CATTLEMEN'S DAY 2010

BEEF CATTLE RESEARCH

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CATTLEMEN'S DAY 2010

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Nutrition

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Biological Variability and Chances of Error

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

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

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

In other papers, you may see an average given as 2.5 ± 0.1. The 2.5 is the average; 0.1 is the standard error. The standard error is calculated to be 68% certain that the real average (with 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.

Current Factors Affecting Feeder Cattle Pricing in Kansas and Missouri Cattle Markets

K.W. Harborth, L.L. Schulz, K.C. Dhuyvetter, and J.W. Waggoner

Introduction

Today's tough economic environment for cattle producers makes each decision critically important, and increased knowledge of the link between pricing and genetic, management, and marketing decisions can increase an operation's sustainability and profitability. Cow-calf producers and cattle feeders have long been interested in the impact of various physical and market characteristics on feeder cattle and calf prices. As demonstrated in many previous studies, significant relationships exist between feeder cattle prices and their physical and market characteristics. Weight, lot size, health, condition, fill, muscling, frame size, breed, time of sale, and horn status significantly affect feeder cattle auction prices. Historically, significant premiums and discounts have been associated with these particular feeder cattle physical characteristics.

The purpose of this study was to gain knowledge of the current link between market pricing and genetic, management, and marketing decisions. Findings from this research will provide updated information regarding how the myriad of industry changes since the 1980s and 1990s has affected the characteristics that influence feeder cattle and calf prices.

Experimental Procedures

Transaction-level feeder cattle market data were collected from feeder cattle auctions in Dodge City, KS, and Carthage, MO, during November and December 2008 and March and April 2009 by trained evaluators. The data represent approximately 4 months of historical cash price information. Data collected totaled approximately 8,200 individual lot transactions encompassing 84,319 head. Data recorded for each transaction included lot size, sex, color, breed, condition, fill, muscle, frame size, weight uniformity, freshness, horn presence, time of sale, weight, and price. In addition to details of individual transactions, a time series of feeder cattle futures prices was collected to approximate market conditions. A hedonic pricing model was applied to estimate the impact of various physical characteristics and market factors on feeder cattle pricing.

Results and Discussion

Breed, muscling, and frame size are important feeder cattle characteristics influenced through genetic selection. Pricing results for genetically influenced factors are reported in Table 1. Cattle buyers paid greater premiums for Angus ($3.10) and Angus × Hereford crossbred calves ($2.72) than for the base breed (Hereford influenced) calves. The greatest discounts were applied to dairy (-$12.22) and longhorn (-$10.86) influenced calves. Compared with the base breed Hereford, price changes among the remaining breed categories were relatively small. A significant premium was paid for black ($2.49), white ($1.01), and mixed hide colors ($1.89) compared with red-colored calves. Because the premiums and discounts are additive, this implies a black Angus calf would bring a $5.59/hundredweight premium ($3.10 + $2.49) relative to the base animal

(red Hereford). Heavy ($6.62) and extremely heavy ($5.25) muscled cattle brought significant premiums compared with average muscled calves. Feeder cattle buyers likely prefer heavily muscled calves as they are expected to produce desirable carcasses. Buyers discounted small-framed calves (-$5.98) and gave a modest premium ($0.75) to large-framed calves. Increased concern about growth patterns and finish weights apparently contributed to larger discounts for calves that are not expected to match cattle feeding and meat processing specifications.

On-farm management of weight, health, condition, and horn presence significantly affects feeder cattle prices. Figure 1 shows discounts attributed to additional weight for steers, heifers, and bulls. Heifers were discounted the least in the fall and spring as weight increased, whereas the largest relative discounts were seen for steers and bulls in the spring. Differences in feeder cattle prices across weights are likely due to the relationship of feeding performance and profitability of feeding programs. Expected fed cattle prices, feeder cattle prices, corn prices, interest rates, and feeding performance all affect cattle feeding profitability. Because feeder cattle prices were explicitly accounted for in the model, the large weight discounts can be attributed to differing expectations about anticipated feeding performance, interest rates, and fed cattle prices. Corn prices were not included in the analysis because they varied little during the study. Effects of other management factors on pricing are shown in Table 2. Buyers discounted calves that appeared unhealthy (-$6.31), had horns (-$2.18), or were in too-thin or too-fat condition. It is evident that buyers prefer healthy calves because unhealthy calves increase the possibility of death loss and poor feeding performance. Moderately conditioned calves were preferred because they show the ability to convert feed to gain. Discounts for horned cattle are likely due to increased injury in confinement and increased handling costs.

Marketing factors including weight uniformity, lot size, gut fill, sale location, and time of sale affected pricing (Table 3). Weight uniformity significantly affected feeder cattle prices as nonuniform lots of cattle were discounted $2.11/hundredweight. Although nonuniform lots received discounts, the relationship between weight uniformity and lot size needs to be considered. Figure 2 shows the price paid for calves on the basis of lot size. As lot size increased, price per hundredweight increased. The highest prices were paid for lot sizes approaching truckload sizes. As lot sizes exceeded truckload sizes, prices leveled off and even decreased, likely because fewer buyers were bidding on these very large lot sizes. Feeder cattle buyers prefer to purchase larger lot sizes because the incidence of health problems decreases with non-mixed cattle and because of the convenience and lower transportation costs of large purchases. Discounts were applied to very full (-$4.02) and full (-$0.72) cattle compared with average fill cattle because cattle with significant amounts of temporary water or forage weight are undesirable. Although the largest premiums were realized for cattle sold in the third quarter of the sale relative to the first quarter of the sale, time of sale may or may not be easily controllable by producers.

Implications

Results should be of interest to a wide variety of industry stakeholders including cow-calf operators, cattle feeders, and agribusiness firms that service the cattle sector. Although cattle producers cannot affect forces that drive the cattle market, they can control factors that affect the premiums and discounts their calves can potentially

obtain. Producers should market healthy, dehorned cattle, ideally in large, uniform lots. Producers should also avoid selling cattle that are extremely thin or fat and/or extremely gaunt or full to obtain the greatest value. Overall, this research effectively gathered market information and allowed for dissemination of this information to industry stakeholders, potentially improving feeder calf value and total returns to producers.

Table 1. Effect of genetic factors on feeder cattle premiums and discounts

Characteristic	Pens, %	Price change, $/hundredweight
Breed		
Angus	21.9	3.10*
Hereford	1.6	Base
Angus/Herford cross	6.6	2.73*
Other English crosses	7.3	0.66
Exotic crosses	50.9	1.78*
Longhorn	0.7	-10.86*
Brahman	3.0	-0.76
Dairy	0.6	-12.22*
Mixed breed	7.2	-0.82
Color		
Black	40.6	2.49*
Red	12.8	Base
White	10.2	1.01*
Mixed color	36.2	1.99*
Muscling		
Light muscling	0.02	5.03
Average muscling	4.5	Base
Heavy muscling	94.3	6.62*
Extremely heavy muscling	1.2	5.29*
Frame size		
Small	0.04	-5.98*
Medium	41.1	Base
Large	58.9	0.75*

* Statistically significant compared with base ($P<0.10$).

Table 2. Effect of management factors on feeder cattle premiums and discounts

Characteristic	Pens, %	Price change, $/hundredweight
Health		
Healthy lot	99.7	Base
Unhealthy lot	0.3	-6.31*
Horns		
No horns	90.9	Base
Mixed horns	7.6	-0.70*
Horns	1.4	-2.18*
Condition		
Very thin	0.1	-10.83*
Thin	16.4	-1.23*
Moderate	77.2	Base
Fat	6.4	-0.86*
Very fat	0.04	-4.87

* Statistically significant compared with base (P<0.10).

Table 3. Effect of marketing factors on feeder cattle premiums and discounts

Characteristic	Pens, %	Price change, $/hundredweight
Weight uniformity		
Uniform lot	98.8	Base
Nonuniform lot	1.2	-2.11*
Fill		
Very gaunt	0.1	-3.60
Gaunt	5.8	-0.99*
Average fill	63.6	Base
Full	30.3	-0.72*
Very full	0.2	-4.02*
Market location		
Joplin	82.1	-5.15*
Dodge City	17.9	Base
Time of Sale		
1st quarter	24.7	Base
2nd quarter	24.9	1.00*
3rd quarter	25.3	2.03*
4th quarter	25.1	0.62*

* Statistically significant compared with base (P<0.10).

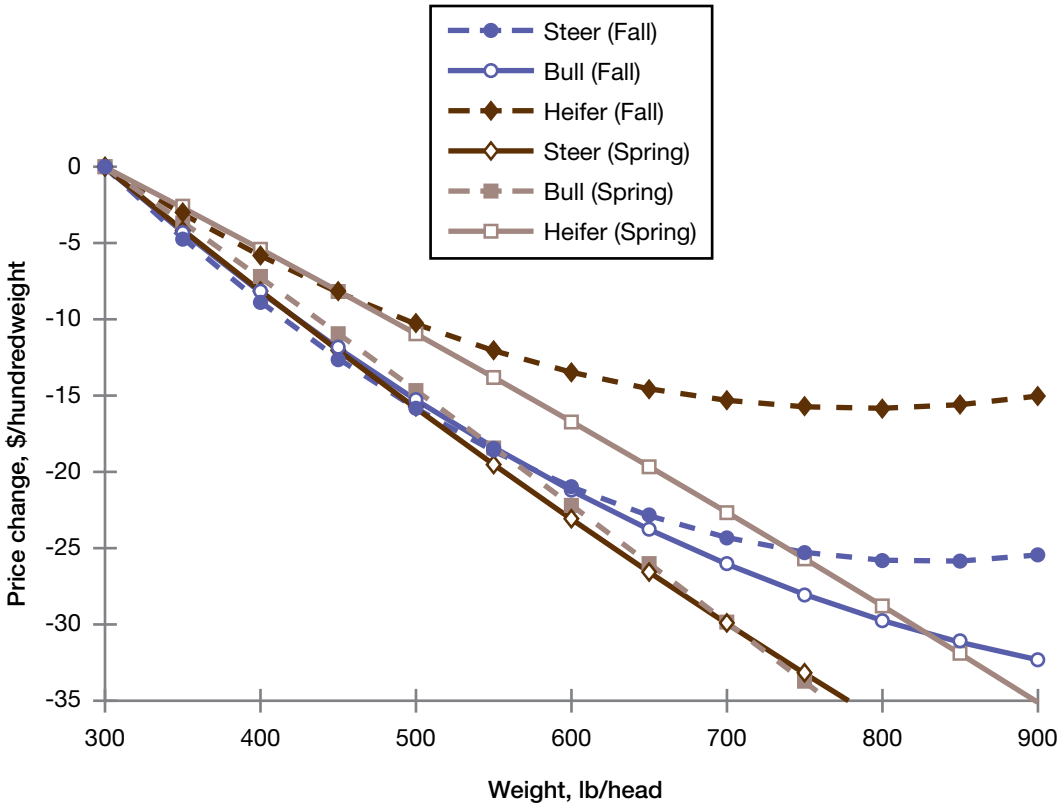

Figure 1. Effect of weight on feeder cattle price.

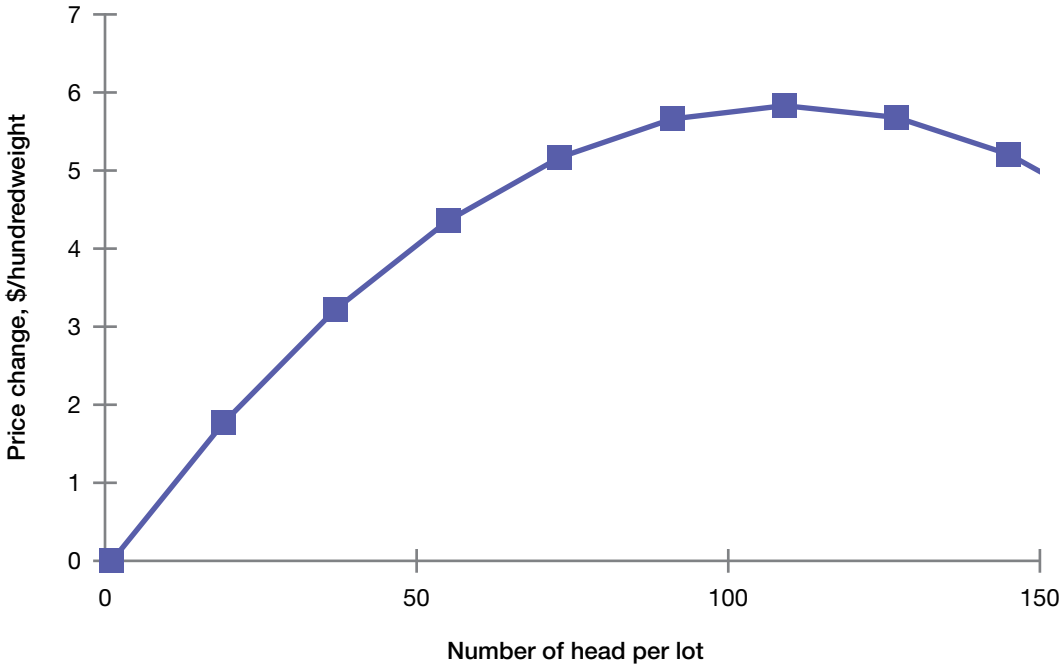

Figure 2. Effect of lot size on feeder cattle price.

Implant Programs Affect Performance and Quality Grade

C.D. Reinhardt

Introduction

Selection of dosage, timing, and number of anabolic implants continues to be a source of controversy for feed yard managers and their consultants. Although the dose-dependent effects on performance are fairly well accepted, impacts on carcass quality continue to be debated. This study was intended to summarize effects of different implant programs on performance and carcass quality on the basis of a cross section of available published research.

Experimental Procedures

A total of 83 studies (61 steer studies and 22 heifer studies) were included in a meta-analysis of the effects of implant program on feedlot performance (daily gain, dry matter intake, and feed conversion) and carcass traits (hot carcass weight, yield grade, and marbling score).

Individual implant programs were consolidated into groups of similar dose programs (Table 1). Any combinations of implant groupings used in reimplant programs were coded according to dosage (e.g., Synovex-S followed by Synovex-Plus = MOD/HIGH). If no implant was given immediately upon feedlot arrival but a full-strength combination estradiol + trenbolone acetate implant was given later in the feeding period, this program was coded DEL for "Delayed."

