CATTLEMEN'S DAY 2012

BEEF CATTLE RESEARCH

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K-STATE Research and Extension

KANSAS STATE UNIVERSITY CATTLEMEN'S DAY

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CATTLEMEN'S DAY 2012

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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.

Bedding Material in Dirt-Floor Pens Reduces Heat

D.J. Rezac, D.U. Thomson, and C.D. Reinhardt

Introduction

Weather-related stressors are a well-recognized opponent to animal welfare and can have important ramifications for animal performance. Sound animal husbandry practices historically have attempted to diminish the effects of deleterious environmental factors. Providing aid to animals when temperatures are above or below their thermal neutral zone (TNZ) can improve animal welfare and/or performance. Because most breeds of cattle are not well equipped to deal with heat, the temperatures at which heat stress can begin to affect cattle can be surprisingly low. The onset of mild heat stress can occur at a temperature humidity index (THI[1]) value of 75, which can correspond to an ambient temperature as low as 78°F.

Aside from food, water, and shelter, arguably the most widely used intervention to counteract the elements is the provision of bedding material during times of cold weather or during events for which the stress of cold may prove too difficult for animals to compensate (i.e., calving, illness, etc.). By providing a layer of insulation as bedding for animals, heat exchange via conduction from their body to the earth is decreased, allowing them to maintain body temperature at a much lower cost to their metabolism. This basic principle of insulation also may be applied in times of heat stress.

In an attempt to decrease the effects of heat stress in feedlot cattle, some producers apply wheat straw or grass hay as bedding material, hypothesizing that bedding acts as an insulator from the pen floor, which otherwise serves as a reservoir and conductor of heat. Bedding materials normally are lighter in color than the pen surface, and therefore have less solar heat gain. To the best of our knowledge, no studies have been conducted to examine the effects of these bedding materials on the temperature of the pen surface. Additionally, determining the effects of varying thicknesses of manure on pen surface temperatures may provide useful information for management decisions regarding pen cleaning and maintenance.

Experimental Procedures

Plots (each approximately 21.5 ft^2) within a dirt-surfaced feeding pen near Manhattan, KS, were assigned randomly to 1 of 4 treatments, with 4 separate plots per treatment. Treatments consisted of a bare pen surface, wheat straw applied at a depth of 6 inches, and manure applied to the bare pen surface to depths of 6 and 12 inches. Surface temperatures of treatment plots were measured by a handheld infrared thermometer (Fluke, Inc., Everett, WA) with an accuracy of ±1.5% and a pre-set emissivity of 0.95. Measurements were collected every 30 minutes for 5 hours from 11:00 a.m. through 4:00 p.m. on June 30, 2011. Temperature measurement was conducted at a similar height and angle at each measurement time point. Environmental weather data were

[1] THI = Dry bulb temperature F° – (0.55–(0.55 × (relative humidity/100))) × (dry bulb temperature F° – 58).

measured using a multi-sensor onsite weather station (Campbell Scientific, Logan, UT) operated by the Kansas State University Turfgrass team. Data were analyzed using the MIXED procedure of SAS (SAS Institute, Cary, NC) with repeated measures over time. Significance was declared at $P < 0.05$ and tendencies at $P < 0.10$.

Results and Discussion

During the period of time when surface temperature measurements were collected, the dry bulb air temperature averaged 97°F (Table 1) with a corresponding relative humidity value of 31%. Although the relative humidity was not considered extreme, the air temperature was high enough to result in a THI that would be considered a time of severe risk for heat stress in cattle.

Application of wheat straw at a depth of 6 inches significantly decreased the surface temperature of the test plot versus all treatments ($P < 0.05$, Table 2). Face temperature was 25°F greater for the bare pen surface and with 6 inches of manures compared with wheat straw bedding ($P < 0.001$); however, surface temperature of the wheat straw plots was only 6°F cooler than the plots with 12 inches of manure ($P = 0.03$). The decreased surface temperature associated with wheat straw likely occurred as a result of a decreased absorbance of radiated solar energy due to the light color of the wheat straw. Pen surfaces absorb and accumulate heat from solar radiation, and the insulative properties of wheat straw likely played a role in diminishing solar heat gain. Materials with properties similar to those of wheat straw (corn stalks, poor-quality grass hay, etc.) could have comparable effects on surface temperatures of cattle feeding pens.

It is plausible that 12 inches of manure provided more insulation from the pen floor than 6 inches of the same material, which resulted in a decreased face temperature ($P < 0.001$), but further investigation is needed, and allowing excessive accumulation of manure is not advised.

Implications

These observations indicate that the use of wheat straw as a bedding material in dry dirt-floor cattle feeding pens can decrease the surface temperature of the bedded area, which may offer cattle a cooler place to rest in times of high heat load.

Acknowledgements

The authors thank the Kansas State University Commercial Cow-Calf Unit for use of facilities, the Kansas State University Turfgrass team for weather readings, and the Livestock and Meat Industry Council for funding of materials. Much gratitude is extended to Tanner Miller, Erica Biel, Taylor Swanson, and Mark Meier for assistance with the project.

Table 1. Environmental conditions during the experimental period

Item	Dry bulb temperature, °F	Relative humidity, %	Wind speed, MPH	Solar radiation, Langley
Mean value	97.9	31	3.6	780

Table 2. Surface temperature of different materials in a cattle feeding pen

	Pen surface treatment					
Item	Bare surface	6 in. wheat straw	6 in. manure	12 in. manure	*P*-value	SEM
Surface temperature, °F	136.6[a]	111.6[b]	136.7[a]	117.8[c]	<0.0001	2.04

[abc] Means with different superscripts differ significantly ($P < 0.05$).

Relationships Between Feedlot Health, Average Daily Gain, and Carcass Traits of Angus Steers

M.L. Hands, C.D. Reinhardt, T.T. Marston[1], J.W. Waggoner, and L.R. Corah[2]

Introduction

Morbidity reduces performance and quality grade, but the effects of morbidity on quality grade independent of its effect on carcass fatness are rarely documented. As feedlot cattle fatten, a greater proportion of their daily carcass gain goes to fat deposition, and greater carcass fat is consistent with greater marbling score. Higher-grading cattle are often assumed to have reduced feedlot performance. Objectives of this research were to document the impacts of various animal and non-animal factors on feedlot average daily gain, health, and carcass traits in Angus steers and to correlate quality and yield grade components of carcass with live performance.

Experimental Procedures

Angus steers (n = 17,919) fed at a single commercial feedlot in southwestern Kansas from 1997 through 2007 were used to correlate average daily gain, health, and carcass traits. Factors of interest were health status, average daily gain, quality grade, and yield grade. Health status categories were as follows: no treatment, single treatment, 2 treatments, and more than 2 treatments for respiratory or other diseases. Animals were also grouped by rate of gain, quality grade, and yield grade.

Calves had been fully preconditioned for a minimum of 30 days prior to delivery to the feedlot. Some groups were placed in backgrounding lots or on pasture at or near the ranch of origin for 60 to 150 days with their original ranch herdmates. Cattle were not commingled with calves from other ranches prior to delivery to or following arrival at the feedlot. Animals were observed daily for morbidity by feedlot personnel. All health evaluators were professional feedlot personnel.

The general manager of the feedlot visually evaluated the animals for degree of finish 60 to 80 days after administration of the terminal implant. Animals determined to be adequately finished were shipped to the packing plant. Animals not shipped with the first marketing group were evaluated for finish again 14 to 21 days later, and those meeting the criteria were shipped. A third group was subsequently shipped an additional 14 to 21 days after the second marketing group. Carcass data were evaluated by USDA personnel.

Results and Discussion

Only 7.7% of the cattle were treated, with 3.1% treated once, 1.9% treated twice, and 3.4% treated 3 or more times (Table 1). Initial body weight, final body weight, and hot carcass weight decreased in linear and quadratic manners with increasing number of

[1] University of Nebraska-Northeast Research and Extension Center, Norfolk, NE. 68728-2828
[2] Certified Angus Beef, Manhattan, KS.

treatments ($P < 0.01$). Average daily gain decreased linearly ($P < 0.01$) with an increasing number of treatments for all causes of morbidity.

Hot carcass weight, quality grade, and yield grade all decreased linearly with increasing number of treatments ($P < 0.01$). As the number of treatments increased, the percentage of cattle grading Choice decreased ($P < 0.01$). The percentage of carcasses qualifying for a premium Choice program was greatest among cattle that were never treated ($P < 0.01$). No significant interactions occurred between the number of treatments and yield grade with respect to any measures of quality grade ($P > 0.10$).

Treated cattle had lower yield grades than their untreated counterparts ($P < 0.01$), and the percentages of yield grade 1 and 2 carcasses increased linearly with increasing number of treatments ($P < 0.01$).

Cattle that had greater quality grade had greater initial body weight (linear, $P < 0.01$; Table 2), final body weight, average daily gain, hot carcass weight, and yield grade (linear and quadratic $P < 0.01$), and reduced number of days on feed (quadratic, $P < 0.01$).

Average daily gain, final body weight, and hot carcass weight differed little among cattle that graded Prime, Choice, or Select, but performance was dramatically less for those cattle that were ungraded. The number of treatments was roughly double for ungraded cattle versus cattle that graded Prime or Choice (0.11 versus 0.05 and 0.06 for ungraded versus Prime and Choice, respectively), which may explain part of the performance difference based on quality grade.

Cattle with greater final yield grade had fewer treatments (linear and quadratic, $P < 0.01$). In cattle not treated for disease, cattle with greater yield grade had greater final body weights, average daily gain, days on feed, and hot carcass weights (linear, $P < 0.01$; Table 3), and greater quality grade (linear and quadratic, $P < 0.01$).

The proportion of cattle that graded Choice increased 16.1 percentage units between yield grade 1 and 2 cattle compared with yield grade 3 cattle, but the proportion increased only an additional 1.6 percentage units in yield grade 4 and 5 cattle (linear and quadratic, $P < 0.01$).

Yield grade was positively correlated to quality grade ($r = 0.167$; Table 4). The number of treatments per animal was negatively correlated with quality grade and average daily gain ($r = -0.070$ and -0.152, respectively). Initial body weight was negatively correlated with the number of treatments ($r = -0.104$) and positively correlated with average daily gain, final body weight, and hot carcass weight ($r = 0.185$, 0.425, and, 0.405, respectively), but initial body weight had nearly no relationship with quality grade or yield grade ($r = 0.035$ and 0.021, respectively).

Implications

The strong inter-relationship between average daily gain, yield grade, and quality grade suggests that beef producers who are attempting to raise and market highly marbled beef do not need to choose between the genetics for performance versus genetics for

marbling, but instead can select for high-performance cattle with high marbling potential. If producers reduce opportunities for nutritional stress (for example, nutrient restriction or health challenges), then ensure that the cattle are fed to their target fat content endpoint, they will more consistently achieve both excellent performance and quality grade.

Table 1. Main effects of number treatments for morbidity on feedlot performance and carcass traits for Angus steers fed in a single Kansas feedlot from 1997 through 2007

	Number of times treated[1]					*P*-value	
						Number of times treated	
Trait	0	1	2	≥ 3	SEM[2]	Linear	Quadratic
Number of cattle	10,700	333	204	360			
Initial body weight, lb	799	710	730	746	3.3	<0.01	<0.01
Final body weight, lb	1273	1293	1244	1229	6.8	<0.01	<0.01
Average daily gain, lb	3.62	3.68	3.27	3.27	0.049	<0.01	0.40
Hot carcass weight, lb	821	834	805	794	4.4	<0.01	<0.01
Prime, %	2.1	2.2	0.8	0.7	1.10	0.96	0.97
Premium Choice, %	18.6	13.0	11.5	12.4	3.00	<0.01	<0.01
Choice, %	69.0	65.5	58.3	57.1	3.50	<0.01	0.03
Ungraded, %	0.9	0.1	1.5	2.1	0.71	0.97	0.94
Yield grades 1 and 2, %	25.8	25.0	32.0	37.3	3.24	<0.01	0.79
Yield grades 4 and 5, %	14.4	15.5	5.4	9.2	2.55	0.93	0.94

[1] Treated: Includes all health treatments received while at feedlot.
[2] SEM = largest standard error in the analysis.

Table 2. Main effects of quality grade on feedlot performance and carcass traits for Angus steers never treated for disease fed in a single Kansas feedlot from 1997 through 2007

	Quality grade					*P*-value	
Trait	Prime	Choice	Select	Ungraded	SEM[1]	Linear	Quadratic
Number of animals	314	9,008	4,336	141			
Initial body weight, lb	814	791	787	778	11.7	0.09	0.01
Final body weight, lb	1279	1281	1268	1232	10.6	0.82	0.01
Average daily gain, lb	3.51	3.66	3.55	3.20	0.068	0.14	0.15
Number of treatments[2]	0.09	0.2	0.31	0.27	0.11	<0.01	0.33
Hot carcass weight, lb	822	825	818	794	6.8	0.85	0.01
Yield grades 1 and 2, %	18.9	20.9	35.7	59.4	3.53	<0.01	<0.01
Yield grades 4 and 5, %	17.1	15.1	11.9	8.1	2.80	<0.01	0.03

[1] SEM = largest standard error in the analysis.
[2] Includes all health treatments received while at feedlot.

Table 3. Effects of yield grade on feedlot performance and carcass traits for Angus steers never treated for respiratory disease fed in a single Kansas feedlot from 1997 through 2007

	Yield grade				*P*-value	
Trait	1+2	3	4+5	SEM[1]	Linear	Quadratic
Number of cattle	4,145	9,912	2,215			
Initial body weight, lb	791	794	789	3.1	0.95	0.29
Final body weight, lb	1261	1287	1321	2.2	<0.01	0.21
Average daily gain, lb	3.57	3.68	3.79	0.013	<0.01	0.72
Number of treatments[2, 3]	0.34	0.19	0.13	0.021	<0.01	<0.01
Hot carcass weight, lb	811	829	849	1.4	<0.01	0.18
Prime, %	1.7	2.4	2.9	0.33	<0.01	0.04
Premium Choice, %	14.9	25.2	1.3	0.85	<0.01	<0.01
Choice, %	57.6	73.7	75.3	0.99	<0.01	<0.01
Ungraded, %	2.1	0.5	0.4	0.2	<0.01	<0.01
Yield grade	1.95	3.00	4.04	0.003	<0.01	0.05

[1] SEM = largest standard error in the analysis.
[2] Includes all health treatments received while at feedlot.
[3] Includes all steers in the complete dataset. Animals that were treated for disease were removed from analysis of all other variables.

Table 4. Correlation coefficients (Pearson) of various traits in Angus steers fed in a single Kansas feedlot from 1997 through 2007 ($P < 0.01$)

Item	Initial body weight, lb	Average daily gain (ADG), lb	Final body weight, lb	Hot carcass weight, lb	Number of treatments[1]	Yield grade
ADG, lb	0.185					
Final body weight, lb	0.425	0.616				
Hot carcass weight, lb	0.405	0.562	0.986			
Number of treatments	-0.104	-0.152	-0.146	-0.140		
Yield grade	0.021	0.131	0.240	0.238	-0.073	
Quality grade[2]	0.036	0.074	0.104	0.097	-0.069	0.167

[1] Includes all health treatments received while at feedlot.
[2] Prime = 4, Choice = 3, Select = 2, Ungraded = 1.

Agreement Between Observational and Necropsy-Derived Diagnosis for Cause of Death for Cattle in a Commercial Beef Feedlot

D. Anspaugh, D.U. Thomson, B. Wileman, M. Apley, W. Taylor[1], T. Noffsinger[1], and C.D. Reinhardt

Introduction

Necropsy information is an integral component for monitoring feedlot disease and designing preventive and therapeutic strategies; however, field necropsy is a laborious and time-consuming procedure and may be an occupational hazard because personnel can become injured or be exposed to zoonotic disease while conducting necropsies. The objective of this study was to determine the accuracy of a pre-necropsy mortality diagnoses made by feedlot personnel compared with diagnoses made from necropsy results.

Experimental Procedures

This study was conducted during the months of June and July 2009 in a feedlot in western Kansas. Each day, mortalities (n = 54 total) were brought to a designated necropsy area, and data pertaining to where the animal was found (i.e., home pen, hospital pen, chronic pen) were recorded. Feedlot health personnel were then asked to determine and record the cause of death for each mortality based on prior medical history and treatments recorded in the electronic animal health system, personal knowledge, and location where the animal was found. Study investigators who were blinded to the pre-necropsy diagnoses then conducted a thorough necropsy to determine the cause of death of each animal and obtained digital images of any lesions found.

The pre-necropsy and post-necropsy cause of death data were placed into 7 categories for data analysis: (1) bovine respiratory disease, (2) atypical interstitial pneumonia, (3) tracheal edema, (4) bloat, (5) traumatic injury/buller, (6) peritonitis, and (7) dystocia. A kappa test was performed to estimate the agreement between pre-necropsy and post-necropsy determined cause of death. Kappa was calculated using Stata version 10 (Stata Corp.; College Station, TX). The kappa equation used was calculated on mortalities by using the formula:

$$Kappa = \frac{(\text{Observed agreement} - \text{Expected agreement})}{1 - \text{Expected agreement}}$$

The resulting kappa values were categorized and interpreted according to Table 1.

Results and Discussion

Of the 54 mortalities observed in this study, the overall kappa value of agreement between pre-necropsy and post-necropsy determined cause of death was 0.6039, indicating a moderate level of agreement.

[1] Production Animal Consulting, Oakley, KS.

This study found 100% agreement between pre- and post-necropsy cause of death for bovine respiratory disease cases (Figure 1); therefore, a necropsy is not warranted on mortalities previously diagnosed and treated for bovine respiratory disease, especially those found in the hospital or chronic pens. Out of the 25 bovine respiratory disease cases, 22 were found in the hospital or chronic pen (Figure 2), and the majority (24/25) had a previous history of treatment for respiratory disease (Figure 3).

Bloat also had an equal pre- and post-necropsy determined cause of death (Figure 1). All 5 of these animals were found in their home pens (Figure 2) and did not have a medical history (Figure 3). This is the second leading cause of mortality in feedlots and the third most prevalent pathology affecting feedlot cattle. This study shows that bloat is easily observed and diagnosed pre-necropsy, indicating that necropsy of bloat mortalities is not warranted.

Atypical interstitial pneumonia was under-reported in pre-necropsy determined cause of death (n = 12) compared with post-necropsy determined cause of death (n = 15; Figure 1). Of atypical interstitial pneumonia cases, 75% (9/12) died in their home pens without receiving treatment (Figure 2). Pre-necropsy under-reporting of the atypical interstitial pneumonia diagnosis suggests that animals found in their home pen without symptoms of bloat or history of bovine respiratory disease treatment should receive a necropsy.

Cattle classified under the injury category (n = 9) were diagnosed pre-mortem as chronically lame, bullers, or had suffered a traumatic injury. The agreement between pre- and post-necropsy diagnosis for injured animals was poor (4/9), but two-thirds (6/9) had died in the hospital or chronic pens and had pre-mortem treatment history (Figure 2). The three animals in the injury category that died in their home pens had traumatic injuries and were either found deceased or were humanely euthanized. Post-necropsy diagnosis of traumatic injury/bullers was under-represented in this study, which could have been because the individual conducting the necropsy did not have the opportunity to observe the animal's gait. Animals that had a traumatic injury may have had multiple disease processes occurring at the same time, and without watching the animals walk, the animals would have been categorized in other, non-injury categories even though they would have been pulled, treated, and recorded as injured. This result supports the concept that for mortalities with a history of severe physical trauma, necropsy is not only unwarranted but also may provide misleading evidence contrary to the obvious, primary lesion.

Implications

Most feedyard mortalities can be accurately diagnosed without the time, expense, and risk of performing necropsy; however, some questionable mortalities should still be investigated.

Acknowledgements

The authors acknowledge Hoxie Feedyard for cooperation in this study.

Table 1. Kappa value interpretation

Kappa value	Interpretation
< 0.10	No agreement
0.10 to 0.20	Slight agreement
0.21 to 0.40	Fair agreement
0.41 to 0.60	Moderate agreement
0.61 to 0.80	Substantial agreement
0.81 to 1.00	Almost perfect agreement

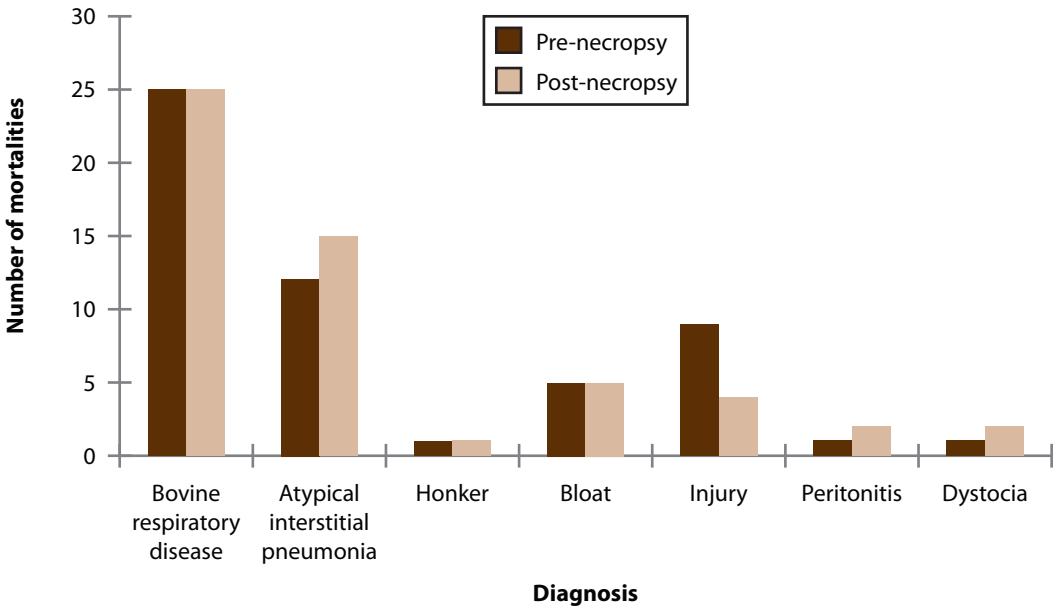


Figure 1. Number of mortalities by category diagnosed either pre- or post-necropsy.

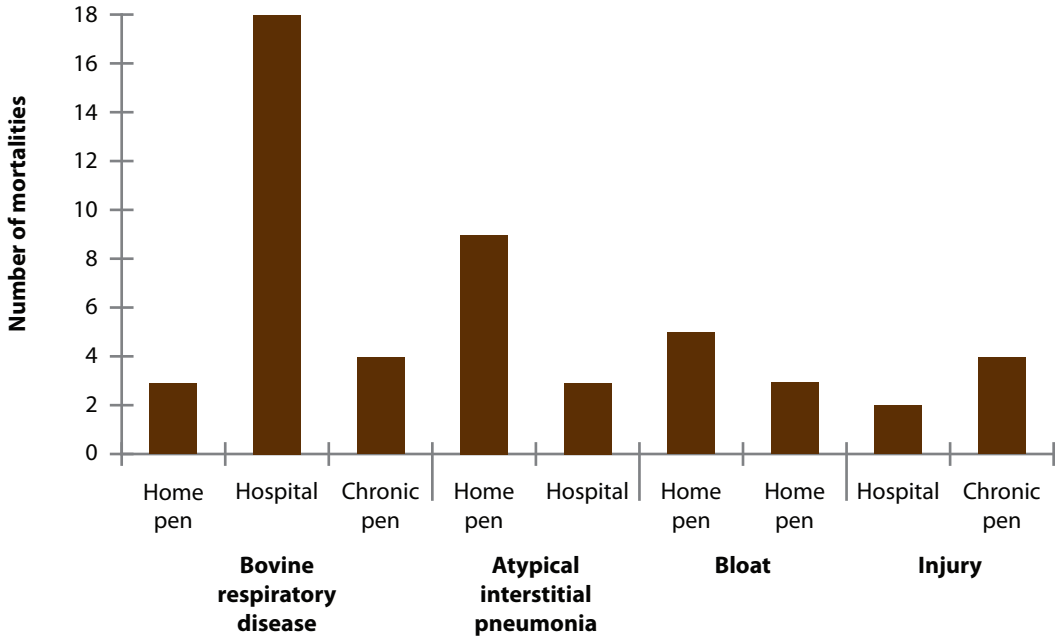


Figure 2. Number of mortalities within each category found in either the home pen, the hospital pen, or the chronic pen.

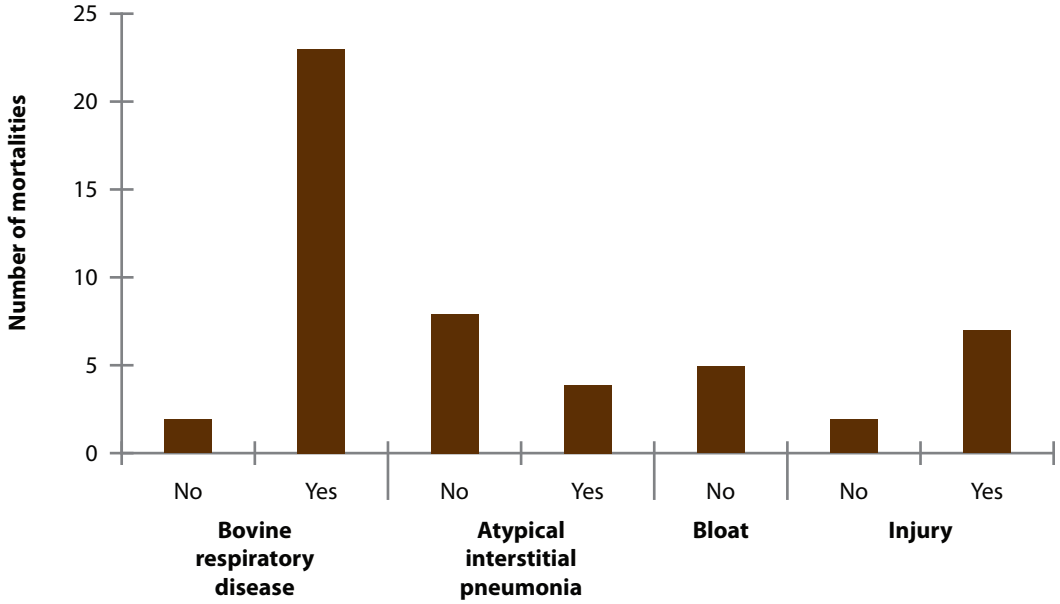


Figure 3. Number of mortalities within each category that either did ("Yes") or did not ("No") receive treatment prior to mortality.

Comparative Efficacy of Two Ivermectin Pour-on Anthelmintics in Beef Steers in a Commercial Feedyard

A.J. Tarpoff, D.U. Thomson, B.W. Wileman, T. Guichon[1], and C. D. Reinhardt

Introduction

Generic products generally have a cost advantage for beef producers over brand-name products. Recently, many beef producers have debated whether to utilize generic anthelmintics in cow/calf herds and feeder cattle. If generics are to be justified, the products must be proven to have efficacy similar to the brand-name product. Previous studies have indicated that generic macrocyclic lactones are less effective in controlling gastrointestinal parasites of cattle than the original brand-name products. The objective of this study was to compare the efficacy of Vetrimec (Norbrook Laboratories Limited, Newry, Co. Down, Northern Ireland) pour-on and Ivomec (Merial Animal Health, Duluth, GA) pour-on by utilizing the fecal egg reduction test in newly arrived feedlot steers.

Experimental Procedures

Five pairs of feedlot pens containing 40 cattle per pen within a single commercial feedlot were randomly assigned to 1 of 2 anthelmintic treatments: Ivomec pour-on or Vetrimec pour-on. Rectal fecal samples were obtained at the time of initial processing prior to treatment on day 0 and again on day 14. Animal weights were obtained on day 0 and again at production sort date (average 118 days on feed), at which time the study was terminated.

Linear and mixed models were fit with treatment, pen, and their interaction terms as predictors of net egg count difference and average daily gain using the statistical software program R (version 2.10.1). Fecal egg count reduction percentages were calculated and used to report treatment efficacy.

Results and Discussion

No anthelmintic treatment × pen interactions occurred for fecal egg count reduction percentages or performance. Treatment groups exhibited no differences in pre-treatment body weights ($P = 0.10$; Table 1) or initial fecal egg counts ($P = 0.17$; Figure 1). Cattle treated with Vetrimec pour-on exhibited greater average daily gain than cattle treated with Ivomec pour-on (3.89 versus 3.74 lb/day, respectively; $P = 0.02$). Final (d 14) egg counts did not differ ($P = 0.15$). Regardless of treatment, only 26% of animals sampled had a fecal egg count reduction percentage of >90% at day 14 (Figure 2).

No differences were observed in parasite control between generic and brand-name products in this study, but neither treatment was entirely effective at reducing internal parasite burden.

[1] Feedlot Health Management Services, Okotoks, Alberta, Canada.

Implications

Pour-on anthelmintics may not be the most effective means for control of internal parasites.

Table 1. Initial weight, final weight (day 118), and average daily gain for feedlot cattle treated with either Vetrimec pour-on or Ivomec pour-on

	Vetrimec	Ivomec	SEM	*P*-value
Initial weight, lb	672	680	9.1	0.10
Out weight, lb	1,121	1,108	10.6	0.46
Average daily gain, lb/day	3.89	3.74	0.056	0.02

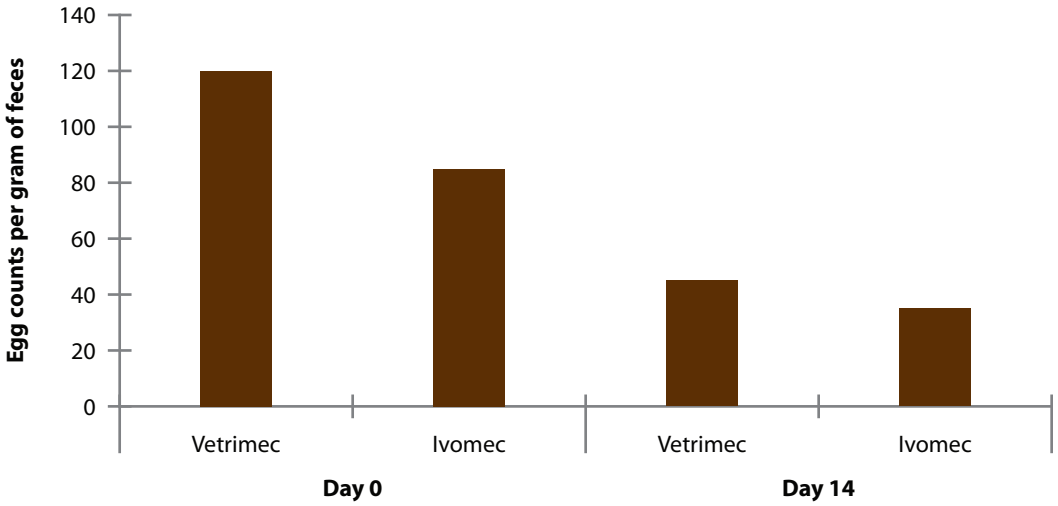


Figure 1. Average fecal egg counts for feedlot cattle treated with either Vetrimec pour-on or Ivomec pour-on (no treatment differences either before or after treatment ($P \geq 0.15$).

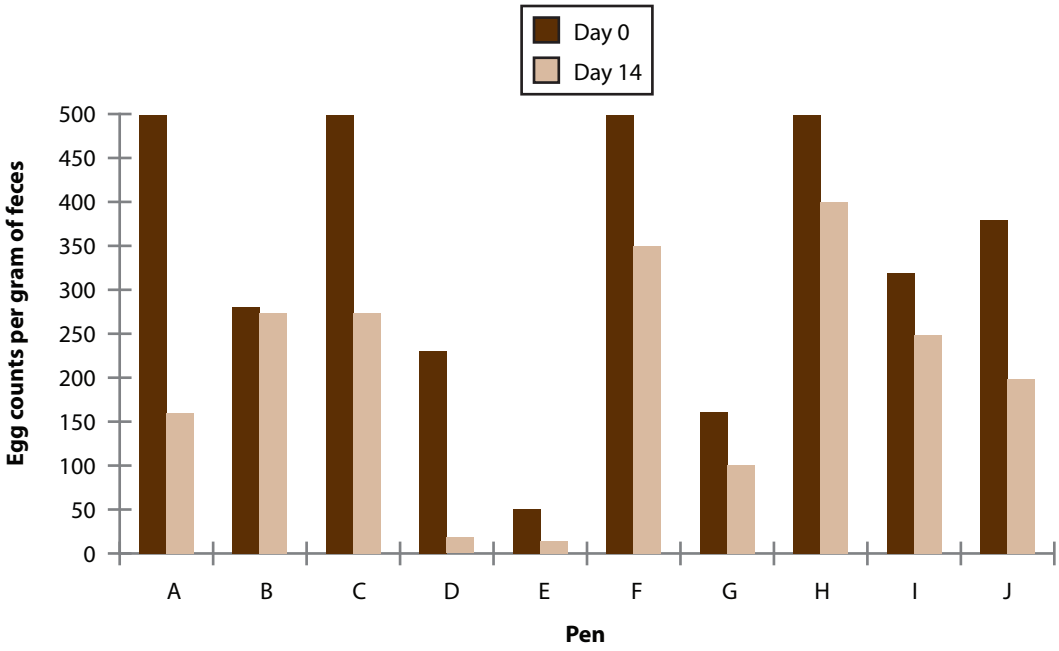


Figure 2. Range (high to low) in individual animal fecal egg counts by pen before and after treatment with either Vetrimec pour-on or Ivomec pour-on.

