonadorelin; Cystorelin; Merial, Athens, GA) at the start of the protocol. After seven days, CIDRs were removed and cows received a 5 mL injection of prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$; Lutalyse; Zoetis, Madison, NJ). Estrus detection aids (Estrotect, Rockway Inc., Spring Valley, WI) were applied at time of $PGF_{2\alpha}$ injection at all locations. Estrus was defined as >50% of the patch coating removed. Group 1 heifers were also visually observed for signs of estrus every four hours for five days following injection of $PGF_{2\alpha}$.

Group 1 heifers were inseminated at 15 to 21 hours after the onset of estrus. The Group 2 young cow group was inseminated using a split-time artificial insemination (AI) system with those showing estrus by 70 hours post $PGF_{2\alpha}$ inseminated at 70 hours. Those with inactive patches were injected with GnRH and were inseminated at 94 hours post $PGF_{2\alpha}$. Group 3 cows with active patches were inseminated at 70 hours post $PGF_{2\alpha}$. Those with inactive patches were administered GnRH and inseminated at 82 hours post $PGF_{2\alpha}$. Group 4 cows were inseminated at 70 hours post $PGF_{2\alpha}$ with cows with inactivated patches getting an injection of GnRH. Females were exposed to bulls approximately 5–7 days after AI for the remainder of the breeding season.

Pregnancy diagnosis was conducted approximately 65–90 days post insemination via transrectal ultrasonography (ReproScan XTC equipped with a 4.0 MHz 60 mm convex rectal probe; ReproScan, Winterset, IA). Fetal size was used to differentiate AI pregnancies from natural service pregnancies. Gender was determined at birth. Gender accuracy to sex-sorted semen for each sire was calculated at the end of the calving season for all AI pregnancies. Gender skew, defined as the number of the desired gender divided by the total in the group, was calculated for each group. All calves were weighed prior to weaning in the fall. An adjusted 200-day calf weight was calculated using the fall weight and an average birth weight of 80 lb using the following equations:

Average daily gain (ADG) = [fall weight - standard birth weight (80 lb)]/days of age.
Adjusted 200-day weight = (ADG × 200 days) + standard birth weight (80 lb).

Results and Discussions

The results of this trial are shown in Table 2. Group 1 yearling heifers had an observed estrus response of 95.1% 5-days post $PGF_{2\alpha}$ injection and AI pregnancy rate of 63.4%. The gender accuracy of the AI calves was 94.3% heifers with an overall gender skew of 77.7% for heifer calves. The pregnancy rate observed was acceptable for sex-sorted

semen and higher than what is typically found in the literature (Thomas et al., 2017). This is likely attributed to the intensive heat detection conducted on the heifers and the increased fertility seen with heifers in general.

Group 2 young cows had an estrus response of 88.2% overall with an AI pregnancy rate of 47.1%. The gender accuracy of AI calves was 89.5% heifers with an overall gender skew being 76.1% heifer calves. Group 3 mature cows had an estrus response of 75% and an AI pregnancy rate of 46.3%. The gender accuracy of AI calves was 91.0% bulls resulting in a gender skew of 68.8% bull calves. Group 4 mature cows had an estrus response of 69.3% and an AI pregnancy rate of 40.2%. The gender accuracy of AI calves was 84.8% bulls resulting in a gender skew of 58.7% bull calves.

Results for Groups 2 and 3 are similar to what has been reported in the literature for sexed semen (Andersen et al., 2020; Thomas et al., 2019). Results for Group 4 are lower than some other reported studies, possibly due to the use of fixed-time AI instead of split-time AI.

Adjusted 200-day weights (Table 2) were approximately 100 lb heavier for Groups 3 and 4 compared to Groups 1 and 2. This is likely due to cows in Groups 3 and 4 being older and implanted, that calves in these groups were sired by high growth Charolais bulls, and that these calves have more heterosis (cows were Angus-Simmental).

Implications

These results show that sex-sorted semen has potential on beef cows and heifers. Steer calves are worth more than heifers, and this difference is increasing due to increased carcass weights. "Bull" sex-sorted semen in terminal sire programs appears to have significant commercial potential.

Acknowledgments

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Table 1. Average age, estrus synchronization method, breeding method, and artificial insemination (AI) sire by group

Group	Number	Average age (years)	Estrus synchronization method	Breeding method	AI sire
Group 1 yearling heifers	101	---	MGA-$PGF_{2\alpha}$[1]	Bred by estrus[2]	Angus[6]
Group 2 young cows	51	2.2 ± 0.5	7-day CO-Synch+CIDR	STAI[3]	Angus[6]
Group 3 mature cows	80	6.0 ± 2.2	7-day CO-Synch+CIDR	STAI[4]	Charolais[7]
Group 4 mature cows	88	6.8 ± 2.6	7-day CO-Synch+CIDR	FTAI[5]	Charolais[7]

[1]Melengestrol Acetate plus Prostaglandin $F_{2\alpha}$.
[2]Heifers were inseminated 15 to 21 hours after the observation of estrus.
[3]Split-Time AI - young cows that did not display estrus by 70 hours after $PGF_{2\alpha}$ received an injection of gonadotropin-releasing hormone (GnRH) and inseminated 24 hours later.
[4]Split-Time AI - cows that did not display estrus at 70 hours after $PGF_{2\alpha}$ received an injection of GnRH and were inseminated 12 hours later.
[5]Fixed-Time AI - all cows were inseminated by 70 hours after $PGF_{2\alpha}$, and cows that did not show signs of estrus by 70 hours received an injection of GnRH.
[6]Angus sire semen was sorted to contain >90% X-chromosome bearing sperm cells at a concentration of 4×10^6 per 0.25 mL straw.
[7]Charolais sire semen was sorted to contain >90% Y-chromosome bearing sperm cells at a concentration of 4×10^6 per 0.25 mL straw.

Table 2. Estrus response, artificial insemination (AI) pregnancy rate, breeding season pregnancy rate, gender accuracy, gender skew, and 200-day adjusted calf weight by group

Group	Estrus response (%)	AI pregnancy rate (%)	Breeding season pregnancy rate (%)	Gender accuracy[1] (%)	Gender skew[2]	200-Day adjusted calf weight[3] (lb)
Group 1 yearling heifers	95.1	63.4	87.0	94.3	77.7% Heifers	496.6
Group 2 young cows	88.2[a]	47.1	92.2	89.5	76.1% Heifers	505.6
Group 3 mature cows	75.0[b]	46.3	92.3	91.0	68.8% Bulls	606.5
Group 4 mature cows	69.3	40.2	90.9	84.8	58.7% Bulls	595.6

[1]Gender accuracy is the total number of AI calves of the desired gender divided by the total number of AI calves born.
[2]Gender skew is the total number of calves born of the desired gender divided by the total number of calves born.
[3]Average daily gain (ADG) = [fall weight - standard birth weight (80 lb)]/days of age.
Adjusted 200-day weight = (ADG × 200 days) + standard birth weight (80 lb).
[a]Response rate is the number of cows showing estrus by 70 hours plus those showing estrus by 94 hours.
[b]Response rate is the number of cows showing estrus by 70 hours plus those showing estrus by 82 hours.

Effects of Betaine on Protein Deposition in Growing Cattle with Modulated Methyl Group Status

M.S. Grant, J.M. Marsh, K.J. Hazlewood, M.D. Miesner, and E.C. Titgemeyer

Abstract

Betaine is a molecule that serves as a methyl group source in the body. It is synthesized when choline is oxidized to betaine and can provide three methyl groups to resynthesize methionine in the body. Creatine is an energy storing molecule that is produced when guanidinoacetic acid is methylated in the liver. Supplemental guanidinoacetic acid can improve performance in swine and poultry and may improve protein deposition in cattle when methionine (i.e., methyl group) supply is adequate. Because creatine synthesis consumes methyl groups from methionine, supplementation of other methyl group sources, such as betaine, in combination with guanidinoacetic acid may improve performance. The objective of this study was to evaluate the effects of guanidinoacetic acid and creatine supplementation in the presence or absence of betaine on protein deposition in growing cattle. Seven ruminally cannulated Holstein steers were housed in metabolism crates to allow for total collection of urine and feces to measure nitrogen retention. The experiment was conducted for six 10-day periods, with each animal receiving one of six treatments during each period. The treatments included: a saline solution (control); 15 g/day guanidinoacetic acid (GAA; consumes methyl groups to synthesize creatine); or 16.8 g/day creatine (spares methyl groups that would otherwise be used for its synthesis), each in the presence or absence of 5.6 g/day supplemental betaine. Betaine supplementation improved protein deposition relative to the control. This may demonstrate that betaine was effectively used to remethylate methionine in the body to improve methionine status and performance. Guanidinoacetic acid and creatine supplementation did not affect protein deposition. It appears that supplemental betaine can improve protein deposition in growing cattle.

Introduction

Betaine is a vitamin-like nutrient that is present in some feedstuffs and can be synthesized in the liver and kidney. In ruminants, most betaine available to the animal is produced in the body because dietary betaine is extensively degraded by ruminal microbes. Betaine is produced when the essential nutrient choline is oxidized to form betaine. Choline is synthesized in the liver when phosphatidylethanolamine accepts three methyl groups from methionine, which forms phosphatidylcholine. Choline can then be cleaved from phosphatidyl choline and participate in numerous reactions in the body. Once choline is oxidized to form betaine, it has the potential to donate three methyl groups to resynthesize methionine in the body. If supplemental betaine improves methyl group availability and methionine use in the body, it may have potential to improve lean tissue growth in growing cattle.

Creatine is a molecule that can store energy in muscle tissues. Creatine is present in feedstuffs of animal origin and can be synthesized in the liver when guanidinoacetic

acid accepts a methyl group from methionine to form creatine. Because ruminants consume diets containing little to no animal protein, they rely almost exclusively on creatine produced in the body. Additionally, because creatine synthesis consumes methyl groups, it has potential to create a methionine (i.e., methyl group) deficiency if methionine supply is not adequate. Growing animals have greater creatine requirements than mature animals, so it is possible that body creatine production may not be large enough to support optimal lean tissue growth in young animals. Although creatine can be supplemented directly in the diet, its precursor guanidinoacetic acid has more potential as a feed additive because it has greater stability and is cheaper to synthesize. Recent work in our lab suggested that providing guanidinoacetic acid supplementation to growing cattle may improve protein deposition when methionine supply is adequate.

Supplementation of guanidinoacetic acid or creatine in conjunction with betaine has not been evaluated. The objective of this study was to evaluate the effects of guanidinoacetic acid, creatine, and betaine supplementation on protein deposition in growing cattle consuming a corn-based diet.

Experimental Procedures

Seven ruminally cannulated Holstein steers (417 lb initial body weight) were housed in a temperature-controlled room in metabolism crates to allow for total collection of urine and feces to measure nitrogen retention. Steers were limit-fed a corn-based diet at 12-hour intervals and had *ad libitum* access to water. The diet contained 75.6% dry-rolled corn, 12.7% alfalfa hay, 6.2% soybean meal, 4.2% cane molasses, and 1.4% vitamin and mineral supplement. Each steer was fed 7.7 lb dry matter daily of the diet which was designed to represent a diet fed in a normal production setting.

There were six experimental periods each 10 days in length, which allowed 6 days for adaptation to treatments and 4 days for sample collection. Each animal received one of six different treatments during each period. The six treatments were arranged in a 3 × 2 factorial with the first factor being supplementation of one of three methyl group modulators: saline solution (control); 15 g/day guanidinoacetic acid (GAA; consumes methyl groups to synthesize creatine); or 16.8 g/day creatine (spares methyl groups that would otherwise be used for its synthesis). The second factor was 0 or 5.6 g/day supplemental betaine, which may improve body methyl group status by providing methyl groups to resynthesize methionine. Treatments were infused continuously into the abomasum. Total collection of urine and feces occurred on days 7 through 9 of each period to measure retained nitrogen.

Results and Discussion

No interactions between betaine and methyl group modulator treatment were observed ($P \geq 0.69$; Table 1). Betaine supplementation improved ($P = 0.03$) nitrogen retention by 2.9 g/day, which would correspond to increases in body weight gain of approximately 0.25 lb/day. Urinary and fecal nitrogen excretion were not affected ($P \geq 0.16$) by betaine supplementation. Because nitrogen retention is a measure of protein deposition and animal performance, it appears that post-ruminal betaine supplementation can improve animal performance. Betaine may have improved performance in cattle as a result of increased methionine remethylation in the body. Because betaine is extensively degraded by ruminal microbes, it must be provided in a ruminally protected form in

ruminant diets. In this model, all treatments were infused directly into the abomasum, so ruminal degradation of betaine was precluded.

There were no effects ($P = 0.63$) of methyl group modulator treatments on retained nitrogen. Methyl group modulator tended ($P = 0.08$) to affect urinary nitrogen excretion, with creatine having greater ($P = 0.04$) urinary nitrogen excretion than the control. Additionally, GAA tended ($P = 0.08$) to produce greater urinary nitrogen excretion relative to control, but GAA and creatine were not different ($P = 0.68$) from each other. Fecal nitrogen excretion was affected ($P = 0.01$) by methyl group modulator, with GAA- and creatine-treated steers excreting more ($P \leq 0.02$) fecal nitrogen than control steers, but creatine- and GAA-supplemented steers did not differ ($P = 0.47$) in fecal nitrogen excretion. Previous work in this lab has demonstrated neutral to positive nitrogen retention responses to GAA supplementation and no response to creatine supplementation. It is unclear why GAA and creatine did not improve retained nitrogen in our cattle.

Implications

Supplemental betaine improved nitrogen retention, demonstrating its potential to improve lean muscle growth in growing cattle.

Acknowledgments

The authors thank AlzChem (Trostburg, Germany) for providing the guanidinoacetic acid and creatine used in this experiment.

Table 1. Effects of guanidinoacetic acid (GAA), creatine, and betaine on protein deposition in growing cattle

	Betaine, g/day									
	0			5.6						
	Methyl group modulator							*P*-value		
Item	Control	Creatine	GAA	Control	Creatine	GAA	SEM[1]	Betaine	Methyl	Betaine × methyl
Number of steers	7	6	7	7	7	6				
Nitrogen, g/day										
Feed	68.9	69.0	69.4	69.1	68.9	69.0	---	---	---	---
Infused	0.00	5.37	5.37	0.67	6.04	6.03	---	---	---	---
Intake[2]	68.9	74.4	74.8	69.8	74.9	75.1	---	---	---	---
Urinary	24.1	26.9	25.9	24.0	25.8	26.0	1.15	0.67	0.08[3]	0.84
Fecal	20.8	25.0	27.2	20.0	23.6	23.8	1.85	0.16	0.01[3]	0.69
Retained	24.1	22.6	21.3	25.7	25.7	25.4	1.99	0.03	0.63	0.71

[1]Average standard error of the mean for all treatments.
[2]Feed nitrogen + infused nitrogen.
[3]Pairwise means were separated within the methyl group modulator treatment as: control < GAA = creatine; $P \leq 0.05$.

Effect of Ruminally-Protected Lysine Supplementation to Growing Cattle on Growth and Subsequent Finishing Performance

K.J. Hazlewood, M S. Grant, D.A. Blasi, G.A. Ducharme,[1] and E C. Titgemeyer

Abstract

Corn-based diets are especially poor in providing lysine to cattle, so supplementation of ruminally-protected lysine may improve performance of growing cattle. The objective of this study was to evaluate the effects of supplementing ruminally-protected lysine to growing cattle limit-fed a corn-based diet. A group of 338 steers was allocated among 32 pens and fed at 2.4% of body weight (BW) daily on a dry matter (DM) basis for 77 days. Pens were assigned to one of four treatments: no supplementation (control), 3 g/day metabolizable lysine from Smartamine ML (Lys-3), 6 g/day metabolizable lysine from Smartamine ML (Lys-6), or blood meal at 0.89% of dietary DM plus 2 g/day of metabolizable methionine from Smartamine M (BM). Cattle were weighed by pen on days 0 and 77 to measure performance during the growing phase. Following the growing period, cattle were shipped to a commercial feedlot where they were fed until slaughter. Cattle received no treatments while at the feedlot. Performance during the finishing phase was measured using carcass data gathered from the slaughter facility. Steers supplemented with Lys-3 appeared to have the greatest response during the growing phase, had the heaviest BW on day 77, and greatest average daily gains and gain:feed ratios. In the finishing phase, Lys-3 maintained the weight advantage, relative to control, established during the growing phase. Cattle receiving Lys-6 during the growing phase performed best during the finishing phase. Cattle receiving Lys-3 and Lys-6 during the growing phase had carcasses that were 8 and 16 lb greater, respectively, than control.

