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Effects of Optaflexx alone or in combination with BoVantage on the performance and carcass merit of finishing heifers

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Cattlemen's Day 2014

Beef Cattle Research

Report of Progress 1101

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Cattlemen's Day 2014

Beef Cattle Research

Contents

Nutrition

Meat and Food Safety

Biological Variability and Chances of Error

Variability among individual animals in an experiment leads to problems in interpreting the results. Animals on treatment X may have higher average daily gains than those on treatment Y, but variability within treatments may indicate that differences in production between X and Y were not the result of treatment alone. Statistical analysis allows us to calculate the probability that such differences are from treatment rather than chance.

In some of the articles herein, you will see the notation $P < 0.05$. That means the probability of the differences resulting from chance is less than 5%. If two averages are said to be significantly different, the probability is less than 5% that the difference is from chance, or the probability exceeds 95% that the difference resulted from the treatments applied.

Some papers report correlations or measures of the relationship between traits. The relationship may be positive (both traits tend to get larger or smaller together) or negative (as one trait gets larger, the other gets smaller). A perfect correlation is one (+1 or -1). If there is no relationship, the correlation is zero.

In other papers, you may see an average given as 2.5 ± 0.1. The 2.5 is the average; 0.1 is the standard error. The standard error is calculated to be 68% certain that the real average (with an unlimited number of animals) would fall within one standard error from the average, in this case between 2.4 and 2.6.

Using many animals per treatment, replicating treatments several times, and using uniform animals increase the probability of finding real differences when they exist. Statistical analysis allows more valid interpretation of the results, regardless of the number of animals. In all the research reported herein, statistical analyses are included to increase the confidence you can place in the results.

Dry Matter Intake Decreases Shortly After Initiation of Feeding Zilmax During the Summer

C.D. Reinhardt, C.I. Vahl, and B.E. Depenbusch

Introduction

Since Zilmax (zilpaterol hydrochloride, ZIL; Merck Animal Health, Summit, NJ) was first launched in the U.S. in 2007, there have been anecdotal reports of reduction in dry matter intake (DMI) in feedlot cattle after initiation of feeding ZIL. Often, no difference in intake was detected, sometimes a small change was reported, and occasionally a substantial reduction of several pounds was observed. In some instances, intake returned to pre-ZIL levels over time; in other cases, intake remained depressed.

Some studies have reported no effect of zilpaterol on DMI, whereas others have reported a decrease in DMI for cattle fed zilpaterol compared with control cattle; on average, published studies report a 0.3-lb reduction in DMI compared with control cattle fed diets without zilpaterol. The objectives of this study were to evaluate relationships between DMI before and after initiation of ZIL feeding in three commercial feedyards and to determine how this relationship is affected by season, gender, and pre-ZIL DMI.

Experimental Procedures

A database of daily feed deliveries for steers and heifers fed from January 1, 2010, through January 31, 2012, at three commercial feedlots in Kansas (n = 1,515 pens of cattle; Table 1) was used to investigate the prevalence and extent of changes in DMI after initiation of ZIL feeding. Each daily feed delivery was divided by the number of animals in the pen and multiplied by diet DM to estimate per animal daily DMI. Because minor dietary changes were made periodically, each DMI value was adjusted to a common net energy (NE_G) content by multiplying the daily DMI value by its corresponding NE_G content and dividing by the average NE_G content across the entire time period. Pre-ZIL baseline DMI was calculated as the average DMI for the 10-day period immediately prior to initiation of ZIL. Post-ZIL DMI was analyzed using daily DMI for days 2 through 9 after initiation of ZIL feeding and the average DMI within each of four 5-day periods of the 20-day ZIL feeding period. The average DMI across the 18 days prior to the 10-day pre-ZIL baseline was used to compare intake trends prior to initiation of ZIL feeding; the change in intake between the pre-baseline and baseline DMI periods was used as a covariate in the models to correct for any pre-existing trend in DMI.

A mixed model approach was used, which included as fixed effects the main and interaction effects of gender (steer and heifer), feedlot (A, B, and C), season (Fall, Winter, Spring, and Summer), day post-ZIL initiation (2–9), and the pre-ZIL DMI change. Seasons were defined as follows: Fall = September, October, and November; Winter = December, January, and February; Spring = March, April, and May; and Summer = June, July, and August. The data were analyzed with day after ZIL initiation treated as repeated measures using an autoregressive covariance structure because data points observed closer together in time should be assumed to be more closely related than data

points farther apart in time. Effects were considered significant if $P < 0.01$ for the type III sums of squares.

Results and Discussion

Of the 1,515 pens of cattle represented in the database, 75% had a numerical decrease in DMI post-ZIL, and 25% had a numerical increase (Figure 1). Season affected the percentage of lots experiencing a decrease in DMI post-ZIL, but there were significant ($P < 0.01$) season × gender, season × feedyard, season × day, and season × period interactions.

Average DMI declined within 1 day after initiation of ZIL feeding (Figure 2); however, this effect was greater on day 2 in the summer and winter than during the spring or fall. The decline in intake eventually plateaued in all seasons (Figure 3); in fall and spring, intake recovered slightly.

Change in intake was greater in summer than other seasons for both steers and heifers (Figure 4); the change in intake was greater in steers than heifers in all seasons but fall.

Feedyard C had a greater decrease in DMI vs. feedyards A and B, but the order of size of decrease between feedyards A and B varied by season (Figure 5). Feedyard A had the smallest decrease in DMI during the spring, fall, and winter and had nearly no change in DMI when started on ZIL in the fall, but feedyard A actually had a greater decrease in intake post-ZIL than feedyard B in the summer (Figure 6).

During the summer months, the percentage of lots that had a decrease in DMI of 2–3 lb and greater than 3 lb were greater (18% and 15%; $P < 0.05$; Figure 7), and the percentage of lots with no decrease was the least (15%; $P < 0.05$), whereas 34% of lots had no decrease in DMI during the fall.

As pre-ZIL DMI increased, the percentage of lots with a decrease in post-ZIL DMI increased from 62% for lots with less than 17 lb to 82% for lots consuming greater than 23 lb ($P < 0.01$; Figure 8). The average dosage of ZIL consumed per animal with an average DMI of 16, 18, 20, 22, and 24 lb was calculated to be 61, 68, 76, 84, and 91 mg per head daily, respectively, which may be related to the differences in decrease in DMI. In lots started on ZIL during the summer months greater pre-ZIL DMI resulted in a linear ($P < 0.05$) increase in the percentage of lots with >3 lb and 2–3 lb and a linear decrease in the percentage of lots with no decrease in DMI (Figure 9). Of those lots with greater than 23 lb pre-ZIL DMI, 27% had DMI decrease of greater than 3 lb. Lots with greater pre-ZIL intake had a greater likelihood of having a decrease in DMI, and the size of the decrease was also greater.

The likelihood of lots exhibiting decreased DMI after initiation of ZIL feeding is greatest during the summer and least during the fall. Lots with greater DMI have greater likelihood to experience a decrease in DMI, and the decrease is greater. Increasing dosage of ZIL consumed may contribute to the DMI decrease, but the increased occurrence of DMI decrease during the summer may indicate presence of an additional physiological mechanism. Some feedlots modify feeding time of day when pens are switched from the common finishing diet to the finisher containing ZIL; this may also contrib-

ute to perturbation in previously normal intake patterns, especially affecting cattle with greater DMI pre-ZIL, but isolating feeding time from intake and ZIL inclusion was impossible in the present analysis.

Implications

Because DMI of cattle fed ZIL declines during the summer months and for cattle consuming greater DMI prior to feeding ZIL, performance and quality grade projections should be adjusted accordingly.

Table 1. Description of the data used in the analysis for daily dry matter feed deliveries for cattle fed in 3 commercial Kansas feedlots from January 1, 2010, through January 31, 2012

	Number of pens	Average	Standard deviation	Min	Max
Feedlot					
A	679	---	---	---	---
B	414	---	---	---	---
C	422	---	---	---	---
Season					
Summer	399	---	---	---	---
Fall	420	---	---	---	---
Winter	338	---	---	---	---
Spring	358	---	---	---	---
Gender					
Steers	523	---	---	---	---
Heifers	992	---	---	---	---
Initial BW on zilpaterol, kg	---	1,138	79.9	873	1,412
Days on feed upon initiation of zilpaterol feeding	---	132	29.2	74	283
Dry matter intake prior to initiation of zilpaterol, kg	---	21.0	3.21	14.2	45.25
Number of animals in each pen	---	134	64.7	50	447

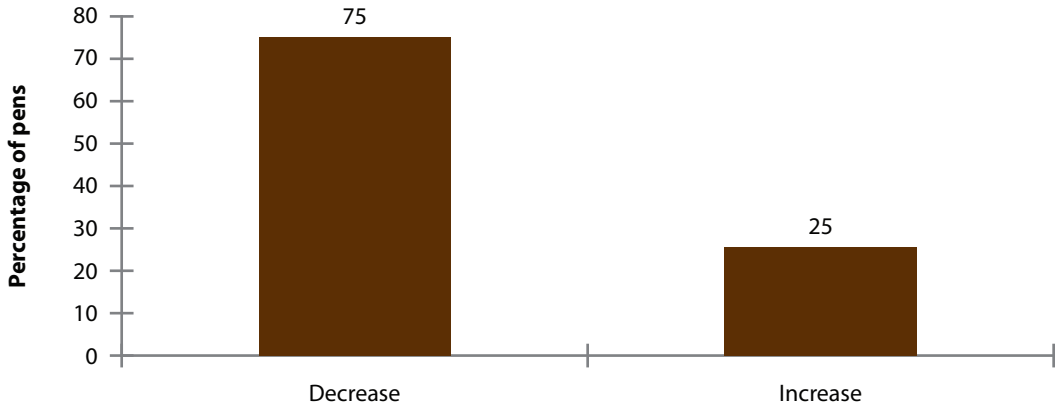

Figure 1. Percentage of pens with either a numerical increase or decrease in dry matter intake after initiation of zilpaterol feeding.

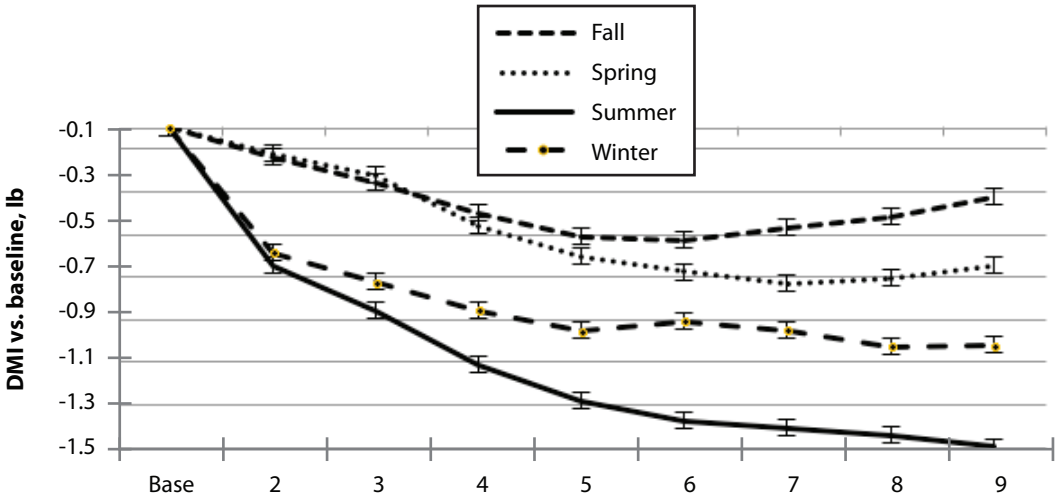

Figure 2. Mean change in daily dry matter intake (DMI) after initiation of zilpaterol feeding by day after initiation of zilpaterol feeding and season when zilpaterol feeding was initiated (season × day, $P < 0.01$). Error bars = largest SEM across season within each day.

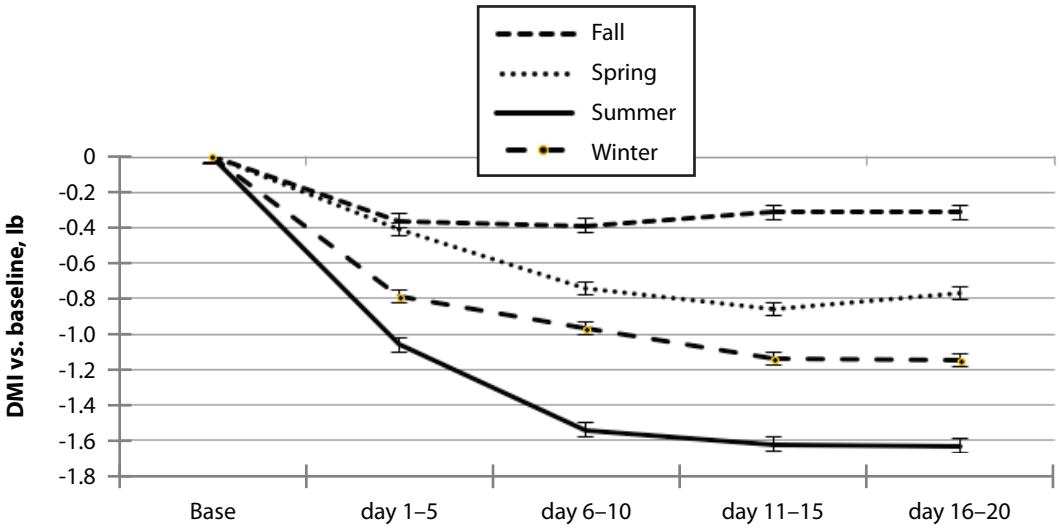

Figure 3. Mean change in daily dry matter intake (DMI) after initiation of zilpaterol feeding by 5-day period and by season when zilpaterol feeding was initiated (season × period $P < 0.01$). Error bars indicate largest SEM within period across seasons.

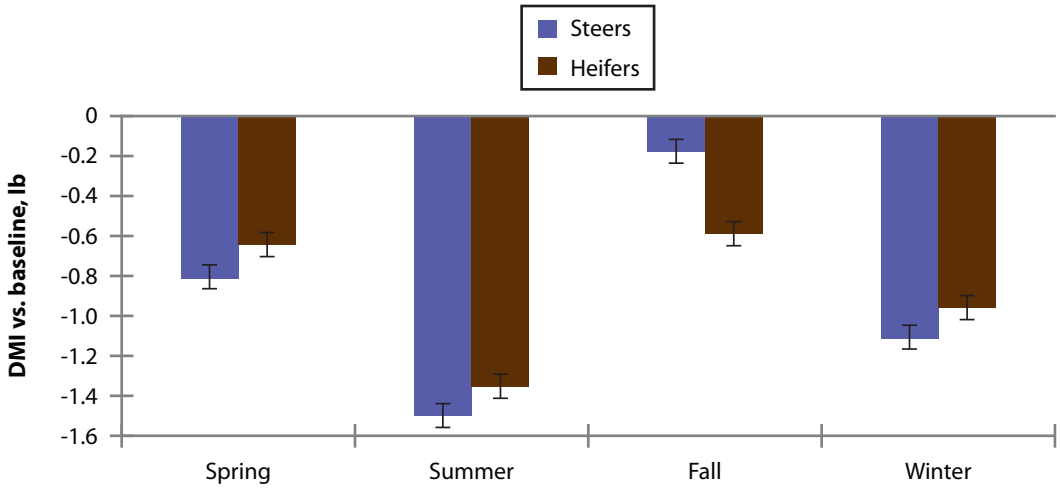

Figure 4. Mean change in daily dry matter intake (DMI) after initiation of zilpaterol feeding for steers and heifers by season when zilpaterol feeding was initiated (gender × season, $P < 0.01$). Error bars indicate the largest SEM within gender across season.

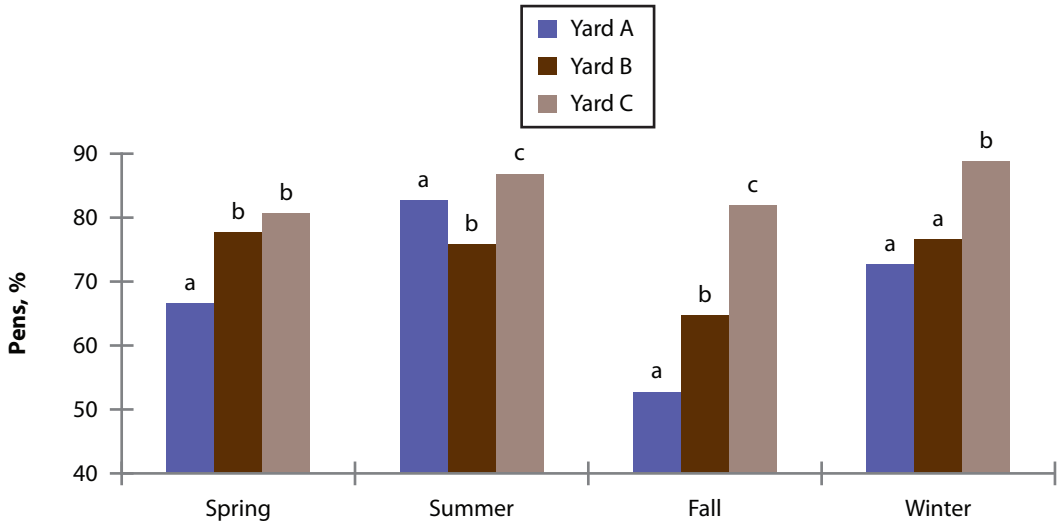

Figure 5. Percentage of pens with a numerical decrease in dry matter intake after initiation of zilpaterol feeding by feedyard and season when zilpaterol feeding was initiated (season × feedyard, $P < 0.01$; means (bars) without a common letter differ, $P < 0.05$.

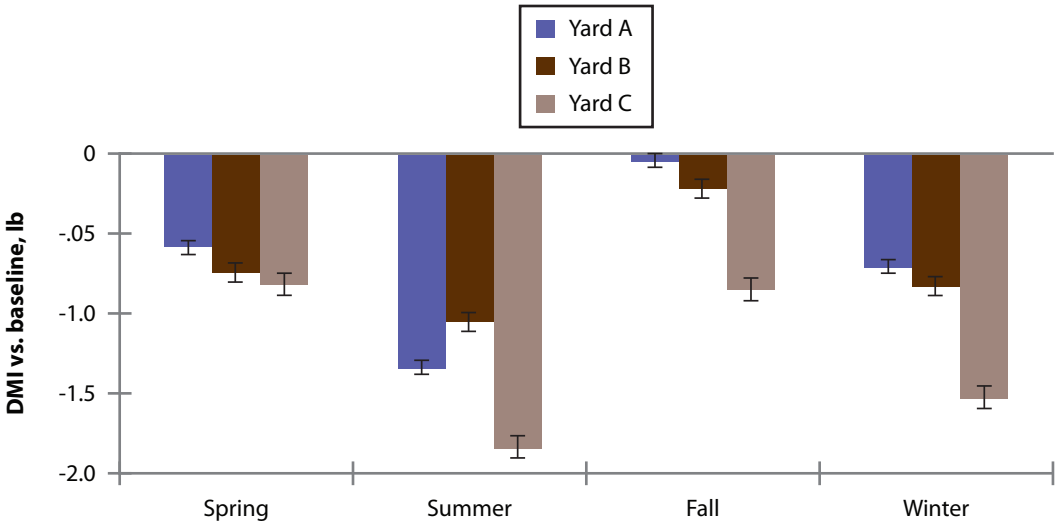

Figure 6. Mean change in daily dry matter intake after initiation of zilpaterol feeding by season and feedyard (season × period, $P < 0.01$). Error bars indicate the largest SEM for each feedyard among the four seasons.

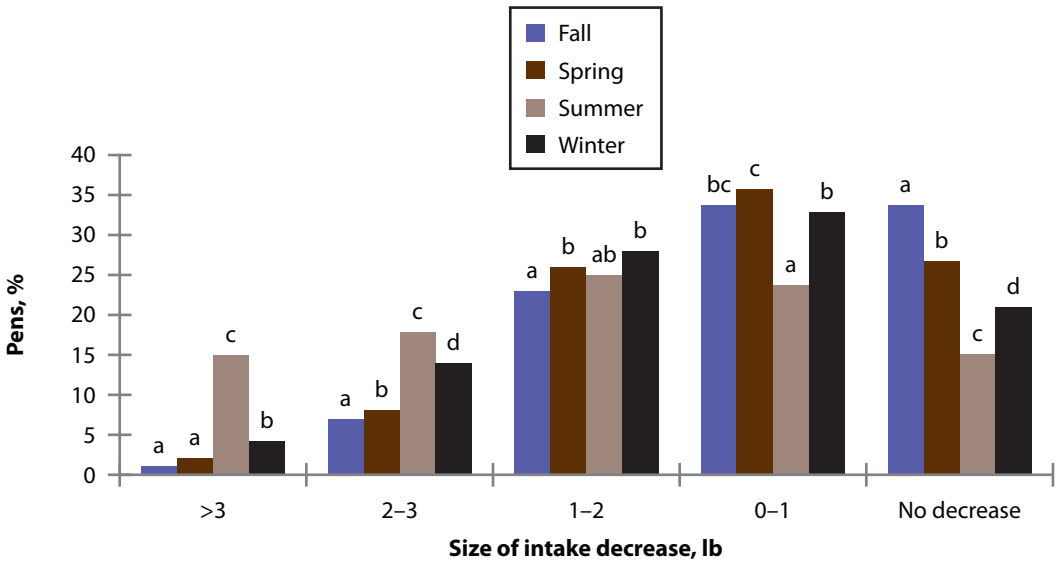

Figure 7. Percentage of pens with a decrease in DMI after initiation of zilpaterol feeding by size of decrease and season (season × size of decrease, $P < 0.01$). Means (bars) without a common letter differ, $P < 0.05$.

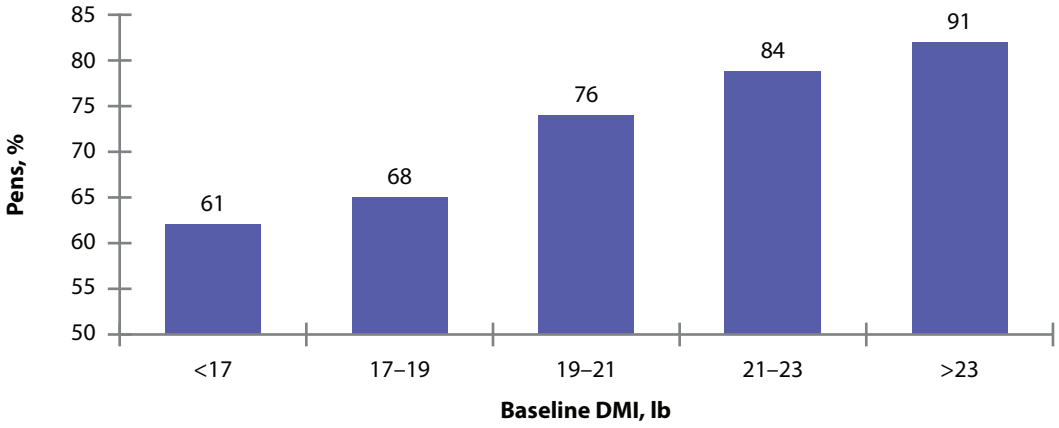

Figure 8. Percentage of pens with a decrease in dry matter intake (DMI) after initiation of zilpaterol feeding by baseline (pre-zilpaterol) DMI. (Effect of pre-zilpaterol DMI, $P < 0.01$). Baseline DMI = mean DMI for the 10 days immediately prior to initiation of zilpaterol feeding. Shown above each column is the zilpaterol intake corresponding to DMI of 16, 18, 20, 22, and 24 lb.

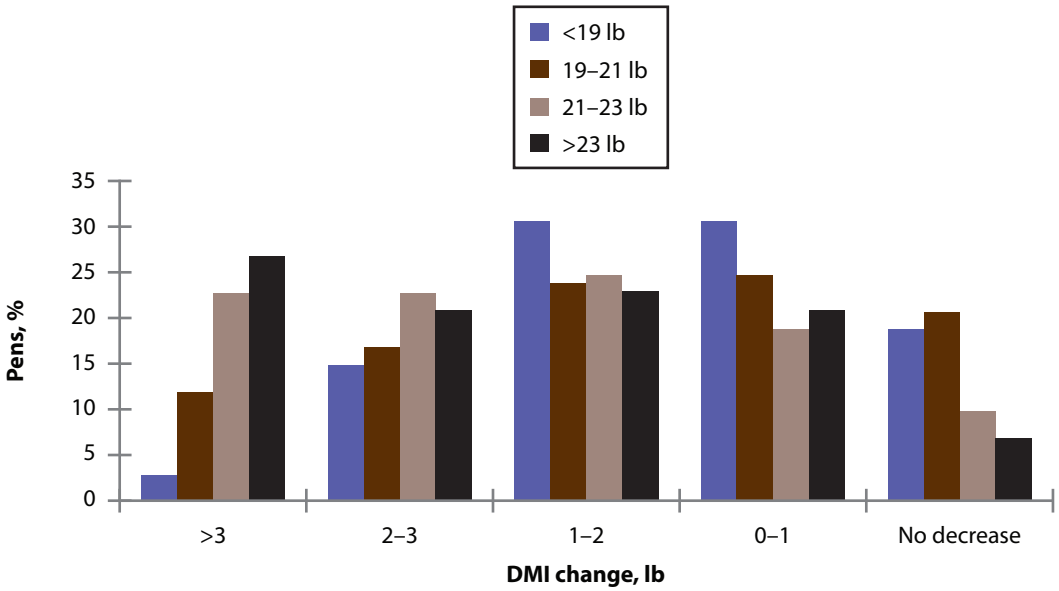

Figure 9. Percentage of pens started on zilpaterol during summer months (June, July, and August) with a decrease in dry matter intake (DMI) after initiation of zilpaterol feeding by size of decrease and baseline DMI (size of decrease × baseline DMI, $P < 0.01$).

High-dose Anabolic Implants Are Not All the Same for Growth and Carcass Traits of Feedlot Steers: A Meta-Analysis

C.D. Reinhardt

Introduction

The beneficial effects of anabolic implants with respect to feedlot performance and carcass weight are nearly unequivocal. Although individual prospective studies may have concluded that there are no significant differences between implant dosages, modern production economics demand that any differences, however small, must be gleaned if they are real. The objective of this study was to conduct a meta-analysis of existing data from peer-reviewed as well as industry sources to compare the effects of different doses of anabolic implants on feedlot performance and carcass traits of steers.

Experimental Procedures

Trials were queried from the Texas Tech North American Implant Database and the *Journal of Animal Science* database in August 2013 for the following key words: implant, carcass, and feedlot. Studies included in the present analysis were drawn from refereed journal publications, state extension research reports, and pharmaceutical company technical bulletins. The studies included in the meta-analysis reported data on some or all of the following variables: initial body weight, days of implant activity, number of pens or individual animals per treatment, average daily gain, feed:gain, dry matter intake, dressing percentage, hot carcass weight, yield grade, and percentage Choice or better.

Implant dosages of interest included negative controls, single estrogenic implants (20 mg estradiol benzoate + 200 mg progesterone; 36 mg zeranol; 72 mg zeranol) and single implants of a combination of estrogen and trenbolone acetate (TBA). Within the meta-analysis, there was only one evaluation of each of the two single zeranol dosages, and no differences were determined between the three dosages of single estrogenic compounds utilized, so these were combined into a single treatment group (EST; Tables 1 and 2). The combination estrogen + TBA dosages included 24 mg estradiol-17ß and 120 mg TBA (ET120), and the other included either 20 mg estradiol-17ß + 200 mg TBA or 28 mg estradiol benzoate + 200 TBA (ET200).

Two separate analyses were conducted using random effects models, with individual study considered a random effect, so that studies were properly weighted based on amount of within-study variation and sample size within each study. Dependent variables of interest included average daily gain, feed:gain, dry matter intake, dressing percentage, hot carcass weight, yield grade, percentage Choice or better, and marbling score. Effect sizes were calculated by subtracting (Comparison 1): treatment means for the non-implanted cattle from treatment means for implanted cattle, for each of the three treatment dosages; and (Comparison 2): treatment means for steers implanted with ET120 from those implanted with ET200. Data were imported from a spreadsheet into Comprehensive Meta Analysis v. 2.2.064 (Biostat, Inc., Englewood, NJ).

Between-study variation, or heterogeneity, was determined using Cochran's Q-statistic, which determines the variability of effect sizes between studies:

$$Q = \sum w_i (T_i - \overline{T})^2$$
$$w_i = 1 / (se^2)$$

where T_i is the effect size within the i^{th} study and T-bar is the mean of all the effect sizes across all studies in the analysis. In Comparison 1, the heterogeneity of effects of the implant dosage treatments (EST, ET120, and ET200 vs. non-implanted controls) was determined by comparing whether the difference between treatments was greater than what would be expected based on random error alone.

Publication bias is always a concern when conducting meta-analyses, and was especially concerning in the present analysis, which utilized a preponderance of data from non-refereed publications in the form of state extension research reports and company technical bulletins. Funnel plots were generated for each variable of interest to visually evaluate the possible existence of publication bias. Theoretically, standard error of the difference (SED) within studies, plotted against the treatment effect size within studies, should be equally and symmetrically distributed on either side of the mean effect size. Studies with smaller SED (greater weight in the meta-analysis) will appear nearer the top of the graph, and studies with greater SED (lesser weight) will appear nearer the bottom; in the absence of significant publication bias, the graph will have a symmetrical shape centered around a vertical line representing the mean effect size. The trim and fill method and Egger's linear regression were utilized to determine presence of publication bias.

Although the funnel plot for the analysis of average daily gain in Comparison 2 indicated a number of missing studies (Figure 1), the Trim and Fill procedure and Egger's linear regression indicated no significant effect of publication bias for any of the variables examined in either Comparison 1 or 2. Effects were considered significant when the P-value fell below $P < 0.05$.

Results

Comparison 1

There was no evidence of publication bias for any variables analyzed. Across all single implant treatments, implanting increased average daily gain, dry matter intake, dressing percentage, and hot carcass weight, and decreased feed:gain, percentage Choice and greater, and marbling score in steers ($P < 0.05$; Table 3) compared with negative controls; however, implant treatment had no effect on average calculated YG either across all treatments vs. negative controls ($P = 0.42$) or among implant treatments ($P = 0.49$).

Implanting with ET200 had a 61%, 48%, and 78% greater influence on average daily gain, feed:gain, and hot carcass weight compared to EST alone ($P < 0.05$; Table 3), but ET120 was numerically intermediate and not different from either EST or ET200 for any of these variables. Implanting with ET200 also tended ($P = 0.06$) to reduce marbling score by 13 units vs. EST; ET120 was intermediate to EST and ET200 and not different from either.

Comparison 2

Implanting with ET200 increased average daily gain by 0.046 lb per day ($P = 0.04$), reduced ($P < 0.01$) feed:gain by 0.12 units, and reduced ($P < 0.01$) percentage of carcasses grading Choice or greater by 5.2% units compared with ET120. Marbling score ($P = 0.33$), hot carcass weight ($P = 0.52$), and yield grade ($P = 0.22$) did not differ between ET200 and ET120.

The effects of ET200 vs. ET120 on average daily gain, feed:gain, and percentage Choice and greater were regressed vs. the number of days the implant was active prior to harvest. No significant relationships were found between days of implant activity and average daily gain, feed:gain, or percentage Choice and greater ($P > 0.05$; Table 4; Figure 4); however, the difference in percentage Choice and greater tended ($P = 0.08$) to increase by 1.1 percentage unit for each 100 days of implant activity prior to harvest.

Implications

Modern production practices and costs of production mandate that small improvements in productivity at the individual animal level, if real, must be investigated and captured.

Table 1. Number of individual treatment means used in the analysis of each response variable in 2 meta-analyses comparing the effects of estrogenic and combination estrogenic/androgenic implants to no implant (Comparison 1) or 2 combination estrogenic/androgenic implants (Comparison 2) in feedlot steers

	Comparison 1[1]			Comparison 2[2]
Item	EST[3]	ET120[4]	ET200[5]	ET200[5]
Average daily gain, lb	16	28	27	34
Feed:gain	16	25	26	32
Dry matter intake, lb/day	15	26	24	33
Hot carcass weight, lb	16	31	28	31
Dressing percentage	7	19	21	22
Yield grade, calculated	12	29	25	23
Percentage Choice and greater, %	7	22	24	30
Marbling score[6]	11	29	25	26

[1] One or more of the test dosages (EST, ET120, and ET200) compared with negative control within each individual study.
[2] Direct comparisons of ET200 vs. ET120 within each individual study.
[3] EST = 36 mg zeranol, 72 mg zeranol, and 20 mg estradiol benzoate (EB)+200 mg progesterone.
[4] ET120 = 24 mg estradiol-17ß+120 mg trenbolone acetate.
[5] ET200 = 20 mg estradiol benzoate+200 mg trenbolone acetate.
[6] Slight-00 = 300, Small-00 = 400, Modest-00 = 500.

Table 2. Implant categories for analysis of the effects of estrogenic and combination estrogenic/androgenic implants vs. no implant (Comparison 1) or two combination estrogenic/androgenic implants in feedlot steers (Comparison 2)

Implant category	Implants or dosages included
EST	36 mg zeranol
	20 mg estradiol benzoate (EB)+ 200 mg progesterone
	72 mg zeranol
ET120	24 mg + 120 mg trenbolone acetate (TBA)
ET200	20 mg estradiol-17ß + 200 mg TBA
	28 mg EB + 200 mg TBA

Table 3. Mean effect size of estrogenic and combination estrogenic/androgenic implants compared with no implant (Comparison 1) or two combination estrogenic/androgenic implants in feedlot steers (Comparison 2) determined from meta-analyses

Response variable	EST, ET120[2], and ET200[3]	Across-treatment *P*-value	Compared vs. negative control			Between-treatment *P*-value	ET120[2] vs. ET200[3]	*P*-value
			EST[1]	ET120[2]	ET200[3]			
Average daily gain, lb	0.59	< 0.01	0.40[a]	0.57[ab]	0.64[b]	0.03	0.046	0.04
Feed:gain	-0.65	< 0.01	-0.50[a]	-0.60[ab]	-0.74[b]	0.01	-0.12	< 0.01
Dry matter intake, lb/day	1.21	< 0.01	1.12	1.12	1.23	0.92	-0.02	0.64
Hot carcass weight, lb	47.1	< 0.01	30.1[a]	47.1[ab]	53.7[b]	< 0.01	3.1	0.52
Dressing percentage, %	0.13	0.04	-0.16	0.32	0.01	0.01	-0.11	0.10
Yield grade, calculated	0.02	0.42	-0.01	0.04	-0.01	0.49	-0.04	0.22
Percentage Choice and greater, %	-9.8	< 0.01	-9.4	-9.6	-11.8	0.88	-5.2	< 0.01
Marbling score[4]	-28	< 0.01	-20.9	-24.0	-33.5	0.06	-3.0	0.33

[1] EST = 20 mg estradiol benzoate + 200 mg progesterone, 72 mg zeranol, or 36 mg zeranol.
[2] ET120 = 24 mg estradiol-17ß + 120 mg trenbolone acetate.
[3] ET200 = 28 mg estradiol benzoate + 200 mg trenbolone acetate or 20 mg estradiol-17ß + 200 mg trenbolone acetate.
[4] Slight-00 = 300, Small-00 = 400, Modest-00 = 500.
[a,b,c] Means within a row without a common superscript differ ($P < 0.05$).

Table 4. Results of meta-regression of the effects of ET200 vs. ET120 by days of implant activity (ET200 = 28 mg estradiol benzoate + 200 mg trenbolone acetate or 20 mg estradiol-17ß + 200 mg trenbolone acetate; ET120 = 24 mg estradiol-17ß + 120 mg trenbolone acetate); only single-implant treatments were included in the meta-regression

Response variable	Slope	Intercept	*P*-value
Average daily gain, lb	-0.0007	0.07	0.44
Feed:gain	0.003	-0.54	0.54
Percentage Choice and greater, %	0.011	-19.6	0.08

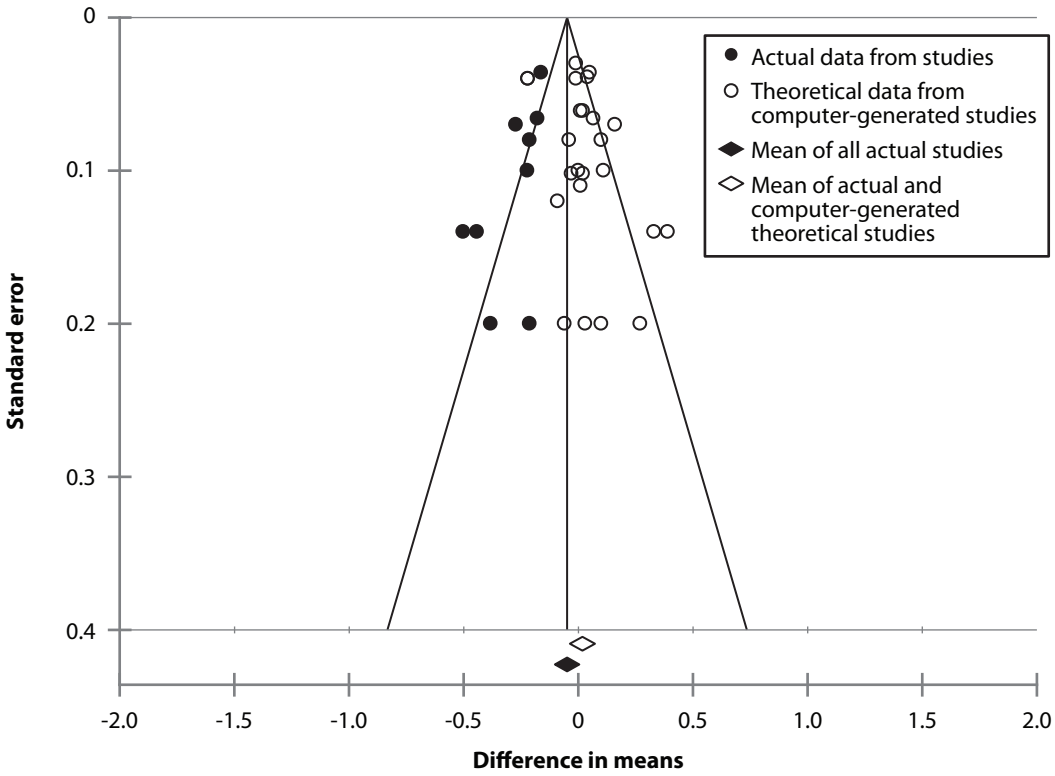

Figure 1. Funnel plot for meta-analysis of average daily gain by implant dosage.

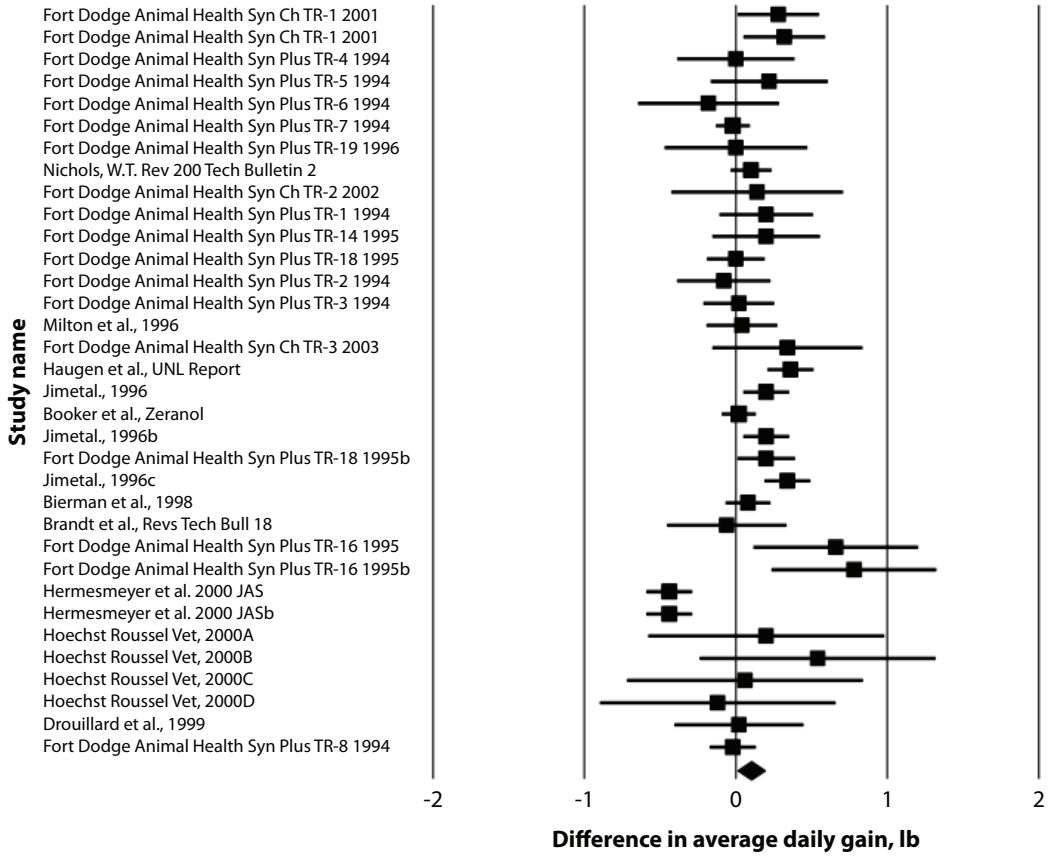

Figure 2. Forest plot for meta-analysis of average daily gain for ET200 vs. ET120.

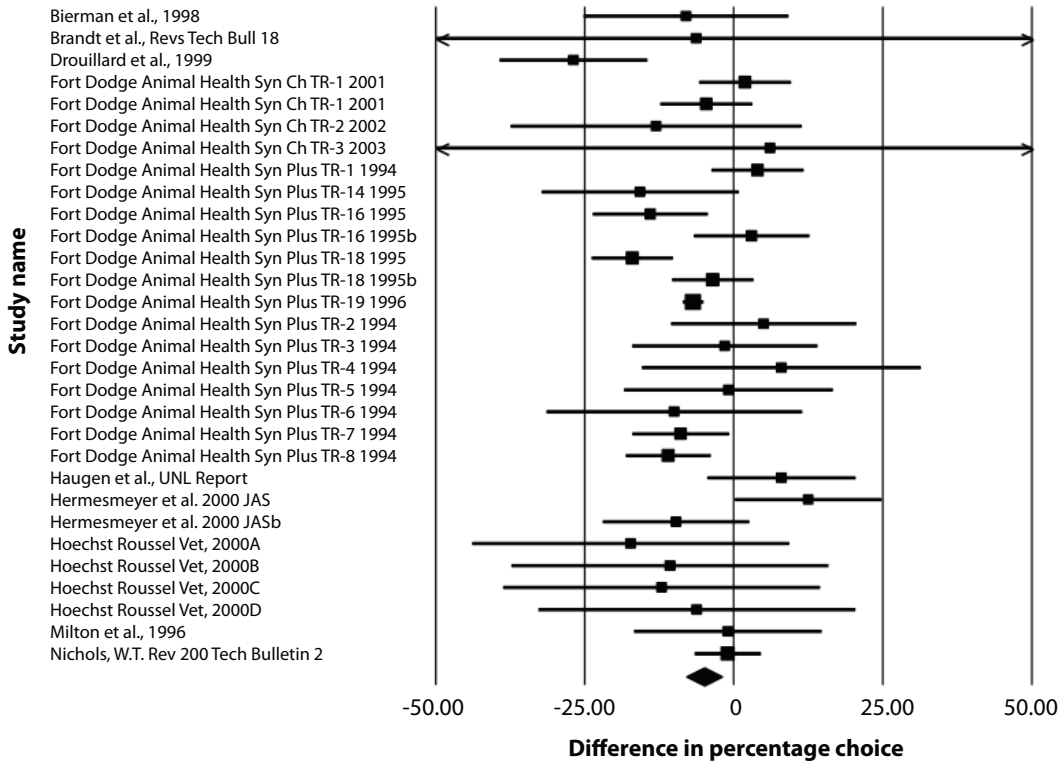

Figure 3. Forest plot of the effects of ET200 vs. ET120 on percentage of carcasses grading Choice or greater.