Comparison of the Effects of Three Different Dehorning Techniques on Behavior and Performance in Feeder Cattle in a Western Kansas Feedlot

C.D. Neely, D.U. Thomson, C.A. Kerr[1], D.E. Anderson, and C.D. Reinhardt

Introduction

Removing the horns of cattle when they arrive at feeding facilities is a common practice to reduce injury to other cattle. Bruising on carcasses of cattle that have been housed in pens containing horned cattle increases noticeably. Horned feeder cattle marketed in Arkansas regional livestock auction barns received average discounts of $3.23/cwt in 2005, giving producers the incentive to dehorn their cattle before marketing.

Three common techniques (tipping, dehorning, and banding) are utilized in the field to remove or reduce horn length in beef cattle. Tipping is the practice of removing the tip of the horn such that the diameter of the horn is approximately 1 to 1.5 inches in diameter. Dehorning is mechanically cutting the horns off at the base of the horn near the head. The use of high-tension rubber bands to dehorn cattle has recently been implemented in some cattle feeding facilities. The band restricts blood circulation to the horns, resulting in necrosis, and the horns eventually fall off. This study was conducted to establish baseline data on behavior and feedlot performance in cattle dehorned using these techniques.

Experimental Procedures

Forty crossbred horned steers and heifers (body weight = 693 ± 10.5 lb) were identified at a commercial feedyard (Dodge City, KS) and used to determine the effects of dehorning methods on cattle behavior and performance. The cattle were blocked by weight and sex and randomly assigned to 1 of 4 treatments within the blocks (n = 10 animals per treatment): (1) non-dehorned control (CON), (2) banded using a high-tension elastic rubber (BAND), (3) mechanically removed (MECH), or (4) tipped horn (TIP). After arrival, cattle were processed and moved to a new home pen and were allowed a 14-day alimentation period after arrival and prior to initiation of treatments. Cattle were dehorned by their respective treatment assignment on d 0 of the trial and were housed together for the duration of the study.

A vocalization score and information on chute behavior were recorded during the dehorning process. Vocalization scores were assigned based on behavior: 0 = no vocalization; 1 = low volume, <1-second vocalization; and 2 = >1-second or greater volume intensity. After dehorning, cattle were placed in a feeding pen where all trial cattle were fed together. Cattle were individually weighed on days 0, 7, 14, 21, and 28. Behavior was evaluated and recorded daily (between 8:00 and 9:30 a.m., following the a.m. feeding) for depression, gait, and posture and lying for 28 days following treatment

[1] Dodge City Veterinary Clinic, Dodge City, KS.

application. The depression scoring was assigned as follows: 0 = bright, alert, responsive, 1 = quiet but rouses only when approached, 2 = quiet but rouses only when pen was entered, 3 = did not move when pen was entered or had to be touched to get up. Cattle that scored 3 were evaluated by the attending veterinarian and treatment according to diagnosis was applied. Gait and posture were documented: 0 = normal; 1 = reluctant to move, stiff gait; 2 = mild incoordination when stimulated, hunched posture; 3 = obvious ataxia or head tilt, hunching, dragging of one or more limbs. Cattle lying down were documented and scored as follows: 0 = lying normally, head up, ruminating; 1 = lying with head down; 2 = lying with full or partial extension of hind legs; 3 = lying in lateral position.

Data were analyzed using the MIXED and GLIMMIX procedures of SAS (Cary, NC), and the independent variables used in the model were treatment and week for vocalization, depression, gait and posture, lying, and average daily gain.

Results and Discussion

Success of the banding technique over the 4-week time period was poor to inconclusive during the trial. Four of the bands fell off without removing the horn in the first 4 days of the trial. During the trial, only 3 horns that had been banded fell off during a 28-day period, leaving 13 out of the 20 horns at the end of the 4-week trial with the bands still attached.

MECH and BAND had greater vocalization scores than CON and TIP ($P < 0.05$; Figure 1). Cattle with the MECH treatment had the most extended vocalization, indicating the greatest discomfort during the procedure. The BAND group had lower vocalization scores than the MECH group at the time of dehorning but greater vocalization post-procedure. Vocalization scores for cattle treated with TIP and CON did not differ.

Cattle from the BAND group tended to have higher depression scores than cattle from other treatment groups ($P < 0.10$; Figure 2). No other differences were measured in depression scores in cattle dehorned by TIP, MECH, or CON.

Cattle in the BAND group tended to exhibit higher gait and posture scores than cattle in other dehorning treatment groups ($P < 0.10$; Figure 3). No other differences were observed in gait and posture due to dehorning methods.

Cattle dehorned with the banding technique had higher abnormal lying scores than cattle dehorned with other techniques ($P = 0.04$; Figure 4). No other lying score differences were observed between cattle dehorned with other methods ($P > 0.10$).

The amount of weight gained by cattle in all four dehorning treatment groups was similar across treatments ($P = 0.81$; Figure 5).

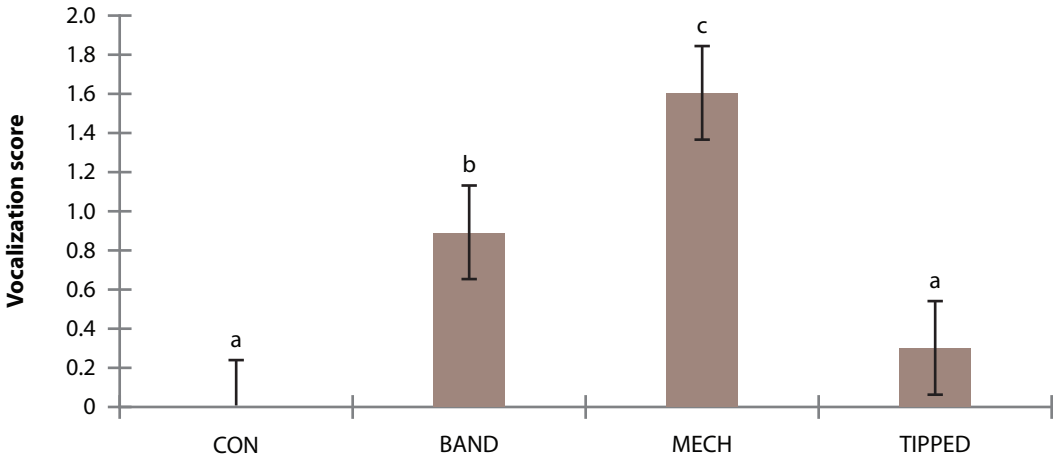
Based on treatment effects on vocalization, depression, abnormal gait and posture, and abnormal lying, banding appears to be a relatively painful process that has lasting effects. Mechanical dehorning is correlated with increases in vocalization ($P < 0.01$) at the time of the procedure, which can be associated with an increase in pain response. Tipping

the horns had the least amount of pain-associated behavior observed throughout the trial and was similar to not dehorning based on the evaluation of vocalization, depression, gait and posture, and lying; however, no difference was detected in performance between the different dehorning procedures ($P = 0.81$).

Other than vocalization during dehorning, mechanical dehorning caused no differences in behavior post-procedure compared with tipping or no dehorning, and tipping was not different than no dehorning with respect to behavior measures.

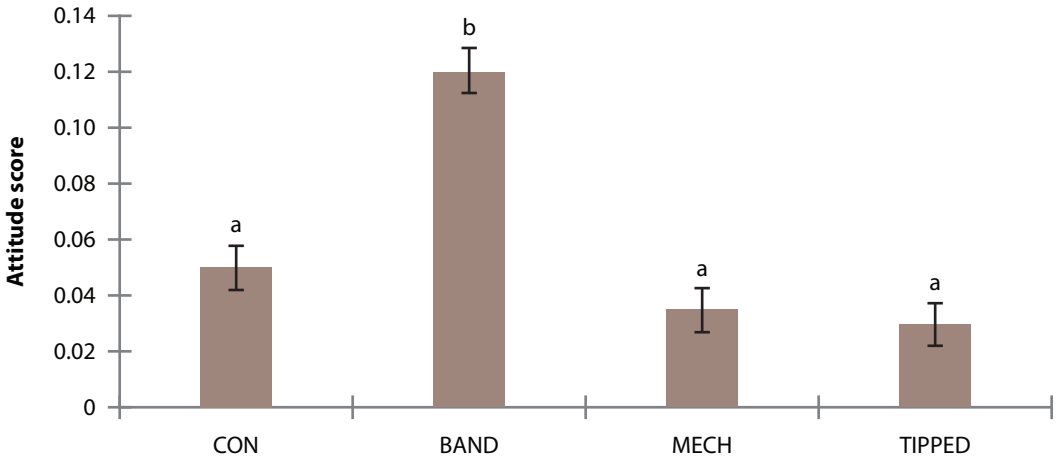
Implications

Dehorning can be a stressful procedure, but if done quickly and properly, stress response on feeder calves can be minimized.



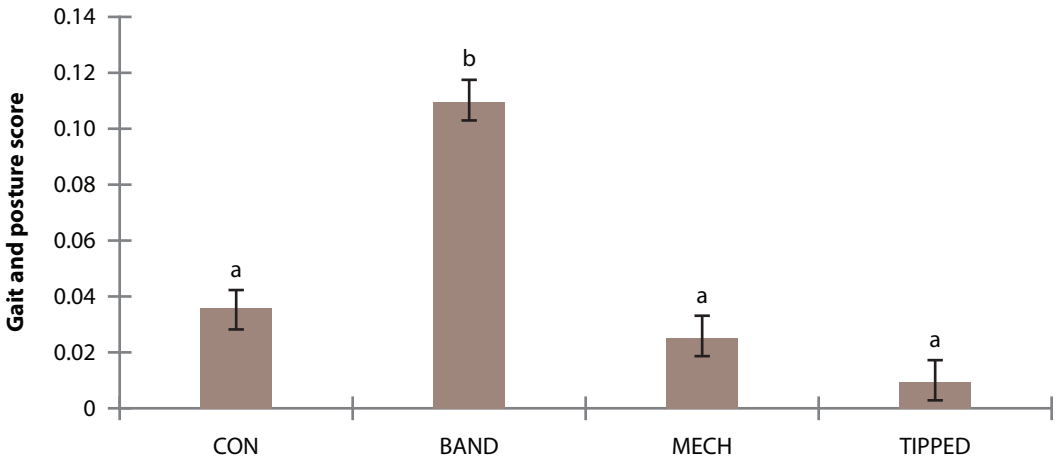
[abc] Means without a common superscript differ ($P < 0.05$).

Figure 1. Vocalization scores on day of treatment in the chute.



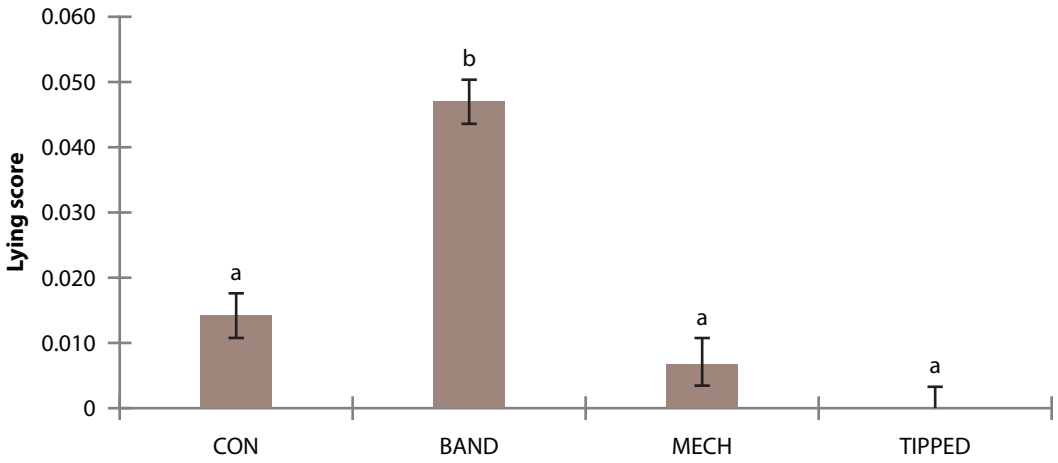
[ab] Means without a common superscript differ ($P < 0.10$).

Figure 2. Attitude score across the entire duration of the trial.



[ab] Means without a common superscript differ ($P < 0.10$).

Figure 3. Gait and posture score for the entire duration of the trial.



[ab] Means without a common superscript differ ($P < 0.10$).

Figure 4. Lying score for the entire duration of the trial.

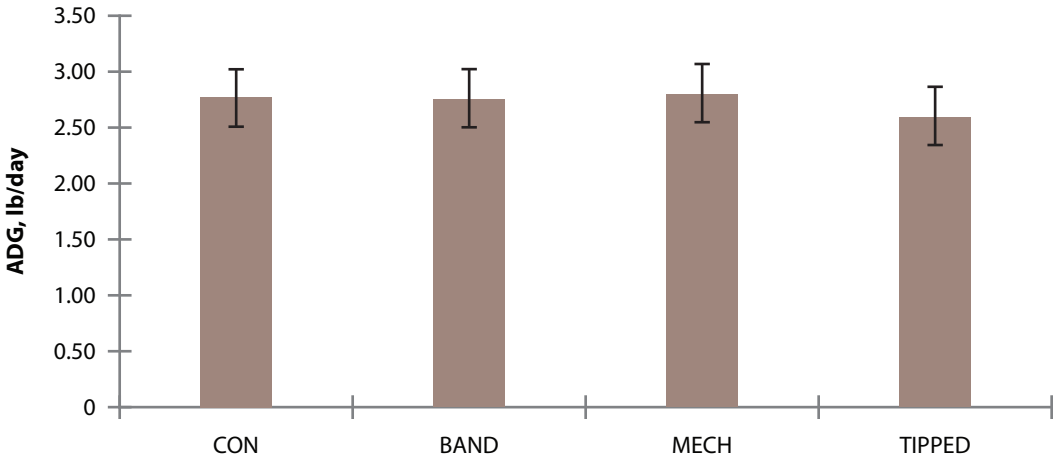


Figure 5. Average daily gain (ADG; lb/day) for the entire 28-day duration of the trial treatment (treatment effect, $P = 0.81$).

Vaccinating with SRP *E. coli* Does Not Affect Feeder Cattle Performance, Health, or Carcass Characteristics

D.J. Rezac, D.U. Thomson, B.A. Butler, B.W. Wileman, and C.D. Reinhardt

Introduction

Siderophore-receptor and porin-based (SRP) *Escherichia coli* vaccine technology functions by starving the *E. coli* organism via competitive exclusion for proteins that scavenge iron, an essential nutrient for *E. coli* viability. Vaccination with SRP *E. coli* technology decreased the prevalence of *E. coli* O157:H7 in artificially inoculated cattle and in cattle naturally shedding the organism. Examination of the effects that SRP *E. coli* vaccines exert on performance parameters has yet to be attempted in a commercial setting.

The use of SRP *E. coli* vaccine technology effectively decreases the prevalence of *E. coli* O157:H7 in feeder cattle and may improve beef safety; however, the vaccine's effects on the economics of cattle feeding are unknown. Therefore, the objective of our study was to assess the effects of vaccinating cattle three times with an SRP *E. coli* vaccine verses a placebo on performance, health, and carcass characteristics of cattle fed in commercial feedlots.

Experimental Procedures

Sixty pens of feeder cattle (4,869 head; initial body weight = 728 ± 12.7 lb) housed in 4 commercial feedlots in Kansas and Nebraska were administered 1 of 2 treatments: (1) subcutaneous injection with 2 mL of SRP *E. coli* O157:H7 vaccine (Pfizer Animal Health, New York, NY) on day 0, between 21 and 29 days on feed, and between 42 and 57 days on feed (VAC), or (2) subcutaneous injection with a placebo containing physiological saline emulsified with a commercial adjuvant on the same days as the VAC cattle (CON). Cattle were individually weighed on day 0. Pen weights were recorded on the day of slaughter. Daily feed delivery to individual pens was recorded. Animal health was observed by trained feedlot personnel daily. Pen-closeout data were provided by each feedlot, and carcass characteristics were recorded by trained personnel at a commercial abattoir.

Results and Discussion

No negative effects on performance or health were observed when feeder cattle were vaccinated with three doses of SRP *E. coli* vaccine compared with CON. Average daily gain was not different between treatments (3.09 versus 3.11 lb for CON and VAC, respectively; $P = 0.73$; Table 1). Likewise, CON and VAC did not differ in percentages of Prime and Choice carcasses (46.1 versus 45.3%, respectively; $P = 0.61$) or percentages of yield grade 1 and 2 carcasses (68.6 versus 69.1% for CON and VAC, respectively; $P = 0.76$). Based on these observations, SRP *E. coli* vaccine may be used to reduce the prevalence of *E. coli* O157:H7 without negative effects on animal performance;

however, we must note that CON cattle were subjected to the same number of pen removals for revaccination as VAC. Examination of the effects of no vaccination and no pen removals versus multiple pen removals for vaccination is warranted.

Implications

Vaccinating feedlot cattle with SRP *E. coli* vaccine may reduce the prevalence of *E. coli* O157:H7 in packing plants, but additional research is needed to determine the effects of the additional handling requirements on growth and carcass performance.

Table 1. Effects of vaccinating feedlot cattle 3 times in the feedyard with SRP *E. coli* on performance, mortality, and carcass traits

Item	CON	VAC	SEM	*P*-value
Initial weight, lb	729	728	12.78	0.72
Slaughter weight, lb	1,184	1,190	11.51	0.16
Average daily gain, lb	3.09	3.11	0.056	0.73
Dry matter intake, lb	19.9	20.5	0.31	0.13
Feed:gain	6.47	6.56	0.11	0.54
Death loss, %	3.2	3.2	0.70	0.98
Dressing percentage	65.1	65.0	0.22	0.57
Prime/Choice, %	46.1	45.3	2.03	0.61
Yield grades 1 and 2, %	68.6	69.1	1.96	0.76

Time of Onset, Location, and Duration of Lameness in Beef Cattle in a Commercial Feedyard

T.M. Green, D.U. Thomson, B.W. Wileman, P.T. Guichon[1], and C.D. Reinhardt

Introduction

Bovine lameness presents itself in a variety of forms. A number of predisposing factors have been reported, such as increased amounts of wet feces and mud from high rainfall; limb trauma from rocks, sticks, or handling facilities; inappropriate animal handling; or improper facility design. Trauma causes lameness directly and often provides an avenue for bacterial agents to enter and colonize a wound. Performance of lame cattle is diminished due to impaired ambulation, resulting in decreased feed intake and decreased body weight. The objective of this study was to determine the timing of the onset of lameness in feeder cattle and to determine the association between lameness and feedlot performance.

Experimental Procedures

This study was conducted at a commercial feedyard with a one-time capacity of 90,000 animals. The majority of cattle arriving during the enrollment and observation period were auction market-derived and weighed 400 to 700 lb. During the months of July and August 2009, a total of 3,243 feedlot steers were observed for lameness prior to processing, immediately following processing, and for 3 weeks post-processing. Pre-processing observations were conducted immediately after calves were placed in a holding pen upon feedlot arrival. All cattle were given a 7-way clostridial vaccine, MLV IBR-BVD Type I & II-PI3-BRSV, and a metaphylactic antimicrobial treatment. Cattle then were placed into feedlot pens (n = 14), where they remained for the duration of the study. Animals were diagnosed as lame based on altered gait; the affected limb also was recorded. A single observer conducted all lameness evaluations.

Cattle were enrolled in our study continuously over 40 days. Because observations were recorded weekly, cattle enrolled late in the study were observed only twice for lameness, whereas cattle enrolled early in the study were observed 4 times for lameness.

Performance data and medical history were collected until approximately 100 days on feed. Treatment records were analyzed to determine the percentage of lameness attributable to foot rot, buller, musculoskeletal, and arthritis diagnoses. Cattle were diagnosed and treated according to established feedlot protocols. Statistical analysis was performed comparing the proportion of lame and non-lame cattle using R version 2.10.1. Cattle history factors (i.e., age, health risk, region of origin, state of origin, and month placed on feed) were included in the analysis as possible contributors to lameness.

[1] Guichon Veterinary Services Inc., Okotoks, Alberta, Canada.

Results and Discussion

The proportion of cattle observed as lame pre-processing was 1.6%, which was less ($P = 0.02$) than the proportion of cattle observed as lame after processing (2.5%; Figure 1). Post-processing lameness peaked immediately (48 animals of 3,243 total cattle, week 0; Figure 2), although most lameness cases were resolved by the end of 3 weeks on feed (36/48 cases; 75.0%). In addition, 44% (21/48 cases) and 66% (32/48 cases) were resolved after 1 and 2 weeks on feed, respectively.

Cattle that were lame during weeks 0 and 1 had similar ($P > 0.15$) average daily gain compared with sound cattle (3.25 versus 3.60 lb/day; Figure 3). Cattle observed as lame at any time tended to have poorer ($P = 0.11$) average daily gain than cattle that were not lame (3.41 versus 3.60 lb/day; Figure 4). Age, risk, region of origin, state of origin, and month placed on feed were not useful for predicting the prevalence of lameness ($P > 0.05$).

Of the 3,243 head observed, 0.15% (5/3,243) had foot rot, 1.94% (63/3,243) were bullers, 1.39% (45/3,243) had musculoskeletal injuries, and 0.22% (7/3,243) had arthritis (Table 1). Four of five animals diagnosed with foot rot were recorded as lame (Table 2). No bullers were recorded as lame. Forty-five musculoskeletal injuries were diagnosed, and 7 were observed as lame. Seven animals were treated for arthritis, but only 2 were observed as lame. A total of 160 calves were diagnosed as chronics and marketed early, with 8 of the 160 chronics (5%) recorded as lame.

Implications

The majority of lameness appeared to be associated with handling events. Further study is warranted to determine if improving facilities or handling techniques can reduce the incidence of lameness.

Table 1. Percentage of animals treated according to diagnosis

Treatment	% diagnosed
Foot rot	0.15 (5/3243)
Buller	1.94 (63/3243)
Musculoskeletal	1.39 (45/3243)
Arthritis	0.22 (7/3243)

Table 2. Number of cattle observed lame by treatment

Treatment	Number observed as lame
Foot rot	4/5
Buller	0/63
Musculoskeletal	7/45
Arthritis	2/7

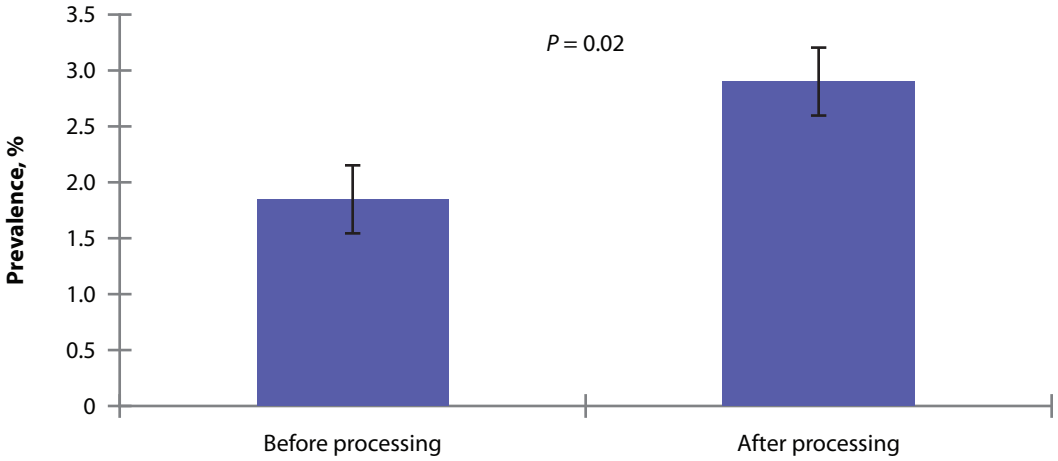


Figure 1. Lameness prevalence observed before and after processing in feeder cattle.

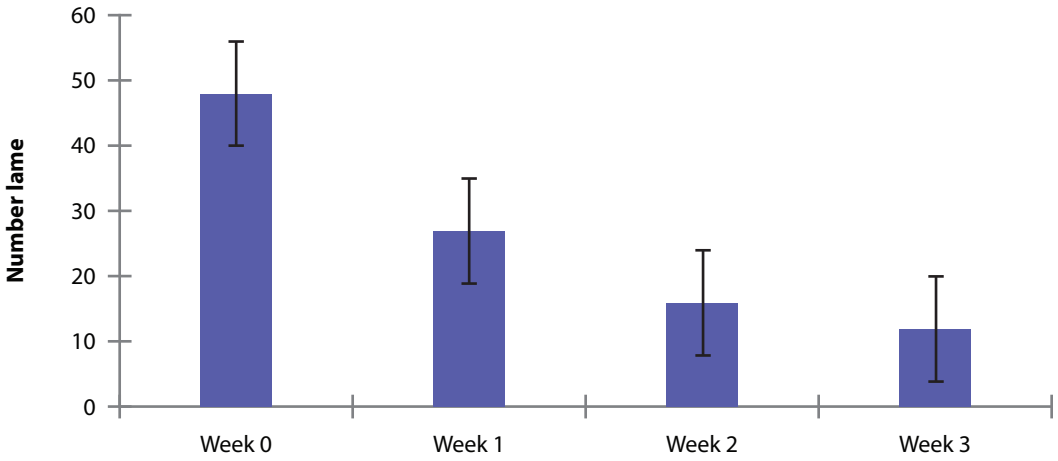


Figure 2. Prevalence of lameness cases post-processing through week 3, excluding new cases of lameness during those weeks.

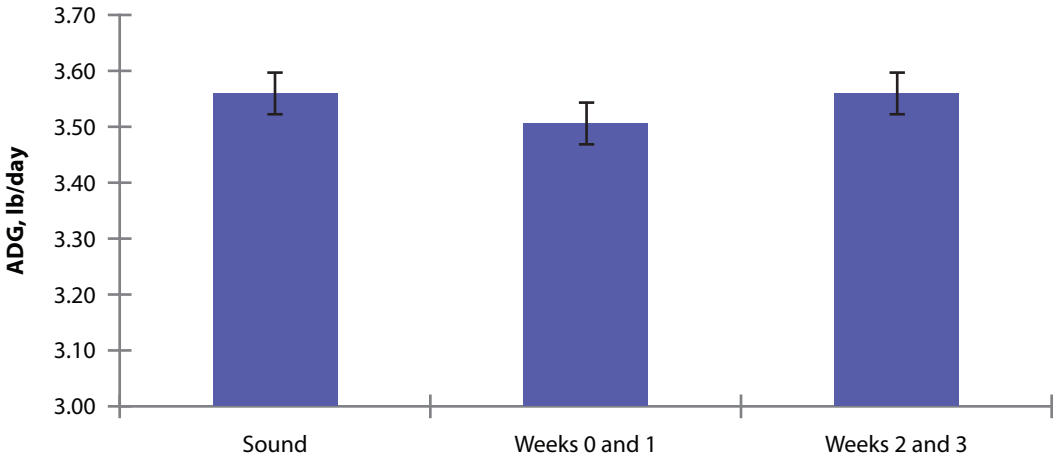


Figure 3. Average daily gain (ADG) in cattle never lame, lame in weeks 0 and 1, and lame in weeks 2 and 3.

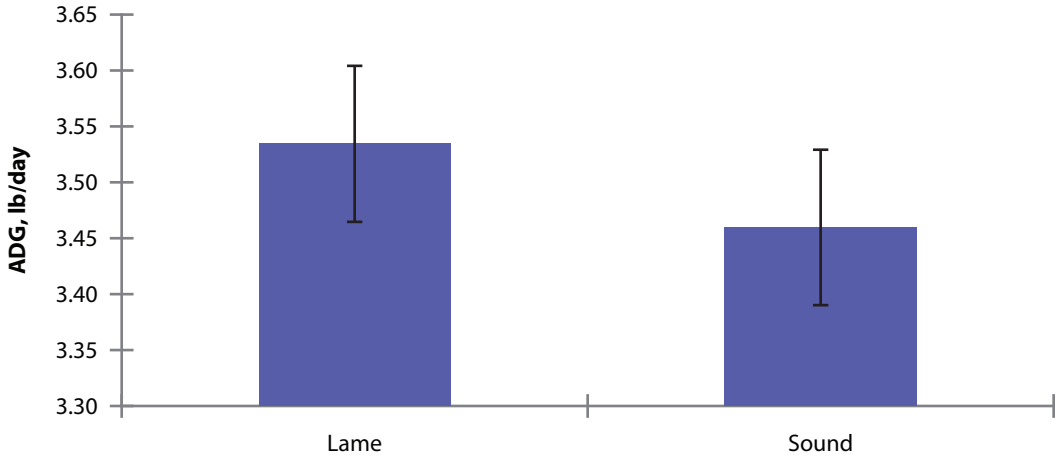


Figure 4. Average daily gain (ADG) in lame and non-lame animals.

Delaying Implant in High-Risk Calves Has No Benefit for Health or Feedlot Performance

R.D. Munson, D.U. Thomson, and C.D. Reinhardt

Introduction

Bovine respiratory disease is the most common and costly disease in the beef industry. Calves affected by bovine respiratory disease have a 53-lb decrease in finished weights and decreased quality grades compared with healthy cattle.

Many stressors influence post-arrival health and nutrient intake, including weaning, marketing, transportation, co-mingling, genetics, previous nutrition, and health history. These stressors can negatively affect the immune system at a time when the animal is more likely to be exposed to infectious agents within the bovine respiratory disease complex. Feed intake by stressed calves is low, and low nutrient intake likely increases the negative effects of stress on the immune system.

Delaying the initial steroid implant may reduce post-transit stress and improve carcass quality of feedlot cattle. This study was designed to examine the effects of administering initial steroid implants at feedlot arrival or 45 days after feedlot arrival on health, performance, and carcass characteristics of feeder calves at relatively high risk for bovine respiratory disease.

Experimental Procedures

Calves (n = 1,601; 604 ± 10.3 lb) were shipped to a commercial feedyard in central Kansas and were allowed to rest overnight prior to processing. At processing, calves were randomized either to receive an initial implant (Revalor XS; 40 mg estradiol 17β + 200 mg trenbolone acetate) on day 1 or to receive the same initial implant on day 45 post-processing. Cattle were randomly assigned to treatment in groups of 5 animals as they were moved through the processing barn. Groups were assigned subsequently to pens within treatment groups (approximately 80 animals/pen; 10 pens/treatment).

Cattle were weighed individually on day 0 and day 45, and their final body weight was estimated by dividing the hot carcass weight by the average dressing percentage of the pen. Weight of feed offered was recorded daily. Feed bunks were managed such that all feed offered was consumed within 24 hours.

Cattle were observed daily by trained feedyard personnel for disease or injury. Cattle deemed sick or injured were removed from the home pen for further diagnosis. Reason for death or removal, date, and body weight were recorded.

Cattle were shipped by replicate to a commercial slaughter facility. Trained abbatoir personnel recorded hot carcass weights. Quality grade and yield grade of all carcasses were assigned by USDA personnel. Trained university personnel recorded lung lesions, liver abscess lesions, and thoracic peel-out lesions at the time of slaughter.

Results and Discussion

Cattle performance and carcass characteristics were not affected by delaying the initial implant by 45 days (Tables 1 and 2). Cattle in the delayed-implant group had similar carcass weights ($P = 0.20$) compared with the arrival-implant group. Yield grades were not affected ($P = 0.16$) by treatment; however, delayed implanting tended to increase ($P = 0.09$) carcass value per pound. There was no difference in death loss or death loss due to respiratory disease for cattle that received their implant on arrival compared with delayed-implant cattle. Treatment did not affect ($P = 0.13$) the percentage of cattle pulled for disease; conversely, delaying implantation decreased ($P = 0.02$) the percentage of cattle railed due to chronic bovine respiratory disease illness (Table 3). Treatment did not affect ($P = 0.11$) case fatality rates.

Delaying implant administration did not affect peel-out rates, lung lesion rates, or liver abscess rates (Table 4). Over 50% of all cattle had lung lesions at slaughter, which indicated that they experienced a severe bovine respiratory disease challenge during the study. Pleural adhesion rates in this study averaged 20.7%.

Implications

High-risk calves can be implanted upon feedlot arrival without increasing risk of disease or harming performance.