Data were analyzed with the MIXED procedure of SAS (SAS Institute Inc., Cary, NC); implant program was the fixed effect, and study was the random effect. Studies were analyzed within sex, and the inverse of squared standard error of the mean for daily gain was used as a weighting factor.

Results and Discussion

In both steers and heifers, increasing the implant dosage (higher anabolic content per implant, combination vs. estrogenic only, or multiple implants vs. single implants) generally increased daily gain and dry matter intake, reduced feed-to-gain ratio, and increased hot carcass weight ($P<0.01$; Tables 2 and 3).

Implant program influenced marbling score in both steers and heifers ($P<0.01$; Tables 4 and 5). Implant program did not affect yield grade in steers ($P=0.11$; Table 4) but did in heifers ($P<0.01$; Table 5). Previous studies have demonstrated that yield grade is correlated with marbling score (Figure 1). Given that implant program affected both yield grade and marbling score in heifers in this meta-analysis, at least a portion of the differences in marbling score among implant treatments may be due to concomitant changes in yield grade. In addition, feed yards tend to market cattle at a fat-constant

endpoint regardless of implant program selection. Therefore, an adjustment was made to actual marbling score by using the following equation:

$$\text{Adjusted marbling score} = (\text{yield grade} - 2.82) \times 43.63$$

where 2.82 = mean yield grade of non-implanted cattle and 43.63 = slope of the relationship between yield grade and marbling score.

After marbling scores were adjusted for differences in yield grade, implant program still had a significant effect on marbling score in steers, but marbling score differences in heifers were eliminated (P=0.50).

Although these data suggest that implant program affects marbling score, it is also important to understand how economically important these differences may be. Therefore, the relationship between average marbling score within a pen and percentage of that pen that graded Choice or higher was determined (Figure 2).

A difference in marbling score of 20 units (similar to the difference between DEL/HIGH vs. MOD/HIGH) resulted in an 8 percentage unit change in percentage Choice for cattle grading roughly 50% Choice but only a 4 percentage unit change in percentage Choice for cattle grading nearly 90% Choice.

Implications

Because of physiological differences between heifers and steers, implants have a more pronounced effect on marbling score in steers than in heifers.

Table 1. Summary of implant program groupings and codes

Implant program	Grouping	Code
No implant	None	NONE
Ralgro	Low	LOW
Synovex-S	Moderate	MOD
Synovex-H	Moderate	MOD
Revalor-IS	Intermediate	INT
Revalor-IH	Intermediate	INT
Synovex-Choice	Intermediate	INT
Revalor-S	High	HIGH
Revalor-H	High	HIGH
Revalor-200	High	HIGH
Synovex-Plus	High	HIGH

Table 2. Effects of implant program on feedlot performance and carcass weight in steers

Implant program	Initial weight, lb	Average daily gain, lb	Feed:Gain	Dry matter intake, lb	Hot carcass weight, lb
NONE	734	3.11	6.51	19.96	737
MOD	735	3.51	6.04	20.97	779
DEL/HIGH	734	3.61	5.80	20.59	787
MOD/MOD	735	3.62	5.92	21.27	790
HIGH	733	3.67	5.84	21.24	786
INT/INT	736	3.68	5.81	21.23	794
LOW/HIGH	734	3.68	5.80	21.19	793
MOD/HIGH	735	3.71	5.75	21.21	798
INT/HIGH	734	3.72	5.77	21.22	800
HIGH/HIGH	735	3.79	5.66	21.34	806
P-value	0.46	<0.01	<0.01	<0.01	<0.01
SEM[1]	1.36	0.047	0.064	0.154	5.8

[1] SEM represents the largest standard error of the mean of all treatments for each dependent variable.

Table 3. Effects of implant program on feedlot performance and carcass weight in heifers

Implant program	Initial weight, lb	Average daily gain, lb	Feed:Gain	Dry matter intake, lb	Hot carcass weight, lb
NONE	707	2.94	6.36	18.88	695
MOD	703	2.96	6.36	18.85	703
MOD/MOD	702	3.01	6.27	18.85	708
LOW/HIGH	706	3.30	5.85	19.31	717
DEL/HIGH	707	3.30	5.74	19.09	731
MOD/HIGH	707	3.33	5.79	19.36	733
INT/INT	708	3.34	5.78	19.35	734
HIGH	707	3.34	5.89	19.65	730
INT/HIGH	706	3.37	5.73	19.44	739
HIGH/HIGH	709	3.40	5.69	19.36	738
P-value	0.18	<0.01	<0.01	<0.01	<0.01
SEM[1]	4.6	0.076	0.102	0.269	9.4

[1] SEM represents the largest standard error of the mean of all treatments for each dependent variable.

Table 4. Effects of implant program on carcass traits in steers

Implant program	Yield grade	Marbling score	Adjusted marbling score
NONE	2.83	550	548
MOD	2.88	538	535
DEL/HIGH	2.85	529	526
MOD/MOD	2.85	524	520
HIGH	2.83	520	521
INT/INT	2.71	521	525
LOW/HIGH	2.83	522	518
MOD/HIGH	2.87	512	507
INT/HIGH	2.80	513	513
HIGH/HIGH	2.82	498	499
P-value	0.11	<0.01	<0.01
SEM[1]	0.061	7.4	6.4

[1] SEM represents the largest standard error of the mean of all treatments for each dependent variable.

Table 5. Effects of implant program on carcass traits in heifers

Implant program	Yield grade	Marbling score	Adjusted marbling score
NONE	2.66	543	546
MOD	2.59	523	522
MOD/MOD	2.68	538	545
LOW/HIGH	2.68	---	---
DEL/HIGH	2.44	535	550
MOD/HIGH	2.39	524	540
INT/INT	2.46	533	547
HIGH	2.55	532	542
INT/HIGH	2.49	528	540
HIGH/HIGH	2.35	512	532
P-value	0.11	<0.01	0.50
SEM[1]	0.135	9.4	9.3

[1] SEM represents the largest standard error of the mean of all treatments for each dependent variable.

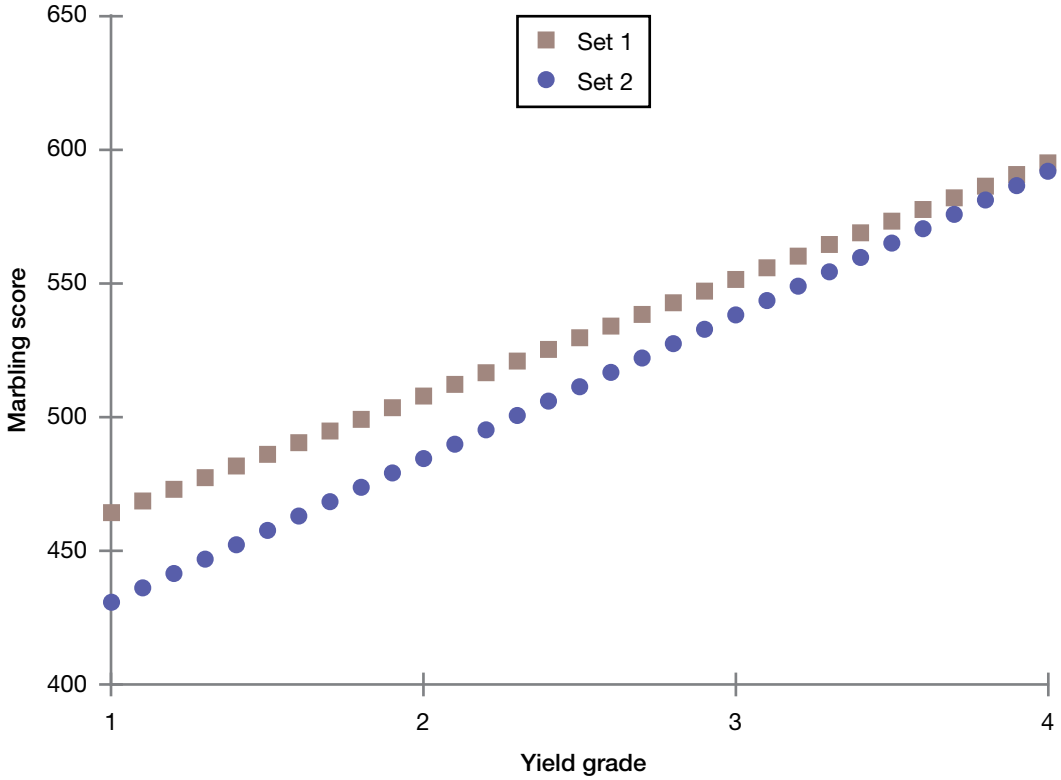

Figure 1. Relationship between yield grade (calculated from carcass measurements) and marbling score (Small^0 = 500).
Set 1 is the current dataset of 83 individual implant studies (marbling score = 53.77 × yield grade + 377.0; R^2 = 0.28). Set 2 is a set of 4,991 Angus-cross steer calves fed in southwestern Iowa from 2002-2006 (marbling score = 43.63 × yield grade + 320.7; R^2 = 0.07).

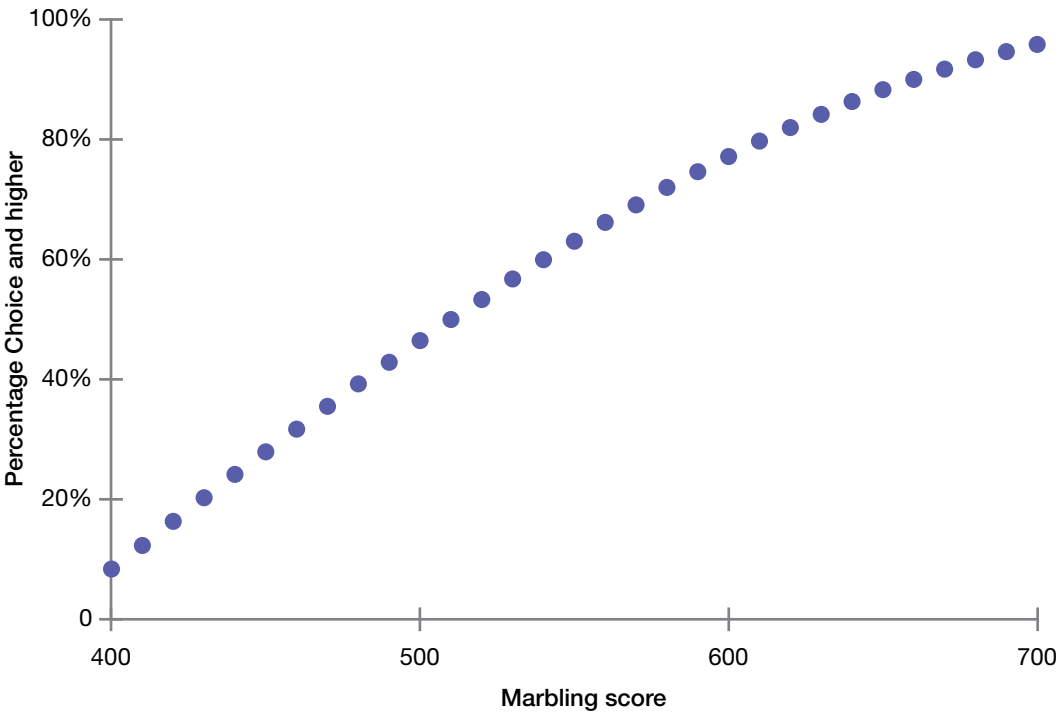

Figure 2. Relationship between average marbling score (Small^0 = 500) in a pen of cattle and the percentage of the pen that graded Choice or higher.
(Percentage Choice = 0.00399 × (sinMarbling Score) – 1.5119; R^2 = 0.78).

Precutting Round Alfalfa and Cornstalk Bales Decreases Time and Fuel Required for Bale Breakup in a Vertical Mixer[1]

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Introduction

Properly mixing and distributing nutrients throughout a ration can be equally as important as including them in the formulation. Many factors, including forage type, particle length, and mixer type, affect the homogeneity of total mixed rations. Particle size plays an important role in digestion and animal performance and, therefore, is an important consideration from harvest through feeding. An increase in particle size results in a less uniform distribution of nutrients throughout the total mixed ration. Typically, diets with a high proportion of forages have the lowest uniformity of nutrients in individual batches of complete feed.

Many operations reduce particle length of forages by placing whole round bales in vertical mixers to break apart the bale prior to adding the remaining ingredients to the total mixed ration. This approach can be time consuming but is rationalized as a necessary step in improving forage utilization and ration homogeneity. Because diet preparation time and energy use affect productivity and profitability of many operations, alternatives that decrease total feed preparation time may save money through decreased fuel usage and opportunity costs. Typically, alfalfa hay or cornstalks are cut by various types of machines and baled in full particle length. This method generally requires that producers further process bales into shorter particle lengths before using the forage in a total mixed ration by either tub grinding or placing bales into a vertical mixer. A baler has been developed that cuts stems prior to bale wrapping to reduce overall particle length, potentially eliminating the need to further process the forage before using it in a total mixed ration. Objectives of this study were to determine the effects of precut and conventional alfalfa and cornstalk bales on (1) mixing time in a vertical mixer, (2) influence of initial field cut method of cornstalks on mixing time, and (3) tractor fuel usage while mixing.

Experimental Procedures

The conventional baling method used a round baler that fed alfalfa through the header and carried it by packer fingers into a baling chamber without further processing. The precut baling method used a round baler that fed alfalfa through a header equipped with serrated knives that cut the alfalfa stems into 3- to 8-in. sections as packer fingers moved the sections from the header to the baling chamber. Because there were no knives on the outer 6 in. of each side, the perimeter of the bale was composed of alfalfa that was of full stem length, which maintained bale structure for hauling or handling.

[1] Appreciation is expressed to John Deere (Ottumwa, IA) for funding of experiments and use of tractors and baler and to Mark Cooksey of Roto-Mix (Scott City, KS) for technical support and donation of the mixer used in this study.

[2] John Deere, Ottumwa, IA.

Experiment 1

One field of alfalfa in northeast Kansas was swathed and raked in mid-July. A total of 31 alfalfa round bales were used to evaluate differences in mixing time of alfalfa baled with different techniques (precut vs. conventional) and in different bale sizes (5 × 4 ft vs. 6 × 4 ft). Treatments were: 5 × 4 ft precut bales, 5 × 4 ft conventional bales, 6 × 4 ft precut bales, and 6 × 4 ft conventional bales. There were eight replicates per treatment, with the exception of the 6 × 4 ft conventional alfalfa bales, which had seven replicates. Core samples were taken from each bale, composited by treatment, and chemically analyzed.