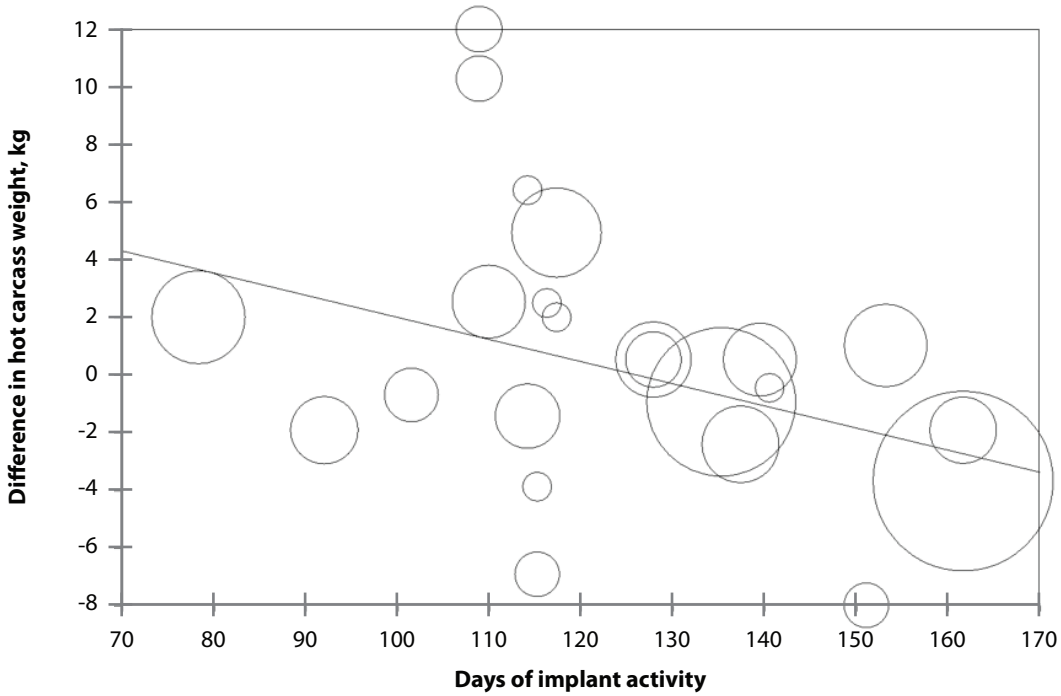

Figure 4. Results of meta-regression of the effects on hot carcass weight of ET200 vs. ET120 by days of implant activity (ET200 = 28 mg estradiol benzoate + 200 mg trenbolone acetate or 20 mg estradiol-17ß + 200 mg trenbolone acetate; ET120 = 24 mg estradiol-17ß + 120 mg trenbolone acetate). Only single implant treatments were included in the meta-regression.

Performance and Health Effects of Zuprevo 18% in Newly Received, Highly Stressed Beef Cattle

E.R. Schlegel, D.A. Blasi, W.R. Hollenbeck, B.E. Oleen, D.G. Renter, and M.F. Spire

Introduction

The objective of this study was to determine the health and performance effects of Zuprevo 18% (tildipirosin, 4 mg/kg body weight) during a 42-day backgrounding period when administered to high-risk transported cattle within 24 hours after arrival.

Experimental Procedures

A total of 729 high-risk calves, over 4 phases from 2012–1013, were procured from an order buying facility in Dickson, TN. Calves were individually identified, weighed, tested for persistent infection with bovine viral diarrhea (BVD-PI), and randomly assigned to treatment group pre-shipment. Eight animals that tested positive for BVD-PI were removed from the group before shipment. Calves were then transported to the Kansas State University Beef Stocker Unit. Upon arrival, calves were housed in dirt-surfaced pens overnight with free access to long-stemmed prairie hay and water. Within 24 hours of arrival, calves were individually weighed (mean weight 462 lb); vaccinated with Cavalry 9 (Schering-Plough Animal Health; Omaha, NE) and either Vista 5 (Intervet; Millsboro, DE) or Vista Once (Intervet); dewormed using Safe-guard (Intervet) oral drench; and implanted with Ralgro (Schering-Plough Animal Health). In addition, calves were mass-medicated with Zuprevo (Merck Animal Health; Summit, NJ) or not (Control). Calves were allocated to 56 pens, each containing 12 to 14 animals. There were 24 pens (309 head) of Control animals and 32 pens (412 head) of calves allocated to the Zuprevo treatment during the four study phases.

All animals were housed and managed the same, with *ad libitum* access to water and a common diet throughout the 42-day study period. Animals were evaluated once daily for clinical signs of bovine respiratory disease and observed to ensure appropriate animal care management for the duration of the experiment. Personnel responsible for daily health monitoring were blinded to treatments. Health status was characterized using a clinical scoring system from 0 to 4, with 0 being normal and 4 being moribund, and a clinical score for each abnormal animal was recorded daily. Animals with clinical scores of 1 (mildly depressed) or 2 (moderately depressed) and a rectal temperature greater than 104°F, or animals with clinical scores of 3 (severely depressed) or greater received antibiotic therapy. First, second, and third antibiotic treatments for the Zuprevo group consisted of Resflor Gold (Intervet, Roseland, NJ), Baytril 100 (Bayer Animal Health, Shawnee Mission, KS), and either Bio-mycin 200 (Boehringer Ingelheim, St. Joseph, MO) or Excede (Zoetis, Exton, PA), respectively. For the control group, first-round treatments consisted of Zuprevo or Resflor Gold, second-round treatments consisted of Resflor Gold or Baytril, and third-round antibiotic treatments, when required, consisted of Baytril or Excede. Three-day post-treatment moratoriums were observed after each antibiotic treatment, with an exception for animals with clinical scores of 3 or greater that were eligible for retreatment after 48 hours. Animals treated $\geq$3 times

were deemed chronic. All animals removed from the study for respiratory disease were weighed at time of removal, and all mortality cases were necropsied to determine cause of death. All animals were individually weighed on day 42 of the studies, and these final weights were used to calculate average daily gains and gain efficiencies.

Results and Discussion

Health

Compared with no metaphylaxis at arrival processing (Control), full processing with Zuprevo metaphylaxis decreased respiratory disease sickness by 41.8% ($P < 0.01$), increased first-treatment success rates by 17.9% ($P = 0.051$), decreased chronicity rate by 55.9% ($P < 0.01$), and decreased mortality rate by 25.6% ($P = 0.31$). Comparisons of respiratory disease morbidity rates, case fatality rates, and overall mortality rates all revealed significant differences between the control and Zuprevo treatment groups (Table 1).

Performance

Compared with no metaphylaxis at arrival, full processing with Zuprevo metaphylaxis at arrival increased average daily gain 10.5% ($P = 0.03$) on a deads-out basis, but not when calculated on a deads-in basis ($P = 0.36$). A non-significant ($P = 0.07$) trend was detected for an interaction between treatment and days on feed for feed intake, which is demonstrated in Figure 1. The main effects of days on feed and treatment both were significant ($P < 0.01$). Gain feed efficiency model-adjusted mean pounds of feed per head per day for Zuprevo cattle (11.51; SEM = 0.41) were 1.3 pounds higher than means for the control, no metaphylaxis treatment (10.21; SEM = 0.41), demonstrating that Zuprevo metaphylaxis improved feed intakes during the receiving period. No significant treatment effects were observed for feed:gain; means and standard errors are displayed in Table 2.

Implications

Cattle given Zuprevo had lower bovine respiratory disease morbidity rates than cattle in the Control group that were not mass-medicated. The number of calves requiring three treatments (chronics) was lower for the Zuprevo group compared with Controls, and cattle in the Zupevo group were more efficient when feed efficiency was calculated on a deads-out basis.

Acknowledgements

This research was supported, in part, by Merck Animal Health, Summit, NJ.

Table 1. Model-adjusted means and corresponding 95% confidence intervals (CI), by treatment group, for important health outcomes[1]

		Control (24 pens; 309 head)			Zuprevo (32 pens; 412 head)		
Item	*P*-value[2]	Mean (SEM)	Lower CI	Upper CI	Mean (SEM)	Lower CI	Upper CI
Respiratory disease morbidity, %	<0.01	65.6 (5.10)	54.9	74.9	38.2 (5.01)	28.9	48.5
First-treatment success rate, %	0.051	48.0 (3.82)	40.5	55.6	58.0 (4.19)	50.1	66.1
Case fatality rate, %	0.97	9.9 (2.75)	5.6	16.8	9.3 (2.92)	5.3	17.3
Chronicity rate (≥3 treatments), %	<0.01	19.7[a] (3.04)	14.3	26.4	8.7[b] (1.64)	5.8	12.5
Overall mortality rate, %	0.31	7.07 (1.93)	4.1	12.0	5.25 (1.45)	3.0	9.0

[1]Models included random effects to account for the lack of independence among pens within study phases.
[2]Where the *P*-value for an overall treatment effect was ≤0.10, treatment group means with different superscripts within rows differed significantly ($P < 0.05$).

Table 2. Model-adjusted means and standard errors (SEM) based on results from linear mixed models[1]

		Control		Zuprevo	
Item	*P*-value	Mean	SEM	Mean	SEM
Deads-out basis[2]					
Average daily gain, lb	0.03	2.46	0.15	2.75	0.13
Feed:gain	0.40	4.41	0.28	4.59	0.25
Deads-in basis					
Average daily gain, lb	0.36	2.33	0.38	2.49	0.37
Feed:gain	0.52	4.81	1.79	6.01	1.60

[1]Models included random effects to account for the lack of independence among pens within study phases.
[2] Deads-out data were not included for Phase 1 [analyses will be re-run on receipt of these data].

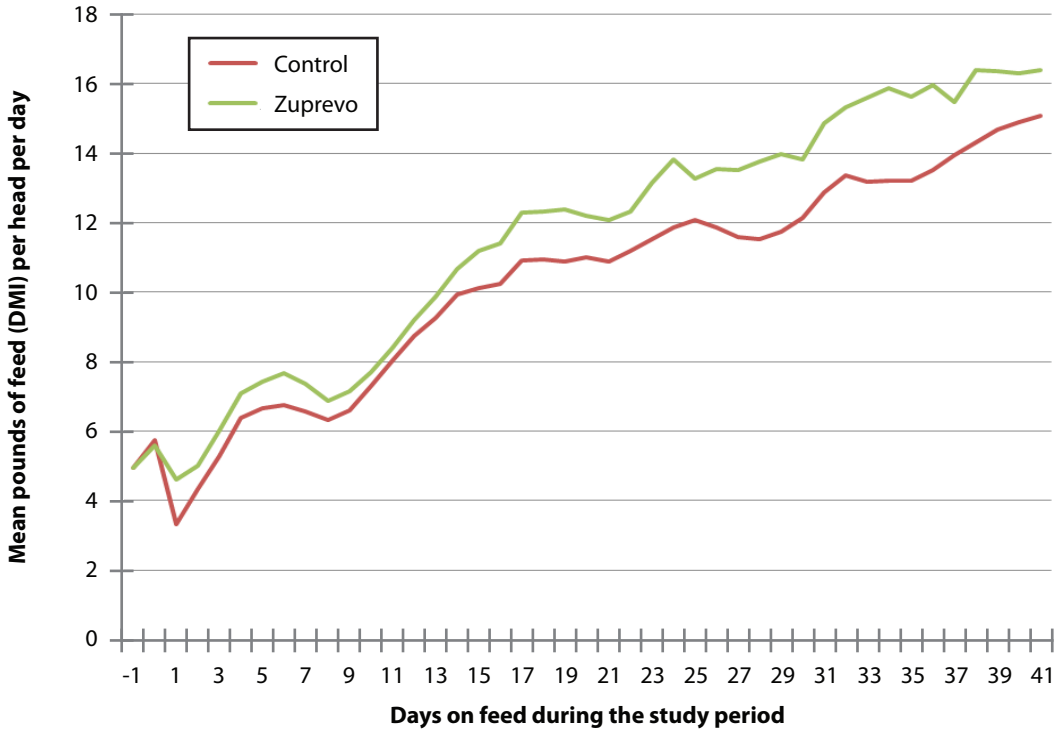

Figure 1. Daily dry matter intake (DMI) by treatment group over the feeding period.

Comparison of Conventional and Alltech Beef PN Finishing Programs: Performance and Carcass Characteristics

K.J. Phelps, K.A. Miller, C.L. Van Bibber-Krueger, A.K. Sexten, J. Jennings[1], B.E. Depenbusch[2], J.M. Gonzalez, and J.S. Drouillard

Introduction

By the year 2050, the global population will be 9 billion people, resulting in an unprecedented global demand for food. American beef producers currently employ a multitude of production programs that use feed additives such as Rumensin or Tylan (Elanco Animal Health, Greenfield, IN) and exogenous growth promotants (EGP) to maximize production efficiency. When Rumensin and Tylan are fed in combination, average daily gain and feed efficiency can be improved by 3% and 4%, respectively. When utilizing growth promotants, producers employ implant programs and feed beta-adrenergic agonists, such as Optaflexx (Elanco Animal Health), to enhance feed efficiency, average daily gain, hot carcass weight, and yield grades of carcasses. The PN Beef Program (Alltech, Nicholasville, KY) consists of two products that are designed to replace components of the conventional feedlot diet. The PN Beef Receiver is intended to be fed during the step-up period of feeding at a rate of 0.5 oz/animal daily, and PN Beef Finisher is intended to be fed during the remainder of the finishing period at a rate of 0.7 oz/animal daily. Because both products are new feed alternatives, the objective of this study was to compare the feedlot and carcass performance of the PN Beef Program in relation to a conventional feedlot diet when both diets are combined with or without exogenous growth promotants.

Experimental Procedures

Crossbred yearling steers (n = 512; 848 ± 17 lb initial body weight) were blocked by body weight and assigned to 64 pens with 8 steers assigned to each pen. The study was conducted as a randomized complete block experiment with a 2 × 2 factorial treatment arrangement. Factors in the study design consisted of a dietary feeding program and EGP regimen. For the dietary program factor, steers were separated into a conventional finishing program treatment or Alltech PN Beef Program treatment (Table 1). The components of the Alltech PN Beef Program diet were premixed into a ground corn carrier and subsequently blended into the total mixed ration. Both supplements contained a proprietary blend of organic trace elements, ascorbic acid, fermentation products, fermentation extracts, and selenium yeast. The PN Receiver portion of the diet was included in the total mixed ration for the first 21 days at a rate of 0.5 oz/animal daily. The PN Finisher was included in the total mixed ration at a rate of 0.7 oz/animal daily for the final 154 days of the feeding period. Each diet was fed with or without exogenous growth promotants. Steers receiving EGPs were administered a Component E-S (Elanco Animal Health,) implant on day 1 of the study, reimplanted with Component TE-IS (Elanco Animal Health) on day 94, and fed Optaflexx at a rate of 400 mg/animal daily the final 28 day before harvest.

[1] Alltech, Nicholasville, KY.

[2] Innovative Livestock Services, Great Bend, KS.

On day 175 of the experiment, animals were harvested at a commercial abattoir, where slaughter data were collected. After a 24-hour chill period, objective and subjective carcass characteristics were measured, including fat thickness over the 12th rib; ribeye area; percentage kidney, pelvic, and heart fat; marbling score; and USDA yield and quality grades.

Results and Discussion

Feedlot performance data for the study are displayed at the top of Table 2. No interaction between dietary program and EGP ($P > 0.10$) was detected for final body weight. Dietary program also did not affect ($P > 0.10$) final body weight, but use of EGPs increased ($P < 0.05$) final body weight by 165 lb. Results also indicate a dietary program and EGP interaction ($P < 0.02$) for dry matter intake. Steers in the PN/EGP+ group had the greatest dry matter intake of all the treatment groups. In addition, no dietary program and EGP interaction ($P = 0.78$) was detected for average daily gain, but the interaction of dietary program and EGPs only tended ($P < 0.10$) to affect feed efficiency. Steers receiving growth promotants possessed greater ($P < 0.01$) dry matter intake, average daily gain, and feed efficiency than steers finished without growth promotants. Dietary program did not affect average daily gain and feed efficiency ($P > 0.10$).

Carcass data for the experiment are also displayed in Table 2. No interaction was observed between dietary program and exogenous growth promotants for all slaughter and carcass data ($P > 0.10$). Dietary program did not affect ($P > 0.10$) the same data, except incidence of liver abscesses ($P = 0.05$). Livers from steers fed the PN Program supplements possessed a liver abscess incidence rate that was 6.4% greater than the steers fed the conventional feedlot diet. The increase in incidence of liver abscesses was expected because Tylan was removed from the PN Program diets. A large body of literature documents that implant regimens and feeding beta-agonists can improve muscle deposition and reduce carcass fat. In agreement with this data, steers finished with the use of implants and Optaflexx had heavier carcasses, larger ribeyes, and less kidney, pelvic, and heart fat. Interestingly, steers administered the growth technologies contained more ($P < 0.05$) 12th-rib fat than non-supplemented steers.

Implications

Replacing conventional feed supplements with Alltech PN supplements yielded similar feedlot performance and carcass characteristics. The use of implants and Optaflexx greatly improves feedlot performance and carcass characteristics in both production systems.

Acknowledgements

We would like to thank Alltech, Inc. for financial support of this experiment.

Table 1. Diets (dry basis) for steers fed conventional feedlot diets[1] or Alltech PN program[2]

Ingredient, %	Conventional	Alltech
Wet corn gluten feed	35.00	35.00
Steam-flaked corn	53.55	53.56
Ground wheat straw	7.00	7.00
Feed additive premix	2.16	-
Mineral/vitamin supplement	2.29	2.23
PN supplement	-	2.21

[1]Conventional diets included vitamin A at 2,200 IU/kg; vitamin E at 22 IU/kg; copper sulfate to provide 10 ppm Cu; cobalt carbonate to provide 0.15 ppm cobalt; ethylenediamine dihydriodide to provide 0.5 ppm iodine; manganous sulfate to provide 60 ppm manganese; sodium selenite to provide 0.3 ppm selenium; zinc sulfate to provide 60 ppm zinc on a dry matter basis; as well as 300 mg/animal daily of monensin and 90 mg/animal daily of tylosin (Elanco Animal Health, Greenfield, IN).

[2]The Alltech (Nicholasville, KY) diet included PN Receiver in the total mixed ration for the first 21 days at the rate of 14 g/animal daily, which contained: zinc proteinate to provide 10.7 ppm zinc; manganese proteinate to provide 7.1 ppm manganese; cobalt proteinate to provide 1.2 ppm cobalt; copper proteinate to provide 2.9 ppm copper; calcium iodate to provide 0.6 ppm iodine; selenium yeast to provide 0.31 ppm selenium on a dry matter basis; as well as ascorbic acid, *Aspergillus oryzae* fermentation product, *Lactobacillus acidophilus* fermentation product, and *Enterococcus faecium* fermentation product. Thereafter, PN Finisher was included in the total mixed ration at the rate of 20 g/animal daily; 10.7 ppm zinc; manganese proteinate to provide 7.1 ppm manganese; cobalt proteinate to provide 1.2 ppm cobalt; copper proteinate to provide 2.9 ppm copper; calcium iodate to provide 0.6 ppm iodine; selenium yeast to provide 0.31 ppm selenium on a dry matter basis; as well as ascorbic acid, *Aspergillus niger* fermentation product, *Lactobacillus acidophilus* fermentation product, and *Enterococcus faecium* fermentation product. Both supplements were premixed into a ground corn carrier and subsequently blended into the total mixed ration.

Table 2. Feedlot performance and carcass characteristics of steers fed conventional feedlot diets or Alltech PN Program[1] diets with and without exogenous growth promotants (EGP)

	Conventional		Alltech PN			*P*-value		
Item	EGP-	EGP+	EGP-	EGP+	SEM	Program	EGP	Prog × EGP
Dry matter intake, lb/day	21.83[a]	23.61[b]	21.73[a]	24.48[c]	0.28	0.052	<0.01	0.02
Average daily gain, lb	2.62	3.55	2.62	3.57	0.05	0.95	<0.01	0.78
Feed:gain	8.29	6.64	8.29	6.85	0.12	0.10	<0.01	0.07
Carcass weight, lb	825.3	933.7	832.9	932.0	11.1	0.59	<0.01	0.40
Dressed yield, %[2]	63.2	63.5	63.7	63.4	0.38	0.63	0.95	0.40
12th-rib fat, in.	0.57	0.63	0.61	0.64	0.02	0.21	0.02	0.35
Ribeye area, sq. in.	13.2	14.7	13.1	14.7	0.13	0.67	<0.01	0.92
Kidney, pelvic, and heart fat, %	1.92	1.90	1.97	1.83	0.03	0.84	0.02	0.08
Total liver abscesses, %	12.6	12.6	22.5	15.5	3.6	0.05	0.28	0.28
Marbling score[3]	655	636	640	630	10.23	0.29	0.13	0.66
USDA yield grade	2.87	2.91	2.95	2.94	0.07	0.40	0.81	0.76

[1] Alltech, Nicholasville, KY.

[2] A 4% pencil shrink was applied to live weight for purposes of calculating dressed yield.

[3] Slight = 400 to 499, Small = 500 to 599, Modest = 600 to 699, Moderate = 700 to 799.

[a,b,c] Values within a row with different letters are significantly different ($P < 0.05$).

Udder Quality is Moderately Heritable in Hereford Cattle

H.L. Bradford, D.W. Moser, J.M. Bormann, and R.L. Weaber

Introduction

Udder quality is an important factor related to cow longevity and calf performance. Cows with tighter udder suspension and smaller teats tend to have greater longevity. When cows stay in the herd longer, fewer replacement heifers need to be developed to maintain herd size. Pendulous, poorly suspended udders and large teats are difficult for newborn calves to nurse, and additional labor might be required to assist those calves. Cows with poor udder quality can have increased calf mortality because the calf struggles to nurse and consumes colostrum later. Because many beef producers sell calves by the pound at weaning, poor udder quality can have a negative impact on profit.

The dairy industry has selected for udder quality for many years. Udder traits are generally moderately heritable in dairy cattle, but limited research has been done in beef cattle. Beef producers would benefit from genetic selection tools for improving udder quality, especially for herds where udder quality affects calf performance.

Our objective was to estimate the heritabilities and genetic correlations for udder quality traits in Hereford cattle. American Hereford Association members have been reporting udder scores for a number of years. The American Hereford Association initially began collecting an overall udder score, which combined all udder characteristics into a single score. In 2008, the Beef Improvement Federation developed udder scoring guidelines, including scores for both udder suspension and teat size. By August 2008, the American Hereford Association began using these new guidelines and collected udder suspension and teat size scores instead of the overall scores. All scores were recorded on a 1 to 9 scale, with scores of 9 considered ideal. Cows are scored at calving and could have multiple records throughout their lifetimes.

Experimental Procedures

Data were obtained from the American Hereford Association and included overall score, suspension, and teat size records along with a three-generation pedigree. A summary of udder quality data used is presented in Table 1. Records were for females ages 2 to 15 at parturition and scored since 2004. A multiple-trait animal model with random effects of additive genetic and permanent environment and fixed effects of cow age and contemporary group was used. Contemporary group was the combination of herd, calving year, and calving season.

Results and Discussion

The mean udder scores and variability for the traits are shown in Table 2. The heritabilities were 0.32 ± 0.01 for overall score, 0.31 ± 0.01 for suspension, and 0.28 ± 0.01 for teat size. All traits were moderately heritable, meaning progress can be made through genetic selection.

Genetic correlations between traits were 0.72 ± 0.02 for overall score and teat size, 0.70 ± 0.02 for overall score and suspension, and 0.83 ± 0.01 for suspension and teat size. The genetic correlations are all strong and positive; thus, selection for one trait should result in improvement in the other two traits as well. These results are consistent with previous research in beef cattle.

The genetic trend for suspension and teat size is displayed in Figure 1. There was little genetic change until 1990, but steady genetic improvement has occurred since then in both suspension and teat size as a result of phenotypic selection.

Implications

Udder quality was moderately heritable, with strong genetic correlations between udder traits, which means producers can use genetic selection to improve udder quality.

Acknowledgements

The authors thank the American Hereford Association for providing the data used in this study.

Table 1. Summary of udder quality data used in the analysis

Item	Number
Overall score	
Records	126,753
Animals	58,805
Suspension	
Records	61,765
Animals	33,299
Teat size	
Records	61,753
Animals	33,293
Total records	188,524
Contemporary groups	3,079
Pedigree animals	196,540

Table 2. Descriptive statistics for udder scores[1]

Trait	Mean	Standard deviation
Overall score	7.25	1.44
Suspension	7.25	1.36
Teat size	7.06	1.43

[1] Overall score (1 = least desirable; 9 = most desirable); teat size (1 = very large, balloon-shaped; 9 = very small); udder suspension (1 = very undesireable, pendulous; 9 = very tight).

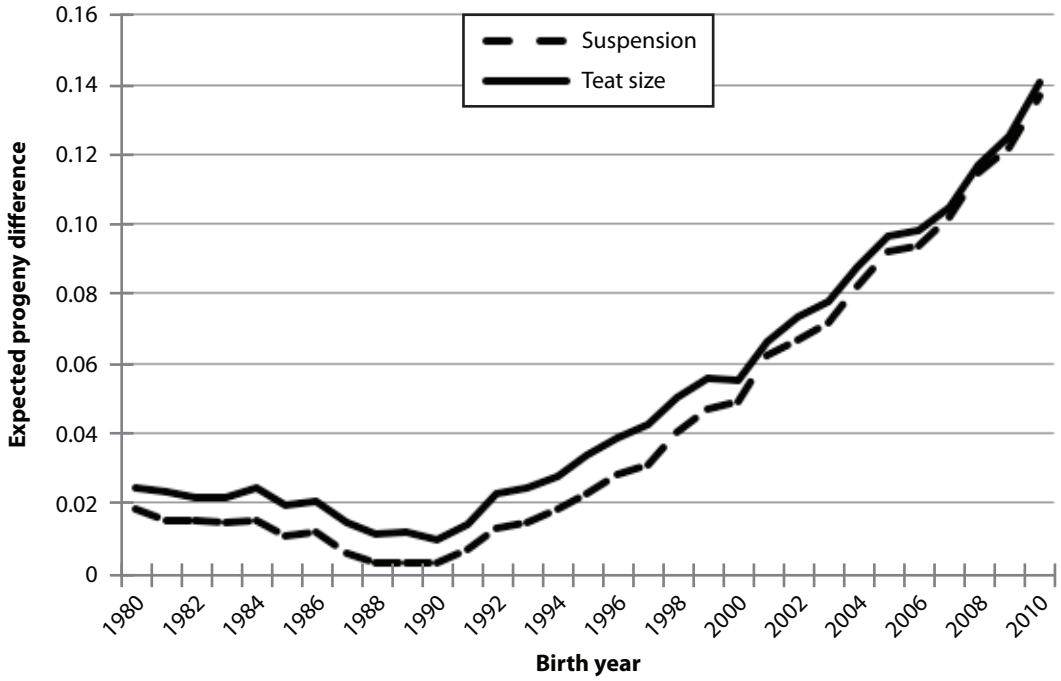

Figure 1. Genetic trend for udder traits in Hereford cattle.

Heifer Calving Rate is Lowly Heritable in Hereford Cattle

H.L. Bradford, D.W. Moser, J.M. Bormann, and R.L. Weaber

Introduction

Reproductive failure is consistently a top reason for culling beef cows from the herd. Culling young females is very costly to commercial producers because a young female hasn't generated enough income to pay for the cost of developing that female. One way to improve reproductive performance in the cowherd is through genetics. Although reproductive traits tend to be lowly heritable, genetic improvement can be made through selection.

Beef producers traditionally have selected for increased scrotal circumference to improve female fertility. Scrotal circumference is an indicator trait and is positively correlated to female reproductive performance. Faster genetic improvement could be made by selecting for an easy-to-measure, economically relevant trait.

The American Hereford Association's whole-herd reporting program has enabled the collection of more difficult-to-measure phenotypes such as reproductive performance. Producers enrolled in the program must report the reproductive status of all breeding-age females on a yearly basis. This reporting system includes information such as if a female was exposed for breeding and if she calved the following year. Traits like heifer calving rate and the likelihood that daughters will calve as a heifer if they were retained as replacements can be developed based on the data reported by Hereford breeders. Our objective was to estimate the heritability of heifer calving rate, an economically relevant trait.

Experimental Procedures

Calving records on females born from 2000 through 2009 were obtained from the American Hereford Association. After editing, 98,844 calving records and a six-generation pedigree with 289,141 animals remained for the analysis. Data were analyzed with a multiple-trait logistic animal model with a random effect for additive genetics and fixed effects for contemporary group and age at calving.

Contemporary group was defined as the combination of herd, yearling weigh date, and yearling group. There were 4,745 contemporary groups represented in the heifer calving records. Contemporary groups with either all females calving or no females calving were not included in the data because there were no phenotypic differences among the heifers in those groups.

Results and Discussion

The heritability estimate for heifer calving rate was 0.15 ± 0.01. Like most reproductive traits, this trait was lowly heritable. Yet, the reproductive success of heifers is relatively easy to measure through the American Hereford Association's whole-herd reporting system, making heifer calving rate a practical trait for selection. Genetic selection for

heifer calving rate can increase the likelihood that a sire's daughters will calve as heifers. The genetic trend for heifer calving rate is presented in Figure 1. In the past decade, genetic improvement has occurred in the likelihood that daughters will calve as heifers.

Implications

Heifer calving rate was lowly heritable, but producers can still select for heifer calving rate to make genetic improvement.

Acknowledgements

The authors thank the American Hereford Association for providing the data used in this study.

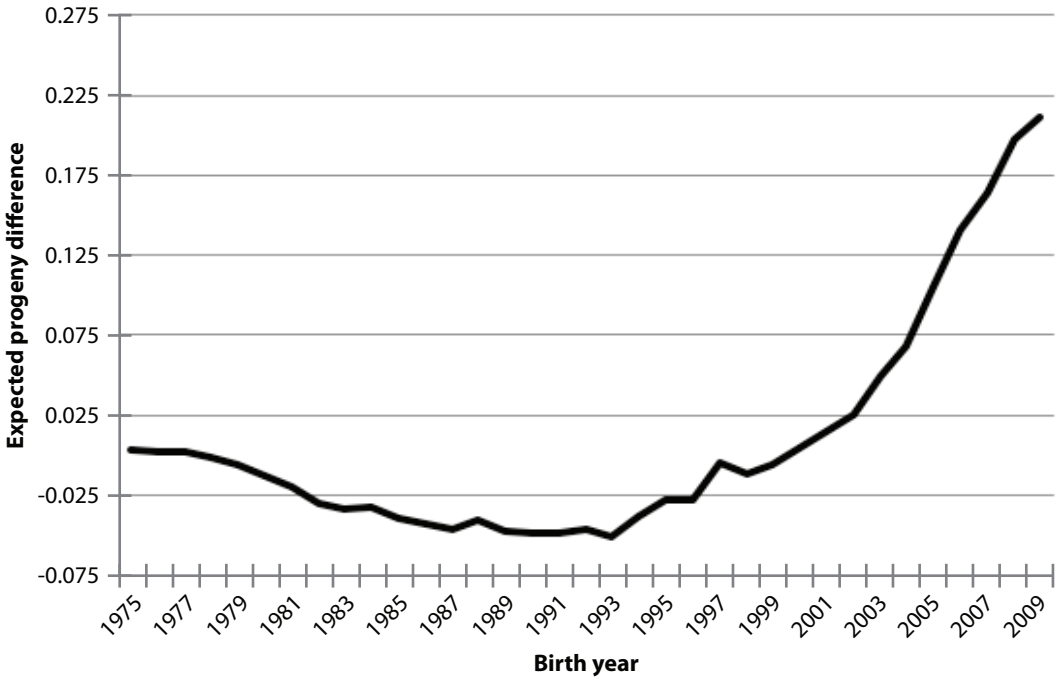

Figure 1. Genetic trend for heifer calving rate in Hereford cattle.

Relationships Between Docility and Reproduction in Angus Heifers

K.L. White, J.M. Bormann, KC Olson, J.R. Jaeger, S.K. Johnson, B. Downey, D.M. Grieger, J.W. Waggoner, D.W. Moser, and R.L. Weaber

Introduction

Reproductive success is relevant in beef cattle operations because income generated by the sale of calves is often a large portion of an operation's income. Selecting for fertility is difficult because it is influenced by a variety of factors. Temperament could be a factor affecting fertility. Physiological responses associated with temperament can influence the probability of cows becoming pregnant because stress hormones in the bloodstream can negatively affect the release of reproductive hormones.

Methods have been developed to assess temperament in cattle. Exit velocity measures the time it takes for an animal to cover a predetermined distance after vacating a chute. Chute scores range from 1 (quiet) to 6 (aggressive) and are based on the animal's behavior when confined in a chute. Positive correlations of chute score and exit velocity with cortisol indicate that both scores are reliable indicators of temperament. Handling of cattle is associated with changes in concentrations of stress hormones. Blood serum collection can provide insight into short-term stressors, and fecal sampling can be reflective of stress experienced 2–3 days before sampling.

This study was conducted to investigate the relationship between animal temperament and heifer fertility as indicated by first-service artificial insemination conception rate.

Experimental Procedures

Data for this project were collected from three different cooperator herds. A total of 337 first-calf heifers were used in this study. Ranch 1 (n = 117) heifers were synchronized using a combined melengestrol acetate (MGA)/prostaglandin (PGF)/gonadotropin-releasing hormone (GnRH) synchronization protocol. Melengestrol acetate was fed at 0.5 mg per head per day for 14 days. On day 33, 5 ml of PGF was injected, exit velocity and chute score were recorded, and fecal samples were collected. Heifers were visually detected for standing estrous for 2 days and bred 1,014 hours after observed standing estrous. On the third day after PGF injection (day 36), all females not previously detected in heat were injected with 2 ml of GnRH and inseminated. Blood samples were collected for cortisol analysis at this time. Cleanup bulls were put in with the females on day 37. Heifers were ultrasounded at 30 days to check pregnancy status.

Ranches 2 (n = 133) and 3 (n = 87) employed CoSynch-controlled internal drug release (CIDR) protocols to synchronize their heifers. On day 0, CIDRs were inserted in addition to a 2-ml injection of GnRH. Exit velocity and chute score were recorded at this time, and fecal samples were collected for cortisol analysis. On day 7, CIDRs were then removed and a 2-ml injection of PGF was given. On day 9, the heifers were given a

second 2 ml injection of GnRH and inseminated, and blood samples were collected for cortisol analysis. Heifers were ultrasounded at 30 days to check pregnancy status.

Fecal samples were taken while the animal was in the chute. Samples were stored in individual containers on ice until they could be delivered to the lab and frozen at -4°F. Blood samples were collected via venipuncture into 15-ml Vacutainer tubes with 18 G × 1.5-in. needles at breeding. Samples were immediately put on ice until they could be transported to the lab, where they were refrigerated for at least 8 hours before centrifugation.

Laboratory analysis

Refrigerated blood samples were centrifuged at 2,400 × g for 20 minutes at 39°F. Plasma was stored at -4°F until assayed. Plasma concentrations of cortisol were determined using a radioimmunoassay kit specific to bovine serum (Coat-A-Count Cortisol, Siemens Medical Solutions Diagnostics, Malvern, PA). The average intra- and inter-assay coefficients of variation were 12% and 3.5%, respectively.

Quantification of fecal corticosterone levels was modeled after protocols outlined by other researchers. Concentrations of fecal corticosterone were determined using a commercial radioimmunoassay kit (MP Biomedicals, Solon, OH) validated for use on bovine samples in July 2012. For extraction, 0.017 oz of thawed fecal matter was placed into a 0.5-oz centrifuge tube. To this, 0.15 oz of 80% methanol was added, and the tubes were placed in a lab rack vortexer for 40 minutes. Following vortexing, tubes were centrifuged at 3,000 × g for 15 minutes. The amount of corticosterone in the supernatant was determined by the I25-corticosterone radioimmunoassay. The average intra- and inter-assay coefficients of variation were 3.5% and 5.5%, respectively.

Statistical analysis

Logistic regression was used to determine the factors that influenced pregnancy rate. Contemporary group was fit as a fixed effect, whereas fecal cortisol, blood cortisol, exit velocity, chute score, weight, and age were included as covariates. Contemporary group was based on ranch. Correlation coefficients were also calculated between fetal cortisol, blood cortisol, exit velocity, chute score, weight, and age.

Results and Discussion

Summary statistics for the study are presented in Table 1. The power of our test could not detect any significant predictors of 30-day pregnancy for ranches 2, 3, and the combined data; however, chute score ($P < 0.0348$) and weight ($P < 0.0082$) were found to have odds ratio estimates different from 1 as significant predictors of 30-day pregnancy. The odds ratio estimate for chute score (Table 2) has a significant interpretation, meaning that a 1-unit increase in average chute score will reduce the probability of pregnancy at ranch 1 by 48.1%. Therefore, poor temperament indicated by increasing chute score was associated with a decreased probability of becoming pregnant. This is consistent with the findings of Cooke et al. (2009), who reported that physiological responses associated with temperament can influence the probability of cows becoming pregnant during the breeding season. The odds ratio estimate for weight is more difficult to interpret, because a 1-lb increase in weight will decrease the probability of pregnancy by 1%.

In contrast to expectations, an increase in heifer weight at breeding was associated with a decrease in the probability of becoming pregnant.

A positive correlation between fetal cortisol and age ($P < 0.0003$) was found for ranch 1, meaning that as age increased, so did fecal corticosterone concentration. Fecal cortisol positively correlated with blood cortisol at ranch 3 ($P < 0.0109$), meaning that as fetal cortisol concentrations increased, so did blood cortisol concentrations.

Blood cortisol positively correlated with exit velocity for the combined data ($P < 0.0001$) and for ranch 2 ($P < 0.0062$). This means that as blood cortisol increased, EV also increased, which is consistent with findings of other researchers. Blood cortisol negatively correlated with age for the combined data ($P < 0.0369$) and for ranch 2 ($P < 0.0327$); in other words, as blood cortisol increased, age seemed to decrease, meaning younger animals tended to have higher blood cortisol concentrations.

Exit velocity positively correlated with chute score for the combined data ($P < 0.0001$), ranch 1 ($P < 0.0302$), and ranch 2 ($P < 0.0001$). This correlation is logical, meaning that as exit velocity increased for an animal, average chute score increased as well. This is consistent with another study which found that exit velocity and chute score were positively correlated. Exit velocity was negatively correlated with both weight and age for both the combined data ($P < 0.0084$ and $P < 0.0321$, respectively) and for ranch 2 ($P < 0.0001$ and $P<0.0061$, respectively). This relationship suggests that as exit velocity increased, both weight and age decreased.

Average chute score was found to negatively correlate with age for the combined data ($P < 0.0127$). According to this result, older animals would have lower average chute score than younger animals. Weight positively correlated with age for the combined data ($P < 0.0001$), ranch 1 ($P < 0.0001$), ranch 2 ($P < 0.0001$), and ranch 3 ($P < 0.0002$). This result is obvious, meaning that weight increased steadily with age.

Implications

Although the results from our combined data were not conclusive for predictors of 30-day pregnancy, results from ranch 1 and the amount of variation in measures of temperament and reproductive status at all locations showed that these traits can be improved.

Table 1. Summary statistics for combined data of all ranches

Variable	N	Mean	SD[1]	Minimum	Maximum
Fecal cortisol, ng/0.5g	333	119.53	34.54	15.80	315.00
Blood cortisol, ng/ml	336	40.96	21.85	4.45	113.50
Exit velocity, ft/second	329	1.89	0.77	0.23	7.32
Chute score[2]	337	1.87	0.74	1.00	4.00
Weight, lb	336	763.64	77.84	510.00	964.00
Age, day	336	413.25	17.19	359.00	464.00

[1]SD = standard deviation.
[2]1 = quiet, 6 = aggressive.

Table 2. Odds ratio estimates (ORE), confidence limits, and *P*-value for the logistic regression of 30-day pregnancy on fecal cortisol, blood cortisol, exit velocity, average chute score, weight, and age for all data

Variable	ORE	Confidence limits		*P*-value
Fecal cortisol, ng/0.5g	1.006	0.998	1.015	0.1451
Blood cortisol, ng/ml	1.007	0.995	1.018	0.2379
Exit velocity, ft/second	0.949	0.677	1.332	0.7639
Chute score[1]	0.706	0.494	1.009	0.0560
Weight, lb	0.993	0.986	1.001	0.0724
Age, day	1.001	0.984	1.017	0.9316

[1]1 = quiet, 6 = aggressive.

Docility and Heifer Pregnancy Estimates in Angus Heifers

K.L. White, J.M. Bormann, D.W. Moser, R.L. Weaber

Introduction

Reproductive success is economically relevant in beef cattle operations because the number of calves born influences the value of calves sold at weaning. Improvements in reproductive performance can be up to four times more important than improvements in end-product traits in an operation selling calves at weaning. Selecting for fertility is difficult because it is influenced by a variety of factors.

Temperament is one of the factors affecting fertility that requires further investigation. Researchers report that physiological responses associated with temperament can influence the probability of cows becoming pregnant. Stress hormones such as cortisol in the bloodstream can negatively affect the release of vital reproductive hormones.

Methods have been developed to assess temperament in cattle. Beef Improvement Federation guidelines describe a temperament scoring system that has been adapted by breed associations for genetic evaluation of docility in cattle. The chute scoring system ranges from 1 to 6. A 1 or 2 score indicates highly acceptable behavior, 3 is average, and 4–6 is unacceptable. Studies have shown selection for cattle with a more favorable docility (chute) score would be effective in producing cattle with more acceptable dispositions. The docility expected progeny differences (EPD) reflect the probability that offspring will inherit genes for acceptable behavior, with a greater EPD associated with progeny exhibiting calmer behavior. Some breed associations have produced EPD rankings for docility. Docility measured by chute score has been found to be moderately heritable. The purpose of this research was to estimate the heritability and variance parameters for heifer pregnancy and docility in Angus cattle.

Experimental Procedures

Data for this study included approximately 26,878 records for only heifer pregnancy and 113,412 records for only docility, with 7,849 animals having both docility and heifer pregnancy records. Pedigree information was also obtained on approximately 508,015 animals over 30 generations, which included 49,091 sires, 292,715 dams, 9,802 paternal grand sires, and 35,068 maternal grand sires. For animals with performance records, 10,137 sires and 92,471dams were represented. Contemporary groups were formed by the concatenation of weaning contemporary group, yearling contemporary group, and breeding contemporary group. There were 12,782 contemporary groups for heifer pregnancy, with an average of 24.33 records per contemporary group, and 12,954 contemporary groups for docility, with an average of 10.59 records per contemporary group. Heifer pregnancy variance components were estimated from a univariate threshold model, with pregnancy outcome as the dependent variable. Animal and contemporary groups were random effects, whereas age at first breeding was a covariate. Docility was fit as a univariate, linear animal model with docility score as the dependent variable. Animal and contemporary groups were both modeled as random effects.

Results and Discussion

The heritability of heifer pregnancy was estimated as 0.16 ± 0.02. These findings are within the range reported by other researchers who found that heifer pregnancy has an estimated heritability between 0.14 and 0.21. The heritability of docility was estimated to be 0.22 ± 0.03, which is lower than the heritabilities for docility reported by the North American Limousin Foundation (0.40) and the American Angus Association (0.37). The heritability estimate for docility obtained from this data is also low compared with the findings of another research group that reported a direct heritability of 0.37 for docility as measured by the chute score. The heritability estimate from this study does, however, fall within the moderately heritable range.

Implications

This study has shown low to moderate heritability estimates of heifer pregnancy and docility, indicating that although progress may be slow, genetic improvement through selection can be made on these traits.

Temperament Can Be an Indicator of Feedlot Performance and Carcass Merit in Beef Cattle

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Introduction

Cattle producers historically have selected for docile temperaments simply for management convenience because calmer animals are conducive to safe environments for their peers as well as their handlers. As many producers would acknowledge, however, there seems to be a relationship between temperament and cattle health, and calmer cattle tend to frequent the working chute for treatment of disease less often.