Table 1. Feedlot performance and cost of gain for steers at high relative risk for bovine respiratory disease that were implanted either immediately upon feedlot arrival (Arrival) or 45 days post-arrival (Delayed)

Item	Arrival	Delayed	SEM	*P*-value
Number of pens	10	10		
Number of cattle	801	800		
Initial body weight, lb	604	603	10.5	0.97
Final body weight, lb	1,303	1,296	12.2	0.56
Average daily gain, lb	3.17	3.09	0.59	0.56
Dry matter intake, lb/day	19.45	19.24	0.24	0.40
Feed:gain	6.21	6.30	0.309	0.77
Days on feed	187	187	3.6	0.96
Cost of gain, deads in, $/cwt	76.24	77.50	4.01	0.76
Cost of gain, deads out, $/cwt	69.87	70.42	1.92	0.78

Table 2. Carcass traits and carcass value for steers at high relative risk for bovine respiratory disease that were implanted either immediately upon feedlot arrival (Arrival) or 45 days post-arrival (Delayed)

Item	Arrival	Delayed	SEM	*P*-value
Number of pens	10	10		
Number of cattle	801	800		
Hot carcass weight, lb	853	842	8.0	0.20
Quality grade				
Choice, %	42.8	44.1	3.00	0.67
Premium Choice, %	3.6	4.4	1.03	0.44
Select, %	52.7	52.2	3.24	0.87
No Roll, %	4.1	3.8	1.11	0.73
Yield grade	2.24	2.10	0.098	0.16
Yield grade 1, %	19	24.7	4.42	0.21
Yield grade 2, %	44.1	45.3	5.04	0.82
Yield grade 3, %	31.5	25.8	4.59	0.23
Yield grade 4, %	4.9	4.3	1.36	0.65
Price, $/cwt	$92.21	$93.62	0.79	0.09
Total sales, $/head	$1,109.10	$1,111.31	29.4	0.94

Table 3. Health data for steers at high relative risk for bovine respiratory disease that were implanted either immediately upon feedlot arrival (Arrival) or 45 days post-arrival (Delayed)

Item	Arrival	Delayed	SEM	*P*-value
Number of pens	10	10		
Number of cattle	801	800		
Morbidity, %	28.5	24.7	2.35	0.13
Days on feed at first treatment	30	27	5.6	0.58
Retreatment, %	9.4	8.2	1.18	0.31
Medicine cost, $/head	22.33	21.74	1.24	0.64
Railed, %	3.3	1.8	0.63	0.02
Mortality, %	7.9	9.0	2.07	0.61
Respiratory mortality, %	3.3	4.5	1.49	0.43
Case fatality rate, %	12.4	19.4	4.11	0.11

Table 4. Liver and lung abnormalities for steers at high relative risk for bovine respiratory disease that were implanted either immediately upon feedlot arrival (Arrival) or 45 days post-arrival (Delayed)

Item	Arrival	Delayed	SEM	*P*-value
Number of pens	10	10		
Number of cattle	801	800		
Pleural adhesions, %	20.1	21.3	2.45	0.63
Lung lesions, %	55.5	58.1	2.94	0.41
None	42.3	41.3	3.22	0.77
Minor	26.7	27.6	3.63	0.80
Severe	28.9	30.5	3.20	0.63
Abscessed livers, %	17.1	19.7	3.54	0.46
A-, %	13.8	15.3	3.62	0.69
Ao, %	2.1	3.2	1.20	0.40
A+, %	1.1	1.3	0.53	0.78

Effect of Transportation on *E. coli* O157:H7 Prevalence and Coliform Concentrations in Feces of Feedlot Cattle

C. Aperce and J.S. Drouillard

Introduction

Foodborne illness from *Escherichia coli* O157:H7 is a major concern for the food industry. Contamination of food products can occur at slaughter by contact with hide or feces. Limiting *E. coli* O157:H7 shedding is important to prevent outbreaks. Previous studies have demonstrated a relationship between stress and levels of pathogens shed in feces. During transport to the slaughterhouse, animals are subjected to large amounts of stress. This stress could increase shedding of *E. coli* O157:H7 prior to slaughter, and in so doing increase the risk of contamination of beef products by contact with hides or feces. Our objective in this study was to evaluate the effects of transportation on fecal shedding of *E. coli* 4 and 24 hours after transport compared with non-transported animals.

Experimental Procedures

The experiment was repeated three times over 29-hour periods. We used groups of 20 steers for each replication. Control steers remained in their pens at all times throughout the experiment. Transported cattle were loaded onto a trailer and transported for 1 hour to mimic the stress of transport to the abattoir, returned to the feedlot, and placed into concrete-surfaced pens to mimic pre-slaughter lairage. We collected fecal samples from freshly voided fecal pats from each animal at hours 0, 5, and 29 relative to loading onto the trailer. After the 0-hour sampling, the hauled group was loaded onto a trailer, transported for 1 hour, unloaded and placed into pens, and left to rest for 4 hours. At the end of the rest period (hour 5), all animals were sampled again. A final sampling was obtained 24 hours later (hour 29). Fecal samples were placed into plastic bags and kept on ice until they were transported to the Preharvest Food Safety Laboratory. Approximately 1 gram of feces was subsampled from each fecal pat, weighed, and transferred to a tube containing 9 mL Gram Negative Broth (Difco) with 0.05 mg/L cefixime, 10 mg/L cefsulodin, and 8 mg/L vancomycin (GNccv) and to another tube containing PBS. Tubes were vortexed for 1 minute. The PBS tube was serially diluted up to 10^{-6} and subsequently plated onto Petrifilm plates for enumeration of *E. coli* and total coliforms. Petrifilm plates were incubated at 99°F for 24 hours. The GNccv tubes were incubated at 104°F for 6 hours. After incubation, tubes were subjected to immunomagnetic separation using serotype-specific beads for *E. coli* O157:H7. Beads were resuspended in 200 µL of phosphate buffer and plated onto two MacConkey Sorbitol plates (CT-SMAC) containing cefixime (0.05 mg/L) and potassium tellurite (2.5 mg/L). Up to 6 non-sorbitol fermenting colonies from the CT-SMAC plate were selected and inoculated into 5 mL TSB. Colonies were grown overnight at 37°C and tested for indole production. Indole-positive colonies were plated on SMAC and further tested for O157 antigen agglutination. Colonies positive for indole production and antigen agglutination were confirmed as *E. coli* O157:H7 by Gram staining and API 20E.

Results and Discussion

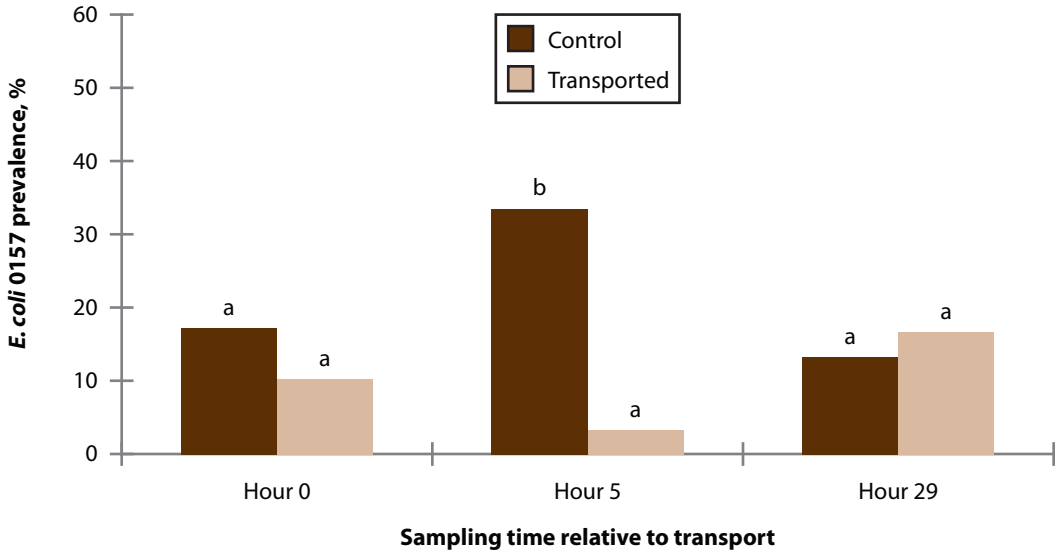
The statistical analysis revealed differences in *E. coli* O157 prevalence in the fecal samples from one replication to the next. This result was to be expected, because shedding of the pathogen is known to be transient. Additionally, we observed an interaction between sampling time and treatment, as well as an effect of treatment (Figure 1). We interpret these observations to suggest that transport may influence the timing of shedding or fecal pathogens. Prevalence of *E. coli* O157 in the transported group was fairly constant across the three sampling times (10, 3.3, and 16.7%, respectively; $P = 0.43$); however, a significant increase in the pathogen prevalence was observed in the control group at hour 5 (33%) compared with hour 0 (17%, $P = 0.06$) and hour 29 (13%, $P < 0.02$). These findings illustrate a change in shedding patterns of transported cattle relative to their non-transported counterparts, which may be the consequence of transport-related stress. The 4-hour lairage period after transport was chosen arbitrarily, and sampling at additional time points could reveal important changes in timing of pathogen shedding by transported and non-transported cattle.

As a secondary objective, we evaluated concentrations of *E. coli* (Figure 2) and other coliforms (Figure 3) in the samples to determine if these populations were related to variations in *E. coli* O157 prevalence. Most *E. coli* bacteria produce glucuronidase and will appear as blue colonies on Petrifilm, whereas the other coliforms will appear red. *Escherichia coli* O157 does not produce beta-glucuronidase, and thus is enumerated along with other coliforms. Numbers of *E. coli* or other coliforms remained fairly constant across replications (replication effect, $P > 0.1$). There were no significant correlations between prevalence of *E. coli* O157 and concentrations of total fecal coliforms. For the control group, coliform concentrations remained relatively stable over the different sampling times (Figure 3). *Escherichia coli* numbers decreased at hour 5 ($P < 0.05$) but rebounded by hour 29. The transported cattle had decreased fecal coliform concentrations at hour 5 (3.2 log CFU/gram; $P < 0.02$), but returned to pre-transport levels of 4.5 log CFU at hour 29. Total enumerable *E. coli* followed the same pattern, decreasing slightly by hour 5, then rebounding ($P < 0.01$) to 6.2 log at hour 29.

These results show a tendency for coliform concentrations to decrease at hour 5 in both of the treatments, suggesting that transport is not the causative factor in this change.

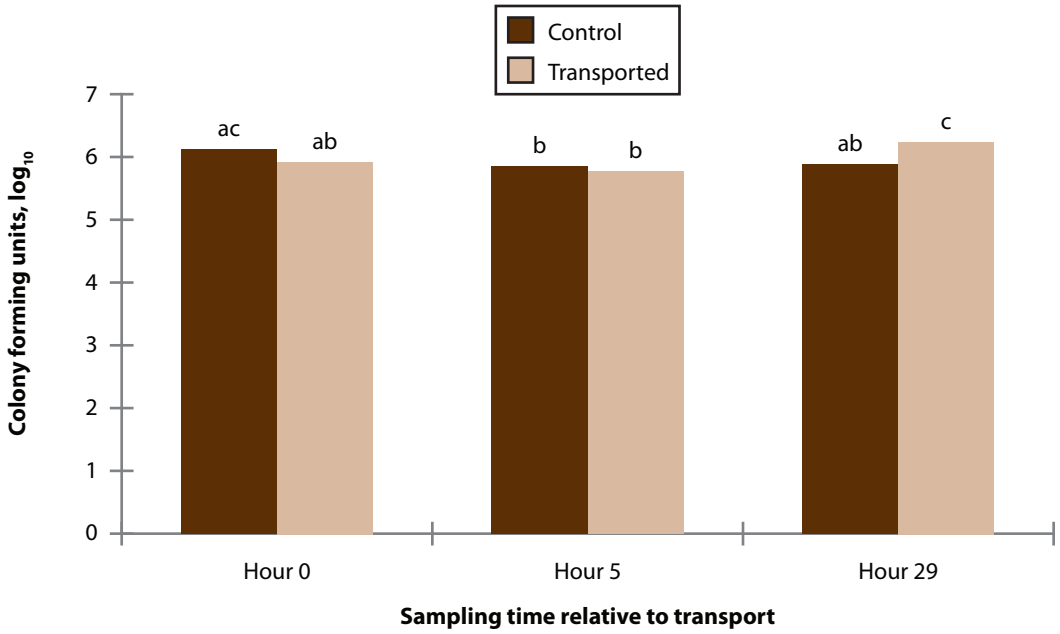
Implications

Our hypothesis was that stress from transport would alter the timing for fecal shedding of *E. coli* O157. Results suggest that shedding patterns for pathogens can indeed be influenced by transportation, which has potentially important ramifications for beef safety. Moreover, the data reveal the highly transient behavior of pathogen shedding within a period of only 29 hours, suggesting that pathogen populations can amplify and decay relatively quickly. In future experiments, investigating additional post-transit sampling times may be useful to determine more precisely the pathogen shedding patterns associated with cattle transportation and lairage.



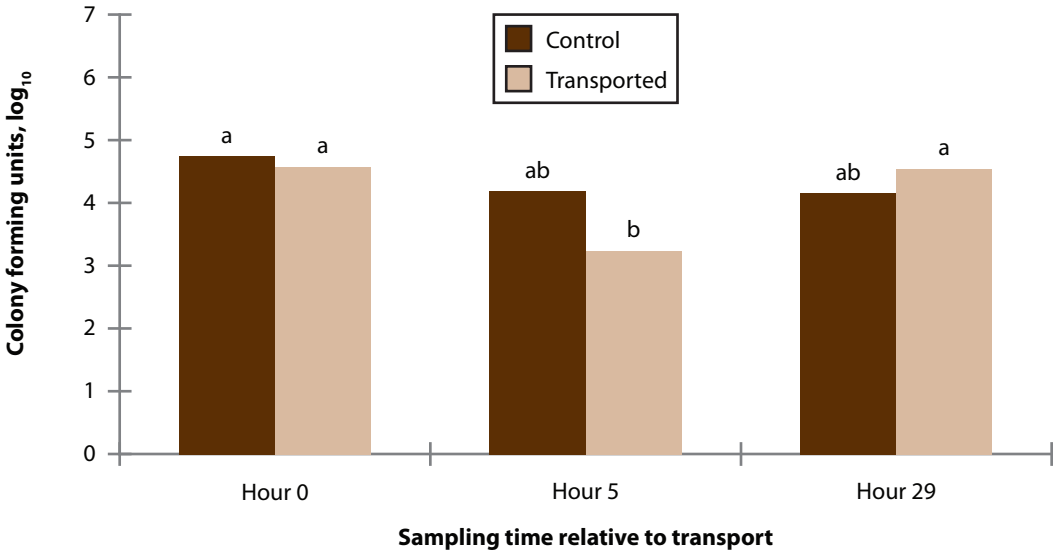
[ab] Columns with different letters differ at $P < 0.05$.

Figure 1. Prevalence of *E. coli* O157 in feces of feedlot cattle following transport and lairage.



[abc] Columns with different letters differ at $P < 0.05$.

Figure 2. Fecal concentrations of generic *E. coli* in feedlot cattle following transport and lairage.



[ab] Columns with different letters differ at $P < 0.05$.

Figure 3. Fecal concentrations of coliforms in feedlot cattle following transport and lairage.

Direct-Fed Microbials for Receiving Cattle I: Effects of ProTernative Stress Formula Fed in a Liquid Suspension on Growth and Health Performance of Receiving Beef Heifers

A.V. Siverson, D.A. Blasi, M.E. Corrigan, J.J. Higgins, and B.E. Oleen

Introduction

Lightweight stocker calves experience variable degrees of physiological stress resulting from weaning, transport, food and water deprivation, diet changes, inclement weather, and infectious diseases. Consequently, preconditioning and specialized nutrition that include direct-fed microbials may become more common in the beef industry as a means of controlling disease and minimizing the effects of stress.

Experimental Procedures

All procedures were approved by the Kansas State University Institutional Animal Care and Use Committee.

Over a 7-day period (June 23 through 30, 2010), 279 heifers (497 lb initial body weight) were assembled through sale-barn market facilities in Tennessee and transported to the Kansas State University Beef Stocker Unit. Upon arrival (day 0), all calves were weighed, given a visual identification tag, tested for bovine respiratory disease, assessed for initial overall health, and placed in a temporary pen. Calves were provided with brome grass hay (1.5% of body weight; 11.0% crude protein, and 0.34 Mcal/lb NEg) and water. Calves were blocked by truckload and randomly assigned to 1 of 24 pens by arrival weight. Treatments (Table 1) were assigned randomly to pen in an incomplete block design. The day after arrival, all calves were vaccinated for clostridial and viral diseases and dewormed. Animals allocated to the low- and high-dose ProTernative SF (Lallemand Animal Nutrition, Milwaukee, WI) treatments were drenched with 0.07 oz/head of their respective treatments in 3.8 oz of water, whereas control calves were drenched with water alone. All calves were revaccinated 14 days later. Feed ingredients were randomly sampled once for each base diet to determine nutrient content. The amount of feed delivered to each pen was recorded on a daily basis. Feed refusals were weighed and recorded. Calves were gradually adapted to their final diets using the step-up diets shown in Table 2. All diets contained Rumensin (Elanco Animal Health, Greenfield, IN) at 660 g/ton of dry matter.

Treatments were administered once daily for 44 days as a liquid top-dress (3.8 oz/head daily) on the morning feed ration. Care was taken to evenly distribute the allotted supplement across the bunk line of each pen. Animals were individually weighed at initial processing (day 0), during revaccination (day 14), and at the end of the study. Weights were collected prior to the morning feed delivery.

All calves were observed twice daily for symptoms of sickness or lameness. Caregivers were blinded to treatment. Calves with a clinical illness score greater than 1 (1 = normal, 2 = slightly ill, 3 = moderately ill, or 4 = severely ill) were removed from their respective pens for physical examination. Animals with a rectal temperature ≥103.6°F were treated for bovine respiratory disease.

Results and Discussion

Incidence of respiratory disease was relatively high; however, treatment had no effect on average daily gain or dry matter intake (Table 3). Similarly, treatment had no effect on the number of heifers treated once or twice for respiratory disease. A greater percentage of heifers in the ProTernative SF groups tended ($P = 0.06$) to require a third treatment for bovine respiratory disease compared with the control group. Control calves also tended to have greater ($P < 0.10$) average daily gain than treated calves.

Implications

ProTernative SF direct-fed microbial delivered as a liquid suspension had no influence on dry matter intake, average daily gain, or health of high-risk beef calves.

Table 1. Direct-fed microbial treatments applied to highly stressed heifers during receiving

Treatment	Dose, oz/head daily
Control	0.0
ProTernative SF, low dose	0.017
ProTernative SF, high dose	0.035

Table 2. Composition of diets fed to highly stressed heifers during receiving

Ingredient	Diet 1	Diet 2	Final diet
Number of days fed	8	10	26
Cracked corn	28.0	29.0	36.0
Wet corn gluten feed	30.0	37.0	37.0
Alfalfa hay	23.0	15.0	9.0
Prairie hay	16.0	16.0	16.0
Supplement	3.0	3.0	3.0
Nutrient composition			
Dry matter %	70.47	66.19	78.04
Crude protein, %	15.33	15.75	13.31
NE_m, Mcal/lb	0.79	0.81	0.82
NE_g, Mcal/lb	0.46	0.48	0.49
Calcium, %	0.93	1.29	0.75
Phosphorus, %	0.38	0.42	0.44

Table 3. Performance of highly stressed heifers during receiving that were orally treated with no direct-fed microbial (Control), a low dose of ProTernative SF, or a high dose of ProTernative SF direct-fed microbial

Item	Control	Low dose	High dose	SEM
Dry matter intake, lb/day	12.52	12.64	12.80	0.48
Average daily gain, lb	2.81	2.93	2.98	0.10
Feed:gain	4.46	4.33	4.28	0.153
Morbidity, %	38.8	47.5	30.3	0.99

Direct-Fed Microbials for Receiving Cattle II: Effects of ProTernative Stress Formula Fed in a Dry Suspension on Growth, Feed Intake, and Health of Receiving Beef Heifers

A.V. Siverson, D.A. Blasi, M.E. Corrigan, J.J. Higgins, and B.E. Oleen

Introduction

Enhanced preconditioning and nutritional management strategies are needed industrywide as a means of controlling stress and related health problems for freshly arrived stocker calves. Direct-fed microbials are feed additives that stimulate natural, nonpathogenic gut flora in an attempt to stimulate competition against potentially pathogenic gut flora. Previous research involving direct-fed microbials offered in a liquid suspension to lightweight stocker calves produced no effects on growth or health performance. Therefore, the objective of our study was to evaluate the effects of a direct-fed microbial offered as a dry suspension on feed intake, average daily gain, and morbidity of highly stressed beef heifers.

Experimental Procedures

All procedures were approved by the Kansas State University Institutional Animal Care and Use Committee.

Over a 7-day period (May 11 through 18, 2011), 287 heifers (497 lb initial body weight) were assembled through auction market facilities in Tennessee and transported to the Kansas State University Beef Stocker Unit in three semi-truck loads. Travel time for the calves was 12 to 18 hours. Upon arrival, all calves were weighed, given a visual identification tag, tested for bovine respiratory disease, assessed for initial overall health, and placed in a temporary pen. Calves were provided with brome grass hay (1.5% of body weight; 11.0% crude protein and 0.34 Mcal/lb NEg) and water overnight. Calves were blocked by truckload and randomly assigned to 1 of 24 pens by arrival weight. Treatments (Table 1) were assigned randomly to pen in an incomplete block design. The day after arrival, calves were vaccinated for clostridial and viral diseases and dewormed. All calves were re-vaccinated 14 days later. Treatments consisted of a control (no probiotic) or ProTernative SF (Lallemand Animal Nutrition, Milwaukee, WI) direct-fed microbial.

Calves were gradually adapted to treatment diets using the step-up system shown in Table 1. Step-up diets consisted of native bluestem prairie hay, alfalfa hay, dry rolled corn, wet corn gluten feed, and a commercial premix pellet that provided Rumensin (Elanco Animal Health, Greenfield, IN) at the rate of 660 g/ton of diet dry matter.

Treatments were administered once daily for the duration of the trial. Treated cattle were fed 0.032 lb of ProTernative SF/head daily, which was premixed with 0.25 lb of dried distillers grains and top-dressed onto the morning feed ration. This supplement

provided 2×10^{10} CFU/animal daily of *Saccharomyces boulardii* (CNCM I- 1079). Control cattle received 0.25 lb/heifer daily of dried distillers grains as a top-dress. Care was taken to evenly distribute the allotted supplements across the bunk line of each pen.

Feed ingredients were randomly sampled once for each base diet to determine nutrient content. The amount of feed delivered to each pen was recorded on a daily basis. Feed refusals were weighed and recorded.

Animals were individually weighed at initial processing (day 0), during revaccination (day 14), and at the end of the study (day 44). Weights were measured before the morning feed delivery.

Calves were observed twice daily for symptoms of sickness or lameness. Caregivers were blinded to treatment. Calves with a clinical illness score greater than 1 (1 = normal, 2 = slightly ill, 3 = moderately ill, or 4 = severely ill) were removed from their respective pens for physical examination. Animals with a rectal temperature ≥103.6°F were treated for respiratory disease.

Results and Discussion

Treatment had no effect ($P > 0.83$) on average daily gain or dry matter intake (Table 2). In general, growth performance and feed intake of all pens was excellent. ProTernative SF had no influence on growth performance or morbidity rate.

Implications

Daily supplementation of ProTernative SF delivered in a dry premix did not influence health, feed consumption, or average daily gain of high-risk beef heifers.

Table 1. Composition of diets fed to highly stressed heifers during receiving

Ingredient	Diet 1	Diet 2	Final diet
Number of days fed	8	10	26
Cracked corn	28.0	29.0	36.0
Wet corn gluten feed	30.0	37.0	37.0
Alfalfa hay	23.0	15.0	9.0
Prairie hay	16.0	16.0	16.0
Supplement	3.0	3.0	3.0
Nutrient composition			
Dry matter %	70.47	66.19	78.04
Crude protein, %	15.33	15.75	13.31
NE_m, Mcal/lb	0.79	0.81	0.82
NE_g, Mcal/lb	0.46	0.48	0.49
Calcium, %	0.93	1.29	0.75
Phosphorus, %	0.38	0.42	0.44

Table 2. Performance of highly stressed heifers during receiving that were orally treated with no direct-fed microbial or ProTernative SF direct-fed microbial

Item	Control	ProTernative SF	SEM
Dry matter intake, lb/day	16.3	16.5	0.16
Average daily gain, lb	4.02	4.02	0.07
Feed:gain	3.98	3.90	0.065
Morbidity, %	17.6	10.9	0.50

MGA and Growth Promotants Administered to Beef Feedlot Heifers Have No Effect on Subsequent Oocyte Quality or *in vitro* Embryo Production

N. Miller, D. Grieger, and K. Fike

Introduction

Beef feedlot heifers have the potential to serve as viable donors of oocytes post-slaughter for *in vitro* embryo production. Oocyte quality is a critical factor affecting the success of *in vitro* embryo production and can be influenced by factors such as age and reproductive status, ovarian follicle size, and nutritional status of the donor female. In a conventional feedlot setting, heifers are typically administered steroid-based growth promotants and fed melengestrol acetate (MGA) for suppression of estrus, which increases circulating concentrations of reproductive steroids, particularly estradiol. The effects of these management practices on oocyte quality and numbers are unknown. The purpose of this study was to compare oocytes harvested from traditionally managed beef feedlot heifers implanted with growth promotants and fed MGA with oocytes from heifers given neither MGA nor growth promotants, and to evaluate potential effects of these feedlot management practices on early embryo development.

Experimental Procedures

Beef heifers (n = 172) were fed a finishing diet at the Kansas State University Beef Research Center feedlot for 120 days. Heifers were divided into 2 treatments: (1) conventionally managed heifers (MGA-Implant) were fed MGA (0.5 mg/head/day) for 120 days and implanted with a single growth promotant 120 days prior to harvest (Revalor IH; 80 mg trenbolone acetate and 8 mg estradiol; Merck Animal Health, Summit, NJ); and (2) control heifers did not receive either MGA or growth promotants during the finishing period.

Heifers were harvested and ovaries were collected within 30 minutes of harvest, then grouped within treatment based on time from harvest to ovary collection. Oocytes were aspirated from collected ovaries using a vacuum pump system and maintained in groups based on time of heifer harvest. All media were provided by Sexing Technologies, Inc. (Navasota, TX). Oocytes were washed twice in TL-Hepes media then evaluated. Oocytes that were denuded, had discolored cytoplasm, or were starting to degenerate were recorded and subsequently removed from the study. Remaining oocytes were placed in M199 holding media until all oocytes were collected. Four to five hours post-slaughter, all oocytes were placed in maturation media and shipped overnight to begin the *in vitro* fertilization (IVF) process at Sexing Technologies, Inc. laboratory facilities.

After 23.5 hours in maturation media, oocytes were placed in fertilization media with semen from a Holstein bull with proven IVF quality (per Sexing Technologies, Inc.) at 1.0 x 10^6 sperm/mL. After 18 hours in fertilization media, the presumptive zygotes were washed twice in TL-Hepes media. All cumulus cells were then removed from the

zygotes. Any zygotes with cracked zona pellucidas, shrinking cytoplasms, or lacking clear polar bodies were recorded and subsequently removed from the study. Remaining zygotes were placed in culture media for 7 days.

On day 2 post-IVF, developmental stages were assessed, including the number that achieved 8-cell, 2- to 4-cell, and 1-cell stages of early embryo development. Any cells that had not divided by day 2 were removed from the study. On day 7, embryo grades were assigned. Morula, early blastocyst, and blastocyst stages of development were classified as C2 embryos but considered to be of insufficient quality for freezing; $C1^{-}$ embryos were those that were blastocyst or expanded blastocyst stages and freezable; and C1 embryos were those with a very compact inner cell mass and were beginning to hatch and were freezable.

Results and Discussion

A total of 1,820 oocytes were harvested from 152 ovaries in the MGA-Implant group. The control group yielded 1,272 oocytes from 145 ovaries. A tendency for a time × treatment interaction was observed for the number of oocytes per ovary ($P = 0.07$). Fertilization rate (zygotes produced per the number of oocytes with opportunity to be fertilized) was similar for both treatments (MGA-Implant: 79.9%, Control: 82.3%; Figure 1), indicating no effect of treatment on the ability of oocytes to be fertilized. A similar percentage of zygotes (successfully fertilized oocytes) per ovary cleaved by day 2 post-IVF (MGA-Implant: 46.8%, Control: 47.9%; Figure 1). Cleavage rates were determined by evaluating the total number of zygotes that had achieved the 2- to 8-cell stage of early embryo development by day 2 post-IVF per number of zygotes produced and are indicative of early embryonic growth. A similar number of embryos per ovary were produced for both the MGA-Implant and control groups (Figure 2). Freezable embryos (C1 and $C1^{-}$) produced were also similar for both treatments (Figure 2). Across both groups, the majority of embryos produced were assigned a grade of C2, which are those embryos that are of sufficient quality for fresh transfer, but not freezable.

Beef feedlot heifers fed MGA and administered steroid-based growth promotants can serve as a viable source of oocytes for *in vitro* embryo production. Feeding MGA and administering growth promotants to heifers does not affect oocyte fertilization rate, early embryo development, or number of *in vitro* embryos produced compared with heifers not fed MGA or administered growth promotants.

Implications

Administration of MGA and growth promotants to feedlot heifers has no subsequent effects on number of oocytes harvested or *in vitro* embryos produced. Beef feedlot heifers have the potential to serve as a source of viable oocytes for large-scale *in vitro* embryo production.

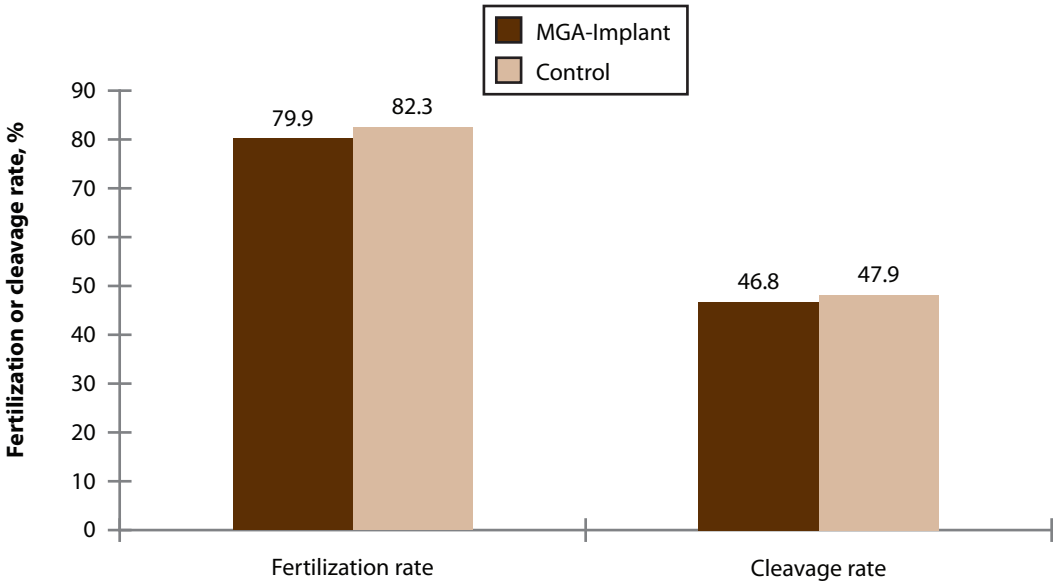


Figure 1. Fertilization (zygotes produced per oocytes with opportunity to be fertilized) and cleavage rates (2- to 8-cell embryos produced per number of zygotes) of oocytes and zygotes, respectively. Oocytes were harvested from beef feedlot heifers fed melengestrol acetate (MGA) and implanted with growth promotants (MGA-Implant) or untreated (Control) and subjected to *in vitro* fertilization.