Each bale was raised to 16 ft by a loader tractor and dropped into a 425 ft^3 vertical double-screw mixer (Vertical Express; Roto-Mix, Dodge City, KS) that had the power engaged. The power take-off speed was set at 540 revolutions per minute during the mixing process. Mixing time was measured as the time from when the bale entered the mixer until the bale core was completely broken apart. Fuel usage was determined with the factory-installed on-board computer display in the tractor. Fuel usage rate (gal/hour) was recorded every 20 seconds of mixing time and averaged by bale, and then fuel usage was calculated.

Experiment 2

A total of 46 cornstalk round bales were used to evaluate differences in mixing time of cornstalks baled with different techniques (precut vs. conventional) and harvested with various field cutting methods. In mid-October, portions of one field of cornstalks in northeast Kansas were prepared with three field cutting methods: New Holland 116 swather (swathed), Model John Deere 27 flail shredder (shredded), and Model HX 15 batwing mower (brush hog). After each cutting method was used, cornstalks were raked using a Darf 17-wheel v-hay rake and then baled as precut or conventional. All bales were 5 × 4 ft. Treatments were: (1) conventionally baled, brush hog; (2) precut baled, brush hog; (3) conventionally baled, flail shredded; (4) precut baled, flail shredded; (5) conventionally baled, swathed, and (6) precut baled, swathed. Core samples were taken from each bale to make a composite sample of each treatment and chemically analyzed. Bales were loaded into the mixer, and data were collected by using the same procedures as in experiment 1.

Data from both experiments were analyzed with the MIXED procedure of SAS (SAS Institute Inc., Cary, NC). Individual bales were the experimental unit. Differences between main effects were declared significant at $P<0.05$ and regarded as tendencies when $P<0.10$. Contrasts comparing bale size and type were evaluated.

Results and Discussion

Experiment 1

The 5 × 4 ft alfalfa bales were lighter ($P<0.001$) than the 6 × 4 ft bales, as expected (Table 1). There was no difference in bale weight ($P>0.10$) between precut and conventionally processed bales. Bale mixing time was shorter ($P<0.05$) for precut bales than for conventional bales regardless of bale size (72 vs. 142 seconds for 5 × 4 ft and 110 vs. 237 seconds for 6 × 4 ft, respectively). The large bales had increased fuel usage on both a gallons-per-hour and gallons-per-bale basis ($P<0.001$). Fuel usage was lower ($P<0.05$) for the 5 × 4 ft precut bales than for the 5 × 4 ft conventional bales but similar between

bale types for the 6 × 4 ft bales. Precut alfalfa bales used less fuel (P<0.001) than conventional bales. Also, the 5 × 4 ft alfalfa bales used less fuel per bale (P<0.001) than the 6 × 4 ft bales.

Experiment 2

Cornstalk bale weights were similar (P>0.05) among treatments (Table 2). Bale mixing time was shorter (P<0.001) for precut bales than for conventional bales. Brush hog precut bale mixing time was decreased (P<0.05) compared with that for brush hog conventional bales (39.8 vs. 85.5 seconds, respectively). Mixing time for flail-shredded and swathed precut bales was less (P<0.001) than that for conventional bales. Brush hog and swathed bales had increased (P<0.02) mixing time compared with flail-shredded bales.

Fuel usage was similar (P=0.20) for precut and conventionally processed bales regardless of field cutting method. However, swathed bales had increased (P=0.04) fuel usage compared with brush hog bales and tended to have increased (P=0.06) fuel usage compared with flail-shredded bales. Brush hog bales had fuel usage similar (P=0.86) to that of flail-shredded bales. Precut bales used less (P<0.01) fuel per bale than conventionally processed bales for each field cutting method. Brush hog bales used more fuel per bale (P=0.02) than flail-shredded bales but showed similar (P=0.33) fuel usage per bale compared with swathed bales. Flail-shredded bales used less fuel per bale (P<0.002) than swathed bales.

Using the precut baling method reduced the time required for bale disassembly by approximately half and reduced fuel usage per bale during mixing, which may lead to increased on-farm time efficiency and could decrease the cost of mixing a total mixed ration.

The observed reduction in fuel usage was apparently due to the shorter particle length of the forage in precut bales, which required less time and power to break apart. Alfalfa stems are smaller in diameter and less fibrous than cornstalk stems. This allowed alfalfa bales to be baled tighter than cornstalk bales as indicated by their heavier weights compared with cornstalk bales of the same physical dimensions. Thus, bales of longer particle length require more time and fuel to achieve complete breakup.

Implications

Precut forage bales required less time to break up in a vertical mixer, which translated into less fuel required per bale.

Table 1. Effects of alfalfa bale type and size on mixing time and fuel usage[1]

	Bale size					Probability, P<	
	5 × 4 ft		6 × 4 ft				
Item	Precut	Conventional	Precut	Conventional	SEM	Precut vs. Conventional	5 × 4 ft vs. 6 × 4 ft
Weight[2], lb	1073[a]	1080[a]	1700[b]	1700[b]	18.1	0.64	0.001
Mix time, seconds	72[a]	142[b]	110[ab]	237[c]	19.5	0.001	0.003
Fuel usage							
Tractor, gal/hour	1.98[a]	2.11[b]	2.44[c]	2.14[c]	0.039	0.16	0.001
Bale, gal/bale	0.04[a]	0.08[b]	0.07[b]	0.16[c]	0.012	0.001	0.001

[1] n = 31 alfalfa bales (treatments 1-3, n = 8; treatment 4, n = 7).
[2] Bale weight on an as-is basis.
Means within a row without a common superscript letter differ (P<0.05).

Table 2. Effects of cornstalk field cutting type and bale type on mixing time and fuel usage[1]

	Bale type							Probability, P<			
	Brush hog		Shredded		Swathed						
Item	Precut	Conv[2]	Precut	Conv	Precut	Conv	SEM	Precut vs. Conv	Brush hog vs. Shredded	Brush hog vs. Swathed	Shredded vs. Swathed
Weight[3], lb	980[b]	946[ab]	973[a]	923[a]	955[a]	963[a]	25.9	0.09	0.41	0.81	0.56
Mix time, seconds	39.8[a]	85.5[c]	39.9[a]	64.6[b]	39.6[a]	83.5[c]	5.33	0.001	0.01	0.77	0.02
Fuel usage											
Tractor, gal/hour	2.9[ab]	2.7[b]	2.9[ab]	2.8[b]	3.1[a]	3.0[ab]	0.16	0.20	0.86	0.04	0.06
Bale, gal/bale	0.03[c]	0.07[a]	0.03[c]	0.05[b]	0.03[c]	0.07[a]	0.003	0.01	0.02	0.33	0.02

[1] n = 46 cornstalk bales (treatments 1-4 and 6, n = 8, treatment 5, n = 7).
[2] Conventionally processed bales.
[3] Bale weight on an as-is basis.
Means within a row without a common superscript letter differ (P<0.05).

Length of Weaning Period But Not Timing of Vaccination Affects Feedlot Receiving Performance and Health of Fall-Weaned, Ranch-Direct Beef Calves

M.J. Macek, J.W. Iliff, KC Olson, J.R. Jaeger, T.B. Schmidt, D.U. Thomson, and L.A. Pacheco

Introduction

Weaning and preconditioning programs are thought to be crucial to calf health and performance during the finishing period. The stress of maternal separation, changes in diet, environmental changes, and exposure to unfamiliar pathogens increase susceptibility of recently weaned calves to bovine respiratory disease. Vaccination programs are implemented near weaning to decrease the incidence of respiratory disease.

Many vaccination strategies are practiced by cow-calf producers in the United States. The most cautious strategy involves vaccination against respiratory disease pathogens 2 to 4 weeks before maternal separation followed by a booster at weaning. This strategy is used in instances in which time, labor, and facilities are available to gather and process calves while they are still suckling. Another common strategy is to defer vaccination until after calves have been shipped to a feedlot. Deferring vaccination until arrival in feedlots is thought to increase incidence of respiratory disease compared with vaccination programs implemented at the ranch of origin. This assumption has not been widely scrutinized for native Kansas cattle that are finished in Kansas feedlots.

Previous research has demonstrated that length of the weaning period at the ranch of origin can influence growth and health of beef calves during the receiving period at a feedlot. Therefore, it is reasonable to expect that vaccination strategy and length of the weaning period may have synergistic effects on calf performance during the receiving phase. The objective of this experiment was to compare the effects of vaccination against respiratory diseases before weaning on the ranch of origin and after arrival at a feedlot for calves weaned 45, 15, or 0 days before feedlot arrival.

Experimental Procedures

Angus × Hereford calves (n = 437; average initial weight = 458 ± 54 lb) were used for this experiment. Calves originated from the Kansas State University commercial cow-calf herds in Manhattan (n = 263) and Hays (n = 174). At the time of maternal separation, calves were 175 to 220 days of age. All calves were dehorned and castrated (if needed) before 60 days of age.

Approximately 60 days before maternal separation, calves were stratified by body weight, sex, and birth date and assigned randomly to a preshipment weaning period (i.e., 45, 15, or 0 days before shipment). Within each weaning period treatment, calves were assigned randomly to one of two vaccination treatments. One group was vaccinated 14 days before maternal separation and again at weaning. The second group

was vaccinated on the day of arrival at the feedlot and again 14 days later. Initial and booster vaccinations against common respiratory pathogens were administered using a modified-live product (Bovi-Shield Gold FP; Pfizer Animal Health, New York, NY). Calves were treated for internal and external parasites using Dectomax (Pfizer Animal Health Exton, PA) and vaccinated against clostridial diseases (Vision 7 with SPUR; Intervet Inc., Millsboro, DE) at the time of maternal separation. Calves were then transported a short distance (<15 miles) to a central weaning facility.

Calves were weaned in dirt-surfaced pens (four pens per treatment) and fed a common weaning diet (Table 1). The weaning diet was formulated to achieve an ADG of 2.0 lb at a dry matter intake of 2.5% of body weight.

Calves were monitored for symptoms of respiratory disease at 7:00 a.m. and 2:00 p.m. daily during the ranch-of-origin weaning period. Calves with clinical signs of respiratory disease (Table 2), as judged by animal caretakers, were removed from home pens and evaluated. Each calf with clinical signs of respiratory disease was weighed, had its rectal temperature measured, and was assigned a clinical illness score (Table 2). Calves that presented with a clinical illness score greater than 1 and a rectal temperature greater than 104°F were treated according to the schedule described in Table 3. Cattle were evaluated 72 hours posttreatment and re-treated as appropriate on the basis of observed clinical signs.

All calves were individually weighed and transported 4 hours from their respective weaning facilities to an auction market located in Hays, KS, on Nov. 5, 2008. Calves from both origins were commingled with respect to gender and treatment and were maintained on the premises of the auction market for 12 hours. This commingling simulated the pathogen exposure typically encountered by market-ready calves. On November 6, calves were shipped 5 miles to the feedlot located at the Agricultural Research Center–Hays. Upon arrival at the feedlot, calves were weighed individually and assigned to a receiving pen on the basis of their weaning and vaccination treatments.

The cattle were adapted to a receiving ration (Table 4), and daily dry matter intake was recorded throughout a 60-day receiving period. Calves were monitored for symptoms of respiratory disease daily at 7:00 a.m. and 2:00 p.m. Clinical symptoms of disease were evaluated and treated as during the weaning phase. Calf body weights were measured again 60 days after arrival at the feedlot.

Results and Discussion

Average daily gain was greater ($P<0.01$) for calves weaned 45 days before shipping to the feedlot than for calves weaned either 15 or 0 days before shipping to the feedlot (Figure 1). This occurred because calves weaned for 45 days before shipping consumed, on average, a more energy-dense diet than calves that suckled their dams for all or part of this period.

Incidence of undifferentiated fever during the 15-day period following maternal separation was greater ($P<0.01$) for calves on the 45-day weaning treatment than for those on the 15-day weaning treatment. Reasons for this response were unclear. Calf average

daily gain and incidence of undifferentiated fever during the preshipping period were similar (P=0.66) between calves vaccinated at the ranch of origin and those that were not vaccinated until they arrived at the feedlot. Evidently, the pathogen challenge and the stress associated with maternal separation were insufficient to increase incidence of respiratory disease among unvaccinated calves during the ranch-of-origin weaning period.

Calf average daily gain during the 60-day feedlot receiving period was similar (P=0.62) between calves weaned for 45 or 15 days before feedlot placement; however, both groups of weaned calves tended to have greater (P<0.07) average daily gain during that period than calves shipped directly to the feedlot after maternal separation (i.e., the 0-day weaning treatment; Figure 2). In contrast, length of the ranch-of-origin weaning period did not affect (P=0.73) incidence of undifferentiated fever during the receiving period.

Timing of vaccination did not affect calf average daily gain during the 60-day feedlot receiving period and was similar for calves vaccinated on their ranch of origin and calves not vaccinated until feedlot arrival (Figure 3).

As during the preshipment weaning period, incidence of undifferentiated fever during the receiving period was similar (P=0.80) between calves vaccinated against respiratory disease-causing organisms on the ranch of origin and those that were not vaccinated until they arrived at the feedlot. Only 4 of 437 calves were treated for presumptive respiratory disease during this period. This result was surprising and seemed to indicate that labor and time savings might be realized by deferring vaccination until after feedlot arrival without sacrificing animal performance; however, caution is urged in extrapolating these results to other situations. The calves in our study had excellent overall health during the receiving period. In addition, these ranch-direct calves probably had less pathogen exposure than is typical for market-sourced cattle.

Feed intake (dry matter basis) during the receiving period increased (P<0.03) successively with length of the ranch-of-origin weaning period (Figure 4). More experience consuming dry diets from a feedbunk before shipping translated to greater feed intake and greater average daily gain during the receiving period. Feed efficiency during receiving was not influenced (P = 0.30) by length of the ranch-of-origin feeding period. Furthermore, the timing of vaccination did not affect (P>0.28) feed intake or feed efficiency during the receiving period (Figure 5).