Positive correlations have been found in cattle between temperament traits (chute scores, pen scores, and chute exit velocities) and cortisol concentration in the blood, suggesting that more excitable cattle are easily stressed (Curley et al., 2006; Cooke et al., 2009). Curley et al. (2007) also found that easily excitable animals sustain elevated cortisol concentrations for a longer duration and have greater pituitary and adrenal responses following a stressor than calm cattle. Temperamental cattle have significantly higher mean temperament responses at all points (Oliphint, 2006). Higher basal serum cortisol concentrations may suggest that easily excitable cattle are chronically stressed (Curley et al., 2007), possibly resulting in a compromised immune system, illness, and decreased fat and protein deposition. This study was conducted to further investigate the relationships between cattle temperament (measured by chute score and exit velocity), immunological factors, and a range of economically relevant performance traits.

Experimental Procedures

The Colorado State University Animal Care and Use Committee approved all experimental procedures. Crossbred steers were provided by a single-source ranch with three locations in western Nebraska. In Year 1 (2007), 1,551 cattle were provided, and 1,319 cattle were provided in Year 2 (2008). In November of each year, cattle were shipped 333 miles to a commercial feedlot in southeastern Colorado and were processed within 2 days of arrival to the feedlot. Initial processing included the administration of a radio frequency and visual identification tag, an oral and pour-on parasiticide, and an implantation of a growth promotant. At this time, a blood sample was taken and weight was recorded. Cattle were not vaccinated in Year 1 so that all animals could be equally challenged; however, 45% of animals experienced bovine respiratory disease (BRD). To avoid similar costs in Year 2, cattle were vaccinated for BRD with Pyramid 2 +

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Type II BVD and Presponse SQ (both from Boehringer Ingelheim, St. Joseph, MO). Cattle were processed again at the time of re-implantation (~day 74) and a third time at approximately day 140. At both of these processing points, weights of the animals were recorded. Growth calculations included the gain between the first and second processing dates (GAIN1), the amount of gain between the second and third processing (GAIN2), and the total gain between the time of feedlot placement and the third processing.

Temperament was assessed using chute score (Grandin, 1993; BIF, 2002) and exit velocity (Burrow et al., 1988) at the first two processing dates. When a steer was restrained in the chute, two evaluators assigned a chute score to the animal. The chute score scale ranged from 1 to 6, where calmer animals were on the lower end of the scale and the most aggressive cattle were at the upper end. The two appraised chute scores were averaged, and chute score was treated as a continuous variable for analysis. Upon release from the chute, the flight time, or the time it takes an animal to cover a defined distance (6 feet), was recorded. Flight time was then converted to exit velocity in units of feet/second.

Cattle were harvested at day 225 on average at JBS Swift and Company plants in Dumas, TX, and Greeley, CO, in Year 1 and 2, respectively. Data recorded at this time included hot carcass weight, calculated yield grade, USDA quality grade, marbling score, ribeye area, and lung score. Two trained evaluators assigned a lung score of the aggregate lung. Lung scores were based on a scale of 0 to 3, where lower scores indicated less lung damage due to respiratory disease.

Assays were performed using the blood sample taken at the time of feedlot placement to determine cortisol and interleukin 8 concentrations in the blood. Both were measured using commercially available kits. Plasma cortisol was measured using a radioimmunoassay following the manufacturer's protocol (Coat-A-Count; Diagnostic Products, Los Angeles, CA). Interleukin 8 was measured using human ELISA kits that have been previously reported to cross-react with bovine interleukin 8 (Shuster et al., 1996, 1997; R&D Systems, Inc., Minneapolis, MN).

Statistical analysis of phenotypic measures was performed in SAS (SAS Institute, Cary, NC). Contemporary group (n = 11) accounted for differences in initial ranch unit, feedlot placement date, feedlot pen, and all processing dates. For all analyses, fixed effects were pre-feedlot BRD treatment and contemporary group. To determine least squares means using the general linear mixed model, BRD treatment in the feedlot was also included as a fixed effect. The multivariate analysis of variance procedure was used to determine correlations among quantitative variables. Odds ratios were produced using the logistic regression procedure with qualitative response variables.

Results and Discussion

Cortisol had a weak but significant correlation with all temperament measures except exit velocity at the time of feedlot placement (Table 1). Positive relationships between circulating cortisol concentrations and temperament have been reported previously, confirming that more excitable animals have significantly greater cortisol concentra-

tions than their calmer peers (Curley et al., 2006; King et al., 2006; Stahringer et al., 1990).

Growth measures, including weights and gains, had few significant correlations with temperament traits, all of which were weak and negative (Table 1). This result suggests that more excitable cattle will weigh and gain less throughout the finishing phase than their calmer peers. Carcass traits also had few significant correlations with measures of temperament, and all that were significant were negative (Table 1). Appraised exit velocity at the time of re-implantation was negatively associated with hot carcass weight and yield grade. Chute score at the time of feedlot placement had a small negative correlation with marbling score, suggesting that temperamental cattle at the time of feedlot arrival will have decreased intramuscular fat deposition compared with their calmer peers.

All correlations were significant among temperament measures, and the strongest correlation was between exit velocity at feedlot placement and exit velocity at re-implantation (Table 2). Repeatabilities of the two temperament measures indicated that exit velocity ($r_p = 0.41 \pm 0.02$) was more repeatable than chute score ($r_p = 0.17 \pm 0.02$), which may be due to the objective nature of exit velocity.

Implications

Results from this study indicate that more temperamental cattle will have slightly worse feedlot performance and carcass merit than their calmer peers.

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Table 1. Partial correlation coefficients of temperament traits with measures of immunity

Trait	Chute score 1[1]	Chute score 2[2]	Exit velocity 1[3]	Exit velocity 2[4]
Cortisol[5]	0.0720**	0.0754**	0.0372	0.1120***
IL-8[6]	-0.0110	-0.0257	0.0157	0.0437
Wt. 1[7]	0.0255	0.0134	-0.0084	-0.0262
Wt. 2[8]	-0.0115	-0.0123	-0.0447	-0.1049***
Wt. 3[9]	-0.0233	-0.0404	-0.0588*	-0.1113***
Gain 1[10]	-0.0335	-0.0253	-0.0480	-0.1080***
Gain 2[11]	-0.0221	-0.0492*	-0.0336	-0.0344
Total gain[12]	-0.0449	-0.0575*	-0.0656*	-0.1174***
Hot carcass weight	0.0185	-0.0236	-0.0371	-0.0799***
Yield grade	-0.0280	-0.0378	-0.0147	-0.0718**
Marbling score[13]	-0.0643**	-0.0141	-0.0178	-0.0445
Ribeye area	0.0226	0.0093	-0.0088	0.0125
Lung[14]	0.0375	0.0040	-0.0090	-0.0111

[1] Average chute score at the time of feedlot placement (first processing).
[2] Average chute score at the time of re-implantation (second processing).
[3] Exit velocity at the time of feedlot placement.
[4] Exit velocity at the time of re-implantation.
[5] Circulating serum cortisol concentration at the time of feedlot placement.
[6] Circulating interleukin-8 concentration at first processing.
[7] Body weight recorded at first processing.
[8] Body weight recorded at second processing.
[9] Body weight recorded at third processing.
[10] Gain between the first and second processing.
[11] Gain between second and third processing.
[12] Total gain between the first and third processing.
[13] Slight = 300 to 399, Small = 400 to 499, and Modest = 500 to 599.
[14] Average lesion score of the aggregate lung.
*$P < 0.05$; **$P < 0.01$; and ***$P < 0.001$.

Table 2. Correlation matrix with the partial correlation coefficients and associated significance of exit velocity and chute score at placement and re-implantation

Trait	Chute score 1[1]	Chute score 2[2]	Exit velocity 1[3]	Exit velocity 2[4]
Chute score 1[1]	1.000			
Chute score 2[2]	0.2351***	1.000		
Exit velocity 1[3]	0.1406***	0.1803***	1.000	
Exit velocity 2[4]	0.1373***	0.2223***	0.4448***	1.000

*$P < 0.05$; **$P < 0.01$; and ***$P < 0.001$.

Genetic Relationships Among Temperament, Immune Function, and Carcass Merit in Beef Cattle

K.E. Bates, R.L. Weaber, J.M. Bormann, D.W. Moser, J.L. Salak-Johnson[1], C.C.L. Chase[2], R.K. Peel[3], H. Van Campen[4], G.H. Loneragan[5], J.J. Wagner[3], P. Bodhireddy[6], K. Prayaga[6], and R.M. Enns[3]

Introduction

Cattle producers historically have selected for docile temperaments simply for management convenience because calmer animals are conducive to safe environments for their peers as well as their handlers. As many producers would acknowledge, there seems to be a relationship between temperament and health, and calmer cattle tend to frequent the working chute for treatment of disease less often.

Positive correlations have been found in cattle between temperament traits (chute scores, pen scores, and chute exit velocities) and cortisol concentration in the blood, suggesting that more excitable cattle are easily stressed (Curley et al., 2006; Cooke et al., 2009). In addition, Curley et al. (2007) found that easily excitable animals sustain elevated cortisol concentrations for a longer duration and had greater pituitary and adrenal responses following a stressor than calm cattle. Temperamental cattle have significantly higher mean temperament responses at all points (Oliphint, 2006). Higher basal serum cortisol concentrations may suggest that easily excitable cattle are chronically stressed (Curley et al., 2007), possibly resulting in a compromised immune system, illness, and decreased fat and protein deposition.

Common measures of cattle temperament are pen scores, chute scores, and exit velocities. Temperament appears to be moderately heritable, with estimates ranging from 0.15 to 0.44 (Burrow and Corbet, 2000; Kadel et al., 2006; Schrode and Hammack, 1971; Stricklin et al., 1980; Fordyce et al., 1988). If genetic correlations are found between temperament and production traits or immunological factors, they may aid cattle breeders in producing profitable cattle. Such relationships have been found between exit velocity and hot carcass weight (r = -0.54), exit velocity and marbling score (r = 0.10), exit velocity and yield grade (r = -0.22) (Nkrumah et al., 2007), and post-weaning weight gain and exit velocity (Weaber et al., 2006). Bovine respiratory disease (BRD) susceptibility has been estimated to be lowly heritable (Muggli-Cockett et al., 1992; Snowder et al., 2005, 2006, 2007; Schneider et al., 2008).

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This study was conducted to further investigate the genetic relationships between cattle temperament measured by chute score and exit velocity, immunological factors, and a range of economically relevant performance traits.

Experimental Procedures

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Assays were performed using the blood sample taken at the time of feedlot placement to determine cortisol and interleukin-8 (IL-8) concentrations in the blood. Both were measured using commercially available kits. Plasma cortisol was measured using a radioimmunoassay following the manufacturer's protocol (Coat-A-Count; Diagnostic Products, Los Angeles, CA). Interleukin-8 was measured using human ELISA kits that have been previously reported to cross-react with bovine IL-8 (Shuster et al., 1996, 1997; R&D Systems, Inc., Minneapolis, MN).

Heritabilities, genetic correlations, and repeatabilities were estimated with ASREML (Ver. 3.0, VSN International, Ltd., Hemel Hempstead, UK) on 2,871 animal records. The pedigree file included records of 7,177 animals with up to 7 generations. Data were analyzed using a multiple-trait mixed animal model with animal as a random effect to estimate additive genetic merit. Fixed effects were the same as for the phenotypic analysis with the inclusion of permanent environment to determine repeatability estimates for temperament traits.

Results and Discussion

Heritabilities and genetic correlations of blood parameters and temperament traits are shown in Table 1. Cortisol is estimated to be lowly to moderately heritable, and IL-8 seems to be more influenced by genetics, with a heritability estimate of 0.34 ± 0.07 (Table 1). The heritabilities of circulating cortisol and IL-8 concentrations have not been previously reported. Cortisol showed no significant genetic relationship with any of the temperament measures, nor with IL-8. Interleukin 8 had a negative correlation with exit velocity at both time points, suggesting that cattle with genetics to be more temperamental will have genetics for decreased circulating IL-8 concentrations.

Temperament has been previously reported to be moderately heritable (Shrode and Hammack, 1971; Stricklin et al., 1980; Fordyce et al., 1988). Previous heritability estimates for chute score specifically range from 0.15 to 0.30 (Burrow and Corbet, 2000; Kadel et al., 2006), whereas previous heritability estimates for exit velocity range from 0.21 to 0.49 (Burrow and Corbet, 2000; Kadel et al., 2006; Nkrumah et al., 2007; Sant'Anna et al., 2012). The current study has estimates for the heritability of chute score and exit velocity at each of the first two processing times, and all estimates except exit velocity at the time of feedlot placement fall within the respective previously estimated ranges (Table 1). Chute score appraised at the initial processing had a significant genetic correlation with exit velocity at feedlot placement and chute score at re-implantation, but not with exit velocity at re-implantation (Table 1). The chute score from the second processing was genetically correlated with exit velocity at both time points as well (Table 1).

Table 2 shows estimated genetic correlations among temperament, immune function, and carcass traits. Cortisol had a negative genetic correlation with both hot carcass weight and ribeye area, suggesting that cattle exhibiting genetic potential for elevated cortisol levels will have decreased hot carcass weight and ribeye area (Table 2). Interleukin 8 was positively genetically associated with hot carcass weight, marbling score, and yield grade (Table 2). Cortisol had a strong negative genetic relationship with BRD incidence in the feedlot segment, whereas IL-8 had a positive relationship with feedlot BRD incidence (Table 2). This indicates that cattle with genetics for greater cortisol concentrations upon feedlot placement may be inherently less susceptible to BRD, whereas those with genetics for greater IL-8 levels may be genetically predisposed to BRD. No previous literature has reported genetic relationships between carcass or immune traits and IL-8 or cortisol.

Chute score at the time of the first processing had a significant positive genetic correlation with hot carcass weight and bovine respiratory disease (Table 2). Exit velocity measured at the time of re-implantation also had a negative genetic relationship

with hot carcass weight. Similar genetic relationships have been previously reported; Nkrumah et al. (2007) found moderate negative genetic associations between exit velocity and hot carcass weight (r = -0.54). Exit velocity at the time of feedlot placement and chute score at the second processing both had significantly positive correlations with ribeye area (Table 2). Such results might indicate that innately more temperamental cattle will generally have genetics for larger ribeye area. Temperament measures from the second processing point were negatively genetically correlated with marbling score; however, this was not true for temperament measures at the time of feedlot placement (Table 2). Exit velocity has previously been reported to have a genetic correlation with marbling score of 0.10 (Nkrumah et al., 2007). All measures of temperament were negatively genetically associated with yield grade (Table 2).

Exit velocity measured at the first processing date had a positive genetic correlation with lung score, but other measures of temperament did not show similar significant relationships (Table 2). Temperament appraised at the second processing had negative genetic correlations with BRD incidence in the feedlot segment, suggesting that cattle with genetics to be more temperamental by the time of re-implantation will be less inherently susceptible to BRD than their peers.

Implications

Results from this study indicate that blood parameters (with the exception of IL-8) and temperament measures all have negative genetic relationships with BRD susceptibility in beef cattle, and more temperamental cattle do not seem to be inherently more susceptible to BRD incidence in the feedlot segment. Measures of temperament are genetically correlated with one another, and exit velocity is estimated to be more repeatable that chute score. Genetic correlations indicate that cattle with genetic potential to be more aggressive or fearful will have genetics for greater ribeye area, reduced marbling score, and reduced yield grade.

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Table 1. Heritabilities (on diagonal ± SE) and genetic correlations (above diagonal ± SE) among temperament and immune traits in beef cattle

Trait	Cortisol	Interleukin 8	Chute score 1	Chute score 2	Exit velocity 1	Exit velocity 2
Cortisol	**0.23** (0.06)	-0.01 (0.16)	0.07 (0.17)	0.09 (0.19)	-0.11 (0.19)	0.11 (0.16)
Interleukin 8		**0.34** (0.07)	-0.04 (0.15)	-0.08 (0.17)	-0.31 (0.17)	-0.22 (0.15)
Chute score 1			**0.23** (0.05)	0.37 (0.17)	0.31 (0.17)	-0.02 (0.17)
Chute score 2				**0.19** (0.05)	0.23 (0.19)	0.27 (0.17)
Exit velocity 1					**0.17** (0.05)	0.73 (0.11)
Exit velocity 2						**0.27** (0.06)

Table 2. Genetic correlations (± SE) among temperament, immune function, and carcass traits in beef cattle

Trait	Hot carcass weight	Marbling score	Ribeye area	Yield grade	Lung lesion score	Bovine respiratory disease
Cortisol	-0.34 (0.17)	-0.06 (0.14)	-0.19 (0.18)	0.08 (0.16)	0.16 (0.31)	-0.68 (0.22)
Interleukin 8	0.40 (0.15)	0.35 (0.11)	-0.01 (0.16)	0.37 (0.14)	-0.44 (0.32)	0.35 (0.20)
Chute score 1	0.18 (0.17)	-0.01 (0.13)	0.39 (0.18)	-0.21 (0.16)	-0.23 (0.33)	-0.01 (0.22)
Chute score 2	0.05 (0.20)	-0.16 (0.15)	0.28 (0.20)	-0.30 (0.17)	-0.28 (0.35)	-0.60 (-0.22)
Exit velocity 1	-0.12 (0.19)	-0.01 (0.15)	0.43 (0.19)	-0.46 (0.16)	0.36 (0.34)	-0.09 (0.24)
Exit velocity 2	-0.24 (0.17)	-0.14 (0.13)	0.17 (0.17)	-0.29 (0.14)	0.16 (0.29)	-0.34 (0.21)

Administration of Prostaglandin to Beef Heifers at Time of Artificial Insemination

S.K. Johnson and J.R. Jaeger

Introduction

Transportation of sperm is a critical component of reproductive success. Another factor in reproductive success are the contractions of the uterine myometrium, which influence the number of sperm that reach the oviduct. Prostaglandin $F_{2\alpha}$ (PG) is present in bull semen and has a variety of functions in reproduction, including stimulating myometrial contractions. Evidence of improved fertility after administration of PG at breeding has been shown in the rabbit, sow, and cow. An injection of PG at the time of insemination improved conception rates in heifers inseminated with semen with only 30% motility. The objective of the study was to determine if administration of prostaglandin $F_{2\alpha}$ at the time of insemination would improve pregnancy rate to artificial insemination (AI) when insemination occurred after observed estrus or at fixed-time insemination.

Experimental Procedures

Angus and Angus cross yearling heifers (n = 268) at a single location were assigned randomly to AI either after observed estrus or at a fixed time. To synchronize estrus, all heifers received a standard melengesterol acetate (MGA)–PG protocol of 0.5 mg/head per day of MGA (Pfizer Animal Health, Whitehouse Station, NJ/Zoetis Florham Park, NJ) for 14 days and 5 mL Prostamate (PG, IVX Animal Health, St. Joseph, MO/Bayer, Shawnee Mission, KS), either 18.5 (n = 117; fixed-time AI) or 19 (n = 151; observed estrus AI) days after the last feeding of MGA (Figure 1). Experienced technicians inseminated heifers in the observed estrus AI group 6 to 12 hours after detected estrus. Sixty hours after the Prostamate injection, heifers in the fixed-time AI group received 2 mL OvaCyst (gonadotropin-releasing hormone, IVX Animal Health/Bayer) and were inseminated. At the time of insemination, every other heifer received 2 mL Estrumate (PG, Intervet-Shering Plough, Millsboro, DE/Merck, Summit, NJ). Seven sires were used and were balanced across treatments. Pregnancy rate to AI was determined via ultrasonography 42 days after AI.

Results and Discussion

Reproductive tract scores, measured 45 to 60 days prior to breeding in a subset of 166 heifers (Table 1) indicated heifers met standard recommendations of 50% or more with tract scores of 3 or greater prior to breeding. The average interval between PG injections on day 18.5 to fixed-time AI was 62.2 ± 1.1 hours. Pregnancy rate to AI ($P < 0.06$) tended to be higher in heifers inseminated after observed estrus (57%) than timed-AI (46%). The interaction of insemination type with PG treatment at AI tended to be significant ($P < 0.08$). Pregnancy rate to AI was lowest in fixed-timed AI heifers that did not receive PG at insemination (Figure 2). The incidence of standing estrus was not recorded for heifers in the fixed-timed AI group. Sperm transport may be improved in fixed-time AI heifers treated with PG that were not in heat at the time of insemination.

Further research is needed to clarify if administration of $PGF_{2\alpha}$ at the time of insemination may improve conception to fixed-time AI.

Implications

This study provides evidence that insemination after observed estrus tends to produce more AI pregnancies than fixed-timed AI at 60 hours after PG in the MGA-PG protocol. The study also shows that additional research is needed to determine the potential benefit of $PGF_{2\alpha}$ at fixed-timed AI.

Table 1. Distribution of reproductive tract scores in yearling heifers

	Reproductive tract score[1]				
	1	2	3	4	5
Proportion of heifers, %	0.6	41	47.6	10.8	0

[1] 1 = infantile; 5 = mature tract and corpus luteum.

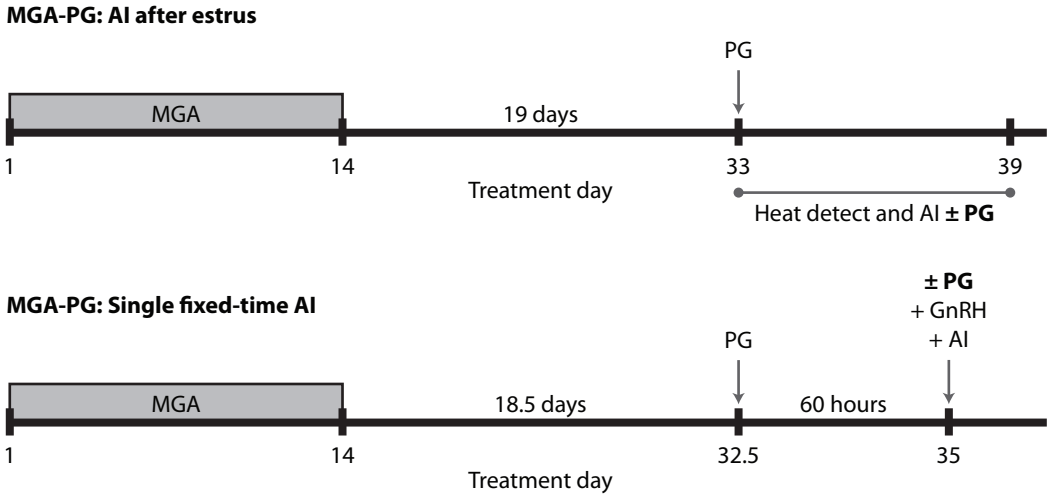

Figure 1. Diagram of treatments for synchronization of estrus and time of artificial insemination (AI). MGA = melengesterol acetate (Pfizer Animal Health, Whitehouse Station, NJ); PG = prostaglandin $F_{2\alpha}$, Prostamate (IVX Animal Health, St. Joseph, MO) day 32–33 and Estrumate (Intervet-Schering Plough, Millsboro, DE) after day 33; GnRH = gonadotropin-releasing hormone (OvaCyst, IVX Animal Health, St Joseph, MO).

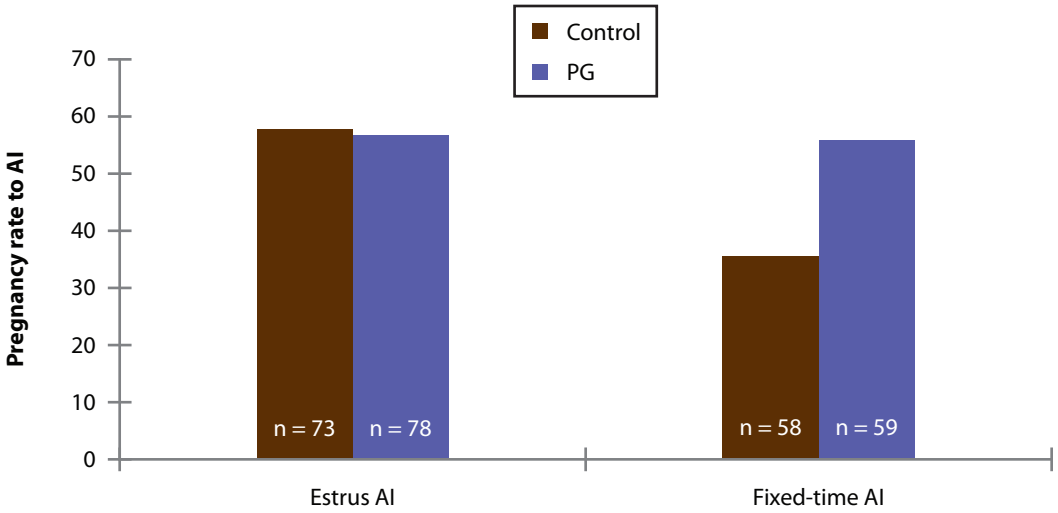

Figure 2. Pregnancy rate for heifers inseminated after observed estrus or at a single fixed-time artificial insemination (AI) that did or did not receive prostaglandin $F_{2\alpha}$ (PG) at time of insemination. Insemination type × prostaglandin $F_{2\alpha}$ treatment, $P < 0.08$.

Variation in Timed Artificial Insemination Pregnancy Rates in Specific Groups of Suckled Beef Cows

S.L. Hill and J.S. Stevenson

Introduction

Insemination of beef cows at a predetermined time is a management tool to reduce labor costs associated with conventional heat detection available to cattle producers. Multiple research trials have examined the timing of the administration of the individual components of the developed protocols associated with timed artificial insemination (TAI). In the current research, we examined various classifications of postpartum beef cows and analyzed their reproductive performance when submitted to TAI protocols. The 7-day CO-Synch + controlled internal drug release (CIDR) insert protocol and the 5-day CO-Synch + CIDR protocol have been shown to effectively initiate ovulation in cycling and non-cycling suckled beef cows, producing pregnancy rates at or greater than 50% in beef cows. We hypothesized that uniformly selected groups of cows based on their progesterone status at CIDR insertion, days postpartum, body condition score, and/or parity would demonstrate improved reproductive performance compared with non-grouped cows.

Experimental Procedures

A total of 1,277 primaparous and 5,676 multiparous cows in 14 states were included in this analysis. All cows were submitted to either a 5- or 7-day CO-Synch + CIDR TAI procedure. Both of these procedures were initiated with 100 μg gonadotropin-releasing hormone (2 mL Factrel, Pfizer Animal Health, Whitehouse Station, NJ) and a simultaneous vaginal insertion of a new CIDR insert (Pfizer Animal Health, Whitehouse Station, NJ) containing 1.38 g progesterone, followed in either 5 or 7 days with CIDR insert removal and concurrent intramuscular administration of 25 mg prostaglandin $F_{2\alpha}$ (5 mL Lutalyse; Pfizer Animal Health, Whitehouse Station, NJ). Insemination was performed from 56 to 72 hours after CIDR insert removal, and a second gonadotropin-releasing hormone treatment was administered concurrent with AI. Body condition scores (1 = thin; 9 = very fat) were assigned 10 days before the initial gonadotropin-releasing hormone injection. Blood samples were collected via caudal vessel puncture 10 days before and at the initial gonadotropin-releasing hormone treatment and CIDR insertion. Blood samples were assayed for progesterone by radioimmunoassay. Cows were classified at both sampling times according to the serum progesterone concentration. The labels of H (≥4 ng/mL), MH (2 to 3.99 ng/mL), LM (1 to 1.99 ng/mL), and L (< 1 ng/mL) were assigned according to progesterone concentration at each sampling time. Days postpartum was calculated as the number of days from calving until the day of TAI.

Cows were either exposed to cleanup bulls beginning 10 to 12 days after TAI or reinseminated at subsequent estrus. At 35 days after AI, pregnancy was confirmed by transrectal ultrasonography (5MHz transrectal transducer, Aloka 500V, Wallingford, CT). A positive pregnancy outcome required presence of a corpus luteum and uterine

fluid or uterine fluid and an embryo with a heartbeat. A final pregnancy diagnosis was determined 35 days after the end of the breeding season via transrectal ultrasonography.

Results

Progesterone concentrations by classification had no influence ($P = 0.66$) on pregnancy when sampled at the time of CIDR insert insertion (Figure 1). The initial sampling of progesterone 10 days earlier, however, indicated that cows in the MH classification were more ($P < 0.05$) likely to become pregnant than the cows in the LM classification, and MH cows tended ($P < 0.10$) to have better pregnancy outcomes than the L cows (Figure 2).

Parity, days postpartum, and body condition score all affected pregnancy outcomes ($P = 0.0001$, 0.0001, and 0.021, respectively; Table 1). None of the two-way interactions among body condition score, parity, and days postpartum resulted in differences in TAI pregnancy rates, but the three-way interaction of body condition score, parity, and days postpartum tended ($P = 0.06$) to differ. This tendency indicated that cows with a body condition score >5 that were more than 73 days postpartum at TAI and had calved at least twice had the greatest pregnancy rate (Table 2). Conversely, cows that had calved only once, were 73 days or less postpartum, and had a body condition score ≤5 were least likely to become pregnant to TAI. All other combinations of body condition score, parity, and days postpartum resulted in TAI pregnancy rates that were intermediate to the previous combinations (Table 2).

Implications

The likelihood of pregnancy success is increased for cattle producers when cows in certain categories are subjected to TAI compared with using the same procedure on all cows in a herd. By sorting cows using easily distinguishable criteria such as body condition and days postpartum, limited economic and labor resources may be utilized more efficiently. For example, a producer might eliminate the CIDR and use only the CO-Synch programs in older, early calving cows in good body condition, which would reduce the per-cow cost of the hormones by more than 50%. Older cows in good body condition that calved early in the breeding season had an 8% greater TAI pregnancy outcome than other older cows in poorer body condition, fewer days postpartum, or both, and all primiparous cows regardless of days postpartum or body condition.

Table 1. Analysis of variance (PROC GLIMMIX[1])

Source of variation	d.f.[2]	F-value	*P*-value
Parity (P)	1	14.50	0.0001
Days postpartum (D)	1	15.06	0.0001
Body condition (BCS)	1	5.33	0.0210
D × P	1	0.61	0.4336
D × BCS	1	0.16	0.6863
BCS × P	1	0.13	0.7179
D × P × BCS	1	3.48	0.0620
PCAT20[3]	3	1.46	0.2241
PCAT10[3]	3	0.53	0.6634
PCAT20 × PCAT10	9	1.37	0.1968

[1] SAS Institute, Inc., Cary, NC.
[2] Degrees of freedom.
[3] Four progesterone concentration categories at 20 or 10 days (day of CIDR insert) before timed artificial insemination: L = 0.01 < progesterone < 1.0 ng/mL; LM = 1.0 ≤ progesterone < 2.0 ng/mL; MH = 2.0 ≤ progesterone < 4.0 ng/mL; and H = progesterone ≥ 4.0 ng/mL.

Table 2. Influence of parity, days postpartum, and body condition on artificial insemination (AI) pregnancy rates per timed AI in suckled beef cattle[1]

Parity	Days postpartum	Body condition score	n	Proportion of total	Raw means	Adjusted means
2	>73	>5	1,066	15.3	59.0	61.2[a]
2	>73	≤5	1,466	21.1	51.5	53.7[b]
2	≤73	>5	1,399	20.1	51.0	53.0[b]
1	>73	≤5	556	8.0	50.2	52.0[b]
2	>73	>5	361	5.2	48.8	51.6[b]
1	≤73	≤5	1,745	25.1	48.8	50.6[b]
1	≤73	>5	139	2.0	43.5	47.2[bc]
1	≤73	≤5	221	3.2	39.4	39.5[c]
	Overall		6,953	100.0	51.1	

[1] Treatment × herd (year) was a random effect in the model. All cows were treated with either the 5-day or 7-day CO-Synch controlled internal drug release (CIDR) program.
[a, b, c] Means within column with different superscript letters differ ($P < 0.05$).

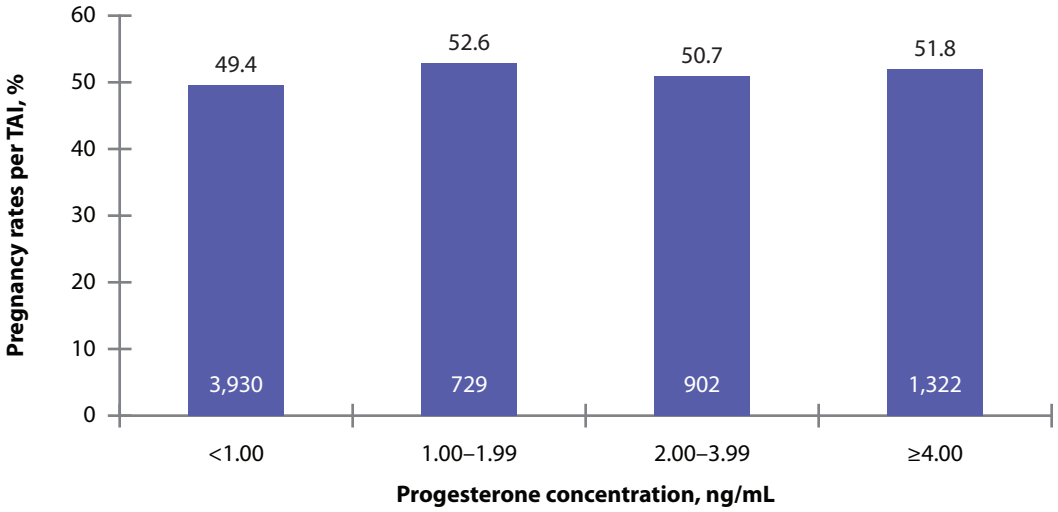

Figure 1. Timed artificial insemination (TAI) pregnancy rates based on progesterone concentration at controlled internal drug release (CIDR) insertion.

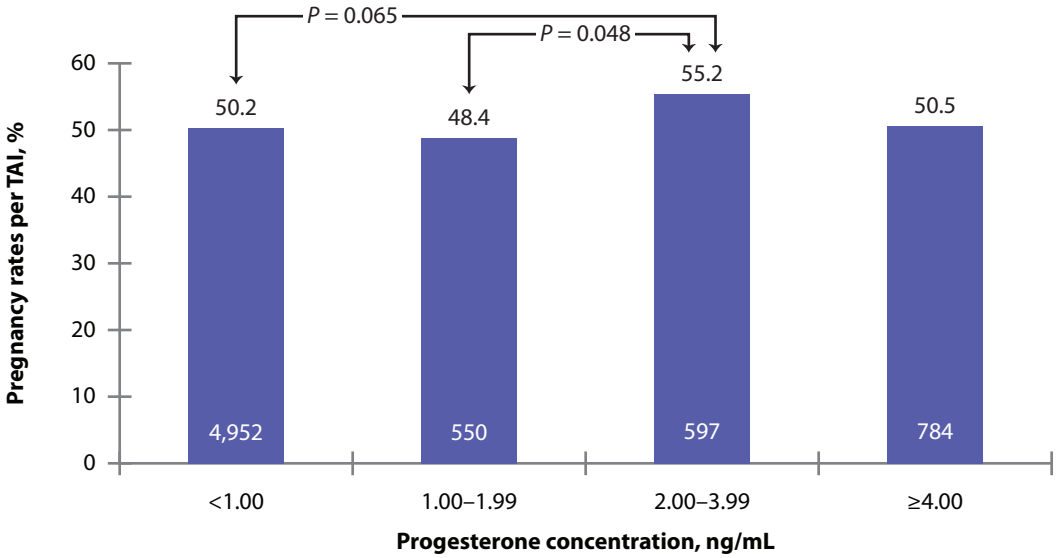

Figure 2. Timed artificial insemination (TAI) pregnancy rates based on progesterone concentration at 10 days before controlled internal drug release (CIDR) insertion.

Effects of Corn Steep Liquor Supplementation on Performance and Herbivory Patterns of Beef Cows Grazing Native Range Infested with Sericea Lespedeza (*Lespedeza cuneata*)

G.W. Preedy, KC Olson, W.H. Fick, and L.W. Murray

Introduction

Sericea lespedeza (*Lespedeza cuneata*) is classified as an invasive plant throughout the Great Plains, and approximately 600,000 acres of grassland in Kansas have been infested with this species. The aggressive nature of the plant decreases native grass production by up to 92% through a combination of prolific seed production, canopy dominance, and production of chemicals that are harmful to other plant species. Herbicides retard the spread of sericea, but their application is expensive. Moreover, herbicides can be lethal to ecologically important, non-target plant species. Goat grazing has been shown to reduce sericea lespedeza seed production significantly, but widespread use of goat grazing faces significant cultural and economic challenges in the Kansas Flint Hills.

Increased grazing pressure on sericea lespedeza by beef cattle, the most economically relevant herbivore in the region, may slow its spread and facilitate some measure of biological control. Unfortunately, mature plants contain high levels of condensed tannins that decrease protein digestion by beef cattle, and these compounds are potent deterrents to grazing. Supplementing corn steep liquor has been shown to alleviate the negative effects associated with ingestion of condensed tannins when beef cattle are fed prairie hay contaminated with sericea lespedeza. In addition, beef cows supplemented with corn steep liquor did not discriminate between sericea lespedeza–contaminated and sericea lespedeza–free prairie hay in a preference trial. Therefore, the objective of our study was to evaluate the effects of supplemental corn steep liquor on herbivory patterns and performance of beef cows grazing native tallgrass rangeland infested with sericea lespedeza.

Experimental Procedures

Our study was conducted from May 1 through October 1, 2011, in Chautauqua County, KS, on nine native tallgrass pastures located approximately 10 miles southeast of Sedan. Pastures were burned April 10. Plant species composition of pastures was estimated immediately before initiation of the trial using a modified step-point technique (Table 1).

Lactating crossbred beef cows with calves (n = 145; initial cow body weight = 1,276 ± 201 lb; initial calf body weight = 306 ± 71 lb) were blocked by age and calving date and assigned randomly to one of two treatments. Treatments consisted of no supplementation or supplementation with corn steep liquor. Cow and calf body weights were measured at monthly intervals from June 1 through October 1; cow body condition scores (scale = 1 to 9; 1 = emaciated, 9 = obese) also were assessed at those times. Cow-calf pairs were allowed to graze freely from May 1 through October 1. Cows were

exposed to natural-service breeding from May 1 through July 15. Calves were weaned September 1 at an approximate age of 200 days. Cow pregnancy rates were determined by rectal palpation 75 days after bulls were removed from pastures.

Native tallgrass pastures (9 pastures; 124 ± 42 acres each) heavily infested with sericea lespedeza were assigned randomly to the unsupplemented and supplemented treatments. Animals were assigned randomly to pastures within designated treatment groups. All pastures were stocked at 1.2 acre/animal unit months (AUM), a rate typical of the Kansas Flint Hills. Beginning June 1, cow-calf pairs were fed supplemental corn steep liquor that was delivered 3 times per week in portable feed bunks (2 linear feet of feeder space per cow). Delivery of corn steep liquor was prorated for an average daily intake of 1.0 gallon/cow daily (i.e., 4 lb dry matter per cow daily). Prior research reported that 4 lb corn steep liquor per cow daily (dry basis) provided complete relief from the symptoms of condensed tannin consumption among beef cows fed prairie hay contaminated with sericea lespedeza. Corn steep liquor, a viscous, liquid byproduct of wet-corn milling, was purchased from Archer Daniels Midland in Columbus, NE, and each truckload was sampled randomly to determine chemical composition (Table 2).

Two permanent 330-foot transects were established in each pasture at the onset of the trial (June 1) to estimate aboveground forage biomass, botanical composition, and sericea lespedeza herbivory. Total forage biomass and sericea biomass were estimated by clipping all live plant material from within randomly placed sampling frames (10 in.^{2}; 10 frames per pasture) at a height of 0.4 in. on June 1, July 1, August, September 1, and October 1. Sericea lespedeza and all other forage plants were placed in separate paper bags. Samples were sun-dried at the collection site for subsequent laboratory analysis. Herbivory of individual sericea lespedeza plants was estimated visually at the end of the study (October 1) at 16-foot intervals along each transect. The closest sericea lespedeza plant to each point was examined for evidence of defoliation (Table 3).

Results and Discussion

No performance differences were observed throughout the duration of the study. Forage quality followed an anticipated pattern from June through October (Table 2) but was generally greater than previously reported for annually burned, native tallgrass prairie during the summer months. Improved forage quality is typical of moderate drought conditions due to abnormally slow rates of forage maturation. Forage crude protein contents were relatively high during May and October and were lowest during August, following the hottest, driest month of the year. Concentrations of neutral detergent fiber (NDF) and acid detergent fiber (ADF) were generally the inverse of crude protein. Interestingly, concentrations of crude protein and NDF in sericea lespedeza were generally more favorable than the average of available pasture forage on a month-by-month basis.

Initial, average, and final total forage biomass and sericea lespedeza biomass did not differ ($P \geq 0.52$) between treatments (Table 3). As expected, corn steep liquor supplementation did not have an immediate, pasture-scale influence on sericea lespedeza biomass availability. The proportion of sericea lespedeza plants with visual evidence of herbivory tended to be greater ($P = 0.09$) on pastures grazed by supplemented cows (94.2%) compared with pastures grazed by unsupplemented cows (80.2%; Table 3).

Supplemental corn steep liquor fed at 4 lb of dry matter per cow daily was associated with increased herbivory of sericea lespedeza during a summer grazing season. Moreover, beef cow and calf performance were not adversely affected by condensed-tannin consumption under these circumstances. As expected, corn steep liquor supplementation did not have an immediate, pasture-scale influence on sericea lespedeza biomass availability; however, we speculated that repeated applications of corn steep liquor supplementation on sericea lespedeza–infested tallgrass pastures may impair seed-producing capabilities of the plants, potentially leading to a long-term decline in plant numbers for sericea lespedeza.

Implications

The cost of the corn steep liquor at the initiation of our trial was $61/ton; cost per cow was estimated at $26.40 for the 120-day period of our study (i.e., 8.8 lb × 120 days × $0.031/lb; as-fed basis).

A liquid feed-handling system and portable feed bunks (10 × 1 ft) were purchased to store and feed the corn steep liquor at an installed cost of $6,000. Assuming a 5-year period of depreciation, the annualized cash cost of this equipment was $1,200. For a 100-head cow herd, cost for the storage system and bunks would have been $12/cow annually. Delivery of corn steep liquor three times weekly (i.e., 40 deliveries/season @ $20/delivery) was estimated at $8/cow annually. Under these conditions, cost for supplementation with corn steep liquor was estimated at $46.40/cow annually. A commonly used stocking rate across the Flint Hills of Kansas is 8 acres/cow during a 6-month summer grazing season, so cost for corn steep liquor supplementation was estimated at $14.28/acre annually (i.e., $46.40 ÷ 8 acres). Treating sericea with herbicides was estimated to cost $12–16/acre annually at the time of this writing. It remains to be seen whether or not supplementation of cows with corn steep liquor will provide a degree of control comparable to that achieved with annual herbicide treatment.

Table 1. Botanical composition of native tallgrass pastures grazed from May 1 through October 1

Item		Percentage
Grasses		**83.22**
Big bluestem	*Andropogon gerardii*	19.50
Little bluestem	*Schizachyrium scoparium*	16.94
Sedges	*Carex* spp.	14.11
Indiangrass	*Sorghastrum nutans*	7.88
Scribner's panicum	*Dichanthelium oligosanthes*	5.00
Tall dropseed	*Sporobolus asper*	4.94
Switchgrass	*Panicum virgatum*	2.44
Sand paspalum	*Paspalum setaceum*	2.17
Green bristlegrass	*Setaria geniculata*	1.89
Hairy grama	*Bouteloua hirsuta*	1.67
Purple top	*Tridens flavus*	1.33
Sideoats grama	*Bouteloua curtipendula*	0.50
Blue grama	*Bouteloua gracilis*	0.17
Other grasses	*n = 21*	4.68
Forbs		**14.29**
Lance-leaf ragweed	*Ambrosia bidentata*	2.38
Western ragweed	*Ambrosia psilostachya*	1.42
Grassleaf goldenrod	*Euthamia graminifolia*	1.28
Sericea lespedeza	*Lespedeza cuneata*	0.96
Heath aster	*Symphyotrichum ericoides*	0.59
Purple prairie clover	*Dalea purpurea*	0.03
Dotted gayfeather	*Liatris punctata*	Trace
Other forbs	*n = 67*	7.63
Woody plants		**2.49**

Table 2. Nutrient composition of range forage, sericea lespedeza, and corn steep liquor available to beef cows and calves grazing native tallgrass pastures (dry matter basis)

	Constituent[1]						
Item	% DM	% OM	% CP	% NDF	% ADF	% Ca	% P
Range forage							
June 1	92.0	92.6	9.1	53.1	37.2	0.91	0.11
July 1	91.7	93.0	9.2	47.3	36.5	1.08	0.08
August 1	91.8	93.0	7.3	53.5	39.0	0.95	0.08
September 1	91.9	93.3	9.9	46.3	36.3	1.02	0.10
October 1	92.1	93.7	11.1	45.4	38.5	1.09	0.12
SEM	0.05	0.10	0.03	0.55	0.56	0.024	0.005
Sericea lespedeza							
June 1	91.5	93.4	13.1	39.2	33.9	1.19	0.12
July 1	91.5	94.0	11.0	41.7	39.5	1.19	0.08
August 1	91.8	94.3	11.3	43.1	38.4	1.07	0.12
September 1	91.8	94.5	10.6	40.5	41.2	1.23	0.10
October 1	91.8	93.9	13.0	37.1	36.6	1.23	0.13
SEM	0.05	0.02	0.04	0.38	0.58	0.029	0.003
Corn steep liquor	45.1	88.1	34.4	3.1	2.0	0.11	1.90

[1] DM = dry matter; OM = organic matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; Ca = calcium; P = phosphorus.