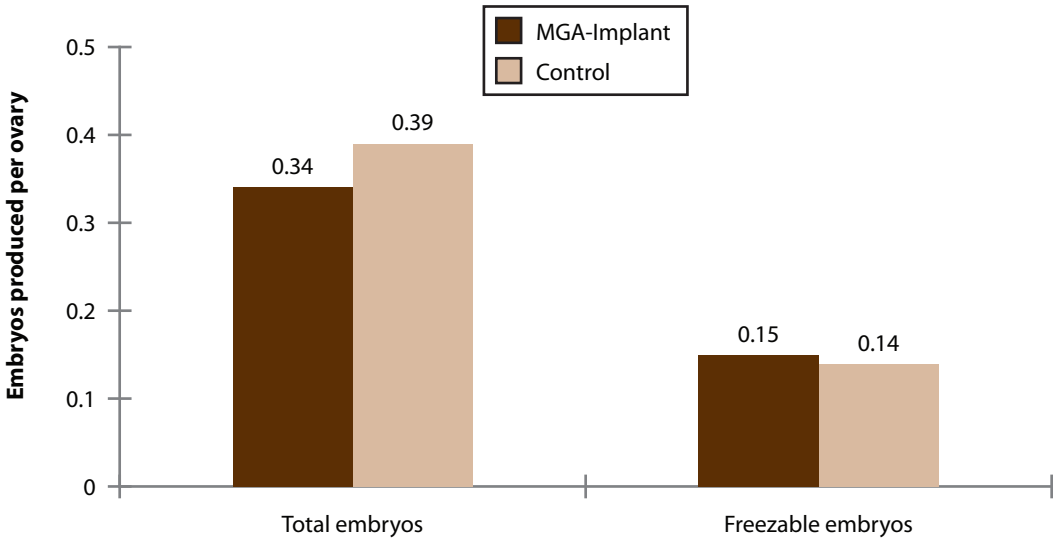


Figure 2. Total and freezable embryos produced per ovary from *in vitro* fertilization of oocytes harvested from beef feedlot heifers fed melengestrol acetate (MGA) and implanted with growth promotants (MGA-Implant) or untreated (Control).

Presynchronizing Prostaglandin $F_{2\alpha}$ Injection before Timed Artificial Insemination CO-Synch + CIDR Program

S.L. Hill, S.L. Pulley, H.I. Mellieon, Jr., KC Olson, J.R. Jaeger, R.A. Breiner, G.A. Perry[1], G.C. Lamb[2], and J.S. Stevenson

Introduction

Fixed-time artificial insemination is an effective management tool that reduces the labor associated with more conventional programs that require detection of estrus. The 7-day CO-Synch + controlled internal drug release (CIDR) insert protocol has been shown to effectively initiate estrus and ovulation in cycling and non-cycling suckled beef cows, producing pregnancy rates at or greater than 50% in beef cows. The gonadotropin-releasing hormone (GnRH) injection that begins the CO-Synch + CIDR program initiates ovulation in a large proportion of cows, particularly anestrous cows. The CIDR, which releases progesterone intravaginally, prevents short estrous cycles that usually follow the first postpartum ovulation in beef cows. Our hypothesis was that inducing estrus with a prostaglandin injection 3 days before applying the 7-day CO-Synch + CIDR protocol might increase the percentage of cycling cows that would exhibit synchronous follicular waves after the onset of the CO-Synch + CIDR protocol, thereby increasing pregnancy outcomes.

Experimental Procedures

A total of 1,537 primiparous and multiparous cows from 9 locations in 4 states (Florida, Georgia, Kansas, and South Dakota) were enrolled in this study. Characteristics of suckled beef cows enrolled by location are summarized in Table 1. Cows were stratified by breed, days postpartum, and parity, then assigned randomly to either of 2 treatments. Control cows received the standard CO-Synch +CIDR program (100 μg GnRH; 2 mL Factrel; Pfizer Animal Health, Whitehouse Station, NJ) 7 days before and 72 hours after 25 mg prostaglandin $F_{2\alpha}$ [PG; 5 mL Lutalyse; Pfizer Animal Health). A new CIDR insert (Pfizer Animal Health) containing 1.38 g progesterone was placed intravaginally at the time of the first GnRH injection (day -10). Treated cows (Figure 1) received 25 mg PG 3 days before (day -13) the CO-Synch + CIDR program began.

Body condition scores (1 = thin; 9 = very fat) were assigned at the time PG $F_{2\alpha}$ was administered to the experimental group on day -13. Estrus-detection patches (Estrotect, Rockway, Inc., Spring Valley, WI) were affixed to all cows. Estrus-detection patches were removed on day -10 and scored (0 = not colored, 1 = partially colored, and 2 = completely colored). On day -3 CIDR inserts were removed, a second estrus-detection patch was applied, and PG was administered to all cows in both treatments. Only 3.6% of patches were scored as 1 (partially colored) by d -10 (3 days after the treatment PG injection) and 5.5% of patches were scored as 1 at the timed artificial insemination. Therefore, we eliminated those cows with patch scores of 1 and assumed that cows with

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patch scores of 0 did not show estrus, whereas those with completely colored patches had been mounted and were in estrus sometime after the PG injections.

Blood samples were collected via caudal vessel puncture at days -23, -13, -10, -3, and 0. Samples were assayed for progesterone using radioimmunoassay. Cows with blood progesterone >0.95 ng/mL on days -23, -13, or -10 or that had a completely colored estrus-detection patch on day -10 were assumed to have reestablished estrous cycles and were classified as cycling. The sample collected at day -3 reflected progesterone concentrations resulting from the CIDR insert, a functional corpus luteum, or both.

Artificial insemination was performed 72 hours after CIDR insert removal on day 0, and estrus-detection patches were removed and scored. Cows were either exposed to cleanup bulls 10 to 12 days later or reinseminated at subsequent estrus. At 35 days after artificial insemination, pregnancy was confirmed by transrectal ultrasonography (Aloka 500V, 5MHz transrectal transducer, Wallingford, CT). A positive pregnancy outcome required the 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. Embryonic losses in cows that conceived to the timed artificial insemination were determined at that time.

Results and Discussion

Cyclicity in the cows averaged 44.7% (range 16.4 to 69.5%) across the nine locations at the beginning of the protocol (Table 1). The percentage of primiparous cows varied by location (0.7 to 37.8%). Average body condition score ranged from 4.3 to 6.0. Multiparous cows treated with PG on day -13 had a greater ($P < 0.05$) incidence of estrus after both $PGF_{2\alpha}$ injections than primiparous cows in both treatments and other multiparous control cows (Figure 2), indicating that more multiparous cows were cycling and responded to PG. Based on the estrus response, an alternative breeding option with the PG treatment could include inseminating cows detected in estrus after the PG injection and apply the timed artificial insemination option to all remaining cows.

Consistency in timed artificial insemination pregnancy outcome among locations was observed with acceptable pregnancy rates >50% at all but one location in both treated and control cows (Figure 3). Pregnancy rates at day 35 and at the end of the breeding season did not differ between treatments (Table 2). Pregnancy loss of cows conceiving at the timed artificial insemination was minimal (<2%) between day 35 of pregnancy and the end of the breeding season. Pregnancy rates at day 35 (60.0 versus 47.7%) and at the end of the breeding season (96.2 versus 92.3%) were greater ($P < 0.001$) for multiparous than primiparous cows, respectively. Body condition score of cows had no effect on pregnancy outcomes.

Implications

Results indicate that the PG treatment and control are equally effective fixed-time artificial insemination protocols even in herds with a large percentage of anestrous cows. Both of these protocols were more effective in multiparous than primiparous cows in terms of greater pregnancy rate after timed artificial insemination. The PG treatment resulted in more visible estrus in multiparous cows. Results may differ if cows detected

in estrus after the first PG injection were inseminated and timed artificial insemination were applied to the remaining cows.

Table 1. Location characteristics of suckled beef cows enrolled in the study

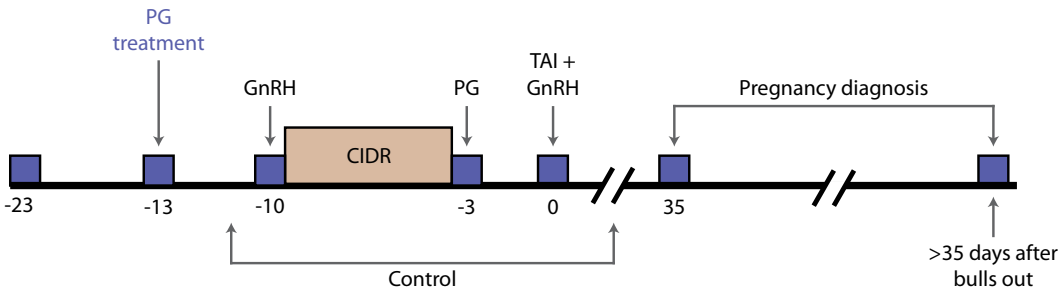
Location	Breed	No. of cows	2-year-olds, %	Days postpartum at artificial insemination[1]	Body condition[1]	Cyclicity, %
FL-1	Angus, Charolais, Brangus	228	10.5	69 ± 0.7	5.0 ± .03	...[2]
FL-2	Angus, Charolais, Brangus	146	8.2	54 ± 0.5	5.3 ± .04	...[2]
GA-1	Angus	126	21.4	75 ± 0.8	5.0 ± .06	65.1
KS-H	Angus × Hereford	195	25.1	80 ± 1.2	5.7 ± .05	53.3
KS-C	Angus × Hereford	205	27.8	71 ± 0.7	6.0 ± .03	50.2
KS-P	Angus, Hereford, Simmental	167	27.0	69 ± 1.2	5.2 ± .05	69.5
SD-A	Angus × Hereford	222	37.8	74 ± 1.1	4.4 ± .03	22.7
SD-C	Angus × Hereford	104	31.1	75 ± 2.1	4.9 ± .06	36.5
SD-CT	Angus × Hereford	144	0.7	67 ± 0.9	4.3 ± .04	16.4

[1] Mean ± SE.
[2] No blood samples were collected at these locations.

Table 2. Pregnancy rates based on treatment, parity, and body condition score

	Treatment[1]	
Item	Control	PG + CO-Synch + CIDR
	----- % (n) -----	
Timed artificial insemination 35-day pregnancy rate, %	52.2 (770)	55.6 (766)
Final pregnancy rate, %	93.8 (766)	95.2 (764)
Pregnancy loss, %	1.4 (427)	1.4 (451)
Parity[2]		
1 (primiparous)	45.7 (165)	49.8 (166)
≥2 (multiparous)	58.6 (605)	61.4 (600)
Body condition score[3]		
≤5	53.0 (455)	55.8 (463)
>5	51.2 (315)	55.7 (303)

[1] See Figure 1 for description of treatments.
[2] Multiparous cows had greater ($P < 0.001$) pregnancy rates than primiparous cows.
[3] 1 = thin, 9 = very fat.



GnRH = gonadotropin-releasing hormone (Factrel); PG = prostaglandin $F_{2\alpha}$ (Lutalyse);
CIDR = controlled internal drug release containing progesterone; TAI = timed artificial insemination.

Figure 1. Experimental protocol illustrating sequence of treatments and measurements.

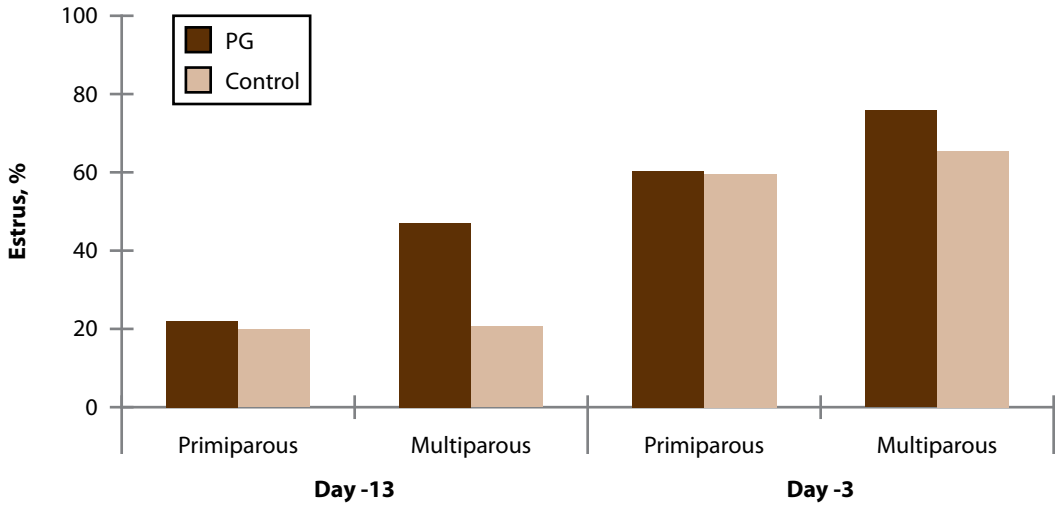


Figure 2. Percentage of cows exhibiting estrus by 72 hours after prostaglandin $F_{2\alpha}$ (PG) injections on day -13 and day -3.

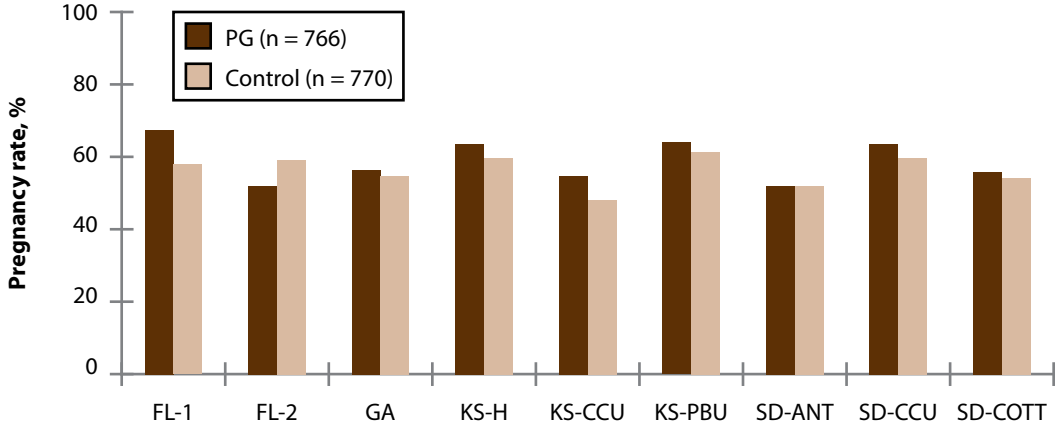


Figure 3. Unadjusted pregnancy rates after timed artificial insemination for cows at 9 locations in 4 states.

Spring Burning of Native Tallgrass Pastures Influences Diet Composition of Lactating and Non-Lactating Beef Cows

N.A. Aubel, KC Olson, J.R. Jaeger, G.J. Eckerle, L.A. Pacheco, M.J. Macek, L.R. Mundell, and L.W. Murray

Introduction

Diet selection is a dynamic process because of seasonal changes in animal and plant characteristics. Nutrient requirements of grazing animals are a function of physiological state; moreover, plant characteristics may be altered with prescribed spring burning of native rangelands. Prescribed spring burning is used to improve the average quality of pasture forage by removing old growth and making new plant growth more accessible to grazing cattle.

Microhistological analysis of fecal material has been a widely used method for quantifying the botanical composition of a grazing animal's diet since it was first described by Baumgartner and Martin in 1939. Little research has been conducted on how diet selection preferences of lactating beef cows with suckling calves and non-lactating beef cows are influenced by prescribed burning. We hypothesized that during the summer grazing season, lactating cows with calves and non-lactating cows would display distinctive preferences for certain species. Furthermore, we anticipated that these diet selection preferences might be influenced by prescribed burning. To that end, our objective was to characterize differences in diet selection between lactating beef cows suckling calves and non-pregnant, non-lactating beef cows grazing either burned or unburned native tallgrass prairie during summer.

Experimental Procedures

The study was conducted on 8 native tallgrass pastures (approximately 240 acres each) located at the Kansas State University Commercial Cow-Calf Unit. Four of the pastures were burned in mid-April and 4 had no recent burning history. Predominant pasture forage species at this location were big bluestem (*Andropogon geradii*) and little bluestem (*Schizachyrium scoparium*), which were grouped together for the purposes of microhistological analysis; sideoats grama (*Bouteloua curtipendula*); blue grama (*Bouteloua gracilis*); switchgrass (*Panicum virgatum*); indiangrass (*Sorghastrum nutans*); leadplant (*Amorpha canescens*); heath aster (*Symphyotrichum ericoides*); dotted gayfeather (*Liatris punctata*); and purple prairie clover (*Dalea purpurea*). Grazing commenced May 15.

Treatments consisted of 32 mature, pregnant, lactating beef cows suckling calves (L; initial body weight = 1,248 ± 123 lb) with 32 mature, non-pregnant, non-lactating beef cows (NL; initial body weight = 1,215 ± 117 lb). Four L and 4 NL cows were grouped randomly and assigned to graze a single burned or unburned pasture for 120 days. The L and NL cows were allowed to commingle within pastures and remained in their assigned pasture throughout the study. Water, salt, and a granular, salt-based mineral

supplement (17% NaCl, 16% Ca, 8% Pl, 0.2% Mg, 3,300 ppm Zn, 1,200 ppm Cu, and 0.22 ppm Se) were available to cattle continually.

Cows were gathered into a corral and fecal grab samples were collected from each animal on day 30, 60, 90, and 120 of the grazing period. Each grab sample was hand-mixed to ensure homogeneity, and a 40-g subsample was retained for analysis. Samples were prepared by soaking overnight in 50% EtOH (volume/volume). After soaking, samples were homogenized and washed with deionized water through a no. 200 US standard sieve to remove contaminants. Samples were then dried and ground to pass a 1-mm screen for slide preparation.

For slide preparation, subsamples of dried, ground, and washed fecal material were soaked to soften them, rinsed with deionized water, homogenized, and rinsed a second time. Subsamples were placed on slides using an eyedropper, 1 to 3 drops of Hertwig's solution was applied, and the slide was placed over a propane flame until dry. One to two drops of Hoyer's solution was added to mount a cover slip. Slides were dried before viewing.

Slides were viewed on a compound microscope at 10× magnification. The microscope was equipped with a digital camera; each slide field was photographed for comparison with standard slides. Twenty fields per slide were selected randomly from the entire slide view and were used to measure the frequency with which plant fragments appeared. Individual plant species were identified according to their histological characteristics. Plant fragment prevalence in slide fields was assumed to be equivalent to prevalence in fecal samples and equivalent to percentage of botanical composition of the diets grazed by beef cows. Plant fragments that were not among the 10 predominant range plants for which standards were prepared were classified as either an unknown grass or an unknown forb.

Results and Discussion

Previous results suggested that lesser maintenance requirements could result in less selective foraging behaviors by non-lactating compared with lactating ruminants. Previous research also indicated lactating cows grazed more selectively than non-lactating, non-pregnant cows; however, we found no treatment differences ($P \geq 0.11$) in the botanical diet composition between lactating and non-lactating cows (Table 1). Similar findings were reported that found no differences in diet composition between lactating ewes and non-lactating ewes.

Cows consumed more ($P = 0.01$; 74.2 versus 71.8%, respectively) grasses and fewer ($P = 0.01$; 25.8 versus 28.2%, respectively) forbs on burned pastures compared with unburned pastures (Table 2). Research suggests that unburned pastures have a greater selection of forbs compared with burned pastures because burning reduced forb availability. Cows ate more ($P < 0.01$) sideoats grama and less ($P \leq 0.02$) switchgrass, leadplant, and purple prairie clover on burned pastures than on unburned pastures.

As the grazing season progressed, selection of switchgrass increased (burn × period effect, $P = 0.09$) sharply in both burned and unburned pastures, whereas selection of sideoats grama generally decreased (burn × period effect, $P < 0.01$; Table 3). Selection

of leadplant doubled (burn × period effect, $P = 0.04$) on burned pastures month-by-month, but selection was inconsistent in unburned pastures. Selection of dotted gayfeather ranged from 12.3 to 20.4% of the diet in June, July, and August and diminished to 8.5 to 8.9% in September (burn × period effect, $P = 0.05$).

Cows selected more ($P < 0.01$) switchgrass, blue grama, leadplant, and heath aster over time, whereas they selected less ($P < 0.01$) indiangrass over time (Table 4). Palatability is a major factor driving selection preferences by grazing herbivores and is reduced as plants approach reproductive maturity and dormancy. Under unrestricted grazing conditions, herbivore preference for specific forage plants is known to change over time. The cows used in our study may have modified their diets over time to select greater proportions of plants that were slower to reach maturity. Alternatively, decreased consumption over time may have been related to diminishing availability or regrowth of certain forage plants.

Consumption of all grasses and all forbs changed slightly ($P < 0.01$, Table 4) from month to month during the grazing season; however, the relative proportions of grasses and forbs remained consistently within the range of 71 to 75% grasses and 25 to 29% forbs.

Implications

The botanical composition of diets grazed by beef cows during summer in the Kansas Flint Hills was influenced by prescribed spring burning but was not influenced by lactation status. We interpreted these data to suggest that forage selection preferences of beef cows can be altered with spring burning of native tallgrass pastures.

Table 1. Effect of collection period on botanical composition of diets (%) selected by lactating cows with calves or non-lactating, non-pregnant cows grazing the Kansas Flint Hills during summer

						P-values		
Item	June 15	July 15	August 15	September 15	SEM	Treatment	Period	Treatment × period
Total grasses, %								
Lactating	74.1	70.8	72.3	72.7	1.03	0.18	<0.01	0.45
Non-lactating	76.7	71.3	73.6	72.4				
Big bluestem + little bluestem, %								
Lactating	6.1	12.9	13.9	10.9	1.15	0.37	<0.01	0.15
Non-lactating	8.2	11.9	13.2	11.8				
Indiangrass, %								
Lactating	50.4	37.7	35.2	29.4	1.36	0.12	<0.01	0.60
Non-lactating	51.6	37.6	38.3	31.3				
Switchgrass, %								
Lactating	4.2	4.4	7.5	10.4	0.76	0.88	<0.01	0.41
Non-lactating	3.7	5.0	7.1	10.8				
Blue grama, %								
Lactating	1.8	2.3	5.4	14.9	0.51	0.83	<0.01	0.16
Non-lactating	2.5	2.5	4.5	10.8				
Sideoats grama, %								
Lactating	8.6	11.7	8.6	4.7	0.69	0.94	<0.01	0.20
Non-lactating	7.5	11.9	8.6	5.5				
Total forbs, %								
Lactating	25.9	29.2	27.7	27.3	1.03	0.18	<0.01	0.45
Non-lactating	23.3	28.7	26.4	27.6				
Purple prairie clover, %								
Lactating	7.4	6.9	6.9	7.9	0.80	0.92	0.25	0.88
Non-lactating	7.5	6.5	6.9	8.5				
Leadplant, %								
Lactating	0.6	0.8	1.7	3.4	0.43	0.25	<0.01	0.41
Non-lactating	0.9	0.9	1.5	4.0				
Dotted gayfeather, %								
Lactating	15.5	19.8	15.9	8.8	1.02	0.11	<0.01	0.35
Non-lactating	12.7	19.5	15.1	8.6				
Heath aster, %								
Lactating	0.6	0.9	2.5	6.2	0.69	0.63	<0.01	0.07
Non-lactating	1.0	0.9	2.1	5.2				

Table 2. Effects of pasture burning regime on botanical composition of diets selected by beef cows grazing the Kansas Flint Hills during summer

Item	Burned	Unburned	SEM	*P*-value
Total grasses, %	74.2	71.8	0.52	0.01
Switchgrass, %	5.3	7.2	0.27	<0.01
Sideoats grama, %	9.0	7.1	0.26	<0.01
Total forbs, %	25.8	28.2	0.52	0.01
Leadplant, %	1.1	1.7	0.12	<0.01
Purple prairie clover, %	6.4	8.3	0.50	0.02

Table 3. Burn regime × collection period effects on botanical composition of diets selected by beef cows grazing the Kansas Flint Hills during summer

Item	June 15	July 15	August 15	September 15	SEM	*P*-value
Switchgrass, %						
Burned	2.9	4.2	6.3	9.9	0.80	0.09
Unburned	5.2	5.3	8.5	11.4		
Sideoats grama, %						
Burned	10.1	13.8	8.9	5.2	0.78	<0.01
Unburned	6.4	10.0	8.4	5.0		
Leadplant, %						
Burned	0.4	0.8	1.5	3.2	0.37	0.04
Unburned	1.2	0.9	1.7	4.2		
Dotted gayfeather, %						
Burned	16.0	18.9	15.8	8.9	1.04	0.05
Unburned	12.3	20.4	15.2	8.5		

Table 4. Effect of collection period on botanical composition of diets selected by beef cows grazing the Kansas Flint Hills during summer

Item	June 15	July 15	August 15	September 15	SEM	*P*-value
Total grasses, %	75.5	71.1	73.0	72.5	0.71	<0.01
Indiangrass, %	51.0	37.7	36.7	30.3	0.97	<0.01
Switchgrass, %	3.9	4.7	7.3	10.6	0.51	<0.01
Blue grama, %	2.1	2.4	5.0	12.7	1.23	<0.01
Total forbs, %	24.5	28.9	27.0	27.5	0.70	<0.01
Leadplant, %	0.7	0.8	1.6	3.7	0.30	<0.01
Heath aster, %	0.8	0.9	2.3	5.7	0.61	<0.01

Increasing Protein Supply to Pregnant Beef Cows When Energy Is Limited Does Not Improve Cow or Calf Performance

E.A. Bailey, E.C. Titgemeyer, R.C. Cochran, T.J. Jones, and KC Olson

Introduction

Pre- and postpartum deficiencies of metabolizable protein have been identified as potentially limiting to productivity of beef cows and calves. Pre-partum supplementation of forage-based diets with ruminally undegraded protein has increased weight gain and breeding performance in prior studies, but the level of ruminally degraded protein fed was not known. Feeding adequate ruminally degraded protein to beef cows maximizes the productivity of microbes in the rumen, so any benefits shown in prior work could have been attributed to increased ruminal fermentation.

Our objectives were (1) to determine the value of supplementing ruminally undegraded protein when dietary ruminally degraded protein supply was estimated to be adequate to support normal ruminal fermentation, and (2) to monitor the changes in intake and digestion that precede parturition in beef cows fed low-quality, warm-season forage.

Experimental Procedures

Pregnant Angus × Hereford cows were used in 2 experiments that measured intake, digestion, and performance of beef cows and calves when provided ruminally undegraded protein in addition to ruminally degraded protein needed for optimal ruminal fermentation. Cows used in both experiments were fed 1 of 3 supplements daily that supplied similar amounts of ruminally degraded protein (0.09% of body weight) and increasing amounts of ruminally undegraded protein: 0.05% (LOW), 0.07% (MOD), or 0.09% of body weight (HI). Supplement composition is shown in Table 1.

Experiment 1

Late-gestation cows (n = 18; body weight = 940 lb; body condition score = 4.5 [1 = thin, 9 = very fat]) were used in a 3-treatment, randomized complete block experiment. Cows were housed individually and assigned to be fed 1 of the 3 supplements described previously. Each cow had free-choice access to low-quality prairie hay (2.1% crude protein) and supplements were fed daily. Fecal grab samples were collected daily at 8:00 a.m. Sample collection corresponded to the period spanning 14 through 5 weeks pre-partum. Hay intakes by individual animals were summarized as 10 weekly means. Proportional intakes (percentage of body weight) were expressed using individual animals' average body weight for each month of the trial.

Experiment 2

Pregnant Angus × Hereford cows (n = 17; body weight = 1,160 lb; body condition score = 5.2) were used in a randomized complete block experiment. Cows were stratified by weight and body condition score and assigned to receive 1 of the 3 supplements evaluated in Experiment 1.

Within treatment, cows were assigned randomly to graze 1 of 3 native tallgrass pastures. Cows were gathered from the pastures each morning and sorted into treatment groups. Supplements were group-fed. This process was repeated daily from November 25 until all cows had calved (average calving date = March 7 $\pm$ 13 days). Treatments were discontinued when calving occurred. Cows were weighed and assigned a body condition score at 4-week intervals until calving was complete. Performance of calves was monitored from birth until weaning the following fall.

Results and Discussion

Experiment 1

Effects of supplemental ruminally undegraded protein on forage intake and digestion are shown in Table 2. Effects of advancing digestion on forage intake are shown in Table 3. Forage dry matter intake, total dry matter intake, and total digestible dry matter intake of cows fed LOW was greater ($P < 0.01$; Table 1) than that of cows fed MOD or HI. Total tract dry matter digestibility did not differ ($P > 0.10$) between treatments. The likelihood of an intake response to supplemental ruminally undegraded protein seems dependent upon adequacy of ruminally degraded protein supply and the total amount of supplement provided. At high levels of supplement intake, forage intake will decrease due to limits in overall intake of nutrients by cattle.

Forage dry matter intake, total dry matter intake, and total digestible dry matter intake increased ($P \leq 0.03$) cubically between 14 and 4 weeks pre-partum, whereas total tract dry matter and neutral detergent fiber digestibilities decreased ($P \leq 0.03$) linearly over time (Table 3). Previous research has noted that increased body weight and nutrient requirements coincident with advancing gestation stimulated dietary intake until fetal tissues reach sufficient size to begin to compress the rumen. Approximately 50% of fetal growth occurs during the final trimester, with a concurrent decrease in ruminal digesta content and capacity. The cattle used in this experiment appear to have compensated for decreased rumen capacity by increasing the rate of passage of nutrients through the digestive system, which led to the decrease in dry matter and neutral detergent fiber digestibility noted above.

Experiment 2

Cow average daily gain and body condition score change did not differ ($P \geq 0.13$) among treatments during the pre-partum period (Table 4). This differs from previous work on the subject. A possible explanation for discrepancies in response to ruminally undegraded protein supplementation is variation in metabolizable protein balance. A positive response to ruminally undegraded protein supplementation is more likely when metabolizable protein supply is inadequate to support the level of performance allowed by the dietary energy provided. In our trial, metabolizable protein supply appeared sufficient to maximize performance within the constraints of energy supply.

Subsequent Julian calving date, pregnancy rate, and calving interval were not different ($P \geq 0.62$) among treatments (Table 4). Pregnancy rate has not usually been influenced by ruminally undegraded protein supplementation, but postpartum interval has been reduced by supplemental ruminally undegraded protein in some cases. In those cases, supplemental ruminally undegraded protein likely increased energy status of the animals by providing the protein necessary for maximal ruminal fermentation. Cows in

our study likely were not lacking in protein needed to maximize ruminal fermentation, so no increase in energy status occurred when additional ruminally undegraded protein was provided. Pre-partum supplementation with ruminally undegraded protein did not affect ($P \geq 0.55$) calf birth weight, average daily gain, or weaning weight (Table 4).

Implications

Pregnant cows consuming low-quality tallgrass forage and supplemented with common feeds to provide ruminally degraded protein at 0.09% of body weight daily appeared to have been fed sufficient protein to maximize performance within the constraints of energy supply. Therefore, altering supplemental protein composition to provide additional ruminally undegraded protein under such conditions is not warranted.

Table 1. Ruminally undegraded protein supplement composition (Experiment 1 and 2)

	Ruminally undegraded protein [1]		
Ingredient	LOW	MOD	HI
Dry matter, %	90.8	91.5	93.4
Feed composition, % of dry matter			
Blood meal	0.1	4.7	9.3
Corn gluten meal	0.2	6.5	12.9
Soybean meal	71.5	63.3	55.1
Sorghum grain	23.8	21.1	18.3
Molasses	4.4	4.4	4.4
Protein composition, % of crude protein			
Ruminally degraded protein	63.4	57.4	52.4
Ruminally undegraded protein	36.6	42.6	47.6

[1] Ruminally undegraded protein: 0.05% (LOW), 0.07% (MOD), or 0.09% of body weight (HI).

Table 2. Effects of ruminally undegraded protein supplementation on intake and digestibility by pregnant beef cows fed low-quality forage (Experiment 1)

	Ruminally undegraded protein[1]			
Item	LOW	MOD	HI	SEM
Total-tract dry matter digestibility, %	51.8	51.8	52.4	0.27
Total-tract neutral detergent fiber digestibility, %	58.4[a]	57.6[b]	58.4[a]	0.24
Forage dry matter intake, % body weight	2.31[a]	2.14[b]	2.10[b]	0.02
Total dry matter intake, % body weight	2.61[a]	2.45[b]	2.42[b]	0.02
Total digestible dry matter intake, % body weight	1.36[a]	1.27[b]	1.26[b]	0.01

[1] Ruminally undegraded protein: 0.05% (LOW), 0.07% (MOD), or 0.09% of body weight (HI).
[ab] Means within rows having common superscripts do not differ ($P < 0.05$).

Table 3. Effects of decreasing time to parturition on intake and digestibility by beef cows fed low-quality forage (Exp. 1)

	Week relative to average calving date											*P*-value		
Item	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	SEM	Linear	Quadratic	Cubic
Total tract digestibility, %														
Dry matter	54.0	53.0	52.6	52.1	52.1	51.8	51.6	50.8	51.1	50.5	0.48	0.01	0.36	0.39
Neutral detergent fiber	58.7	58.5	58.4	58.0	58.3	58.3	58.3	57.2	57.9	57.5	0.51	0.03	0.81	0.88
Intake, % of body weight														
Forage	1.7	2.0	2.1	2.1	2.2	2.3	2.4	2.2	2.4	2.5	0.04	0.01	0.01	0.01
Total	2.0	2.3	2.4	2.4	2.5	2.6	2.7	2.5	2.8	2.8	0.04	0.01	0.01	0.01

Table 4. Effects of of ruminally undegraded protein supplementation on cow and calf performance (Exp. 2)

	Ruminally undegraded protein [1]			
Item	LOW	MOD	HI	SEM
Cow				
Average daily gain (ADG), lb/day	0.22	0.15	0.04	0.072
Body condition score change	-0.19	-0.20	-0.39	0.094
Julian calving date	68	66	64	2.2
Pregnancy rate, %	95	95	92	4.4
Calving interval, day	364	368	366	3.6
Calf				
Birth weight, lb	90	86	86	2.0
Weaning weight, lb	538	540	536	12.6
ADG (birth to weaning), lb/day	2.18	2.18	2.14	0.02

[1] Ruminally undegraded protein: 0.05% (LOW), 0.07% (MOD), or 0.09% of body weight (HI).