Implications

This study is in agreement with previous Kansas State University research, which reported that ranch-of-origin weaning periods longer than 15 days do not improve health or performance at the feedlot for cattle that are moved quickly from their ranch of origin to a feedlot and not commingled with market-sourced cattle. This study also raises the possibility that preshipment vaccination may not improve health or performance of ranch-direct cattle relative to vaccination that is deferred until feedlot arrival. Further research will be necessary to verify this finding.

Table 1. Ingredient and nutritional composition of the weaning diet

Ingredient[1]	%, dry matter basis
Extender pellets (alfalfa)	41.82
Corn gluten feed	18.22
Wheat midds	14.68
Cracked corn	10.78
Cottonseed hulls	7.68
Dried distillers grain	3.01
Molasses	1.67
Limestone	1.85
Nutrient composition	
Crude protein	15.31
Calcium	0.56
Phosphorus	0.43
NE_m, Mcal/lb	0.65
NE_g, Mcal/lb	0.39

[1] Diet also included salt, zinc sulfate, and Rumensin 80.

Table 2. Scoring system used to classify the severity of clinical illness

Clinical illness score	Description	Clinical appearance
1	Normal	No abnormalities noted
2	Slightly ill	Mild depression, gaunt, +/- cough
3	Moderate illness	Severe depression, labored breathing, ocular/nasal discharge, +/- cough
4	Severe illness	Moribund, near death, little response to human approach

Table 3. Treatment schedule used to treat calves diagnosed with bovine respiratory disease complex

Treatment	Drug	Dose	Route of injection
1st Pull	Baytril (enrofloxacin)	5 mL/cwt	Subcutaneous
2nd Pull	Nuflor (florfenicol)	6 mL/cwt	Subcutaneous
3rd Pull	Biomycin (oxytetracycline)	5 mL/cwt	Subcutaneous

Table 4. Average ingredient and nutritional composition of the receiving diet

Ingredient[1]	%, dry matter basis
Rolled milo	59.43
Sorghum silage	25.47
Soybean meal	11.04
Limestone	2.08
Ammonium sulfate	0.44
Urea	0.06
Salt	0.06
Nutrient composition	
Crude protein, %	15.90
Calcium, %	1.01
Phosphorus, %	0.33
NE_m, Mcal/lb	0.79
NE_g, Mcal/lb	0.51

[1] Diet also included salt, Rumensin 80, Tylan 40, and trace minerals.

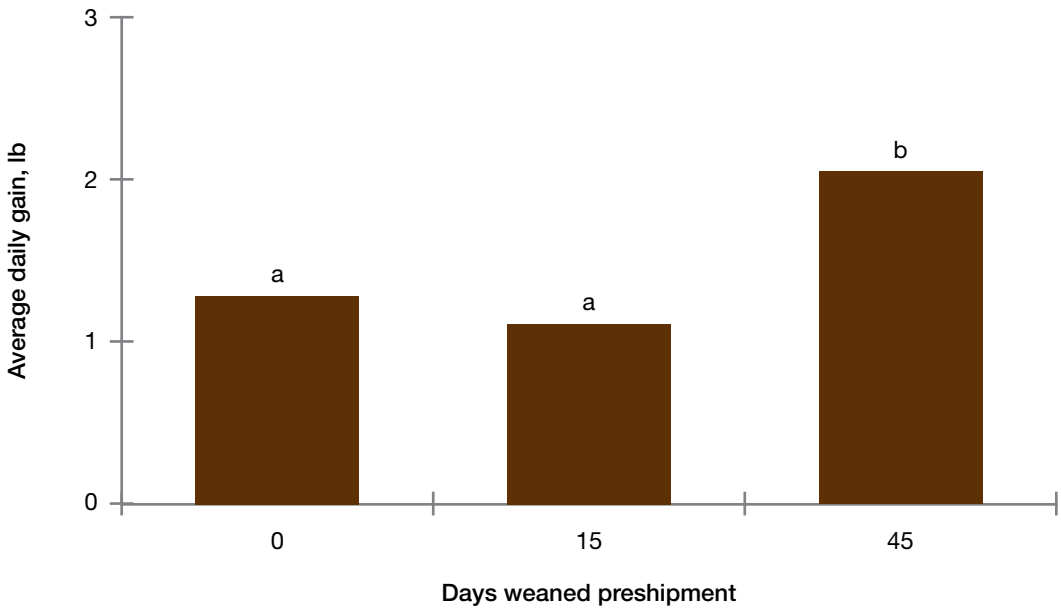


Figure 1. Effect of length of the weaning period at the ranch of origin on average daily gain of calves before feedlot arrival.

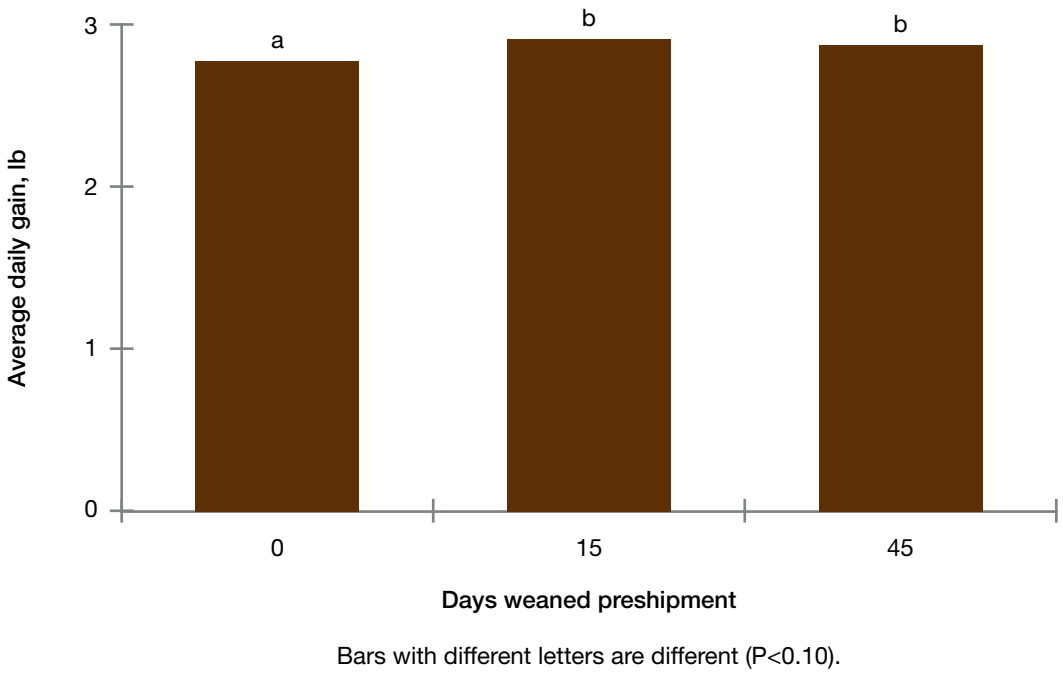


Figure 2. Effect of length of weaning period at the ranch of origin on average daily gain of calves during a 60-day feedlot receiving period.

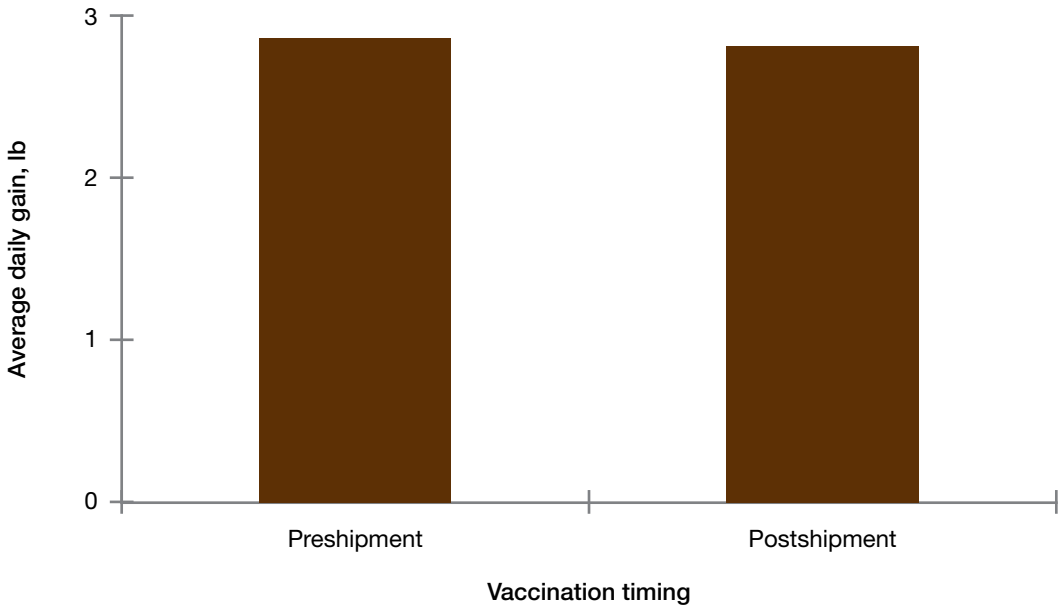


Figure 3. Effect of timing of vaccination on average daily gain of calves during a 60-day feedlot receiving period.

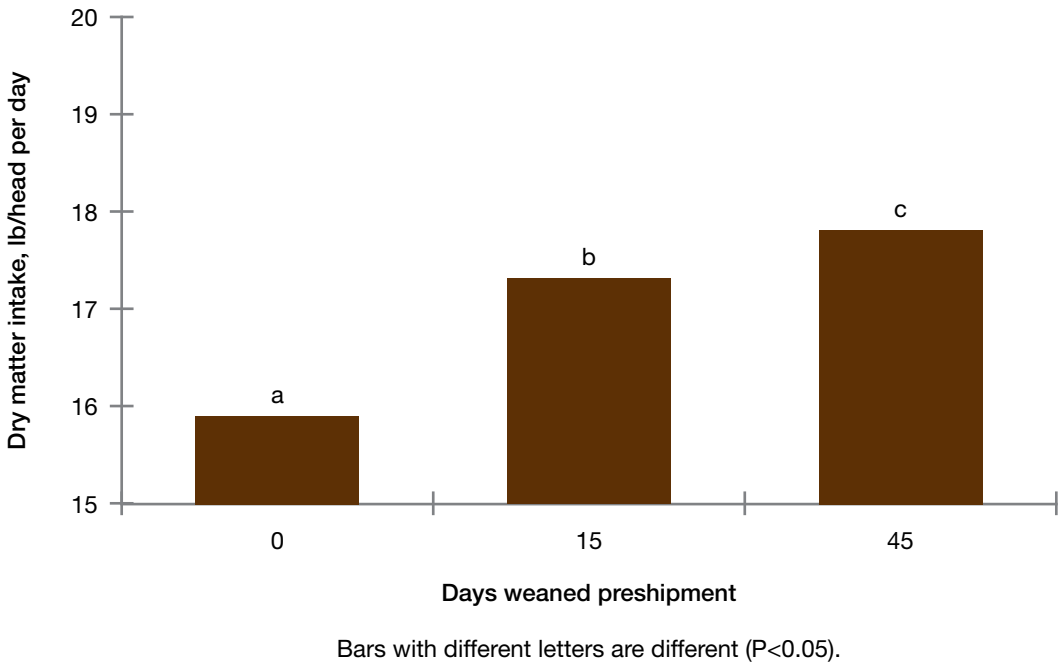


Figure 4. Effect of length of the ranch-of-origin weaning on dry matter intake by calves during a 60-day feedlot receiving period.

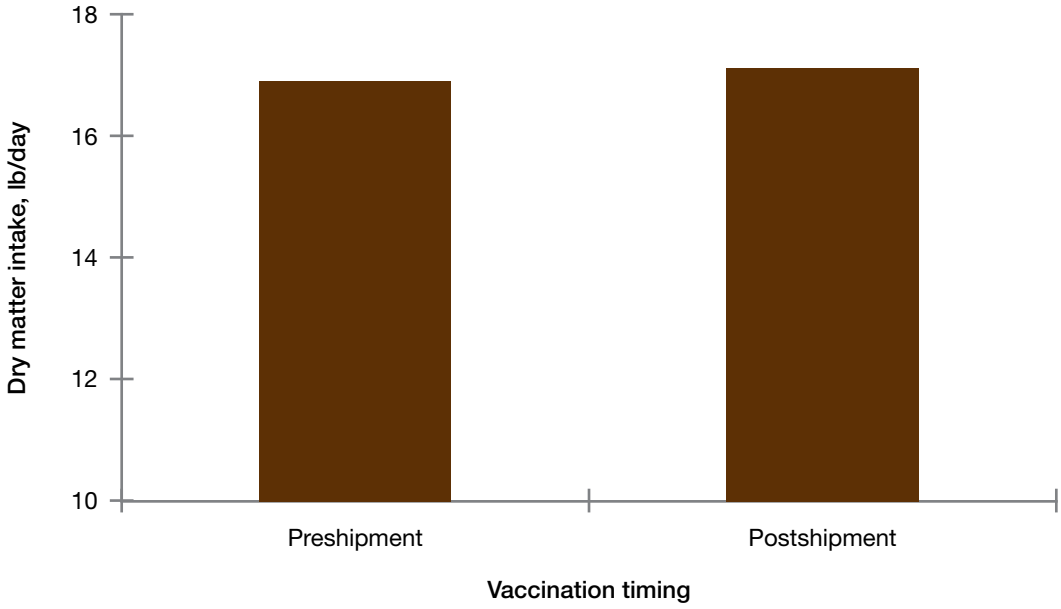


Figure 5. Effect of timing of vaccination on dry matter intake by calves during a 60-day feedlot receiving period.

Comparison of Medicinal Feed Additives on Health and Growth Performance of Beef Calves Grazing Native Grass Pasture

D.A. Blasi, M.P. Epp, and B. Greenwood

Introduction

Optimizing growth rate is an important contributor to overall profitability for stocker cattle grazing native Flint Hills pasture. Disease challenges from pinkeye and foot rot have traditionally been problems that compromise health and productivity of stocker cattle in this grazing region. Use of medicinal feed additives as a part of a supplementation program may prevent health problems and improve overall productivity during a spring/summer grazing season.

Experimental Procedures

A 90-day grazing study was conducted at the Kansas State University Beef Stocker Unit starting in May 2008 to determine the efficacy of supplementation programs that provide medicinal feed additives for managing growth and health of stocker calves grazing native grass pastures in the Flint Hills region of Kansas. All steers used in this study (306 head) were previously involved in a receiving study that focused on arrival mass medication programs. Off-test weights collected at the conclusion of the receiving study were used to randomly assign each animal to grazing treatments. Steers were assigned to two grazing treatments with six pasture replicates per treatment. All paddocks were stocked at 250 lb beef per acre.