Table 3. Effects of corn steep liquor supplementation on range forage biomass, sericea lespedeza biomass, and sericea lespedeza herbivory by beef cows and calves grazing native tallgrass pastures

Item	Unsupplemented	Supplemented	SEM	*P*-value
Initial total forage biomass, lb dry matter/acre	1,852	2,019	809	0.87
Average total forage biomass, lb dry matter/acre	2,312	2,445	867	0.88
Final total forage biomass, lb dry matter/acre	3,309	4,014	809	0.52
Initial sericea lespedeza biomass, lb dry matter/acre	231	310	568	0.92
Average sericea lespedeza biomass, lb dry matter/acre	703	1,048	563	0.55
Final sericea lespedeza biomass, lb dry matter/acre	1,939	2,214	568	0.72
Sericea lespedeza stems grazed, % of total	80.2	94.2	6.7	0.09

Botanical Composition of Beef Cow Diets Shifts When Native Range Infested with Sericea Lespedeza (*Lespedeza cuneata*) is Supplemented with Corn Steep Liquor

G.W. Preedy, KC Olson, L.W. Murray, and W.H. Fick

Introduction

Over 600,000 acres of grasslands in Kansas are infested with the noxious weed sericea lespedeza. Herbicide treatment of sericea lespedeza is expensive; moreover, grassland acreage affected by the weed increased more than 60-fold between 1988 and 2000 despite routine use of herbicide during that period.

Increased grazing pressure on sericea lespedeza by beef cattle may slow the weed's spread and facilitate a measure of biological control. Nutrient composition of sericea lespedeza appears favorable for livestock production, but elevated condensed-tannin content strongly deters voluntary consumption of sericea lespedeza by beef cattle. Feedstuffs with tannin-binding properties may promote voluntary consumption of sericea lespedeza by beef cattle. Confined beef steers fed polyethylene glycol ate more sericea lespedeza than steers not fed polyethylene glycol; however, use of polyethylene glycol as an anti-tannin feedstuff is cost-prohibitive and disallowed from a regulatory standpoint in the United States. Moderate amounts of supplemental corn steep liquor (1.3 to 4 lb/day) have been reported to normalize dry matter intake and protein digestion by confined beef cows fed prairie hay contaminated with sericea lespedeza. In addition, beef cows supplemented with corn steep liquor did not discriminate between sericea lespedeza-contaminated and sericea lespedeza-free prairie hay in a preference trial. An inexpensive and palatable byproduct of corn wet-milling, corn steep liquor is Generally Recognized as Safe (GRAS) by the U.S. Food and Drug Administration when used as a feedstuff for cattle.

Corn steep liquor supplementation indicated that a higher percentage of sericea lespedeza plants were defoliated in pastures grazed by corn steep liquor–supplemented cows than in pastures grazed by unsupplemented cows; however, it was unknown if defoliation was related directly to grazing activity of cows. Therefore, our objective was to evaluate the effects of supplemental corn steep liquor on botanical composition of the diets of beef cows grazing native tallgrass rangeland infested with sericea lespedeza in the Kansas Flint Hills.

Experimental Procedures

Our study was conducted from May 1 through October 1, 2011, in Chautauqua County, KS, on nine native tallgrass pastures located approximately 10 miles southeast of Sedan. Pastures were burned April 10. Plant-species composition of pastures was estimated immediately before initiation of the trial using a modified step-point technique. Frequently occurring graminoids included big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), sedges (*Carex* spp.), and indiangrass (*Sorghastrum*

nutans). Frequently occurring forbs included ragweeds (*Ambrosia* spp.), grassleaf goldenrod (*Euthamia graminifolia*), and sericea lespedeza (*Lespedeza cuneata).*

Nine pastures (124 ± 42 acres each) infested heavily with sericea lespedeza were assigned randomly to one of two grazing treatments consisting of unsupplemented cow-calf pairs or cow-calf pairs supplemented with corn steep liquor (45% dry matter; 34.4% crude protein). All pastures were stocked at 1.2 acres/animal unit months (AUM), a rate typical of the Kansas Flint Hills. Cow-calf pairs were fed supplemental corn steep liquor that was delivered three times per week in portable feed bunks (2 linear feet of bunk space per cow) beginning on June 1. Corn steep liquor was fed to achieve an average intake of 1.0 gallon per cow-calf pair daily (approximately 4 lb dry matter per pair daily).

Lactating, crossbred beef cows with calves (n = 145; initial cow body weight = 1,276 ± 201 lb) were blocked by age and calving date and assigned randomly to treatments and to pastures. Cow-calf pairs were allowed to graze assigned pastures freely from May 1 through October 1. Cows were exposed to natural-service breeding from May 1 through July 15. Calves were weaned September 1 at an approximate age of 200 days. Cow pregnancy rates were determined by rectal palpation 75 days after bulls were removed from pastures.

Beef cows were gathered on the first of each month from June through October, individually restrained in a squeeze chute (~2 min), and fresh fecal-grab samples were collected from each animal. Each sample was hand-mixed to ensure homogeneity and a 0.1-lb subsample was retained for analysis. Grab samples were sealed in plastic containers, immediately placed on ice, and transported to Kansas State University. Samples were stored frozen until microhistological analyses were performed.

Wet fecal samples were soaked overnight in 50% ethanol (v/v). After soaking, ethanol was decanted and samples were homogenized and washed with deionized water through a No. 200 US-standard sieve. Samples were then re-homogenized, strained, and dried in a forced air-oven for 96 hours at 122°F. Dried samples were ground (#4 Wiley Mill, Thomas Scientific, Swedesboro, NJ) to pass a 0.12-in. screen and stored in plastic bags for slide preparation (Bennett et al., 1999)[1].

Dried fecal samples were cleaned, decolorized, and mounted on microscope slides. Slides were evaluated with a compound microscope at 10-fold magnification. The microscope was equipped with a digital camera, and each slide field was photographed for comparison with standard slides. Twenty random fields per slide were selected from the entire slide and used to measure the frequency with which plant fragments appeared. Individual plant species were identified according to their histological characteristics using standard slides for comparison. Due to histological similarities, big bluestem and little bluestem were grouped together for purposes of analysis. Plant fragment prevalence in slide fields was assumed to be equivalent to prevalence in fecal samples and equivalent to the botanical composition (percentage of each plant) of diets grazed

[1] Bennett L. L., A. C. Hammond, M. J. Williams, C. C. Chase Jr., and W. E. Kunkle. 1999. Diet selection by steers using microhistological and stable carbon isotope ratio analyses. J. Anim. Sci. 77:2252–2258.

by beef cows. Plant fragments that were not among the 11 range-plant species for which standards were prepared were classified as either unknown grass or unknown forb.

Whole-plant sericea samples were collected from each pasture (40 plants/pasture) on the first day of each month from June through October. Stems were clipped 0.4 in. above the soil surface and sun-dried at the collection site for subsequent analysis of condensed tannins and condensed tannin protein-binding capacity. At the laboratory, sericea lespedeza stems were dried in a forced-air oven (96 hours; 122°F), weighed, ground (#4 Wiley Mill) to pass a 0.04-in. screen, and composited within collection date.

Tannins were extracted using a methanol extraction procedure. Samples were combined with 50% methanol (volume/volume), agitated in an ultrasonicator (Blackstone Ultrasonics, Sheffield, PA) for two 10-minute periods, then centrifuged at 3,000 × *g* (39°F) for 15 minutes to remove solids. The supernatant was removed and used for further analysis. Condensed tannin concentrations were measured using a modified butanol-HCl reaction. Reaction mixtures were read at 550 nm using a UV spectrophotometer equipped with Gen5 software (Biotech Inc., Winooski, VT). Absorbance was adjusted to CT concentration using leucocyandin as a standard.

Protein-precipitable phenolics were determined through a reaction between ferric chloride and tannin phenolics. This reaction produced a pink chromatophore that could be read spectrophotometrically. Absorbance was measured at 510 nm using a UV spectrophotometer equipped with Gen5 software (Biotech Inc.). Concentrations were determined using a standard curve after accounting for the amount of added sodium dodecyl sulfate solution.

Results and Discussion

Concentration of condensed tannin (Table 1) in sericea lespedeza increased ($P < 0.01$) as the grazing season advanced, reaching its peak during the August collection period (Table 1). Thereafter, condensed tannin concentration declined. Protein-binding capacity of condensed tannin in sericea lespedeza generally mirrored condensed tannin concentration, but peak protein-binding capacity occurred one month later (September 1) than peak condensed tannin concentration.

Prevalence of sericea lespedeza in beef cow diets was influenced ($P < 0.01$) by corn steep liquor supplementation and by collection period (Figure 1). Although sericea lespedeza selection by corn steep liquor–supplemented beef cows was numerically greater than that by unsupplemented beef cows at each of the five collection dates, prevalence of sericea lespedeza in beef cow diets was sufficiently variable that no difference ($P \geq 0.55$) between treatments was detected when concentration and protein-binding capacity of condensed tannin were relatively low (June, July, and October sampling days; Table 1). Conversely, corn steep liquor–supplemented cows selected 30 and 49% more sericea lespedeza than unsupplemented cows during the August and September sampling periods ($P < 0.01$). These times corresponded to greatest condensed tannin concentration and condensed tannin protein-binding capacity in sericea lespedeza.

The relative abundance of sericea lespedeza (Figure 1) in the diets of beef cows in our study ranged from a low of 3.5% (unsupplemented cows on September 1) to a high of

7.5% (corn steep liquor–supplemented cows on October 1). We interpreted this to indicate that, under the conditions of our study, sericea lespedeza was an important forb component of the diet in both supplemented and unsupplemented beef cows. The significance of increased voluntary selection of sericea lespedeza by corn steep liquor–supplemented beef cows during August and September is that these months correspond to flowering and seed production by sericea lespedeza in the Kansas Flint Hills. Increased grazing pressure achieved with goats during this interval of time resulted in drastically reduced seed production by sericea lespedeza.

Supplemental corn steep liquor had no influence ($P \geq 0.10$) on voluntary selection of other plant species that were examined in our study; however, there were important temporal differences in selection of various critical grasses and forbs. Displayed preferences for individual forage plants are influenced by animal perceptions of palatability, plant growth form, plant nutrient composition, and animal experience. Moreover, preferences may change dramatically over time in native range production systems due to temporal fluctuations in availability of key species and maturity-driven changes in palatability, growth form, and nutrient content.

Voluntary selection of all grass species (Figure 2) decreased ($P < 0.01$) from June to October. We speculated that selection of these species was inversely related to nutrient content: native tallgrasses tend to have excellent nutrient profiles while vegetative, but quality declines rapidly as plant maturity advances.

Voluntary selection of forbs (Figure 2) increased during the same interval ($P < 0.05$). We speculated that selection of these plants may have increased over time due to increasing availability and high relative forage quality as the grazing season advanced. In general, the magnitude of change in forb selection from the beginning to end of the grazing season was greater than that previously reported. The abnormally warm, dry conditions under which our study was conducted may have influenced availability and quality of forb plants we monitored.

Implications

Supplemental corn steep liquor increased beef cow tolerance for and acceptance of high–condensed tannin sericea lespedeza in a commercial-scale, native-range production system. We concluded that supplemental corn steep liquor allowed for a desirable change in selection preference by beef cows that stemmed from a critical modification of the post-ingestive consequences associated with condensed tannin consumption.

Supplemental corn steep liquor did not influence voluntary selection by beef cows of any other forage-plant species monitored in our study; however, there were noteworthy temporal shifts in selection. We speculated that these shifts in voluntary selection were driven by changes in plant availability, changes in nutrient composition, or both.

Table 1. Effect of harvest date on concentration[1] and protein-binding capacity of condensed tannins in sericea lespedeza

Item	Condensed tannins, %	Protein binding capacity, %
June 1	10.39[a]	46.2[a]
July 1	15.11[b]	45.5[a]
August 1	19.11[d]	49.2[c]
September 1	16.94[c]	52.3[d]
October 1	14.54[b]	47.9[b]
SEM	0.105	0.15

[a–d] Within a column, means without a common superscript differ ($P < 0.01$).
[1] Percentage of total phenolic compounds that precipitated proteins.

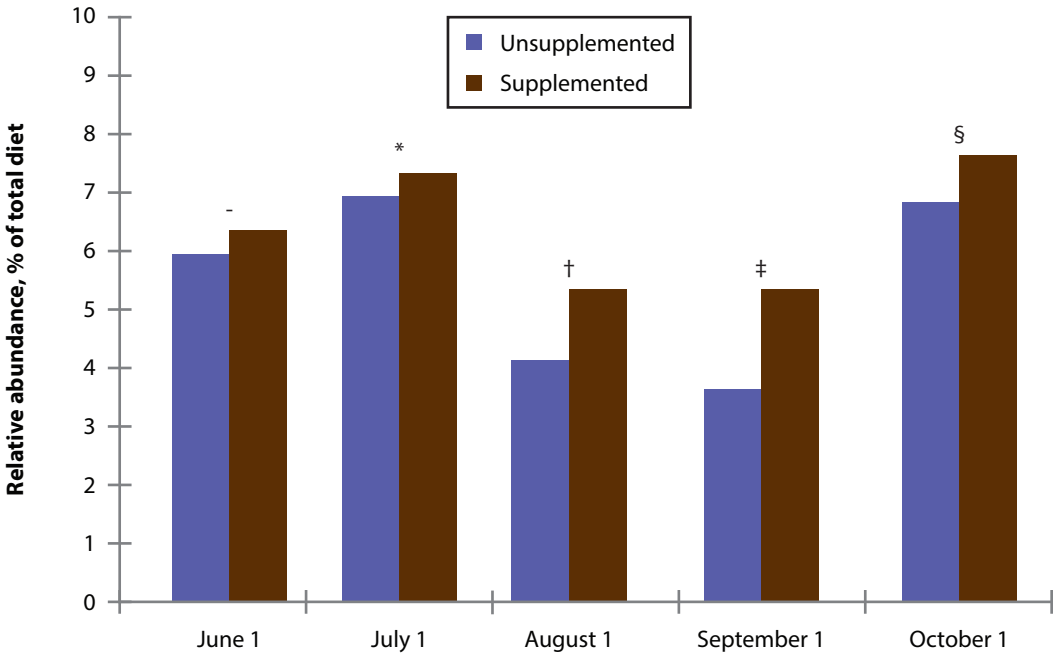

Figure 1. Effects of corn steep liquor supplementation on the relative abundance of sericea lespedeza in diets of beef cows grazing native range in the Kansas Flint Hills.
- Baseline value at beginning of study. Treatments not different; $P > 0.10$.
* July 1 consumption of sericea similar for supplemented and unsupplemented cows; $P = 0.93$.
† August 1 consumption of sericea greater for supplemented than for unsupplemented cows; $P < 0.01$.
‡ September 1 consumption of sericea greater for supplemented than for unsupplemented cows; $P < 0.01$.
§ October 1 consumption of sericea similar for supplemented and unsupplemented cows; $P = 0.35$.

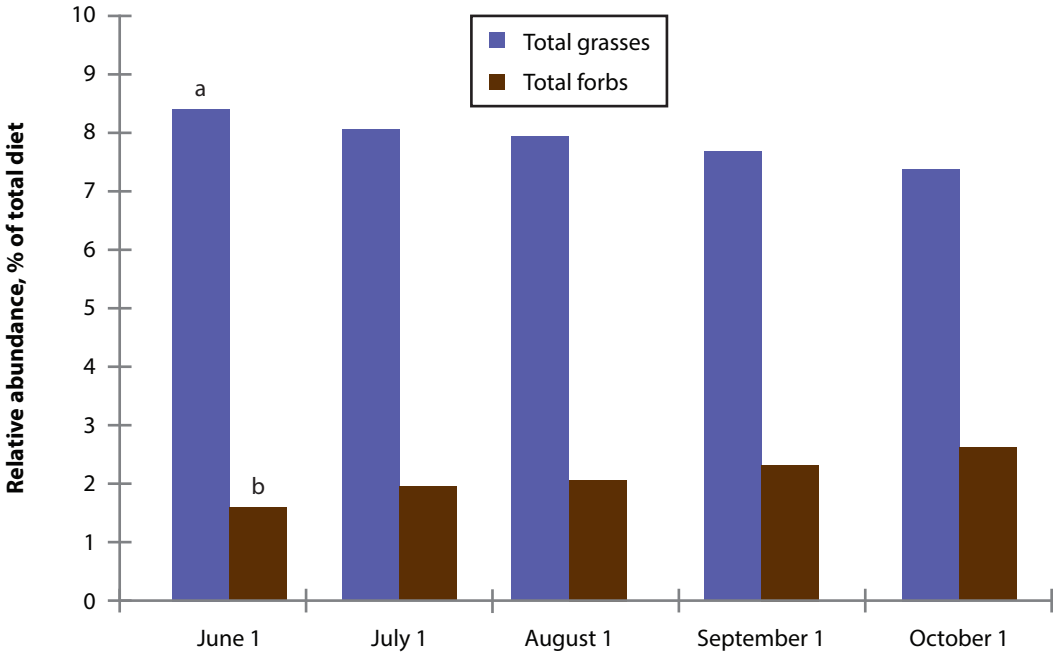

Figure 2. Relative abundance of grasses and forbs in diets of beef cows grazing native range in the Kansas Flint Hills.

[a] Effect of time on selection of all graminoid species (quartic, $P < 0.01$).

[b] Effect of time on selection of all forb species (quartic, $P < 0.01$).

Combining Ruminally Protected Choline and Flaxseed in Cattle Diets to Increase the Assimilation of Omega-3 Fatty Acids from the Diet

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Introduction

Omega-3 fatty acids are an essential part of a healthy human diet. If consumed regularly, these fatty acids attenuate inflammation and lower risk of inflammatory diseases, such as heart disease and rheumatoid arthritis. The human body cannot synthesize adequate amounts of omega-3 fatty acids; they must be obtained by consuming foods that are rich in omega-3s. Omega-3 fatty acids can be found in foods like fish, some oilseeds, and some nut oils. Overall consumption of these foods is relatively low compared with the consumption of red meat such as beef, which typically contains relatively small amounts of omega-3 fatty acids. Flaxseed contains high levels of omega-3 fatty acids, and when fed to cattle, these fats are absorbed and deposited into beef tissues. The transfer of omega-3 fatty acids from the diet to tissues is very poor, however, due to extensive alteration of fats by microbes in the rumen. If transfer efficiency from diet to tissues could be improved, beef could become a viable source of omega-3 fatty acids for consumers. Choline plays an important role in the metabolism of fats, and deficiencies of dietary choline could limit the absorption and tissue deposition of polyunsaturated fatty acids, including omega-3 fatty acids. Our objective was to evaluate the effects of combining ruminally protected choline and flaxseed on changes in plasma concentrations of long-chain fatty acids.

Experimental Procedures

Crossbred heifers (108 heifers; 628 ± 30 lb) were stratified by initial body weight and allocated randomly, within strata, to 36 concrete-surfaced pens (3 heifers/pen). Heifers were fed diets with: (1) no flaxseed/no choline; (2) flaxseed/no choline; (3) choline/no flaxseed; and (4) flaxseed and choline. Diets (Table 1) were fed *ad libitum* once daily for 14 days. At the end of the 14-day feeding period, cattle were weighed and blood was sampled by jugular puncture. Average daily gain, dry matter feed consumption, and feed conversion efficiency were calculated for each pen of animals. Blood samples were chilled and centrifuged to recover blood plasma. Fatty acid methyl esters were measured in blood plasma by gas chromatography. Data were analyzed using the mixed model procedure of SAS (SAS Institute, Cary, NC) with fixed effects of flaxseed, choline, and flaxseed × choline. The random effect was weight block, and the experimental unit was the feedlot pen.

Results and Discussion

The levels of alpha-linolenic acid, the principal omega-3 fatty acid found in flaxseed, were relatively low on day 0 of the trial (data not shown). This was expected because the cattle were fed diets that contained no appreciable quantities of omega-3 fatty acids

prior to starting the experiment. Concentrations of long-chain fatty acids in blood plasma collected after 14 days of consuming the experimental diets are represented in Table 2. Plasma concentrations of alpha-linolenic acid increased dramatically ($P < 0.05$) for cattle fed diets containing flaxseed, whereas concentrations of omega-3 fatty acids remained relatively low in plasma of cattle fed diets without flaxseed. Feeding ruminally protected choline had no appreciable impact on blood concentrations of omega-3 fatty acids, regardless of whether or not flaxseed was fed. We had hypothesized that feeding ruminally protected choline would enhance absorption of omega-3 fatty acids due to choline's important role in transport of lipids, but our hypothesis is refuted by the results of this experiment. Figures 1 and 2 illustrate the effects of our experimental diets on average daily gain and feed efficiency. Feeding flaxseed had no notable impact on performance; however, cattle fed ruminally protected choline tended to gain more ($P = 0.11$) and were more efficient ($P = 0.06$) compared with their counterparts fed diets without supplemental choline.

Implications

Ruminally protected choline improved gain efficiency by approximately 10%, which is consistent with our observations in previous studies. The extruded flaxseed product increased plasma concentrations of omega-3 fatty acids, but including ruminally protected choline resulted in no further improvement in assimilation of dietary fats.

Table 1. Composition of experimental diets[1]

	Without ruminally protected choline		With ruminally protected choline	
Ingredients, %	Without flaxseed	With flaxseed	Without flaxseed	With flaxseed
Corn silage	25.00	25.00	25.00	25.00
Wet corn gluten feed	25.00	25.00	25.00	25.00
Steam-flaked corn	27.01	19.58	25.51	18.04
Ground alfalfa hay	15.00	15.00	15.00	15.00
Corn steep liquor	1.86	1.86	1.86	1.86
Feed additive premix[2]	1.80	1.80	1.80	1.80
Supplement[3]	4.33	1.76	4.60	2.08
Extruded flaxseed product[4]	-	10.00	-	10.00
Ruminally protected choline	-	-	1.23	1.23

[1] Treatments were: 0% flaxseed and 0 g/day ruminally protected choline, 10% flaxseed and 0 g/day ruminally protected choline, 0% flaxseed and 113 g/day ruminally protected choline, and 10% flaxseed and 113 g/day ruminally protected choline.
[2] Provided 300 mg/animal daily of Rumensin (Elanco Animal Health, Greenfield, IN).
[3] Formulated to provide 1,000 IU/lb vitamin A, 0.3% salt, 0.8% calcium, 0.1 ppm cobalt, 10 ppm copper, 0.6 ppm iodine, 60 ppm manganese, 0.25 ppm selenium, and 60 ppm zinc in the total diet on a 100% dry matter basis.
[4] Product contains 50% flaxseed.

Table 2. Effects of flaxseed and ruminally protected choline on plasma concentrations of long-chain fatty acids in growing heifers

	Without ruminally protected choline		With ruminally protected choline			Treatment effect		
Item, g/mL[1]	Without flaxseed	With flaxseed	Without flaxseed	With flaxseed	SEM	Flax	Chol	F×C
C14:0	12.3	10.9	11.4	12.8	0.86	No	No	No
C16:0	176.6	184.9	196.1	203.3	8.4	No	No	No
C18:0	276.0	356.4	326.3	359.8	14.9	Yes	No	No
C18:3n3	33.3	132.5	42.9	131.0	4.9	Yes	No	No

[1] Long-chain fatty acids are identified as follows: C14:0, myristic acid (saturated); C16:0, palmitic acid (saturated); C18:0, stearic acid (saturated); C18:3n3, alpha-linolenic acid (polyunsaturated omega-3 fatty acid).
[2] Effects of flaxseed, choline, and the interaction between flaxseed and choline. "Yes" indicates a significant effect of treatment ($P < 0.05$).

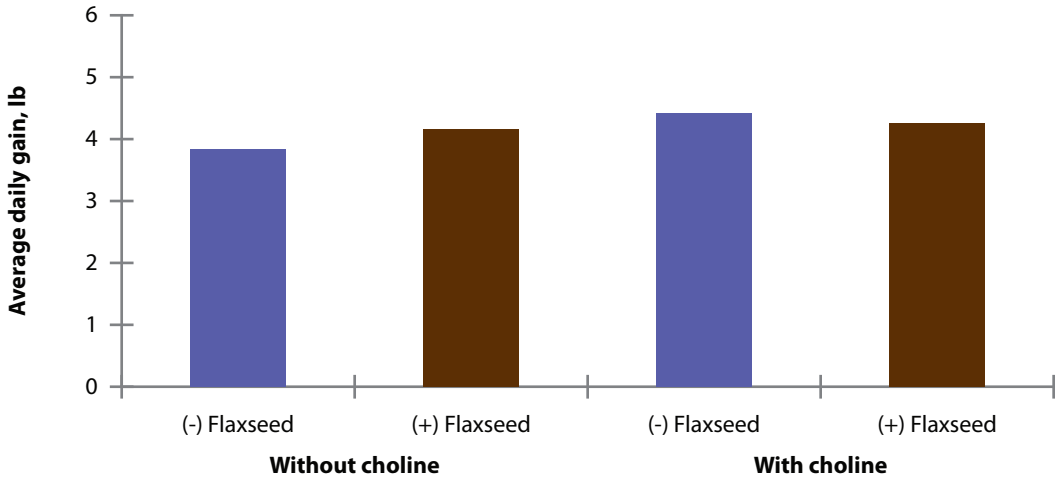

Figure 1. Average daily gain of cattle for the 14-day feeding period.
SEM: 0.125; effect of flaxseed, $P = 0.76$; effect of choline, $P = 0.11$; flaxseed × choline, $P = 0.26$.

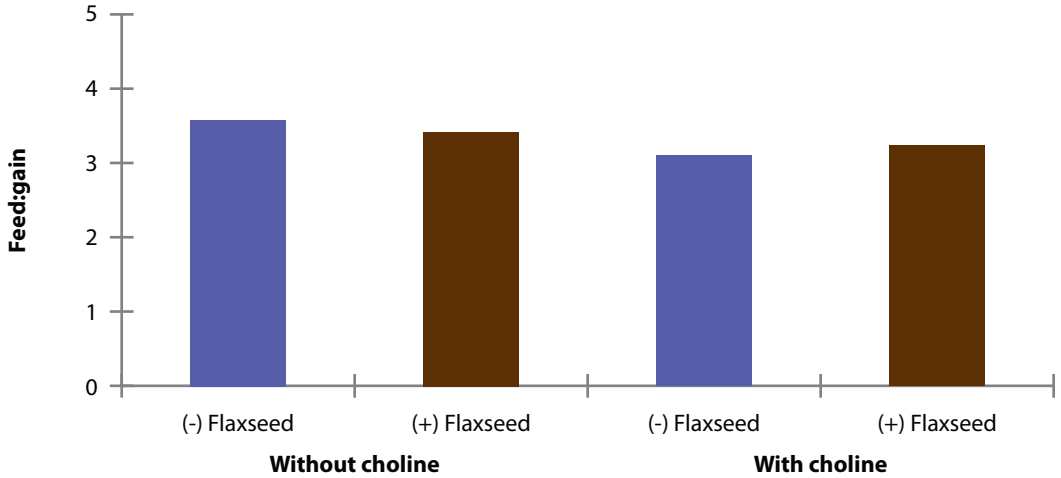

Figure 2. Feed efficiency for the 14-day feeding period, shown as feed:gain ratio.
SEM: 0.21; effect of flaxseed, $P = 0.93$; effect of choline, $P = 0.06$; flaxseed × choline, $P = 0.33$.

Wheat Straw Improved by Half-Rate Application of Anhydrous Ammonia

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Introduction

Many tons of crop residues and other low-quality forages are produced in Kansas each year. Use of these forages often is limited by their low nutrient content and poor digestibility. The process of applying anhydrous ammonia to low-quality forages enhances their feeding value by increasing crude protein content and dry matter digestibility. In the summer of 2012, the persistence of drought conditions throughout Kansas reduced forage supplies and resulted in a dramatic increase in forage prices. In an effort to aid livestock producers, the K-State Beef Extension Specialist Team, in conjunction with the Livestock Production Program Focus Team, conducted wheat straw ammoniation demonstrations at 6 locations across Kansas. The objectives of these demonstrations were to: (1) demonstrate the process of using anhydrous ammonia to treat low-quality roughages, and (2) determine if the recommended rate of 3% anhydrous ammonia application (dry weight) could be decreased as a cost-saving measure. The effects of two anhydrous ammonia application rates (1.5 and 3.0% dry matter weight of stack, equivalent to 30 or 60 lb anhydrous ammonia/ton of dry forage) on subsequent forage quality and digestibility were evaluated.

Experimental Procedures

Approximately 130 to 140 round bales of wheat straw were arranged in two separate stacks (3-2 configuration) at six independent locations. Stacks were assigned randomly at each location to one of two anhydrous ammonia application rate treatments. Anhydrous ammonia application rate treatments were 1.5% (HALF) and 3.0% (FULL) of estimated stack dry matter content. Stacks were covered with 6-mil black plastic and sealed with approximately 12 in. of soil along the bottom edge of the stack. Anhydrous ammonia was released into the stacks via three 30-foot, 1/2-in. braided-polyvinyl anhydrous hoses connected to a 3/4-in. black iron cross that was adapted to fit an anhydrous ACME fitting (Fairbank Equipment, Wichita, KS). The lines were inserted under the plastic and secured at approximately equal distances along the length of the stack. Forage samples were obtained prior to and 14 days after anhydrous application. Forage samples were submitted to a commercial laboratory (SDK Laboratories, Hutchinson, KS) and analyzed for contents of dry matter, crude protein, acid detergent fiber, and total digestible nutrients. Subsamples also were submitted to the New Mexico State University Nutrition Lab (Las Cruces, NM) for *in vitro* dry matter disappearance analysis, which is used to estimate digestibility.

The effects of anhydrous ammonia application rate on dry matter, crude protein, acid detergent fiber, total digestible nutrients, and *in vitro* dry matter disappearance were evaluated using PROC MIXED in SAS (SAS Institute, Cary NC). Least-squares means are presented, and differences were considered significant at $P \leq 0.05$.

Results and Discussion

Dry matter, acid detergent fiber, and total digestible nutrient concentrations were unaffected by anhydrous ammonia application rate ($P = 0.68$; Table 1). Crude protein and *in vitro* dry matter disappearance both were affected by anhydrous ammonia application rate ($P < 0.01$). The relative improvement in both crude protein and *in vitro* dry matter disappearance were greatest at the HALF (1.5%) application rate compared with pretreatment values. Crude protein content was increased by 5.3 units at the HALF (1.5%) application rate, and by an additional gain of 2.2 percentage units with the FULL (3.0%) application rate (quadratic, $P < 0.05$). *In vitro* dry matter disappearance increased linearly ($P < 0.01$) as application rate increased, but also exhibited a tendency ($P = 0.10$) toward a quadratic response. The observed quadratic response in crude protein content and the tendency for a quadratic response for *in vitro* dry matter disappearance suggests that response to anhydrous ammonia diminishes as anhydrous ammonia application rate increased from the HALF to the FULL rate.

Implications

The feeding value (crude protein and *in vitro* dry matter disappearance) of wheat straw may be improved by anhydrous ammonia application rates as low as 1.5% dry matter weight of the stack (30 lb anhydrous ammonia/dry ton forage).

Table 1. Mean acid detergent fiber, crude protein, and *in vitro* dry matter disappearance of wheat straw before (pretreatment) and following application of 1.5 (HALF) or 3.0% (FULL) anhydrous ammonia on a dry basis

		Ammoniation rate[1]			
Item	Pretreatment	HALF	FULL	SEM	*P*-value
Dry matter, %	92.1	91.0	91.1	1.01	0.68
Crude protein, %[2]	3.3[a]	8.6[b]	10.8[c]	0.50	<0.01
Acid detergent fiber, %	51.0	51.9	52.1	1.34	0.84
Total digestible nutrients, %	33.2	32.5	32.3	1.90	0.93
IVDMD, %[3]	31.0[a]	42.0[b]	46.2[c]	1.60	<0.01

[1] Treatment with 1.5% (HALF) or 3.0% (FULL) of anhydrous ammonia on a dry weight basis.
[2] Linear effect, $P < 0.01$; quadratic effect, $P = 0.02$.
[3] *In vitro* dry matter disappearance; linear effect, $P < 0.01$; quadratic effect, $P = 0.10$.
[a,b,c] Within a row, means without a common superscript are different ($P \leq 0.10$).

Evaluation of Ammoniated Wheat Straw in Receiving and Growing Diets

E.R. Schlegel, S.P. Montgomery, J. Waggoner, C.I. Vahl, W.R. Hollenbeck, B.E. Oleen, and D.A. Blasi

Introduction

Drought conditions in the past have created a shortage of prairie hay and other grass hays that are used as roughage sources for growing beef diets. Ammoniated wheat straw historically has been available for purchase at a lower than prairie hay. Although some research has been conducted using ammoniated wheat straw as a feedstuff for mature cows, little information is available on the use and outcome its inclusion in beef cattle receiving and growing diets. Our objective was to compare the performance outcomes of newly arrived and growing calves fed total mixed rations containing either ammoniated wheat straw, wheat straw, or a traditional blend of prairie hay and alfalfa hay.

Experimental Procedures

Crossbred beef steers (n = 301; initial body weight 598 lb) were purchased from three separate sources (Lindsborg, KS; Boliver, MO; and Seymour, TX) via online live auctions. Cattle arrived at the Kansas State University Beef Stocker Unit over a 3-day period (June 4–6, 2013). Upon arrival, all calves were weighed, ear-tagged, moved to pens with *ad libitum* access to long-stemmed prairie hay and water, and held overnight. The following day, calves were vaccinated with Bovi-Shield Gold 5 (Zoetis, Exton, PA), Nuplura (Novartis Animal Health, Larchwood, IA), and Bar-Vac 7 (Boehringer Ingelheim, St. Joseph, MO); mass-medicated with Zuprevo (Merck Animal Health, Summit, NJ); and dewormed using Safe-Guard (Intervet, Millsboro, DE) oral drench. Animals were revaccinated on day 28 with Bovi-Shield Gold 5, Bar-Vac 7, and Nuplura. Each load was blocked by arrival date and randomly assigned to treatment for a total of 24 pens with 12 cattle in each pen. A portion of the cattle (13 animals) was excluded from the trial due to pre-existing health conditions. All animals were observed daily for clinical signs of disease, any abnormalities or signs of illness were documented, and cattle so identified received appropriate therapeutic treatments as described by standardized operating procedures for the facility. Experimental treatments consisted of diets containing 30% (dry basis) of either wheat straw, ammoniated wheat straw, or a blend of prairie hay and alfalfa hay. Diets (Table 1) were balanced to contain comparable energy content and to meet or exceed the nutrient recommendations for receiving calves as listed in Nutrient Requirements of Beef Cattle (NRC, 7th revised edition, 1996 update).

Feed bunks were evaluated at approximately 7:00 a.m. and feed was delivered at approximately 9:00 a.m. each day in amounts sufficient to allow for approximately 0.25 lb/animal daily of feed refusals the following morning. Feed was weighed into the bunk and the remaining feed in the bunk from the prior day was estimated and recorded daily. Unconsumed feed remaining in the bunk was weighed back on days 28, 56, and 70. Total mixed ration feed samples were taken weekly and ingredient samples were taken at arrival for each load to determine nutrient content and dry matter content.

Calves were fed their respective diets for 56 days, after which they were fed a common diet (control) for an additional 14 days to equalize gut fill. Weights were taken on days 0, 28, 56, and 70. Dry matter intakes, average daily gains, and feed efficiencies were calculated for each period for each pen of calves. Body weights taken after Day 0 were analyzed separately in a mixed model using the MIXED procedure in SAS (SAS Institute, Cary, NC) with treatment as a fixed effects factor, day-0 bodyweight as a fixed covariate, and source of cattle as a random effect. Resulting least squares treatment means for these ANCOVA models were computed at the mean of the day-0 bodyweights. All other response variables were analyzed in a mixed model with treatment as a fixed effect and source of cattle as a random effect.

Results and Discussion

Growth performance is shown in Table 2. No effects of straw ammoniation were observed compared with the wheat straw diet. Final body weight and average daily gain were not different between ammoniated wheat straw and wheat straw ($P > 0.60$). Our results suggest that in diets containing 40% wet corn gluten feed, feeding 30% of diet dry matter as wheat straw yields performance similar to that obtained by feeding ammoniated wheat straw.

Implications

Feeding wheat straw at 30% inclusion on a dry matter basis during the receiving and growing period has the same performance as ammoniated wheat straw at a decreased cost.

Table 1. Composition of diets fed to crossbred beef steers during the receiving and growing phase (100% dry matter basis)

	Diet		
Ingredient, % of dry matter	Control	Straw	Ammoniated straw
Dry-rolled corn	23.57	23.57	23.57
Supplement	6.43	6.43	6.43
Alfalfa hay	15.00		
Prairie hay	15.00		
Wheat straw		30.00	
Ammoniated wheat straw			30.00
Wet corn gluten feed	40.00	40.00	40.00
Nutrient content			
Dry matter, %	73.0%	73.4%	72.2%
Crude protein, %	15.73	14.63	14.50
Calcium, %	0.91	0.72	0.71
Phosphorus, %	0.56	0.52	0.52
Salt, %	0.32	0.32	0.32
Potassium, %	1.22	1.10	1.10
Magnesium, %	0.26	0.27	0.25
Fat, %	3.04	2.74	2.65
Acid detergent fiber, %	16.20	21.84	21.24
NE maintenance, Mcal/100 lb	81.84	81.54	83.34
NE gain, Mcal/100 lb	52.55	46.40	50.00

Table 2. Growth performance of crossbred steers fed diets containing wheat straw, ammoniated wheat straw, or a blend of prairie hay and alfalfa hay (Control) at 30% inclusion during the receiving and growing periods

Item	Control	Wheat straw	Ammoniated wheat straw	SEM	*P*-value
Initial weight, lb	616	616	617	23	0.64
Day 28 weight, lb	696	698	698	2.5	0.78
Day 56 weight, lb	800[a]	780[b]	782[b]	3.5	<0.001
Final weight (day 70), lb	827[a]	812[b]	810[b]	3.1	<0.001
Dry matter intake, lb/day					
Day 0 to 28	16.54	16.85	16.53	0.32	0.52
Day 0 to 56	18.76	18.37	18.60	0.38	0.60
Day 0 to 70	19.69	19.02	19.28	0.62	0.19
Day 56 to 70	23.42[a]	21.58[b]	22.00[b]	0.43	<0.001
Average daily gain, lb					
Day 0 to 28	3.08	3.15	3.16	0.12	0.78
Day 0 to 56	3.45[a]	3.09[b]	3.14[b]	0.14	<0.001
Day 0 to 70	3.13[a]	2.91[b]	2.89[b]	0.07	<0.001
Day 56 to 70	1.88	2.18	1.89	0.28	0.39
Feed:gain, lb/lb					
Day 0 to 28	5.35	5.34	5.21	0.05	0.73
Day 0 to 56	5.45[a]	5.94[b]	5.94[b]	0.15	<0.001
Day 0 to 70	6.28[a]	6.53[b]	6.67[b]	0.16	0.01
Day 56 to 70	12.30	9.79	11.40	1.89	0.19

[a,b,c]Means in a row without a common superscript are different, $P < 0.05$.

Consumption and Performance by Beef Heifers Provided Dried Distillers Grains in a Self-Fed Supplement Containing Either 10 or 16% Salt While Grazing Flint Hills Native Grass

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Introduction

Optimizing cattle performance and maintaining pasture health are important considerations when striving to maximize profitability and sustainability on a Flint Hills pasture yearling grazing operation. The two growing seasons prior to initiation of this study were droughty and stressful to pastures. This situation provided an opportunity to evaluate the value of dried distillers grains with solubles (DDGS) as a self-fed supplement to ensure that nutritional resources were adequate for a 78-day grazing period. Grazing density was increased from 200 to either 225 or 250 lb of beef while simultaneously providing salt-limited DDGS supplements containing 10 and 16% salt, respectively.

Experimental Procedures

One 78-day grazing study was conducted at the Kansas State University Beef Stocker Unit starting in May 2013 to determine the consumption and resulting growth from supplemental DDGS when provided at two levels of salt addition. All heifers used in this study (n = 279) were previously involved in a receiving study that focused on mass medication programs at arrival. Off-test weights collected at the conclusion of the receiving study were used to randomly assign each animal to grazing treatments. Heifers were assigned to three grazing treatments with four pasture replicates per treatment. All calves were tagged, dewormed with LongRange (Merial Limited, Duluth, GA) for control of internal and external parasites, and sorted to their pre-assigned paddock groups.

The typical stocking rate is 250 lb of beef per acre, but this study employed lower stocking rates to account for drought conditions and the addition of DDGS. The control (CONT) treatment was stocked conservatively at 200 lb of beef per acre, whereas the HIGH and LOW treatments were more heavily stocked (225 and 250 lb of beef per acre, respectively).

To accommodate the heavier stocking rates for the HIGH and LOW treatments, the daily targeted DDGS consumption allowances were set at 0.6% and 1.0% of body weight (3.3 and 5.7 lb DDGS daily on a dry matter basis) for the HIGH and LOW treatments, respectively. The daily intake levels targeted for the LOW and HIGH DDGS treatments were based upon previous research conducted at the K-State Beef Stocker Unit. A publication by Rich et al. (1976)[1] was consulted to determine the salt level required to achieve desired intakes.

[1] "Limiting Feed Intake With Salt." Great Plains Beef Cattle Handbook, GPE-1950, 1976. Great Plains States Cooperative Ext. Service, Oklahoma St. Univ., Stillwater, OK.

All pasture treatments received a free-choice mineral formulated with Rumensin (Elanco Animal Health, Greenfield, IN; 200 mg per head daily). The mineral in the feeder of each paddock was checked weekly for manure, water, or other foreign matter that could interfere with normal supplement consumption. Bull Master feeders (Mann Enterprises, Inc., Waterville, KS) were used for mineral delivery in all paddocks. When inclement weather was forecasted, rubber flap covers on all feeders were closed to minimize exposure to moisture. All flaps were reopened immediately after the threatening storm event. Each mineral feeder was weighed weekly, and the readings were recorded and used to calculate mineral consumption during the previous week. If mineral intake was beyond target, the feeder was moved further away from the primary water source. If this initial action did not effectively reduce mineral intake, salt blocks were placed next to the mineral feeders.

Supplementation with DDGS commenced on June 17 and was provided through portable creep feeders to the designated LOW and HIGH DDGS pastures for the remainder of the study. All feeders were weighed weekly to determine consumption of DDGS during the previous week. If DDGS intake was beyond target, the feeder was moved further away from the primary water source.

Data were analyzed as a completely randomized design with pasture as the experimental unit. All response variables were analyzed in a one-way ANOVA model with treatment as a fixed effect using the GLM procedure in SAS (SAS Institute, Cary, NC). Levene's test for unequal treatment-group variances was performed for each response variable, but no differences among treatment-group variances were detected for any variable.

Results

Overall and as anticipated, the consumption rates of DDGS between paddocks provided with the LOW and HIGH DDGS treatments were different (Table 1). Changes in nutritional composition of native prairie throughout the study period are shown in Table 2. Cattle in the LOW treatment consumed approximately 3 lb/day more DDGS than their counterparts in the HIGH group.