Introduction

Lysine is an essential amino acid, meaning it is not synthesized in the body in adequate quantities to support the body's demand and, therefore, must be supplied through the diet. However, some feedstuffs, including corn, do not provide lysine at a sufficient level to meet animal requirements. As a result, lysine may become a limiting amino acid for the animal. Because corn is a primary ingredient in cattle diets, lysine may be deficient and limit growth performance. Supplemental lysine may improve performance in deficient cattle, but because lysine is extensively degraded in the rumen, it is not beneficial to add lysine in an unprotected form to the diet. Commercially available ruminally-protected lysine products (e.g., Smartamine ML) can escape ruminal degradation and allow for absorption of lysine from the small intestine. The objective of this study was to evaluate the effects of ruminally-protected lysine supplementation fed during the growing phase to cattle limit-fed a corn-based diet, and to evaluate the subsequent finishing performance.

[1] Adisseo, Alpharetta, GA.

Experimental Procedures

A 77-day growth trial was conducted using 338 crossbred steers of Arkansas, Missouri, and Nebraska origin (560 lb initial weight) at the Kansas State University Beef Stocker Unit, Manhattan, KS. Cattle were blocked by truck load (4) and stratified by individual arrival body weight to eight pens per block (32 pens total) containing nine to 12 steers each. Steers were implanted with Revalor G (40 mg trenbolone acetate, 8 mg estradiol; Merck Animal Health, Madison, NJ), at initiation of the trial. Within block, pens were allocated to one of four experimental treatments: no supplemental amino acids/protein (control); 3 g/day metabolizable lysine from Smartamine ML (Adisseo, Alpharetta, GA; Lys-3); 6 g/day metabolizable lysine from Smartamine ML (Lys-6); or supplemental blood meal (AAdvantage; Perdue Agribusiness, Kings Mountain, NC; BM) at 0.89% of dietary dry matter (DM) plus 2 g/day metabolizable methionine provided from Smartamine M (BM). The BM treatment was designed to match the supplemental metabolizable lysine of Lys-3 and ensure methionine was not limiting for the BM treatment. Supplemental levels were formulated to provide 3 or 6 g/day metabolizable lysine or 2 g/day metabolizable methionine when cattle consumed a target of 14.33 lb/day DM. Cattle were limit-fed a corn-based diet (Table 1) once daily at 2.4% of body weight (BW) on a DM basis. Therefore, as BW increased during the trial, cattle received 77 to 142% of targeted treatment amounts due to feed intakes being lesser or greater than the target intake.

Throughout the experiment, treatments were incorporated into the ration during feed mixing. Cattle were weighed on the initial day (day 0) and on the final day of the experiment (day 77) to measure growth performance and efficiency of gain. After 77 days, cattle were shipped to a commercial feedlot and mixed into two finishing pens. At the feedlot, cattle did not receive any treatment. One finishing pen was fed for an average of 185 days and the other for 206 days. After the finishing period, cattle were slaughtered at a commercial facility and carcass data were acquired, including hot carcass weight, ribeye area, back fat depth, and quality grades of each carcass. Slaughter weights were calculated using hot carcass weights and the average dressing percentages of the two finishing pens.

Results and Discussion

Statistical analyses were used to determine the linear and quadratic effects of lysine supplementation during growing and finishing phases. Linear responses demonstrate increases (or decreases) in response as the amount of lysine increased. Quadratic responses indicate the middle treatment (Lys-3) has a different response than the average of control and Lys-6.

During the growing phase, lysine supplementation tended to improve average daily gain compared to the control, with Lys-3 yielding the greatest growth response (quadratic effect, $P = 0.12$; Table 2). Supplementation with Lys-3 increased daily gains by 0.25 lb/day above the control. The Lys-3 treatment also tended to improve feed efficiency (quadratic effect, $P = 0.08$; Table 2). Control and BM led to similar responses during the 77-day growing period.

In the finishing phase, when treatments were no longer supplemented, steers that had received Lys-6 during the growing period had the greatest daily gains (linear effect,

$P = 0.17$; Table 3). During the finishing phase, the Lys-6 group had daily gains that were 0.11 lb/day greater than control and Lys-3.

The net effect of the growing and finishing phases combined was that lysine supplementation during the growing phase resulted in a tendency for linear increases in hot carcass weight (linear effect, $P = 0.20$; Table 3) and subsequent calculated slaughter BW (linear effect, $P = 0.20$; Table 3). Supplementation with Lys-6 led to 16 lb more carcass weight and 25 lb more slaughter weight than control. Relative to control, Lys-3 maintained the advantage in BW gained during the growing phase, as shown by 8 lb more carcass weight and 12 lb more BW at slaughter compared to control. However, the greater gains for Lys-6 than for Lys-3 during the finishing period allowed Lys-6 to exceed Lys-3 for carcass weight and slaughter weight.

Treatments Lys-3 and Lys-6 led to greater muscling than control, as indicated by the increases in ribeye areas (linear effect, $P = 0.05$; Table 3). In addition, Lys-3 cattle had leaner carcasses with the least amount of back fat (quadratic effect, $P = 0.04$; Table 3). Control and BM both had lower slaughter weights, hot carcass weights, and ribeye areas than cattle supplemented with lysine from Smartamine ML.

Implications

When fed corn-based diets, supplementation of ruminally-protected lysine during the growing phase tended to improve growth performance of cattle during the growing and/or finishing phase, leading to tendencies for greater carcass weights.

Acknowledgments

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Table 1. Diet composition (% of DM[1])

	Treatment diet[2]			
Ingredient	**Control**	**Lys-3**	**Lys-6**	**BM**
Smartamine ML	0	0.129	0.259	0
Smartamine M	0	0	0	0.051
Blood meal	0	0	0	0.89
Dry-rolled corn	10.0	9.87	9.74	9.06
Steam-flaked corn	29.5	29.5	29.5	29.5
Sweet Bran[3]	40.0	40.0	40.0	40.0
Alfalfa hay	6.5	6.5	6.5	6.5
Prairie hay	6.5	6.5	6.5	6.5
Supplement[4]	7.5	7.5	7.5	7.5

[1]DM = dry matter.
[2]Control = No supplemental amino acids/protein; Lys-3 = 3 g/day metabolizable lysine from Smartamine ML (Adisseo, Alpharetta, GA); Lys-6 = 6 g/day metabolizable lysine from Smartamine ML; BM = supplemental blood meal (AAdvantage; Perdue Agribusiness, Kings Mountain, NC) at 0.89% of dietary DM plus 2 g/day metabolizable methionine provided from Smartamine M.
[3]Cargill Corn Milling (Blair, NE).
[4]Supplement pellet formulated to contain (DM basis): 8.4% calcium, 5% sodium chloride (NaCl), and 360 mg/kg monensin. Supplement ingredients (DM basis): 72.15% wheat middlings, 22.0% calcium carbonate, 5.0% NaCl, 0.35% soybean oil, 0.18% Rumensin 90 (Elanco), 0.11% zinc sulfate, 0.08% manganese (Mn) sulfate (32% Mn), 0.06% vitamin E premix (500,000 IU/kg), 0.05% copper sulfate, 0.01% selenium (Se) premix (0.99% Se), 0.007% ethylenediamine dihydriodide (EDDI) premix (11.4% EDDI), and 0.004% vitamin A premix (650,000 IU/g).

Table 2. Growing phase - cattle performance

	Treatment[1]					Lysine (*P*-value)	
Item	**Control**	**Lys-3**	**Lys-6**	**BM**	**SEM[2]**	**Linear**	**Quad**
Body weight, lb							
Day 0	549	547	548	548	3.2	0.83	0.60
Day 77	868	885	877	866	8.5	0.45	0.26
DM intake, lb/day	16.89	17.04	16.93	16.82	0.13	0.77	0.41
Daily gain, lb/day	4.14	4.39	4.28	4.12	0.09	0.32	0.12
Gain:feed, lb/lb	0.247	0.259	0.254	0.247	0.0040	0.25	0.08

[1]Control = No supplemental amino acids/protein; Lys-3 = 3 g/day metabolizable lysine from Smartamine ML (Adisseo, Alpharetta, GA); Lys-6 = 6 g/day metabolizable lysine from Smartamine ML; BM = supplemental blood meal (AAdvantage; Perdue Agribusiness, Kings Mountain, NC) at 0.89% of dietary dry matter (DM) plus 2 g/day metabolizable methionine provided from Smartamine M.
[2]SEM = standard error of the mean.

Table 3. Finishing phase - cattle performance

	Treatment[1]					Lysine (*P*-value)	
Item	**Control**	**Lys-3**	**Lys-6**	**BM**	**SEM[2]**	**Linear**	**Quad**
Daily gain, lb/day	3.02	3.02	3.13	3.04	0.13	0.17	0.39
Slaughter weight,[3] lb	1483	1495	1508	1482	13.0	0.20	0.98
Carcass weight, lb	957	965	973	956	8.4	0.20	0.99
Ribeye area, sq in	14.7	15.1	15.1	14.9	0.2	0.05	0.18
Back fat, in	0.74	0.66	0.71	0.70	0.02	0.36	0.04
USDA Choice + Prime, %	98.3	97.1	99.2	95.5	2.3	0.75	0.53

[1]Cattle received treatments only through 77-day growing phase. Control = No supplemental amino acids/protein; Lys-3 = 3 g/day metabolizable lysine from Smartamine ML (Adisseo, Alpharetta, GA); Lys-6 = 6 g/day metabolizable lysine from Smartamine ML; BM = supplemental blood meal (AAdvantage; Perdue Agribusiness, Kings Mountain, NC) at 0.89% of dietary dry matter (DM) plus 2 g/day metabolizable methionine provided from Smartamine M.
[2]SEM = standard error of the mean.
[3]Calculated from hot carcass weights and average dressing percentages.

Impact of Disclosing Labeling Information on Consumer Sensory Evaluation of Ground Beef From a Similar Source

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Abstract

The objective of this study was to determine the effect of providing labeling information prior to evaluation on consumers' palatability ratings of ground beef from a similar source. Ground beef (80% lean/20% fat) chubs (n = 15) were procured from the same production lot and day and fabricated into patties. Prior to fabrication, each chub was assigned randomly to one consumer panel session. Pairs of patties were then randomly assigned to different labeling terms: all natural, animal raised without antibiotics (WA), animal raised without added hormones (WH) fresh never frozen (FNF), grass-fed, locally sourced, premium quality, organic (ORG) and a blank sample (NONE). Each sample was evaluated by consumers (n = 105) for tenderness, juiciness, flavor liking, texture liking, overall liking, and purchasing intent on 0-to-100-point line scales, as well as was rated as either acceptable or unacceptable for each trait. Additionally, consumers were provided with labeling information about each of the samples prior to evaluation. No differences ($P > 0.05$) were found by consumers for tenderness, juiciness, texture liking, overall liking, tenderness acceptability, flavor acceptability, and texture acceptability across the samples evaluated for all 8 treatments. When evaluating flavor liking, samples labeled as grass-fed had a larger increase ($P < 0.05$) in ratings than samples labeled as WA, WH, and premium quality. Moreover, when products were labeled as all natural, WA, WH, FNF, locally sourced, premium quality and ORG there was a large increase ($P < 0.05$) in the overall liking ratings from consumers. Labeling samples as WA resulted in a larger decrease ($P < 0.05$) in the percentage of samples rated as acceptable overall when compared to all other treatments. Ultimately, adding production claims that consumers recognize improves the palatability experience perceived by the consumer.

Introduction

Now more than ever consumers are tasked to choose products with numerous labels and marketing terms, compared to when products were just marketed on the commodity itself with minimal labeling and marketing surrounding them. Previous meat science research evaluating various labeling and production practices has all been conducted in manners in which actual product quality differences existed. However, little information exists regarding how the consumer's eating experience is impacted by the information utilized to purchase their products. Therefore, the objective of this study was to evaluate the impact of providing additional labeling information on consumers' palatability ratings of ground beef from the same source.

Experimental Procedures

Prior to fabrication of ground beef into 0.25 lb patties, chubs (n = 15) of 80% lean/20% fat ground beef were procured from a commercial purveyor to be from the same

production lot and day and were transported to the Kansas State University Meat Lab. Chubs were randomly assigned to one consumer panel session, in order to keep samples as identical as possible to each other. Patties were kept in pairs and were randomly labeled with the labeling terms: all natural, animal raised without added antibiotics (WA), animal raised without added hormones (WH), fresh never frozen (FNF), grass-fed, locally sourced, premium quality, U.S. Department of Agriculture organic (ORG), and a blank sample (NONE). Consumers (n = 105) were recruited, offered each sample, and they completed a digital survey during the evaluation of samples. For each sample, consumers rated the tenderness, juiciness, flavor liking, texture liking, overall liking, and purchasing intent on 0-to-100-point line scales. Additionally, each trait was rated as acceptable or unacceptable by consumers. Prior to sample evaluation, consumers were informed about the labeling information and no information was provided for the NONE sample.

Results and Discussion

When labeling ground beef as locally sourced, there was an increase in consumer ratings across all of the palatability traits evaluated (Figure 1). The events of 2020 and 2021 have set the stage for consumers to be more adapted to wanting foods that are locally sourced, which are likely a direct cause of the results we found. Previous research looking at other food products labeled as being locally sourced has found a perceived quality "halo" around locally sourced products despite there being no differences in product quality (Kumpulainen et al., 2018; Bacig and Young, 2019). Similarly, other authors also report there being a perceived health halo around products labeled as organic, grass-fed, and all natural (Van Loo et al., 2010; Dominick et al., 2018).

Consumers in the current study rated grass-fed, ORG, and all natural as similar ($P > 0.05$) for flavor liking and purchasing intent. They rated a similar ($P > 0.05$) percentage of those samples as acceptable for juiciness, and overall. We hypothesize along with other authors, that consumers group these three labeling terms into a similar category and therefore, expect there to be minimal differences in taste and quality among them despite the differences in what products can be labeled as such (Ellison et al., 2017; Carabante et al., 2018). Alternatively, of the ground beef evaluated by consumers, labeling ground beef as being from an animal raised without added antibiotics tended to have a negative perception associated with it (Figure 2). In an initial assessment of consumers in this study, they rated antibiotic usage as being similar in importance to other production claims evaluated; however, they did not carry this over into their eating experience.

Implications

The entire beef industry has focused heavily on the marketing and branding of the beef products offered to consumers. Results from this study indicate that consumers' eating experiences are swayed by the labeling terms found on packages. Ultimately, those marketing products to consumers need to carefully select and consider what information is being put on the labeling and marketing that surrounds products as the information has an impact on consumers palatability experience.