On April 30, all calves were tagged, dewormed with Eprinex (Merial, Duluth, GA), and sorted to their preassigned paddock groups. The grazing season began on May 1 and ended on July 30. Treatment 1 (herein referred to as BA) consisted of a free-choice mineral formulated with Bovatec and Aureomycin (Alpharma Inc., Ridgefield Park, NJ; 200 and 350 mg/head per daily, respectively). Treatment 2 (herein referred to as RU) consisted of a free-choice mineral formulated with micronutrient content equal to BA but instead containing Rumensin (Elanco Animal Health, Indianapolis, IN; 200 mg/head daily). Both treatments were provided throughout the duration of the grazing study. Intake level for both self-fed supplements was targeted at 0.25 lb/head per day to achieve intended drug levels.

Mineral in the feeder of each paddock was checked weekly for manure, water, or other foreign matter that could interfere with normal supplement consumption. Bull Master feeders (Mann Enterprises, Inc., Waterville, KS) were used for mineral delivery in all paddocks. When inclement weather was forecasted, rubber flap covers on all feeders were closed to minimize moisture contamination. All flaps were reopened immediately after the threatening storm event. Each mineral feeder was weighed weekly, and the readings were recorded. The collected numbers were used to calculate the previous week's mineral intake. If mineral intake was beyond target, the feeder was moved further away from the primary water source. If this initial action did not effectively reduce mineral intake, salt blocks were placed next to feeders.

All calves were inspected daily for symptoms of sickness or lameness. Cattle diagnosed with foot rot and pinkeye received the label dosage of Bio-Mycin 200 (Boehringer-Ingelheim, Ridgefield, CT). First-treatment bovine respiratory disease diagnosed calves received the label dosage of Baytril 100 (Bayer Animal Health, Shawnee Mission, KS), and second-treatment bovine respiratory disease diagnosed calves received the label dosage of Nuflor (Intervet/Schering-Plough Animal Health, The Netherlands). Upon conclusion of the study, all steers were placed in drylot for 5 days and fed at a constant level of 2.5%/head per day (dry matter basis) to equalize gut fill. The diet consisted of cracked corn, wet corn gluten feed, prairie hay, and alfalfa hay. At the end of the 5-day post-grass period, all steers were individually weighed.

Performance and health data were analyzed by using the mixed model procedure of SAS (SAS Institute Inc., Cary, NC). Data were arranged in a randomized complete block design; pasture served as the experimental unit for growth and health outcomes as affected by treatment. In the model, fixed effects were treatment and pasture, and random effects were pasture × treatment, pasture, and animal ID. Percentages of foot rot morbidity and mortality were tested by using the Chi-Square test, and significance was declared at $P<0.05$.

Results and Discussion

Table 1 shows average intake of the supplemental mineral treatments during the 90-day grazing study. Although intake of the BA mineral slightly exceeded the targeted level, intake of the RU treatment was 40% lower than desired. Actual concentrations of Bovatec and Aureomycin were well within the desired dosage range, especially compared with the very low consumption of Rumensin that was realized as a consequence of poor mineral intake.

Figure 1 graphically depicts weekly mineral consumption throughout the entire trial and reveals a significant week × mineral treatment effect ($P<0.0001$). At the onset of the trial, BA mineral consumption exceeded desired intake targets. Intake of this mineral was abruptly reduced by week 6 and gradually increased to the desired intake target for the remainder of the study. In contrast, RU mineral intake never reached desired target levels.

Although RU mineral consumption was significantly less ($P<0.01$) than BA mineral consumption throughout the entire grazing season, there were no significant differences ($P=0.45$) in daily gain between treatments (Table 2).

There were no significant differences between treatments for pink eye and respiratory disease, (Table 3), but incidence of foot rot was reduced in cattle consuming BA mineral ($P<0.09$).

Table 1. Average intake of mineral mixes used in experiment

	Treatment		
Item	Aureomycin/ Bovatec	Rumensin	SEM
No. of stockers	155	148	
No. of pasture groups	6	6	
Mineral intake, oz/head per day	4.22	2.39	0.01
Medication intake, mg/head per day – calculated (actual)			
Aureomycin	369 (325)		
Lasalocid	211 (186)		
Rumensin		120 (105)	

Table 2. Effect of mineral medication treatments on stocker performance

	Treatment			
Item	Aureomycin/ Bovatec	Rumensin	SEM	P-value
On-test stocker weight, lb	583	582	4.1	0.84
Off-test stocker weight, lb	739	743	5.3	0.61
90-d daily gain	1.732	1.796	0.06	0.4495

Table 3. Effect of mineral medication treatments on incidence of stocker health problems

	Treatment			
Item	Aureomycin/ Bovatec	Rumensin	SEM	P-value
No. of stockers	155	148		
Percentage of cattle treated for illness				
Foot rot	4.68	16.88	4.65	0.0930
Pink eye	0.63	0.0	0.45	0.3409
Respiratory diseases	0.67	0.62	0.64	0.9572

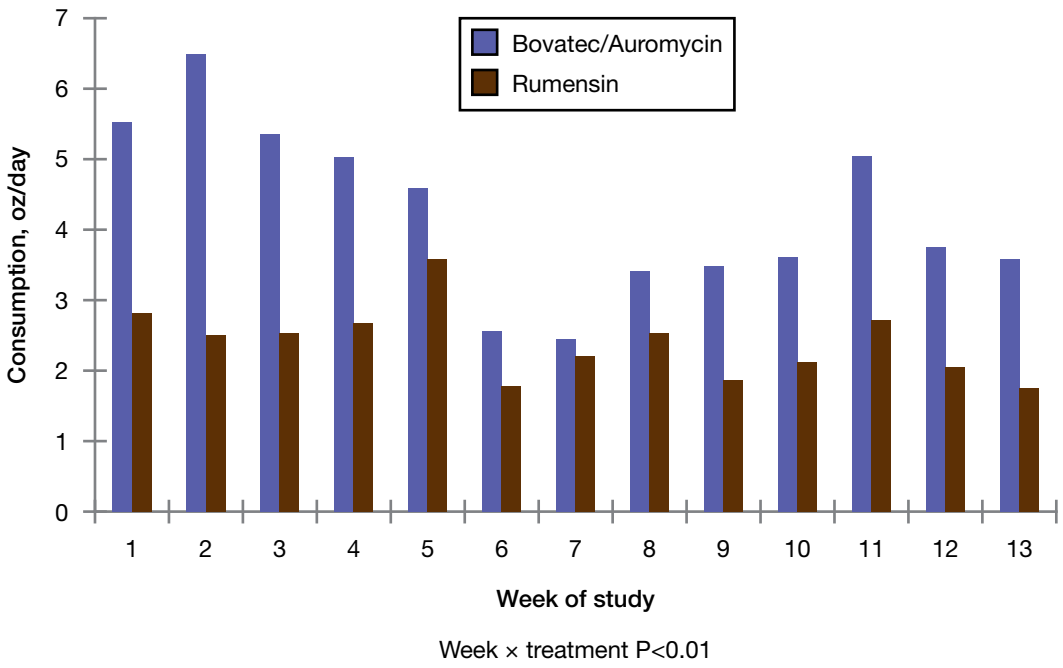


Figure 1. Weekly consumption of medicated mineral mixtures.

Feed-Based Metaphylaxis Programs Did Not Affect Health or Performance of High-Risk Calves Mass Medicated with Draxxin on Arrival

D.A Blasi, M P. Epp, and R. Derstein

Introduction

Bovine respiratory disease continues to be the most costly disease affecting productivity and profitability in the stocker segment. Despite their high cost, longer-acting, injectable therapeutic antimicrobials such as Draxxin (Tulathromycin; Pfizer Animal Health, New York, NY) can extend the window of treatment duration, thereby reducing the incidence and severity of bovine respiratory disease. Use of feed-based metaphylaxis programs, such as therapeutic administration of multiple 5-day pulses of Aureomycin (Alpharma, Inc., Bridgewater, NJ), in conjunction with an injectable metaphylaxis program may be a cost-effective way to improve bovine respiratory disease therapy without having to physically handle and stress cattle.

Experimental Procedures

One 55-day receiving study was conducted at the Kansas State University Beef Stocker Unit during May 2008 to determine the response of high-risk stocker calves to concurrent metaphylaxis with Draxxin and Aureomycin. All cattle were sourced from an order buyer in Tennessee, and cattle were received over 3 consecutive days. Upon arrival, all calves were weighed, tagged, mass medicated with Draxxin (1.1 mL/100 lb), and palpated for gender (bull or steer). Calves were then given free-choice access to long-stem prairie hay and water. The following day, calves were vaccinated against clostridial and respiratory diseases and dewormed, and bulls were surgically castrated. Each load (three total) was then blocked by arrival date and randomly assigned to one of three treatments for a total of 24 pens. Castrated bulls were distributed equally among the eight pens within each alley. Cattle were weighed and revaccinated 12 days after initial processing and weighed again following the 55-day feeding period. Calves were stepped up using three sequential growing diets ranging from 29% to 36.5% concentrate. Diets were fed with addition of one of the following three treatments: (1) no top-dress pellets (control); (2) top-dressed with Aureomycin-containing pellets (10 mg chlortetracycline per pound of body weight) on days 8 to 12, 14 to 18, 20 to 24, and 26 to 30 post-arrival; or (3) top-dressed with Aureomycin pellets on days 0 to 4, 6 to 10, 12 to 16, 18 to 22, and 24 to 28 followed by 25 days of administration of AS-700 (Alpharma, Inc.), which provided 350 mg/head per day of both chlortetracycline and sulfamethazine. All treatments received Bovatec (Alpharma, Inc.) at 250 to 300 mg/head daily in the complete feed for the first 28 days on study. The control and Aureomycin-only treatments received Bovatec from day 29 until conclusion of the study.

Cattle were observed daily for signs of illness and injury by personnel blinded to treatments. Calves were treated for respiratory disease with Draxxin only after a moratorium of 5 days post-metaphylaxis. Calves determined to need treatment were given Baytril (Bayer Animal Health, Shawnee Mission, KS) at 5 mL/100 lb body weight as a first treatment; Nuflor (Intervet/Schering-Plough Animal Health, Millsboro, DE) at

6 mL/100 lb body weight as a second treatment, if needed; and Bio-Mycin 200 (Boehringer Ingelheim, Ridgefield, CT) at 4.5 mL/100 lb body weight as a third treatment, if needed.

Bunks were checked twice daily, and feed was delivered in amounts sufficient to result in slick bunks both morning and afternoon. Calves were fed their respective diets at approximately 7:00 a.m. and 3:00 p.m. daily for 55 days.

Daily dry matter intake, gains, and feed efficiencies were determined for each pen of calves. Health records were used to determine the number of animals treated and percentage of death loss.

Performance and health data were analyzed by using the random effects MIXED model procedure SAS (SAS Institute, Inc., Cary, NC). Treatments were arranged in a randomized incomplete block design; pen served as the experimental unit for growth and health characteristic analysis. In the model, fixed effects were treatment, lot, and gender, and random effects were lot × treatment, pen, and animal ID. Percentages of morbidity and mortality were evaluated by the Chi-Square test, and differences were declared significant at $P<0.05$.

Results and Discussion

There were no significant differences among treatments in the percentage of steers treated once, twice, or one or more times for bovine respiratory disease ($P>0.30$; Table 1). There were no significant differences in daily gain ($P=0.66$), daily dry matter intake ($P=0.68$), or feed efficiency ($P=0.50$) among the three treatments.

Implications

This experiment showed no benefit of feeding Aureomycin for four 5-day periods after receiving when calves were mass medicated with Draxxin upon arrival. These results may be beneficial to producers who are evaluating treatment protocols for newly received high-risk stocker calves.

Table 1. Treatment incidence for bovine respiratory disease (BRD), percentage of death loss, and growth performance of newly arrived stocker calves receiving injectable and feed-based metaphylaxis programs during a 55-day receiving study

	Treatment[1]				
Item	Draxxin	Draxxin plus Aureomycin	Draxxin plus Aureomycin plus AS-700	SEM	P-value
No. of pens	8	8	8		
No. of steers	32	32	31		
No. of castrated bulls	72	73	73		
Initial weight, lb	453	449	452	4.0	0.79
Weight at revaccination, lb	507	507	505	5.0	0.97
Final weight, lb	616	613	622	6.0	0.58
Treatments for BRD, % of calves					
Treated only once	15.2	22.6	18.8	3.3	0.30
Treated two times or more	24.6	21.2	16.6	4.7	0.49
Total BRD treatment, one or more times	39.8	43.8	35.4	4.8	0.48
Death loss, %	0	0.84	2.18	1.2	0.39
Daily dry matter intake, lb	14.54	14.31	14.68	0.31	0.68
Average daily gain, lb	3.02	3.04	3.15	0.10	0.66
Feed:Gain	4.92	4.81	4.78	0.08	0.50

[1] Draxxin, calves administered Draxxin upon arrival; Draxxin plus Aureomycin, calves administered Draxxin upon arrival in addition to pulse dosing of Aureomycin on days 8 to 12, 14 to 18, 20 to 24, and 26 to 30 post-arrival; Draxxin plus Aureomycin plus AS-700, calves administered Draxxin upon arrival in addition to pulse dosing of Aureomycin on days 0 to 4, 6 to 10, 12 to 16, 18 to 22, and 24 to 28 followed by 25 days of AS-700.

Capacity of the Bovine Intestinal Mucus and Its Components to Support *Escherichia coli* O157:H7 Growth[1]

C. Aperce, J. Heidenreich, and J. Drouillard

Introduction

Escherichia coli O157:H7 contamination of human food products is a major concern for the beef industry. The pathogens responsible for outbreaks often originate from cattle, and *E. coli* O157:H7 can thrive in healthy cattle. To control contamination in the food chain, it is essential to understand how this pathogen is able to grow and compete with other bacteria in the gastrointestinal tracts of cattle.