The level of salt recommended by Rich et al. (1976) resulted in acceptable supplement consumption rates for the HIGH treatment targets, but supplement intake for the LOW treatment exceeded our target by approximately 12%. Compared with CONT, both LOW and HIGH treatments resulted in significantly greater average daily gain ($P < 0.001$); however, gains were not different for the LOW and HIGH groups ($P > 0.17$). No differences in efficiency of supplement utilization were detected between LOW and HIGH groups ($P = 0.27$; 11.2 vs. 7.7 lb DDGS per pound of added gain for LOW and HIGH groups, respectively). As expected, mineral consumption declined markedly in the LOW and HIGH treatments when the DDGS supplements were fed (Figure 1).

Table 1. Performance of stocker heifers provided free-choice supplements of dried distillers grains with solubles (DDGS) containing 16 or 10% salt while grazing Flint Hills native summer pastures

		(Percentage salt) in DDGS			
Item	CONTROL	HIGH (16%)	LOW (10%)	SEM	*P*-value
No. of pastures	4	4	4		
No. of cattle	85	100	94		
Initial weight, lb	582	580	579	1.08	0.17
Final weight, lb	730	768	784	6.71	0.001
Average daily gain, lb/day	1.91	2.41	2.62	0.09	0.001
Total DDGS per heifer, lb (dry basis)		162	304	22.4	0.004
DDGS/heifer, lb/day (dry basis)		(3.4)	(6.4)		
lb DDGS/lb added gain		7.69	11.15	2.00	0.27

Table 2. Nutritional quality of native pastures at the Kansas State University Beef Stocker Unit[1]

	Sampling date					
	May 17	June 3	June 20	July 2	July 16	August 2
Dry matter, %	50.60	46.18	45.55	43.97	47.85	49.35
Crude protein, %	8.03	7.50	7.79	7.26	7.01	5.69
Acid detergent fiber, %	43.72	43.77	42.76	41.95	42.70	42.01
Neutral detergent fiber, %	64.14	64.90	63.71	62.99	64.55	64.29
Net energy gain, Mcal/cwt	0.17	0.16	0.18	0.20	0.18	0.19
Net energy maintenance, Mcal/cwt	0.49	0.49	0.51	0.52	0.51	0.52
Total digestible nutrients, %	47.31	47.25	48.44	49.40	48.52	49.33
Calcium, %	0.54	0.52	0.56	0.63	0.58	0.53
Phosphorus, %	0.14	0.15	0.15	0.15	0.15	0.13
Potassium, %	0.97	1.00	0.94	0.99	0.97	0.67
Magnesium, %	0.10	0.11	0.11	0.14	0.11	0.13

[1] Average of four pastures.

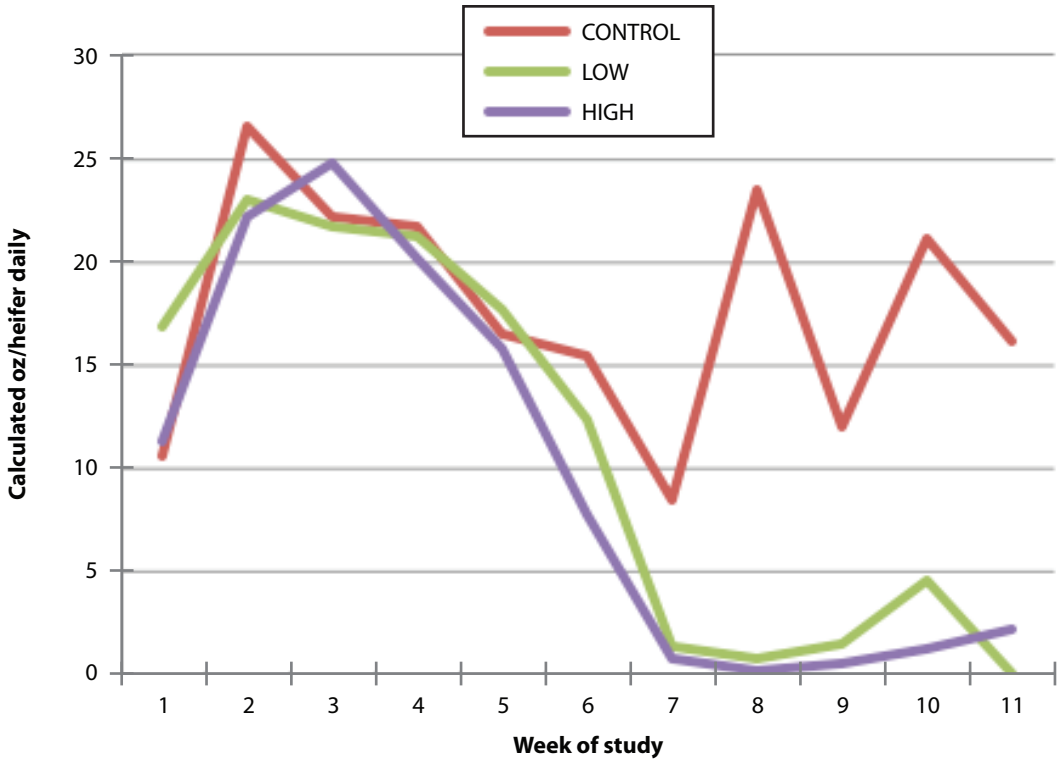

Figure 1. Calculated intake of mineral provided to heifers.

Effects of Optaflexx Alone or in Combination with BoVantage on the Performance and Carcass Merit of Finishing Heifers

J.S. Drouillard, C.L. Van Bibber-Krueger, and K.A. Miller

This study is under further review.

Utilization of Omega-3 Fatty Acids is Improved by Embedding Flaxseed in a Matrix of Dolomitic Lime Hydrate

C. Alvarado Gilis, C.L. Van Bibber-Krueger, K.A. Miller, E. San Vito, G. Feltrin, D. Klamfoth, and J.S. Drouillard

Introduction

Omega-3 fatty acids are essential nutrients for humans, but American diets are often deficient in these important long-chain fats. Incorporating greater proportions of omega-3 fatty acids into beef offers a means of increasing daily consumption of essential fats, while also enhancing the perceived value of beef. In cattle, dietary polyunsaturated fats are extensively hydrogenated into saturated fats by microbes in the rumen. This effectively decreases the efficiency of transfer for fats from the animal's diet into edible beef tissues, because the bacteria convert more than 90% of the polyunsaturated fats into saturated fats before they are absorbed into the animal's blood stream. Preventing this saturation process in the rumen would increase the proportion of dietary omega-3 fatty acids that are available for deposition into beef, thus making the production of omega-3-enriched beef more cost-effective. We have devised a method for improving the stability of fats in the rumen that effectively increases their resistance to the hydrogenating actions of rumen microbes. Sources of polyunsaturated fats are combined with dolomitic lime hydrate, water is added, and the mixture is blended at a high rate of rotation, yielding a densified matrix with improved ruminal stability. Our objective in this study was to evaluate feedlot performance, carcass characteristics, and blood profiles of long-chain fatty acids in cattle fed diets containing varying concentrations of ground flaxseed or ground flaxseed embedded in the dolomitic lime matrix.

Experimental Procedures

Crossbred heifers (454 heifers, 763 ± 44 lb) were blocked by weight, randomly assigned to dietary treatments, and placed into small feedlot pens (11 replicates). This experiment included six treatment groups in a randomized complete block design. Treatments consisted of a control diet without flaxseed; diets with 3 or 6% ground flaxseed, and diets with 2, 4, or 6% of a matrix containing 50% ground flaxseed and 50% dolomitic lime hydrate. Heifers were fed a basal diet containing a combination of steam-flaked corn, wet corn gluten feed, and roughage supplemented with vitamins A and E, macro minerals (calcium, potassium), inorganic trace minerals (Na, Co, Cu, I, Mn, Se, and Zn), Rumensin, and Tylan (Elanco Animal Health, Greenfield, IN) (Table 1). For the treatments containing the flaxseed/lime matrix, ground flaxseed was combined with dolomitic lime hydrate in a 50:50 ratio, then processed to form dense granules. Cattle were fed once daily and had *ad libitum* access to feed and water. Heifers were implanted (Component TE-200; Zoetis, Florham Park, NJ), dewormed (Dectomax; Zoetis), and vaccinated against common viral and clostridial diseases (Ultra-Bac 7 and Bovi-shield Gold 5; Zoetis Inc.).

Blood samples were taken from the jugular vein for analysis of long-chain fatty acids at the beginning of this experiment after 29 days on feed. Blood was collected in heparinized vacuum tubes, which were immediately placed on ice and centrifuged (1200 x *g* for 20 minutes), and plasma was collected and frozen for later analysis by gas chromatography. Starting 23 days before harvest, zilpaterol hydrochloride was added to the diet for 20 days, followed by a 3-day withdrawal. We harvested the six heaviest pens from each treatment on day 140 and the remaining 5 pens from each treatment on day 168 at a commercial abattoir, where we collected slaughter data (hot carcass weight and liver abscesses). Carcasses were chilled for 24 hours, then evaluated for fat thickness over the 12th rib; percentage of kidney, pelvic, and heart fat; ribeye area, marbling score, and USDA yield and quality grades. Data were statistically analyzed using the MIXED procedure of SAS (Version 9.1; SAS Institute, Cary, NC) with treatment as fixed effects, block as the random effect, and pen as the experimental unit.

Results and Discussion

Plasma concentrations of long-chain fatty acids in blood plasma are shown in Table 2. The day-0 values were used as a baseline, as all animals had consumed a similar diet up to this point. As expected, no significant treatment differences were detected in plasma concentrations of long-chain fatty acids on day 0 of the experiment. Feedlot diets, including the one used prior to the start of this trial, normally contain only small amounts of omega-3 fatty acids. Concentrations of alpha-linolenic acid, the principal omega-3 fatty acids found in plants, averaged 40 μg/mL of plasma, which is consistent with low levels of the fatty acid in the diet. When plasma was evaluated after 29 days of feeding the experimental diets, concentrations of alpha-linolenic acid increased sharply for cattle fed diets containing flaxseed, regardless of the form. The greatest concentration of omega-3 fats was achieved by feeding the diet with 6% ground flaxseed. Feeding different levels of ground flaxseed and flaxseed embedded in the lime matrix allowed us to determine the relative efficiencies for assimilation of alpha-linolenic acid from the diet into the blood stream. Based on linear regression slopes, embedding flaxseed in limestone improved transfer efficiency by approximately 42% compared with ground flaxseed.

Table 3 summarizes feedlot performance. Cattle fed diets without flaxseed, 3 or 6% ground flaxseed, and 2% of the hydrate/flax blend all had comparable dry matter intakes; however, feeding 4 or 6% of the hydrate/flax combination decreased feed intake in a linear manner. The sharp decrease in feed intake for cattle fed these treatments resulted in poorer average daily gain and lighter final weights compared with other treatments, but efficiencies were unchanged. The specific cause of this decrease in feed consumption is unclear, and was not observed in previous studies with cattle fed the hydrate:flaxseed blend in combination with forage-based diets. We have speculated that the higher concentrations of hydrate may disrupt normal cation-anion balance, thus leading to feed intake depression.

Carcass characteristics follow a pattern similar to that observed for live animal performance (Table 4). Compared with their counterparts fed the control, flaxseed, and 2% hydrate:flaxseed treatments, heifers fed diets containing 4 or 6% of the hydrate:flaxseed had lighter carcasses that generally were leaner. This was most evident in the group fed

the 6% hydrate:flaxseed blend, and they were further distinguished by having the lowest percentage of carcasses in the USDA Prime and premium Choice categories.

Implications

Flaxseed can be used effectively as a of source alpha-linolenic acid, and it can be protected against rumen biohydrogenation by embedding it in a matrix of dolomitic lime hydrate. Encapsulating ground flaxseed in a matrix of dolomitic lime hydrate increased omega-3 fatty acid assimilation efficiency by 42% compared with ground flaxseed alone, but incorporation of more that 2% of the diet dry matter as the hydrate blend can decrease feed intake and daily gain.

Acknowledgements

Funding for this project was provided by Lhoist North America.

Table 1. Experimental diets

Ingredients, %	Control	3% flax	6% flax	2% flax/ lime	4% flax/ lime	6% flax/ lime
Steam-flaked corn	54.58	52.47	50.49	53.47	52.37	51.26
Corn gluten feed	30.00	30.00	30.00	30.00	30.00	30.00
Corn silage	5.00	5.00	5.00	5.00	5.00	5.00
Wheat straw	3.00	3.00	3.00	3.00	3.00	3.00
Soybean meal	1.66	0.84	--	1.46	1.26	1.06
Flaxseed	--	3.00	6.00	--	--	--
Flaxseed/lime	--	--	--	2.00	4.00	6.00
Supplement[1]	5.76	5.69	5.51	5.07	4.37	3.68

[1] Formulated to provide 300 mg/day Rumensin (Elanco Animal Health, Greenfield, IN), 1,000 IU/lb vitamin A, 0.25% salt, 0.7% calcium, 0.7% potassium, 0.1 ppm cobalt, 10 ppm copper, 0.6 ppm iodine, 60 ppm manganese, 0.25 ppm selenium, and 60 ppm zinc in the total diet on a 100% dry matter basis.

Table 2. Fatty acids concentration in plasma (µg/mL of plasma) in the control diet and supplemented with ground flaxseed or flaxseed encapsulated within a matrix of dolomitic lime hydrate at day 0 and 29[1]

Fatty acid[2]	Control	3% flax	6% flax	2% flax/ lime	4% flax/ lime	6% flax/ lime	SEM	*P*-value
Day 0								
C16:0	324.9	334.9	319.4	298.5	315.3	316.4	11.92	0.179
C18:0	418.2	440.6	423.9	392.8	423.8	423.1	15.80	0.209
C18:1n9c	247.9	245.5	252.3	223.1	241.7	240.7	13.13	0.325
C18:2n6c	1,341.8	1,398.4	1,302.9	1,292.9	1,327.8	1,326.7	62.43	0.648
C18:3n6	10.8	11.5	10.4	9.8	11.5	11.0	1.34	0.934
C18:3n3	41.5	40.2	43.2	36.7	41.8	39.6	2.59	0.370
Day 29								
C16:0	216.6^{b}	241.9^{a}	243.6^{a}	227.2^{ab}	221.1^{b}	238.3^{ab}	7.37	0.012
C18:0	325.2^{d}	401.9^{ab}	422.6^{a}	347.9^{cd}	363.1^{c}	375.9^{bc}	14.22	<0.001
C18:1n9c	116.4^{b}	132.9^{a}	144.3^{a}	135.7^{a}	134.8^{a}	142.9^{a}	5.20	<0.001
C18:2n6c	$1,206.7^{b}$	$1,422.9^{a}$	$1,472.8^{a}$	$1,234.4^{b}$	$1,265.9^{b}$	$1,227.9^{b}$	43.61	<0.001
C18:3n6	8.6^{a}	4.5^{c}	1.4^{d}	7.8^{ab}	6.0^{bc}	4.7^{c}	0.73	<0.001
C18:3n3	21.4^{e}	145.9^{c}	278.0^{a}	72.3^{d}	138.7^{c}	208.1^{b}	5.86	<0.001

[1] Ground flaxseed was encapsulated into a matrix consisting of 50% flaxseed and 50% dolomitic lime hydrate.
[2] Expressed as ug/mL of blood plasma. C16:0 is palmitic acid; C18:0 is stearic acid; C18:1n9 is oleic acid; C18:2n6 is linoleic acid (an omega-6 fatty acid); C18:3n6 is gamma linolenic acid (an omega-6 fatty acid); and C18:3n3 is alpha-linolenic acid (an omega-3 fatty acid).
[a,b,c,d,e] Means in the same row without a common superscript letter are different, $P < 0.05$.

Table 3. Feedlot performance of heifers supplemented with flaxseed or flaxseed encapsulated in a dolomitic lime matrix[1]

Item	Control	3% flax	6% flax	2% flax/ lime	4% flax/ lime	6% flax/ lime	SEM	*P*-value
Initial weight, lb	764.7	762.1	754.6	763.3	765.5	764.6	13.74	0.261
Final weight, lb	1217.5^{a}	1234.1^{a}	1223.4^{a}	1223.7^{a}	1185.6^{b}	1116.9^{c}	14.15	<0.001
Daily gain, lb	2.97^{a}	3.11^{a}	3.09^{a}	3.03^{a}	2.77^{b}	2.32^{c}	0.076	<0.001
Feed intake, lb/day (dry basis)	19.7^{a}	19.4^{a}	19.4^{a}	19.6^{a}	18.6^{b}	16.4^{c}	0.353	<0.001
Feed:gain	6.80	6.62	6.67	6.85	6.80	6.80	0.137	0.717

[1] Ground flaxseed was encapsulated into a matrix consisting of 50% flaxseed and 50% dolomitic lime hydrate.
[a,b,c] Means in the same row without a common superscript letter are different, $P < 0.05$.

Table 4. Carcass traits of heifers supplemented with flaxseed or flaxseed encapsulated in a dolomitic lime matrix[1]

Item	Control	3% flax	6% flax	2% flax/ lime	4% flax/ lime	6% flax/ lime	SEM	*P*-value
Carcass weight, lb	773.1[a]	781.5[a]	776.8[a]	775.9[a]	751.7[b]	709.2[c]	9.02	<0.001
Ribeye area, sq. in.	13.52[b]	13.65[ab]	13.95[a]	13.92[a]	13.19[bc]	13.11[c]	0.161	<0.001
12th-rib fat, in.	0.61[a]	0.63[a]	0.61[a]	0.60[a]	0.59[a]	0.48[b]	0.021	<0.001
Kidney, pelvic, and heart fat, %	2.63	2.59	2.88	2.87	2.56	2.69	2.08	0.440
Marbling score	493[a]	499[a]	491[a]	490[a]	497[a]	449[b]	12.4	0.040
USDA yield grade	2.73[a]	2.76[a]	2.62[a]	2.57[ab]	2.76[a]	2.32[b]	0.101	0.012
Yield grade 1, %	5.33	5.33	9.09	9.33	8.00	18.18	3.40	0.104
Yield grade 2, %	30.67	28.00	29.87	36.00	30.67	35.06	5.42	0.854
Yield grade 3, %	50.67	52.00	50.65	42.67	40.00	42.86	5.81	0.506
Yield grade 4, %	12.00	14.67	10.39	12.00	20.00	3.90	3.90	0.078
Yield grade 5, %	1.33	0.00	0.00	0.00	1.33	0.00	0.77	0.505
Liver abscesses, %	14.67	16.00	7.79	14.67	12.00	10.39	3.92	0.631
Prime, %	4.00	1.33	9.09	5.33	2.67	1.30	2.26	0.119
Premium Choice, %	24.00[bc]	40.00[a]	29.87[ab]	37.33[ab]	32.00[ab]	15.58[c]	5.26	0.010
Choice, %	86.67[ab]	90.67[a]	76.62[b]	74.67[b]	80.00[ab]	75.32[b]	4.69	0.036
Select, %	8.00	6.67	14.29	16.00	13.33	18.18	4.12	0.136
No roll, %	1.33	1.33	0.00	4.00	4.00	5.20	0.95	0.690

[1] Ground flaxseed was encapsulated into a matrix consisting of 50% flaxseed and 50% dolomitic lime hydrate.
[a,b,c] Means in the same row without a common superscript letter are different, $P < 0.05$.

Encapsulation of Flaxseed in a Dolomitic Lime Matrix: Effects on Feedlot Performance and Carcass Characteristics of Steers vs. Heifers

G. Feltrin, C. Alvarado Gilis, C.L. Van Bibber-Krueger, D. Klamfoth[1], and J.S. Drouillard

Introduction

Polyunsaturated fatty acids, when fed to cattle, are subject to extensive alteration by ruminal microbes, effectively converting the polyunsaturated fats into saturated fats. The oil of flaxseed is rich in alpha linolenic acid (~55% of the oil), which is an essential polyunsaturated, omega-3 fatty acid. Enrichment of feedlot cattle diets with flaxseed has been used effectively as a means of increasing the proportions of omega-3 fatty acids incorporated into beef, but efficiency of transfer from the animal's diet to beef is relatively low. Encapsulating the flaxseed or flaxseed oil in a matrix that is resistant to the actions of ruminal microbes could provide a mechanism for increasing the efficiency with which polyunsaturated fats are absorbed and deposited into tissues.

We have investigated the potential for using hydrated lime to form protective matrices with oil-rich feeds, such as flaxseed, to increase the incorporation of omega-3 fatty acids into meat. Dolomitic lime is mixed with ground flaxseed, water is added, the mixture is blended in a high-speed turbulizer, and the resulting material is then dried to form a granular matrix. During the manufacturing process, a portion of the hydrated lime becomes recarbonated. This recarbonated matrix is ruminally stable, which prevents rumen microbes from converting polyunsaturated oils to saturated fats. Additional recarbonation occurs in the rumen due to exposure to high concentrations of carbon dioxide produced by rumen microbes, further stabilizing the matrix. The objective of this study was to compare feedlot performance and carcass characteristics of heifers and steers fed traditional finishing diets to those of cattle supplemented with encapsulated blends of ground flaxseed and dolomitic lime hydrate.

Experimental Procedures

Forty crossbred steers with an average initial body weight of 921 ± 57 lb and 40 crossbred heifers with an average initial body weight of 814 ± 62 lb were used in a randomized complete block design with a 2 × 4 factorial arrangement of treatments to test interactions between gender (steers and heifer) and diet. Finishing diets consisted of: (1) Control (no flaxseed); (2) 4% of a 50:50 mixture of dolomitic lime and flaxseed; (3) 6% of a dolomitic hydrate flaxseed mixture containing 67% lime and 33% flaxseed; and (4) 6% of a 33:67 dolomitic hydrate:flax blend for the latter half of the finishing period. Composition of experimental diets is summarized in Table 1. Diets were mixed immediately before feeding and delivered to each pen once daily at 11:30 a.m. Ten steers and 10 heifers were assigned to each dietary treatment. Cattle were divided equally into heavy and light groups; the heavies half were marketed after 116 days on feed, and the lighter group was marketed after 144 days of feedlot finishing. Cattle were harvested at a commercial abattoir in Holcomb, KS. On the day of harvest, incidence of liver abscesses was recorded as well as hot carcass weight. Carcasses were chilled for 24

hours, then graded. Carcass measurements included 12th-rib subcutaneous fat thickness; ribeye area; percentage of kidney, pelvic, and heart fat; marbling score; and USDA quality and yield grade. Data were analyzed using the MIXED model procedure of SAS (Version 9.0; SAS Institute, Cary, NC) with gender, diet, and the gender × diet interaction as fixed effects and weight group as a random effect. Animal was the experimental unit. Frequency data (liver abscesses and USDA yield and quality grades) were analyzed as binomial proportions with the GLIMMIX procedure of SAS using the same model as described previously.

Results and Discussion

Feedlot performance is summarized in Table 2. There were no interactions between diet and gender. Regardless of diet, steers consumed more feed and had more rapid rates of gain than heifers ($P < 0.01$). Efficiency tended to be better for steers than for heifers, but these differences were not statistically different. Feeding lime-encapsulated flaxseed decreased intake markedly ($P < 0.01$), but gains and efficiencies were not statistically different from controls. The 4% and 6% lime treatments yielded similar gain and efficiency, however. The substantial decrease in feed intake associated with addition of lime-encapsulated flaxseed (12% decrease for heifers and 10% decrease for steers) was not expected. No such observations were made in previous studies with growing cattle fed forage-based diets. The hydrate matrix is very alkaline, which may have affected palatability, but the absence of this effect in forage-based diets suggests that poor palatability may not be the cause of this change. It is conceivable that we altered cation-anion balance sufficiently to disrupt normal feeding behavior. Future studies are being planned to examine this effect in greater detail.

As expected, steer carcasses were heavier than those of heifers (722 vs. 619 lb, respectively; $P < 0.01$; Table 3). Steers also had greater ribeye areas than heifers ($P < 0.01$), and steer carcasses generally were leaner and graded more poorly than those of the heifers. Feeding lime-encapsulated flaxseed generally decreased carcass weight ($P = 0.03$), which we attribute to the rather dramatic decrease in feed intake for these treatments. Carcass characteristics other than carcass weight were unaffected by treatment.

Implications

Feeding ground flaxseed embedded within a protective matrix consisting of dolomitic lime hydrate decreased feed intake and carcass weight of feedlot steers and heifers. Average daily gain and most other carcass attributes were unaffected by diet, although the measures generally followed patterns that were consistent with reduced feed intake.

Acknowledgements

The hydrated lime embedding process is the subject of a U.S. patent application jointly submitted by Kansas State University and Lhoist North America (Fort Worth, TX).

Table 1. Composition of experimental diets on a 100% dry matter basis

	Diets		
Item	Control	4% 50:50	6% 67:33
Steam-flaked corn	56.36	54.48	52.97
Wet corn gluten feed	30.00	30.00	30.00
Corn silage	5.00	5.00	5.00
Wheat straw	3.00	3.00	3.00
50:50 lime:flax	-	4.00	-
67:33 lime:flax	-	-	6.00
Supplement[1]	3.48	1.35	0.87
Feed additive premix[2]	2.16	2.16	2.16

[1] Formulated to provide 0.3% salt, 0.1 ppm cobalt, 10 ppm copper, 0.6 ppm iodine, 60 ppm manganese, 0.25 ppm selenium, 60 ppm zinc, 1,000 IU/lb vitamin A, and 20 IU/lb vitamin E on a dry matter basis.
[2] Formulated to provide the following: 300 mg/d of Rumensin and 90 mg/day Tylan (Elanco Animal Health, Indianapolis, IN). Heifers also received 0.4 mg/day of Heifermaxx (Elanco Animal Health).

Table 2. Feedlot performance of heifers and steers fed finishing diets with or without lime-encapsulated flaxseed[1]

	Diets					*P*-value	
Item	Control	4% 50:50	6% 67:33	6% 67:33 Late	SEM	Gender	Diet
Dry matter intake, lb/day							
Heifers	16.75[a]	14.90[b]	14.71[b]	14.77[b]	0.329	<0.01	<0.01
Steers	18.96[a]	17.02[b]	16.67[b]	17.57[c]	0.329		
Average daily gain, lb							
Heifers	2.60	2.45	2.49	2.36	0.121	0.03	0.18
Steers	3.31	3.06	2.98	3.00	0.121		
Feed:gain							
Heifers	6.44	6.08	5.90	6.25	0.008	0.16	0.28
Steers	5.72	5.56	5.59	5.86	0.008		

[1] Cattle were fed diets containing (dry basis) no flaxseed (Control); 4% of an encapsulated 50:50 blend of dolomitic hydrate and flaxseed for the entire finishing period; 6% of an encapsulated 67:33 blend of dolomitic hydrate and ground flaxseed for the entire finishing period; or 6% of an encapsulated 67:33 blend of dolomitic hydrate and ground flaxseed for the final half of feedlot finishing (Late).
[a–c] Means in a row without a common superscript are different, $P < 0.05$.

Table 3. Carcass characteristics of heifers and steers fed finishing diets with or without lime-encapsulated flaxseed[1]

	Diets					*P*-value	
Item	Control	4% 50:50	6% 67:33	6% 67:33 Late	SEM	Gender	Diet
Hot carcass weight, lb							
Heifers	639[a]	611[b]	619[b]	608[b]	7.8	<0.01	0.03
Steers	747[a]	723[b]	710[b]	706[b]			
Ribeye area, sq. in.							
Heifers	14.0	13.2	13.6	13.2	2.7	<0.01	0.26
Steers	14.8	15.1	14.9	14.0			
Kidney, pelvic, and heart fat, %							
Heifers	2.4	2.2	2.6	2.3	0.12	0.25	0.08
Steers	2.6	2.1	2.2	2.3			
12th-rib fat, in.							
Heifers	0.61	0.56	0.57	0.51	0.162	0.07	0.22
Steers	0.56	0.41	0.40	0.46			
Liver abscess, %							
Heifers	0	20	10	20	9.9	0.53	0.15
Steers	0	20	0	10			
USDA yield grade							
Heifers	2.4	2.7	2.6	2.3	0.33	0.47	0.91
Steers	2.6	2.1	2.1	2.3			
Marbling score[2]							
Heifers	486	432	491	417	40	0.10	0.22
Steers	398	375	386	368			
USDA Prime, %							
Heifers	10	0	10	0	6	0.57	0.31
Steers	0	0	10	0			
Premium Choice, %							
Heifers	20	10	30	20	11	0.09	0.70
Steers	0	0	0	10			
Choice, %							
Heifers	80	50	70	70	18	0.03	0.55
Steers	40	30	20	20			
Select, %							
Heifers	10	40	20	20	21	0.07	0.64
Steers	60	60	70	80			

[1] Cattle were fed diets containing (dry basis) no flaxseed (Control); 4% of an encapsulated 50:50 blend of dolomitic hydrate and flaxseed for the entire finishing period; 6% of an encapsulated 67:33 blend of dolomitic hydrate and ground flaxseed for the entire finishing period; or 6% of an encapsulated 67:33 blend of dolomitic hydrate and ground flaxseed for the final half of feedlot finishing (Late).

[2] Marbling scores determined by USDA graders; Slight = 300 to 399, Small = 400 to 499, and Modest = 500 to 599.

[a,b] Means in a row without a common superscript are different, $P < 0.05$.

Aging Time Affects Color Stability and Sensory Properties of Ground Beef Patties Adjusted to a Similar Fat Composition by Combining Subprimals from the Chuck Roll and Knuckle

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Introduction

Ground beef is the most commonly consumed beef product in the United States. Fat can typically range from ≤5 to 30% in ground beef, and the product may become less palatable as the fat level decreases, especially below 10% fat. The amount and composition of fat in subprimals can be influenced by the subprimal type, quality grade, and fatness of the carcass from which it was derived. Processors can combine different subprimals of varying fat percentages to obtain an overall target percentage.

In retail, consumers use color as the major criteria in selecting meat products and associate a bright red color with freshness. Longer display life without discoloration can result in more opportunities to sell the product and greater potential profit for retailers. Display life can vary for different muscles based on their fiber type and metabolic activity.

Palatability traits of flavor, juiciness, and tenderness are associated with consumer satisfaction. Although grinding offers an opportunity to mechanically minimize differences in tenderness, muscle source and product quality may still affect the sensory properties of ground beef. The objective of this study was to determine the effects of two quality grades (Premium Choice and Select) and vacuum storage aging time (7, 21, and 42 days) before processing on ground beef patty display color from chuck roll and knuckle subprimals combined to obtain a common percentage of fat.

Experimental Procedures

At the end of each aging time (7, 21, or 42 days), four knuckles or two chuck rolls, representing their respective quality grade categories (upper 2/3 Choice and Select), were combined and ground through a 3/8-in. plate followed by a 1/8-in. plate to form a grind batch. These batches were evaluated for percentage of fat using a Hobart Fat Percentage Indicator (Model F-100, Hobart Manufacturing Company, Troy, OH). Using this fat analysis, chuck roll and knuckle grind batches from the same quality grade and aging time were used to formulate Premium Choice and Select sample batches that contained similar percentages of fat. Each treatment combination of 2 quality grades × 3 aging times (n = 6) was replicated 6 times. Ground beef patties (1/4-lb patties) for display and sensory characteristics were made using a patty machine (Supermodel 54 Food Portioning Machine, Hollymatic Corporation, Countryside, IL).

For display color, ground beef patties were packaged in polyvinyl chloride–overwrapped trays and displayed at 36°F in a coffin-type retail case under 150-foot candles of contin-

uous fluorescent lighting. A minimum of 6 trained color panelists evaluated patty visual color to the nearest 0.5 using an 8-point scale, with 1 = extremely bright cherry-red, 2 = bright cherry-red, 3 = moderately bright cherry-red, 4 = slightly bright cherry-red, 5 = slightly dark cherry-red, 6 = moderately dark red, 7 = dark red, and 8 = extremely dark red. Ground beef patties were visually evaluated by the trained color panelists at 0, 24, 48, and 72 hours of display.

For sensory panels and instrumental tenderness (slice shear force, textural profile analysis, and Lee-Kramer shear), patties were crust-frozen at -40° F before vacuum-packaging, stored at -4°F, thawed at 36°F for 24 hours, and cooked on a griddle to an internal endpoint temp of 160°F. For sensory panels, patties were cut into eight wedge slices and evaluated by a trained sensory panel. Trained sensory panelists used a scale of 1 to 8 to evaluate firmness (1 = extremely soft, 8 = extremely firm), cohesiveness (1 = not cohesive at all, 8 = extremely cohesive), juiciness (1 = extremely dry, 8 = extremely juicy), beef flavor intensity (1= extremely bland, 8 = extremely intense), mouth coat (1 = abundant, 8 = none), off-flavor intensity (1 = abundant, 8 = none), and desirability (1 = extremely dislike, 8 = extremely like).

For instrumental properties, the cooked patties were cooled to room temperature for approximately 30 minutes before the measurements were taken. For slice shear force, two 1.2-in. strips were removed from each patty, and each strip was sheared twice. Two patties per sample were used, resulting in eight measurements that were averaged for analysis. The blade was attached to the crosshead of an Instron Universal Testing Machine (Model 5569, Instron Corporation, Canton, MA) with a 220-lb load cell and crosshead speed of 9.8 in/minute.

To determine Lee-Kramer shear values, two patties from each sample were cut into 2.4 × 2.4-in. subsamples, weighed, and sheared in the Lee-Kramer cell attached to the Instron with a 220-lb load cell and a crosshead speed of 13.8 in./minute. Peak force was determined and divided by the sample weight to obtain force/ounce. The average of the two patty measurements was used for analysis.

For texture profile analysis, three 1-in.-diameter cores were removed perpendicular to the flat surface of each of two patties from each sample. Each core was compressed by 30% of its height for two cycles. We used the Instron with a 220-lb load cell and a cross-head speed of 7.9 in./minute. Sample averages for hardness (peak force of first compression), cohesiveness (total energy of second compression ÷ total energy of the first compression), springiness (base depth of second compression ÷ base depth of first compression), and gumminess (hardness × cohesiveness) were used for statistical analysis.

Results and Discussion

Since Premium Choice subprimals had higher percentages of fat, the resulting Premium Choice treatments had lower percentages of chuck roll and higher percentages of knuckle than the Select treatments (Table 1). The resulting percentages of total fatty acids were similar ($P > 0.05$) for the two quality grade treatments. As expected, there were no differences ($P > 0.05$) due to aging time for subprimal composition or percentages of total fatty acids.

In a quality grade × display time interaction ($P < 0.05$), visual color became ($P < 0.05$) progressively darker/browner with each increase in days of display for patties from both Premium Choice and Select subprimals (Figure 1). At 0, 24, and 48 hours of display, ground beef patties from Select subprimals had ($P < 0.05$) lower (brighter red) visual color scores than those from Premium Choice subprimals. These results were expected because patties from Premium Choice subprimals had a higher percentage of knuckles, which have been characterized as having muscles with lower color stability.

In an aging time × display time interaction ($P < 0.05$), visual color became ($P < 0.05$) progressively darker/browner with each increase in days of display for patties from subprimals aged 7, 21, and 42 days (Figure 2). At 0 hours of display, ground beef patties aged 21 days had ($P < 0.05$) the lowest color scores (brightest red), and those aged 7 days had ($P < 0.05$) the highest (darkest) color scores. At 24 hours of display, patties aged 7 days maintained their color and had ($P < 0.05$) the brightest red color scores. At 48 hours, patties aged 42 days had ($P < 0.05$) the darkest color scores, and patties aged 21 days had ($P < 0.05$) darker color scores than those aged 7 days. At 72 hours of display, patties aged 42 days had the darkest color scores, and patties aged 7 days had ($P < 0.05$) the least dark/brown color scores. Overall, patties were less able to maintain their color stability with increased days of aging.

For sensory analysis properties, few differences were detected between quality grades for cookery, sensory panel, or instrumental properties (Table 1). Patties from Premium Choice subprimals that contained a higher percentage of knuckle had ($P < 0.05$) less hardness and gumminess as measured by texture profile analysis.

The sensory panel indicated that patties from subprimals aged 42 days had ($P < 0.05$) more juiciness than those from subprimals aged 7 days. They also found patties from subprimals aged 7 days had ($P < 0.05$) less mouth coat (higher scores) than those from subprimals aged 21 and 42 days, and patties aged 21 days had ($P < 0.05$) less off flavor (higher scores) than those from subprimals aged 42 days.

For both the slice and Lee-Kramer shear forces, patties from subprimals aged 21 and 42 days had ($P < 0.05$) lower (more tender) shear forces than those from subprimals aged 7 days. The texture profile analysis found patties from subprimals aged 42 days had ($P < 0.05$) less hardness and the second-highest compression and gumminess than those from subprimals aged 7 and 21 days.

Implications

Extended aging for 42 days results in more rapid deterioration in display color and more off flavors, and instrumental measures indicate that aging increases tenderness and reduces hardness.

Table 1. Effects of quality grade and aging time on composition, sensory traits, and instrumental characteristics of ground beef patties

	Quality grade			Aging time			
Composition	Premium Choice	Select	SE	7 days	21 days	42 days	SE
Chuck roll, %	26.3[a]	76.6[b]	2.47	51.2	54.6	48.6	3.0
Knuckle, %	73.7[a]	23.4[b]	2.47	48.8	45.4	51.4	3.0
Total fatty acids, %	11.8	12.2	0.42	11.8	12.0	12.2	0.52
Sensory traits[1]							
Firmness	5.1	5.1	0.06	5.1	5.0	5.1	0.07
Cohesiveness	5.1	5.1	0.05	5.1	5.1	5.2	0.06
Juiciness	5.3	5.2	0.08	5.1[a]	5.3[ab]	5.4[b]	0.10
Beef flavor	5.4	5.3	0.06	5.3	5.3	5.4	0.07
Mouth coat	7.0	6.9	0.07	7.1[b]	6.9[a]	6.8[a]	0.07
Off-flavor	7.6	7.7	0.11	7.7[ab]	7.9[b]	7.4[a]	0.13
Desirability	5.2	5.2	0.11	5.1	5.3	5.1	0.14
Shear force							
Slice (lb)	6.35	6.42	0.15	6.64[b]	6.13[a]	6.39[a]	0.18
Lee-Kramer, lb/oz	184.4	191.3	3.12	202.5[b]	180.6[a]	181.3[a]	4.2
Texture profile analysis[2]							
Hardness, lb	6.17[a]	6.99[b]	0.22	7.10[b]	6.92[b]	5.71[a]	0.26
2nd peak force, lb	5.64[a]	6.35[b]	0.20	6.46[b]	6.33[b]	5.20[a]	0.24
Cohesiveness	0.58	0.58	0.01	0.59	0.57	0.58	0.01
Gumminess, lb	3.57[a]	4.01[b]	0.18	3.97[b]	3.75[b]	3.33[a]	0.21
Springiness	3.75	3.55	0.08	3.66	3.62	3.68	0.09

[1] Sensory traits: firmness (1 = extremely soft, 8 = extremely firm); cohesiveness (1 = not cohesive at all, 8 = extremely cohesive); juiciness (1 = extremely dry, 8 = extremely juicy); beef flavor intensity (1 = extremely bland, 8 = extremely intense); mouth coat (1 = abundant, 8 = none); off-flavor intensity (1 = abundant, 8 = none); desirability (1 = extremely dislike, 8 = extremely like).
[2] Texture profile analysis: hardness: (peak force of first compression); second peak force: (peak force of second compression); cohesiveness: (total energy of second compression ÷ total energy of the first compression); gumminess: (hardness × cohesiveness); springiness: (height that the food recovers during the time elapsed between the end of the first compression and the start of the second compression).
[a-b] Means within a row and main effect with a different superscript letter differ ($P < 0.05$).

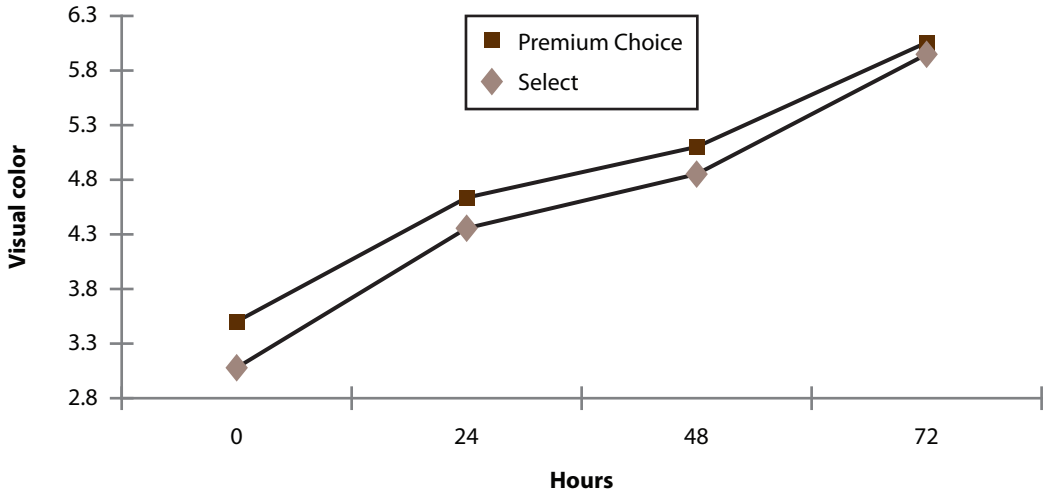

Figure 1. Quality grade × display time interaction means for visual color (2 = bright cherry-red, 5 = slightly dark cherry-red, and 8 = extremely dark red) of ground beef patties displayed for 72 hours (SE = 0.084).

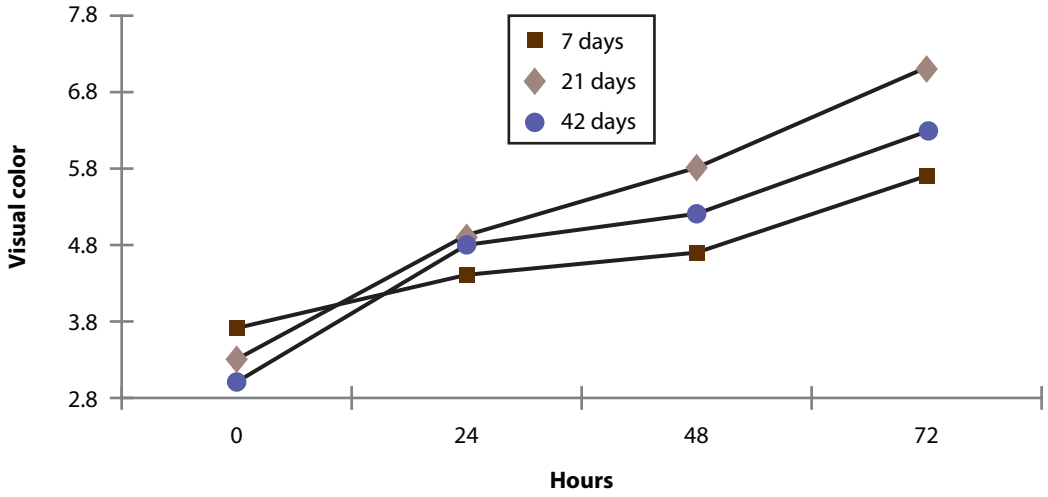

Figure 2. Aging time × display time interaction means for visual color (2 = bright cherry-red, 5 = slightly dark cherry-red, and 8 = extremely dark red) of ground beef patties displayed for 72 hours (SE = 0.103).

Subprimal Type and Quality Grade Affect Fatty Acid Composition and Cooked Firmness of Ground Beef Patties

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Introduction

Beef tenderness, juiciness, and flavor contribute to consumer satisfaction and therefore price differentiation of beef products. Ground beef is the most commonly consumed beef product in the United States. Historically, the source of ground beef comes from lower quality cuts, trimmings from subprimals, and subprimals from cull cows; however, alternative grinds from whole and/or premium quality subprimals are becoming more popular with consumers. Subprimals from the chuck and round are logical subprimals that could be used for premium ground beef production because they cost less than other subprimals, such as those from the rib and loin. Ground beef products from higher quality grades such as Premium Choice (upper two-thirds of Choice) offer merchandising potential and are commonly utilized as a higher-quality product. The inherent lean and fat property differences that may exist in these subprimals could potentially influence palatability of the resulting ground beef products.