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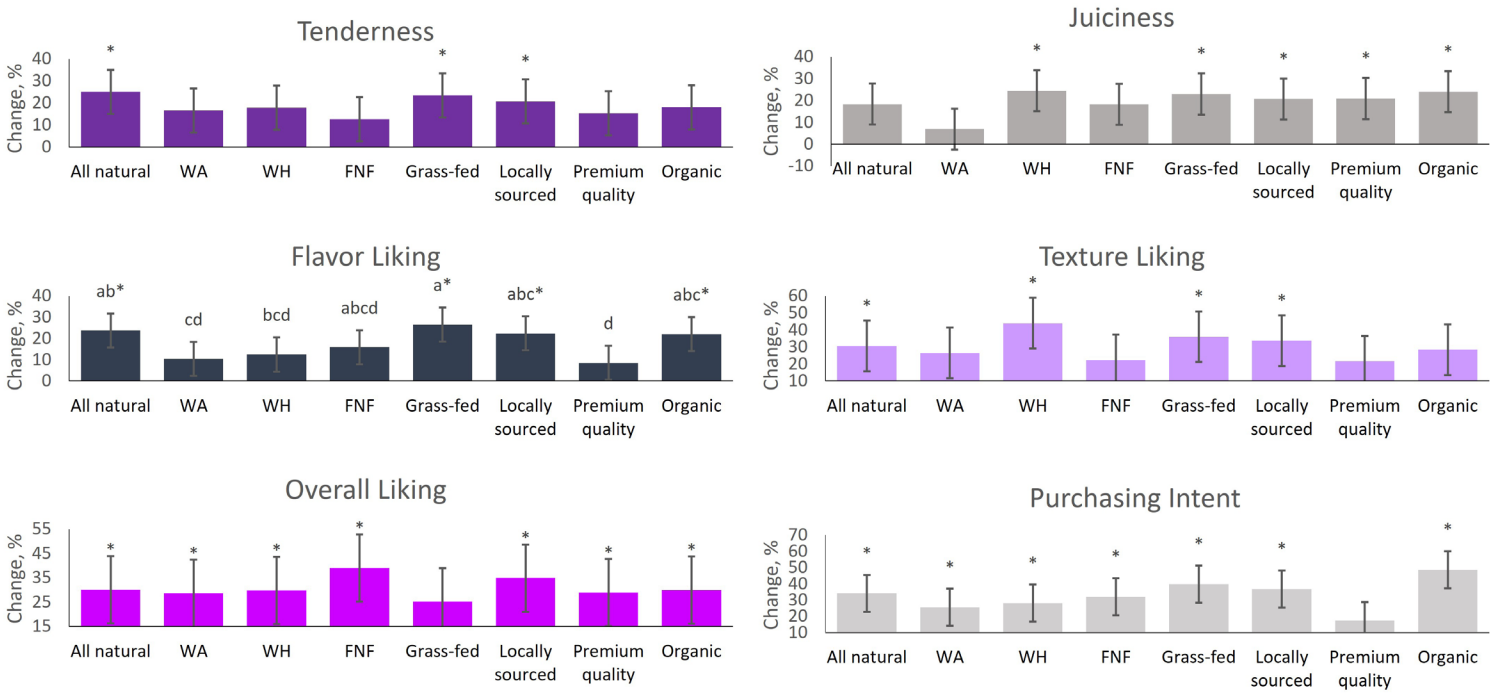

Figure 1. Change in sensory scores due to labeling information disclosure prior to sample evaluation. [abcd] Least square means within the same trait lacking a common superscript differ ($P < 0.05$). * Mean differs from zero ($P < 0.05$). WA = without antibiotics. WH = without added hormones. FNF = fresh never frozen.

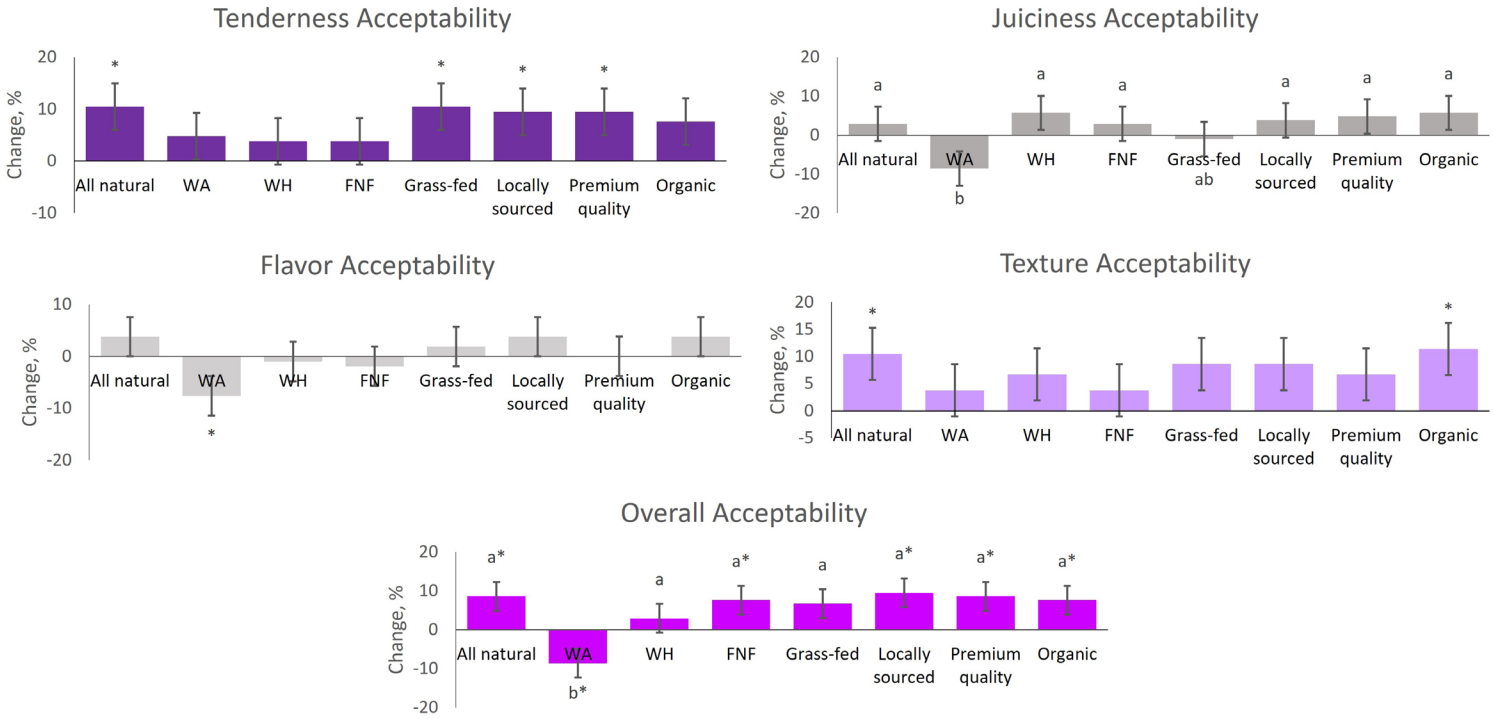

Figure 2. Change in the percentage of samples rated as acceptable by consumers due to labeling information disclosure prior to sample evaluation. [ab] Least square means within the same trait lacking a common superscript differ ($P < 0.05$). * Mean differs from 0 ($P < 0.05$). WA = without antibiotics. WH = without added hormones. FNF = fresh never frozen.

Impact of Disclosing Fat Content on Consumer Sensory Evaluation of Ground Beef From a Similar Source

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Abstract

The objective of this study was to determine the effect of providing information regarding fat content prior to evaluation on consumers' palatability ratings on ground beef from a similar source. For this study, 80% lean/20% fat ground beef chubs (n = 15/panel type) were obtained, and 0.25-lb patties were fabricated from the chubs. Chubs were assigned randomly to panels. Panels received samples labeled as the following: 90% lean/10% fat (90/10), 80% lean/20% fat (80/20), 73% lean, 27% fat (73/27), lean, extra lean, and one sample with no information given (NONE). Samples were evaluated by consumers (n = 105), who were provided information regarding treatment prior to evaluation, on 0- to 100-point line scales for tenderness, juiciness, flavor, texture overall liking, and purchasing intent. Consumers also rated each trait as acceptable or unacceptable. The 90/10, 80/20, and 73/27 labels on ground beef resulted in a large increase ($P < 0.05$) in consumer ratings for tenderness, flavor, and overall liking. Conclusively, presenting information regarding fat content to consumers influences perceived palatability of ground beef.

Introduction

Consumers are consistently provided with information regarding fat content/leanness of ground beef at the point of purchase. The effect of fat content on ground beef palatability has been comprehensively researched (Berry and Leddy, 1984; Troutt et al., 1992; Miller et al., 1993; Berry, 1994; Wong and Maga, 1995). However, these studies were all conducted on ground beef products varying in quality. Research exists in other segments of the food industry on the effect of disclosing fat content on consumers' perceived palatability (Solheim and Lawless, 1996; Westcombe and Wardle, 1997), there have not been studies evaluating this in ground beef. Therefore, the objective of this study was to determine the impact of providing consumers with information regarding the fat content of ground beef on the consumer's eating experience.

Experimental Procedures

Chubs (n = 15) of 80% lean/20% fat ground beef were obtained from a food purveyor to be from the same production lot and day, and were transported to the Kansas State University Meat Lab. The chubs were then fabricated into 0.25-lb patties. Chubs were randomly assigned to one or two consumer panel sessions, so all samples were as identical as possible. The patties were randomly designated and labeled with the following labeling terms: 90% lean/10% fat (90/10), 80% lean/20% fat (80/20), 73% lean/27% fat (73/27), lean, extra lean, or a blank sample (NONE). Consumers (n = 105) were recruited, given each sample, and completed a digital survey during the assessment of samples. Information regarding treatment was provided to consumers prior to evaluation of each sample, and surveys consisted of 0- to 100-point line scales for tenderness,

juiciness, flavor, texture, overall liking, and purchasing intent. Moreover, consumers also determined each trait as acceptable or unacceptable.

Results and Discussion

Although only limited differences in consumer ratings existed, consumers' perception of ground beef products did change when additional labeling information was provided (Figure 1). There was an increase ($P < 0.05$) in the ratings for tenderness for 90/10 (20.1%), 80/20 (21.2%), and 73/27 (24.2%) labeled products when fat content information was provided to consumers. Moreover, large increases ($P < 0.05$) were found in flavor likeability ratings for 90/10 (25.2%), 80/20 (25.3%), 73/27 (32.6%), and lean (15.3%) labeled ground beef. There was a considerable increase ($P < 0.05$) in ratings for overall likeability for 90/10 (22.2%), 80/20 (27.5%), and 73/27 (27.1%) labeled ground beef when labeling information was provided. When labeled 90/10, 80/20, and 73/27 there was an increase ($P < 0.05$) in the percentage of samples rated as acceptable for tenderness, in contrast to extra lean labeled products which had a decrease ($P < 0.05$) in the percentage rated as acceptable when information was provided about the treatment. Retrospectively, when assessing juiciness, extra lean and 90/10 labeled samples had a larger ($P < 0.05$) decrease in the percentage of samples rated as acceptable when compared to 80/20 and 73/27 labeled samples when fat content was revealed. Samples labeled as 90/10 and extra lean resulted in a decrease ($P < 0.05$) in the percentage of samples rated as acceptable for juiciness. Providing the fat content to consumers did not increase/decrease ($P > 0.05$) the percentage of samples rated as acceptable for flavor and overall, for any of the treatments.

Implications

Modern consumers are paying closer attention to labeling statements than their past counterparts. Results from this study support this trend, indicating consumers' eating experiences are affected by the fat content labeling found on ground beef packages. Ground beef marketing decisions should consistently consider the information incorporated on packaging, including fat content, as there is an impact on consumers' palatability experience.

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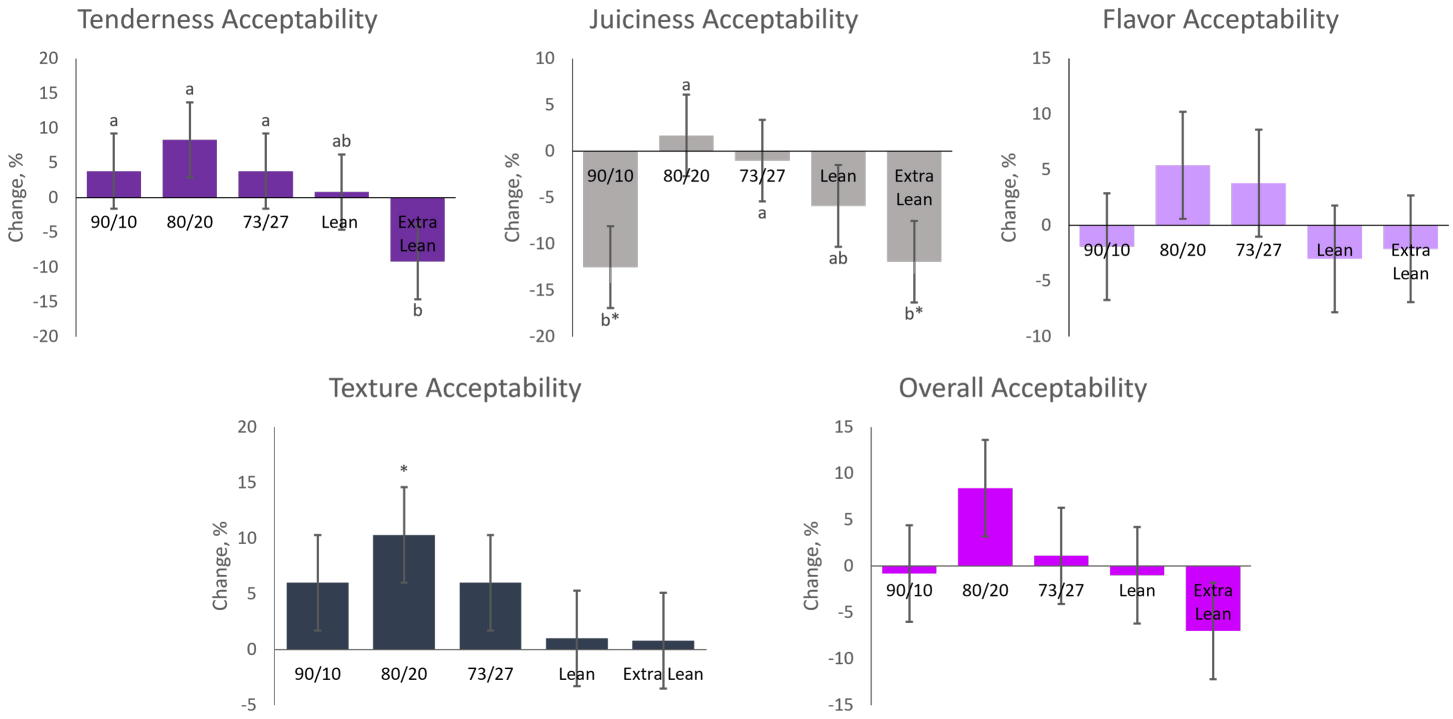

Figure 1. Change in the percentage of samples rated as acceptable by consumers due to lean content disclosure prior to sample evaluation. Fat content is presented as percentage lean/percentage fat. [ab] Least square means within the same trait lacking a common superscript differ ($P < 0.05$). * Mean differs from zero ($P < 0.05$).

Changes in the Perception of Ground Beef Quality as a Result of Price Per Pound Labeling

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

Abstract

The objective of this study was to determine the effect of perceived palatability on ground beef patties by providing consumers with differing price per pound labels. Ground beef chubs (n = 15) of 80% lean/20% fat composition were used for all samples. The consumers (n = 105) were asked to evaluate each sample independently with the following information provided prior to sampling: Ultra-High $6.25/lb; High $5.00/lb; Medium $3.75/lb; Low $2.5/lb; Ultra-Low $1.25/lb; or no information provided (NONE). The consumers were asked to evaluate each sample for tenderness, juiciness, texture liking, flavor liking, and overall liking. Also, the consumers reported their likelihood to purchase each sample. Consumers were equally as likely ($P > 0.05$) to purchase all samples regardless of the price label. However, the consumers listed price as one of the top purchasing motivators ($P > 0.05$). Moreover, consumers found the ultra-high, medium, and ultra-low price label to be more juicy ($P < 0.05$) than the low price or NONE label. Also, consumers gave a higher ($P < 0.05$) flavor liking score to the ultra-high, high, medium, and ultra-low price labels in comparison to the NONE label. The ultra-high and medium price labels had a greater ($P < 0.05$) change in ratings for overall liking than the ultra-low and low price labels when compared to the NONE label. Furthermore, almost every price label for every trait resulted in increased ($P < 0.05$) palatability ratings, aside from the low price label for juiciness, tenderness, and overall liking. Even though all samples were the same, consumer perceptions of palatability traits were influenced by price labels. While the higher price was perceived to have advantages in some quality aspects, consumers were still not more likely to purchase the higher priced sample.

Introduction

Understanding the influence price labels have on consumers can allow for more targeted marketing of ground beef and other commodities. Consumers can be influenced by certain labeling differences, leading to changes in the perceived quality (Roger et al., 1992; Lunardo et al., 2016). Consumers use a combination of visual quality differences and extrinsic factors such as labeling claims to make inferences about the eating experience (McIlveen et al., 2001). There have been few studies to explicitly look at the quality perception of beef with different prices, making it a gap in the current research. Therefore, the objective of this study was to determine the effect of perceived palatability on ground beef patties by providing consumers with differing price per pound labels.