Effects of Corn Steep Liquor Supplementation On Intake and Digestion of Tallgrass Prairie Hay Contaminated with Sericea Lespedeza

G.J. Eckerle, KC Olson, J.R. Jaeger, and L.A. Pacheco

Introduction

Sericea lespedeza (*Lespedeza cuneata*) is a noxious weed that infests approximately 600,000 acres of native range in Kansas. Intake of sericea lespedeza by grazing beef cattle is poor due to the presence of condensed tannins in the plant. Condensed tannins reduce protein digestion by beef cattle and may also decrease plant palatability because of their astringent nature.

Prolific seed production, in combination with little or no grazing pressure, has contributed to the rapid spread of sericea lespedeza in the Flint Hills. Increasing grazing pressure on sericea lespedeza may reduce seed production and slow its advance; however, the presence of condensed tannins inhibit consumption by grazing animals. Reports have indicated that feed-grade polyethylene glycol may inhibit formation of tannin-protein complexes in the rumen, but beef producers have not widely adopted polyethylene glycol because, at the rates necessary to increase intake of sericea lespedeza, it is cost-prohibitive and disallowed by regulations. Therefore, identifying substances that are generally regarded as safe (GRAS) by the U.S. Food and Drug Administration, cost-effective, and that mitigate the consequences of consuming a diet high in tannins is advantageous. Such information could lead to a degree of biological control of this noxious weed using the most economically important grazer (i.e., beef cattle) in the Flint Hills.

Preliminary research in our laboratory indicated that corn steep liquor has binding affinity for condensed tannins that is similar to polyethylene glycol. Therefore, the objective of our study was to determine the effects of corn steep liquor supplementation on intake and digestion of tallgrass prairie hay contaminated by sericea lespedeza.

Experimental Procedures

Tallgrass prairie forage contaminated with sericea lespedeza was harvested from a single pasture in Greenwood County, KS, sun-cured, packaged in bales, and stored at the Kansas State University Commercial Cow-Calf Unit. Forage was harvested in late July, which corresponded to the budding stage of sericea lespedeza. Concentrations of condensed tannins in the plant are typically greatest at this stage of growth. Plant-species composition on the study site was estimated using a modified step-point technique. Sericea lespedeza comprised 19.3% of all plants encountered during the procedure. Aboveground biomass of sericea lespedeza averaged 893 lb/acre. Bales of contaminated hay selected for the study were ground separately to a 4-inch particle size.

Corn steep liquor was purchased from Archer Daniels Midland in Columbus, NE, transported to the Kansas State University Commercial Cow-Calf Unit, and stored in a polyvinyl chloride container.

Twenty-four mature beef cows (average initial weight = 1,022 ± 153 lb; average initial body condition score = 4.2 ± 0.8 [1 = thin, 9 = very fat]) were used in the study. Cows were housed in a single pen and were fed individually using a Calan gate system (American Calan, Northwood, NH). Cows were stratified by body weight and body condition score and were assigned randomly to be supplemented with 0, 1.34, 2.68, or 4.03 lb/day (dry basis) of corn steep liquor (equivalent to 0, 3, 6, and 9 lb/day on an as-is basis; Table 1).

Cows were trained to use the Calan gate feeding system over a period of approximately 30 days. During this time, all cows were fed sericea lespedeza-contaminated forage free choice. When dry matter forage intake stabilized at approximately 1.2% of body weight, the trial was initiated. All cows were fed sericea lespedeza-contaminated forage free choice for the first 14 days of the trial. Beginning on day 15, supplemental corn steep liquor was abruptly introduced into cow diets at assigned feeding levels; it was offered once daily and was consumed by cows within 30 minutes. Forage and supplement intake were monitored during the following 14 days. The purpose of the abrupt introduction of corn steep liquor into cow diets was to minimize the opportunity for ruminal microbes to adapt to nutrients in corn steep liquor.

Daily voluntary dry matter intakes were determined by subtracting daily refusals from the total amount of hay offered. Intakes were expressed as a percentage of initial cow body weight. Total-tract diet digestion was assessed from day 23 to 29. Forage samples were collected from day 23 to 28. Fecal grab samples were collected every 4 hours on days 24 through 29. The collection interval was staggered 2 hours each day to account for diurnal variation in fecal output and composition.

Results and Discussion

Prior to the introduction of corn steep liquor, voluntary forage dry matter intake did not differ ($P = 0.52$) between treatments. After introduction of corn steep liquor (day 15 through 29), supplemented cows ate more ($P \leq 0.01$) forage dry matter than unsupplemented cows; however, there were no differences ($P \geq 0.38$) in forage dry matter intake for cows fed varying amounts of corn steep liquor (Table 2). The smallest dose of corn steep liquor used in our trial (i.e., 1.34 lb/day) stimulated maximum intake of tallgrass prairie hay contaminated with sericea lespedeza in a short-term experiment.

Total-tract dry matter digestibility was greater ($P < 0.01$) for cows fed 2.68 or 4.03 lb/day corn steep liquor than for cows fed 0 or 1.34 lb/day (Table 2). Total-tract crude protein digestion was least ($P < 0.01$) in cows fed no corn steep liquor, was slightly greater ($P < 0.01$) in cows fed 1.34 lb/day corn steep liquor, and was greatest ($P < 0.01$) in cows fed either 2.68 or 4.03 lb/day corn steep liquor. Total digestible dry matter intake by cows fed 2.68 or 4.03 lb/day corn steep liquor was greater than that of cows fed 0 or 1.34 lb/day corn steep liquor. The amount of corn steep liquor needed to optimize digestion characteristics of the diet was equal to or greater than 2.68 lb/day. Further research is warranted to evaluate the optimal corn steep liquor dose needed to mitigate the consequences of consuming high-tannin diets.

Implications

Supplementation of corn steep liquor may increase tolerance of beef cows for high-tannin forages. In our study, supplemental corn steep liquor ameliorated the negative consequences of tannin consumption in a dose-dependent manner when fed to beef cows in confinement. Whether supplemental corn steep liquor can influence forage selection preference when grazing cattle have the opportunity to eat either uncontaminated forage or forage contaminated by sericea lespedeza remains unknown.

Table 1. Chemical composition (dry matter basis) of corn steep liquor and tallgrass prairie hay contaminated by sericea lespedeza

Item, %	Corn steep liquor	Contaminated forage
Dry matter	44.7	93.7
Organic matter	95.2	87.2
Crude protein	32.8	4.6
Acid detergent fiber	-	40.7
Neutral detergent fiber	0.4	65.2
Calcium	0.03	0.35
Phosphorus	0.62	0.07

Table 2. Effects of increasing dose of corn steep liquor on intake and digestion of tallgrass prairie hay contaminated by sericea lespedeza

	Corn steep liquor, lb/day (dry basis)				
Item	0	1.34	2.68	4.03	SEM
Feed intake, % of body weight					
Forage dry matter	1.38^{a}	1.59^{b}	1.58^{b}	1.63^{b}	0.065
Digestible dry matter	0.86^{a}	1.16^{ab}	1.58^{bc}	1.86^{c}	0.062
Total-tract digestibility, %					
Dry matter	52.6^{a}	55.6^{a}	65.6^{b}	66.3^{b}	2.08
Crude protein	−1.5^{a}	18.6^{b}	51.7^{c}	52.3^{c}	4.53

^{abc} Means within a row lacking common superscripts are different.

Effects of Corn Steep Liquor Supplementation on Voluntary Selection of Tallgrass Prairie Hay Contaminated with Sericea Lespedeza and Uncontaminated Tallgrass Prairie Hay

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Introduction

Sericea lespedeza (*Lespedeza cuneata*) is classified as a noxious weed throughout the Great Plains. It produces copious amounts of seed annually and contains high levels of condensed tannins during much of the growing season, which deters grazing by large domestic herbivores. In Kansas alone, this plant infests approximately 600,000 acres of native range, reducing native grass production by up to 92%. Increased grazing pressure on sericea lespedeza by beef cattle may slow its spread and facilitate some measure of biological control. Feedstuffs or feed additives with tannin-binding properties may promote voluntary consumption of this plant by grazing beef cattle.

In previous studies, confined beef cattle fed polyethylene glycol daily ate more sericea lespedeza than cattle that were not fed polyethylene glycol; however, use of polyethylene glycol by commercial beef producers is problematic because feeding it at the rates necessary to increase intake of sericea lespedeza is cost-prohibitive and disallowed from a regulatory standpoint. We reported previously that low to moderate amounts of supplemental corn steep liquor (i.e., 0.6 to 1.8 kg/day) increased intake of tallgrass prairie hay contaminated with sericea lespedeza by beef cows fed in confinement. Corn steep liquor is an inexpensive, palatable, and abundant by-product of wet-corn milling and is generally regarded as safe (GRAS) by the U.S. Food and Drug Administration. Whether beef cattle supplemented with corn steep liquor will readily consume forage contaminated by sericea lespedeza when uncontaminated forage is available simultaneously is unknown. Therefore, the objective of our study was to determine the effects of low-level corn steep liquor supplementation on voluntary selection of tallgrass prairie hay contaminated by sericea lespedeza when uncontaminated tallgrass prairie hay was also available.

Experimental Procedures

Tallgrass prairie forage contaminated with sericea lespedeza was harvested from a single pasture in Greenwood County, KS, sun-cured, packaged in bales, and stored at the Kansas State University Commercial Cow-Calf Unit. Forage was harvested in late July, which corresponded to the budding stage of sericea lespedeza. Concentrations of condensed tannins in the plant are typically greatest at this stage of growth. Plant-species composition on the study site was estimated using a modified step-point technique; sericea lespedeza comprised 19.3% of all plants encountered during the procedure. Aboveground biomass of sericea lespedeza averaged 893 lb/acre.

Uncontaminated tallgrass prairie forage was harvested in Pottawatamie County, KS, also in late July. Species composition of contaminated and uncontaminated forage

was similar in all respects, except for the presence of sericea lespedeza in the contaminated forage. Bales of each forage type were sampled to measure crude protein and acid detergent fiber concentration and paired based on similarity in those values. Average crude protein and acid detergent fiber concentrations in contaminated and uncontaminated hay are shown in Table 1. Purposeful selection for similarity in protein and fiber concentrations between forage types was intended to prevent confounding of differences in forage quality with effects on intake. Bales of contaminated and uncontaminated hay selected for the study were ground separately to a 4-inch particle size.

Corn steep liquor was purchased from Archer Daniels Midland in Columbus, NE, transported to the Kansas State University Commercial Cow-Calf Unit, and stored in a polyvinyl chloride container.

Sixteen mature beef cows (average initial weight = 1,022 ± 153 lb; average initial body condition score = 4.2 ± 0.8 [1 = thin, 9 = very fat]) were used in the study. Cows were housed in individual pens and were fed individually using a Calan gate system (American Calan, Northwood, NH). Cows were stratified by body weight and body condition score and were assigned randomly to be supplemented with 0 or 1.32 lb/day of corn steep liquor (dry basis; equivalent to 0 or 3 lb/day as-fed).

Cows were individually confined in 5 × 20 ft pens and offered uncontaminated hay and contaminated hay in separate feed bunks free choice. Access to both contaminated and uncontaminated tallgrass prairie hay was simultaneous and allowed cows the opportunity to display preference for one forage type over the other.

Supplemental corn steep liquor was offered to treated cows for a period of 24 days; it was consumed completely within 30 minutes. Forages were fed twice daily during that period at 6:00 a.m. and 6:00 p.m. Daily forage refusals were collected and weighed at 5:30 a.m. Daily voluntary dry matter intakes of contaminated and uncontaminated tallgrass prairie forage were determined by subtracting daily refusals from the total amount of hay offered. Intakes were expressed as a percentage of initial cow body weight. Total-tract diet digestion was assessed on days 18 through 24. Forage samples were collected on days 18 through 23. Fecal grab samples were collected every 4 hours on days 19 through 24. The collection interval was staggered 2 hours each day to account for diurnal variation in fecal output and composition.

Results and Discussion

Uncontaminated hay dry matter intake was not different ($P = 0.65$) between supplemented and unsupplemented cows (Table 2). Conversely, cows supplemented with corn steep liquor ate 25% more ($P < 0.01$) sericea lespedeza-contaminated forage than unsupplemented cows. Cows supplemented with corn steep liquor also ate more ($P = 0.05$) total forage dry matter than unsupplemented cows.

Beef cows supplemented with corn steep liquor voluntarily consumed more tallgrass prairie hay contaminated with sericea lespedeza than unsupplemented beef cows, even when uncontaminated hay was available concurrently. These data were interpreted to indicate that low levels of supplemental corn steep liquor may increase beef cow acceptance of and tolerance for high-tannin forages.

Total-tract dry matter and crude protein digestibilities did not differ ($P \geq 0.17$) between treatments. We previously reported that total-tract dry matter and crude protein digestibilities by beef cows fed tallgrass prairie hay contaminated with sericea lespedeza were maximized at corn steep liquor supplementation levels of 2.68 lb/day (dry basis) or greater. Further research is warranted to evaluate feeding rates of corn steep liquor necessary for optimal digestion of low-quality tallgrass prairie hay contaminated with sericea lespedeza.

Total digestible dry matter intake by cows fed corn steep liquor was 23% greater ($P < 0.01$) than that by unsupplemented cows. We previously reported that unadapted cattle fed 2.68 to 4.03 lb/day (dry basis) of corn steep liquor had comparable total digestible dry matter intake. Cows supplemented with corn steep liquor in our study appeared to have greater dietary energy availability than unsupplemented cows, even though the estimated increase in NE_m supply associated with supplementing corn steep liquor at 1.32 lb/day was only 1.1 Mcal/day. Over a longer feeding period, this may have translated to improved performance.

Implications

Low-level supplementation of corn steep liquor may increase both acceptance of and tolerance for high tannin-forages by beef cows. Corn steep liquor fed at 1.32 lb/day ameliorated some of the negative consequences of tannin consumption on digestible dry matter intake. In addition, voluntary consumption of high-tannin forage increased by 25% in supplemented compared with unsupplemented beef cows. Whether supplemental corn steep liquor can promote voluntary selection of actively growing sericea lespedeza by beef cattle grazing native rangeland in the Kansas Flint Hills remains unknown.

Table 1. Chemical composition (dry matter basis) of corn steep liquor, tallgrass prairie hay, and tallgrass prairie hay contaminated with sericea lespedeza

Item, %	Corn steep liquor	Uncontaminated forage	Contaminated forage
Dry matter	45.1	93.1	92.6
Organic matter	95.1	87.0	86.0
Crude protein	31.6	4.1	4.1
Acid detergent fiber	-	40.8	40.2
Neutral detergent fiber	0.5	65.2	65.3
Calcium	0.04	0.27	0.31
Phosphorus	0.63	0.08	0.08

Table 2. Effects of low-level corn steep liquor supplementation on forage intake and digestion by beef cows simultaneously offered tallgrass prairie hay that was contaminated with sericea lespedeza and uncontaminated by sericea lespedeza[a]

	Corn steep liquor, lb/day (dry basis)			
Item	0	1.32	SEM	*P*-value
Dry matter intake, % of body weight				
Uncontaminated forage	0.91	0.87	0.066	0.65
Contaminated forage	1.06	1.33	0.055	<0.01
Total forage	1.97	2.20	0.086	0.05
Digestible dry matter	1.97	2.35	0.087	<0.01
Total-tract digestibility, %				
Dry matter	50.5	53.9	1.66	0.17
Crude protein	17.1	18.5	2.15	0.64

[a] Corn steep liquor was fed from days 1 through 24. The first 14 days of the experiment were used to adapt cattle to corn steep liquor, and intake and digestion measurements commenced on day 15.

Effects of Prepartum and Postpartum Bolus Injections of Trace Minerals On Performance of Beef Cows and Calves Grazing Native Range

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Introduction

Adequate dietary intakes of trace minerals are thought necessary to maximize cow reproduction, calf health, and calf performance. Diets grazed by beef cattle are generally deficient to marginal in copper (Cu), manganese (Mn), selenium (Se), and zinc (Zn) concentrations; therefore, these trace minerals are usually added to the diet in supplement form.

The most widely used means of trace-mineral supplementation for grazing cattle is self-fed, salt-based, loose mineral supplements. Although cattle do not balance their mineral needs when consuming a self-fed mineral supplement, usually no other practical way of supplying mineral needs exists under grazing conditions. The greatest limitation to using self-fed mineral supplements is variation in animal intake. More direct methods of mineral supplementation include adding minerals to drinking water or feed, oral drenching, ruminal boluses, and injection. Variation in mineral intake is reduced relative to self-fed supplementation, and the additional labor requirement and expense are relatively small.

Delivery of supplemental trace minerals using an injectable solution may be a more reliable means of achieving adequate trace-mineral status than using self-fed, salt-based, loose mineral supplements. Bolus injections of trace minerals have been associated with improved average daily gain, feed efficiency, feed intake, or health status of beef calves fed in confinement; however, trace mineral delivery methods of this type have not been fully evaluated with respect to performance of beef cows and suckling calves. The objective of our study was to evaluate the effects of pre- and postpartum bolus injections of a trace mineral solution on beef cow reproductive performance, body weight change, and body condition score change, as well as performance of suckling calves.

Experimental Procedures

Angus cross cows and heifers (n = 460; initial body weight 1,095 ± 196 lb) managed in 2 locations were used in our study (193 cows and 81 heifers at Manhattan, KS, and 132 cows and 54 heifers at Hays, KS). At the end of December 2009, cows were stratified by body condition score (1 = thin, 9 = very fat), parity, and predicted calving date and assigned randomly to 1 of 2 treatments: (1) subcutaneous injection with a trace mineral solution (TM; Table 1) or (2) subcutaneous injection with autoclaved physiological saline (SA). Injections were administered to cows (1 mL/200 lb body weight) 105 days before the first projected calving date and again approximately 30 days before

fixed-time artificial insemination. Calves received the same treatment as their dams and were injected (1 mL/100 lb body weight) at birth and again at 71 ± 21 days of age.

Within location, cows and heifers were managed as a single group from December 17 through the end of the calving season. In Manhattan, cows were evenly distributed by treatment and parity into 5 native pastures on May 15; in Hays, cows were evenly distributed by treatment and parity into 2 native pastures on May 1. Cows grazed assigned pastures until October 5; self-fed TM supplements (19% Ca, 6.5% P, 17% NaCl, 1300 ppm Cu, 26 ppm Se, and 2,000 ppm Zn) and white salt were available to all cattle free choice for a minimum of 12 months before and throughout the study. Availability of self-fed TM and white salt were visually verified on a daily basis.

Cow body weight and body condition measurements were obtained 105 days before the first projected calving date, at calving, at the time of fixed-time artificial insemination, and at weaning. Calf body weight measurements were recorded at birth, on June 16, and at weaning.

Blood samples were collected from each cow 17 and 8 days before fixed-time artificial insemination via jugular venipuncture and immediately placed on ice. Resulting serum was analyzed for progesterone concentration. When either or both samples contained concentrations of progesterone ≥ 1 ng/mL, cows were considered to be cycling.

Ovulation was synchronized using a 5-day Co-Synch + controlled internal drug release (CIDR) protocol, and cows were inseminated 60 to 64 hours after CIDR removal. Cows were exposed to fertile bulls for natural-service breeding beginning 10 days after fixed-time artificial insemination for 50 days. Conception to fixed-time artificial insemination was determined via ultrasound 36 days after artificial insemination and final pregnancy rate was determined via rectal palpation 120 days after artificial insemination.

Results and Discussion

Change in cow body weight and body condition score from initiation of the study to calving and from artificial insemination breeding to weaning did not differ ($P \geq 0.15$) between cows injected with TM and cows injected with saline (Tables 1 and 2). Conversely, TM cows had greater ($P = 0.04$) body condition score increase than SA cows between calving and artificial insemination.

The proportion of cows with estrus cycles 17 or 8 days prior to timed artificial insemination was similar ($P \geq 0.51$) between treatments. In contrast, conception to fixed-time artificial insemination was greater ($P = 0.05$) for cows receiving TM (60.2%) than for cows receiving SA (51.2%); however, overall pregnancy did not differ ($P = 0.24$) between treatments and averaged 92% (Table 3). The strong timed-artificial insemination response to trace mineral injection was not anticipated because all cows in our study had free-choice access to self-fed oral trace mineral supplements and white salt for a minimum of 12 months prior to and during our study. Consumption of self-fed trace mineral on a per-pasture basis was within manufacturer recommendations before and during our study; therefore, we speculated that the trace mineral status of individual

cows may not have been optimal due to non-consumption or erratic intake of self-fed trace mineral supplement.

Calf body weight at birth did not differ ($P > 0.91$) between treatments (Table 4). Calf average daily gain from birth to June 16, from June 16 to weaning, and from birth to weaning also did not differ ($P \geq 0.36$) between TM and SA. Similarly, adjusted 205-day body weights did not differ ($P = 0.48$) between treatments.

Implications

Under the conditions of our study, pre- and postpartum trace mineral injections improved conception to fixed-time artificial insemination by beef cows. Supplementing trace minerals to beef cows using an injectable solution may be a more reliable way of assuring adequate trace-mineral status than offering a self-fed, salt-based, granular mineral supplement alone; however, further research is warranted to substantiate this idea. At the time of this writing, cost of the injectable trace mineral product used in our study was approximately $0.40/mL. Cost per dose (1 mL/200 lb body weight) for a beef cow weighing 1,200 lb was $2.40 and total treatment cost (i.e., 2 doses) for a beef cow weighing 1,200 lb, as described in our study, was $4.80.

Table 1. Effects of pre- and postpartum bolus injections of either a trace-mineral solution or physiological saline (1 mL/200 lb body weight) on body weight and body weight change of beef cows grazing native range

	Treatment			
Item	Saline	Trace mineral[a]	SE	*P*-value
Cow body weight, lb[b]				
Pregnancy check	1,108	1,108	5.8	0.97
Parturition	1,090	1,089	5.6	0.96
Artificial insemination (AI) breeding	1,175	1,175	8.0	0.98
Weaning	1,188	1,193	12.4	0.83
Cow body weight change, lb				
Pregnancy check to parturition	-17.4	-19.2	0.09	0.85
Parturition to AI breeding	84.7	86.4	3.33	0.81
AI breeding to weaning	95.9	101.2	6.00	0.59

[a] Multimin® 90, Multimin USA, Ft Collins, CO.
[b] Cow body weights were measured at pregnancy check (12/17), parturition (average date = 04/06), AI breeding (06/16), and weaning (10/29).

Table 2. Effects of pre- and postpartum bolus injections of either a trace-mineral solution or physiological saline (1 mL/200 lb body weight) on body condition score and body condition score change of beef cows grazing native range

	Treatment			
Item	Saline	Trace mineral[a]	SE	*P*-value
Cow BCS[bc]				
Pregnancy check	5.51	5.45	0.009	0.29
Parturition	5.17	5.08	0.004	0.13
Artificial insemination (AI)	5.44	5.47	0.029	0.66
Weaning	5.29	5.28	0.003	0.94
Cow BCS change				
Pregnancy check to parturition	-0.34	-0.37	0.013	0.57
Parturition to AI	0.26	0.38	0.021	0.04
AI to weaning	0.10	0.19	0.008	0.15

[a] Multimin 90, Multimin USA, Ft. Collins, CO.
[b] Body condition score units, 1 to 9 scale (1 = thin, 9 = very fat).
[c] Cow BCS were assigned at pregnancy check (December 17), parturition (average date = April 6), AI breeding (June 16), and weaning (October 29).

Table 3. Effects of pre- and postpartum bolus injections of either a trace-mineral solution or physiological saline (1 mL/200 lb body weight) on reproductive performance of beef cows grazing native range

	Treatment			
Item	Saline	Trace mineral[a]	SE	*P*-value
Cows cycling before timed artificial insemination (AI), %[b]	56.3	59.5	0.04	0.51
Timed-AI pregnancy, %[c]	51.2	60.2	0.03	0.05
Final pregnancy, %[d]	89.9	93.0	0.02	0.24

[a] Multimin 90, Multimin USA, Ft. Collins, CO.
[b] Determined from serum samples collected 17 and 8 days before timed AI.
[c] Proportion of cows classified as being pregnant from timed AI only.
[d] Proportion of cows classified as pregnant from either timed AI or natural-service breeding.

Table 4. Performance of beef calves treated at birth and at 71 ± 21 days of age with bolus injections of either a trace mineral solution or physiological saline (1 mL/100 lb body weight)

	Treatment			
Item	Saline	Trace mineral[a]	SE	*P*-value
Calf body weight, lb[b]				
Birth	84.7	84.7	0.02	0.92
Artificial insemination	324.6	322.4	0.57	0.90
Weaning	469.2	461.1	2.16	0.28
Adjusted 205-day body weight[c]	510.5	505.9	1.90	0.48
Average daily gain, lb				
Early season (birth to June 16)	2.07	2.07	0.009	0.89
Late season (June 16 to weaning)	2.01	1.96	0.022	0.36
Overall (birth to weaning)	2.07	2.05	0.011	0.48

[a] Multimin 90, Multimin USA, Ft. Collins, CO

[b] Calf body weights were measured at birth (average date = April 6), artificial insemination breeding of cows (June 16), and weaning (October 29).

[c] Adjusted 205-day body weight = birth weight × 205 × overall average daily gain.

Influence of Linpro and Dietary Copper on Feedlot Cattle Performance, Carcass Characteristics, and Fatty Acid Composition of Beef

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Introduction

Human diets often contain high levels of saturated fatty acids that can have deleterious health consequences such as obesity, diabetes, and heart disease. In contrast, omega-3 fatty acids, which are essential for human nutrition, are consumed at relatively low levels despite of their positive effects on health. Natural sources of omega-3 fatty acids include fresh legumes, cool-season grasses, flaxseed, and fish oil. In spite of the fact that fresh forages often are a key part of the cattle diet, beef is a relatively poor source of omega-3 fatty acids because of biohydrogenation, the action of microorganisms in the rumen that convert polyunsaturated fatty acids, including the omega-3 fats, into saturated fats. Previous research at Kansas State University has shown that feeding cattle flax-based feeds can increase concentrations of omega-3 fatty acids in beef. Researchers at Colorado State University have reported that elevated levels of dietary copper can inhibit the biohydrogenation process to yield beef with greater proportions of polyunsaturated fatty acids. Our objective was to evaluate whether feeding elevated copper concentrations in conjunction with Linpro (O&T Farms; Regina, Saskatchewan, Canada), a co-extruded blend of field peas and flaxseed, could be used to further improve the levels of omega-3 fatty acids in beef.

Experimental Procedures

The study was conducted as a randomized complete block experiment with a 2 × 2 factorial treatment arrangement. Supplementation consisted of dietary copper (10 or 100 ppm added copper) and Linpro (0 or 10% of diet, dry basis). Linpro is an extruded blend of flaxseed and field peas containing 12% α-linolenic acid (the primary omega-3 fat in plants) with added vitamins and minerals (22% crude protein, 23% fat). We used 261 crossbred yearling heifers (775 ± 51 lb initial body weight), which were blocked by weight into heavy and light groups and assigned randomly to experimental pens containing 10 or 11 heifers each. Twenty-four feedlot pens were assigned randomly to each of the 4 treatments. We fed cattle once daily with free-choice access to feed and water. Basal diets included (dry matter basis) 35% wet corn gluten feed; 35% cracked corn; 15.8% pelleted soybean hulls; 10% corn silage, vitamins, and minerals; and provided 14% crude protein, 300 mg/day Rumensin (Elanco Animal Health, Greenfield, IN), 90 mg/day Tylan (Elanco Animal Health), 1000 IU/lb vitamin A, 10 IU/lb vitamin E, 0.1% added Na, 0.15% added Cl, 0.10 ppm Co, 0.6 ppm I, 0.25 ppm Se, 60 ppm Mn, and 60 ppm Zn (Table 1). For Linpro diets, the extrudate was added at 10% of dry matter, replacing soybean hulls. Heifers were implanted (Revalor-200; Merck Animal Health, Summit, NJ), dewormed (Safe Guard, Merck Animal Health), and vaccinated against common viral and clostridial diseases (Vista 3 and Vision 7;

Merck Animal Health). Starting 23 days before harvest, Zilmax (Merck Animal Health) was added to the diet for 20 days. We harvested the heavy and light blocks on day 117 and 136, respectively, in a commercial abattoir where we collected slaughter data. After a 24-hour chill period, we evaluated the animals for fat thickness over the 12th rib; percentage kidney, pelvic, and heart fat; ribeye area; marbling score; and USDA yield and quality grades. Furthermore, we obtained loin samples from one side of three carcasses randomly selected from each pen. Data were statistically analyzed using the MIXED procedure of SAS (Version 9.1; Cary, NC) with Linpro, copper, the interaction between Linpro and copper, and block as fixed effects; pen nested within Linpro, copper, and block as the random effects; and pen as the experimental unit.

Results and Discussion

During this trial we observed no negative effects on the health (toxicity) of our heifers fed with the high level of copper, which is reflected on the feedlot performance presented in Table 2. No effect of copper or interaction between Linpro and the level of copper ($P > 0.20$) was found. Final weight and average daily gain were not different for heifers fed deits with and without Linpro ($P > 0.20$), but dry matter intakes were less for heifers fed Linpro compared with those fed the control diets ($P = 0.03$; 30.0 and 31.10 lb/day, respectively). Efficiency (gain:feed) and net energy for maintenance (NEm) and growth (NEg) were therefore greater when we fed Linpro ($P < 0.01$).

We found no effects ($P > 0.10$) of Linpro, copper, or the interaction between Linpro and copper on carcass traits (Table 3). Numerically, final weights were 12 lb lighter for cattle fed 100 ppm copper compared with those fed 10 ppm supplemental copper. We found an average of 64.0% of dressed yield and longissimus muscle area of 92.2 in^2. The mean marbling score was 516, which represents a moderate level of intramuscular fat.

In Table 4 we present a summary of fatty acid profiles of beef. No significant interactions occurred between Linpro and the level of copper with respect to beef composition. Linpro had no effect on total fat, saturated fat, or monounsaturated fat ($P > 0.10$), but, as expected from previous research, polyunsaturated and omega-3 fatty acids were greater ($P < 0.01$) for heifers fed Linpro. Additionally, the ratio of omega-6 and omega-3 fatty acids decreased from 7.03 in beef from heifers fed the control diet to 3.98 in that of heifers fed Linpro. We observed no effect of copper on the proportions of saturated and unsaturated fatty acids in beef ($P > 0.20$).

Implications

Copper was ineffective as a strategy for improving assimilation of polyunsaturated fatty acids into beef. Linpro can be used effectively as an energy source and to modify tissue concentrations of omega-3 fatty acids in beef.

Table 1. Experimental diets without (Control) and with supplemental Linpro containing 10 or 100 ppm of added copper (Cu)

	Control		Linpro	
Item	10 Cu	100 Cu	10 Cu	100 Cu
Ingredients, %				
Dry rolled corn	35.0	35.0	35.0	35.0
Wet corn gluten feed	35.0	35.0	35.0	35.0
Corn silage	10.0	10.0	10.0	10.0
Soybean hulls	15.8	15.8	5.71	5.68
Linpro	-	-	10.0	10.0
Supplement[a]	4.16	4.19	4.29	4.32
Composition (%)				
Dry matter	67.16	67.16	67.61	67.62
Crude protein	14.71	14.71	15.65	15.65
Ether extract	2.70	2.70	4.76	4.76
Neutral detergent fiber	28.02	28.00	23.42	23.40
Calcium	0.63	0.66	0.65	0.63
Phosphorus	34.12	34.12	34.10	34.10
Potassium	0.88	0.89	0.77	0.78

[a] Formulated to provide 10 or 100 ppm Cu, 300 mg/day Rumensin and 90 mg/day Tylan (Elanco Animal Health, Greenfield, IN), 1000 IU/lb vitamin A, 10 IU/lb vitamin E, 0.1% added Na, 0.15% added Cl, 0.10 ppm Co, 0.6 ppm I, 0.25 ppm Se, 60 ppm Mn, and 60 ppm Zn.