Subprimals can be stored in a vacuum package for extended periods of time at low storage temperatures. The number of days that subprimals may be held before processing can be influenced by the distribution chain, accessibility, and subprimal price fluctuations. Extended vacuum storage before grinding could affect biochemical, oxidative, and microbial properties of these subprimals and influence sensory properties. Our objective was to determine the effects of two subprimal types (chuck roll and knuckle), two quality grades (Premium Choice and Select), and three vacuum-packaged storage aging times before processing (7, 21, and 42 days) on ground beef patty sensory properties.

Experimental Procedures

At the end of each aging time (7, 21, or 42 days), four knuckles or two chuck rolls representing their respective quality grade categories (upper two-thirds of Choice and Select), were combined and ground using a 3/8-in. plate to form a treatment or sample batch. Six replications were made for each of the 12 treatment combinations. After the second final grind using a 1/8-in. plate, fatty acid analyses were conducted on raw ground beef samples. For sensory panels and instrumental tenderness (slice shear force, textural profile analysis, and Lee-Kramer shear), 1/4-lb patties were formed using a Hollymatic patty machine, crust-frozen at -40°F before vacuum-packaging, and stored at -4°F. Patties were thawed at 36°F for 24 hours and cooked on a griddle to an internal endpoint temp of 160°F. For sensory panels, cooked patties were cut into eight wedge slices and evaluated by a trained sensory panel. Trained sensory panelists used a scale of 1 to 8 to evaluate firmness (1 = extremely soft, 8 = extremely firm), cohesiveness (1 = not cohesive at all, 8 = extremely cohesive), juiciness (1 = extremely dry, 8 = extremely juicy), beef flavor intensity (1= extremely bland, 8 = extremely intense), mouth coat

(1 = abundant, 8 = none), off-flavor (1 = abundant, 8 = none), and desirability (1 = extremely dislike, 8 = extremely like).

To determine instrumental properties, the cooked patties were cooled to room temperature for approximately 30 minutes before the measurements were taken. For slice shear force, two 1.2-in. strips were removed from each patty, and each strip was sheared twice. Two patties per sample were utilized, resulting in eight measurements that were averaged for analysis. The blade was attached to the crosshead of an Instron with a 220-lb load cell and crosshead speed of 9.8 in./minute.

To determine Lee-Kramer shear values, two cooked patties from each sample were cut into 2.4 × 2.4-in. subsamples, weighed, and sheared in the Lee-Kramer cell attached to the Instron with a 220-lb load cell and a crosshead speed of 13.8 in/minute. Peak force was determined and divided by the sample weight to obtain force/oz. The average of the two patty measurements was used for analysis.

For texture profile analysis, three 1-in.-diameter cores were removed perpendicular to the flat surface of each of two cooked patties from each sample. Each core was compressed to 30% of its height for two cycles. We used an Instron with a 220-lb load cell and a crosshead speed of 7.9 in/minute. Sample averages for hardness (peak force of first compression), peak force of the second compression, cohesiveness (total energy of second compression ÷ total energy of the first compression), springiness (base depth of second compression ÷ base depth of first compression), and gumminess (hardness × cohesiveness) were used for statistical analysis.

Results and Discussion

In a subprimal type × quality grade interaction, Premium Choice chuck roll subprimals (19.6%) had ($P < 0.05$) the highest percentage of total fatty acids per lb of tissue, and those from Select knuckle subprimals (5.9%) had ($P<0.05$) the lowest percentage. In addition, Select chuck roll subprimals (13.8%) had ($P < 0.05$) higher percentages of total fatty acids than Premium Choice knuckle subprimals (8.2%). Ground beef samples from chuck roll subprimals had ($P < 0.05$) greater percentages of saturated fatty acids (SFA) and lower percentages of polyunsaturated fatty acids (PUFA) than those from knuckle subprimals (Table 1). As a result, ground beef samples from chuck roll subprimals had ($P < 0.05$) lower monounsaturated (MUFA):SFA and PUFA:SFA ratios than those from knuckle subprimals. Premium Choice subprimals had ($P < 0.05$) higher percentages of MUFA (primarily oleic acid) than those from Select subprimals; however, Select subprimals had ($P < 0.05$) greater percentages of SFA and PUFA than those from Premium Choice subprimals. As a result, Premium Choice subprimals had ($P < 0.05$) higher MUFA:SFA ratios and lower PUFA:SFA ratios than Select subprimals.

For ground beef patties from chuck roll subprimals, sensory panelists found those from Select subprimals were ($P < 0.05$) firmer and had ($P < 0.05$) less mouth coating (higher scores) than those from Premium Choice subprimals (Table 2). For ground beef patties from knuckle subprimals, those from Premium Choice and Select subprimals had ($P > 0.05$) similar scores for all sensory panel traits.

For instrumental tenderness measures of slice shear force and Lee-Kramer shear, ground beef patties from knuckle subprimals had ($P < 0.05$) greater peak force values than those from chuck roll subprimals (Table 3). In addition, ground beef patties from Select subprimals had ($P < 0.05$) greater peak force values than those from Premium Choice subprimals. Furthermore, ground beef patties from subprimals aged 7 days had ($P < 0.05$) greater peak force values than those from subprimals aged for 21 and 42 days.

For texture profile analysis, ground beef patties from knuckle subprimals had ($P < 0.05$) greater hardness (first compression peak force), gumminess, and springiness than those from chuck roll subprimals. Ground beef patties from Select subprimals had ($P < 0.05$) greater hardness values than those from Premium Choice subprimals. Patties aged 42 days had ($P < 0.05$) greater hardness than those aged 7 days, and springiness declined with increased aging.

Overall, patties from fatter chuck roll and Premium Choice subprimals were softer (lower peak forces and hardness) than those from knuckle and Select subprimals, respectively. This difference was observed by a sensory panel for patties from chuck rolls in which those from Select subprimals were firmer.

Implications

Patties from Premium Choice chuck rolls provide the softest characteristics to the palate and instrumentally, whereas those from Select knuckles provide the greatest firmness and instrumental resistance.

Acknowledgement

This work was funded by The Beef Checkoff.

Table 1. Effect of subprimal type and quality grade on the percentages (expressed as percentage of total fatty acids[1]) and ratios for fatty acid categories of ground beef patties

	Subprimal type[2]			Quality grade[3]		
Trait[4]	CR	KN	SE	PCH	SEL	SE
SFA (%)	46.8[b]	45.0[a]	0.3	45.3[a]	46.5[b]	0.3
MUFA (%)	49.4	49.9	0.6	50.6[b]	48.7[a]	0.6
PUFA (%)	3.77[a]	5.07[b]	0.39	4.03[a]	4.81[b]	0.39
MUFA:SFA ratio	1.06[a]	1.11[b]	0.02	1.12[b]	1.05[a]	0.02
PUFA:SFA ratio	0.08[a]	0.11[b]	0.01	0.09[a]	0.11[b]	0.01

[1] Total fatty acids (gm/100 gm tissue): PCH CR (19.6) > SEL CR (13.8) > PCR KN (8.2) > SEL KN (5.9).
[2] Subprimal type: CR = chuck roll; KN = knuckle.
[3] Quality grade: PCH = Premium Choice; SEL = Select.
[4] SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids.
[a,b] Means within a row and main effect with a different superscript letter differ ($P < 0.05$).

Table 2. Effect of quality grade and aging time on sensory traits for ground beef patties

	Quality grade			Aging time (days)			
Trait[1]	Premium Choice	Select	SE	7	21	42	SE
Chuck roll							
Firmness	4.7[a]	4.9[b]	0.07	4.8	4.7	4.8	0.08
Cohesiveness	4.8	4.9	0.07	4.9	4.8	4.9	0.08
Juiciness	5.5	5.3	0.11	5.4	5.4	5.5	0.13
Beef flavor	5.3	5.3	0.10	5.1	5.4	5.4	0.11
Mouth coat	6.7[a]	6.8[b]	0.06	6.8	6.8	6.8	0.07
Off-flavor	7.6	7.6	0.10	7.3[a]	7.8[b]	7.8[b]	0.12
Desirability	5.4	5.4	0.12	5.2	5.5	5.4	0.13
Knuckle							
Firmness	5.0	5.1	0.09	5.1	4.9	5.0	0.09
Cohesiveness	4.9	5.0	0.07	5.0	4.9	5.1	0.08
Juiciness	5.1	5.2	0.10	4.8[a]	5.1[b]	5.5[c]	0.11
Beef flavor	5.3	5.2	0.06	5.1	5.2	5.3	0.07
Mouth coat	7.0	7.1	0.04	7.2[c]	7.0[b]	6.9[a]	0.05
Off-flavor	7.7	7.6	0.09	7.5[a]	7.8[b]	7.5[a]	0.09
Desirability	5.2	5.0	0.11	4.8[a]	5.2[b]	5.3[b]	0.12

[1] Firmness (1 = extremely soft, 8 = extremely firm); cohesiveness (1 = not cohesive, 8 = extremely cohesive); juiciness (1 = extremely dry, 8 = extremely juicy); beef flavor intensity (1 = extremely bland, 8 = extremely intense); mouth coat (1 = abundant, 8 = none); off-flavor intensity (1 = abundant, 8 = none); desirability (1 = extremely dislike, 8 = extremely like).
[a–c] Means within a row and main effect with a different superscript letters differ ($P < 0.05$).

Table 3. Effects of subprimal type, quality grade, and aging time for instrumental tenderness traits for ground beef patties

	Subprimal type[1]			Quality grade[2]			Aging time (days)			
	CR	KN	SE	PCH	SEL	SE	7	21	42	SE
Slice shear force										
Peak force (lb)	5.97[a]	7.10[b]	0.16	6.28[a]	6.79[b]	0.16	7.34[b]	6.02[a]	6.24[a]	0.20
Lee-Kramer shear force										
Peak force (lb/oz)	161.3[a]	195.6[b]	2.6	168.1[a]	188.8[b]	2.6	195.5[b]	175.6[a]	167.5[a]	3.2
Texture profile analysis[3]										
Hardness (lb)	7.83[a]	8.93[b]	1.03	8.07[a]	8.66[b]	1.03	8.14[a]	8.25[ab]	8.73[b]	1.04
2nd peak force (lb)	7.03[a]	8.18[b]	0.91	7.32[a]	7.89[b]	0.91	7.41	7.50	7.89	0.92
Cohesiveness	0.55	0.67	0.09	0.66	0.56	0.09	0.56	0.55	0.72	0.11
Gumminess (lb)	4.12[a]	4.48[b]	0.29	4.21	4.41	0.29	4.30	4.23	4.39	0.30
Springiness	4.03[a]	3.68[b]	0.05	3.87	3.84	0.05	4.20[c]	3.91[b]	3.46[a]	0.06

[1] Subprimal type: CR = chuck roll; KN = knuckle.
[2] Quality grade: PCH = Premium Choice; SEL = Select.
[3] Hardness (peak force of first compression); 2nd peak force (peak force of the second compression); cohesiveness (total energy of second compression ÷ total energy of the first compression); gumminess (hardness × cohesiveness); springiness (depth of second compression ÷ depth of first compression).
[a–c] Means within a row and main effect with a different superscript letter differ ($P < 0.05$).

Aging Premium Choice Chuck Rolls for Minimal Days Maximizes Color Stability and Extends Retail Display Life

C.M. Garner, J.A. Unruh, M.C. Hunt, E.A.E. Boyle, and T.A. Houser

Introduction

In retail markets, color stability without discoloration is an economically important trait because it can allow for extended retail sale opportunities, fewer discounts, and reduced product loss. Ground beef is the most commonly consumed beef product in the United States. Historically, the source of ground beef comes from lower quality cuts, trimmings from subprimals, and subprimals from cull cows; however, alternative grinds from whole and/or premium quality subprimals are becoming more popular with consumers. Subprimals from the chuck and round are logical subprimals that could be used for premium ground beef production because they cost less than other subprimals such as those from the rib and loin. Ground beef products from higher quality grades such as Premium Choice (upper two-thirds of Choice) offer merchandising potential and are commonly utilized as a higher quality product. The inherent lean and fat property differences that may exist in these subprimals could potentially influence the color display stability of the resulting ground beef products.

Subprimals can be stored in a vacuum package for extended periods of time. The number of days that subprimals may be held before processing can be influenced by the distribution chain, accessibility, and subprimal price fluctuations. Extended vacuum storage before grinding could affect biochemical, oxidative, and microbial properties of these subprimals and influence their color stability. Our objective was to determine the effects of two subprimal types (chuck roll and knuckle), two quality grades (Premium Choice and Select), and three vacuum-packaged storage aging times before processing (7, 21, and 42 days) on ground beef patty display color stability.

Experimental Procedures

At the end of each aging time (7, 21, or 42 days), four knuckles or two chuck rolls representing their respective quality grade categories (upper two-thirds of Choice and Select), were combined and ground using a 3/8-in. plate to form a treatment or sample batch. Six replications were made for each of the 12 treatment combinations. After the second final grind using a 1/8-in. plate, proximate analysis, myoglobin concentrations, and pH were conducted on raw ground beef samples. For display color, 1/4-lb patties were formed using a Hollymatic patty machine (Hollymatic Corporation, Countryside, IL), packaged in polyvinyl chloride-overwrapped trays, and displayed at 36°F in a coffin-type retail case under 150-foot candles of continuous fluorescent lighting. Six trained color panelists evaluated patty visual color and discoloration to the nearest 0.5 using 8-point scales, with 1 = extremely bright cherry-red, 2 = bright cherry-red, 3 = moderately bright cherry-red, 4 = slightly bright cherry-red, 5 = slightly dark cherry-red, 6 = moderately dark red, 7 = dark red, and 8 = extremely dark red for visual color; and 1 = very bright red, 2 = bright red, 3 = dull red, 4 = slightly dark red, 5 = moderately dark

red, 6 = dark red to tannish red, 7 = dark reddish tan, and 8 = tan to brown for visual discoloration. Ground beef patties were evaluated at 0, 24, 48, and 72 hours of display by the trained color panelists, and a HunterLab MiniScan (Reston, VA) was used to evaluate instrumental color. At the beginning of display, ground beef patties were evaluated for microbial (aerobic plate count) and lipid oxidation (thiobarbituric acid reactive substances, or TBARS) properties.

Results and Discussion

Ground beef pH values were similar ($P > 0.05$) for subprimal type and quality grade; however, myoglobin concentration was greater ($P < 0.05$) for knuckle than chuck roll subprimals (Table 1). Ground beef patties from knuckle and Select subprimals had higher ($P < 0.05$) percentages of moisture and protein but lower percentages of fat than those from chuck roll and Premium Choice subprimals, respectively.

Ground beef patties from Premium Choice subprimals had ($P < 0.05$) 0.5 lower visual color scores (brighter red) and 0.7 lower discoloration scores (less discoloration) than those from Select subprimals. A subprimal type × aging time × display time interaction ($P < 0.05$) was observed for visual color (Figure 1) and discoloration (Figure 2). For visual color and discoloration, all subprimal type × aging time treatments increased linearly (i.e., became darker red and more discolored) over display time ($P < 0.05$). For all aging time × display time means, patties from chuck roll subprimals had ($P < 0.05$) brighter red and less discolored visual scores than those from knuckle subprimals; however, the largest differences due to aging time were observed for patties from chuck roll subprimals, in which those aged 42 days had ($P < 0.05$) much darker and more discolored scores at 48 and 72 hours of display than those aged for 7 and 21 days. Instrumental color measures supported the visual observations, with ground beef patties from chuck roll and Premium Choice having lighter (higher L*), redder (higher a*), yellower (higher b*), and greater intensity (higher chroma) color than those from knuckle and Select subprimals, respectively. During hours of display, patties initially (0 hour) had higher L* values than at the remaining display times (24, 48, and 72 hours) and a*, b*, and chroma decreased, indicating a decline in redness, yellowness, and color intensity with increased hours of display.

If a visual and discoloration score of 5 was set as the threshold of consumer acceptability, patties from chuck roll subprimals aged 7 and 21 days would have 48 more hours of color shelf life than patties from knuckle subprimals from all aging times (which passed this threshold prior to 24 hours of display) and 24 more hours of color shelf life than patties from chuck roll subprimals aged 42 days (which passed this threshold at 48 hours of display). The accelerated discoloration could lead to less opportunity for sale and an earlier potential for discounting/discarding of the patties.

At the beginning of display, patties from knuckle subprimals had higher ($P < 0.05$) aerobic plate counts (colony-forming units per gram) than those from chuck roll subprimals (Table 2). As days of aging increased, plate counts also increased ($P < 0.05$). In addition, patties from subprimals aged 7 days had ($P < 0.05$) less lipid oxidation (lower TBARS) than those aged 21 and 42 days. This result suggests that fewer days of aging would result in ground beef patties with lower initial microbial levels and less lipid oxidation at the initiation of display.

Implications

Premium Choice chuck rolls aged for fewer than 21 days are recommended to maximize color stability and extend display life; patties from knuckle subprimals should be displayed for a minimal time because color deteriorates rapidly, especially with extended aging times.

Table 1. Subprimal type × quality grade interaction means for percentages of moisture, fat, and protein; myoglobin concentration; and pH of ground beef patties

	Chuck roll		Knuckle		
Trait	Premium Choice	Select	Premium Choice	Select	SE
pH	5.84	5.82	5.83	5.82	0.045
Myoglobin, mg/g[1]	6.27	5.81	6.53	6.63	0.181
Moisture, %	62.2[a]	66.5[b]	70.7[c]	72.7[d]	0.31
Fat, %	19.8[a]	14.3[b]	8.5[c]	5.8[d]	0.42
Protein, %[2]	17.5	18.5	19.3	20.0	0.16

[1] Myoglobin concentration = mg/g meat; main effect ($P > 0.05$) in which knuckle > chuck roll.
[2] Main effect ($P > 0.05$) in which knuckle > chuck roll.
[a-d] Means within a row with a different superscript letter differ ($P < 0.05$).

Table 2. Effects of subprimal type, quality grade, and aging time on aerobic plate count (APC) and lipid oxidation (TBARS) of ground beef patties

	Subprimal type[1]			Quality grade[2]			Days of aging			
Trait	CR	KN	SE	PCH	SEL	SE	7 days	21 days	42 days	SE
APC[3]	4.2[a]	4.6[b]	0.12	4.3	4.5	0.12	2.9[a]	3.9[b]	6.4[c]	0.13
TBARS[4]	0.46	0.54	0.03	0.48	0.51	0.03	0.27[a]	0.58[b]	0.65[b]	0.03

[1] Subprimal type: CR = chuck roll; KN = knuckle.
[2] Quality grade: PCH = Premium Choice; SEL = Select.
[3] APC (log colony-forming units per gram [CFU/g] or log CFU/cm^2).
[4] Thiobarbituric acid reactive substances (mg malonaldehyde/kg).
[a-c] Means within a row and main effect with a different superscript letter differ ($P < 0.05$).

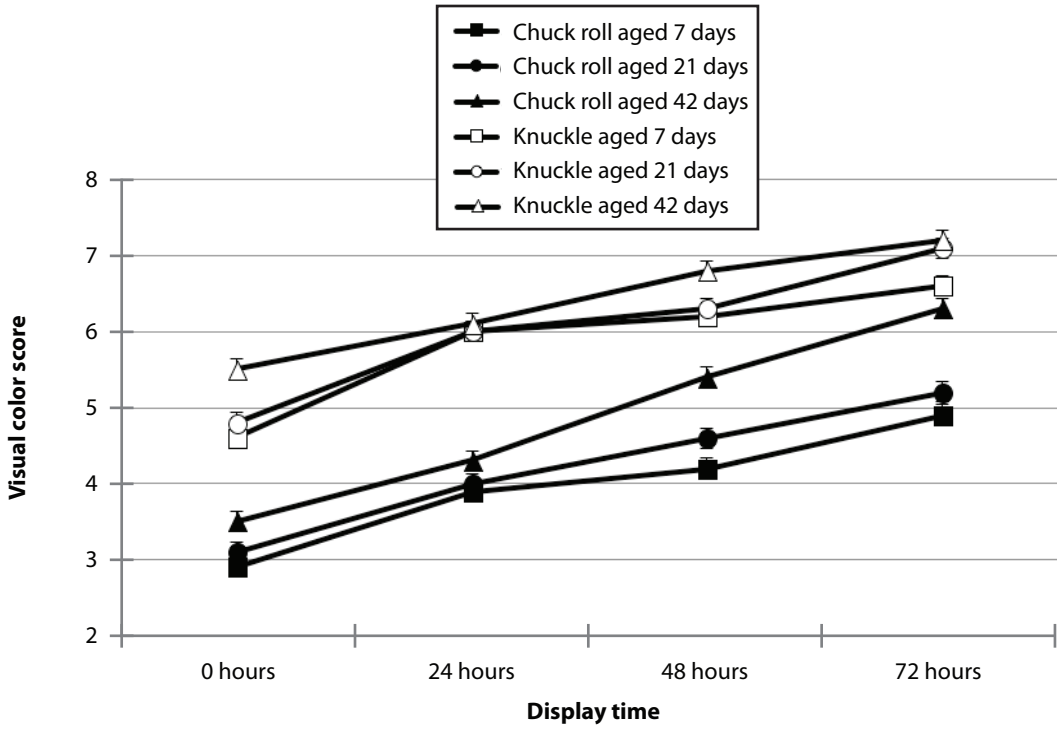

Figure 1. Subprimal type × aging time × display time interaction means for visual color scores (2 = Bright cherry-red; 5 = Slightly dark cherry-red; 8 = Extremely dark red) of ground beef patties (SE = 0.13).

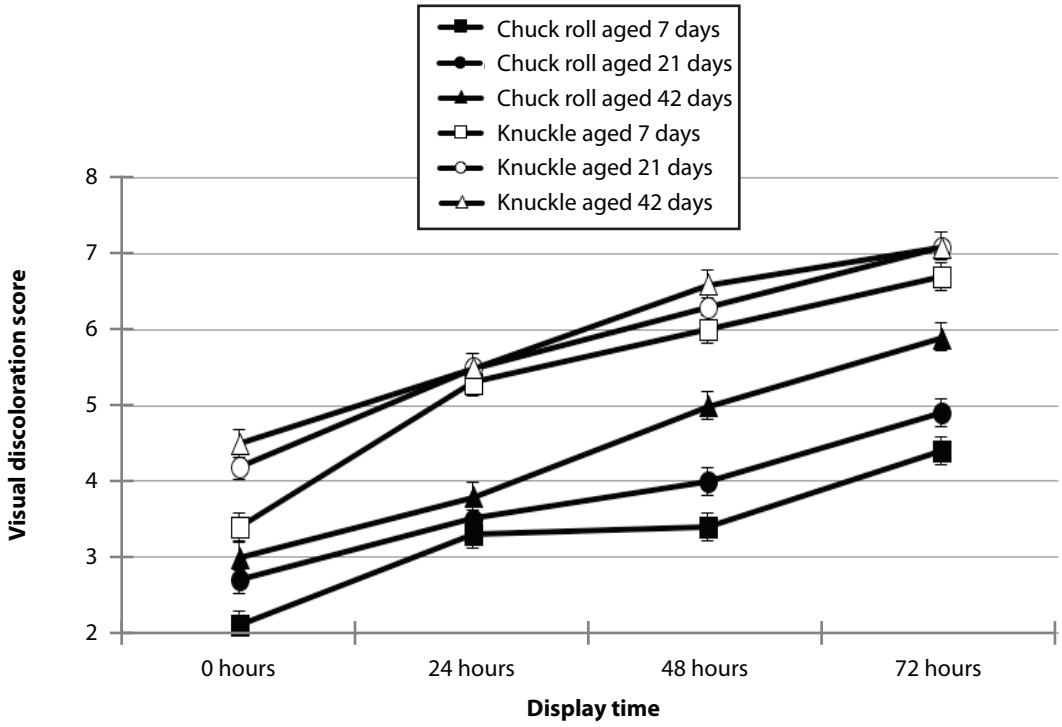

Figure 2. Subprimal type × aging time × display time interaction means for visual color discoloration scores (2 = Bright red; 5 = Moderately dark red; 8 = Tan to brown) of ground beef patties (SE = 0.18).

Quality Classification Affects Firmness of Ground Beef Patties From the Chuck Roll

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Introduction

Ground beef is the most commonly consumed beef product; the average American consumes over 28 lb of ground beef per year. The source of ground beef has historically been lower quality cuts, trimmings from subprimals, and subprimals from cull cows, but consumer demand for distinctive ground beef items has led to alternative grinds from whole and/or premium quality subprimals.

Consumers often use color as the main criteria in selecting meat products, and they associate a bright red color with freshness. Longer display life without discoloration can result in more opportunities to sell the product and greater potential for profit. Flavor, juiciness, and tenderness are also associated with consumer satisfaction. Although grinding offers an opportunity to mechanically minimize differences in tenderness, product quality can affect these sensory properties of ground beef. The objective of this study was to determine the effects of three quality classifications and their combinations on ground beef patty display color stability and sensory attributes evaluated by a trained sensory panel and consumer panel.

Experimental Procedures

A total of 18 chuck roll (NAMP 116A) subprimals from Choice, Select, and non-graded (older maturity) quality grade categories were obtained from a commercial purveyor. The product originated from two sources. The Choice and Select subprimals originated from a commercial steer and heifer harvest facility, whereas the older maturity meats originated from a commercial fed-cow harvest facility. Two chuck rolls representing each quality category were combined and ground though a 3/8-in. plate followed by a 1/8-in. plate to form a grind batch. Treatments consisting of Choice, Select, older maturity, 50% Choice/50% older maturity, and 50% Select/50% older maturity were produced and replicated 3 times. At the time of grinding, all products were 7 to 9 days past the box date. After grinding, samples were evaluated for percentage of fat using a Hobart Fat Percentage Indicator (Troy, OH). Using a Hollymatic patty machine (Hollymatic Corporation, Countryside, IL), 1/4-lb ground beef patties were made for display and sensory evaluation.

For display color, ground beef patties were packaged in polyvinyl chloride-overwrapped trays and displayed at 36°F in a coffin-type retail case under 150-foot candles of continuous fluorescent lighting. Six trained color panelists evaluated patty visual color to the nearest 0.5 using an 8-point scale, with 1 = extremely bright cherry-red, 2 = bright cherry-red, 3 = moderately bright cherry-red, 4 = slightly bright cherry-red, 5 = slightly dark cherry-red, 6 = moderately dark red, 7 = dark red, and 8 = extremely dark red. Ground beef patties were evaluated by trained color panelists and a HunterLab MiniScan (Reston, VA) to evaluate visual and instrumental color at 0, 24, and 48 hours of display.

For the trained sensory panel and consumer panels, ground beef patties were crust-frozen at -40°F before vacuum-packaging, stored at -4°F, thawed at 36°F for 24 hours, and cooked in a forced-air convection oven set at 325°F to an internal endpoint temperature of 160°F. Patties were cut into eight wedge slices, and duplicate samples were served warm to a 7-member trained sensory panel. Trained sensory panelists used a scale of 1 to 8 to evaluate firmness (1 = extremely soft, 8 = extremely firm), cohesiveness (1 = not cohesive at all, 8 = extremely cohesive), juiciness (1 = extremely dry, 8 = extremely juicy), beef flavor intensity (1= extremely bland, 8 = extremely intense), mouth coat (1 = abundant, 8 = none), off-flavor (1 = were abundant, 8 = none), and desirability (1 = extremely dislike, 8 = extremely like).

For the consumer panel, 117 beef consumers from the 2013 Cattlemen's Day, 2013 Meat Processors Workshop, and Spring 2013 Meat Science class evaluated wedge slices that were prepared similarly to those served the trained sensory panel. A scale of 1 to 8 was used to evaluate juiciness (1 = extremely dry, 8 = extremely juicy), flavor (1 = extremely bland, 8 = extremely intense), firmness (1 = extremely soft, 8 = extremely firm), and overall acceptability (1 = extremely acceptable, 8 = extremely unacceptable).

For slice shear force, patties were cooled to room temperature for approximately 30 minutes before two 1.2-in. strips were removed from each patty; each strip was sheared twice. Two patties per sample were used, resulting in eight measurements that were averaged for analysis. The blade was attached to the crosshead of an Instron with a 220-lb load cell and crosshead speed of 9.8 in/minute.

Results and Discussion

No treatment differences were detected ($P > 0.05$) for fat percentage (Table 1) or visual or instrumental display color (Table 2). Although not significant ($P > 0.05$), patties from the older maturity treatment visually appeared to have the darkest, most discolored score. Ground beef patties declined in visual color from 0 to 48 hours of display (Table 3), with the darkest, most discolored visual scores at 48 hours of display and the brightest red scores at 0 hours of display ($P < 0.05$). This agreed with instrumental color values that showed patties were darker (lower L*) at 48 hours ($P < 0.05$) than patties at 0 and 24 hours, and that they were progressively less red (lower a*) and less yellow (lower b*), resulting in less color intensity (lower chroma values) from 0 to 24 hours and 24 to 48 hours.

The trained sensory panel found that ground beef patties from older maturity beef were ($P < 0.05$) firmer than those from the Choice, Select, and Select/older maturity treatments. In addition, patties from the Choice/older maturity treatment were firmer ($P < 0.05$) than those from the Select and Select/older maturity treatments. Patties from the Choice, Select, and Select/older maturity treatments were more tender ($P < 0.05$) than those from the older maturity and Choice/older maturity treatments; however, patties from the Select/older maturity treatment were ($P < 0.05$) evaluated as the juiciest, and those from the older maturity treatment were ($P < 0.05$) juicier than those from the Choice treatment. Patties from the older maturity treatment were ($P < 0.05$) more flavorful than those the Select and Choice/older maturity treatments, and those from the Choice and Select/older maturity treatments were ($P < 0.05$) more flavorful than those from the Select treatment.

The consumer panel found patties from the older maturity and choice/older maturity treatments were ($P < 0.05$) firmer than those from the Choice and Select treatments. Patties from the older maturity treatment had greater ($P < 0.05$) slice shear forces (were tougher) than those from the Choice and Select treatments.

Overall, the data would suggest that ground beef patties from the older maturity treatment were firmer/tougher than those from the Choice and Select treatments. Patties from the older maturity treatment had greater firmness ($P < 0.05$) and less tenderness as evaluated by a trained sensory panel, greater firmness as evaluated by a consumer panel, and greater slice shear force than those from the Choice and Select treatments.

Implications

With minimal differences in composition (fat percentage) and display color, patties from Choice and Select chuck rolls provided softer characteristics to the palate and instrumentally than those from older maturity chuck rolls.

Table 1. Effects of quality classification on fat percentage, trained sensory panel, consumer panel, and slice shear force characteristics

Trait	Choice	Select	Choice/ older maturity	Select/ older maturity	Older maturity	SE
Fat, %	16.1	13.9	15.4	14.3	14.7	1.1
Trained panel[1]						
Firmness	5.5^{ab}	5.3^{a}	5.7^{bc}	5.4^{a}	5.9^{c}	0.1
Cohesiveness	5.4	5.3	5.6	5.5	5.6	0.08
Tenderness	6.4^{b}	6.5^{b}	6.0^{a}	6.4^{b}	6.0^{a}	0.12
Juiciness	5.5^{a}	5.6^{ab}	5.6^{ab}	6.0^{c}	5.7^{b}	0.07
Flavor	5.6^{bc}	5.3^{a}	5.5^{ab}	5.6^{bc}	5.7^{c}	0.07
Off-flavor	7.7	7.5	7.6	7.9	7.8	0.13
Consumer panel[2]						
Juiciness	5	4.9	4.9	5.2	4.9	0.15
Flavor	5.1	5.2	5.1	5.2	5.2	0.11
Firmness	4.3^{a}	4.4^{a}	4.7^{b}	4.5^{ab}	4.8^{b}	0.16
Acceptability	5.1	5.1	5	5.2	5.1	0.12
Slice shear force, lb	6.6^{a}	6.4^{a}	7.9^{ab}	7.5^{ab}	8.8^{b}	0.4

[1] Scores of 1 to 8: firmness (1 = extremely soft, 8 = extremely firm), cohesiveness (1 = not cohesive at all, 8 = extremely cohesive), juiciness (1 = extremely dry, 8 = extremely juicy), beef flavor intensity (1= extremely bland, 8 = extremely intense), mouth coat (1 = abundant, 8 = none), off-flavor (1 = were abundant, 8 = none), and desirability (1 = extremely dislike, 8 = extremely like).
[2] Scores of 1 to 8: juiciness (1 = extremely dry, 8 = extremely juicy), flavor (1 = extremely bland, 8 = extremely intense), firmness (1 = extremely soft, 8 = extremely firm), and overall acceptability (1 = extremely acceptable, 8 = extremely unacceptable).
[a-c] Means with different superscript letters differ ($P < 0.05$).

Table 2. Effects of quality classification on visual and instrumental display color

Trait	Choice	Select	Choice/ older maturity	Select/ older maturity	Older maturity	SE
Visual color[1]	4.0	3.8	4.1	4.2	4.7	0.24
L*[2]	44.9	45.2	44.1	44.3	44.1	0.66
a*[3]	23.0	21.7	21.2	20.8	22.8	0.57
b*[4]	22.1	21.2	20.8	22.2	21.1	0.54
Chroma	31.8	30.1	29.4	31.7	29.8	0.75

[1] Visual color scores: 1 = extremely bright cherry-red, 2 = bright cherry-red, 3 = moderately bright cherry-red, 4 = slightly bright cherry-red, 5 = slightly dark cherry-red, 6 = moderately dark red, 7 = dark red, and 8 = extremely dark red.
[2] L* lightness (0 = black, 100 = white).
[3] a* redness/greenness (positive values = red, negative values = green).
[4] b* yellowness/blueness (positive values = yellow, negative values=blue).

Table 3. Effects of display time on visual and instrumental color

	0 hours	24 hours	48 hours	SE
Visual color[1]	2.9[a]	4.4[b]	5.3[c]	0.12
L*[2]	45.6[a]	45.0[a]	42.9[b]	0.50
a*[3]	26.6[a]	20.8[b]	18.1[c]	0.47
b*[4]	23.3[a]	21.3[b]	19.8[c]	0.46
Chroma	35.4[a]	29.8[b]	26.8[c]	0.64

[1] Visual color scores: 1 = extremely bright cherry-red. 2 = bright cherry-red, 3 = moderately bright cherry-red, 4 = slightly bright cherry-red, 5 = slightly dark cherry-red, 6 = moderately dark red, 7 = dark red, and 8 = extremely dark red.
[2] L* lightness (0 = black, 100 = white).
[3] a* redness/greenness (positive values = red, negative values = green).
[4] b* yellowness/blueness (positive values = yellow, negative values=blue).
[a-c] Means with different superscript letters differ ($P < 0.05$).

Increasing Postmortem Aging Time Decreases Color and Flavor Stability of Top Sirloin Steaks

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Introduction

Consumers perceive fresh meat color as the most important characteristic in purchasing fresh meat cuts at retail. Bright-pink to bright-red meat color is the most desirable to consumers, and any deviation from this is less acceptable. The *gluteus medius* is found in a variety of valuable retail cuts such as strip steaks and sirloin steaks. It is known that the *gluteus medius* has a more limited color shelf life compared to *longissimus dorsi*. Decreases in color shelf life from the combination of the inherent properties of the *gluteus medius* and postmortem aging results in a higher percentage of retail cuts being marked down in price or removed from the retail case, leading to significant monetary losses across the beef industry.

Color stability has been widely studied using metmyoglobin reducing activity and oxygen consumption rate. Postmortem aging is known to decrease metmyoglobin reducing activity and increase the oxygen consumption rate, which results in diminished color stability in the retail case.

Postmortem aging is beneficial not only for tenderness, but also for beef flavor; however, increased product aging under anaerobic conditions (vacuum-packaging) is known to increase the production of lactic acid bacteria. Some undesirable off-flavors may be produced with the additional growth of lactic acid bacteria and lipid oxidation.

Top sirloin butts are commonly blade-tenderized to significantly increase tenderness, but minimal data have shown the relationship between blade tenderization and color stability as well as the effect of extended postmortem aging periods past 30 days on color stability. Tenderness plays a significant role in consumer satisfaction with beef products, and blade tenderization and extended postmortem aging periods are effective ways to ensure that beef cuts are tender. Therefore, the objectives of this study were to: (1) determine color and flavor stability of beef *gluteus medius* during extended postmortem aging times with and without mechanical tenderization, and (2) determine the biochemical factors responsible for color stability of beef *gluteus medius* at five different aging periods.

Experimental Procedures

Fifteen top sirloin butts were transported to the Kansas State University Meat Laboratory from three commercial beef harvest facilities and were randomly assigned to five different aging periods. The five postmortem aging treatments were 5, 19, 33, 47, and 61 days. Each beef top sirloin butt was then stored in the original vacuum package at 35 to 39°F throughout the aging period. On the final day of each postmortem aging treatment, top sirloin butts were removed from their vacuum packages and the *gluteus medius* was removed and trimmed of excess fat. The *gluteus medius* was then cut down

the center, parallel with the muscle fibers, to yield two pieces of equal size, which were randomly assigned to a blade tenderization or a control treatment. The blade tenderized treatment was processed twice through a commercial blade tenderization machine. After tenderization treatment, the *gluteus medius* pieces were sliced perpendicular to the muscle fibers into eight 1-in. steaks. The first top sirloin steak, starting at the anterior end, was immediately vacuum-packaged with oxygen-impermeable film and stored at -112°F for approximately 7 days before assessment of lipid oxidation using the thiobarbituric acid reactive substances method. The second steak was used for metmyoglobin reducing activity and oxygen consumption rate determination, the third steak was used for simulated retail display, and the fourth steak was immediately vacuum-packaged with oxygen-impermeable film and frozen at -112°F until needed for sensory analysis. The fifth steak was immediately vacuum-packaged into oxygen-impermeable film and frozen at -112°F until needed for Warner-Bratzler Shear Force measurements, and the sixth steak was placed in a sterilized bag and immediately used to analyze lactic acid bacteria counts.

Results and Discussion

As expected, both extended postmortem aging and blade tenderization significantly increased tenderness in beef top sirloin steaks. Postmortem aging was not as effective as blade tenderization in improving tenderness until day 61 of the study (data not shown).

With increased postmortem aging time, steaks cut from aged top sirloin butts were much less color-stable, as shown by increased display color and discoloration scores. Using a limit of 25% surface browning (metmyoglobin), top sirloin butts aged 5, 19, 33, 47, and 61 days yielded steaks with a color shelf of 4 days, 2 days, 1 day, 1 day, and 1 day, respectively (data not shown). In addition, top sirloins that were blade-tenderized were darker in appearance and had higher discoloration scores than controls for comparable postmortem aging days. Quality traits for the interaction of aging and tenderization are shown in Table 1.

Fresh meat undergoes constant change between the three pigments of myoglobin (purple), oxymyoglobin (red), and metmyoglobin (brown) and relies on enzyme systems and substrate availability to make that happen. As postmortem age increased, enzyme activity and substrate availability decreased, resulting in lower metmyoglobin reducing activity. This lower metmyoglobin reducing ability directly related to the decreased color stability observed in this study.

Lactic acid bacteria significantly increased with increased aging times (data not shown); however, this did not affect pH significantly or change the flavor profile dramatically. Oxidative rancidity significantly increased for samples with increased aging periods. As a result, samples that were aged longer had more warmed-over flavor. Longer aging periods also resulted in product with less bitter flavor and less bloody/serumy flavor, indicating that flavor changes did occur as aging time increased (data not shown). Sensory traits for the interaction of aging and blade tenderization are shown in Table 2.

Implications

Extended postmortem aging and blade tenderization are effective tools in increasing tenderness of top sirloin steaks, but they may decrease retail color shelf life and flavor characteristics.

Acknowledgements

This project was funded by the Beef Checkoff.

Table 1. Least squares means of aging × tenderization interaction for quality traits of beef top sirloin steaks subjected to different postmortem aging and tenderization treatments

	Control					Blade-tenderized					
	Aging period (days)					Aging period (days)					
	5	19	33	47	61	5	19	33	47	61	SEM
Lipid oxidation[1]	0.07	0.10	0.14	0.19	0.17	0.06	0.14	0.15	0.19	0.20	0.018
Metmyoglobin reducing activity[2]	85.1	72.2	64.9	69.1	62.3	85.2	74.5	61.3	73.2	61.3	3.78
Oxygen consumption rate[3]	49.3	42.2	57.5	44.8	77.5	47.5	55.2	57.1	52.9	89.6	6.25
L*[4]	44.1^{f}	46.4^{de}	47.7^{d}	53.5^{ab}	53.1^{bc}	43.6^{f}	45.2^{ef}	47.2^{d}	51.8^{c}	54.8^{a}	0.563
a*[5]	24.3^{cd}	24.4^{cd}	22.8^{e}	29.8^{a}	25.9^{b}	23.8^{de}	23.9^{de}	25.8^{bc}	28.7^{a}	26.8^{b}	0.566
b*[6]	19.9	21.8	22.9	35.3	28.7	19.8	21.4	24.8	34.5	31.2	0.764
Initial color panel[7]	4.4	3.3	3.5	3.8	3.7	4.5	3.6	3.7	4.0	3.6	0.16
Display color panel[8]	3.73^{f}	4.14^{e}	4.51^{d}	5.65^{b}	5.54^{b}	4.03^{e}	4.80^{c}	4.95^{c}	6.32^{a}	6.42^{a}	0.099
Discoloration panel[9]	2.52^{f}	3.61^{d}	4.07^{c}	4.45^{b}	4.41^{b}	2.97^{e}	4.15^{c}	4.82^{a}	4.85^{a}	4.75^{a}	0.100
Warner-Bratzler shear force, lb	9.9^{a}	7.8^{b}	7.4^{b}	7.3^{b}	5.6^{c}	6.9^{b}	5.8^{c}	5.3^{c}	5.6^{c}	5.0^{c}	0.37
Lactic acid bacteria (log CFU/g)	1.07	1.79	2.69	3.14	3.76	1.27	1.91	2.70	3.05	3.95	0.243
pH	5.5	5.5	5.4	5.5	5.5	5.5	5.5	5.4	5.5	5.5	0.016

[1] Thiobarbituric acid reactive substances, ppm malonaldehyde.
[2] Percentage metmyoglobin reduced.
[3] Percentage oxymyoglobin reduced.
[4] L* lightness (0 = black, 100 = white).
[5] a* redness/greenness (positive values = red, negative values = green).
[6] b* yellowness/blueness (positive values = yellow, negative values=blue).
[7] 1 = bleached red, 2 = very light cherry-red, 3 = moderately cherry-red, 4 = cherry-red, 5 = slightly dark red, 6 = moderately dark red , 7 = dark red, 8 = very dark red.
[8] 1 = very bright red, 2 = bright red, 3 = dull red, 4 = slightly dark red, 5 = moderately dark red, 6 = dark red to dark reddish tan, 7 = tannish red, 8 = tan to brown.
[9] 1 = 0% surface discoloration, 2 = 1 to 10% surface discoloration, 3 = 11 to 25% surface discoloration, 4 = 26 to 50% surface discoloration, 5 = 51 to 75% surface discoloration, 6 = 76 to 99% surface discoloration, 7 = 100% surface discoloration.
[a–f] Means within a row with different superscripts differ ($P < 0.05$).