Experimental Procedures

Ground beef chubs (n = 15) of 80% lean/20% fat composition were procured from a beef processor from the same processing lot. The ground beef chubs were held at 30°F

before further processing. Patties were formed 11 days after processing into 0.25 lb patties using a commercial patty former. Every two patties were packaged together with a four-digit identification code with one of the following price labels: Ultra-High, High, Medium, Low, Ultra-Low, and no information (NONE). The patties were packaged in a commercial Rollstock machine and stored frozen at -4°F until further analysis.

For all panels, samples were thawed 24 hours in advance and cooked on a clamshell grill (Griddler Deluxe, Cuisinart, East Windsor, NJ) to an internal temperature of 160°F measured using a ThermoWorks (Salt Lake City, UT) Thermopens Mk4. The consumers (n = 105) were asked to evaluate each sample independently with the following information provided prior to sampling: Ultra-High $6.25/lb; High $5.00/lb; Medium $3.75/lb; Low $2.5/lb; Ultra-Low $1.25/lb; or no information provided. For each round, all consumers were given the same information about the price per pound for each sample. The consumers were asked to evaluate each sample for tenderness, juiciness, texture liking, flavor liking, and overall liking. Each attribute was measured on a 0-100 line scale using an electronic ballot made in Qualtrics (Version 2417833; Provo, UT) using an electronic tablet. Additionally, the consumers were asked to list if the sample was acceptable for all traits and the importance of purchasing motivators. Lastly, the consumers reported their likelihood to purchase each sample.

Data were analyzed using SAS Proc GLIMMIX (v. 9.4; SAS Institute, Inc., Cary, NC) as a completely randomized design. A Kenward-Rogers adjustment was made to all data. A *P*-value of $P < 0.05$ was considered significant.

Results and Discussion

There were no differences ($P > 0.05$) among any of the various price labels for tenderness, texture liking, and overall liking (Table 1). Consumers were equally as likely ($P > 0.05$) to purchase all samples regardless of the price label. However, the consumers listed price as one of the top purchasing motivators, similar ($P > 0.05$) to fat content, and appearance (Table 2). Moreover, consumers found the ultra-high, medium, and ultra-low price label to be more juicy ($P < 0.05$) than the low price or NONE label. Also, consumers gave a higher ($P < 0.05$) flavor liking score to the ultra-high and medium price labels in comparison to the NONE label. The ultra-high and medium price labels had a greater ($P < 0.05$) change in ratings for overall liking than the ultra-low and low price labels when compared to the NONE label (Table 3). Furthermore, almost every price label for every trait resulted in increased ($P < 0.05$) palatability ratings, aside from the low price label for juiciness, tenderness, and overall liking. A greater ($P < 0.05$) percentage of samples with the ultra-high and medium price level were rated as acceptable for juiciness in comparison to the low price and NONE label. Moreover, a greater ($P < 0.05$) percentage of samples labeled with the ultra-high and medium price labels were considered acceptable for flavor in comparison to all other price labels. Lastly, a greater ($P < 0.05$) percentage of samples labeled with the ultra-high, high, and medium price labels were considered acceptable overall when compared to the NONE label. Even though all samples were the same, consumer perceptions of palatability traits were influenced by price labels. While the higher price was perceived to have advantages in some quality aspects, consumers were still not more likely to purchase the higher priced sample. This indicates that even though consumers perceived the quality to be higher with a higher price label, the added quality did not justify their willingness to purchase over the lower perceived quality and priced samples.

Implications

Understanding the role of labeling claims and price can allow for more targeted marketing. This research can be used as a marketing resource to help retailers and the industry have a better understanding of consumers' purchasing habits as it relates to price differences. Based on this research, consumers' quality perception is affected by price variations, but not the willingness to purchase, indicating consumers are not willing to pay more for ground beef even with an improved eating experience.

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Table 1. Consumer (n = 105) palatability ratings[1] for 80/20[2] ground beef patties when additional information was given about the price

Prices[3]	Tenderness	Juiciness	Flavor liking	Texture liking	Overall liking	Purchasing
Ultra-high	72.8	73.9[a]	68.6[a]	66.2	69.6	62.4
High	67.3	70.9[ab]	61.5[abc]	62.6	63.8	59.6
Medium	69.4	73.3[a]	66.3[ab]	64.7	68.8	66.8
Low	66.5	65.3[bc]	59.9[bc]	62.6	61.4	57.9
Ultra-low	70.7	74.0[a]	63.9[abc]	64.7	65.0	61.1
NONE	66.7	62.6[c]	56.5[c]	60.4	58.8	55.3
SE[4]	2.5	2.6	2.7	2.7	3.0	3.0
P-value	0.29	< 0.01	0.02	0.62	0.06	0.07

[a-c] Least square means within the same panel type of the same column lacking a common superscript differ ($P < 0.05$).
[1] Sensory scores: 0 = not tender/juicy, dislike flavor/overall extremely, or extremely unlikely; 50 = neither tender nor tough, juicy nor dry, neither like nor dislike flavor/overall, or neither likely or unlikely; 100 = very tender/juicy, like flavor/overall extremely, or very likely.
[2] 80% lean/20% fat ground beef.
[3] Prices: Ultra-High - $6.25/lb; High - $5.00/lb; Medium - $3.75/lb; Low - $2.50/lb; Ultra-Low - $1.25/lb; NONE - no price given/lb.
[4] SE (largest) of the least square means.

Table 2. Ground beef purchasing motivators[1] of consumers (n = 105) who participated in 80/20[2] ground beef consumer sensory panels when given additional labeling information

Trait	Importance
Animal fed a grass-based diet	40.9^{fg}
Animal fed a grain-based diet	39.0^{fg}
Animal not administered antibiotics	45.6^{ef}
Animal welfare	64.0^{bc}
Appearance – lean to fat ratio	73.5^{a}
Brand of product	33.3^{gh}
Color	65.8^{abc}
Fat content	70.4^{ab}
Growth promotant use in the animal	42.9^{f}
Fresh never frozen	46.5^{ef}
Locally raised	45.2^{ef}
Natural or organic claims	40.0^{fg}
Nutrient content	57.8^{cd}
Packaging type	38.5^{fg}
Preformed patty	28.8^{h}
Price	73.5^{a}
Primal source	52.8^{de}
Size, weight, and thickness	58.0^{dc}
SE[3]	2.9
P-value	< 0.01

$^{a-h}$ Least square means within the same panel lacking a common superscript differ ($P < 0.05$).
[1]Purchasing motivators: 0 = extremely unimportant, 100 = extremely important.
[2] 80% lean/20% fat ground beef.
[3]SE (largest) of the least square means.

Table 3. Percentage change in consumer (n = 105) ratings of palatability traits[1] for 80/20[2] ground beef patties when information about price is given versus no information[2] given

Prices[3]	Tenderness	Juiciness	Flavor liking	Texture liking	Overall liking	Purchasing
Ultra-high	23.9*	46.1*	44.6*	42.6*	53.2[a]*	56.9*
High	17.4*	44.4*	42.2*	35.3*	46.4[ab]*	59.8*
Medium	19.4*	47.6*	47.1*	39.6*	57.0[a]*	76.3*
Low	12.0	28.7	40.2*	28.6*	27.9[b]	45.8*
Ultra-low	20.3*	46.3*	34.2*	32.5*	30.6[b]*	49.3*
SE[4]	8.4	17.2	13.2	11.7	14.0	22.1
P-value	0.43	0.12	0.80	0.64	< 0.01	0.38

[ab] Least square means within the same panel type of the same column lacking a common superscript differ ($P < 0.05$).
*Indicates a significant difference from 0% change.
[1] Sensory scores: 0 = not tender/juicy, dislike flavor/overall extremely, or extremely unlikely; 50 = neither tender nor tough, juicy nor dry, neither like nor dislike flavor/overall, or neither likely or unlikely; 100 = very tender/juicy, like flavor/overall extremely, or very likely.
[2] 80% lean/20% fat ground beef.
[3] Prices: Ultra-High - $6.25/pound; High - $5.00/pound; Medium - $3.75/pound; Low - $2.50/pound; Ultra-Low - $1.25/pound.
[4] SE (largest) of the least square means.

Changes in the Perception of Ground Beef Quality as a Result of Primal Labeling

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

Abstract

The objective of this study was to determine the effect of providing primal source information to consumers on palatability ratings of 80% lean/20% fat ground beef. Ground beef chubs (n = 15) that were obtained from the same production lot and day were formed into patties. Consumers (n = 105) were asked to independently evaluate a sample for tenderness, juiciness, texture liking, flavor liking, overall liking, and likelihood of purchase. Prior to serving, consumers were informed of the sample's primal source which were labeled as: ground chuck, ground round, ground sirloin, and store ground along with a sample that had no information (NONE). While primal source was not one of the top five high purchasing factors, consumers' palatability ratings were greatly impacted by primal blend type disclosure. Consumers rated ground chuck and ground sirloin labeled samples higher ($P < 0.05$) for juiciness than ground round labeled and NONE labeled samples, but scored them similar ($P > 0.05$) to store ground labeled samples. In addition, ground chuck and ground sirloin labeled samples were identified as more ($P < 0.05$) tender than NONE by consumers but ranked similar ($P > 0.05$) to ground round and store ground labeled samples. On the contrary, the ground sirloin labeled ground beef ranked higher ($P < 0.05$) for flavor liking in comparison to ground round labeled and NONE samples but scored similar ($P > 0.05$) to ground chuck and store ground labeled ground beef. Ground chuck labeled samples were rated higher ($P < 0.05$) for texture liking than ground round, store ground, and NONE samples. Furthermore, NONE was ranked lower ($P < 0.05$) for overall liking than ground chuck, ground sirloin, ground round, and store ground labeled products. Lastly, ground chuck was more likely ($P < 0.05$) to be purchased by consumers than ground round, store ground, and NONE. Primal source labeling improved ($P < 0.05$) flavor liking ratings by more than 45% and texture liking ratings ($P < 0.05$) by more than 25% when the information for the four primal sources was offered. While all samples were deemed acceptable for tenderness, juiciness, flavor, texture, and overall liking, the overall liking and purchasing intent ratings increased ($P < 0.05$) when consumers were told the primal source information before sample evaluation. This indicates that the addition of primal source labeling enhances consumers' perception of their palatability experience in ground beef.

Introduction

The influence of labeling and information on marketing ground beef and other products is essential for the sale of those products to consumers. While research has been performed to understand the effects of labeling differences and affected perception, these studies actually had product differences in quality, primal source, or other various factors researched (Kerin et al., 1992; Lunardo et al. 2016). Nonetheless, minimal information exists on the impact of the actual labeling difference and the way consumers utilize labeling and marketing information in their purchasing decisions. Thus, the

objective of this study was to assess the impact of primal source labeling information on consumers' palatability ratings of ground beef.

Experimental Procedure

Chubs (n = 15) of 80% lean/20% fat ground beef were procured from the same source and production lot. The chubs were held in the Kansas State University Meat Lab at a constant temperature of 30°F before processing. After an 11-day hold, the chubs were processed into 0.25 lb patties using a patty former. The patties were kept in pairs and assigned an identification code and one of the following label sources: ground chuck, ground round, ground sirloin, store ground, or blank with no information (NONE). The patties were vacuum packaged in a Rollstock machine and frozen at -4°F until further analysis.

Samples were thawed 24 hours in preparation for consumer panels and cooked to an internal temperature of 160°F on a clamshell grill (Griddler Deluxe, Cuisinart, East Windsor, NJ). Temperature was measured using a Thermoworks Thermopen Mk4 (Salt Lake City, UT).

Consumers (n = 105) were recruited to complete an independent palatability survey of the eating quality of the samples. Immediately prior to consumption of each sample, consumers were informed of the primal source information for the samples. Samples were rated on tenderness, juiciness, flavor liking, texture liking, overall liking, and likelihood of purchase on a scale of 0 to 100. After rating the traits, consumers were asked if each trait met the threshold of acceptability of purchase (yes/no).

Results and Discussion

While primal source was not one of the top five high purchasing factors, consumers' palatability ratings were greatly impacted by primal blend type disclosure (Table 1). Consumers rated ground chuck and ground sirloin labeled samples higher ($P < 0.05$) for juiciness than NONE labeled samples, but scored them similar ($P > 0.05$) to ground round and store ground labeled samples. In addition, ground chuck and ground sirloin labeled samples were listed as more ($P < 0.05$) tender than ground round and NONE labeled samples by consumers but rated similar ($P > 0.05$) to store ground labeled samples. On the contrary, the ground sirloin labeled ground beef ranked higher ($P < 0.05$) for flavor liking in comparison to ground round labeled and NONE samples, but were comparable ($P > 0.05$) to ground chuck and store ground labeled ground beef. Ground chuck labeled samples were rated higher ($P < 0.05$) for texture liking in comparison to ground round, store ground, and NONE samples. Furthermore, NONE was rated lower ($P < 0.05$) for overall liking than ground chuck, ground sirloin, and store ground labeled products. Lastly, ground chuck was more likely ($P < 0.05$) to be purchased by consumers than ground round, store ground, and NONE samples.

Primal source labeling improved ($P < 0.05$) flavor liking ratings by more than 45% and texture liking ratings by more than 25% when the information for all primals was presented (Table 2). While all samples were deemed acceptable for tenderness, juiciness, flavor, texture, and overall liking, the overall liking, and the purchasing intent ratings increased ($P < 0 .05$) when consumers were told the primal source information before sample evaluation.

Implications

These results indicate the addition of primal source labeling enhances consumers' perceptions of their palatability experience and likelihood of purchase in ground beef. Though differences among primal source labeling on palatability ratings were found, labeling of all primal sources positively influenced consumer ratings. Retailers who market ground beef with primal-source labels should benefit in consumer's improved eating experience over products without primal-source labels.

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Lunardo, R., and F. Livat. 2016. Congruency between colour and shape of the front labels of wine: effects on fluency and aroma and quality perceptions. International Journal of Entrepreneurship and Small Business. 29(4): 528-541.

Table 1. Consumer (n = 105) palatability ratings[1] for ground beef patties when additional information was given about the primal blend

Treatment	Tenderness	Juiciness	Flavor liking	Texture liking	Overall liking	Purchasing intent
Ground chuck	72.3^{a}	73.6^{a}	65.9^{ab}	70.3^{a}	70.4^{a}	70.2^{a}
Ground round	65.8^{b}	69.9^{ab}	61.0^{bc}	64.2^{bc}	64.3^{ab}	63.2^{bc}
Ground sirloin	71.5^{a}	73.9^{a}	69.4^{a}	69.7^{ab}	70.1^{a}	69.5^{ab}
Store ground	67.7^{ab}	70.9^{ab}	63.2^{abc}	63.8^{c}	65.4^{a}	62.4^{c}
NONE[2]	65.6^{b}	65.8^{b}	57.5^{c}	59.1^{c}	58.8^{b}	56.9^{c}
SE[3]	2.1	2.1	2.4	2.1	2.3	2.6
P-value	0.04	0.03	0.01	< 0.01	< 0.01	< 0.01

[1] Sensory scores: 0 = not tender/juicy, dislike flavor/texture/overall extremely, or extremely unlikely to purchase; 50 = neither tender nor tough, juicy nor dry, neither like nor dislike flavor/texture/overall, or neither likely or unlikely; 100 = very tender/juicy, like flavor/texture/overall extremely, or extremely likely to purchase.
[2] NONE: No information was provided.
[3] Standard error (largest) of the least squares means.
[a-c] Least square means within the same panel type of the same column lacking a common superscript differ ($P < 0.05$).