Table 2. Performance of crossbred heifers fed Control or Linpro diets containing 10 or 100 ppm of added copper (Cu)

	Control		Linpro			*P*-value[a]		
Item	10 Cu	100 Cu	10 Cu	100 Cu	SEM	L	C	L×C
Initial weight, lb	776	774	778	771	3.95	0.70	0.34	0.50
Final weight, lb	1279	1268	1296	1274	10.8	0.27	0.15	0.52
Average daily gain, lb	4.03	3.98	4.19	4.03	0.077	0.20	0.21	0.64
Dry matter intake, lb	31.09	31.09	30.42	29.54	0.463	0.03	0.29	0.28
Feed:gain	7.52	7.69	7.09	7.14	0.002	<0.01	0.41	0.47
NEm, Mcal/100 lb	91.5	89.8	96.0	95.5	1.00	<0.01	0.30	0.58
NEg, Mcal/100 lb	61.6	60.2	65.7	65.2	0.86	<0.01	0.31	0.58

[a] L: effect of Linpro; C: effect of copper level; L×C: Interaction between Linpro and copper level.

Table 3. Carcass traits of crossbred heifers fed Control or Linpro diets containing 10 or 100 ppm added copper (Cu)

	Control		Linpro			*P*-value[a]		
Item	10 Cu	100 Cu	10 Cu	100 Cu	SEM	L	C	L×C
Hot carcass weight, lb	818	810	832	816	7.32	0.20	0.13	0.57
Dressed yield, %	64.0	63.9	64.1	64.0	0.31	0.79	0.79	0.79
Ribeye area, in2	14.1	14.5	14.5	14.2	0.21	0.88	0.69	0.10
Kidney, pelvic, and heart fat, %	2.6	2.7	2.6	2.6	0.08	0.64	0.74	0.55
12th rib fat, in.	0.87	0.67	0.67	0.75	0.07	0.37	0.41	0.13
Marbling score	508	520	523	512	17.9	0.89	0.97	0.54
Prime, %	4.7	9.1	9.2	6.1	3.55	0.85	0.86	0.31
Choice, %	89.1	75.8	76.9	75.8	6.01	0.33	0.25	0.33
USDA yield grade	2.66	2.49	2.66	2.64	0.10	0.43	0.32	0.47
Liver abscesses, %	10.9	19.7	12.3	7.6	4.31	0.23	0.66	0.13

[a] L: effect of Linpro; C: effect of copper level; L×C: interaction between Linpro and copper.

Table 4. Total saturated, monounsatured, polyunsaturated, omega-3, and omega-6 fatty acids in loin samples from crossbred heifers fed Control and Linpro diets containing 10 or 100 ppm added copper (Cu)

	Control		Linpro			*P*-value[a]		
Fatty acids, %	10 Cu	100 Cu	10 Cu	100 Cu	SEM	L	C	L×C
Saturated	3.17	3.45	3.43	3.11	0.329	0.90	0.97	0.37
Monounsaturated	3.71	4.08	3.93	3.57	0.399	0.72	0.99	0.38
Polyunsaturated	0.36	0.39	0.45	0.42	0.019	<0.01	0.94	0.17
Omega-3	0.041	0.047	0.086	0.081	0.003	<0.01	0.89	0.15
Omega-6	0.301	0.317	0.341	0.318	0.015	0.19	0.83	0.20
Omega-6:omega:3	7.27	6.78	4.02	3.93	0.125	<0.01	0.03	0.13
Total fatty acids	7.24	7.92	7.80	7.10	0.743	0.87	0.99	0.37

[a] L: effect of Linpro; C: effect of copper level; L×C: interaction between Linpro and copper.

Accelerated Step-Up Regimes for Feedlot Heifers Following Oral Dosing with Lactipro (*Megasphaera elsdenii* strain NCIMB 41125)

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

Introduction

Cattle entering feedlots typically are adapted to finishing diets over a period of 2 to 4 weeks by gradually replacing forages with concentrate feeds using a series of step-up diets. Without proper adaptation, naïve cattle are highly susceptible to ruminal acidosis, a disorder associated with excessive production and accumulation of organic acids within the rumen. One of the key metabolic intermediates associated with the manifestation of acidosis is lactic acid, which is derived from fermentation of readily available starches and sugars. *Streptococcus bovis* is a prolific, rapidly growing, and opportunistic organism that thrives in the presence of readily fermented starches and sugars, and is an important inhabitant of the rumen that is recognized for its ability to produce large quantities of lactate. In unadapted cattle, the relative absence of lactate-utilizing bacteria can lead to the accumulation of lactate, thus predisposing the animals to acidosis. In traditional step-up programs, the gradual replacement of roughages with concentrate feeds provides ample time for proliferation of lactate-utilizing species of bacteria, the most important of which is *Megasphaera elsdenii*.

Lactipro (MS Biotech, Inc., Wamego, KS) is a novel class of probiotic consisting of a highly prolific strain of *Megasphaera elsdenii*. Because *Megasphaera elsdenii* is an obligate anaerobe, it must be administered orally to avoid exposure to oxygen. In previous experiments with Lactipro, we have observed that a single oral dose results in rapid colonization of *Megasphaera elsdenii* within the rumen, effectively preventing the accumulation of lactate following an abrupt diet change from forage to concentrate. The present study was designed to evaluate different step-up regimens, with the objective of decreasing the time and number of diets required to place cattle on high-concentrate finishing diets.

Experimental Procedures

Three hundred seventy-eight spayed, crossbred heifers (initial body weight 849 ± 24 lb) were utilized in a randomized complete block design to evaluate the efficacy of *Megasphaera elsdenii* in accelerated step-up regimens. Heifers were procured from a grazing operation in Cody, WY, in November 2010, and transported to the Kansas State University Beef Cattle Research Center in Manhattan. Cattle arrived at the research site on a Friday evening and were fed free-choice alfalfa hay until being removed from their pens for processing on Sunday morning. Heifers were weighed individually, uniquely identified with numbered ear tags, vaccinated against common viral and clostridia diseases, treated for internal parasites, and implanted with Revalor 200 (Intervet Inc., Millsboro, DE). After weighing, cattle were stratified by weight and assigned randomly, within strata, to 54 feedlot pens containing 7 heifers each. Pens were randomly assigned to each of 6 experimental treatments, providing 9 replications per treatment. Experimental treatments consisted of 6 different step-up regimes, as summa-

rized in Table 1. The control regimen utilized a total of 5 diets (Table 2), identified as Step 1, Step 2, Step 3, Step 4, and the Finisher. In this regimen, designated as 1234F, heifers did not receive Lactipro, the first 4 transition diets each were fed for 5 days, and the final finishing diet was fed from days 21 to 129. For the remaining step-up regimes, cattle were orally dosed with 100 mL of Lactipro, then started on diets containing progressively less roughage. As with the control regime, the initial diets each were fed for 5 days before changing to the next diet in the sequence. The accelerated step-up regimens consisted of steps 2, 3, and 4, followed by the finisher (234F); steps 3, 4, and the finisher (34F); step 3 and the finisher (3F); step 4 and the finisher (4F); or direct placement onto the finishing diet (F), as shown in Table 1.

Heifers were fed their respective diets free-choice once dailyfor 129 days. Rumensin and Tylan (Elanco Animal Health, Greenfield, IN) were fed at 300 and 90 mg/animal daily. Starting 23 days prior to harvest, Zilmax (Merck Animal Health, Summit, NJ) was included in the diet at the rate of 60 mg/head daily for 20 days, followed by a 3-day withdrawal. Heifers were weighed and subsequently transported to a commercial abattoir where carcass weight and liver abscess scores were collected on the day of harvest. USDA yield and quality grades; 12th rib fat thickness; percentage kidney, pelvic, and heart fat; ribeye area; and marbling score were recorded after chilling carcasses for 24 hours. Statistical analyses were conducted using the MIXED procedure of SAS (Cary, NC). Pen was the experimental unit, step-up regimen was the fixed effect, and block was the random variable. Treatment differences were determined using linear and quadratic contrasts.

Results and Discussion

Overall, health of cattle was excellent throughout the experiment. During the first week, one heifer was treated for respiratory disease, another was diagnosed and treated for possible coccidiosis, and a third heifer was treated for infectious lameness. On day 119 of the experiment, one heifer from the 4F regimen was found dead in the pen, but gross necropsy revealed no obvious cause of death.

Feedlot performance is summarized in Table 3. Step-up regimen had little effect on dry matter intake, although there was a tendency (quadratic effect, $P = 0.07$) for heifers started on the intermediate steps to consume less dry matter. Figure 1 illustrates daily feed intake for each treatment, revealing similar intake patterns throughout the 129-day experiment. Average daily gain and gain efficiency tended to be greatest for heifers stepped up on either the control (1234F) regimen or when placed directly onto feed (F) after processing (quadratic effects, $P < 0.07$ and $P < 0.10$, respectively).

The beneficial effects of *Megasphaera elsdenii* are most often attributed to its ability to metabolize lactic acid under acidic conditions. The capacity for *Megasphaera* to effectively colonize the rumen when pH is low is a characteristic that distinguishes it from other lactate-utilizing species. In previous challenge experiments, we have observed that oral administration of Lactipro following a carbohydrate challenge results in rapid colonization of the rumen by *Megasphaera*, effectively preventing accumulation of lactic acid. Low ruminal pH and the presence of lactic acid likely provide a competitive advantage for *Megasphaera*, thus facilitating its colonization within the gastrointestinal tract. In the present experiment, it is conceivable that some of the step-up regimens

were not sufficiently aggressive to yield ruminal conditions that are conducive to extensive amplification and colonization by *Megasphaera elsdenii*. For example, in the 234F and 34F regimes, little evidence supports a benefit associated with administration of Lactipro, whereas cattle placed directly onto the finishing diet clearly were able to maintain acceptable performance with no evidence of metabolic insult. Cattle started on the 3F regimen also are of notable interest. Again, starting cattle on the step 3 diet may not yield sufficient lactic acid and ruminal acidity to promote optimal colonization by *Megasphaera esldenii*, such that when the cattle are then switched abruptly to the finishing diet, they do not have the full protective effects of *Megasphaera*. Cattle started on step 4 or cattle placed directly onto the finishing diet fared much better, again suggesting that presence of lactate and/or low ruminal pH may be essential for establishment of the organism.

Feed efficiency responded in a quadratic manner to progressive elimination of transition diets ($P = 0.01$), with heifers on the 3F step-up regimen having the poorest efficiency. The magnitude of differences between treatments was less pronounced when gain was adjusted to account for differences in dressing percentage ($P = 0.12$), but reveal a similar relationship. Again, these observations may suggest that adopting a more aggressive step-up strategy is necessary to fully exploit the benefits of Lactipro.

Elimination of diets and the time required to place cattle on feed has obvious logistical advantages for feedlots as a result of simplifying and streamlining the step-up process by decreasing the number of loads of feed that must be prepared, potentially decreasing fuel usage and labor requirements, as well as use and handling of roughages.

Step-up regimen had no significant effects on incidence or severity of liver abscesses. Carcass weight; dressed yield; percentage kidney, pelvic, and heart fat; and 12th rib fat thickness also were not affected by step-up regimen (Table 4). Effect of step-up regimen on ribeye area was quadratic ($P = 0.01$) and smallest for carcasses from heifers on the 34F step-up regimen. Additionally, step-up regimen had a quadratic affect on the percentage of yield grade 1 carcasses, with the 34F regimen having the lowest percentage of yield grade 1 carcasses (Table 5). Marbling score was influenced by step-up regimen (Linear, $P = 0.12$; quadratic, $P = 0.02$), with the greatest improvements realized with cattle placed on the more aggressive step-up regimens. Quality grades (Table 6) followed similar trends, but differences among treatments were not significant.

Implications

Heifers can be transitioned to finishing diets more rapidly when *Megasphaera* is dosed at processing without negatively affecting performance or carcass characteristics; however, if heifers are not stepped up aggressively enough, the full benefits from dosing *Lactipro* may not be realized.

Table 1. Step-up regimes for treatment groups

	Control	Lactipro (*Megasphaera elsdenii*) treatments				
Days on feed	(1234F)	234F	34F	3F	4F	F
1–5	Step 1	Step 2	Step 3	Step 3	Step 4	Finisher
6–10	Step 2	Step 3	Step 4	Finisher	Finisher	Finisher
11–15	Step 3	Step 4	Finisher	Finisher	Finisher	Finisher
16–20	Step 4	Finisher	Finisher	Finisher	Finisher	Finisher
21–129	Finisher	Finisher	Finisher	Finisher	Finisher	Finisher

Table 2. Composition of experimental diets on a 100% dry matter basis

	Step-up diets				
Ingredient, % of dry matter	Step 1	Step 2	Step 3	Step 4	Finisher
Dry rolled corn	5.69	15.69	25.69	35.69	45.69
Modified wet corn distillers grains	40.00	40.00	40.00	40.00	40.00
Corn silage	50.00	40.00	30.00	20.00	10.00
Supplement[1]	2.14	2.14	2.14	2.14	2.16
Feed additive premix[2,3]	2.16	2.16	2.16	2.16	2.16
Nutrient analyses, %					
Dry matter	48.41	52.21	56.66	61.93	68.28
Crude protein	15.88	15.97	16.06	16.15	16.24
Neutral detergent fiber	38.07	33.87	29.67	25.47	21.27
Crude fat	6.62	6.74	6.86	6.98	7.10
Calcium	0.78	0.76	0.74	0.72	0.70
Phosphorus	0.46	0.47	0.48	0.48	0.49
Potassium	0.94	0.88	0.82	0.76	0.70

[1] Formulated to provide 0.3% salt, 0.1 ppm Co; 1.0 ppm Cu; 0.6 ppm I; 60 ppm Mn; 0.25 ppm Se; 60 ppm Zn; 1,000 IU/lb vitamin A; and 10 IU/lb vitamin E on a dry matter basis.
[2] Formulated to provide 300 mg Rumensin and 90 mg Tylan (Elanco Animal Health, Greenfield, IN) per heifer daily.
[3] Zilmax (Merck Animal Health, Summit, NJ) was fed for 20 days followed by a 3-day withdrawal before harvest.

Table 3. Feedlot performance of heifers orally dosed with Lactipro (*Megasphaerea elsdenii*) at initial processing and placed onto accelerated step-up regimens

Item	Control (1234F)	Lactipro (*Megasphaera elsdenii*) treatments					SEM	F-test *P*-value	Step-up regimen, *P*-value	
		234F	34F	3F	4F	F			Linear	Quadratic
No. of cattle	63	63	63	63	62	63				
Days on feed	129	129	129	129	129	129				
Initial weight, lb	850	850	849	849	848	851	24	0.28	0.89	0.14
Final weight, lb[1]	1322	1314	1307	1297	1310	1316	26.0	0.48	0.50	0.07
Average daily gain, lb/day	3.66	3.59	3.55	3.48	3.59	3.62	0.07	0.52	0.50	0.10
Dry matter intake, lb/day	26.85	27.17	26.78	26.86	26.81	26.70	0.69	0.95	0.29	0.07
Feed:gain, lb/lb	7.29	7.52	7.52	7.71	7.36	7.37	0.200	0.08	0.89	0.01
Carcass adjusted[2]										
Average daily gain, lb/day	3.64	3.60	3.60	3.51	3.56	3.64	0.08	0.82	0.76	0.28
Feed:gain, lb/lb	7.32	7.53	7.43	7.65	7.41	7.30	0.205	0.55	0.88	0.12

[1] Final body weight shrunk (4%).
[2] Hot carcass weight was divided by a common dressing percentage (63.5) and used as final body weight to calculate carcass adjusted average daily gain and gain:feed.

Table 4. Carcass characteristics and liver abscess scores of heifers orally dosed with Lactipro (*Megasphaera elsdenii*) at initial processing and placed onto accelerated step-up regimes

Item	Control (1234F)	Lactipro (*Megasphaera elsdenii*) treatments					SEM	F-test *P*-value	Step-up regimen, *P*-value	
		234F	34F	3F	4F	F			Linear	Quadratic
Hot carcass weight, lb	838	834	833	826	830	838	17.4	0.78	0.75	0.20
Dressed yield, %	63.4	63.5	63.8	63.7	63.3	63.7	0.28	0.78	0.65	0.64
Ribeye area, in.^{2}	14.2	13.8	13.8	13.9	13.7	14.3	0.23	0.10	0.73	0.01
Kidney, pelvic, and heart fat, %	2.47	2.52	2.50	2.42	2.46	2.50	0.06	0.81	0.86	0.67
12th-rib fat, in.	0.44	0.46	0.40	0.44	0.38	0.43	0.02	0.10	0.20	0.31
Liver abscesses, %	15.9	22.2	7.9	11.1	8.0	14.3	4.39	0.15	0.18	0.25
Abscess severity, %										
A-	6.4	6.4	0	3.2	3.2	3.2	2.47	0.41	0.27	0.24
A	1.6	7.9	3.2	3.2	0.0	6.4	2.44	0.17	0.99	0.78
A+	7.9	7.9	4.8	4.8	4.8	4.8	3.03	0.91	0.31	0.64

Table 5. USDA yield grades of heifers orally dosed with Lactipro (*Megasphaera elsdenii*) at initial processing and placed onto accelerated step-up regimes

Item	Control (1234F)	Lactipro (*Megasphaera elsdenii*) treatments					SEM	F-test *P*-value	Step-up regimen, *P*-value	
		234F	34F	3F	4F	F			Linear	Quadratic
USDA yield grade	2.4	2.5	2.4	2.4	2.2	2.3	0.11	0.51	0.18	0.76
Yield grade 1, %	15.9	6.4	11.1	14.3	11.3	20.6	4.57	0.25	0.24	0.10
Yield grade 2, %	42.6	44.4	50.8	46.0	59.7	38.1	6.28	0.22	0.75	0.13
Yield grade 3, %	31.8	44.4	28.6	30.2	27.4	31.8	5.90	0.36	0.32	0.84
Yield grade 4, %	9.5	4.8	9.5	9.5	1.6	9.5	3.43	0.38	0.73	0.67

Table 6. USDA quality grades and marbling scores of heifers orally dosed with Lactipro (*Megasphaera elsdenii*) at initial processing and placed onto accelerated step-up regimes

Item	Control (1234F)	Lactipro (*Megasphaera elsdenii*) treatments					SEM	F-test *P*-value	Step-up regimen, *P*-value	
		234F	34F	3F	4F	F			Linear	Quadratic
Marbling[1]	467	467	466	449	471	497	10.87	0.07	0.12	0.02
Prime, %	0	3.2	0	0	3.2	3.2	1.58	0.30	0.23	0.51
Premium Choice, %	12.7	11.1	9.5	14.3	17.8	17.5	4.44	0.71	0.18	0.50
Total Choice, %	68.3	71.4	73.0	65.1	71.0	71.4	5.85	0.94	0.89	0.95
Select, %	27.0	17.5	15.9	28.6	17.7	15.9	5.27	0.26	0.32	0.98
Sub-Select	0	0	1.6	0	0	0	0.65	0.42	0.77	0.29
Other[2]	1.6	1.6	3.2	0	0	3.2	1.64	0.54	0.99	0.51

[1] Marbling score determined by USDA graders. Values ranging from 400 to 499 represent a small degree of marbling.
[2] The "Other" category includes dark cutters and B-maturity carcasses.

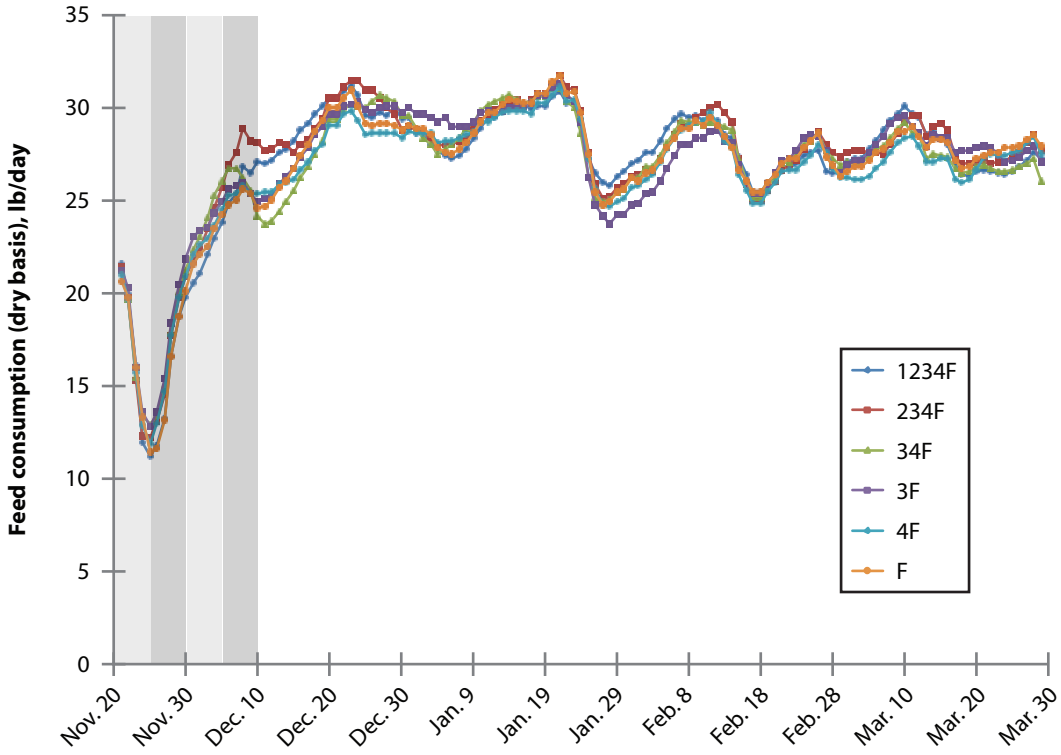


Figure 1. Daily dry matter consumption for finishing cattle stepped up to a final finishing ration using a traditional 5-step regimen (no Lactipro) compared with cattle stepped up to the final finisher using accelerated regimes after oral dosing with Lactipro (*Megasphaera elsdenii*). Step-up diets 1, 2, 3, and 4 each were fed for 5 days before switching to the next diet.

Zilmax Alters Blood Constituents of Finishing Cattle

C.L. Van Bibber and J.S. Drouillard

Introduction

The purpose of this experiment was to determine the effects of Zilmax (Merck Animal Health, Summit, NJ) on changes in blood metabolites. Zilmax is a feed additive designed to improve production efficiency in cattle when fed during the last phase at the feedlot. Zilmax works by redirecting the energy use in the body to form more lean muscle at the expense of fat deposition. The blood metabolites measured in our experiment were glucose and lactate, which are the energy sources for various body functions including muscle growth. Plasma urea nitrogen was measured as an indicator of protein catabolism. Non-esterified fatty acids also were measured as they were released into the bloodstream with the breakdown of adipose tissue.

Experimental Procedures

Treatments consisted of diets with and without Zilmax administered for 23 days prior to harvest with a 3-day withdrawal period. Steers (n = 18) were stratified by initial body weight and randomly assigned, within strata, to the 2 treatment groups. Cattle were then allotted to individual, partially covered feeding pens equipped with concrete floors, fence line feed bunks, and automatic water fountains. Steers were identified with ear tags displaying a number unique to each study animal.

Feed intakes were monitored daily, and unconsumed feed was removed from the bunk, weighed, and dried at weekly intervals or as needed to determine actual feed intake. Body weights were captured for each steer at 7-day intervals and again on the day of harvest. Blood was drawn from each steer via jugular venipuncture prior to feeding on days 0, 7, 14, and 21. A small amount of whole blood was used to determine concentrations of glucose and lactate, and the remaining sample was centrifuged immediately to recover plasma. Plasma was stored in microcentrifuge tubes and subsequently analyzed to determine concentrations of plasma urea nitrogen, non-esterified fatty acids, glucose, and lactate.

At the end of the finishing phase, cattle were weighed, loaded onto a truck, and transported to a commercial abattoir in Holcomb, KS. Harvest data were collected, including incidence and severity of liver abscesses; carcass weight; USDA yield grade; USDA quality grade; marbling score; 12th-rib fat thickness; loin-eye area; percentage kidney, pelvic, and heart fat; and incidence and severity of dark cutting beef.

Results and Discussion

Feeding Zilmax decreased dry matter intake by 8% ($P < 0.10$) but did not affect live weight gain or efficiency ($P > 0.10$; Table 1). Feeding Zilmax resulted in greater carcass weights, increased dressing percentage, and greater ribeye area ($P < 0.10$; Table 2). Zilmax numerically decreased marbling score and yield grade but did not influence other carcass traits ($P > 0.10$). Zilmax decreased glucose as well as plasma urea nitrogen

concentrations ($P < 0.10$) in whole blood (Table 3). A Zilmax × day interaction also was observed ($P < 0.10$) for plasma urea nitrogen. Plasma concentrations of lactate, non-esterified fatty acids, and beta hydroxyl butyrate were unaffected ($P > 0.10$) by addition of Zilmax to the diet.

Implications

Zilmax decreased circulating concentrations of plasma urea nitrogen, suggesting that protein catabolism was at least partially inhibited.

Table 1. Feedlot performance of steers fed diets with or without Zilmax

Item	Control	Zilmax	SEM	*P*-value
Dry matter intake, lb	26.12	24.12	1.01	0.02
Average daily gain, lb	4.22	4.21	0.75	0.99
Gain:feed	6.19	5.73	1.12	0.78
Initial body weight, lb	1407	1411	27.98	0.21
Final body weight, lb	1510	1517	31.61	0.72

Table 2. Carcass characteristics of steers fed diets with or without Zilmax

Item	Control	Zilmax	SEM	*P*-value
Hot carcass weight, lb	915	946	19.80	0.02
Dressed yield, %	63.1	65.0	0.68	0.08
Liver abscesses, %	0	0	-	-
Average yield grade	2.63	2.00	0.26	0.12
Marbling score[a]	408	378	28.53	0.47
Prime, %	0	0	-	-
Premium Choice, %	0	0	-	-
Choice, %	26.1	44.4	17.59	0.44
Select, %	73.9	55.6	17.59	0.44
12th-rib fat depth, in.	0.36	0.33	0.04	0.63
Kidney, pelvic, and heart fat, %	2.062	2.056	0.17	0.98
Ribeye area, in.^{2}	13.7	15.4	0.55	0.07

[a] Marbling scores were obtained by a USDA certified grader; slight = 300–399, small = 400–499, modest = 500–599.

Table 3. Blood components on days 0, 7, 14, 21 for steers fed diets with or without Zilmax

	Day 0		Day 7		Day 14		Day 21			*P*-value	
Item, mM	Control	Zilmax	Control	Zilmax	Control	Zilmax	Control	Zilmax	SEM	Zilmax	Zilmax × day
Whole blood glucose	3.32	3.39	3.33	3.01	3.48	3.12	3.48	3.09	0.24	0.42	0.06
Whole blood lactate	2.83	2.80	2.45	1.43	2.37	1.37	2.16	1.54	0.48	0.17	0.31
Plasma glucose	5.17	5.21	5.33	4.77	5.23	4.96	5.38	5.10	0.36	0.52	0.37
Plasma lactate	3.58	3.93	3.21	2.22	3.28	2.17	2.85	2.52	0.20	0.22	0.19
Non-esterified fatty acids	126	175	172	192	164	184	140	174	36.0	0.25	0.97
Beta hydroxyl butyrate	0.01	0.08	0.02	0.07	0.01	0.06	0.02	0.06	0.83	0.20	0.72
Plasma urea nitrogen	4.18	3.74	4.51	3.36	4.94	3.30	4.47	3.26	0.24	<0.10	0.06

Feeding Crude Glycerin Decreases Fecal Shedding of *E. coli* O157:H7 in Growing Cattle

C. Aperce and J.S. Drouillard

Introduction

Crude glycerin is a byproduct of ethanol production and is used as a carbohydrate source for cattle feed. Glycerin levels in previous studies have ranged from 0 to 20% of diet dry matter, and concentrations of 8% or less generally improve feedlot performance. At even low levels of glycerin, however, the activity of cellulolytic bacteria is depressed, ultimately leading to poorer fiber digestion. This observation suggests that glycerin may affect a specific population of bacteria in the gut. Crude glycerin can account for 8 to 10% of the weight of dried distillers grains with solubles, because it is one of the primary end-products when yeast ferments sugars to produce ethanol. Addition of 25% dried distillers grains with solubles to a feedlot diet increased the prevalence of *Escherichia coli* O157:H7 in feces of cattle. These observations led us to question whether glycerin might be the component of distillers grains responsible for the increases in prevalence of *E. coli* O157:H7 that often are observed in cattle fed distillers grains. To address this question, we added glycerin to diets of growing cattle and subsequently evaluated fecal shedding of *E. coli* O157:H7.

Experimental Procedures

We added three levels of crude glycerin, 0, 4, or 8%, to growing diets containing dry-rolled corn, corn silage, alfalfa hay, and corn steep liquor (Table 1). We formulated all diets so they would be isonitrogenous.

Each treatment was represented by 16 pens, each containing 7 to 8 heifers. We obtained fecal samples by fecal grab at the chute once a week for 6 weeks. Fecal samples were kept on ice until analysis. We weighted approximately 1 gram of feces and placed it in 9 mL Gram Negative broth (Difco, Inc., Corpus Christi, TX) with cefixime (0.05 mg/L), cefsulodin (10 mg/L), and vancomycin (8mg/L; GNccv) for a 6-hour incubation at 104°F. We added 1 mL of GNccv to a sterile tube containing 20 µL of *E. coli* O157-specific beads and subjected it to immunomagnetic separation. We then resuspended the resulting *E. coli* O157 beads in 100 µL of phosphate buffer and plated them onto a selective agar for *E. coli* O157:H7 for an overnight incubation at 98°F. After incubation, we picked up to 6 non-sorbitol fermenting colonies and tested them for indole production. We further analyzed indole-positive colonies using an O157 antigen agglutination kit. We considered colonies positive for agglutination and indole production as *E. coli* O157:H7.

Results and Discussion

The crude glycerin used in this experiment contained 81.5% glycerol. After statistical analysis, we concluded that no interaction occurred between sampling date and the levels of crude glycerin ($P > 0.2$). Sampling date, however, did have an effect ($P < 0.01$), as shown in Figure 1. For the first 2 weeks, percentages of samples that tested positive for *E. coli* O157:H7 were 1.3 and 0.8%, respectively. The prevalence then increased to

a peak of 8.8% during the fourth week, then stabilized around 4.3 to 5.8% during the final 2 weeks of the experiment. We also observed an effect of glycerin inclusion levels ($P < 0.01$; Figure 2). Fecal incidence rates of *E. coli* O157:H7 were 5.8, 4.3, and 2.4% for heifers fed 0, 4, and 8% glycerin, respectively. The prevalence we observed in heifers fed 4% glycerin tended to differ from that of cattle fed 8% glycerin ($P = 0.06$), but was not different from that of cattle fed the diet with 0% glycerin. Glycerin previously has been shown to inhibit the activity of cellulolytic bacteria in the rumen. Consequently, changes in fecal prevalence of *E. coli* O157:H7 observed in this study might be explained by alterations in gastrointestinal flora, with higher levels of glycerin producing a less favorable environment for the proliferation of pathogenic *E. coli* O157:H7.

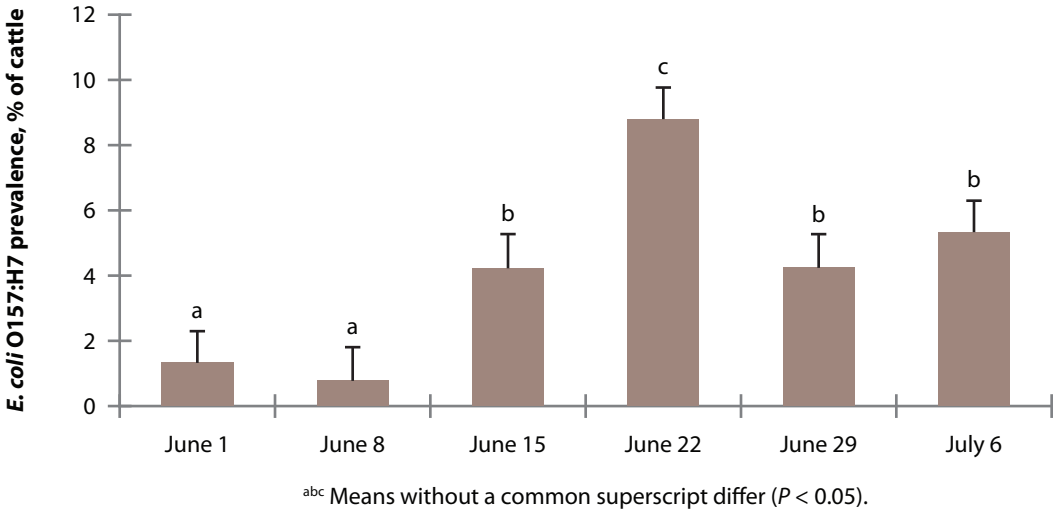
Implications

Our goal in this study was to determine if feeding glycerin would affect shedding of *E. coli* O157:H7 in cattle feces. Our results demonstrated that increasing levels of crude glycerin decreased the prevalence of *E. coli* O157:H7, and that this could be a useful pre-harvest strategy for controlling the shedding of pathogenic *E. coli* in cattle.