Table 2. Least squares means of aging × tenderization interaction for sensory traits of beef top sirloin steaks subjected to different postmortem aging and tenderization treatments

	Control					Tenderized					
	Aging period (days)					Aging period (days)					
	5	19	33	47	61	5	19	33	47	61	SEM
Overall tenderness[1]	9.1^{c}	9.2^{c}	9.0^{c}	9.2^{c}	10.0^{b}	9.4^{b}	10.3^{ab}	10.1^{b}	10.2^{b}	10.5^{a}	0.26
Myofibrillar tenderness[1]	9.4^{b}	9.6^{b}	9.3^{b}	9.6^{b}	10.4^{a}	9.7^{a}	10.6^{a}	10.5^{a}	10.6^{a}	10.8^{a}	0.32
Beef identity[2]	9.2	9.5	8.9	9.1	9.3	9.2	9.3	9.3	9.2	8.9	0.24
Brown/roasted[2]	7.8	8.1	8.1	8.0	8.3	8.0	8.1	8.1	8.0	7.9	0.71
Bloody/serumy[2]	3.6^{ab}	3.3^{bcd}	3.4^{abcd}	3.0^{d}	3.5^{abc}	3.5^{ab}	3.8^{a}	3.2^{bcd}	3.4^{abcd}	3.1^{cd}	0.47
Liver-like[2]	1.3	1.2	1.5	1.4	1.7	1.3	1.6	1.5	1.5	1.6	0.27
Metallic[2]	2.0^{abc}	1.8^{bc}	1.9^{abc}	1.9 ^{abc}	1.9 ^{abc}	1.7^{c}	2.2^{a}	2.0^{ab}	2.0^{abc}	2.1^{a}	0.20
Fat-like[2]	1.7	1.7	1.8	1.5	1.7	1.7	1.9	1.7	1.7	1.5	0.15
Green[2]	0.66	0.61	0.55	0.52	0.55	0.60	0.50	0.56	0.54	0.62	0.22
Rancid[2]	0.77	0.48	0.63	0.79	0.64	0.71	0.84	0.94	0.76	0.87	0.21
Spoiled[2]	0.30	0.23	0.47	0.23	0.50	0.33	0.45	0.40	0.46	0.61	0.14
Warmed over[2]	1.8	1.9	2.0	2.0	2.0	1.7	1.8	2.1	2.1	2.0	0.49
Overall sweet[2]	1.4^{bc}	1.6^{a}	1.4^{abc}	1.4^{cd}	1.5^{ab}	1.5^{abc}	1.4^{bc}	1.5^{abc}	1.4^{bcd}	1.2^{d}	0.23
Sour[2]	2.5	2.6	2.5	2.6	2.6	2.5	2.7	2.7	2.7	2.8	0.15
Bitter[2]	3.3^{abcd}	3.1^{cd}	3.0^{d}	3.4^{ab}	3.1^{bcd}	3.1^{cd}	3.4^{ab}	3.3^{abc}	3.5^{a}	3.4^{a}	0.29
Salty	1.9	1.9	1.8	1.8	1.8	1.9	2.0	1.8	1.9	1.7	0.23
Umami[2]	2.0	2.2	1.9	2.1	2.2	1.9	2.2	2.0	2.2	1.9	0.22

[1] 15 = very tender, 1 = very tough.
[2] 15 = extremely strong, 0 = none.
[a–d] Means within a row with different superscripts differ ($P < 0.05$).

Aging for 35 Days Does Not Improve Tenderness of Strip Loin Steaks From Heifers Fed Zilmax

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Introduction

As the world's population continues to expand, demand for food animal products is also increasing; therefore, efficient production is vital. Implants and beta-adrenergic agonists such as Zilmax (Merck Animal Health, Summit, NJ) improve average daily gain and feed efficiency in feedlot cattle. Use of these growth technologies also increases hot carcass weight and muscle mass. Although use of implants and Zilmax increases efficiency of beef production, these products also negatively affect meat quality characteristics such as marbling and tenderness. Some research reports conclude that wet aging meat for extended periods of time can alleviate tenderness issues caused by exogenous growth promotants. The objective of this experiment was to examine the effects of implants and Zilmax on meat tenderness across five aging periods and to evaluate moisture retention during the cooking process.

Experimental Procedures

Thirty-three crossbred yearling heifers (1,022 ± 5 lb initial body weight) were blocked by body weight and randomly assigned to three treatment groups. Treatments consisted of a control group (no implant, no Zilmax), an implant-only group that was implanted with Component TE-200 (Elanco Animal Health, Greenfield, IN) on day 1 of the study, and an implant + Zilmax group that received Component TE-200 on day 1 of the study and Zilmax 23 days prior to slaughter with a 3-day withdrawal period. After 75 days on feed (Table 1), animals were harvested at a commercial abattoir; slaughter and carcass data were collected. After a 36-hour chill period, strip loins were removed from one side of each carcass and transported to Kansas State University. Five 1-in.-thick steaks were cut from each loin, beginning at the posterior end, and were assigned randomly to wet aging periods of 3, 7, 14, 21, or 35 days at 33°F.

Steaks were cooked and objective tenderness was measured by Warner-Bratzler shear force. Weight of each steak was recorded before and after cooking to calculate moisture loss, which was derived using the equation: [(initial weight-cook weight)/initial weight] × 100. Steaks were cooked on an indoor-outdoor grill (Hamiton Beach, Southern Pines, NC) to an internal temperature of 158°F, then chilled overnight at 33°F. Six cores were removed from each steak, parallel to the muscle fibers, and sheared through the center using an Instron Universal Testing Machine with a Warner-Bratzler shear head. Peak force for each core was recorded, and the average of the six values was used to characterize tenderness of the steak.

Results and Discussion

Numerous studies have demonstrated that the use of beta agonists and implants improve feedlot performance and carcass characteristics. In this experiment, no differences were detected between treatments for dry matter intake, average daily gain,

or final body weight ($P > 0.10$; Table 2). Cattle in the implant and Zilmax/implant treatments had numerically greater average daily gains (17%) and final body weights (2%) than the control animals. Compared with the control group, the combined use of implants and Zilmax increased hot carcass weight, ribeye area, and backfat thickness ($P < 0.05$). The implant-only group was intermediate and tended to increase these measurements compared with the control group ($P < 0.10$), but the measurements did not differ from the implant/Zilmax group ($P > 0.10$). The increase in ribeye area and decrease in subcutaneous fat demonstrates that growth promotants redirect nutrient utilization toward muscle rather than fat. The depot-specific nature of this nutrient partitioning can be seen by tendency of treatments to affect ($P < 0.10$) marbling score and the inability of treatments to affect ($P > 0.10$) kidney, heart, and pelvic fat percentage. Finally, the increase in muscling and decrease in subcutaneous fat catalyzed by the implant and Zilmax/implant treatments resulted in a tendency for the treatments to increase ($P < 0.10$) carcass dressing percentage.

Previous studies have shown that the use of growth promotants can adversely affect meat tenderness. Several research groups recently have concluded that subjecting meat originating from a growth promoting program to extended aging periods can ameliorate negative effects on tenderness. We examined the effects of extended aging on weight loss during cooking and objective measures of tenderness (Table 3) and found no interaction between duration of aging and usages of exogenous growth promotants ($P > 0.10$) for weight loss during cooking. For Warner-Bratzler shear force, there was an interaction ($P < 0.01$) between treatment and day of aging. Wet aging generally improved tenderness of loin steaks, and the magnitude of change was greatest for the Zilmax/implant group. On day 3 postmortem, shear force values for Zilmax/implant steaks were 1.78 and 4.13 pounds greater than the implant and control treatments, respectively ($P < 0.05$). Extended aging to 35 days postmortem appeared to resolve the tenderness issue stimulated by the implant treatment, as indicated by implant and control steaks having similar ($P > 0.10$) shear force values. In contrast to the implant treatment, extending aging did not benefit the Zilmax/implant group as indicated by steaks from this treatment that had shear force values greater than the implant and control steaks ($P < 0.05$).

Implications

Warner-Bratzler shear force of strip loin steaks improves with longer aging times, but adverse effects of exogenous growth promotants are only partially overcome by wet aging.

Table 1. Diet composition, dry matter basis

Ingredient	Percentage of diet
Steam-flaked corn	53.59
Corn gluten feed	35.00
Ground alfalfa hay	4.00
Ground wheat straw	3.00
Vitamin/mineral supplement[1]	2.25
Feed additive premix[2]	2.16

[1]Formulated to provide 0.7% calcium, 0.7% potassium, 0.3% salt, 0.1 ppm cobalt, 10 ppm copper, 60 ppm manganese, 0.3 ppm selenium, 60 ppm zinc, 1000 KIU/lb vitamin A, and 20 IU/lb vitamin E on a dry matter basis.
[2]Formulated to provide 300 mg/day Rumensin and 90 mg/day Tylan per animal in a ground corn carrier.

Table 2. Feedlot performance and carcass characteristics for heifers finished with or without TE-200 implants[1] and/or Zilmax[2]

Item	Control	Implant	Zilmax/ implant	SE	*P*-value
Dry matter intake, lb/day	18.66	17.98	17.83	0.5	0.48
Average daily gain, lb	1.99	2.33	2.33	0.17	0.30
Feed:Gain	9.09	7.69	7.69	0.19	0.06
Final body weight, lb	1170	1194	1194	15	0.31
Hot carcass weight, lb	$762.5^{a,x}$	$781.3^{b,y}$	797.7^{b}	9.1	0.01
Dressing percentage, %	65.2	65.4	66.8	0.51	0.07
Ribeye area, in.^{2}	$12.12^{a,x}$	$13.77^{b,y}$	14.29^{b}	0.57	0.04
Backfat, in.	$0.79^{a,x}$	$0.60^{b,y}$	0.51^{b}	0.07	0.04
Kidney, pelvic, and heart fat, %	2.5	2.4	2.4	0.1	0.54
Marbling score[3]	611	534	561	24	0.10

[a,b] Values within a row are significantly different ($P < 0.05$).
[x,y] Values within a row tend to be different ($P < 0.10$).
[1]TE-200 Component implant, Elanco Animal Health, Greenfield, IN.
[2]Zilmax, Merck Animal Health, Summit, NJ.
[3]Marbling scores were obtained by a USDA grader; slight = 400–499, small = 500–599, modest = 600–699.

Table 3. Warner-Bratzler shear force and weight loss during cooking for strip loin steaks aged 3, 7, 14, 21, or 35 days and cooked to an internal temperature of 158°F

Item	Control	Implant[‡]	Zilmax/implant[3]	SEM
Weight loss[1,2], %				
Day 3	19.9	20.7	20.8	1.05
Day 7	16.7	19.5	17.5	1.05
Day 14	22.0	21.9	23.1	1.05
Day 21	20.3	21.5	19.8	1.05
Day 35	21.9	21.7	21.5	1.05
Warner-Bratzler Shear Force, lb				
Day 3	9.3^{a}	11.6^{b}	13.4^{c}	0.59
Day 7	7.8^{a}	9.8^{b}	11.0^{b}	0.59
Day 14	8.7^{a,x}	10.0^{b,y}	12.0^{c}	0.59
Day 21	8.94^{a,x}	9.5^{a,b}	10.1^{b,y}	0.59
Day 35	8.7^{a}	9.4^{a}	10.6^{b}	0.59

^{a,b,c} Means in a row with a common superscript are the same ($P < 0.01$).
^{x,y} Means in a row with different superscripts are different ($P < 0.10$).
[1] [(initial weight-final weight)/ initial weight] ×100.
[2] No day of aging × growth promotant interaction ($P > 0.10$).
[3] TE-200 Component implant, Elanco Animal Health, Greenfield, IN; Zilmax, Merck Animal Health, Summit, NJ.

Electrostatic Spray Cabinet Evaluation to Verify Uniform Delivery of Chemical and Biological Solutions to Pre-Chilled Meat Animal Carcasses

R.C. Phebus, N.J. Sevart, N.W. Baumann, and R.K. Phebus

Introduction

Shiga toxin-producing *Escherichia coli* (STEC) are a group of bacteria that cause an estimated 265,000 illnesses, 3,600 hospitalizations, and 30 deaths annually in the United States. STEC are frequently associated with raw or undercooked meat products, prompting the beef industry to develop and apply various antimicrobial intervention technologies during processing operations. The application of chemical antimicrobials to carcasses and fabricated cuts using an electrostatic spray (ESS) system (Figure 1) offers several potential advantages for controlling disease-causing pathogens, including enhanced chemical deposition (coverage) profiles, reduced overspray wastage of food-grade antimicrobials, and reduced water requirements. The objectives of this study were to (1) calibrate an ESS carcass cabinet installed at the Kansas State University Biosecurity Research Institute, (2) test the chemical deposition profile of the ESS cabinet onto a meat carcass using fluorescent dye, and (3) determine if the ESS could be used to uniformly apply a biological inoculum to a carcass to support pathogen-inoculated validation studies of different chemical intervention technologies to support the needs of the beef processing industry.

Experimental Procedures

Calibration of the 8 ESS nozzles inside the cabinet was accomplished by testing and adjusting the air pressure and fluid flow at each nozzle. The air pressure was measured with an air flow meter (King Instrument Company, Garden Grove, CA). Two 500-mL graduated cylinders were used to measure the water flow rate (mL/minute) at each of the nozzles. A 30XR-A Auto Ranging Digital Multimeter with VolTect (Amprobe, Everett, WA) was used to measure the negative electrical charge of the fluid generated at each nozzle and used with the water flow rate to calculate a charge-to-mass ratio. To ensure adequate attraction of spray to the grounded carcass surface, a charge-to-mass ratio between -5 mC/kg and -12 mC/kg was needed.

A fluorescent dye carcass deposition test was conducted by spraying ~6.8 oz of a 1:100 concentrated dye solution (Risk Reactor IFWB-C0 Fluorescent Clear Blue Water Based Tracer Concentrate, Santa Ana, CA) within the sealed ESS cabinet containing a skinned pre-chilled pig carcass side as a model (Figure 1). The dye solution was applied to two separate one-quarter pig carcasses, then to half a pig carcass. A black light (American Fluorescent, Waukegan, IL) was used to observe the uniformity of dye deposition onto all carcass surfaces (exterior and internal body cavity; Figure 2).

A carcass inoculation study was conducted using the ESS cabinet. Stationary phase inoculum (6.3 quarts, ~8.8 log cfu/mL) was prepared using a 2-strain cocktail of non-pathogenic *Escherichia coli* biotype 1 (ATCC BAA-1429 and 1431), and ~6.8 oz of this inoculum was electrostatically sprayed onto two separate pig carcass sides.

After 30 minutes of microbial attachment, each carcass side was sampled at 8 different anatomic locations using surface tissue excision. Duplicate excised tissue samples were taken from the upper, middle, and lower regions of both the internal and external body cavity surfaces. Sponge samples were also taken at the top and the bottom of the half carcasses. A comparison of *E. coli* levels achieved at each anatomic carcass location during ESS spraying was determined by plating serial dilutions of samples using Eosin Methylene Blue agar, with incubation at 79°F for 24 hours.

Results and Discussion

Both the fluorescent dye test and the *E. coli* inoculation test showed highly uniform coverage. The fluorescent dye test appeared to cover all carcass surfaces in a uniform manner, including body cavity, split line, and hock areas (Figure 2). The inoculation test showed a uniform recovery of ~5–6 log cfu/cm^2 (100,000 to 1 million bacteria/cm^2) across all anatomic regions, except a slightly lower inoculum level at the top hock area (Figure 3). The lower inoculum level at the top hock area could have been due to the difference in sampling technique (sponge sampling compared to tissue excision).

Implications

This study suggests that ESS technology has the potential to greatly reduce the volume of chemical antimicrobial sprays and processing water used in commercial carcass decontamination processes while facilitating uniform carcass coverage. Assuming that relevant pathogen reductions can be achieved using defined antimicrobial chemicals that are food-grade (the focus of future pathogen-inoculated studies at K-State), ESS technology would allow food processing companies to both cut costs on their current antimicrobial treatments by spraying less volume and allow the practical use of more expensive antimicrobials that may provide enhanced antimicrobial effectiveness. This study also showed that an ESS system installed at the Kansas State University Biosecurity Research Institute can be used to inoculate an entire carcass uniformly with target pathogens, including *Salmonella* and Shiga toxin-producing *E. coli*, to support studies to validate the effectiveness of carcass and primal/subprimal antimicrobial intervention technologies, ultimately supporting regulatory approval of such technologies and adoption by meat processors as critical components of integrated meat safety programs.

Figure 1. ESS cabinet dimensions were 6 feet × 5.87 feet × 11.42 feet.

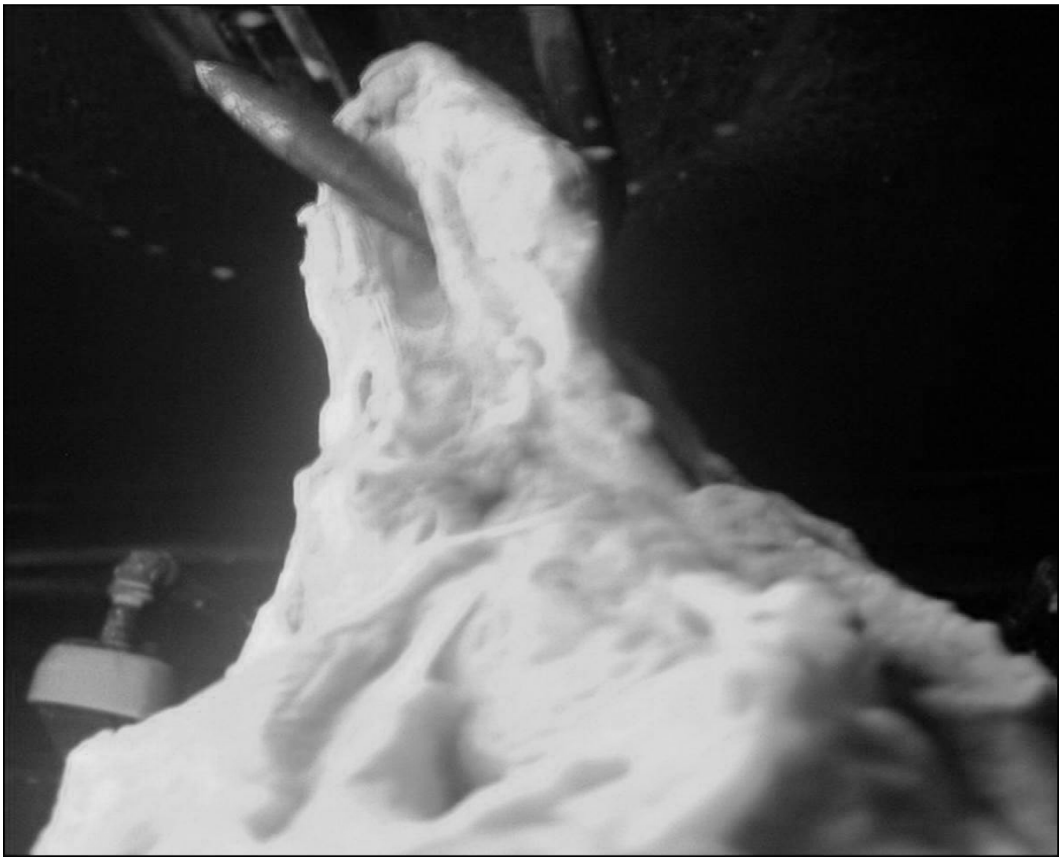

Figure 2. After application of fluorescent dye, the hock area was observed using a black light to determine the uniformity of dye deposition onto all carcass surfaces.

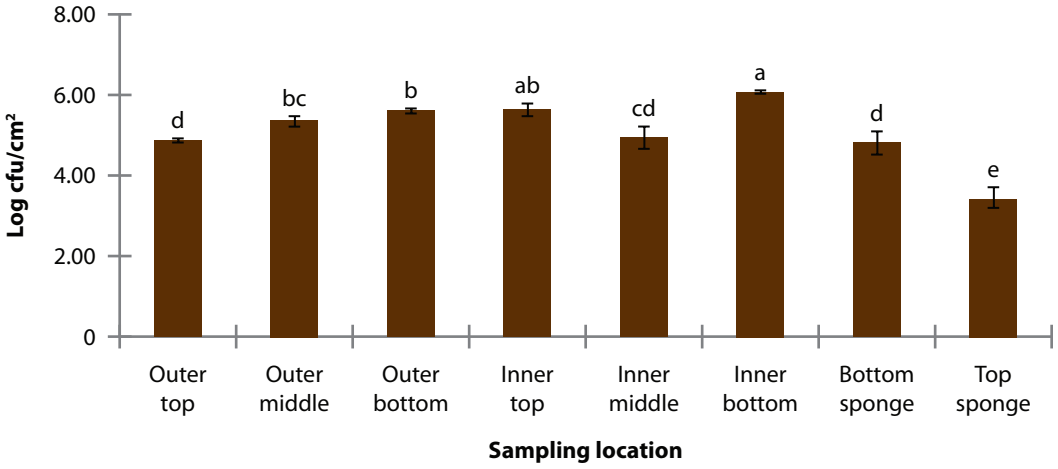

Figure 3. *E. coli* (log cfu/cm2) recovery at each sample location. Mean *E. coli* recoveries at locations labeled with different letters are statistically different ($P \leq 0.05$).

Effects of Media Type on Shiga Toxigenic *E. coli* Growth Patterns

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Introduction

Escherichia coli O157:H7 was declared to be an adulterant in raw ground beef in 1994 by the United States Department of Agriculture Food Safety and Inspection Service following a large and deadly foodborne disease outbreak in the Pacific Northwest involving undercooked hamburgers sold at Jack-in-the-Box restaurants. Due to their recognition as significant human foodborne pathogens, six additional strains (serotypes) of Shiga toxin-producing *E. coli* (STEC) were also deemed to be adulterants in raw beef products in 2012.

The beef processing industry has worked diligently since the mid-1990s to control the presence of *E. coli* O157:H7 in finished raw products through the implementation of aggressive microbial testing programs and the incorporation of antimicrobial intervention technologies validated to substantially reduce the presence of this pathogenic organism. This effort has occurred within the framework of Hazard Analysis and Critical Control Points (HACCP) programs. With the addition of six additional STEC strains that also must be controlled through these programs, laboratory-testing methods must be developed and implemented to afford the industry a means to accurately document their control programs. Shiga toxin-producing *E. coli* cultivation, identification, and quantification methods are currently lacking.

Establishing behavior patterns for these STECs will allow the beef processing industry to better develop methods for controlling or eliminating them in the food supply. To accomplish this, the prevalence of these organisms must first be established through sampling, but research into which media type is best for enriching samples to recover and identify all STEC organisms has been limited. To determine which media type was best suited for recovery of STECs, we inoculated multiple enrichment media types with the target strains and observed their growth patterns.

Experimental Procedures

Strains of the newly designated STEC adulterants (O26, O45, O103, O111, and O145), O157:H7, and O104:H4 (isolate from a German sprout outbreak) were evaluated. Eight types of liquid enrichment media were evaluated to compare STEC growth profiles over incubation time: buffered peptone water, universal pre-enrichment broth, tryptic soy broth, tryptic soy broth with 8mg/L novobiocin (mTSB M), *Escherichia coli* broth, as well as three levels of novobiocin added at 4, 8, and 20 mg/L (mEC L, mEC M, and mEC H, respectively). Each of these media types was individually inoculated with a separate strain of STEC and placed in an incubator at 99°F. At 4, 8, 12, 18, and 24-hour points, aliquots of each media/strain combination were removed and plated on tryptic soy agar. These plates were then placed in a separate incubator for 24 hours at 99°F. The plates were removed from the incubator and enumerated.

Results and Discussion

The average log count (cfu) of *E. coli* O26, O45, O103, O111, O145, O157:H7, and O104:T4 held in each enrichment media at 99°F for up to 24 hours and then plated on tryptic soy agar for enumeration are shown in Figures 1–8. Of the media types used, buffered peptone water, universal pre-enrichment broth, and tryptic soy broth are classified as general, non-selective enrichment media and allow growth of most organisms present in a sample. *E. coli* broth is selective for *E. coli* serotypes, and novobiocin antibiotic is commonly added to enrichments to detect *E. coli* O157:H7 to further suppress growth of non-*E. coli* competing microflora. One of the standard *E. coli* O157:H7 enrichments currently used in the beef industry is *E. coli* broth with high levels of novobiocin, but our results indicated that growth of most of the other non-O157:H7 STEC strains was severely inhibited when subjected to any level of novobiocin in *E. coli* broth. Because the use of *E. coli* broth containing no novobiocin showed growth levels for all STEC serotypes comparable to non-selective media types, it can be surmised that the use of unmodified *E. coli* broth may be preferable when enriching beef samples to determine possible presence of STEC.

Implications

The documented ability of *E. coli* broth containing no novobiocin to recover all target STECs will help the beef processing industry by allowing for the use of a single enrichment that will promote growth of target STEC organisms while simultaneously suppressing natural background flora, thereby reducing testing costs. Common selective enrichment broths utilized in beef testing for *E. coli* O157:H7 containing novobiocin may lead to false negatives for the other STEC strains that cannot tolerate the presence of this antibiotic.

Acknowledgements

Funding was provided from the K-State Livestock and Meat Industry Council and the Agriculture and Food Research Initiative Grant No. 2012-68003-30155 from the USDA National Institute of Food and Agriculture, Prevention, Detection and Control of Shiga Toxin Producing *Escherichia coli* (STEC) from Pre-Harvest Through Consumption of Beef Products Program –A4101.

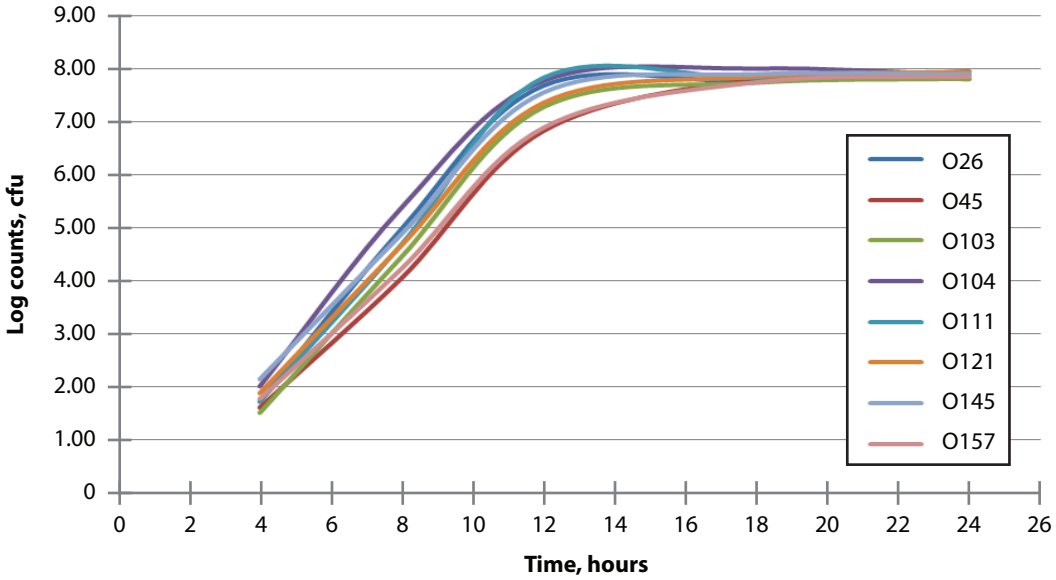

Figure 1. The average log count (cfu) of *E. coli* O26, O45, O103, O111, O145, O157:H7, and O104:T4 enriched using buffered peptone water at 99°F for up to 24 hours then plated on tryptic soy agar for enumeration.

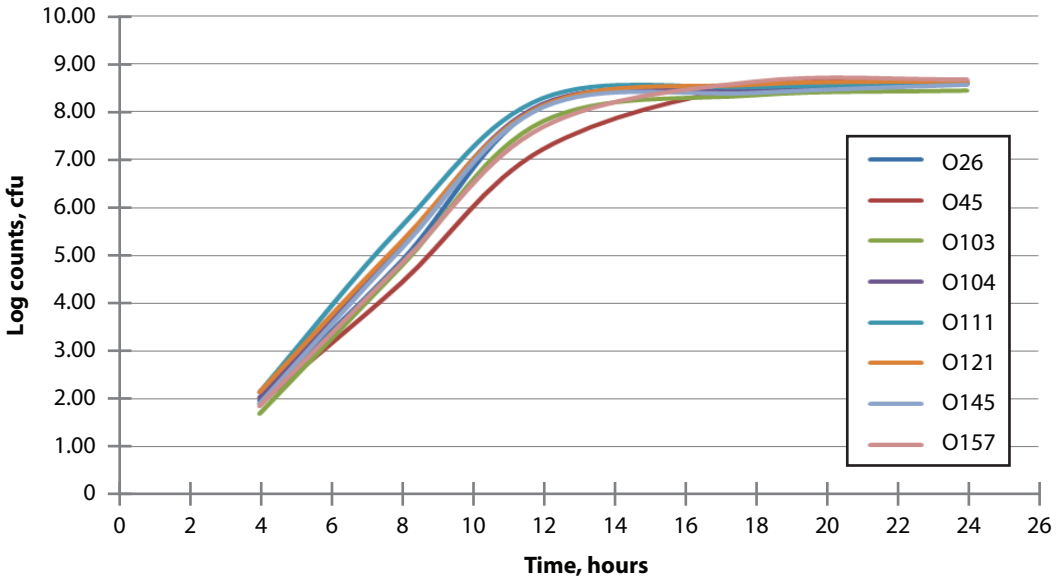

Figure 2. The average log count (cfu) of *E. coli* O26, O45, O103, O111, O145, O157:H7, and O104:T4 enriched using unversial pre-enrichment broth at 99°F for up to 24 hours then plated on tryptic soy agar for enumeration.

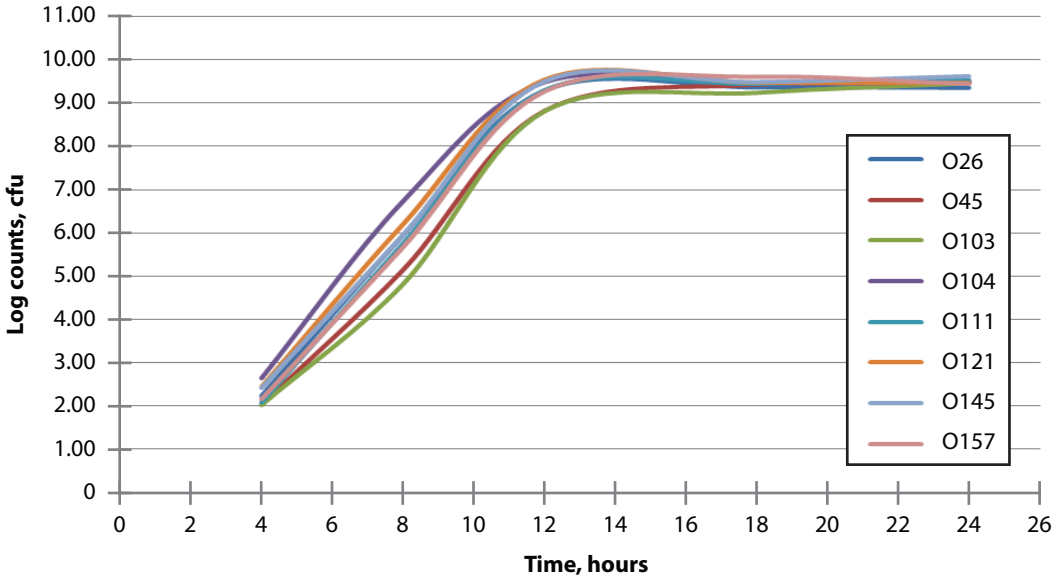

Figure 3. The average log count (cfu) of *E. coli* O26, O45, O103, O111, O145, O157:H7, and O104:T4 enriched using tryptic soy broth at 99°F for up to 24 hours then plated on tryptic soy agar for enumeration.

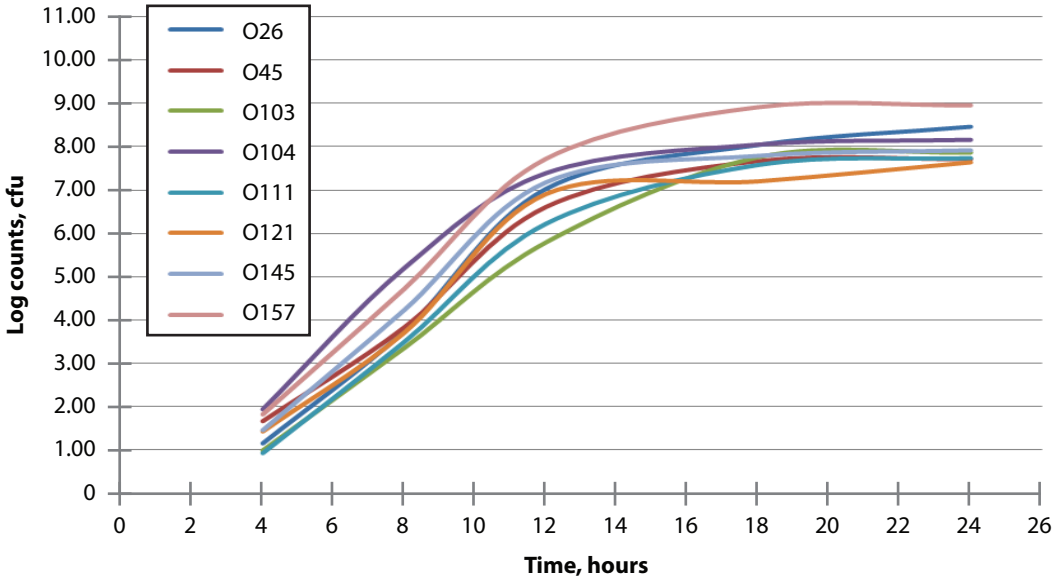

Figure 4. The average log count (cfu) of *E. coli* O26, O45, O103, O111, O145, O157:H7, and O104:T4 enriched using modified tryptic soy broth with 8 mg/L Novobiocin at 99°F for up to 24 hours then plated on tryptic soy agar for enumeration.

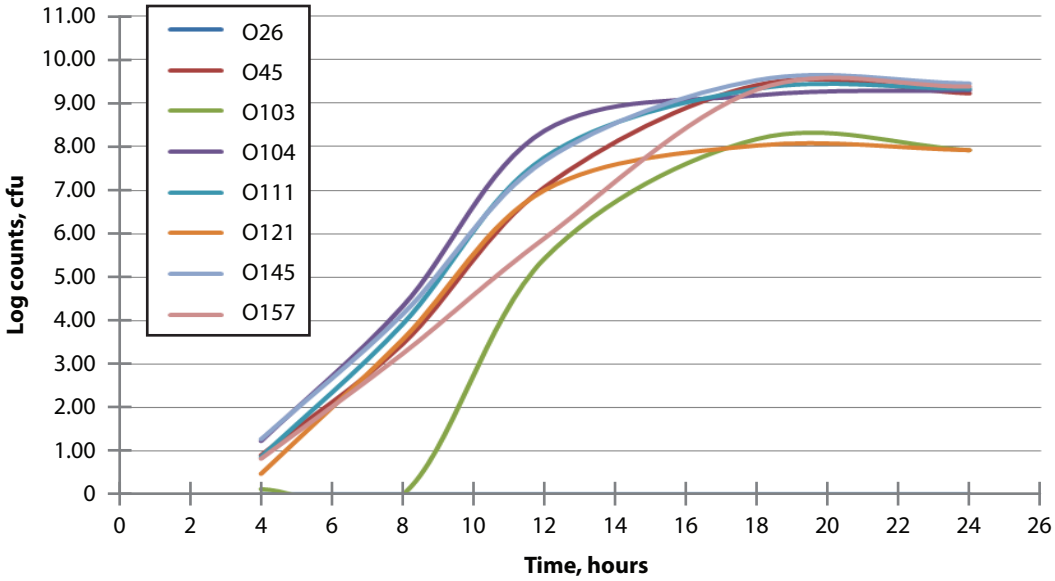

Figure 5. The average log count (cfu) of *E. coli* O26, O45, O103, O111, O145, O157:H7, and O104:T4 enriched using *E. co*li broth at 99°F for up to 24 hours then plated on tryptic soy agar for enumeration.

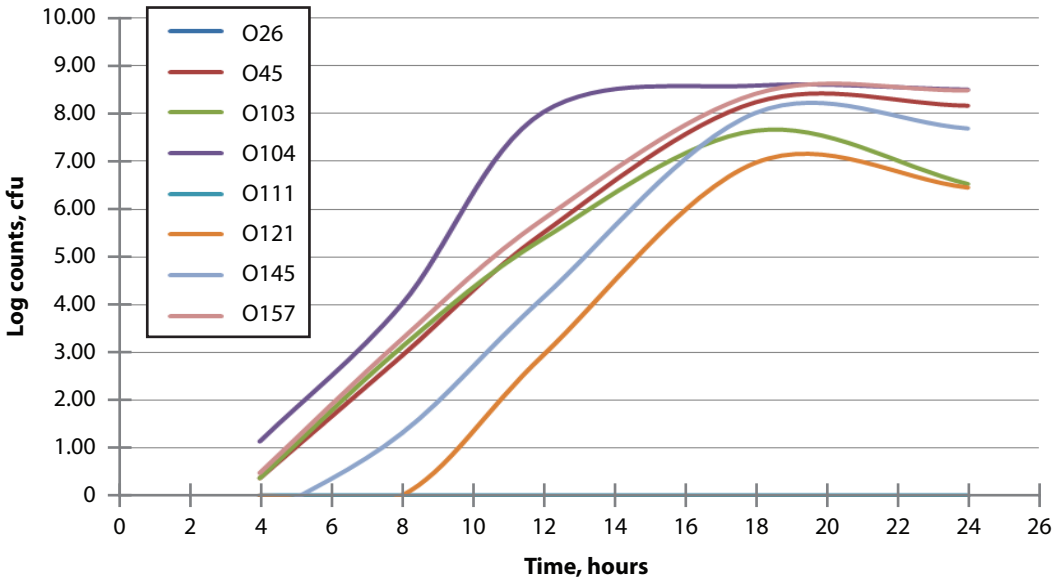

Figure 6. The average log count (cfu) of *E. coli* O26, O45, O103, O111, O145, O157:H7, and O104:T4 enriched using modified *E. coli* broth with 4mg/L Novobiocin at 99°F for up to 24 hours then plated on tryptic soy agar for enumeration.

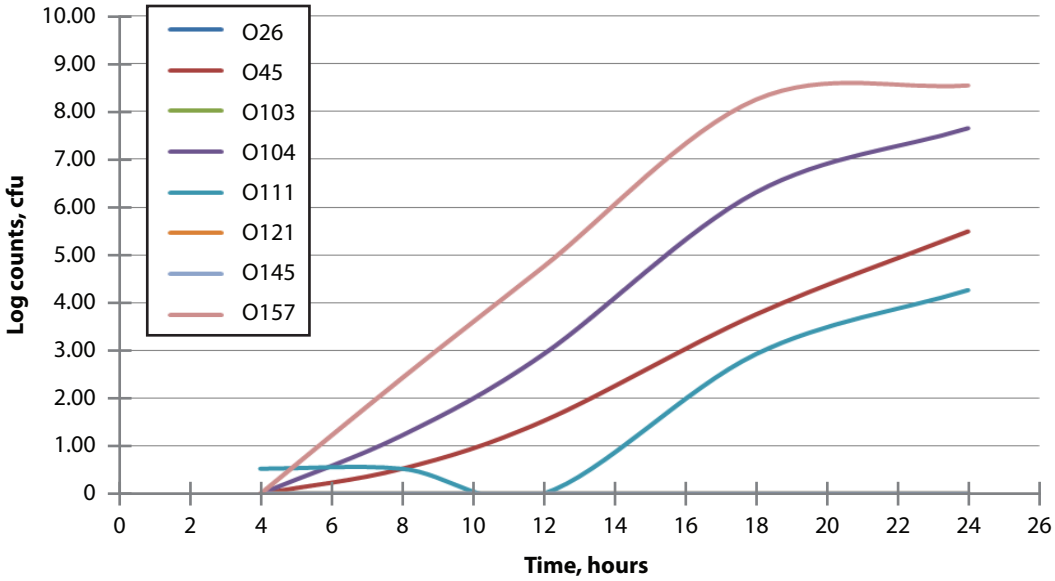

Figure 7. The average log count (cfu) of *E. coli* O26, O45, O103, O111, O145, O157:H7, and O104:T4 enriched using modified *E. coli* broth with 8mg/L Novobiocin at 99°F for up to 24 hours then plated on tryptic soy agar for enumeration.

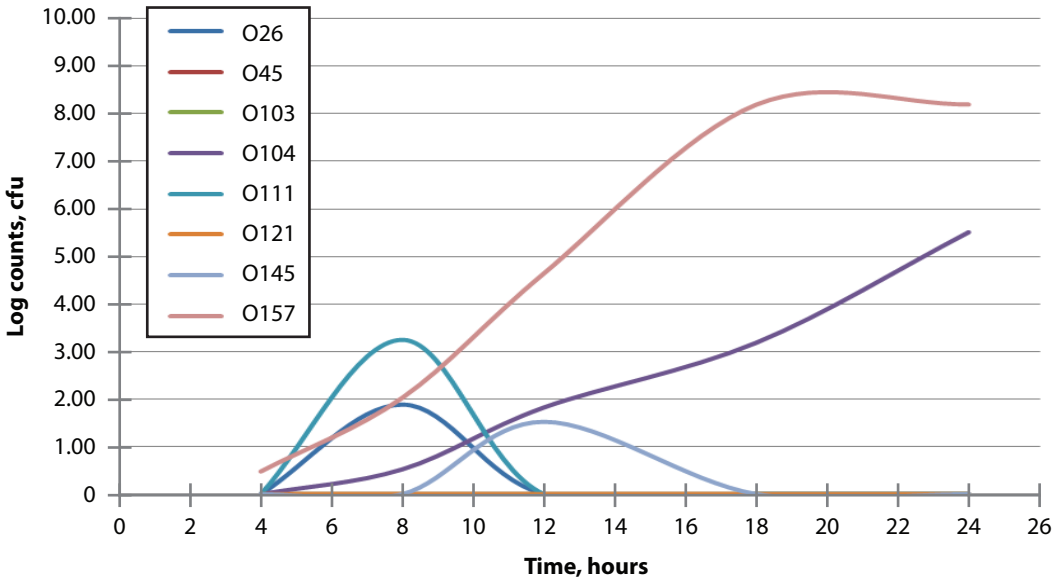

Figure 8. The average log count (cfu) of *E. coli* O26, O45, O103, O111, O145, O157:H7, and O104:T4 enriched using modified *E. coli* broth with 20mg/L Novobiocin buffered peptone water at 99°F for up to 24 hours then plated on tryptic soy agar for enumeration.

Evaluating the Effectiveness of Transport Media on Shiga Toxin-Producing *E. coli* Serotypes

N. Baumann, A. West, and R.K. Phebus

Introduction

One of the key issues involved in accurately testing beef and the environment for the presence of specific bacteria, particularly pathogens such as Shiga toxin-producing *Escherichia coli* (STEC), is maintaining the viability of the microorganisms when transporting samples from the field to the laboratory. This process may take up to three days when considering collection, shipping and laboratory preparation times. Allowing the target bacteria to increase or decrease in numbers during transit is undesirable, so samples must be kept chilled and the media used for transport must offer a stable but non-nutritive environment. Three commonly used non-selective transport media were evaluated for their ability to maintain original STEC levels during transport. Holding temperature may vary during shipping, so this study evaluated two separate temperatures as co-variables.

Experimental Procedures

Buffered peptone water (BPW; Becton, Dickinson and Company, Sparks, MD), Cary-Blair transport media (CB; Oxoid LTD, Basingstoke, Hampshire, England), and maximum recovery diluent (MR; Oxoid LTD) media were selected for evaluation. Sets of these media types were individually inoculated with STEC serotypes O26, O45, O103, O111, O145, and O157 before being placed in refrigerators at 30 °F or 50 °F. Samples were removed and plated from each media/strain/temperature combination at 0, 12, 24, 48, and 72 hours. Plates were placed in an incubator at 99 °F for 24 hours before enumeration and comparison.

Results and Discussion

The average log counts of each serotype on each media type at 39 °F and 50 °F are shown in Figures 1–6.

When transport medium samples were held at the desired refrigeration temperature 39 °F, all media types performed similarly; at the simulated abuse temperature of 50 °F, the Cary-Blair medium was the only one that maintained the bacteria at close to the original inoculation level.

Implications

The use of Cary-Blair transport medium in conjunction with proper chilled storage temperatures will help ensure that accurate results are obtained for field-based research studies, and for daily beef processing samples being transported to analytical laboratories for enumeration of STEC.