Table 2. Percentage change in consumer (n = 105) ratings[1] of palatability traits when information about primal source is given on ground beef versus no information[2] given

	Percentage					
Treatment	Tenderness	Juiciness	Flavor liking	Texture liking	Overall liking	Purchasing intent
Ground chuck	29.1[a]*	36.3*	49.3*	41.5*	47.4*	64.8*
Ground round	14.6[b]*	29.0*	45.9*	36.1*	27.6*	59.7*
Ground sirloin	25.3[ab]*	34.3*	69.0*	33.6*	45.5*	73.1*
Store ground	17.3[b]*	29.5*	50.5*	25.1*	28.1*	54.7*
SE[2]	7.2	8.8	22.1	9.4	13.5	23.5
P-value	0.04	0.40	0.25	0.21	0.27	0.52

[1] Percentage change in ratings: (consumer trait scores – consumer blank scores) / consumer blank scores.
[2] Standard error (largest) of the least squares means.
*Mean differs from 0 ($P < 0.05$).
[ab] Least square means within the same panel type of the same column lacking a common superscript differ ($P < 0.05$).

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

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Abstract

The objective of this study was to determine the palatability traits of beef cuts of differing bone status and quality grade. Paired (n = 12) beef short loins, export ribs, and boneless ribeye rolls were collected from a commercial abattoir. Short loins were fabricated into boneless strip loins with corresponding bone-in tenderloins or bone-in strip loins with boneless tenderloins at Kansas State University. Product was aged in vacuum packages for 28 days and fabricated into 1-in thick steaks. A total of 18 trained sensory panels were conducted. Steaks were cooked on clamshell style grills to a peak temperature of 160°F. Panelists ranked the samples on 100-point continuous line scales with descriptive anchors at 0, 50, and 100. Bone-in tenderloins and bone-in ribeyes were rated more flavorful ($P < 0.05$) than boneless cuts from the same muscle. There were no beef flavor intensity differences observed for bone-in and boneless strip steaks. Bone state had no effect ($P > 0.05$) on initial juiciness, myofibrillar tenderness, or overall tenderness. Bone-in strip loin samples were rated juicier ($P < 0.05$) than tenderloins and boneless ribeye samples. Tenderloin samples were rated higher ($P < 0.05$) for myofibrillar and overall tenderness than strips and ribeyes, which were similar ($P > 0.05$). U.S. Department of Agriculture (USDA) Choice samples were rated higher ($P < 0.05$) for all palatability traits than USDA Select samples. Nuances observed within palatability traits show that bone-in and boneless cuts of the same muscle rated similar regardless of bone state. This provides evidence that a comparable overall eating experience can be derived from a bone-in or boneless steak from the same muscle and grade.

Introduction

The evolution of consumer demands and processing practices over the past several decades, specifically in the beef industry, have caused a shift to marketing primarily boneless subprimals (Bass, 2018). Consequently, there is increased interest and novelty surrounding bone-in cuts in high-end steakhouses and retail markets. Consumers continue to prefer the aesthetic and visual stimulation of bone-in cuts (Bass, 2018). Moreover, bone-in cuts are believed to have a more flavorful eating experience for consumers (Lopez, 2013; Chicago Steak Company, 2016; Goldwyn, n.d.). There has been minimal research evaluating the impact of bone on beef palatability and whether the impact depends on quality grade. Therefore, the objective of this study was to determine the palatability attributes of beef cuts (strip loin, tenderloin, and ribeye) of varying bone states and quality grades.

Experimental Procedures

Left and right sides of 12 beef carcasses representing U.S. Department of Agriculture (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. K-State research personnel collected quality and yield grade data prior to fabrication. 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. After arriving at K-State, short loins from each animal 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 three days postmortem. Following the initial fabrication, product was vacuum-packaged and aged for 28 days at 32–39°F. Frozen subprimals were then fabricated into 1-in thick steaks using a band saw. Steaks designated for trained sensory analysis were thawed at 36 to 39°F for 24 hours prior to cooking. 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 the trained panelists. For ribeye samples, only the longissimus muscle was served. Panelists were trained according to the American Meat Science Association sensory guidelines (American Meat Science Association, 2016). A total of 18 panels were conducted at the Kansas State University Meat Science Sensory Lab. For each session, eight panelists were seated at individual booths under low-intensity red incandescent lights and given eight samples in a randomized order. Panelists ranked the samples on a 100-point continuous line scale with descriptive anchors at 0, 50, and 100 for initial juiciness, sustained juiciness, myofibrillar tenderness, connective tissue amount, overall tenderness, beef flavor intensity, and off-flavor intensity. Trained sensory panelists recorded their responses using a digital survey (Qualtrics XM, Provo, UT) on an electronic tablet (Lenovo TB-8505F). Warner-Bratzler Shear Force (WBSF) analysis was also performed. A total of six cores (0.5-in diameter) were cut from each cooked steak parallel to the muscle fiber. The cores were sheared perpendicular to the muscle fiber using an Instron testing machine. Measurements of the six cores per steak were averaged and results were recorded as average peak force (lb). Data were analyzed as a split-plot design with a whole plot factor of quality grade and sub-plot factors of muscle and bone.

Results and Discussion

Trained sensory panel analysis results for bone state and muscle are listed in Table 1. Overall, bone status had a minimal impact on palatability traits. Nonetheless, bone-in tenderloins and bone-in ribeyes were rated more flavorful ($P < 0.05$) than boneless cuts from the same muscle. There were no ($P > 0.05$) beef flavor intensity differences observed for bone-in and boneless strip steaks. Bone state had no effect ($P > 0.05$) on initial juiciness, myofibrillar tenderness, or overall tenderness for any cut. Bone-in strip loin samples were rated juicier ($P < 0.05$) than tenderloins and boneless ribeye samples. Furthermore, tenderloin samples were rated higher ($P < 0.05$) for myofibrillar and overall tenderness than strip loin and ribeye steaks, which were rated similar ($P > 0.05$) by trained panelists. Trained sensory panel results for quality grade are found in Table 2. USDA Choice samples were rated higher ($P < 0.05$) for all palatability traits than Select samples. There was a significant interaction between quality grade × bone state × muscle with results listed in Table 3. Both Choice and Select tenderloins of both bone states had the least ($P < 0.05$) amount of detectable connective tissue. Moreover, there was no difference ($P > 0.05$) in the WBSF values for strips and ribeyes, with tenderloin samples having the lowest ($P < 0.05$) average peak force as shown in Table 4. The

USDA Choice samples were rated higher ($P < 0.05$) for all palatability traits and had lower WBSF values than Select samples.

Implications

The results observed within palatability traits show that regardless of bone state, bone-in and boneless cuts of the same muscle are rated similar 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 trained sensory panel ratings[1] for strip, tenderloin, and ribeye steaks of varying bone states

	Strip		Tenderloin		Ribeye			
Trait	**Bone-in**	**Boneless**	**Bone-in**	**Boneless**	**Bone-in**	**Boneless**	**SEM[2]**	***P*-value**
Initial juiciness	60.6^{a}	59.0^{ab}	56.2^{b}	55.7^{b}	58.0^{ab}	56.4^{b}	1.4	0.06
Sustained juiciness	55.0	53.8	51.3	50.9	52.4	51.2	1.6	0.24
Myofibrillar tenderness	63.2^{b}	63.7^{b}	85.9^{a}	85.1^{a}	63.1^{b}	61.9^{b}	1.6	<0.0001
Overall tenderness	59.7^{b}	61.2^{b}	85.2^{a}	83.9^{a}	60.5^{b}	59.0^{b}	1.8	<0.0001
Beef flavor intensity	37.3^{ab}	37.5^{a}	37.1^{ab}	34.6^{c}	37.8^{a}	35.8^{bc}	0.9	0.002
Off-flavor intensity	0.0	0.1	0.0	0.0	0.2	0.0	1.0	0.55

[1]Sensory scores: 0 = extremely dry/tough/non/extremely bland/no off-flavor; 50 = neither dry nor juicy/neither tough nor tender; 100 = extremely juicy/tender/abundant/extremely intense.
[2]SEM (largest) of the least square means in the same section of the same row.
[a-c]Least squares means in the same section of the same row without a common superscript differ ($P < 0.05$).

Table 2. Least squares means for trained sensory panel ratings[2] for Choice and Select USDA quality grades[2]

Trait	Choice	Select	SEM[3]	*P*-value
Initial juiciness	60.5[a]	54.8[b]	0.8	<0.0001
Sustained juiciness	55.6[a]	49.2[b]	0.9	<0.0001
Myofibrillar tenderness	73.3[a]	67.7[b]	1.1	0.0006
Overall tenderness	71.4[a]	65.1[b]	1.6	0.0006
Beef flavor intensity	38.1[a]	35.2[b]	0.6	<0.0001
Off-flavor intensity	0.04	0.05	0.05	0.85

[1]Sensory scores: 0 = extremely dry/tough/non/extremely bland/no off-flavor; 50 = neither dry nor juicy/neither tough nor tender; 100 = extremely juicy/tender/abundant/extremely intense
[2]Quality grade: Choice = USDA High Choice (upper 2/3) with marbling scores ranging from moderate 0 to 100; Select = USDA Select with marbling scores ranging from slight 0 to 100.
[3]SEM (largest) of the least square means in the same section of the same row.
[ab]Least squares means in the same section of the same row without a common superscript differ ($P < 0.05$).

Table 3. Interactive effects for trained sensory panel ratings[1] for strip, tenderloin, and ribeye steaks of varying bone states[2] and USDA quality grade[3]

	Choice						Select							
	Strip		Tenderloin		Ribeye		Strip		Tenderloin		Ribeye			
Trait	BI	BL	BI	BL	BI	BL	BI	BL	BI	BL	BI	BL	SEM[4]	*P*-value
Connective tissue amount	6.0[bc]	4.7[c]	1.1[d]	1.3[d]	5.8[bc]	5.6[c]	10.9[a]	6.7[bc]	1.3[d]	1.3[d]	7.4[bc]	8.6[ab]	1.5	0.04

[1]Sensory scores: 0 = extremely dry/tough/non/extremely bland/no off-flavor; 50 = neither dry nor juicy/neither tough nor tender; 100 = extremely juicy/tender/abundant/extremely intense.
[2]Bone-in = BI; Boneless = BL.
[3]Quality grade: Choice = USDA High Choice (upper 2/3) with marbling scores ranging from moderate 0 to 100; Select = USDA Select with marbling scores ranging from slight 0 to 100.
[4]SEM (largest) of the least square means of the same row.
[a-d]Least squares means in the same section of the same row without a common superscript differ ($P < 0.05$).

Table 4. Least squares means for Warner-Bratzler shear force of strip, tenderloin, and ribeye steaks of varying bone states[1] and USDA quality grade[2]

	Strip		Tenderloin		Ribeye							
Trait	BI	BL	BI	BL	BI	BL	SEM[3]	*P*-value	Choice	Select	SEM[3]	*P*-value
Shear force (lb)	8.2[a]	7.9[a]	6.0[b]	6.0[b]	8.4[a]	8.4[a]	0.2	<0.001	6.8[b]	8.2[a]	0.2	0.005

[1]Bone-in = BI; Boneless = BL.
[2]Quality grade: Choice = USDA High Choice (upper 2/3) with marbling scores ranging from moderate 0 to 100; Select = USDA Select with marbling scores ranging from slight 0 to 100.
[3]SEM (largest) of the least square means in the same section of the same row.
[a,b]Least squares means in the same section of the same row without a common superscript differ ($P < 0.05$).

Native Beef Collagenase MMP-9 May Contribute to Tenderness Improvement by Degrading Connective Tissues in Extended Aged Beef

L.A. Koulicoff, A.A. Welter, P.A. Hammond, C.K.Y. Chun, T.G. O'Quinn, G. Magnin-Bissel, and M.D. Chao

Abstract

The objective of this study was to characterize native beef collagenase activity and understand how its activity may impact postmortem connective tissue degradation. Beef boneless striploin, top sirloin butt and heel were acquired from ten U.S. Department of Agriculture high choice beef carcasses, fabricated into steaks and aged for 3, 21, 42, and 63 days. Steaks from each aging period from each subprimal were assigned to instrumental and sensory tenderness analyses, collagen biochemical analysis, collagenase activity characterization, and collagenase identification. Heel and top sirloin butt were considered tougher than striploin. After 21 days of aging, overall steaks and connective tissue texture become more tender. Collagen content did not change ($P > 0.10$) in the different aging periods. Denaturation temperature of connective tissue decreased ($P < 0.01$) after 42 days of aging. In contrast, collagen crosslink density increased ($P < 0.05$) after 42 days of postmortem aging. Striploin had a decrease ($P < 0.05$) in the connective tissue (CT) degradation product from 3 to 21 to 42 days, and heel had a reduction ($P < 0.01$) in the CT degradation product from 3 to 42 days. A collagenase at 72 kDa was identified as matrix metalloproteinase-9 (MMP-9) through Western blot. The MMP-9 activity was detected throughout the different muscles and aging periods and had the greatest activity at three days of aging, which decreased ($P < 0.01$) from 3 to 21 to 42 days.

Introduction

Beef tenderness is mostly dictated by myofibrillar protein and connective tissue properties with the former receiving much greater research focus than the latter. Collagen is one of the main components in connective tissue (CT) and contributes to background toughness in beef. It is known that in living animals, collagen can be degraded and remodeled by collagenase matrix metalloproteinases (MMP); however, it is unclear if collagenase MMPs can impact CT texture during postmortem aging of beef. Therefore, this study aimed to characterize native beef collagenase activity and understand how its activity may impact tenderness by postmortem connective tissue degradation in three different beef cuts and four different aging periods.

Experimental Procedures

Beef boneless striploin, top sirloin butt, and heel from both sides were acquired from ten U.S. Department of Agriculture high choice beef carcasses. Each muscle was fabricated into steaks and aged at 35.6°F for four different aging periods: 3, 21, 42, and 63 days. Warner-Bratzler shear force (WBSF), connective tissue shear force (CTSF), and evaluations by trained panelists were performed to measure tenderness.

Native collagenase activity was measured by zymography gels casted with bovine type I collagen, and collagenase identity was identified as MMP-9 through Western blot. To identify changes in intramuscular connective tissue (IMCT) components, collagen content, denaturation temperature of CT, collagen crosslinks density, and CT degradation product were performed.

Results and Discussion

It was expected to find heel and top sirloin butt being tougher than striploin ($P < 0.01$; Table 1). Cuts from muscles used for locomotion usually have a greater proportion of connective tissue due to their needs to sustain greater force in their functions. This research demonstrated a decrease in connective tissue amount detected by the trained panelists ($P < 0.05$; Table 2) and CTSF ($P < 0.05$; Table 3) during the aging process. These results are evidence indicating that CT can also go through a weakening/degradation process during postmortem aging. Locomotive muscles had more ($P < 0.01$) collagen content than supportive muscles as expected; however, no changes in collagen content during the aging period was detected ($P > 0.10$). However, an increase in mature collagen crosslink density was detected ($P < 0.05$) with extended aging period, but denaturation temperature of connective tissue decreased ($P < 0.01$) with advanced aging time. This was unexpected as mature collagen crosslinks are known to be thermally stable and likely contribute to meat toughness. This finding indicates that there may be modifications in other connective tissue components or other type of collagen crosslinks. The MMP-9 was identified at the 72 kDa band in the zymography gels (Figure 1). Evidence is provided in this study that collagen is being modified by MMPs as MMP-9 activity was found in beef from all four aging periods evaluated. Moreover, there was a decrease ($P < 0.01$) in MMP-9 activity after extended aging, which might be explained by the gradual inactivation of endogenous enzymes throughout the aging process. Finally, CT degradation product decreased ($P < 0.01$) during aging, and this phenomenon could also suggest a further breakdown occurring. Although CT degradation product is independent of collagen degradation, this noted degradation is also due to the action of MMPs.

Implications

This study showed that IMCT is going through some changes that softened IMCT during postmortem aging, and MMP-9 is active in postmortem beef muscles. Understanding this mechanism may assist the beef industry to improve tenderness in lower quality beef cuts through the manipulation of MMP-9 activity in beef.

Acknowledgment

The Beef Checkoff.