Previous studies have shown that bovine intestinal mucus supports bacterial colonization and can selectively influence makeup of the bacterial population. Intestinal mucus is made of mucins, which are gel-forming glycoproteins. Mucin molecules contain sialic acid that must be removed by neuraminidase enzyme to allow for complete degradation of mucin. *E. coli* O157:H7 lacks neuraminidase and should have little ability to degrade the complex mucin molecules. Our objective was to evaluate bovine intestinal mucus and its components in terms of their capacity to support *E. coli* O157:H7 growth in the presence or absence of feces and to understand the roles various enzymes play in this process.

Experimental Procedures

Intestinal tissues from freshly harvested cattle were collected and transported to our laboratory in chilled saline. Sections of the ileum and colon were washed with buffer solution, and mucus was harvested by gently scraping the epithelium. We prepared a mix of five selected strains of Shiga toxin-producing *E. coli* O157:H7 resistant to nalidixic acid (Nal^R) and added the mix to a buffer or a similar amount of fecal inoculums collected from the rectum of a steer fed a high-grain diet.

Subsequently, we added harvested intestinal mucus or individual mucus components to the culture to assess which components were most capable of supporting Nal^R *E. coli* O157:H7 growth. Intestinal mucus was added at a concentration of 10 mg/mL. Single components of mucus (galactose, D-galacturonic acid, D-gluconic acid, D-glucuronic acid, mannose, L-alpha-phosphatidylserine, sialic acid, and N-acetyl-D-glucosamine) were added at the same concentration, except for L-alpha-phosphatidylserine, which was added at 1 mg/mL. Initial concentrations of *E. coli* O157:H7 and fecal bacteria in the cultures were 10^3 and 10^4 CFU/mL, respectively.

We also evaluated the impact of adding enzymes and enzyme inhibitors associated with mucus degradation on *E. coli* O157:H7 growth. Proteases, endoglycosidases, sialidases, or lipases were added to the batches at a concentration of one unit per milliliter. Beta-galactosidase inhibitor was added at a final concentration of 200 μM, and protease inhibitor was added at either 0.25 or 2.5 mL/g of *E. coli* O157.

[1] Funding for this project was provided by the Beef Checkoff.

After 0, 6, 8, and 12 hours of anaerobic incubation at 104°F on a laboratory shaker, we plated 100 µL of culture at different dilutions on agar selective for Nal^R *E. coli* O157:H7. After incubating the plates for 24 hours at 98°F, we counted the Nal^R *E coli* O157:H7 colonies and established the Nal^R *E coli* O157:H7 growth within the different batches (expressed in Log_{10} of CFU/mL).

Results and Discussion

There were no significant differences ($P>0.10$) in *E. coli* O157:H7 growth between mucus derived from the large intestine (colon) and small intestine (ileum). The bacteria increased from 10^3 CFU/mL of culture at time zero to 10^7 to 10^8 CFU/mL at hour 8. There was an overall time effect on bacteria growth but no significant difference between hour 8 and 12, which drove us to use hour 8 as a point of comparison. Presence or absence of fecal inoculums in the culture affected ($P<0.01$) *E. coli* O157:H7 growth. The final concentration of bacteria decreased from 10^7 to 10^5 CFU/mL, which is likely due to competition for nutrients with the fecal bacteria.

Figure 1 depicts *E. coli* O157:H7 growth after 8 hours of anaerobic incubation without feces but with whole mucus or selected components of mucous as substrates. With the exception of L-alpha-phosphatidylserine, almost all of the mucus components tested increased growth of the bacteria compared with the batch containing only buffer ($P<0.05$). However, mucus originating from the large and small intestines supported greater growth than the individual mucus fractions ($P<0.05$). Of the individual mucus components evaluated, only gluconic acid resulted in growth similar to that achieved with whole intestinal mucus. These observations suggest *E. coli* O157:H7 may need a combination of components to ensure optimal growth or that the bacteria are utilizing a key element present in the mucus that we did not evaluate in this experiment.

In our attempt to analyze the stimulatory effect of mucus-degrading enzymes on growth of Shiga toxin-producing *E. coli* O157:H7, we found no significant difference in growth of cultures treated with enzymes or protease inhibitors compared with untreated batches ($P>0.05$). Conversely, as illustrated in Figure 2, addition of beta-galactosidase enzyme inhibitor increased the growth of Nal^R *E. coli* O157:H7 cultured with either small or large intestinal mucus ($P<0.05$). The increase of growth, instead of the expected inhibition, could be due to the bacteria's inability to use the inhibitor as a source of protein. However, the amount of inhibitor added to the culture was very small and, therefore, seems an unlikely explanation. It is equally possible that mucus galactosides that have not been enzymatically degraded are more stimulatory to *E. coli* O157:H7 growth. Additional controlled experiments are needed to further investigate the increase of growth induced by the beta-galactosidase inhibitors.

Figure 3 illustrates *E. coli* O157:H7 growth in response to small intestinal mucus or sialic acid substrates in the presence or absence of a fecal inoculum. *E. coli* O157 growth was significantly lower in sialic acid than in mucus ($P<0.01$), indicating the pathogen has limited capacity to use sialic acid as a substrate for growth. When fecal inoculum was added to the culture with small intestinal mucus, there was a significant decrease in *E. coli* growth compared with the same culture without feces. This again suggests the bacteria are competing for nutrients. However, *E. coli* O157:H7 growth increased when fecal inoculum was added to the culture containing sialic acid. Bacteria present in feces

may have the ability to degrade sialic acid, thus allowing *E. coli* O157:H7 to use the intermediates or end products of the degradation as a substrate for growth.

Cattle fed distillers grains have been shown to have an increase in *E. coli* O157 shedding, and distillers grains contain a substantial proportion of yeast, which has a high sialic acid content (3% of dry weight). It is possible that sialic acid or other glycoprotein constituents of distillers grains are the active components that stimulate proliferation of *E. coli* O157:H7 in cattle fed distillers grains.

Implications

This study offers insight regarding the potential of intestinal mucus and its components to promote *E. coli* O157:H7 growth in cattle. Further investigations are needed to establish whether one of these components could inhibit, or at least regulate, the proliferation of important foodborne pathogens.

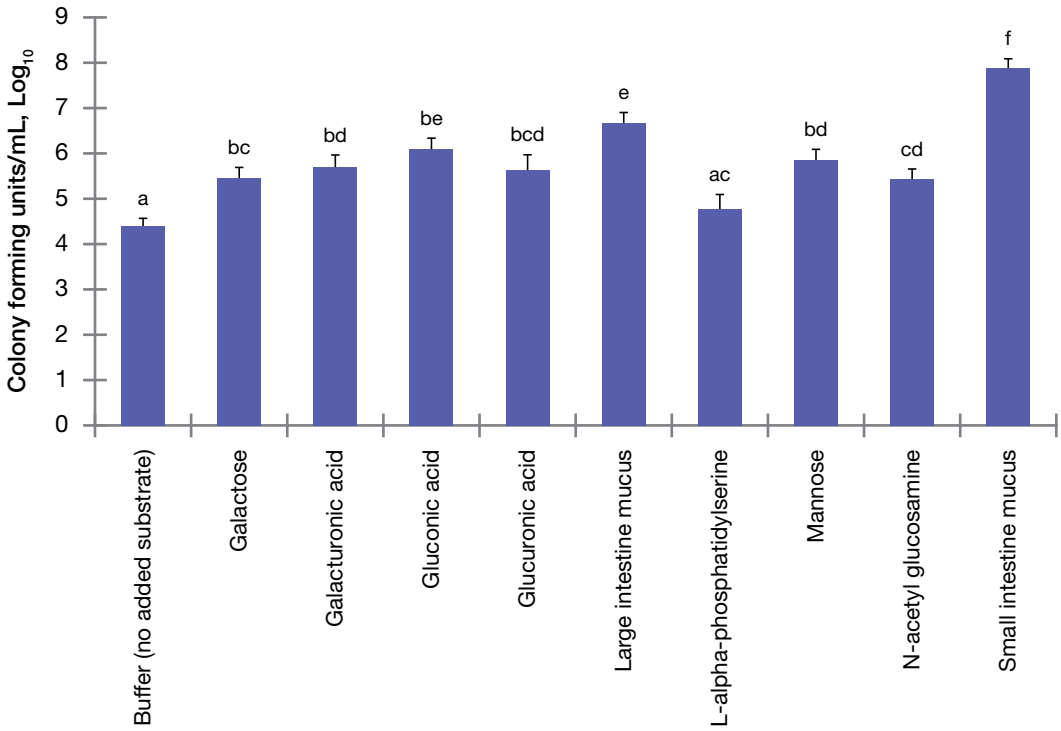


Figure 1. Growth of nalidixic acid-resistant *Escherichia coli* O157:H7 on small intestinal mucus, large intestinal mucus, or components of mucus after 8 hours of incubation. Cultures were inoculated with 10^3 CFU/mL of nalidixic acid-resistant *E. coli* O157:H7 prior to incubation.

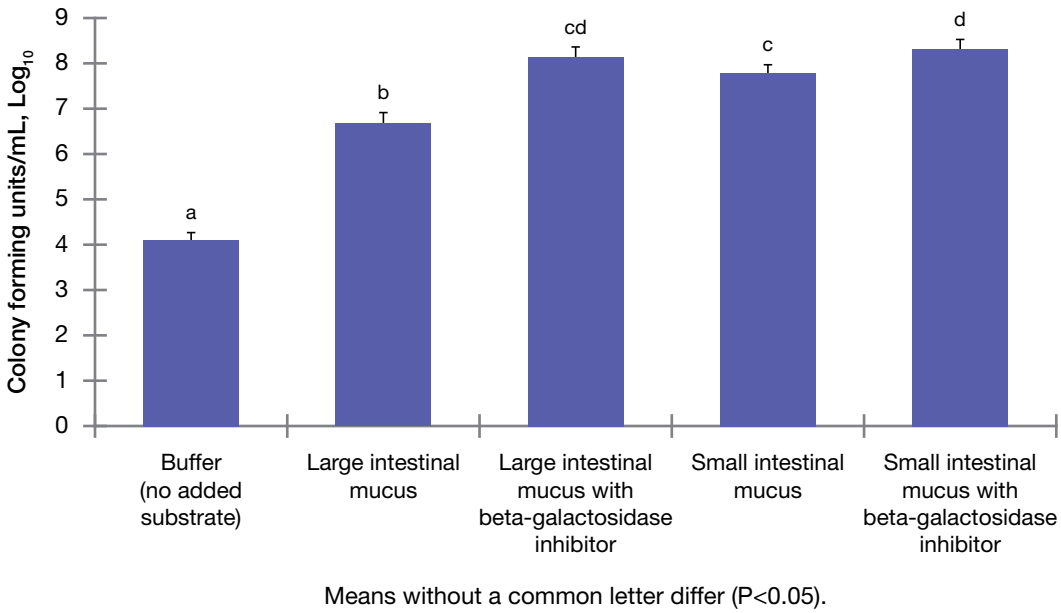


Figure 2. Growth of nalidixic acid-resistant *Escherichia coli* O157:H7 with small or large intestinal mucus in the presence and absence of beta-galactosidase enzyme inhibitor.

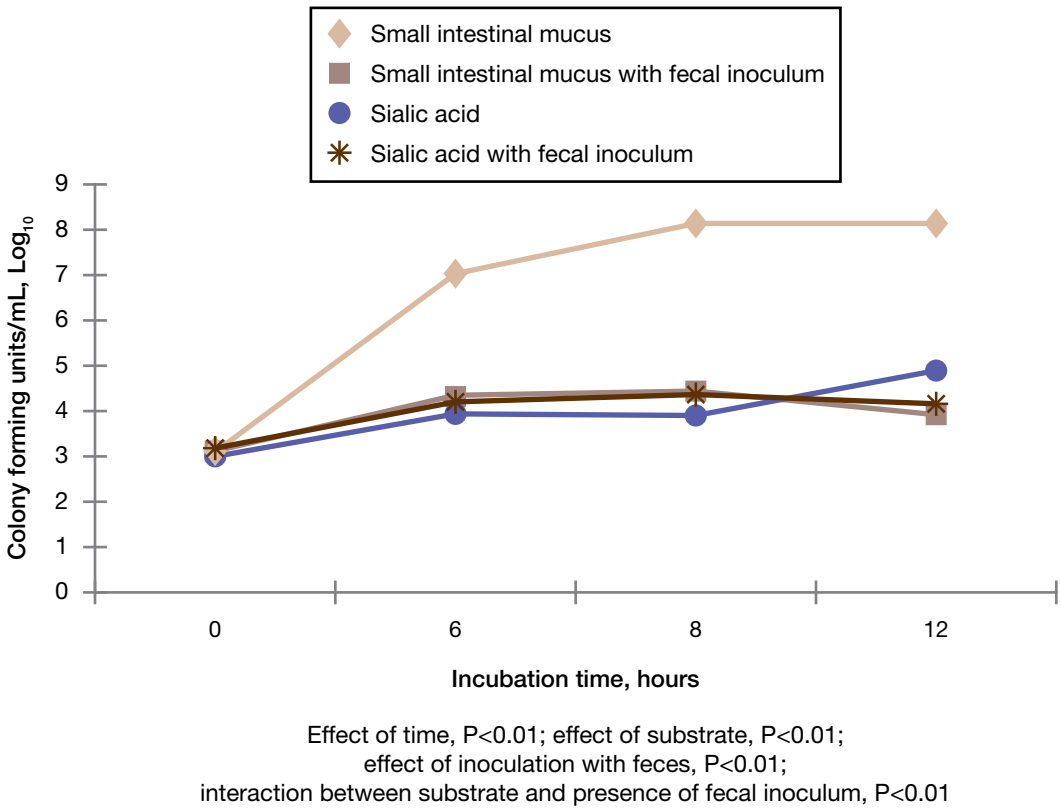


Figure 3. Growth of nalidixic acid-resistant *Escherichia coli* O157:H7 in response to small intestinal mucus or sialic acid as substrate in the presence and absence of a fecal inoculum.

Increased Concentrations of Bovine Intestinal Mucus Encourage Growth of *Escherichia coli* O157:H7

J. Heidenreich, C. Aperce, and J. Drouillard

Introduction

Cattle have been implicated as carriers of the human pathogen *Escherichia coli* O157:H7. Contamination of the beef supply by *E. coli* O157 can occur during harvest and processing, causing costly recalls or human illness. Many interventions have been applied in attempts to prevent contamination of carcasses in processing plants, such as development of HACCP procedures, carcass washes, and steam pasteurization, but contaminations still occur. Mechanisms that allow *E. coli* O157:H7 to thrive in cattle at sporadic times and in such large numbers are poorly understood. Understanding factors that stimulate *E. coli* O157 growth in cattle will aid in identifying effective interventions that can be applied in feedlots and processing plants to reduce the numbers of this pathogen.