Table 1. Composition of experimental diets (dry basis)

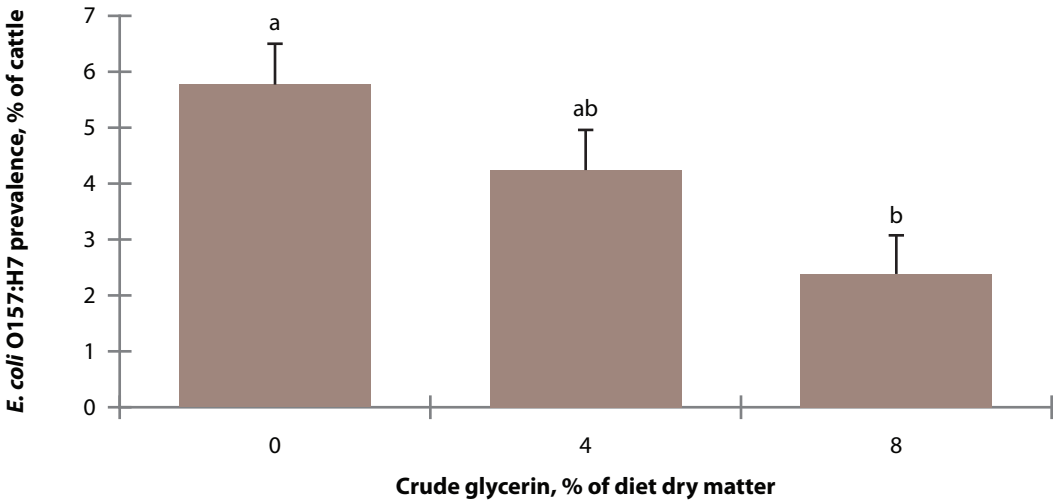
Ingredients, %	0% glycerin	4% glycerin	8% glycerin
Corn silage	60	60	60
Wet corn gluten feed	35	30.2	25.4
Crude glycerin	-	4	8
Soybean meal	-	0.8	1.6
Limestone	1.6	1.6	1.6
Urea	0.4	0.4	0.4
Vitamin/mineral premix[1]	0.3	0.3	0.3
Feed additive premix[2]	2.7	2.7	2.7
Nutrient composition			
Dry matter, %	43.3	43.7	44.2
Crude protein, %	13.0	12.5	12.1
Neutral detergent fiber, %	36.2	34.7	33.2
Calcium, %	0.75	0.75	0.75
Phosphorus, %	0.51	0.47	0.42

[1] Formulated to provide (dry basis) 0.1 ppm cobalt, 10 ppm copper, 0.6 ppm iodine, 60 ppm manganese, 0.25 ppm selenium, 60 ppm zinc, 0.3% salt, 1,000 IU/lb vitamin A in the total diet.
[2] Provided 300 mg of Rumensin (Elanco Animal Health, Greenfield, IN) per heifer daily in a ground corn carrier.



[abc] Means without a common superscript differ ($P < 0.05$).

Figure 1. *E. coli* O157:H7 prevalence in growing cattle fed crude glycerin.



[ab] Means without a common superscript differ ($P < 0.05$).

Figure 2. Effect of crude glycerin levels fed to growing cattle on *E. coli* O157:H7 prevalence.

Carryover Effects of Crude Glycerin Fed During the Growing Phase on Finishing Cattle Performance and Carcass Characteristics

C. Aperce and J.S. Drouillard

Introduction

Crude glycerin is a byproduct of biodiesel production, and its use as a feedstuff for cattle has expanded in the last decade due to increased availability and favorable pricing compared with other energy concentrates such as cereal grains. Incorporation of glycerin into cereal-based finishing diets, at levels up to 8%, has been shown to improve cattle performance; however, it decreases activity of cellulolytic microorganisms in the rumen, ultimately decreasing fiber digestion. Most of the studies conducted to date have evaluated glycerin in finishing diets that contain relatively small amounts of fiber, but little is known of its value as an energy source for growing cattle that typically are fed diets containing greater proportions of fiber. Moreover, possible carryover effects from feeding glycerin in the growing phase and effects on finishing performance and carcass characteristics are unknown. In this study, we wanted to evaluate glycerin as a component of diets fed throughout a 90-day backgrounding phase to determine its impact on performance and carcass characteristics of heifers during the subsequent finishing phase when they were no longer fed glycerin.

Experimental Procedures

We used 368 crossbred heifers (515 ± 7 lb body weight) that we randomly allocated to treatments and concrete-surfaced pens (7 to 8 heifers/pen). Heifers were fed once daily and had free-choice access to feed and water. During the growing period (days 0 to 90), the diet consisted of 60% corn silage and 40% concentrate (predominantly wet corn gluten feed). We added crude glycerin derived from soybean oil at 0, 4, or 8% of the diet dry matter, substituting for a portion of the corn gluten feed. All diets were formulated to contain similar amounts of protein (Table 1).

During the subsequent finishing period (days 91 to 210), all heifers were fed finishing diets containing 90% concentrate (30% wet corn gluten feed, dry rolled corn, 10% corn silage, and supplement). We weighed cattle at the beginning and end of each period and collected feed refusals throughout the experiment to assess dry matter intake, average daily gain, and feed:gain ratio. We collected carcass data at harvest. Data were analyzed using the MIXED procedure SAS (SAS Inc., Cary, NC).

Results and Discussion

Statistical analysis of the growing period data illustrate that gain and feed intake were not affected by the different levels of crude glycerin added to the diet (Table 2), but heifers fed crude glycerin were more efficient ($P < 0.05$). During the subsequent finishing period, heifers previously fed glycerin at 4 or 8% of the diet dry matter ate more, gained more weight, and were more efficient than heifers that were not previously exposed to glycerin (Table 2). At harvest, heifers receiving glycerin during the growing phase had heavier final body weights ($P < 0.01$), improved marbling scores ($P < 0.01$),

and heavier hot carcass weights ($P < 0.05$) compared with animals fed growing diets without glycerin.

Implications

Glycerin added to growing diets fed for 90 days improved average daily gain and efficiency in the subsequent 120-day fattening period. Marbling score, carcass weight, and final body weight also increased in response to feeding glycerin in the previous growing period. These findings suggest that carryover effects of glycerin feeding influence growth performance and carcass characteristics subsequent to its removal from the diet.

Table 1. Composition of diets fed during the background phase (dry basis)

Ingredient, % of dry matter	0% glycerin	4% glycerin	8% glycerin
Corn silage	60	60	60
Wet corn gluten feed	35	30.2	25.4
Crude glycerin	-	4	8
Soybean meal	-	0.8	1.6
Supplement[1]	3.0	3.0	3.0
Nutrient composition			
Crude protein, %	13.0	12.5	12.1
Neutral detergent fiber, %	36.2	34.7	33.2
Calcium, %	0.75	0.75	0.75
Phosphorus, %	0.51	0.47	0.42

[1] Formulated to provide (dry basis) 0.1 ppm cobalt, 10 ppm copper, 0.6 ppm iodine, 60 ppm manganese, 0.25 ppm selenium, 60 ppm zinc, 0.3% salt, 1,000 IU/lb vitamin A in the total diet. Also provided 300 mg of Rumensin (Elanco Animal Health, Greenfield, IN) per heifer daily in a ground corn carrier.

Table 2. Carryover effects of glycerin fed during the backgrounding phase on performance and carcass characteristics of feedlot heifers

	Glycerin fed during backgrounding phase, % of diet dry matter				*P*-values	
Item	0	4	8	SEM	Linear	Quadratic
Backgrounding phase						
Dry matter intake, lb/day	19.58	19.00	18.81	0.293	0.069	0.166
Average daily gain, lb	3.26	3.33	3.31	0.055	0.753	0.518
Feed:gain	6.06	5.81	5.75	0.069	0.005	0.271
Finishing phase						
Dry matter intake, lb/day	21.25	21.76	22.18	0.604	0.025	0.919
Average daily gain, lb	2.56	2.76	2.84	0.119	0.0003	0.367
Feed:gain	8.47	8.00	7.87	0.132	0.01	0.384
Final live weight, lb	1116	1142	1153	21.2	0.009	0.466
Carcass characteristics						
Hot carcass weight, lb	688	703	710	6.4	0.028	0.554
Ribeye area, in.^{2}	12.2	12.6	12.7	0.15	0.053	0.364
12th rib fat thickness, in.	0.622	0.598	0.630	0.049	0.738	0.270
Kidney, pelvic, and heart fat, %	2.33	2.31	2.39	0.043	0.340	0.373
Marbling score[a]	Sl66	Sl80	Sl99	8.4	0.009	0.845
USDA yield grade	2.74	2.67	2.72	0.093	0.896	0.614
Choice or better, %	82.5	81.0	87.1	0.034	0.4161	0.7566

[a] Sl0 to Sl99 is equivalent to a Slight degree of marbling.

LED Lighting Extends Color Shelf Life for Three Beef Products Compared with Fluorescent Lighting

K.S. Steele, M.J. Weber[1], E.A.E. Boyle, M.C. Hunt, A.S. Lobaton-Sulabo, C. Cundith[1], Y.H. Hiebert[2], K.A. Abrolat[2], J.M. Attey[2], S.D. Clark[2], D. Johnson, and T.L. Roenbaugh

Introduction

Consumers are not able to estimate tenderness, juiciness, or flavor when selecting beef cuts at retail stores. Instead, they rely on color as one of the major criteria to select beef cuts. During refrigerated display, fresh meat color changes and consumers discriminate against discolored meats. Meat items with discoloration must be discounted or discarded, leading to up to $1 billion in revenue loss nationally for the meat industry.

Lighting type and intensity have a major impact on the appearance and shelf life of fresh beef in refrigerated retail display. Light emitting diode (LED) lighting offers advantages for display because it is more energy-efficient and generates less heat than fluorescent lights. These advantages may be beneficial for fresh meat color stability.

The objective of this study was to determine the effects of LED and fluorescent (FLS) lighting on visual and instrumental meat color and shelf-life properties of three fresh beef products displayed in two retail display cases that were set up to run at similar temperature profiles when case lighting was off prior to the initiation of the study.

Experimental Procedures

Select/low choice beef *semimembranosus* subprimals, beef *longissimus dorsi* steaks enhanced at 8% pump (beef stock, lactate, phosphate, salt, and natural flavorings), and coarse ground beef (85% lean and 15% fat) were obtained from a commercial supplier (Cargill Meat Solutions, Wichita, KS). The beef was reprocessed by cutting into 1-inch-thick steaks or grinding and/or repackaging on foam trays with a moisture-absorbent pad, then overwrapped with PVC for display.

Two refrigerated retail display cases equipped with fluorescent or LED lighting were adjusted to operate at similar temperature profiles with the lights turned off so lighting would be the sole variable. Each display case had four adjustable shelves consisting of two sections and a fixed bottom shelf. Shelves were arranged identically in both cases and were similar in vertical spacing to cases in Manhattan, KS, supermarkets.

Within each product type, products were randomly selected for replication and display location on a specific shelf. For each case, one shelf held 6 replications of 6 beef *longissimus dorsi* steaks, another shelf held 4 replications of 6 ground beef packages, and the bottom shelf held 6 replications of 6 beef *semimembranosus* steaks. In total, 72 beef

[1] Cargill, Wichita, KS.
[2] Hussmann Corporation, Bridgeton, MO.

longissimus dorsi steak packages, 48 ground beef packages, and 72 beef *semimembranosus* steak packages were evaluated for initial pH, visual and instrumental color, internal temperature, subjective odor, thiobarbituric acid reactive substances, and except for beef *semimembranosus* steaks, microbial populations during display. Packaged products were displayed immediately after final packaging (0 days) and displayed until the end of visual color life as determined by an average visual color panel score of 4.

The meat products in both cases were illuminated 24 hours per day. In the LED case, a canopy lighting fixture positioned above the top shelf had a correlated color temperature of 2,867 K and a color rendering index of 93. The bottom four shelves were illuminated with LED light bars with a correlated color temperature of 3,007 K and a color rendering index of 95.7. Lighting intensity in the LED case averaged 1,627 lm. The FLS lighting had a correlated color temperature of 3,500 K, a color rendering index of 82, and lighting intensity averaging 1,712 lm. Case temperatures were recorded every 10 minutes throughout display.

A minimum of 8 trained visual color panelists from Kansas State University evaluated beef color daily to the nearest 0.5 increment using 8-point scales unique to each product. The beef loin steak, ground beef, and beef inside round superficial portion color scale was: 1 = very bright red, 4 = slightly dark red, 8 = tan to brown. The beef inside round deep portion steak visual color scale was: 1 = very bright pinkish red, 4 = slightly dark pinkish red, 8 = tan to brown. An average visual panel score of 4 represented the end of product color shelf life (estimated as the point of objectionable color in retail displays). The color of beef loin steaks and beef inside round steaks was evaluated by panelists once per day at a standardized time. The superficial and deep portions of the inside round steaks were evaluated separately for color. Ground beef color was visually scored every 12 hours through day 2 of display, then every 24 hours for the remaining display time.

Instrumental color of the meat products was recorded using a HunterLab MiniScan EZ (Model 4500; Reston, VA) for values of L* (lightness), a* (redness), and b* (yellowness). Saturation index (degree of redness) was calculated using the a* and b* measurements. Internal product temperature was measured daily at the geometric center of samples using a thermocouple (Omegaette HH300 Series Thermometer, Stamford, CT). Odor was scored immediately after opening a package on day 0 and at the end of display. Three trained odor panelists subjectively evaluated off-odors using a 5-point scale: 1 = no off-odor, 2 = slight, 3 = small, 4 = moderate, and 5 = extreme off-odor. Product oxidation was analyzed using the thiobarbituric acid reactive substances procedure on samples collected from the upper ¼ in. of the displayed surface on day 0 and at the end of display.

Two packages of each product under fluorescent and LED lighting were evaluated for microbial populations at the beginning, middle, and end of color shelf life. Initial microbial testing was performed on day 0 for all products. The middle and end sampling day was determined by an average visual color panel score of 2 and 4, respectively. As a result, each product had a unique middle and end microbial sampling day. Aerobic Plate Count and *Enterobacteriaceae* populations were determined using Petrifilm (3M Microbiology Products; St. Paul, MN). Plates for Aerobic Plate Count and *Enterobac-*

teriaceae populations were incubated at 89.6°F for 48 hours and 24 hours, respectively, prior to enumeration.

Results and Discussion

Throughout display, the LED case temperature was 1.2°F lower ($P < 0.05$) than the fluorescent case (Figure 1). Temperatures at the front of the shelves were from 3.5 to 4.2°F higher ($P < 0.05$) than temperatures at the back of the shelves. No differences ($P > 0.05$) were observed for temperatures among the 5 shelves. The average case condenser cycle during display for LED and fluorescent cases was 10.7 cycles/hour and 18.0 cycles/hour, respectively. Although numerous factors affect case operation efficiency, lower temperatures indicate shelf life advantages for products held under LED lighting. An LED case not only operates with greater energy efficiency, but also sustains lower temperatures than a fluorescent lighted case.

Ground beef and beef inside round steaks in the LED case had lower ($P < 0.05$) internal temperatures than under FLS (Figure 2). The internal temperature of beef loin steaks was similar ($P > 0.05$) regardless of lighting type.

All three beef products on display had better ($P < 0.05$) color stability under LED lighting based on evaluations by trained color panelists except the deep potion of the beef inside round steak (Figure 3), resulting in an extended color shelf life and economic benefits for retailers. As expected, the discoloration of products increased over the duration of the study. End product color shelf life, as determined by the panelists' scores, were 2, 4, and 4 days for beef loin steaks, ground beef, and beef inside round steaks, respectively.

Visual color results shown in Figure 3 demonstrate that the superficial portion of beef inside round steaks should be displayed under LED lighting for extended shelf life. Using instrumental color parameters to support the subjective comparison of visual scores can give an indication of shelf life extension. The deep portion beef inside round steaks had greater ($P < 0.05$) a* redness values under LED lighting compared with fluorescent lighting. Redness or a* values decreased ($P < 0.05$) over time for beef loin steaks, ground beef, and the deep and superficial portions of beef inside round steaks. The superficial and deep portions of beef inside round steaks had 1.1 and 1.4 more ($P > 0.05$) red saturation units under LED lighting compared with fluorescent lighting, but no difference existed for the other two beef products. The visual differences observed for the superficial portion of beef inside round steaks under LED or fluorescent lighting were confirmed by instrumental data, where redness saturation values were higher for LED lighting.

All products had no off-odor on day 0 except for the beef loin steaks, which had a very slight off-odor, possibly because they were 9 days post-case-ready packaging at the initiation of the study. Over the duration of the study, beef loin steaks and ground beef had odor scores of 3, equating to small amounts of detectable odor at the end of their color life.

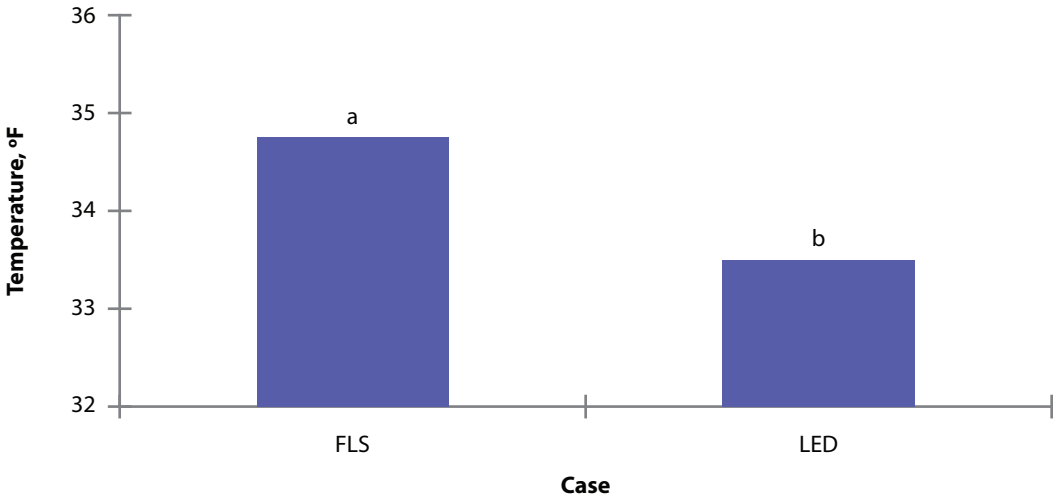
Beef inside round steaks had higher ($P < 0.05$) oxidation values when displayed under LED lighting than fluorescent lighting, and there was a day effect, with higher ($P < 0.05$) oxidation values on the last day of display compared with the first day. Consumers can

begin to detect rancid flavors when oxidation or thiobarbituric acid reactive substances values reach 2 mg malonaldehyde/kg. Beef inside round steaks had 1.98 mg malonaldehyde/kg by the final day of display.

No differences were measured ($P > 0.05$) in Aerobic Plate Count or *Enterobacteriaceae* growth for any of the beef products due to lighting type.

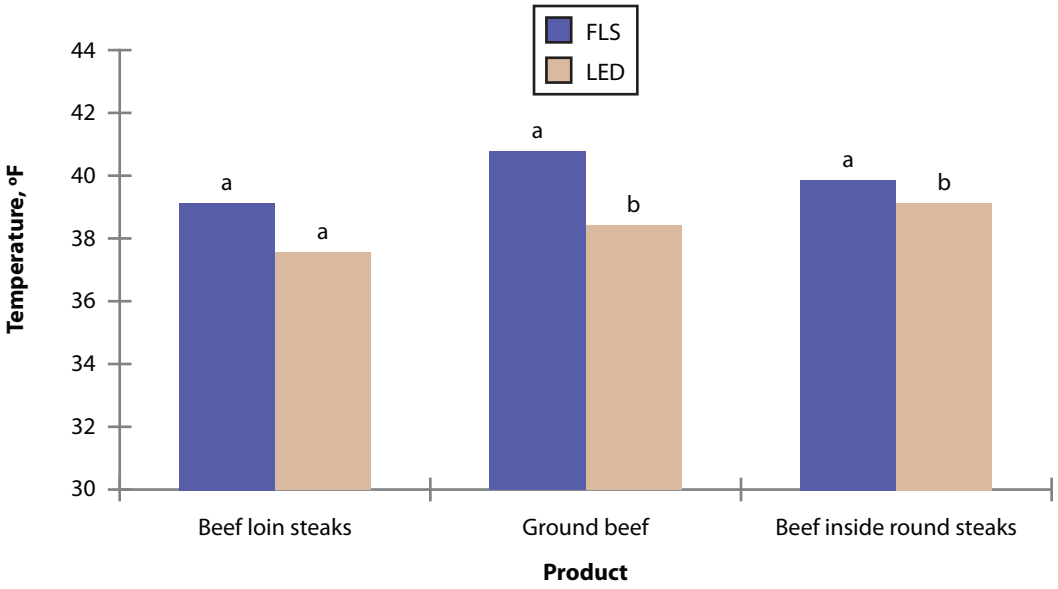
Implications

Using LED lighting in retail meat display cases will save money by reducing overhead operational costs while extending the color life of beef loin steaks, ground beef, and beef inside rounds.



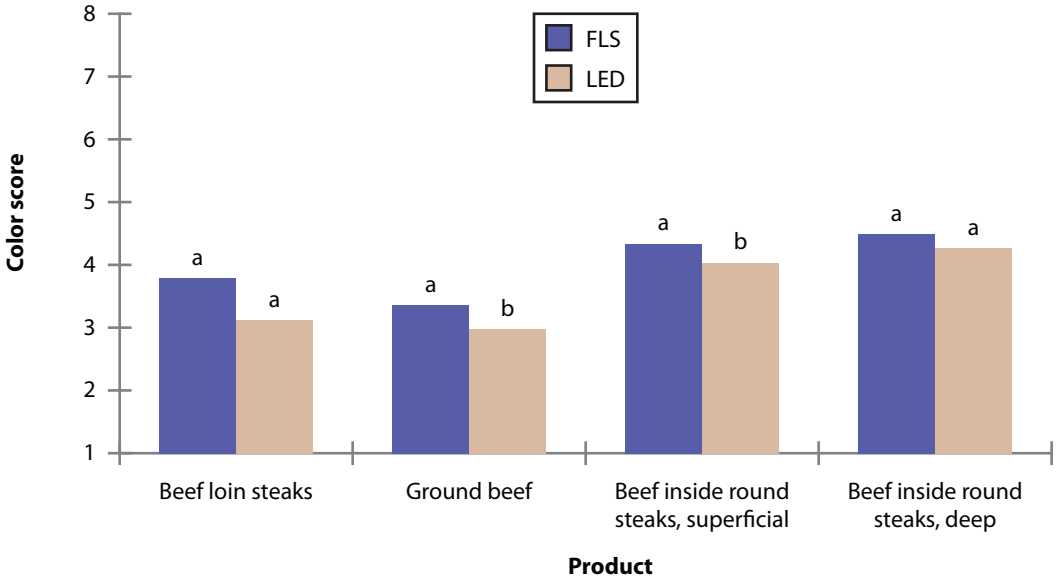
[ab] Means without a common superscript differ ($P < 0.05$).

Figure 1. Case temperature for cases equipped with fluorescent (FLS) or light emitting diode (LED) lighting.



[ab] Columns with different letters differ at $P < 0.05$.

Figure 2. Internal product temperature.



[ab] Columns with different letters differ at $P < 0.05$.

Figure 3. Visual color of five products displayed in two meat retail display cases equipped with fluorescent (FLS) or light emitting diode (LED) lighting.
Beef loin steak color scale: 1= very bright red, 4 = slightly dark red, 8 = tan to brown. Ground beef visual color scale: 1 = very bright red, 4 = slightly dark red, 8 = tan to brown. Beef inside round superficial portion steak visual color scale: 1 = very bright red, 4 = slightly dark red, 8 = tan to brown. Beef inside round deep portion steak visual color scale: 1 = very bright pinkish red, 4 = slightly dark pinkish red, 8 = tan to brown.

A Commercially Available SRP Vaccine Reduces Prevalence of *E. coli* O157:H7 in Feces of Beef Cattle Under Commercial Feedlot Conditions

B.A. Butler, D.U. Thomson, T.G. Nagaraja, G.H. Loneragan[1], and C.D. Reinhardt

Introduction

Of all food safety challenges facing the beef industry, *Escherichia coli* O157:H7 has consistently presented the greatest economic remonstrance to meat packers and retailers. Cattle naturally shed *E. coli* O157:H7 in their feces, and it is a source of carcass contamination at harvest. If contaminated trim enters the food supply and is subsequently prepared incorrectly, it can lead to the human condition known as hemorrhagic colitis. In children or elderly people, an *E. coli* O157:H7 infection may lead to a more serious form known as hemolytic uremic syndrome, which is potentially lethal. Although the majority of previous research has been dedicated to reduction in contamination post-harvest, recent focus has shifted to pre-harvest mitigation of *E. coli* O157:H7. Post-harvest procedures are effective, so there is less room for improvement than in pre-harvest mitigation. Also, reducing the *E. coli* O157 burden entering the plant may improve the efficacy of post-harvest tools and ultimately reduce human illness.

Most previous research efforts have been focused on controlling *E. coli* within the abbatoir. Over the last 10 years, the National Cattlemen's Beef Association has estimated *E. coli* O157 to cost the industry $2.67 billion. The *E. coli* O157 siderophore-receptor and porin-based (SRP) vaccine has been shown to reduce fecal shedding of *E. coli* in cattle in laboratory conditions as well as field conditions. In 2007, the vaccine received conditional licensure from the USDA. The objective of this study was to determine the efficacy of the SRP vaccine by (1) quantifying the prevalence of *E. coli* O157:H7 in vaccinated cattle under field conditions and (2) monitoring anti-SRP antibody titer levels immediately prior to harvest.

Experimental Procedures

Beef cattle from 10 commercial feedlots located in Nebraska and Colorado were used in the field trial, with a total of 200,000 animals enrolled in the study. Feedlots were randomly assigned to 1 of 2 treatments: (1) all incoming cattle were injected with 2 ml of SRP *E. coli* O157:H7 vaccine (Pfizer Animal Health, New York, NY) subcutaneously at arrival and again at time of re-implant (approximately 100 days prior to harvest) or (2) all incoming cattle were used as controls and did not receive the vaccine. Feedlots were assigned letters (A–J), and samples were labeled with the appropriate feedyard letter code, sample number, and sampling date to blind laboratory personnel to treatment assignment.

[1] Department of Animal and Food Sciences, Texas Tech University, Lubbock.

Cattle were housed in pens with pipe-and-cable fences, concrete feed bunks, and automatic waterers. Approximately 80 to 120 cattle were housed in each pen, depending on bunk space availability. Cattle did not co-mingle during the study. Cattle were fed a similar ration at all feedyards, consisting of a mixture of high-energy grains, roughage, and supplement.

Upon arrival, cattle were unloaded into an arrival pen and allowed to rest for 24 hours prior to processing. The next morning, cattle were processed, subjected to normal processing procedures (vaccination, deworming, and administration of a steroid implant), and administered the 2-ml dose of SRP *E. coli* O157 vaccine. Per label, the vaccine was administered subcutaneously in the neck. As part of the 2-dose regimen, cattle received a second 2-ml dose of the SRP vaccine at time of re-implant, which varied from 1 to 3 months after initial vaccination (approximately 80 to 100 days before harvest).

Pen floor fecal samples were taken from feedyards at 4 sampling intervals over the course of the summer (May, June, July, and August) of 2010. Within each feedyard, 5 pens of market-ready cattle were selected for sampling each week; cattle within these pens were shipped to the abbatoir the following week. Samples from 20 fresh fecal pats were collected using a clean spoon, cup, and lid. A 0.35-oz fecal sample was collected, and the sample cup was labeled and sealed in a plastic bag. The sealed bags containing the sealed sample cups were stored on ice in coolers. After sampling, coolers shipped overnight to the Epitopix laboratory in Willmar, MN, for microbiological analysis.

Coinciding with the fecal sample collection, pre-harvest blood samples were taken from cattle entering the packing plant. Samples were collected on 3 occasions throughout the summer (June, July, and August). For each sampling month, 1 lot of 5 animals representing each feedyard was sampled. Samples were shipped frozen on dry ice to Epitopix laboratory for anti-SRP antibody determination using enzyme-linked immunosorbant assay.

Pen-level prevalence of *E. coli* O157:H7 was converted to odds ratios, and these values were log transformed for statistical analysis. This statistical design entailed a repeated measure on the feedyard. Outcomes of interest were modeled using categorical linear regression techniques. Pen-level binomial response variables were analyzed using the LOGIT format of PROC GLIMMIX in SAS (SAS Inc., Cary, NC).

For fecal samples, 2 statistical models were found to be relevant in this trial. The first model took into account the random effect of feedyard, which incorporates interdependency between animals within a pen, as well as the interdependence of pens within the feedyard. This model revealed an interaction between feedyards and sampling month, so a second model was created to force this interaction into the model as a random variable. For the second model to converge, the random effect of feedyard was removed. From these models, least squared means were computed to determine statistical significance. Means were considered different using a protected F-test with $\alpha = 0.10$.

Results and Discussion

A significant vaccine status × sampling time interaction occurred for prevalence of *E. coli* O157:H7 in the feces of cattle ($P = 0.0004$). After accounting for this interaction, prevalence of *E. coli* O157:H7 was lower in the feces of vaccinated cattle (12.83%) when compared with feces of control cattle (20.25%; $P = 0.07$; Figure 1). This model demonstrates a reduction in *E. coli* O157 shedding with the use of 2 sequential doses of SRP vaccine. Prevalence was also lower in May than in June, July and August (Figure 2).

Anti-SRP antibody titer level was higher in vaccinates (0.622) versus controls (0.075; $P < 0.001$; Figure 3). Titers were also compared within the vaccinate cohort by days on feed since last vaccination. Cattle were placed into 1 of 3 bins based on the length of time since receiving the second vaccination. There was no difference in sample:positive ratios among the 3 groups.

Because vaccinated cattle demonstrated elevated titers when sampled at the packing plant immediately prior to harvest, the vaccine is effective at inducing a prolonged immune response throughout the feeding period. There was no difference in titer response with increasing days on feed following the final vaccination (Figure 4). Regardless of how many days prior to harvest calves were vaccinated, a measurable anti-SRP antibody response was evident at the time of slaughter. Results of this study suggest that a simple ELISA blood test at harvest could be used as a tool for vaccination compliance.

Implications

Vaccination of feedlot cattle with SRP *E. coli* vaccine may be an effective tool to reduce the prevalence of *E. coli* O157:H7 in feedlot cattle upon arrival at the packing plant, reducing the risk of foodborne illness from beef products.

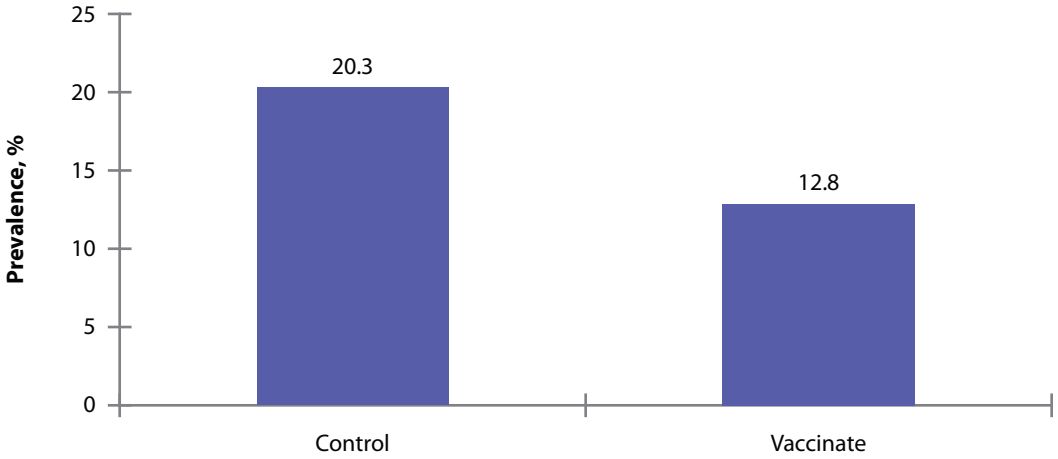


Figure 1. Effect of SRP technology on *E. coli* O157:H7 prevalence in feeder cattle (vaccinates vs. control, $P = 0.07$).