Table 1. Main effect of beef cut for Warner-Bratzler shear force (WBSF), connective tissue amount and overall tenderness evaluated by the trained panelists, collagen content, and MMP-9 activity of three different beef muscles aged for 3, 21, 42, or 63 days (n = 120)

	Muscle				
Items	Boneless striploin	Top sirloin butt	Heel	SEM[1]	*P*-value
WBSF, lb	7.52[b]	9.68[a]	9.46[a]	0.14	< 0.01
Connective tissue amount scores[2]	12.72[b]	16.68[a]	17.93[a]	1.24	< 0.01
Overall tenderness scores[3]	60.28[a]	50.28[b]	57.94[a]	1.26	< 0.01
Collagen, %	0.50[b]	0.80[a]	0.91[a]	0.82	< 0.01
MMP-9, fold change	0.80[b]	1.04[b]	1.91[a]	0.14	< 0.01

[a-b] Values within a row with different superscripts differ significantly at $P < 0.05$.
[1]SEM = Standard error of the mean.
[2]Connective tissue scores: 0 = none; 100 = extremely abundant.
[3]Overall tenderness scores: 0 = extremely tender; 50 = neither tender or tough; 100 = extremely tough.

Table 2. Main effect of aging period for Warner-Bratzler shear force (WBSF), connective tissue amount, and overall tenderness evaluated by the trained panelists, transition temperature of connective tissue, collagen crosslink density, and MMP-9 activity of three different beef muscles aged for 3, 21, 42, or 63 days (n = 120)

	Aging (days)					
Items	3	21	42	63	SEM[1]	*P*-value
WBSF, lb	10.32[a]	8.66[b]	8.58[b]	8.02[b]	0.13	< 0.01
Connective tissue amount score[2]	19.44[a]	14.01[b]	13.87[b]	14.34[b]	1.69	< 0.05
Overall tenderness score[3]	50.69[b]	56.12[a]	58.45[a]	59.43[a]	1.52	< 0.01
Denaturation temperature of collagen, °F	149.74[a]	149.92[a]	148.71[b]	148.5[b]	0.20	< 0.01
Collagen crosslink density, mol/mol	0.13[b]	0.14[ab]	0.16[a]	0.16[a]	0.01	< 0.05
MMP-9, fold change	2.46[a]	1.05[b]	0.72[c]	0.75[c]	0.12	< 0.01

[a-c] Values within a row with different superscripts differ significantly at $P < 0.05$.
[1]SEM = Standard error of the mean.
[2]Connective tissue amount scores: 0 = none; 100 = extremely abundant.
[3]Overall tenderness scores: 0 = extremely tender; 50 = neither tender or tough; 100 = extremely tough.

Table 3. Connective tissue shear force (CTSF) and aggrecan fragmentation of three different beef muscles aged for 3, 21, 42, or 63 days (n = 120)

Items	Age (days)	Muscles: Boneless striploin	Muscles: Top sirloin butt	Muscles: Heel	SEM[1]	*P*-value: Muscle × age
CTSF, lb	3	7.41^{Aa}	7.67^{Aa}	8.44^{Aa}	0.18	< 0.05
	21	6.55^{ABa}	7.19^{Aa}	6.75^{Ba}		
	42	5.95^{Bb}	8.16^{Aa}	7.19^{Ba}		
	63	5.51^{Bb}	7.39^{Aa}	7.25^{Ba}		
CT degradation product, fold change	3	0.77^{Aa}	0.09^{Ab}	0.70^{Aa}	0.1	< 0.01
	21	0.50^{Ba}	0.02^{Ab}	0.52^{ABa}		
	42	0.17^{Ca}	0.04^{Aa}	0.29^{Ba}		
	63	0.06^{Ca}	0.04^{Aa}	0.22^{Ba}		

[a-b]Within a row, means without a common superscript differ at $P < 0.05$.
[A-B]Within a column of one item, means without a common superscript differ at $P < 0.05$.
[1]SEM = Standard error of the mean.

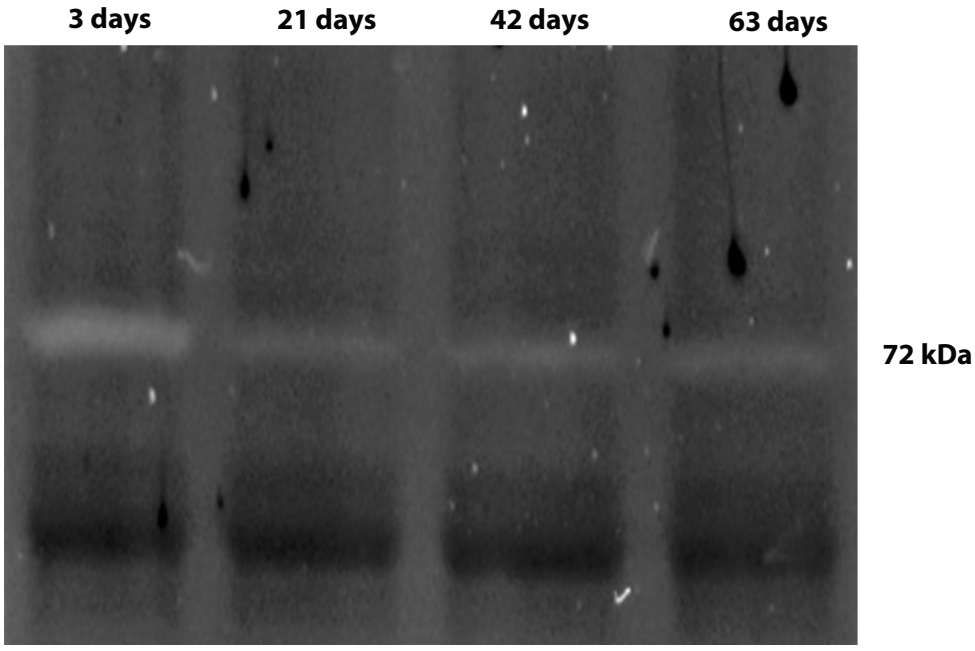

Figure 1. Representative image of MMP collagenase identified by collagen zymography in beef boneless striploin.

An Investigation on the Influence of Various Biochemical Tenderness Factors on Eight Different Bovine Muscles

P.A. Hammond, C.K.Y. Chun, W. Wu, A.A. Welter, T.G. O'Quinn, G. Magnin-Bissel, E. Geisbrecht, and M.D. Chao

Abstract

The objective of this study was to identify the relative contribution of tenderness factors for eight beef muscles with various tenderness ratings. Top sirloin butt (TS), ribeye (R), brisket (B), flank (F), knuckle (K), eye of round (ER), chuck tender (CT), and shoulder clod (SC) were collected from ten U.S. Department of Agriculture upper 2/3 choice beef carcasses and were assigned to a 2- or 21-day aging period (n = 160). Sarcomere length, protein degradation, collagen content, mature collagen crosslink density, intramuscular lipid content, Warner-Bratzler Shear Force (WBSF), and trained sensory panel analysis were determined. Based on the correlation analysis, overall tenderness of F, CT, and SC were largely driven by the proteolysis of muscle fiber fibers (r = 0.45, 0.55, and 0.55, respectively; $P < 0.05$). In contrast, overall tenderness for B was determined by collagen content (r = -0.48; $P < 0.05$). Finally, overall tenderness of TS was correlated with lipid content (r = 0.51; $P < 0.05$). Interestingly, when all the cuts were combined together and analyzed as a whole, all of the biochemical measurements conducted in this study played a small but important role as an overall tenderness contributor ($P < 0.05$). Results from this study filled in some of the knowledge gap on the relative contribution of each tenderness component to the overall perception of tenderness from each cut. The industry can utilize this information to provide tenderness management strategies for each cut as well as improve the robustness of current tenderness predicting technology.

Introduction

Tenderness encompasses a universal term describing the amount of force required to bite through a piece of meat. Three factors underlie the complexity of tenderness: 1) the actomyosin effect or the influence of muscle fibers; 2) the background effect or the influence of connective tissue; and 3) the bulk density or lubrication effect, or the tenderness contributed by intramuscular fat. Each of these factors are further influenced by many different components contributing to the overall beef tenderness. Countless studies over the past three decades have evaluated the impact of various individual tenderness contribution components on meat tenderness. These components include proteolysis, sarcomere length, fat content, collagen content, and collagen crosslinks. However, the overall perception of beef tenderness is dependent on all the tenderness components as well as the interaction among them, and evaluating one or two tenderness components does not provide the whole picture. Therefore, the objective of this study was to better understand the relationships of various biochemical tenderness-contributing components to the overall tenderness perception of eight different beef muscles.

Experimental Procedures

Ten U.S. Department of Agriculture upper 2/3 choice beef carcasses at one day postmortem were selected from a Midwest beef packing plant. Muscles TS, R, B, K, ER, and SC were collected only from the left side of the carcass. The F and CT muscles were collected from both sides of the carcass. The selected cuts of beef were vacuum packaged and transported to the Kansas State University Meat Lab for fabrication. The muscles were fabricated into steaks and assigned to two aging periods: 2 or 21 days. After aging, the sarcomere length, protein degradation, collagen content, mature collagen crosslink density, intramuscular lipid content, Warner-Bratzler Shear Force (WBSF), and trained sensory panel analysis were determined. The data were analyzed as a split plot design, with the whole plot being the beef cut, and the sub-plot factors being the aging time and the cut × aging time interaction.

Results and Discussion

As expected, all muscles studied increased in protein degradation from 2 to 21 days of postmortem storage ($P < 0.05$; Table 1). It is interesting to note that different muscles have different levels of protein degradation after aging. For example, R, B, K, ER, CT, and SC had more protein degradation ($P < 0.05$) compared to F after 21 days of aging. Due to the muscle function difference, B, K, CT, ER, and SC displayed greater collagen content ($P < 0.01$) compared to R and F (Figure 1), while TS was not different in collagen content ($P < 0.01$) compared to R and F. Muscles B and ER had greater collagen crosslink densities ($P < 0.01$) compared to the rest of the muscles (Figure 2). This result was expected since locomotive functions tend to display greater amounts of collagen content and higher collagen crosslink densities than muscles with a more postural or support function. Connective tissue layers specifically support and provide framework for transmission of contractile forces, therefore muscles that undergo more mechanical stress would be expected to contain higher amounts of collagen.

The differences in sarcomere length are potentially the result of differences in muscle fiber type. Muscles B and F displayed the longest sarcomeres, while R and TS displayed the shortest sarcomeres among the eight muscles evaluated ($P < 0.01$; Figure 3). The muscles that contain mainly oxidative muscle fibers displayed longer sarcomeres compared to muscles that contain mainly glycolytic muscle fibers. This may be because oxidative muscle fibers tend to contain lower levels of adenosine triphosphate (ATP) and reach rigor much faster than glycolytic fibers.

Most likely due to muscle function differences and muscle fiber type, F and R displayed the first and second greatest lipid contents, followed by TS, K, ER, and B, with CT having the lowest lipid content among the eight muscles evaluated ($P < 0.01$; Figure 4). Locomotive muscles tend to have lower lipid content compared to support muscles. Also, F most likely contains a large amount of lipid due to the prevalence of oxidative muscle fibers, which tend to be higher in lipid content.

As expected, B had the greatest WBSF value, while F and R exhibited the lowest WBSF values ($P < 0.05$; Figure 5). According to the biochemical analysis, R was expected to have one of the lowest WBSF values due to large amounts of protein degradation, low amounts of collagen content and collagen crosslink density, and a relatively high lipid content compared to the other muscles. On the other hand, B displayed long sarcomere lengths and displayed a fair amount of protein degradation at 21 days; however,

B still had the highest WBSF values. The high WBSF value for B was likely attributed to the high amount of collagen and the highest collagen crosslink density found in the muscles. The higher rating for F's overall tenderness was likely attributed to the bulk density effect, for it had the highest lipid content. In addition, F displayed one of the longest sarcomere lengths. Shorter sarcomere lengths in comparison to longer sarcomere lengths are usually contracted muscle fibers and tend to increase toughness of the muscle due to the increased overlap of thick and thin filaments, requiring more penetration force. Furthermore, correlations between sarcomere length and tenderness tend to be strong in muscles that contain mainly oxidative fibers.

At 21 days of aging, R, F, and SC displayed the highest overall tenderness rating, followed by TS, K, CT, and ER, with B displaying the lowest rating for overall tenderness when evaluated by trained panelists ($P < 0.05$; Table 1). It is interesting to note that K and B only improved minimally in overall tenderness after 21 days of postmortem aging, while the other muscles improved significantly in overall tenderness. The correlation analysis is displayed in Table 2. The overall tenderness for TS showed a positive correlation with lipid content (r = 0.51; $P < 0.05$). The overall tenderness for B showed a negative correlation with collagen content (r = -0.48; $P < 0.05$) and a positive correlation with collagen crosslink density (r = 0.52; $P < 0.05$). There was a positive correlation for overall tenderness and protein degradation for F, CT, and SC (r = 0.45, 0.55, and 0.55, respectively; $P < 0.05$). On the other hand, overall tenderness for B may be driven by collagen content (r = -0.48; $P < 0.05$), and overall tenderness for TS was correlated with lipid content (r = 0.51; $P < 0.05$). Finally, the overall tenderness value for the combination of all eight cuts used in this study (n = 160) showed positive correlations for protein degradation (r = 0.33; $P < 0.05$) and lipid content (r = 0.22; $P < 0.05$), and a negative correlation for collagen content (r = -0.23; $P < 0.05$), collagen crosslink density (r = -0.24; $P < 0.05$), and sarcomere length (r = -0.41; $P < 0.05$).

Implications

Results from this study filled in some of the knowledge gap on the relative contribution of each tenderness component to the overall perception of tenderness from each cut. The industry can utilize this information to provide a tenderness management strategy for each cut as well as improve the robustness of current technology to predict tenderness.

Table 1. Interaction effects of eight retail beef cuts[1] aged for 2 or 21 days (n = 160)

Items	Days of aging	TS	R	B	F	K	ER	CT	SC	SEM[2]	*P*-value
Protein degradation, %										4.88	<0.05
	2	36.45^{Babc}	39.43^{Bab}	20.33^{Bd}	26.72^{Bcd}	44.56^{Ba}	30.64^{Bbcd}	36.53^{Babc}	28.77^{Bbcd}		
	21	50.87^{Abc}	62.23^{Aab}	55.47^{Aab}	40.88^{Ac}	64.67^{Aa}	53.89^{Aab}	61.29^{Aab}	60.47^{Aab}		
Overall tenderness[3]										2.87	<0.05
	2	42.30^{Bcd}	57.61^{Ba}	16.94^{Ae}	44.84^{Bbc}	50.23^{Bab}	37.95^{Bcd}	37.15^{Bd}	51.69^{Bab}		
	21	54.74^{Ac}	70.23^{Aa}	19.85^{Ad}	61.50^{Ab}	53.08^{Ac}	54.16^{Ac}	51.11^{Ac}	60.64^{Ab}		
Connective tissue amount[3]										2.84	<0.05
	2	31.05^{Ade}	19.95^{Af}	69.33^{Aa}	38.98^{Abc}	25.4^{Aef}	35.08^{Acd}	43.28^{Ab}	25.71^{Aef}		
	21	17.20^{Bd}	9.09^{Ae}	67.13^{Aa}	28.41^{Bb}	26.3^{Ab}	18.69^{Bcd}	23.70^{Bbc}	18.16^{Bd}		

$^{A-B}$Within a column, means without a common superscript differ at $P < 0.05$.

$^{a-f}$Within a row, means without a common superscript differ at $P < 0.05$.

[1]TS = Top sirloin butt; R = Ribeye; B = Brisket; F = Flank; K = Knuckle; ER = Eye of round; MT = Mock tender; SC = Shoulder clod.

[2] Standard error mean.

[3] Sensory scores: 0 = extremely tough/none 50 = neither tough nor tender; 100 = extremely tender/abundant.

Table 2. Correlation coefficient (r) of overall tenderness (trained panel) with different tenderness components of eight retail beef cuts[1]

Treatment	All cuts	TS	R	B	F	K	ER	CT	SC
Protein degradation	0.33*	0.15	0.43	0.37	0.45*	0.29	0.55*	0.37	0.55*
Collagen content	-0.23*	-0.08	0.37	-0.48*	-0.17	0.08	-0.29	0.13	0.05
Collagen crosslink density	-0.24*	-0.12	-0.07	0.52*	-0.21	0.34	0.35	0.07	-0.12
Lipid content	0.22*	0.51*	-0.36	0.20	0.05	-0.19	0.11	-0.38	-0.07
Sarcomere length	-0.41*	0.09	0.16	-0.16	-0.21	-0.28	-0.31	-0.14	-0.31

*$P < 0.05$

[1]TS = Top sirloin butt; R = Ribeye; B = Brisket; F = Flank; K = Knuckle; ER = Eye of round; MT = Mock tender; SC = Shoulder clod.