E. coli O157 resides in the intestinal tracts of cattle. Mucin is a major component of intestinal mucus and is composed of proteins, lipids, and carbohydrates, which many bacteria can use as a source of food. The amount of mucin available in the intestinal tract depends on the stimulation of intestinal mucus-producing cells (goblet cells), which may be influenced by the animal's diet, stress, and a variety of other factors. Our objective in this experiment was to determine if mucin produced in the small or large intestine could affect growth of *E. coli* O157:H7.

Experimental Procedures

We isolated mucus from the small and large intestine of freshly harvested cattle. Protein and organic matter concentrations of the mucus were determined.

Five Shiga-toxin-producing *E. coli* O157:H7 strains resistant to the antibiotic nalidixic acid (Nal^R) were grown overnight at 98.6°F in a nutrient-rich broth and combined to create a five-strain mixture of *E. coli* O157:H7. To simulate natural conditions of the bovine intestinal tract, a fecal inoculum was prepared. Fresh bovine feces were added to a buffer solution, blended, and then strained through cheesecloth to remove large particulates.

The *E. coli* O157 mixture, McDougall's buffer, and fecal inoculum were added to test tubes containing various concentrations of small intestinal mucus (0, 0.5, 1.0, 2.0, 4.4, 10, or 15 mg organic matter/mL) to determine competiveness of *E. coli* O157:H7 in the presence of background bacteria. The cultures were gassed with oxygen-free CO_2, stoppered, and incubated at 104°F. Samples were taken after 0, 6, 8, and 12 hours of incubation and plated onto both Aerobic Petrifilm (3M, St. Paul, MN) for total anaerobic bacteria counts and onto MacConkey sorbitol agar plates containing nalidixic acid (CTN-SMAC) for Nal^R *E. coli* O157:H7 counts. The Aerobic Petrifilm was incubated at 104°F under oxygen-free conditions. The CTN-SMAC plates were incubated at

98.6°F under ambient conditions. The numbers of bacteria were expressed as colony forming units per milliliter of liquid sample (CFU/mL). Additionally, following the same procedures, *E. coli* O157 mixture, McDougall's buffer, and/or fecal inoculum were added to test tubes containing either large or small intestinal mucus at a concentration of 4.4 mg of organic matter/mL.

Results and Discussion

E. coli O157:H7 grew from a concentration of 10^3 CFU/mL to 10^8 CFU/mL of culture after 12 hours of incubation (Figure 1). Growth was similar in mucus derived from the small and large intestines ($P>0.10$). *E. coli* O157:H7 grew less in cultures containing feces than in cultures without feces ($P<0.01$). This reduction in growth was probably due to competition for nutrients between *E. coli* O157:H7 and the naturally occurring bacteria present in feces.

The effect of increasing concentrations of small intestinal mucus is shown in Figure 2. The total count of anaerobic bacteria was stable across concentrations from hour 0 to hour 8 ($P>0.10$). Unlike anaerobic bacteria, the number of *E. coli* O157:H7 increased as mucus concentration increased ($P<0.01$). These results suggest that intestinal mucus stimulates growth of *E. coli* O157:H7 and that pathogenic *E. coli* outcompete other intestinal bacteria for utilization of proteins and carbohydrates contained within mucus.

Implications

These experiments provide valuable information regarding the influence of mucus on growth of *E. coli* O157:H7 in cattle. The study suggests the amount of intestinal mucus available to *E. coli* O157 may influence growth of foodborne pathogens in the intestines of cattle. This provides insight for further investigations toward development of preharvest interventions to limit growth of foodborne pathogens in cattle.

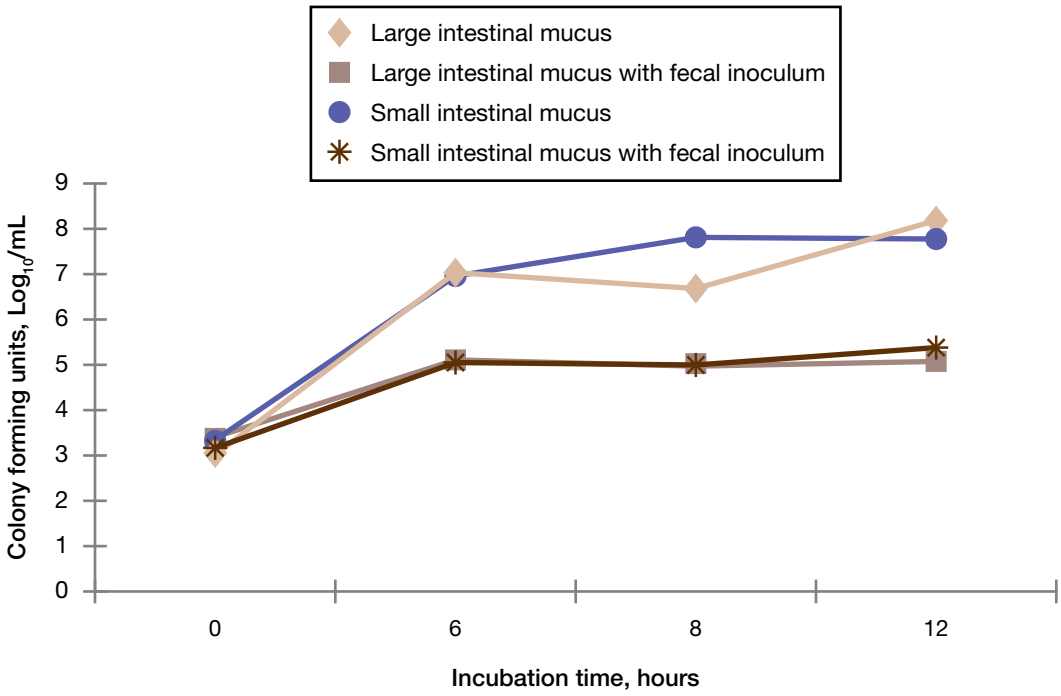


Figure 1. Growth of *Escherichia coli* O157:H7 in mucus isolated from bovine small intestine or large intestine in the presence or absence of bovine feces.

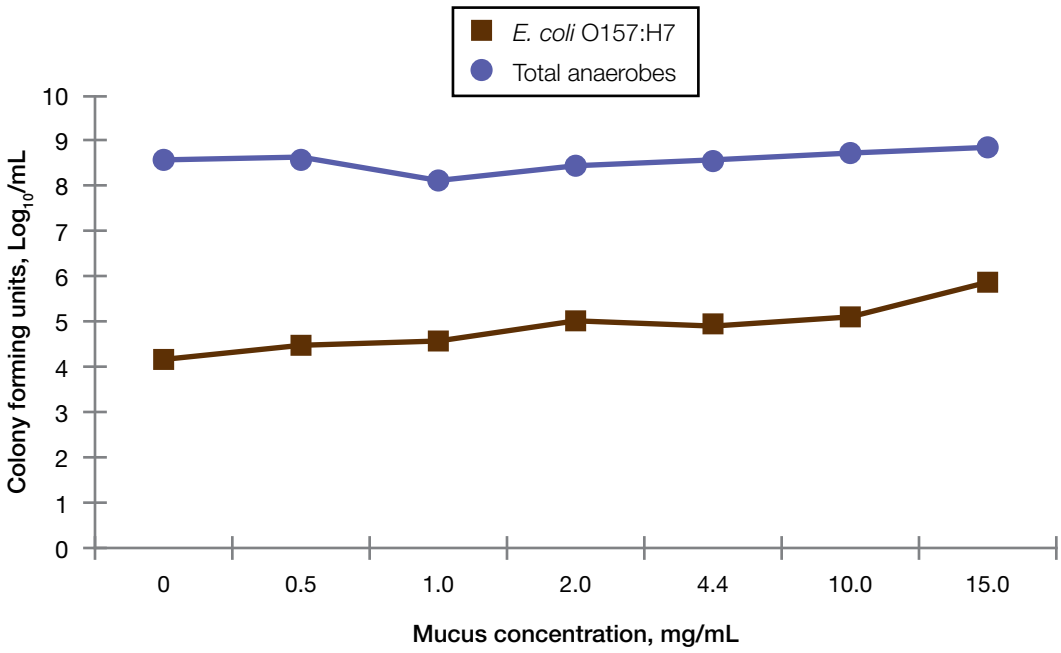


Figure 2. Growth of total fecal anaerobic bacteria or *Escherichia coli* O157:H7 in response to increasing concentrations of bovine intestinal mucus after 8 hours.

Long-Term CIDR Program for Synchronization of Estrus in Beef Heifers Produces Acceptable AI Pregnancy Rates

S.K. Johnson, J.R. Jaeger, and J.W. Bolte

Introduction

Routinely achieving pregnancy rates greater than 50% with fixed-time artificial insemination (AI) in heifers has been difficult. The Beef Reproduction Task Force recently added the intravaginal progesterone-releasing device (CIDR)-Select to its list of recommended fixed-time AI protocols. Research and field trials in Missouri have achieved AI pregnancy rates in the range of 55% to 60%. Another relatively new protocol is the 5-day CO-Synch, a timed AI protocol + CIDR that has produced pregnancy rates similar to or higher than those obtained with the standard 7-day CO-Synch + CIDR protocol. It is not known whether these two systems differ in terms of estrous response. The objective of the current study was to compare effects of a long-term, 14-day CIDR-Select protocol and a 5-day CO-Synch + CIDR protocol on estrous distribution and AI pregnancy rate in yearling beef heifers.

Experimental Procedures

In 2008 (n = 69) and 2009 (n = 74), Angus and Angus cross yearling heifers were assigned to one of two treatments on the basis of age and weight. Heifers assigned to the CIDR-Select protocol (Figure 1) received an EAZI-BREED CIDR insert (1.38 g, Pfizer Animal Health, New York, NY) from day -30 through day -16, 2 mL Fertagyl (gonadotropin-releasing hormone; Intervet-Schering Plough Animal Health, De Soto, KS) intramuscularly on day -7, and 5 mL Prostamate (prostaglandin $F_{2\alpha}$; Teva Animal Health, St. Joseph, MO) intramuscularly on day 0. Heifers assigned to the 5-day CO-Synch + CIDR protocol (Figure 1) received a CIDR insert and 2 mL Fertagyl intramuscularly on day -5 and 5 mL Prostamate intramuscularly and CIDR removal on day 0. On day 0, heifers received either an Estrotect patch (Estrotect, Inc., Spring Valley, WI; 2008) or a Kamar patch (Kamar, Inc., Steamboat Springs, CO; 2009). Heifers were observed at least twice daily for estrus until 60 hours after Prostamate injection. Heifers observed in estrus prior to 60 hours were inseminated using the AM/PM rule. At 72 hours, all heifers not previously observed in estrus were inseminated and received 2 mL Fertagyl intramuscularly (clean-up timed AI). Bulls were introduced at least 10 days after timed-AI. Pregnancy to AI was determined by transrectal ultrasonography between 28 and 35 days after AI.

Serum samples for determination of progesterone concentrations were collected 10 days before and at the start of each treatment. Heifers with progesterone concentrations greater than or equal to 1 ng/mL in one or both samples were considered cycling.

Results and Discussion

Heifers were younger ($P<0.05$) on day 0 in 2009 than in 2008 (13.6 vs. 14.6 months, respectively; Table 1). A majority of heifers were cycling prior to initiation of treatments, and the proportion did not differ with treatment or year.

Interval to estrus was longer (P<0.01) in 2008 than in 2009 (63.4 ± 1.5 hours and 55.9 ± 1.9 hours, respectively). There was no difference in interval to estrus due to treatment (60.6 ± 1.4 hours and 58.6 ± 1.4 hours for CIDR-Select and 5-day CO-Synch + CIDR, respectively). The proportion of heifers displaying estrus by 60 hours after Prostamate injection was 34% (48/143) and did not differ with treatment.

Conception rate after observed estrus was higher (P<0.01) for CIDR-Select than for 5-day CO-Synch + CIDR, as was pregnancy rate to clean-up timed AI and overall AI pregnancy rate (Table 2). Final pregnancy rate was 82% and 90% for CIDR-Select and 5-day CO-Synch + CIDR, respectively, and did not differ between estrous synchronization treatments.

This is one of the first studies to show a lower conception rate after observed estrus following a 5-day CO-Synch + CIDR protocol compared with other synchronization treatments. Most available data compares fixed-time AI pregnancy rate of the 5-day CO-Synch + CIDR protocol with that of the standard 7-day treatment protocol. Pregnancy rate to AI after the 5-day protocol has either been equal to or greater than that in the 7-day protocol. In some of those studies, a second injection of prostaglandin (Prostamate in this study) was administered 12 hours after the first injection at the time of CIDR removal. Two injections of prostaglandin have been used to ensure regression of corpora lutea induced by the gonadotropin-releasing hormone injection administered at CIDR insertion. If luteal regression had been deficient in this study, the estrus response or interval to estrus may have been affected, but that was not the case. The relatively low number of heifers per treatment in this study and the amount of data from other studies with much higher conception rates suggests the poor pregnancy rate in the 5-day treatment may be a result of small treatment groups and the challenges presented by variation of categorical (yes/no) data.

Implications

The CIDR-Select protocol for synchronization of estrus and ovulation in beef heifers results in industry-acceptable pregnancy rates; however, the need to handle animals five times may limit its application.

Table 1. Characteristics of heifers

Year	Treatment	n	Age, days	Cycling, %
2008	CIDR-Select	35	438 ± 3.2	97
	5-day CO-Synch + CIDR	34	437 ± 3.2	94.3
			438 ± 2.2	96
2009	CIDR-Select	37	411 ± 3.1	86.5
	5-day CO-Synch + CIDR	37	409 ± 3.1	97.3
			410 ± 2.2	92

Table 2. Conception rate to estrus AI, pregnancy rate to clean-up fixed-time AI, and overall AI pregnancy rate in beef heifers[1]

Treatment	Conception rate, estrus AI, % (n)	Pregnancy rate, clean-up fixed-time AI, % (n)	AI pregnancy rate, % (n)
CIDR-Select	78[a] (23)	61[a] (49)	67[a] (72)
5-day CO-Synch + CIDR	32[b] (25)	37[b] (46)	35[b] (71)

[1] AI, artificial insemination.
Means within columns with a different superscript letter differ (P<0.05).