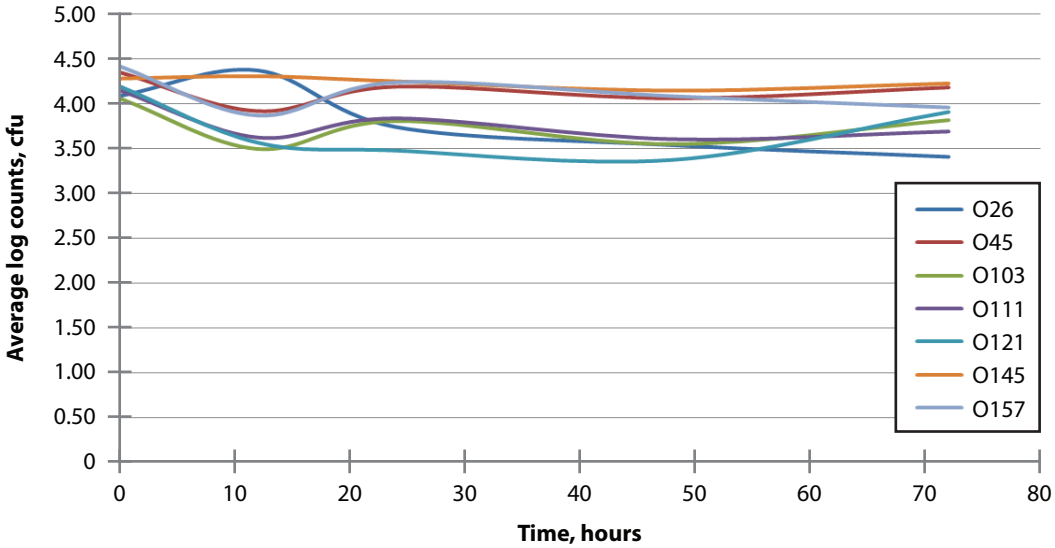

Figure 1. The average log count (cfu) of E. coli O26, O45, O103, O111, O145, and O157 on buffered peptone water and incubated at 39 °F for up to 72 hours.

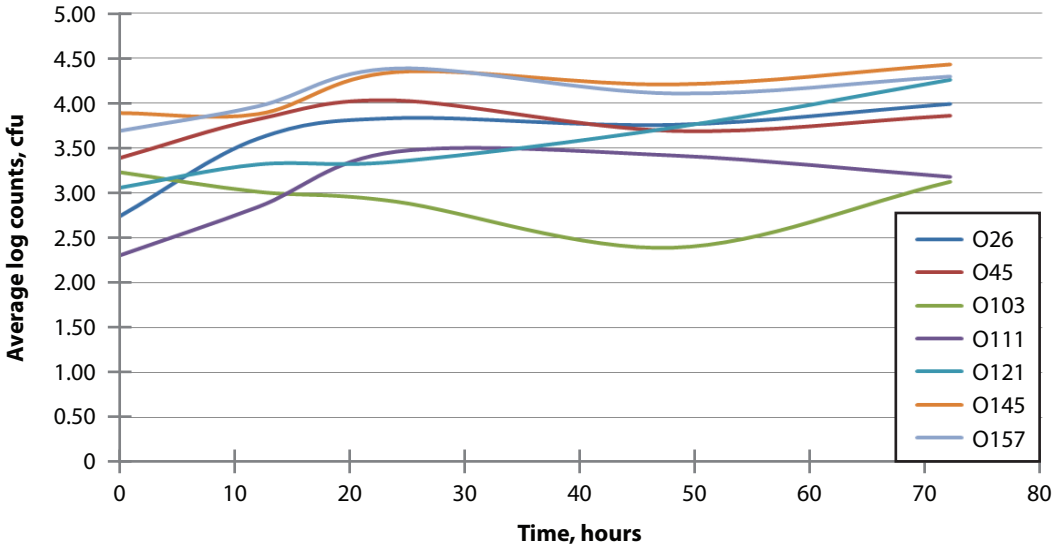

Figure 2. The average log count (cfu) of E. coli O26, O45, O103, O111, O145, and O157 on Cary-Blair transport media and incubated at 39 °F for up to 72 hours.

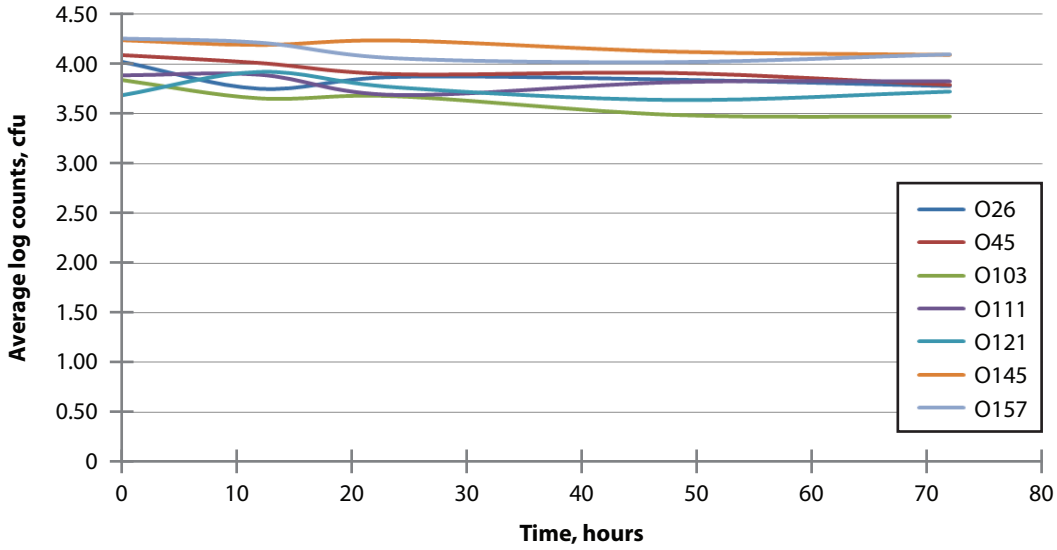

Figure 3. The average log count (cfu) of E. coli O26, O45, O103, O111, O145, and O157 on maximum recovery diluent and incubated at 39° F for up to 72 hours.

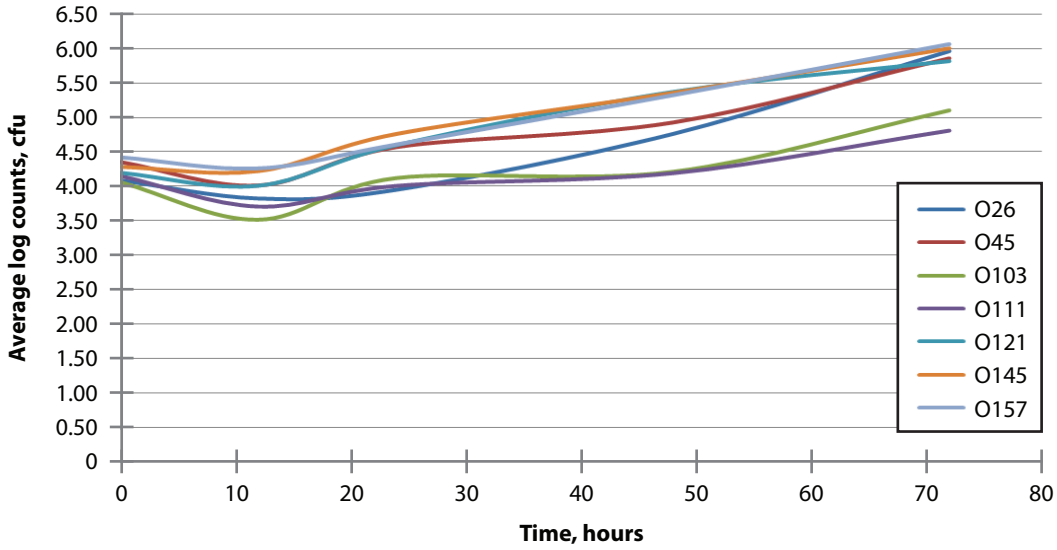

Figure 4. The average log count (cfu) of E. coli O26, O45, O103, O111, O145, and O157 on buffered peptone water and incubated at 50° F for up to 72 hours.

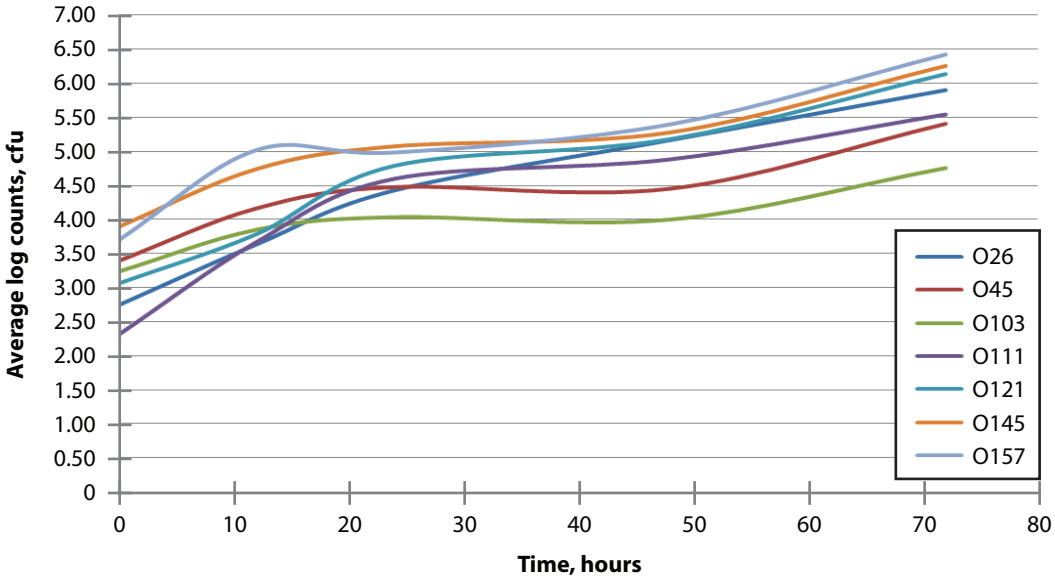

Figure 5. The average log count (cfu) of E. coli O26, O45, O103, O111, O145, and O157 on Cary-Blair transport media and incubated at 50 °F for up to 72 hours.

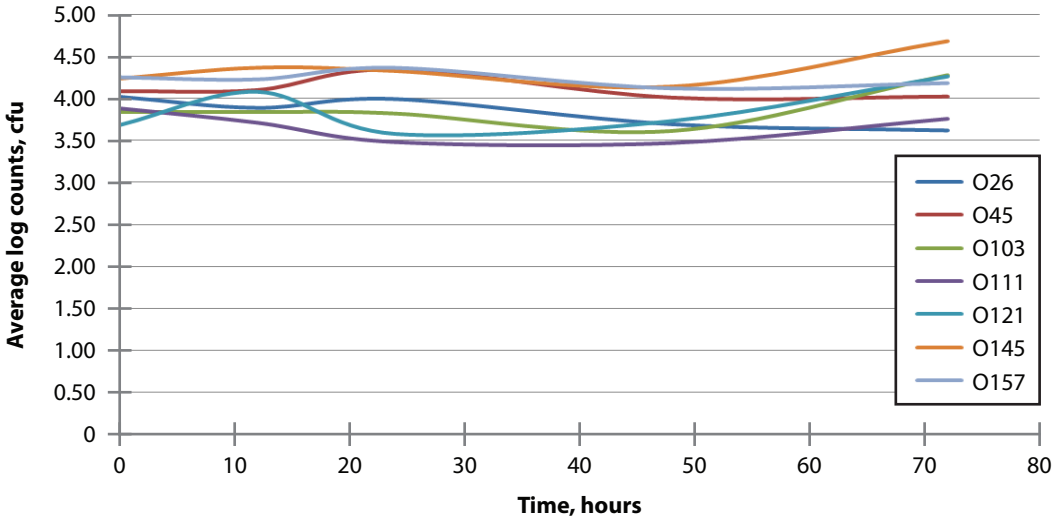

Figure 6. The average log count (cfu) of E. coli O26, O45, O103, O111, O145, and O157 on maximum recovery diluent and incubated at 50 °F for up to 72 hours.

Comparison of Conventional and Alltech Beef PN Finishing Programs: Meat Color Characteristics

K.J. Phelps, K.A. Miller, C.L. Van Bibber-Krueger, J. Jennings[1], B.E. Depenbusch[2], J.S. Drouillard, and J.M. Gonzalez

Introduction

To maximize efficiency and profit when producing beef, American producers currently employ a multitude of production programs that use feed additives such as Rumensin or Tylan (Elanco Animal Health, Greenfield, IN) and growth promotants such as implants and Optaflexx (Elanco Animal Health). Rumensin and Tylan fed in combination can improve average daily gain and feed efficiency, and utilizing growth promotants enhances feed efficiency, average daily gain, hot carcass weight, and yield grades of carcasses. Although these products improve production efficiency, they can affect meat quality characteristics such as retail shelf life, necessitating better understanding of how management decisions in the feedlot can affect retail display. The Alltech PN Beef Program (Alltech Inc., Nicholasville, KY) consists of two products that are designed to replace components of a conventional feedlot diet. The PN Beef Receiver is intended to be fed during the step-up period of feeding, whereas PN Beef Finisher is intended to be fed during the remainder of finishing period. Because both products are new feed alternatives, the objective of this study was to compare the effects of the Alltech PN Feed Program to a conventional diet on fresh meat retail shelf life color when both diets were fed with or without implants and Optaflexx.

Experimental Procedures

Crossbred yearling steers (n = 512; 848 ± 17 lb initial body weight) were blocked by body weight and assigned to 64 pens with 8 steers assigned to each pen. The study was conducted as a randomized complete block experiment with a 2 × 2 factorial treatment arrangement. Factors in the study design consisted of dietary program and growth promotant regimen. For the dietary program factor, steers were separated into a conventional finishing program treatment or the Alltech PN Beef Program treatment (Table 1). The components of the Alltech PN Beef Program diet were premixed into a ground corn carrier and subsequently blended into the total mixed ration. Both supplements contained a proprietary blend of organic trace elements, ascorbic acid, fermentation products, fermentation extracts, and selenium yeast. The PN Receiver portion of the diet was included in the total mixed ration for the first 21 days at a rate of 0.5 oz/animal daily. The PN Finisher was included in the total mixed ration at a rate of 0.7 oz/animal daily for the final 154 days of the feeding period. Each diet was fed with or without growth promotants. Steers receiving growth promotants were administered a Component E-S (Elanco Animal Health) implant on day 1 of the study, reimplanted with Component TE-IS (Elanco Animal Health) on day 94, and fed Optaflexx at a rate of 400 mg/animal daily the final 28 days before harvest.

[1] Alltech, Nicholasville, KY.
[2] Innovative Livestock Services, Great Bend, KS.

On day 175 of the experiment, animals were harvested at a commercial abattoir, where slaughter and carcass data were collected. After a 24-hour chill, strip loins were randomly selected from two carcasses per pen and transported back to Kansas State University. Upon arrival, strip loins were weighed, vacuum-packaged, and stored for 14 days. On day 14, packages were opened and a 1-in. steak was cut for a 7-day retail shelf life display.

Results and Discussion

Consumer perception of meat color is an important consideration for retailers because it is the most important attribute the consumer utilizes to determine whether to purchase a product. Because the PN Beef Program removes vitamin E from the mixed ration and this vitamin is vital to maintaining color stability, valid concerns have been voiced about the program's impact on meat color. Strip loins were aged for 14 days before objective measurements of color, including steak surface metmyoglobin percentage (Figure 1), lightness (L*; Figure 2), and redness (a*; Figure 3) were measured during a 7-day simulated retail display study. As expected, day of display had an effect on surface discoloration, lightness, and redness of steaks ($P < 0.01$). Metmyoglobin formation on the surface of steaks increased throughout the display period. All steaks became darker from day 0 to 4, but they faded during the remainder of the display period to obtain lightness values similar to day-0 values. Steaks from all treatments reached peak redness on day 2 of the display period and decreased in redness through the remainder of the display period. For all retail display characteristics measured, no two-way or three-way interactions were observed between dietary program, growth promotants, and day of display ($P > 0.10$). In addition, no growth promotant effects were detected on any of the measured retail display characteristics ($P > 0.10$). Dietary program had an effect ($P < 0.02$) on steak lightness measurements, with strip loin steaks from steers fed the Alltech PN Beef Program objectively measuring darker during the entire retail display period. Although lightness was affected, dietary treatment did not affect surface discoloration, as indicated by surface metmyoglobin formation or steak redness ($P > 0.10$)

Implications

Using the Alltech PN supplements minimally affected meat color during retail display, and use of implants and Optaflexx did not affect meat color.

Acknowledgements

We would like to thank Alltech, Inc. for financial support of this experiment.

Table 1. Diets (dry basis) for steers fed conventional feedlot diets[1] or Alltech PN program[2]

Ingredient, %	Conventional	Alltech
Wet corn gluten feed	35.00	35.00
Steam-flaked corn	53.55	53.56
Ground wheat straw	7.00	7.00
Feed additive premix	2.16	–
Mineral/vitamin supplement	2.29	2.23
PN supplement	–	2.21

[1] Conventional diets included vitamin A at 1,000 IU/lb; vitamin E at 10 IU/lb; copper sulfate to provide 10 ppm copper; cobalt carbonate to provide 0.15 ppm cobalt; ethylenediamine dihydriodide to provide 0.5 ppm iodine; manganous sulfate to provide 60 ppm manganese; sodium selenite to provide 0.3 ppm selenium; zinc sulfate to provide 60 ppm zinc on a dry matter basis; and 300 mg/animal daily of monensin and 90 mg/animal daily of tylosin (Elanco Animal Health; Greenfield, IN).

[2] The Alltech diet (Alltech, Nicholasville, KY) included PN Receiver in the total mixed ration for the first 21 days at the rate of 14 g/animal daily, which contained: zinc proteinate to provide 10.7 ppm zinc; manganese proteinate to provide 7.1 ppm manganese; cobalt proteinate to provide 1.2 ppm cobalt; copper proteinate to provide 2.9 ppm copper; calcium iodate to provide 0.6 ppm iodine; selenium yeast to provide 0.31 ppm selenium on a dry matter basis; as well as ascorbic acid, *Aspergillus oryzae* fermentation product, *Lactobacillus acidophilus* fermentation product, and *Enterococcus faecium* fermentation product. Thereafter, PN Finisher was included in the total mixed ration at the rate of 20 g/animal daily: 10.7 ppm Zn; manganese proteinate to provide 7.1 ppm manganese; cobalt proteinate to provide 1.2 ppm cobalt; copper proteinate to provide 2.9 ppm copper; calcium iodate to provide 0.6 ppm iodine; selenium yeast to provide 0.3 ppm selenium on a dry matter basis; as well as ascorbic acid, *Aspergillus niger* fermentation product, *Lactobacillus acidophilus* fermentation product, and *Enterococcus faecium* fermentation product. Both supplements were premixed into a ground corn carrier and subsequently blended into the total mixed ration.

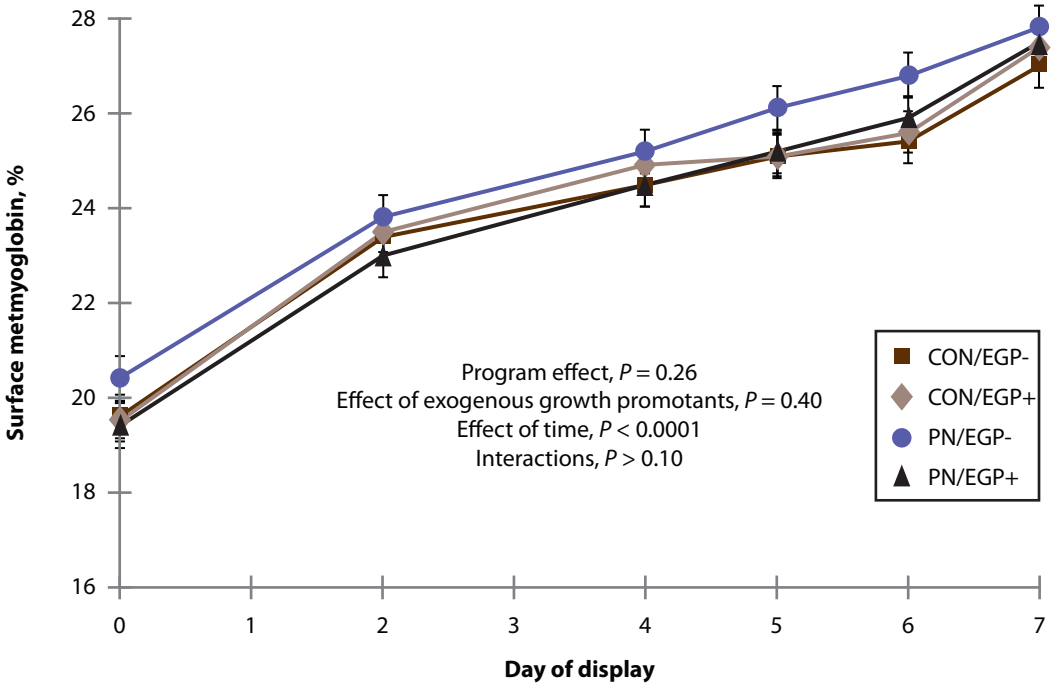

Figure 1. Surface discoloration of strip loin steaks displayed for 7 days.
CON/EGP- = conventional feeding program; CON/EGP+ = conventional feeding program with exogenous growth promotants; PN/EGP- = Alltech Programmed Nutrition (PN) without exogenous growth promotants; PN/EGP+ = Alltech PN with exogenous growth promotants.

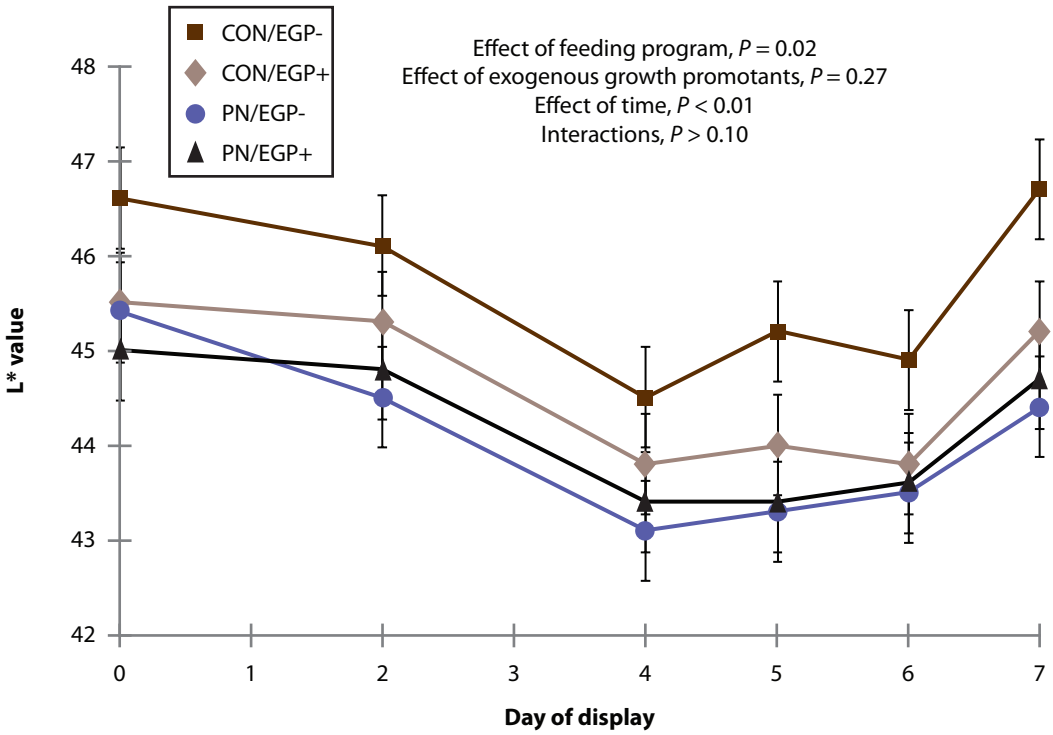

Figure 2. L* (lightness) value of strip loin steaks displayed for 7 days.
CON/EGP- = conventional feeding program; CON/EGP+ = conventional feeding program with exogenous growth promotants; PN/EGP- = Alltech Programmed Nutrition (PN) without exogenous growth promotants; PN/EGP+ = Alltech PN with exogenous growth promotants.

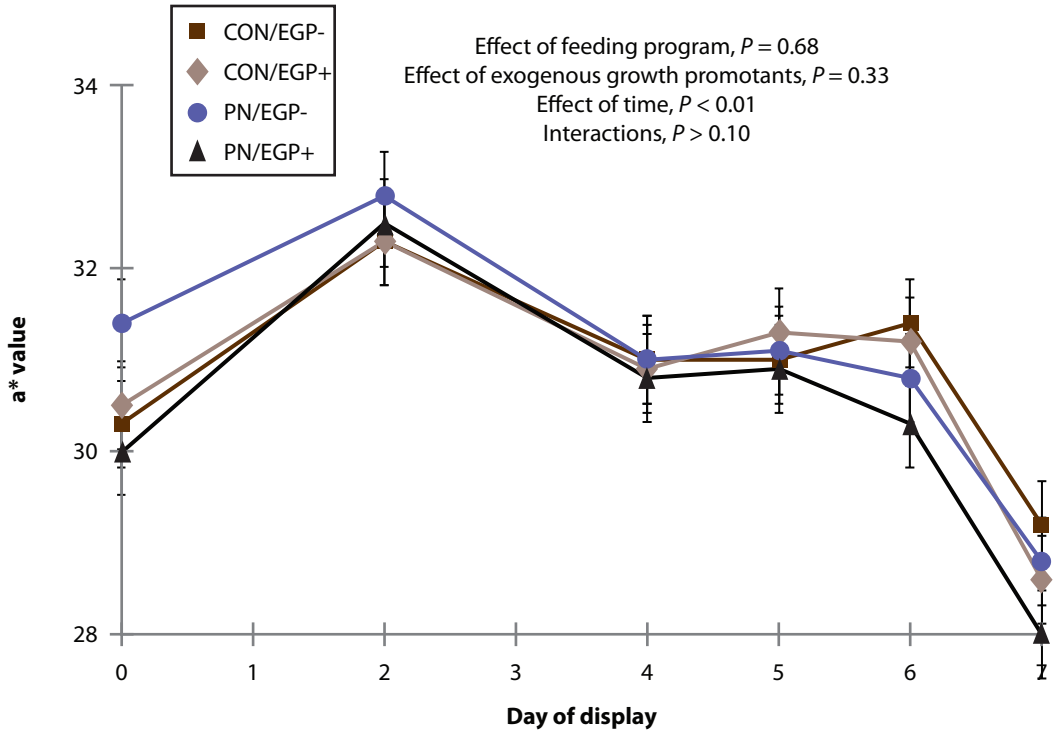

Figure 3. a* (redness) value of strip loin steaks displayed for 7 days.
CON/EGP- = conventional feeding program; CON/EGP+ = conventional feeding program with exogenous growth promotants; PN/EGP- = Alltech Programmed Nutrition (PN) without exogenous growth promotants; PN/EGP+ = Alltech PN with exogenous growth promotants.

Comparison of Conventional and Alltech Beef PN Finishing Programs: Meat Water-Holding Capacity and Tenderness

K.J. Phelps, K.A. Miller, C.L. Van Bibber-Krueger, J. Jennings[1], B.E. Depenbusch[2], J.S. Drouillard, and J.M. Gonzalez

Introduction

Tenderness, juiciness, and flavor play important roles in a satisfactory beef eating experience. All three factors can be affected by management decisions made by producers during the production of beef. Beef producers currently use a multitude of production programs that utilize feed additives such as Rumensin or Tylan (Elanco Animal Health, Greenfield, IN), and growth promotants such as implants and Optaflexx (Elanco Animal Health). Rumensin and Tylan are fed in combination to improve feedlot performance, whereas growth promotants improve feed efficiency, average daily gain, hot carcass weight, and yield grades of carcasses. Although the use of feed additives and growth promotants improves production efficiency, they can affect meat characteristics such as tenderness and water-holding capacity. The Alltech PN Beef Program (Alltech Inc., Nicholasville, KY) consists of two products that are designed to replace components of the conventional feedlot diet. The PN Beef Receiver is intended to be fed during the step-up period of feeding, whereas PN Beef Finisher is intended to be fed during the remainder of finishing period. Because both products are new feed alternatives, the objective of this study was to compare the fresh cooked meat quality of the Alltech PN Beef Program to a conventional feedlot diet when both diets are combined with or without growth promotants.

Experimental Procedures

Crossbred yearling steers (n = 512; 848 ± 17 lb initial body weight) were blocked by body weight and assigned to 64 pens with 8 steers assigned to each pen. The study was conducted as a randomized complete block experiment with a 2 × 2 factorial treatment arrangement. Factors in the study design consisted of dietary program and growth promotant regimen. For the dietary program factor, steers were separated into a conventional finishing program treatment or Alltech PN Beef Program treatment (Table 1). The components of the Alltech PN Beef Program diet were premixed into a ground corn carrier and subsequently blended into the total mixed ration. Both supplements contained a proprietary blend of organic trace elements, ascorbic acid, fermentation products, fermentation extracts, and selenium yeast. The PN Receiver portion of the diet was included in the total mixed ration for the first 21 days at a rate of 0.5 oz/animal daily. The PN Finisher was included in the total mixed ration at a rate of 0.7 oz/animal daily for the final 154 days of the feeding period. Each diet was fed with or without growth promotants. Steers receiving growth promotants were administered a Component E-S (Elanco Animal Health) implant on day 1 of the study, reimplanted with Component TE-IS (Elanco Animal Health) on day 94, and fed Optaflexx at a rate of 400 mg/animal daily the final 28 days before harvest.

[1] Alltech, Nicholasville, KY.

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On day 175 of the experiment, animals were harvested at a commercial abattoir where slaughter and carcass data were collected. After a 24-hour chill, strip loins were randomly selected from two carcasses per pen and transported back to Kansas State University. Upon arrival, strip loins were weighed, vacuum-packaged, and stored for 14 days. On day 14, packages were opened and loins were patted dry and reweighed for moisture loss calculations. Two 1-in.-thick steaks were cut for subjective and objective measurements of cooked meat characteristics.

Results and Discussion

Moisture retention during aging and cooking is an important quality attribute of fresh meat. The ability of meat to hold more moisture through aging and cooking can result in a juicier and more tender final product. Results show no interaction between dietary program and growth promotant (Figure 1; $P > 0.10$) for moisture retention during aging. In addition, growth promotants did not affect ($P > 0.10$) moisture retention during aging, but dietary program did ($P < 0.05$). Loins from animals fed the Alltech PN Program retained more moisture during aging than loins from animals fed the conventional program. In addition to moisture retention during aging, moisture retention during cooking was measured. No dietary program and growth promotant interaction was detected on moisture retention during cooking (Figure 2; $P > 0.10$). Dietary program and growth promotants individually influenced moisture loss during cooking ($P < 0.05$). Steaks from steers in the Alltech PN Beef Program treatment retained 1.3% more moisture during cooking and growth promotants increased moisture loss by 1.6%.

Tenderness is continuously reported as the most important quality attribute consumers use to determine the acceptability of the beef eating experience. Analysis of objective steak tenderness was conducted on strip loin steaks aged for 14 days. For objective tenderness, there was no interaction between dietary program and growth promotants (Figure 3; $P > 0.10$). In addition, dietary program did not affect ($P > 0.10$) the tenderness of steaks. Numerous research studies have concluded that utilizing both implants and beta-agonists can decrease meat tenderness when products are aged for 14 days or less. In the current study, we aged loins for 14 days and duplicated these previously published studies, because use of growth promotants during finishing decreased ($P < 0.05$) tenderness. When utilizing objective measures to quantify tenderness, the literature reports that shear values above 9.0 lb correlate to a negative consumer eating experience. Although average tenderness for all treatment groups was below the rating considered tough by a consumer, 14.5% (Alltech PN Beef Program) and 25% (conventional program) of steaks from steers administered growth promotants would have been perceived as tough.

To further explore these results, a trained taste panel evaluated steaks from the same loins aged 14 days for six attributes (Table 2). Results indicate a dietary program and growth promotant interaction for myofibrillar tenderness, connective tissue amount, and overall tenderness score ($P < 0.01$) but no interaction for juiciness and beef flavor intensity. The impact of the growth promoting programs can be seen by the steaks from the PN Beef Program and conventional program that were subjected to growth promotants being myofibrillarly tougher than their counterparts without growth promotants ($P < 0.05$). When the growth promotants were applied to the PN Beef Program, this resulted in panelists detecting more connective tissue in these steaks compared with

other treatment groups ($P < 0.05$). This result, combined with the myofibrillar tenderness data, caused the steaks originating from steers in the PN Beef Program that were administered growth technologies to be rated tougher overall than all other treatment groups ($P < 0.05$). In addition, steaks originating from steers in the conventional program that were administered growth technologies were also rated tougher overall than the remaining two treatment groups without growth promotants ($P < 0.05$).

Implications

Using the Alltech PN supplements can favorably impact water-holding capacity without compromising tenderness, and use of implants and Optaflexx negatively affected water-holding capacity and steak tenderness.

Acknowledgements

We would like to thank Alltech, Inc. for financial support of this experiment.

Table 1. Diets (dry basis) for steers fed conventional feedlot diets[1] or Alltech PN program[2]

Ingredient, %	Conventional	Alltech
Wet corn gluten feed	35.00	35.00
Steam-flaked corn	53.55	53.56
Ground wheat straw	7.00	7.00
Feed additive premix	2.16	–
Mineral/vitamin supplement	2.29	2.23
PN supplement	–	2.21

[1] Conventional diets included vitamin A at 1,000 IU/lb; vitamin E at 10 IU/lb; copper sulfate to provide 10 ppm Cu; cobalt carbonate to provide 0.15 ppm Co; ethylenediamine dihydriodide to provide 0.5 ppm I; manganous sulfate to provide 60 ppm Mn; sodium selenite to provide 0.3 ppm Se; zinc sulfate to provide 60 ppm Zn on a dry matter basis; as well as 300 mg/animal daily of Rumensin and 90 mg/animal daily of Tylan (Elanco Animal Health; Greenfield, IN).

[2] The Alltech diet included PN Receiver (Alltech, Nicholasville, KY) in the total mixed ration for the first 21 days at the rate of 14 g/animal daily, which contained: zinc proteinate to provide 10.7 ppm Zn; manganese proteinate to provide 7.1 ppm manganese; cobalt proteinate to provide 1.2 ppm cobalt; copper proteinate to provide 2.9 ppm copper; calcium iodate to provide 0.6 ppm iodine; selenium yeast to provide 0.3 ppm selenium on a dry matter basis; as well as ascorbic acid, *Aspergillus oryzae* fermentation product, *Lactobacillus acidophilus* fermentation product, and *Enterococcus faecium* fermentation product. Thereafter, PN Finisher was included in the total mixed ration at the rate of 20 g/animal daily: 10.7 ppm Zn; manganese proteinate to provide 7.1 ppm manganese; cobalt proteinate to provide 1.2 ppm cobalt; copper proteinate to provide ppm mg/kg copper; calcium iodate to provide 0.6 ppm iodine; selenium yeast to provide 0.3 ppm selenium on a dry matter basis; as well as ascorbic acid, *Aspergillus niger* fermentation product, *Lactobacillus acidophilus* fermentation product, and *Enterococcus faecium* fermentation product. Both supplements were premixed into a ground corn carrier and subsequently blended into the total mixed ration.

Table 2. Interaction least squares means of trained sensory panel scores[1] of steaks from steers fed conventional diets or Alltech PN[2] program with and without exogenous growth promotants (EGPs)

	Conventional		Alltech PN			*P*-value		
Item	EGP-	EGP+	EGP-	EGP+	SEM	Program	EGP	Program × EGP
Myofibrillar tenderness	5.59[a,y]	5.36[b]	5.77[a,x]	5.03[c]	0.09	0.30	< 0.01	0.01
Juiciness	5.21	5.02	5.12	4.97	0.07	0.18	0.003	0.70
Beef flavor intensity	5.28	5.30	5.23	5.26	0.05	0.39	0.62	0.96
Connective tissue amount	6.51[a]	6.44[a]	6.71[b]	6.18[c]	0.08	0.75	< 0.01	0.01
Overall tenderness	5.59[a]	5.37[b]	5.80[c]	5.00[d]	0.09	0.27	< 0.01	< 0.01
Off-flavor intensity	7.70	7.68	7.65	7.61	0.05	0.24	0.57	0.84

[1] Myofibrillar tenderness (1 = extremely tough, 8 = extremely tender); juiciness (1 = extremely dry, 8 = extremely juicy); beef flavor intensity (1 = extremely bland, 8 = extremely intense); connective tissue amount (1 = abundant, 8 = none); overall tenderness (1 = extremely tough, 8 = extremely tender); off-flavor intensity (1 = abundant, 8 = none).
[2] Alltech; Nicholasville, KY.
[a,b,c,d] Values within a row with different letters are significantly different ($P < 0.05$).
[x,y] Values within a row with different letters tend to be different ($P < 0.10$).

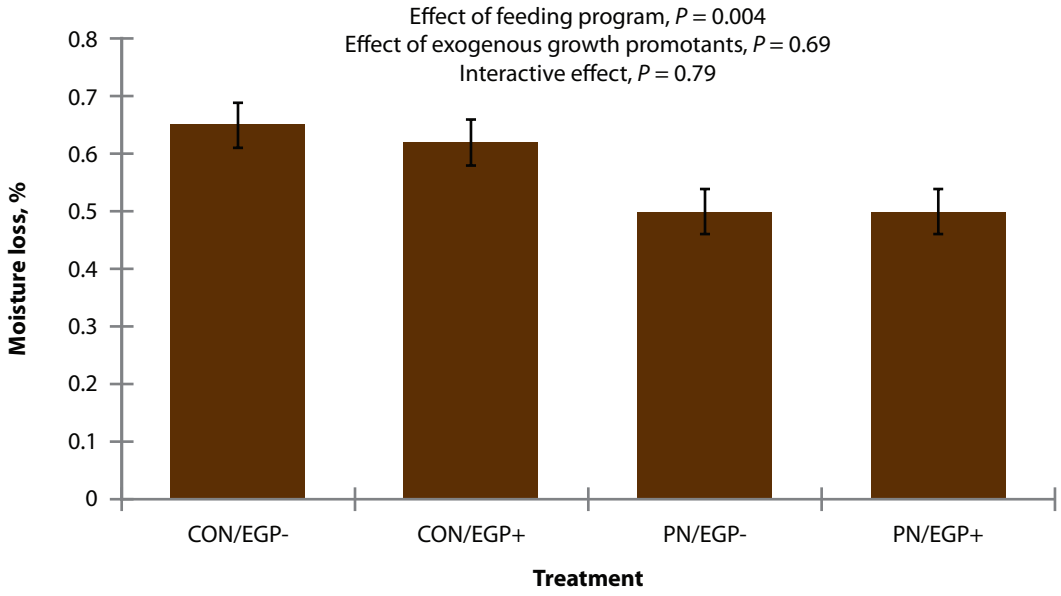

Figure 1. Beef strip loin moisture loss during wet-aging for 14 days.
CON/EGP- = conventional feeding program; CON/EGP+ = conventional feeding program with exogenous growth promotants; PN/EGP- = Alltech Programmed Nutrition (PN) program with no exogenous growth promotants; PN/EGP+ = Alltech PN program with exogenous growth promotants.

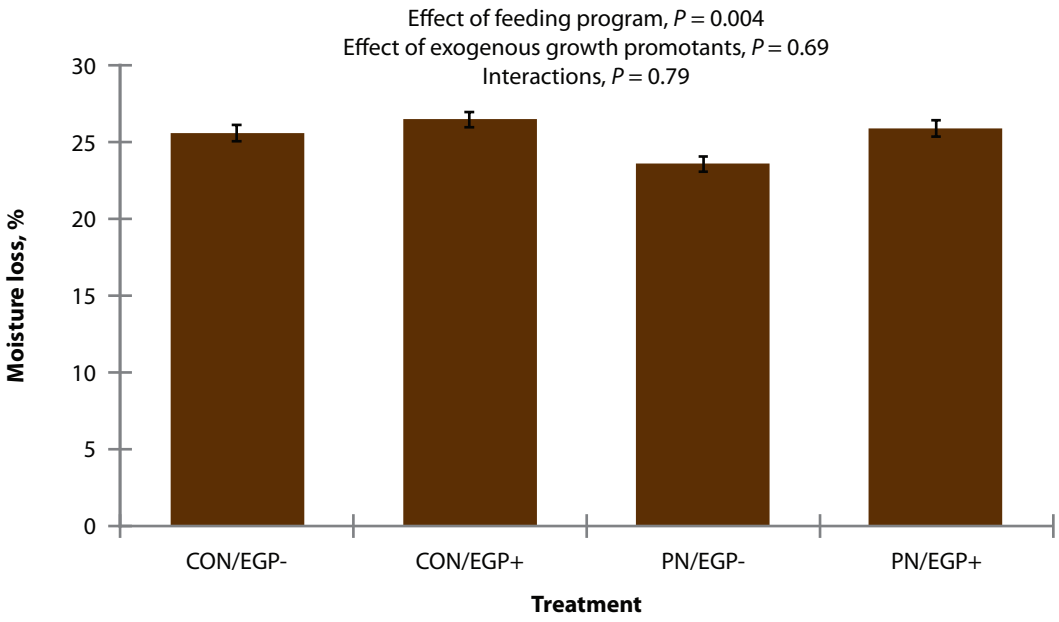

Figure 2. Moisture loss during cooking.
CON/EGP- = conventional feeding program; CON/EGP+ = conventional feeding program with exogenous growth promotants; PN/EGP- = Alltech Programmed Nutrition (PN) program with no exogenous growth promotants; PN/EGP+ = Alltech PN program with exogenous growth promotants.

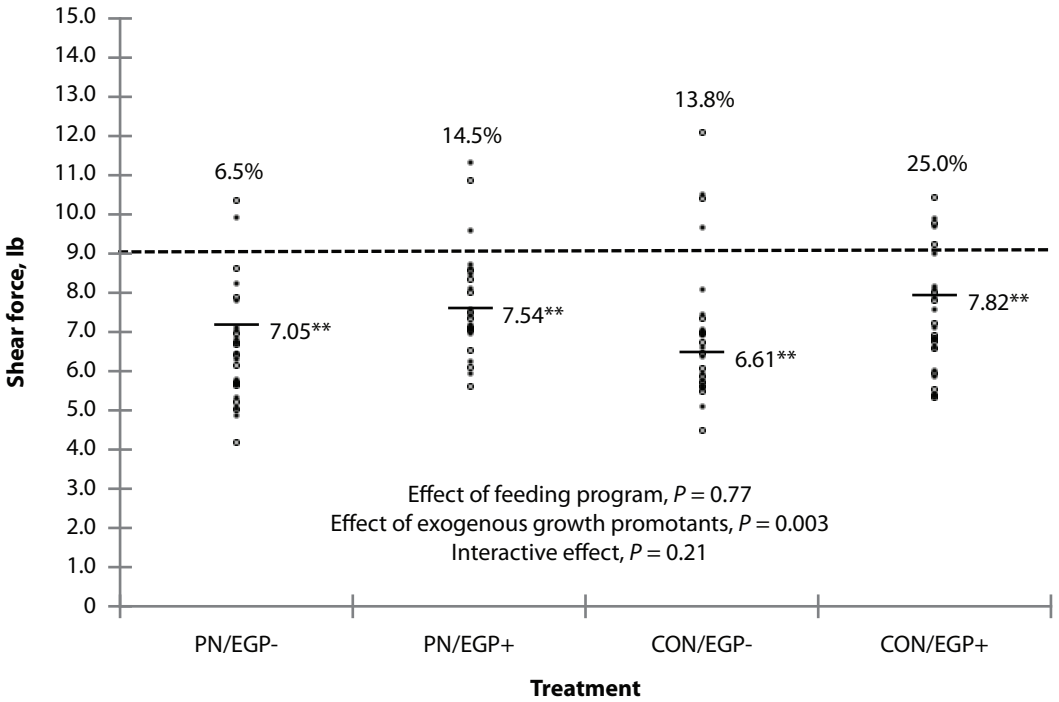

Figure 3. Tenderness of strip loin steaks wet-aged for 14 days.
CON/EGP- = conventional feeding program; CON/EGP+ = conventional feeding program with exogenous growth promotants; PN/EGP- = Alltech Programmed Nutrition (PN) program with no exogenous growth promotants; PN/EGP+ = Alltech PN program with exogenous growth promotants.

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