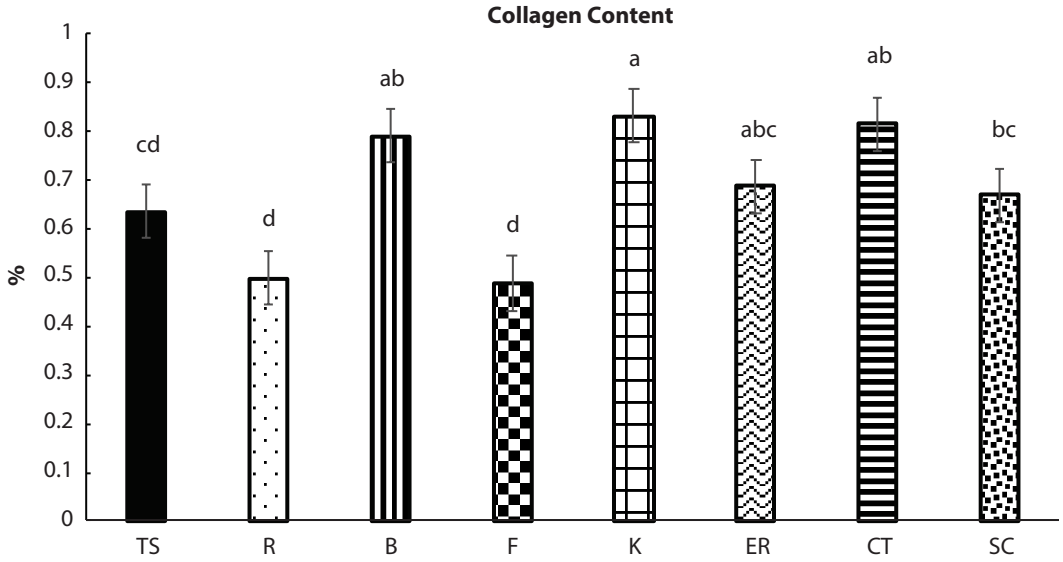

Figure 1. Collagen content of eight retail beef cuts (n = 160). TS = Top sirloin butt; R = Ribeye; B = Brisket; F = Flank; K = Knuckle; ER = Eye of round; MT = Mock tender; SC = Shoulder clod.

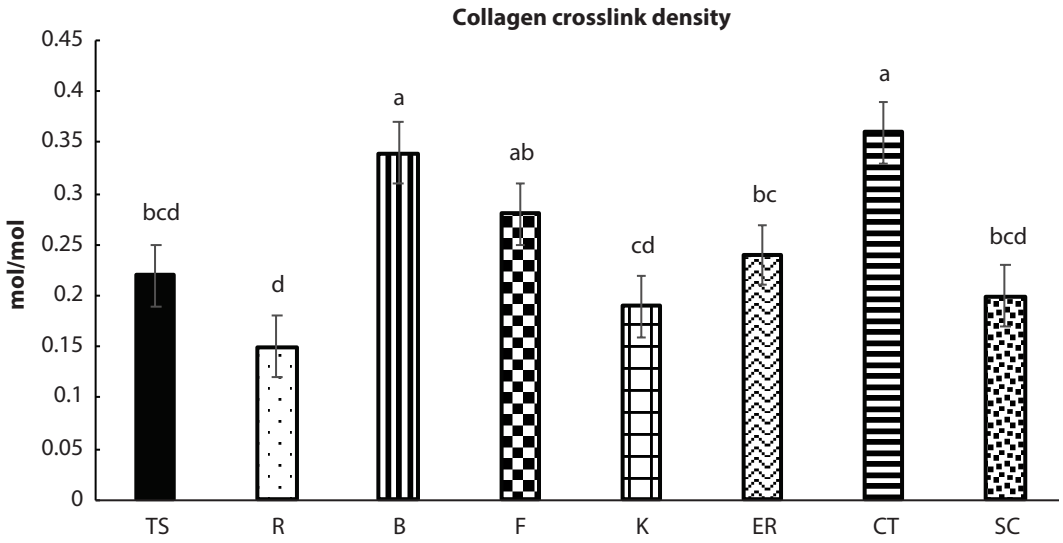

Figure 2. Collagen crosslink density of eight retail beef cuts (n = 160). TS = Top sirloin butt; R = Ribeye; B = Brisket; F = Flank; K = Knuckle; ER = Eye of round; MT = Mock tender; SC = Shoulder clod.

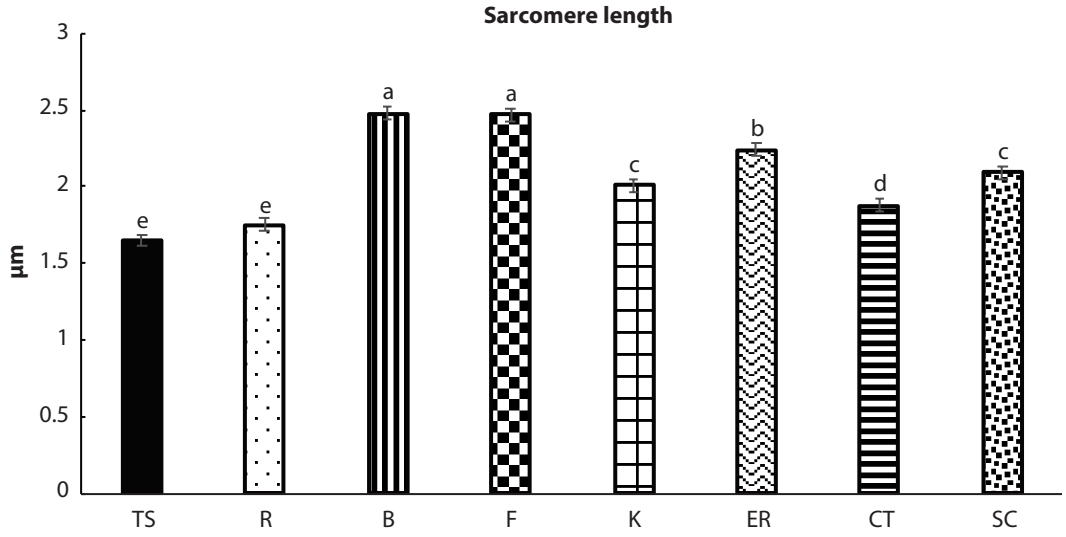

Figure 3. Sarcomere length of eight retail beef cuts (n = 160). TS = Top sirloin butt; R = Ribeye; B = Brisket; F = Flank; K = Knuckle; ER = Eye of round; MT = Mock tender; SC = Shoulder clod.

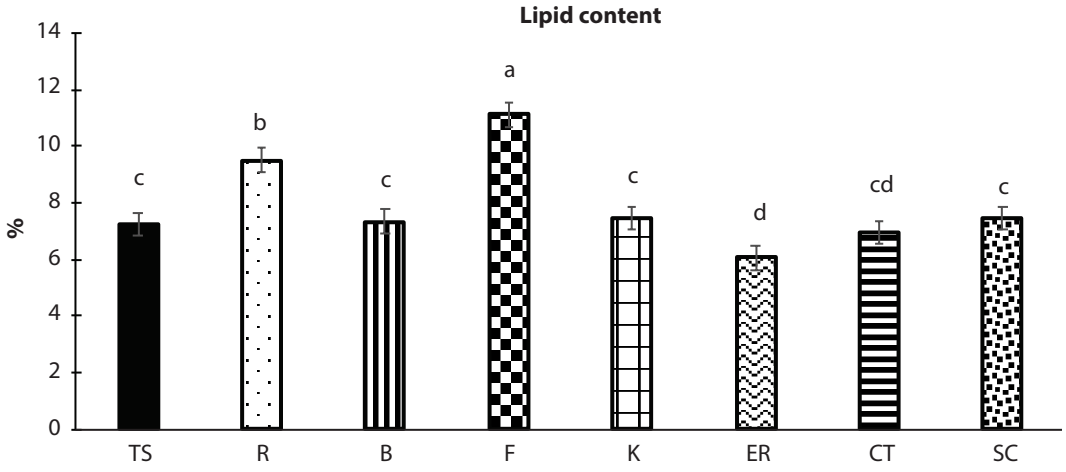

Figure 4. Lipid Content of eight retail beef cuts (n = 160). TS = Top sirloin butt; R = Ribeye; B = Brisket; F = Flank; K = Knuckle; ER = Eye of round; MT = Mock tender; SC = Shoulder clod.

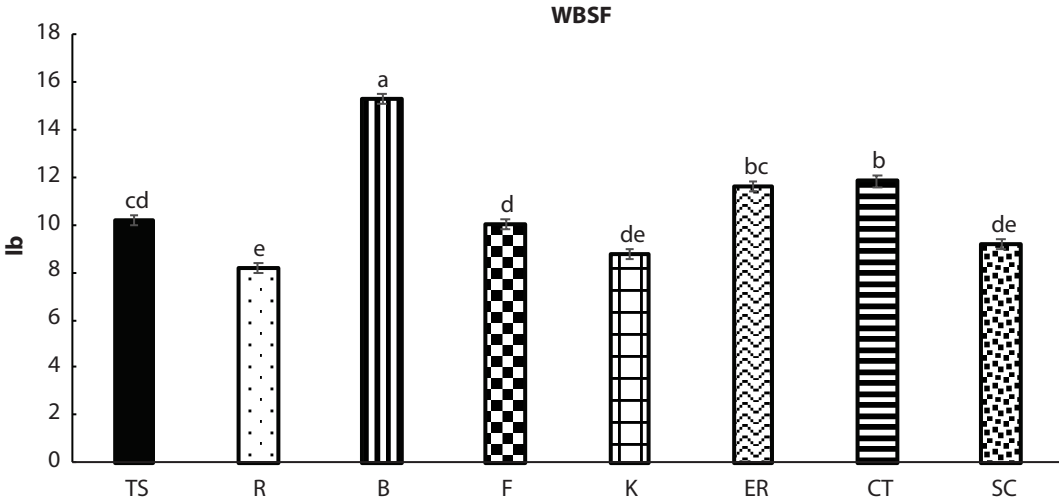

Figure 5. Warner-Bratzler Shear Force (WBSF) of eight retail beef cuts (n = 160). TS = Top sirloin butt; R = Ribeye; B = Brisket; F = Flank; K = Knuckle; ER = Eye of round; MT = Mock tender; SC = Shoulder clod.

Exploring the Potential Effect of Phospholipase A2 Antibody to Extend Beef Shelf-Life in a Beef Liposome Model System

C.K.Y. Chun, R. Welti, M. Roth, M.P. Richards,[1] and M.D. Chao

Abstract

The objective of this study was to utilize a beef liposome model system to investigate if phospholipase A2 antibody (aPLA2) can be used to inhibit phospholipase A2 (PLA2) activity to potentially improve beef shelf-life. The phospholipid (PL) from 10 steaks were split into six different treatments in a 2.5 mL buffer solution: 1) PL (25 mg of PL); 2) aPLA10 (PL+ 25 μg of aPLA2); 3) aPLA20 (PL + 50 μg of aPLA2); 4) PLA2 (PL + 10 μg of PLA2); 5) PLA2+aPLA10 (PL + PLA2 + 25 μg of aPLA2); and 6) PLA2+aPLA20 (PL + PLA2 + 50 μg of aPLA2). An aliquot was taken from each of the 6 treatments for PL profile analysis and product ion analysis by mass spectrometry. Eighty μM of bovine myoglobin was added to the remaining samples and exposed to retail display conditions (39°F; 2300 lux) for 7 days. At day 0, 1, 4, and 7, aliquots were taken for lipid oxidation analysis. There was a display × treatment interaction *(P* < 0.01) for lipid oxidation. At day 7 of display, PLA2, PLA2+aPLA10, and PLA2+aPLA20 treatments had greater (*P* < 0.01) lipid oxidation compared to the samples without PLA2. This trend was seen in the other retail display periods. The PL profile analysis showed clear differences between treatments with or without PLA2. The PLA2 treatments showed greater *(P* < 0.01) relative percent of total lysophosphatidylcholine (LysoPC) than treatments without PLA2. The PLA2 treatments had less *(P* < 0.05) relative percent of total ether-linked phosphatidylcholine (ePC) than treatments without PLA2, specifically, ePC 34:1, 34:2, 34:4, 36:1, 36:3, and 36:4. Finally, it appeared that aPLA2 had no effect on inhibiting PLA2 hydrolysis as there was no difference *(P* > 0.10) between PLA2 and aPLA+PLA2 treatments in relative percent of total ePC, phosphatidylcholine (PC) as well in LysoPC composition.

Introduction

Phospholipase-A_2 (PLA2) is the ubiquitous enzyme that cleaves a fatty acid tail at the sn-2 position from a phosphatidylcholine (PC), an abundant phospholipid (PL) class in cell membranes. The resulting free fatty acids (FFA) are typically polyunsaturated fatty acids (PUFA) which are prone to lipid oxidation when exposed to pro-oxidants such as light and oxygen. A PLA2 antibody (aPLA2) can be mass-produced through laying hens, and the egg powder containing aPLA2 has been used as a feed supplement to improve growth performance for various livestock. We hypothesized that the aPLA2 from egg powder may inhibit PLA2 activity, thus preventing the formation of FFA, which can potentially improve the shelf stability of beef. Therefore, the objective of this study was to utilize a beef liposome model system to investigate this proposed mechanism.

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Experimental Procedures

Total lipid was extracted from 10 U.S. Department of Agriculture choice beef loins at 3 days post-mortem via chloroform, methanol, and water. Phospholipids were separated from each lipid pool using solid phase extraction with amino propyl silica cartridges. Solvents were evaporated under vacuum and nitrogen gas. Phospholipids from each steak were further split into six different treatments: 1) PL (25 mg of PL); 2) aPLA10 (PL + 25μg of aPLA2); 3) aPLA20 (PL + 50μg of aPLA2); 4) PLA2 (PL + 10μg of PLA2); 5) PLA2+aPLA10 (PL + PLA2 + 25μg of aPLA2); 6) PLA2+aPLA20 (PL + PLA2 + 50 μg of aPLA2). Phospholipase A2 antibody was extracted from hyperimmunized eggs, and porcine pancreatic PLA2 was used. Treatments were mixed with a tris/$CaCl_2$ buffer (pH 8.0) and incubated at 98°F for 2 hours to activate PLA2. After incubation, an aliquot was immediately taken for PL profile analysis and product ion analysis by mass spectrometry. Eighty μM of bovine myoglobin was added to the remaining model system and exposed to retail display conditions (39°F; 2300 lux) for 7 days. At days 0, 1, 4, and 7, aliquots were taken for lipid oxidation analysis as determined with the 2-thiobarbituric acid reactive substances protocol (TBARS) and calculated as mg of malondialdehyde (MDA) per mg of phospholipid.

Results and Discussion

As expected, the PL profile analysis showed clear differences between treatments with or without PLA2. The PLA2 treatments showed greater relative percent of total lysophosphatidylcholine (LysoPC) than treatments without PLA2 (Figure 1; $P < 0.01$). Again, in PLA2 treatments individual LysoPC species 16:0, 16:1, 18:0, and 18:1 had higher relative percent than treatments without PLA2 (Figure 2; $P < 0.01$). The PLA2 treatments had significantly less relative percent of total ePC than treatments without PLA2 (Figure 1), specifically, ePC 36:1, 36:2, 36:3, 36:4, and 36:5 (Figure 3; $P < 0.05$). Also, in phosphatidylethanolamine (PE), PLA2 treatments had significantly less relative percent than treatments without PLA2 (Figure 1; $P < 0.01$). Interestingly, the PLA2 treatments did not seem to have significant effect on relative percent of total PC as seen in ePC as treatments were not significantly different (Figure 1; $P > 0.10$). It appears that aPLA2 had no effect on inhibiting PLA2 hydrolysis as there was no difference between PLA2 and PLA2+aPLA treatments in relative percent of total ePC, PC, or in PL degradation products ($P > 0.10$). Product ion analysis revealed for ePC species the major fatty acid combinations consisted of 18:0/18:1, 18:0/18:1, 18:1/18:2, and 18:2/18:2 (Table 1). There was a display × treatment interaction for lipid oxidation (Figure 5; $P < 0.01$). At 7 days of display, PLA2, PLA2+aPLA10, and PLA2+aPLA20 treatments had greater lipid oxidation than treatments without PLA2 added ($P < 0.01$). A similar trend was seen within earlier display days as well. At 4 days, PLA2+aPLA20 had less oxidation than 4-day PLA2 ($P < 0.05$). Interestingly, 7-day aPLA10 and aPLA20 had less lipid oxidation than 7-day PL and less oxidation than 4-day PLA2 ($P < 0.05$), potentially through an oxidation effect. This study confirms that PLA2 significantly alters PL composition and that the hydrolysis of PL by PLA2 influences lipid oxidation. Although no inhibition effect was observed for PLA2 by aPLA2, there appears to be an antioxidant effect for aPLA2 for lipid oxidation. However, PLA2 appears to attack ePC more effectively than PC and shows a preference for hydrolyzing PL containing 18:2 over 20:4.