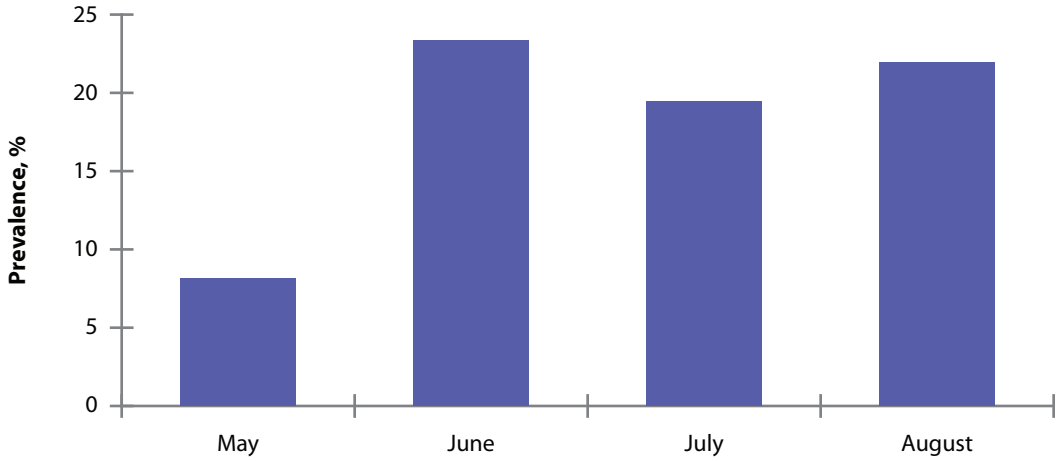


Figure 2. Prevalence of *E. coli* O157:H7 in feeder cattle during summer months (effect of month, $P = 0.04$).

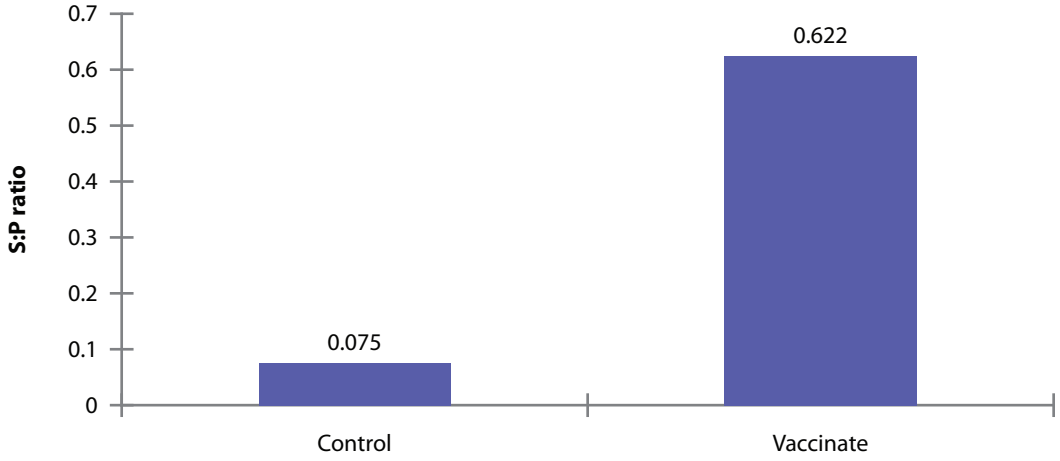


Figure 3. Effect of SRP vaccination on serum anti-*E. coli* O157:H7 sample:positive (S:P) ratio in feeder cattle (vaccinates vs. controls, $P < 0.01$).

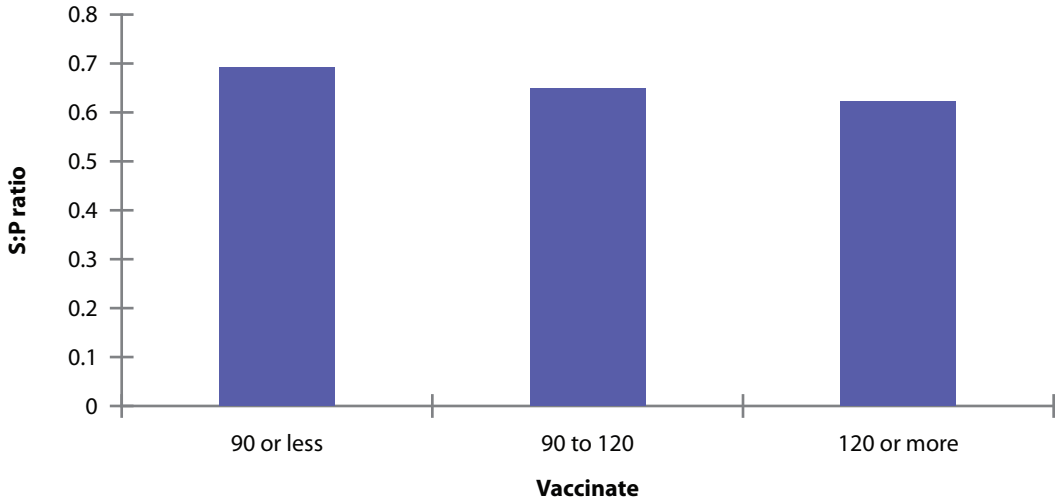


Figure 4. Sample:positive (S:P) ratio of vaccinates relative to days on feed since last vaccination (effect of days on feed, $P = 0.31$).

Aging Method, USDA Quality Grade, and Endpoint Temperature Affect Eating Quality of Beef *Longissimus lumborum* Steaks

M.E. Dikeman, E. Obuz, V. Gok, and L. Akaya

Introduction

Tenderness is one of the most important factors affecting consumers' perceptions and acceptance of palatability. Tenderness is affected by both myofibrillar proteins and connective tissue content and quality. Both marbling and carcass maturity can have a significant effect on beef palatability, with higher consumer sensory scores generally given to USDA Choice loin steaks than to Select steaks for tenderness, juiciness, and overall palatability. Endpoint temperature can also have a significant effect, with higher endpoint temperatures generally decreasing palatability.

Aging beef is a common practice in the meat industry because it increases tenderness and flavor development. The meat industry generally utilizes two types of aging, vacuum and dry aging. Vacuum aging, in which meat is aged in a sealed barrier package at refrigerated temperatures, is the most widely used practice. Dry aging refers to aging meat without packaging, and requires greater environmental control to achieve consistent product quality. Vacuum-aged beef has a sourer and stronger bloody/serumy flavor, whereas dry-aged beef has a more beefy, brown-roasted flavor. Dry aging generally results in greater aged flavor of steaks with no advantage for tenderness, and it is a costly procedure because of decreased yields due to greater weight and trim losses than vacuum aging. Flavor benefits of dry aging and distinct yield advantages of vacuum aging stimulated researchers to develop a "special bag" with a very high water vapor transmission rate and very low oxygen transmission rate to decrease shrink and trim loss but create a dry-aged flavor.

Although some studies have compared the effects of vacuum and dry aging and dry and "special bag" aging, no study has compared all three aging methods. Therefore, the objectives of our study were to determine the effects of vacuum, dry, and special bag aging of USDA Choice and Select grade boneless strip loin steaks cooked to endpoint temperatures of 145°F or 160°F on yield, physical properties, chemical properties, instrumental tenderness, instrumental color, visual cooked color, and sensory properties of beef steaks.

Experimental Procedures

Beef boneless strip loins from USDA Choice (n = 9) and USDA Select (n = 9) carcasses were purchased from a commercial processor. Each loin was cut into halves and randomly assigned to 1 of 3 aging treatments (vacuum aging, dry aging, or aging in a special bag; VAC, DRY, or SB, respectively). Loin sections allocated to VAC aging were packaged in bags (Cryovac Sealed Air Corporation, Duncan, SC). Loin sections destined for DRY aging were aged unpackaged with direct exposure to air in the cooler. Loin sections assigned to the SB treatment were vacuum packaged in dry-aging bags (MacPak, LLC, Wayzata, MN). Loin sections were aged from the time they were

received at 8 days postmortem for 21 days at 4°F on wire racks, with the subcutaneous fat surface down. On day 21 of aging, 4 1-inch-thick steaks were removed from the anterior end and randomly assigned to 1 of 2 endpoint cooking temperatures (145 or 160°F) for Warner-Bratzler shear force determination and sensory analysis. A sample was also taken for fat and moisture analyses. For DRY and SB aging, loin sections were trimmed after aging to remove dried and discolored portions. Vacuum-aged loins were blotted with dry paper towels. Samples of *longissimus lumborum* tissue were prepared for moisture and fat analyses.

Color measurements on raw steaks were taken before and after aging with a Hunter colorimeter as well as on the cooked steaks. Visual color was evaluated on a 6-point scale with 1 = raw red center, pink border, tan edge (medium rare); 3 = pinkish red center, pink to light brown/tan to outer surface; and 6 = dry, brown throughout (well done). Steaks were cooked in a Blodgett gas-fired, forced-air-convection oven at 325°F until the center temperature reached 145 or 160°F. After cooking, steaks were overwrapped in polyvinyl chloride film and cooled for 24 hours at 4°F, then 6 round 1/2-inch cores per steak were removed parallel to the long axis of the muscle fibers and sheared once through the center using a Warner-Bratzler shear attachment (V-notch blade). Shear-force steaks were also used to determine cooking losses.

Six steaks for trained sensory evaluation were cooked at a session in the same way as for Warner-Bratzler shear force testing. Each steak was cut into 1/2 × 1/2 × 1-inch pieces for serving. Trained panelists (n = 6) evaluated palatability attributes on an 8-point scale for myofibrillar tenderness, juiciness, flavor, off-flavor, connective tissue, and overall tenderness (1 = extremely tough, dry, bland, intense, tough, and abundant; 8 = extremely tender, juicy, intense, none, tender, and none) for each sample.

The overall treatment structure was a split-split plot design with the incomplete assignment of the treatment combinations to the experimental units. The whole plot treatment was quality grade (USDA Select or Choice), the sub-plot treatment was aging method (DRY, VAC, or SB), and the sub-sub-plot treatment was endpoint temperature (145 or 160°F). Random effects included loin within quality grade and aging method × loin within quality grade. The treatment combinations were replicated 6 times. Data were analyzed using the PROC MIXED procedure of SAS (2009; SAS Inc., Cary, NC). Least squares means for all significant effects were calculated and separated when significant ($P < 0.05$). Least significant differences for all significant factors were calculated and presented for ease of mean separation.

Results and Discussion

USDA Select loins had higher ($P < 0.05$) weight loss during aging than Choice loins (Table 1, 11.37% for Select and 9.92% for Choice), likely because of higher initial moisture content ($P < 0.05$) of Select loins (72.56% versus 71.43%). VAC-aged loins had dramatically less ($P < 0.0001$) weight loss during aging than both DRY and SB aging methods (2.90% versus 15.56% and 13.48%, respectively). Both DRY and SB aging methods resulted in higher ($P < 0.0001$) trim loss than VAC aging, and SB aging resulted in greater ($P < 0.05$) trim loss than DRY aging (26.55% versus 24.05%; Table 1). Both DRY and SB aging resulted in similar combined losses, but combined

losses were dramatically lower for VAC aging. Therefore, aging in the SB does not offer advantages over DRY aging as far as trim and combined losses are concerned.

After aging, VAC loins had the highest moisture content and DRY aged loins had higher ($P < 0.05$) fat content than SB aged loins (5.53 versus 4.37%, Table 2). Fat content was lowest ($P < 0.05$) for SB aging after cooking. As expected, higher endpoint temperature resulted in lower ($P < 0.0001$) moisture content (Table 2). VAC aging resulted in higher L* (lighter color) values than DRY or SB aging. A decrease ($P < 0.05$) in a* values (decreased redness) with increased endpoint temperature was less pronounced in DRY aged steaks than it was in VAC-aged or SB-aged steaks. Steaks from SB-aged loins were considerably redder for Select than for Choice. The mean visual color scores of steaks cooked to 145°F and 160°F were 3.14 and 4.67 (3 = pinkish red center, pink to light brown/tan to outer surface; 5 = tan/brown center and edges, no evidence of pink; $P < 0.01$), respectively.

Neither quality grade nor aging method had an effect ($P > 0.05$) on Warner-Bratzler shear force of steaks (Table 2); however, Warner-Bratzler shear force increased ($P < 0.0001$) from 6.42 to 7.44 lb as endpoint temperature increased. Quality grade was not a factor ($P > 0.05$) for cooking loss (Table 2). Cooking loss for steaks cooked to 160°F was about 5% higher ($P < 0.0001$) than for steaks cooked to 145°F (Table 2).

Quality grade and aging method did not affect ($P > 0.05$) juiciness, but, as expected, steaks cooked to 145°F were juicier ($P < 0.05$) than those cooked to 160°F (data not presented). Neither quality grade nor aging method affected ($P > 0.05$) myofibrillar tenderness, connective tissue amount, overall tenderness, or off-flavor intensity (data not presented), but VAC-aged loins cooked to 160°F had the lowest ($P < 0.05$) myofibrillar tenderness score. In addition, there was a three-way quality grade × aging method × endpoint temperature interaction ($P < 0.01$) for beef flavor intensity in which Select, DRY-aged steaks had higher beef flavor intensity than VAC- or SB-aged steaks, but the small difference (0.3) might not be detectable by consumers. Choice, VAC-aged steaks cooked to 145°F had higher ($P < 0.01$) beef flavor intensity than those cooked to 160°F.

In summary, DRY and SB aging resulted in excessive trim loss and required extensive labor. Our trained sensory panel revealed few, if any, differences among DRY, VAC, and SB aging.

Implications

VAC aging remains an economical and practical aging method to optimize the palatability of strip loins.

Table 1. Least squares means of quality grade and aging methods on weight loss (%), trim loss (%), and combined loss (%) for *Longissimus lumborum* muscles

Source of variance	Weight loss, %	Trim loss, %	Combined loss, %
Quality grade			
Select	11.37	18.04	26.81
Choice	9.92	18.05	25.66
P-value	0.01	0.99	0.28
SEM[1]	0.52	--	--
LSD[2]	1.10	--	--
Aging method			
Dry	15.56	24.05	35.98
Vacuum	2.90	3.53	6.32
Special bag	13.48	26.55	36.41
P-value	<0.0001	<0.0001	<0.0001
SEM	0.60	1.03	0.95
LSD	1.22	2.10	1.96

[1] SEM: Standard error of mean.
[2] LSD: Least significant difference ($\alpha = 0.05$).

Table 2. Least squares means of quality grade, aging methods and endpoint temperature on Warner-Bratzler shear force (WBSF) values and cook loss (%) of *Longissimus lumborum* steaks

Source of variance	WBSF, lb	Cook loss, %
Quality grade		
Select	7.16	20.37
Choice	6.70	19.88
P-value	0.39	0.42
SEM1	--	--
LSD2	--	--
Aging method		
Dry	6.90	18.75
Vacuum	6.94	20.24
Special bag	6.93	21.38
P-value	0.99	0.01
SEM	--	0.79
LSD	--	1.70
Endpoint temperature, °F		
145	6.42	17.81
160	7.44	22.43
P-value	<0.0001	<0.0001
SEM[1]	0.08	0.62
LSD[2]	0.17	1.26

[1] SEM: Standard error of mean.
[2] LSD: Least significant difference ($\alpha = 0.05$).

Combined Microwave and Convection Cooking Increases Post-Cooking Temperature Rise of Beef *Biceps femoris* Muscles More Than Convection Cooking

A. Gaschler and M.E. Dikeman

Introduction

Combined microwave and convection cooking has gained popularity in the last 20 years because of more accurate heat control and more efficient use of energy. Combination microwave/convection cooking allows for more rapid cooking, but it does not have the same even heat distribution as convection cooking. Cooking is a critical stage when preparing meat. The main factors to consider during cooking are: temperature on the surface of meat, internal temperature throughout, and the method of heat transfer. Temperature on the surface and method of heat exchange primarily affect surface color and aroma, whereas internal temperature affects protein structure and flavor as well as aroma. At any temperature above 230°F, Maillard browning reactions start to occur and give meat its typical brown, caramelized appearance; however, high humidity prevents Maillard browning from occurring and dilutes flavor and odor components. All sensory attributes can, therefore, be significantly influenced by the cooking technique used. Different cooking methods allow for tenderness, flavor development, and color changes, all of which can be either acceptable or unacceptable for consumers.

Different cuts of beef are cooked using different cooking methods to ensure that even a low-quality cut of meat can be acceptable for consumption. The objectives of our study were to investigate the differences between convection cooking and a combination of microwave and convection cooking and endpoint temperatures to observe how these factors affect post-cooking temperature rise, cooking yields, and tenderness.

Experimental Procedures

Eight bottom round muscles (*Biceps femoris*) were cut into 4 sections (approximately 2 to 3 lb each) at approximately 18 to 19 days postmortem, making a total of 32. Roasts were cooked in a convection/microwave oven (Amana Microwave Oven with Convection, Model AMC71597AB, Maytag Corp., Benton Harbor, MI) that allowed for 2 cooking methods: convection and a combination of microwave and convection cooking. Roasts were cooked at 225°F to endpoint temperatures of 145 or 165°F. A 2 × 2 factorial design was used for investigating interactions between cooking method and endpoint temperature. To ensure that the endpoint temperature was reached during the combination of microwave and convection cookery, roasts were checked with a calibrated thermocouple every 15 minutes until the roasts were close to reaching their endpoint temperature. When the temperature approached its target, the temperature was taken more often (every 2 to 5 minutes) to ensure that the desired endpoint temperature was reached. When the temperature was achieved, roasts were removed from the oven, weighed, and the post-cooking temperature rise was monitored using a thermocouple logging system. When the temperature dropped 1° after the post-cooking

temperature rise, roasts were weighed and samples were taken to measure tenderness using the slice shear force procedure. Cooking loss was calculated using the formula ([(thawed weight – cooked weight) / thawed weight] × 100), whereas total cooking loss was calculated using [(thawed weight – cooked weight after final temperature was reached/thawed weight] × 100.

The data were analyzed as a completely randomized block design with a 2 × 2 treatment structure. The blocking term was roast and the main effects were cookery method and endpoint temperature. Means were separated ($P < 0.05$) using the Least Significant Difference procedure (SAS Inc., Cary, NC) when respective F-tests were significant ($P < 0.05$).

Results and Discussion

Means for cooking losses are reported in Table 1. We observed a cooking method × endpoint temperature interaction ($P < 0.0001$) for both cooking loss and total cooking loss. For both endpoint temperatures, the combination of microwave and convection cooking resulted in a greater cooking loss and total cooking loss than convection cooking. A greater loss was observed when cooking to an endpoint temperature of 165°F versus 145°F. Convection cooking to an endpoint temperature of 145°F had the least cooking loss, and microwave and convection cooking to 165°F had the most cooking loss. The difference between cooking methods at 145°F was quite large, with convection cooking having much lower losses than microwave and convection cooking.

The maximum temperature reached was recorded in each roast after reaching its targeted endpoint temperature. Microwave and convection cooking showed a much greater ($P < 0.05$) temperature rise when compared with convection cooking (14.4° F greater rise; Table 2). There was no difference in post-cooking temperature rise between roasts cooked to 145°F and those cooked to 165°F. The time required by each roast to reach its maximum temperature was not different between cooking methods (Table 2), but the roasts cooked to an endpoint temperature of 145°F took longer ($P < 0.05$) to reach their highest post-cooking temperature than roasts cooked to an endpoint temperature of 165°F. In other words, rate of post-cooking temperature rise was slower at the lower endpoint temperature. There were no main effects or interactions for slice shear force (Table 2) due to cooking method. All roasts were comparatively tough, primarily because they contained relatively large amounts of collagen.

Implications

When cooking with microwave and convection in combination, one should remove roasts from the oven at an approximately 14°F lower temperature than for convection cooking to result in the same final endpoint temperature.

Table 1. Cooking method × endpoint temperature interaction means and standard errors (SE) for cooking and total cooking losses

	Cooking method				
	Microwave/convection		Convection		
Trait	145°F	165°F	145°F	165°F	SE
Cooking loss, %[1]	30.47[b]	35.14[a]	16.2[d]	28.02[c]	0.84
Total cooking loss, %[2]	37.04[b]	40.61[a]	17.7[d]	32.25[c]	0.97

[1] Cooking loss = [(thawed weight – cooked weight)/thawed weight] ×100.
[2] Total cooking loss = [(thawed weight – cooked weight after final temperature reached)/thawed weight] × 100.
[abcd] Means within a trait with different superscripts letters differ ($P < 0.05$).

Table 2. Cooking method and endpoint temperature main effect means and standard errors (SE)

	Cooking method			Endpoint temperature		
Trait	Microwave/ convection	Convection	SE	145°F	165°F	SE
Maximum temperature reached	171.03[a]	156.59[b]	1.87	153.23[b]	174.40[a]	1.80
Minutes to reach maximum temperature	14.06	12.59	1.11	16.57[a]	10.08[b]	1.07
Slice shear force, lb	49.19	45.66	3.30	46.39	48.46	3.39

[ab] Means within a trait and main effect with different superscripts differ ($P < 0.05$).

Steam-Generation Cooking Versus Dry Heat Convection of Beef Roasts Differing in Connective Tissue

L J. Bowers, M.E. Dikeman, L. Murray, and S.L. Stroda

Introduction

Foodservice managers strive to control factors that affect yield, serving cost, and palatability of beef. Beef roasts are traditionally roasted at temperatures from 325°F to 350°F for both home and institutional use. Roasts relatively high in connective tissue cooked with moist heat generally are more tender than when cooked with dry heat. Roasts cooked to 150, 160, or 170°F could be expected to have cooking losses ranging from 20% to over 40%. The issue of cooking loss led Winston Industries to develop the CVap Cook and Hold Vapor Oven (Winston Industries, Louisville, KY). CVap technology controls evaporation by creating a moist environment, which creates an opposing vapor pressure that minimizes moisture loss and should improve cooking yields. The objectives of our research were to compare the effects of moist-heat cookery in a CVap oven and dry-heat cookery in a Blodgett forced-air convection oven on cooked yield, cooked color, tenderness, and sensory attributes of beef roasts differing in connective tissue content cooked to different endpoint temperatures.

Experimental Procedures

Vacuum-packaged Choice grade beef outside round-flats, boneless briskets, and boneless strip loins were aged at 1 to 2°F until 28 to 32 days postmortem. Two cooking phases occurred during this project. During cooking phase I, roasts were cooked in a CVap oven following the protocol of Winston Industries, where 8 roasts from each of the 3 subprimals were cooked for approximately 8 hours to a temperature of 160°F with the browning level set at 4. The CVap oven generates a heating curve based on user input for cooking time, desired endpoint temperature, and browning level. The Blodgett forced-air convection oven (G.S. Blodgett Co., Burlington, VT) temperature could not be set as low as for the CVap to duplicate the CVap cooking cycle; therefore, we could directly compare the 2 ovens only by cooking roasts in the CVap for a constant time that matched the average times to reach the 3 temperatures for the 3 muscles in the Blodgett established in preliminary research. Roasts of the 3 muscles were cooked to endpoint temperatures of 150, 160, and 170°F in the Blodgett to determine the average time required to reach those temperatures, which were then used as the cooking times in the CVap. This comparison is referred to as phase II.

Two roasts were cut from each subprimal to evaluate the 2 ovens. Two 4-lb *Biceps femoris* roasts were removed from the center, and 2 3-lb *Deep pectoralis* roasts (point end removed) and 2 4-lb *Longissimus lumborum* roasts were removed from the anterior ends. For direct comparisons between ovens (phase II), 2 roasts from different subprimals were cooked in the Blodgett at 200° F and removed when they reached the target temperatures +/- 2°F. On the same days, 4 roasts were placed in the CVap (2 were from different subprimals, and 2 were from the same subprimal) and cooked for the times determined in the Blodgett. External and internal cooked color was visually evalu-

ated. One-inch-thick sections were cut from the roasts to measure slice shear force and Warner-Bratzler shear force.

After the aging period, 2 4-lb roasts were cut from additional *Biceps femoris* (n = 18) and *Longissimus lumborum* (n = 18) and frozen at −40 °F until sensory panels were conducted. Roasts were then thawed and cooked using the same oven settings as Phase II. Panelists evaluated warm 1 × 0.5 × 0.5-inch samples for myofibrillar tenderness, juiciness, connective tissue amount, beef flavor intensity, overall tenderness, and off-flavors. The scale was 1 = extremely tough, bland, dry, or abundant connective tissue; and 8 = extremely tender, intense, juicy, or no connective tissue. A minimum of 6 trained panelists participated in each sensory panel session.

For the statistical analysis, the primary focus was to compare ovens and evaluate their consistency across 3 temperatures for the 3 muscles. Statistical analyses for muscle responses were conducted separately for each muscle. Simple-effect pairwise comparisons were made to compare oven types within temperatures when the temperature × oven interaction was significant. More roasts were cooked in the CVap (n = 72) than were cooked in the Blodgett (n = 36) for all treatment combinations. When a temperature × oven interaction was significant, ovens within a temperature were compared with each other rather than making all possible comparisons. Pairwise comparisons of sensory data on the temperature main effect and temperature × oven interaction were conducted.

Results and Discussion

Phase II cooking yield main effect means × endpoint temperature and oven for *Biceps femoris* roasts cooked to 150°F had the highest ($P < 0.05$) cooking yield at 84.6%, whereas roasts cooked to 160 and 170°F had the lowest ($P < 0.05$) yields at 70.4% and 66.5%, respectively. When averaged across temperatures, there was no difference ($P > 0.05$) between ovens (69.0% in the CVap versus 66.0% in the Blodgett). When cooking *Deep pectoralis* roasts to 150°F, roasts cooked in the CVap had a higher ($P < 0.05$) mean percentage cooking yield at 84.0% than roasts cooked in the Blodgett (77.4%). In contrast, when cooking *Deep pectoralis* roasts to 170°F, those cooked in the CVap had a lower ($P < 0.05$) cooking yield (62.7%) than those cooked in the Blodgett (68.6%) (statistical interaction). Cooking yields of *Deep pectoralis* roasts generally decreased with increasing temperatures at a faster rate in the CVap than in the Blodgett. *Longissimus lumborum* roasts cooked to the lowest endpoint temperature also had the highest ($P < 0.05$) cooking yields (82.6%); roasts cooked to 170°F had the lowest ($P < 0.05$) cooking yield (66.6%). No difference ($P > 0.05$) was measured in cooking yields between ovens.

Results from roasts cooked according to the protocol of Winston Industries during phase I cannot be statistically compared with cooking in phase II because of differences in cooking protocols. *Biceps femoris* roasts cooked to 160°F in the CVap according to the phase I protocol had a mean cooking yield of 72.5%, whereas those cooked in the CVap or Blodgett for phase II had mean cooking yields of 69.0% and 66.0%, respectively. *Deep pectoralis* roasts cooked to 160°F in phase I had a cooking yield 61.8%, whereas using phase II protocols, *Deep pectoralis* roasts has a mean cooking yield of 73.6% in the CVap and 76.3% in the Blodgett oven. Therefore, cooking *Deep pectoralis*

roasts to 160°F according the protocol of Winston Industries appears detrimental to cooking yield when compared with using the phase II cooking protocol for the Blodgett or CVap ovens. *Longissimus lumborum* roasts cooked to to 160°F in phase I had a mean cooking yield of 73.6%. Using the phase II cooking protocol, *Longissimus lumborum* roasts had a mean cooking yield of 74.6% in the CVap and 72.9% in the Blodgett; therefore, cooking *Longissimus lumborum* roasts according to the protocol of Winston Industries in the CVap oven did not offer a cooking yield advantage.

Roasts cooked in the CVap in phase II were tan in color with more moisture on the external surface. In contrast, roasts cooked in the Blodgett were a dark, mahogany-red color with a more caramelized, drier surface. External fat color from the CVap cooked roasts was whiter, whereas the color was more yellow for roasts cooked in the Blodgett. Internal cooked color was not different between ovens.

In phase II, neither endpoint temperature nor oven type affected ($P > 0.10$) slice shear force or Warner-Bratzler shear force of *Biceps femoris* roasts (Table 1). Cooking *Deep pectoralis* roasts in the Blodgett to 170°F resulted in higher ($P < 0.05$) Warner-Bratzler shear force than cooking in the CVap. In addition, *Deep pectoralis* slice shear force values in the CVap decreased considerably from 150 to 170°F (92.0 lb versus 38.1 lb), suggesting that the moist environment in the CVap is advantageous as temperature increases for *Deep pectoralis* roasts, which have a high collagen content, but in the dry environment of the Blodgett, optimum tenderness appears to occur at 160°F. Slice shear force increased in *Deep pectoralis* roasts cooked in the CVap as temperature increased. Collagen solubilization also might be optimum for the *Deep pectoralis* at 160°F in the Blodgett, but myofibrillar toughening likely occurs after that temperature.

In phase II, neither endpoint temperature nor oven type affected ($P > 0.10$) slice shear force or Warner-Bratzler shear force of *Longissimus lumborum* roasts (Table 1). The differences in Warner-Bratzler shear force among the 3 temperatures for the *Longissimus lumborum* were much lower than for the other 2 muscles. *Longissimus lumborum* roasts had slice shear force values that were about half as high as those for the *Deep pectoralis* and *Biceps femoris*. When roasts were cooked according to the phase I protocol of Winston Industries, *Biceps femoris* roasts had a mean slice shear force value of 35.8 lb, which is more tender than roasts cooked in the Blodgett with a slice shear force value of 67.1 lb using the phase II cooking protocol. It was also more tender than roasts cooked in the CVap during phase II, with a slice shear force value of 64.2 lb. Therefore, cooking *Biceps femoris* roasts according to the phase I protocol of Winston Industries provides an advantage in slice shear force tenderness. *Deep pectoralis* roasts cooked using the phase I protocol had a slice shear force of 26.4 lb, which was dramatically lower than roasts cooked using the phase II protocol, which had shear slice force of 64.5 lb for roasts cooked in the Blodgett and 68.4 lb when cooked in the CVap. For *Longissimus lumborum* roasts, there was no slice shear force advantage using the CVap, likely because of its low connective tissue content.

Biceps femoris roasts cooked according to phase I protocol had a mean Warner-Bratzler shear force value of 7.5 lb, which is lower than roasts cooked in the Blodgett or CVap using the phase II protocol, which had Warner-Bratzler shear force values of 9.0 lb and 9.5 lb, respectivley. *Deep pectoralis* roasts cooked using the phase I protocol had a low mean Warner-Bratzler shear force value of 5.5 lb, whereas those cooked using the

phase II protocol in the Blodgett or CVap had a mean Warner-Bratzler shear force of 10.8 lb and 9.5 lb, respectively. In contrast to the *Biceps femoris* and *Deep pectoralis*, cooking the *Longissimus lumborum* according to the phase I protocol offered no Warner-Bratzler shear force tenderness advantage.

Sensory panels conducted on *Biceps femoris* roasts cooked in the CVap and Blodgett ovens using the phase II protocol to target temperatures of 160 and 170°F found no differences among endpoint temperatures or ovens for beef flavor intensity and off-flavors. Roasts cooked to 170°F in the Blodgett had lower ($P < 0.05$) myofibrillar tenderness scores (5.8) than those cooked in the CVap (6.7). In a similar pattern, overall tenderness score was lower ($P < 0.05$) for roasts cooked to 170°F in the Blodgett than those cooked in the CV (5.5 versus 6.5). Therefore, cooking *Biceps femoris* roasts in the CVap oven at the higher temperature, but not at the lower temperature, appears to bestow tenderness advantage.

No oven effect ($P > 0.10$) was detected for sensory scores of *Longissimus lumborum* roasts. As expected, roasts cooked to an internal endpoint temperature of 160°F had a higher ($P < 0.05$) mean juiciness score (4.2) than roasts cooked to an endpoint temperature of 170°F (3.7).

Implications

Cooking *Biceps femoris* and *deep pectoralis* roasts in a CVap steam-generation oven according to the protocol of Winston Industries provides some advantages over a dry-heat convection oven for cooking yields and/or tenderness but no advantages for *Longissimus lumborum* roasts.

Table 1. Oven means for slice shear force (SSF) and Warner-Bratzler shear force (WBSF) within endpoint temperatures for *Biceps femoris* (BF), *Deep pectoralis* (DP), and *Longissimus lumborum* (LL) roasts cooked to 3 endpoint temperatures in a Blodgett (B) or CVap oven using 2 cooking protocols

		Phase I		Phase II								
		160°F		150°F			160°F			170°F		
		CVap	SE[1]	B	CVap	SE[1]	B	CVap	SE[1]	B	CVap	SE[1]
BF	SSF	39.4	2.6	64.5	64.7	6.4	62.7	67.3	6.4	74.4	60.7	6.4
	WBSF	7.5	0.3	8.4	9.7	0.7	8.1	8.4	0.8	10.6	10.1	0.7
DP	SSF	26.4	1.5	71.3	92.0	6.7	61.8	75.2	6.7	60.3	38.1	6.7
	WBSF	5.5	0.1	12.8	12.5	0.4	8.8	9.9	0.4	11.0[a]	6.8[b]	0.4
LL	SSF	32.8	1.9	35.9	34.8	2.1	25.1	29.0	2.1	26.8	26.0	2.1
	WBSF	7.3	0.3	5.7	5.1	0.3	6.2	5.5	0.3	6.4	4.4	0.3

[ab] Oven means within 170°F endpoint temperature with different superscripts differ ($P < 0.05$). Oven means within 150 and 160 °F endpoint temperatures did not differ ($P > 0.05$).

[1] SE = standard error.

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