Implications

Phospholipase A2 significantly alters beef phospholipids composition, making it more susceptible to lipid oxidation. Although no inhibition effect was observed for PLA2 by aPLA2, there appears to be an antioxidant effect for aPLA2 for lipid oxidation.

Acknowledgments

The authors appreciate the Kansas State University Global Food System Initiative for funding this project. The lipid analyses described in this work were performed at the Kansas Lipidomics Research Center Analytical Laboratory. Instrument acquisition and lipidomics method development was supported by the National Science Foundation, K-IDeA Networks of Biomedical Research Excellence (INBRE) of National Institute of Health (P20GM103418), and Kansas State University.

Table 1. Likely combinations of fatty acids identified

Apparent lipid molecular species (total acyl carbons:total double bonds)	Fatty acid combinations identified	Relative abundance (%)
ePC[1]		
36:1	18:0/18:1	54.64
36:2	18:0/18:2	46.48
	18:1/18:1	37.82
36:3	18:1/18:2	78.13
	16:0/20:3	9.51
36:4	18:2/18:2	46.10
	16:1/20:3	22.73
	16:0/20:4	21.60
36:5	16:1/20:4	78.69
PC[2]		
36:1	18:0/18:1	81.70
36:2	18:1/18:1	47.22
	18:0/18:2	43.62
	16:0/20:2	3.80
36:3	18:1/18:2	83.39
	16:0/20:3	10.56
	18:0/18:3	6.05
36:4	16:0/20:4	65.32
	18:2/18:2	19.00
	18:1/18:3	7.9
36:5	16:1/20:4	69.36
	16:0/20:5	18.13

[1]ePC = ether-linked phosphatidylcholine.
[2]PC = phosphatidylcholine.

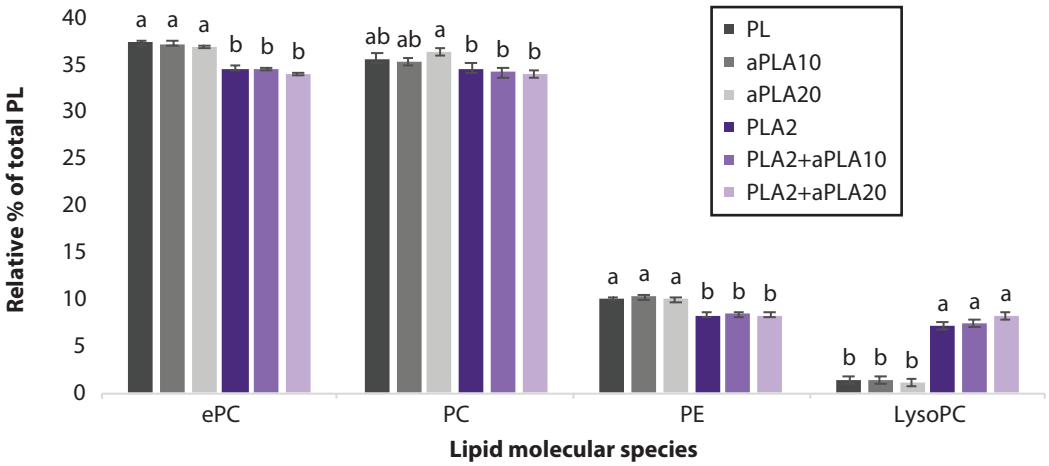

Figure 1. Effects of treatment on relative percent of ether-linked phosphatidylcholine (ePC), phosphatidylcholine (PC), phosphatidylethanolamine (PE) and lysophosphatidylcholine (LysoPC) of total phospholipid (PL). [ab]Means within molecular species differ ($P < 0.01$). Treatments: PL (25 mg of PL); aPLA10 [PL + 25 μg of phospholipase-A_2 antibody (aPLA2)]; aPLA20 (PL + 50 μg of aPLA2); PLA2 (PL + 10 μg of PLA2; 5) PLA2+aPLA10 (PL + PLA2 + 25 μg of aPLA2); and PLA2+aPLA20 (PL + PLA2 + 50 μg of aPLA2).

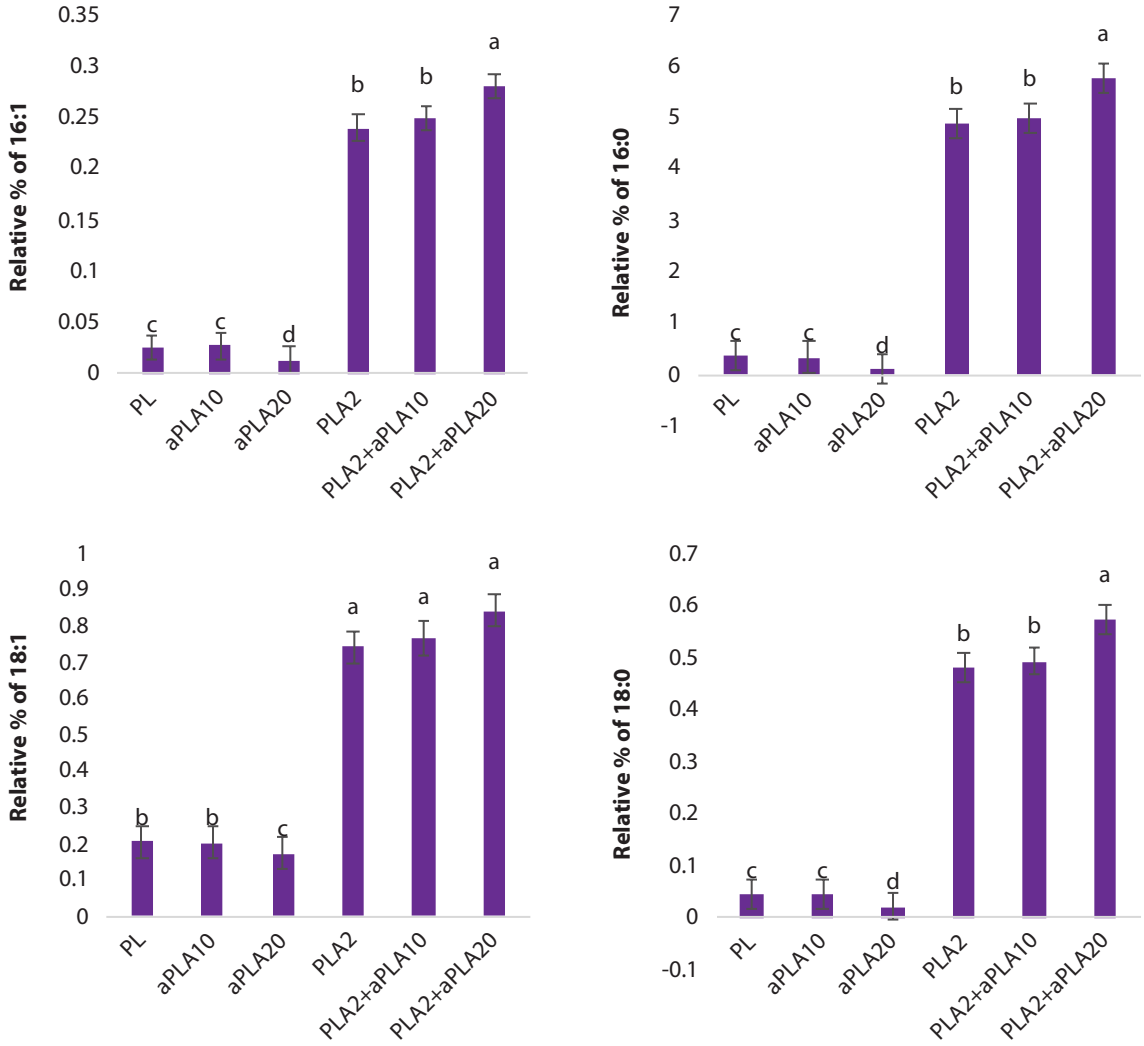

Figure 2. Effects of treatment on relative percent of individual lysophosphatidylcholine (LysoPC) species. [a-d]Means within treatment for each LysoPC species differ ($P < 0.05$). Treatments: PL (25 mg of PL); aPLA10 [PL + 25 µg of phospholipase-A_2 antibody (aPLA2)]; aPLA20 (PL + 50 µg of aPLA2); PLA2 (PL + 10 µg of PLA2); 5) PLA2+aPLA10 (PL + PLA2 + 25 µg of aPLA2); and PLA2+aPLA20 (PL + PLA2 + 50 µg of aPLA2).

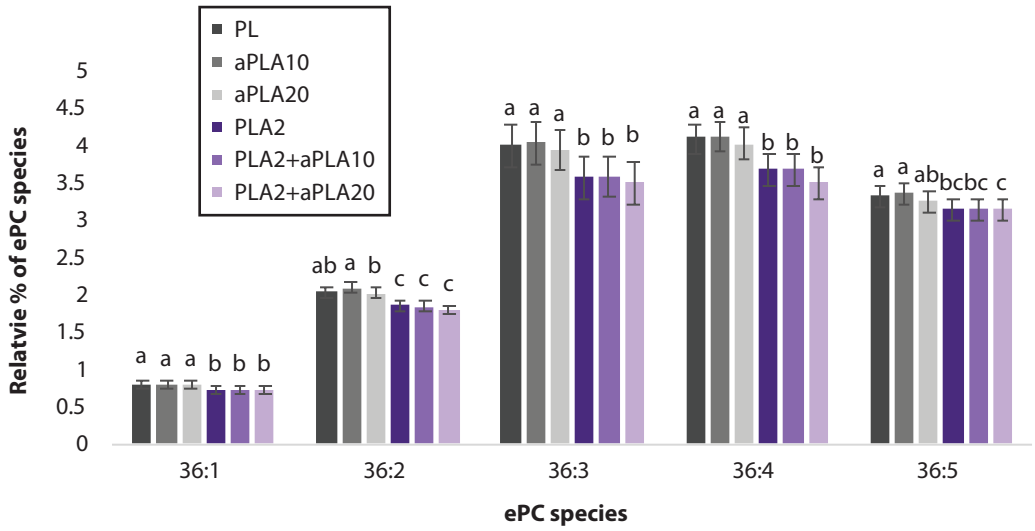

Figure 3. Effects of treatment on relative percent of ether-linked phosphatidylcholine (ePC) species. [a-c]Means within ePC species differ ($P < 0.05$). Treatments: PL (25 mg of PL); aPLA10 [PL + 25 µg of phospholipase-A_2 antibody (aPLA2)]; aPLA20 (PL + 50 µg of aPLA2); PLA2 (PL + 10 µg of PLA2); 5) PLA2+aPLA10 (PL + PLA2 + 25 µg of aPLA2); and PLA2+aPLA20 (PL + PLA2 + 50 µg of aPLA2).

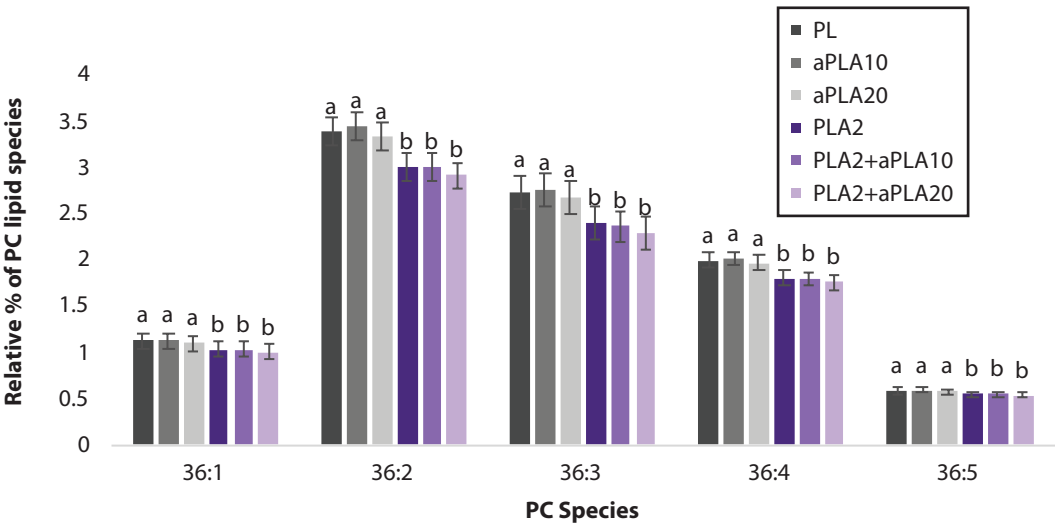

Figure 4. Effects of treatments on relative percent of phosphatidylcholine (PC) species. [ab]Means within PC species differ ($P < 0.05$). Treatments: PL (25 mg of PL); aPLA10 [PL + 25 µg of phospholipase-A_2 antibody (aPLA2)]; aPLA20 (PL + 50 µg of aPLA2); PLA2 (PL + 10 µg of PLA2); 5) PLA2+aPLA10 (PL + PLA2 + 25 µg of aPLA); and PLA2+aPLA20 (PL + PLA2 + 50 µg of aPLA2).

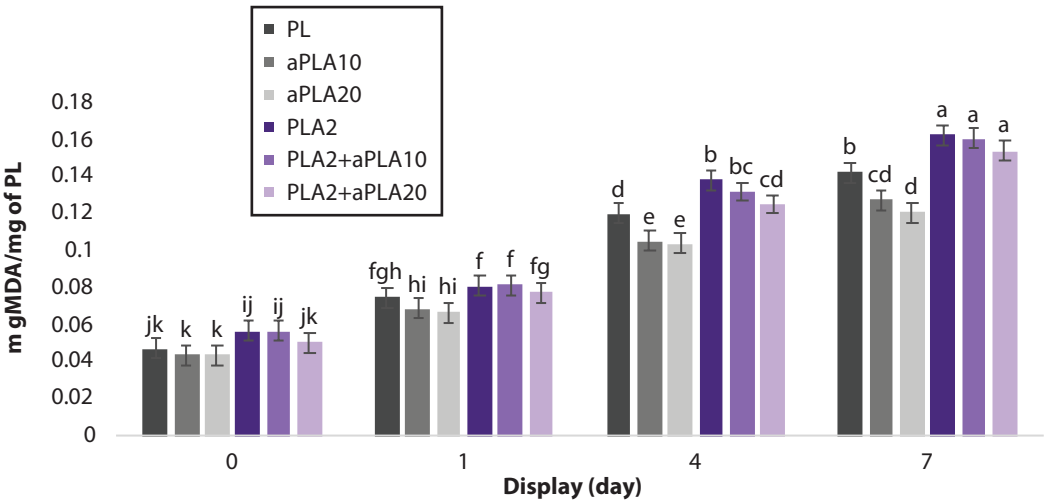

Figure 5. Effects of display and treatment on lipid oxidation analysis. [a-k]Means within bars differ ($P < 0.01$). MDA = malondialdehyde; PL = phospholipid. Treatments: PL (25 mg of PL); aPLA10 [PL + 25 μg of phospholipase-A_2 antibody (aPLA2)]; aPLA20 (PL + 50 μg of aPLA2); PLA2 (PL + 10 μg of PLA2); 5) PLA2+aPLA10 (PL + PLA2 + 25 μg of aPLA2); and PLA2+aPLA20 (PL + PLA2 + 50 μg of aPLA2).

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