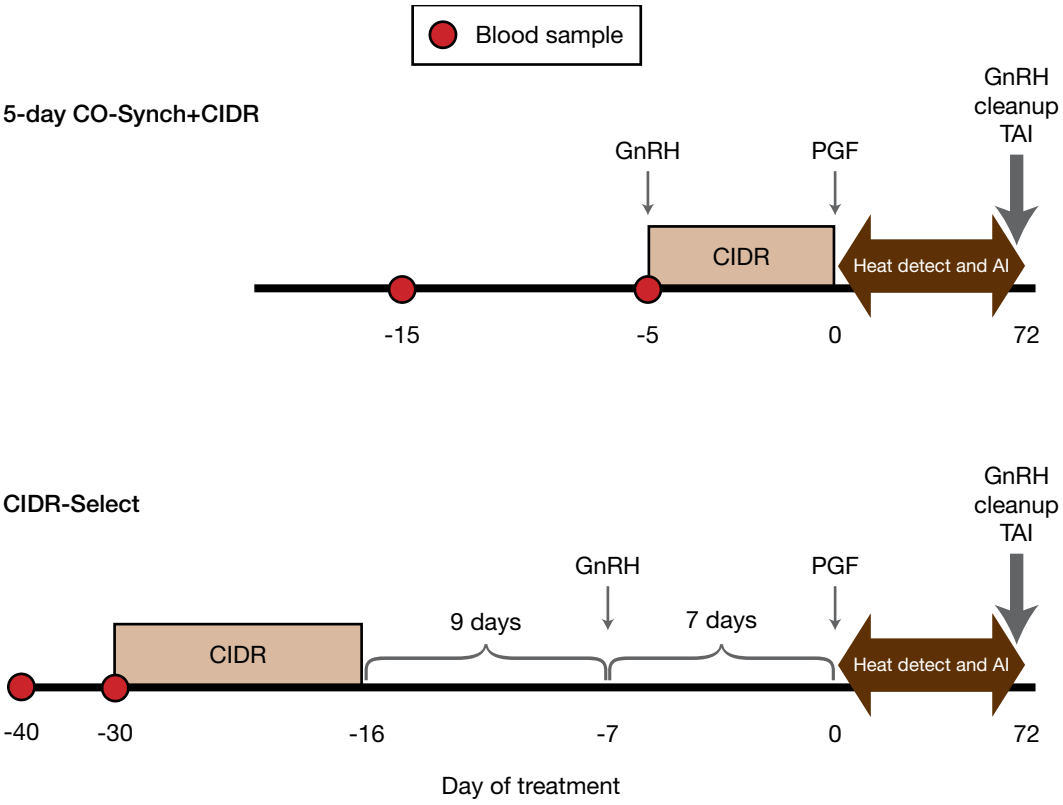


Figure 1. Description of treatments.
GnRH, gonadotropin-releasing hormone (Fertagyl); PGF, prostaglandin $F_{2\alpha}$ (Prostamate); CIDR, intravaginal progesterone-releasing device (EAZI-BREED CIDR).

Cornstalk Round Bale Processing Method Does Not Influence Feeding Characteristics or Feed Refusals[1]

S.Q. Jones, J.M. DeRouchey, J.W. Waggoner, T.T. Marston, R.M. Breiner, and T.J. Kraus[2]

Introduction

Nutritionists and producers often assume that ingredients in a total mixed ration are uniformly mixed. However, many factors can affect ration homogeneity, including particle size, particle shape, differences in density of feed ingredients, and relative point at which the mixture is discharged from a mixer batch. Forages often are ground prior to mixing in a total mixed ration to reduce variation in forage particle length. Preprocessing forages during baling may facilitate particle length reduction, eliminating the need to grind forages prior to mixing. The objectives of this study were to determine the effects of forage processing on (1) uniformity of the ration discharged from the mixer at different points, (2) particle length throughout the mixing process by bale type, and (3) difference in feed refusals of mixed rations based on forages processed by different methods.

Experimental Procedures

A total of 60 heifers (730 lb initial body weight) were used to evaluate the effects of cornstalk processing methods on forage particle size length and heifer growth performance. In mid-October 2009, a portion of a cornstalk field in northeast Kansas was cut with a flail shredder (John Deere 27) and raked (Darf 17 wheel v-hay rake) on a single day. Cornstalks were either conventionally baled or precut and baled. Precut stalks were baled using a round baler equipped with serrated knives that cut the forage into 3- to 8-in. sections as the packer fingers moved the forage from the header to the baling chamber. No knives were present on the outer 6 in.; thus, the full-stem-length forage on the ends and perimeter maintained the structural integrity of the bale. The treatments were: (1) 5 × 4 ft conventionally baled cornstalks, (2) 5 × 4 ft precut cornstalks, and (3) 5 × 4 ft conventionally baled cornstalks that were later tub ground. Before the start of the experiment, conventional bales were unrolled on a concrete slab. Precut bales were broken apart by being raised approximately 16 ft with a tractor grapple fork and dropped onto concrete. Tub-ground bales were ground with a Haybuster H-1000 (DuraTech Industries International, Inc., Jamestown, ND) using a 2-in. screen. Rations (Table 1) were prepared with a horizontal mixer (Forage Express, Roto-Mix, Dodge City, KS) and fed at an average of 2.45% of body weight (dry basis) over the 15-day period.

Plastic containers (12 in. × 9 in. × 6 in.) were placed at the first, middle, and last third of the bunk line for collection of discharge location samples. Unconsumed feed remain-

[1] Appreciation is expressed to John Deere (Ottumwa, IA) for funding and use of tractors and baler and to Mark Cooksey of Roto-Mix (Scott City, KS) for technical support and donation of the mixer used in this study.

[2] John Deere, Ottumwa, IA.

ing in the bunk was collected and weighed before the next feeding period for determination feed refusals. Bale cores, discharge samples, and feed refusals were analyzed to compare concentrations of dry matter, crude protein, acid detergent fiber, and neutral detergent fiber. To calculate average dry matter intake, feed refusals were subtracted from initial dry matter of the total mixed ration that was fed and divided by total number of animals. Animals were weighed on 2 consecutive days at the beginning and end of the study for determination of weight change during the 15-day experimental period. Diet particle length was determined by measuring the percentage of forage remaining on the top two screens (>12.7 mm), the overall particle length, and standard deviation of particle size.

Results and Discussion

Average dry matter intake for the 15-day feeding period was 17.9 lb per animal each day. Final average body weight for the heifers was 785 lb, and average daily gain for the entire 15-day feeding period was 3.52 lb/day. Chemical analysis revealed no ($P>0.32$) mixer discharge site × bale type interactions. Different discharge locations for batches of feed representing the different cornstalk treatments had similar ($P>0.11$) dry matter, crude protein, acid detergent fiber, and neutral detergent fiber. Total mixed ration samples taken from the beginning of the mixer discharge had lower ($P=0.02$) dry matter and higher ($P=0.04$) crude protein levels than samples taken at the end of the mixer discharge (Tables 2 and 3). Samples taken during the middle of the mixer discharge had lower ($P=0.01$) acid detergent fiber and neutral detergent fiber percentages, higher ($P=0.01$) protein levels, and a tendency for greater ($P=0.09$) dry matter content compared with samples taken at the end of the mixer discharge. Feed refusals were similar ($P>0.25$) among all three treatments (Table 4). Chemical analysis of the refusals revealed similar ($P>0.12$) levels of dry matter, crude protein, acid detergent fiber, and neutral detergent fiber for mixed rations made from forages processed by different methods.

There were no differences in the amount of feed refusals between the different cornstalk processing methods. The lack of a difference in chemical analysis of the feed refusals indicates there was limited sorting of ingredients due to initial cornstalk bale processing method.

Implications

Precutting forages during baling resulted in responses similar to those for conventionally baled and processed forages at the levels fed in this experiment.

Table 1. Diet composition

Ingredient, % dry matter basis	
Cornstalks	45.00
Wet corn gluten feed	44.95
Steam flaked corn	6.14
Premix[1]	3.91
Calculated composition	
Dry matter, %	70.85
NE_m, Mcal/lb	0.70
NE_g, Mcal/lb	0.43
Crude protein, %	14.00
Calcium, %	0.76
Phosphorus, %	0.55

[1]Total mixed diet contained 1,500 IU/lb of vitamin A; 10 IU/lb vitamin E; 0.3% salt; 0.1 ppm cobalt; 10 ppm copper; 0.6 ppm iodine; 60 ppm manganese; 0.3 ppm selenium; 60 ppm zinc; 30 g/ton Rumensin; and 9 g/ton Tylan.

Table 2. Effects of cornstalk bale type and mixer discharge location on ration composition[1]

	Bale type									
	Conventional			Precut			Tub ground			
Item %	First third	Middle third	Last third	First third	Middle third	Last third	First third	Middle third	Last third	SEM
Dry matter	67.6	69.5	73.7	70.0	68.8	71.8	68.6	70.6	69.9	1.16
Crude protein	12.6	13.1	11.8	12.2	12.5	11.1	12.6	12.7	12.2	0.45
Acid detergent fiber	28.2	27.0	28.3	28.6	26.1	31.8	28.2	27.6	29.9	1.45
Neutral detergent fiber	51.6	50.0	53.7	54.6	49.8	56.7	53.3	53.3	54.7	1.78

[1]15 days of feeding different cornstalk bale types on discharge location in a total mixed ration chemical analysis.

Table 3. Probabilities of effects of cornstalk bale type and discharge site on ration composition[1]

	Probabilities, P<						
Item, %	First third vs. Middle third	First third vs. Last third	Middle third vs. Last third	Conventional vs. Precut	Conventional vs. Tub ground	Precut vs. Tub ground	Site × Type
Dry matter	0.49	0.02	0.09	0.98	0.65	0.67	0.32
Crude protein	0.41	0.04	0.01	0.12	0.92	0.14	0.86
Acid detergent fiber	0.23	0.17	0.01	0.41	0.55	0.83	0.60
Neutral detergent fiber	0.15	0.21	0.01	0.19	0.18	0.97	0.56

[1]Probabilities of 15 days of feeding different cornstalk bale types on discharge location in a total mixed ration chemical analysis.

Table 4. Refusal amount and composition according to cornstalk bale type and discharge site[1]

					Probability, P<		
	Bale type				Conventional	Conventional	Precut vs.
Item	Conventional	Precut	Tub ground	SEM	vs. Precut	vs. Tub ground	Tub ground
Dry matter refusals, lb/day	51.9	55.0	40.0	31.77	0.81	0.33	0.25
Crude protein, %	5.1	5.1	4.9	0.32	0.97	0.55	0.58
Acid detergent fiber, %	50.6	51.2	49.4	1.05	0.71	0.42	0.24
Neutral detergent fiber, %	76.7	77.7	79.2	1.07	0.53	0.13	0.35

[1]Refusal dry matter and chemical analysis of 15 days of feeding cornstalk bales in a total mixed ration.

Round Bale Alfalfa Processing Method Affects Heifer Growth but Does Not Influence Wastage or Eating Preference[1]

S.Q Jones, J.M. DeRouchey, J.W. Waggoner, T.T Marston, R.M. Breiner, and T.J. Kraus[2]

Introduction

Many factors affect forage quality, including moisture level at baling, compaction, bulk density, and maturity at harvest. Losses of dry matter and nutrient value occur during field curing. Hay baled at or above 18% moisture should have less nutrient loss in the field. However, hay baled at these moisture levels has the potential to heat during storage, causing dry matter loss and nutrient degradation. Also, as particle length of forage decreases, packing ability of forage and bulk density of bales increase. Although particle length is reduced by grinding baled forage, this can result in nutrient losses. Also, when cattle are fed free choice in a ring feeder, precutting forage may help reduce waste because the smaller particles fall within the ring and are not pulled out by the animals and lost on the ground. Objectives of these experiments were to compare the effects of precutting alfalfa during round baling and conventional baling on heifer performance, forage wastage, and eating preference.

Experimental Procedures

One field of alfalfa in northeast Kansas was swathed and raked in mid-July. In the conventional baling method, alfalfa was fed through the header of a round baler and carried by packer fingers into a baling chamber without further processing. In the precut method, alfalfa was fed through the header of a round baler equipped with serrated knives that cut the alfalfa stems into 3- to 8-in. sections as the packer fingers moved the stems from the header to the baling chamber. Because there were no knives on the outer 6 in. of each side, the perimeter of the bale was composed of alfalfa of full stem length, which maintained bale structure during hauling and handling. Experiments were conducted at the Kansas State University Purebred Beef Unit.

Experiment 1

A total of 46 heifers (595 lb initial body weight) were used to evaluate the effect of free choice feeding of precut and conventionally baled alfalfa hay on heifer performance in a 27-day study. Treatments were 5 × 4 ft conventional alfalfa bales and 5 × 4 ft precut alfalfa bales. There were four pens of beef heifers (two pens of 10 heifers, two pens of 13 heifers) with two pens per treatment. The treatments were offered free choice in 8-ft ring feeders. All heifers were fed 2.8 lb/day of wet corn gluten feed. Each individual bale of alfalfa was weighed before being placed into the ring feeders. Heifers were weighed on 2 consecutive days at the beginning and end of the 27-day trial to calculate gains. To calculate alfalfa dry matter intake, dry matter wastage by treatment (determined in experiment 2) plus remaining orts were subtracted from initial dry matter bale weights.

[1] Appreciation is expressed to John Deere (Ottumwa, IA) for funding of experiments and use of equipment.
[2] John Deere, Ottumwa, IA.

Core samples were taken from each bale and combined to make composite samples for each treatment, which were then chemically analyzed.

Experiment 2

Experiment 2 was conducted concurrently with experiment 1 to evaluate the effect of baling method on forage wastage from ring feeders. Three 5-day collection periods were used for a total of six replications per bale type. Prior to the start of each 5-day period, ring feeders and surrounding soil were scraped free of residual forage. Initial bale weights were recorded, and alfalfa wastage around the ring was collected every day at 7:00 a.m. for 5 days. Wastage was collected with a lawn rake from the feeder to a distance of 8 ft around the feeder. Collection of manure was minimized but could not be avoided in all circumstances. Wasted forage was collected and weighed every day. The entire amount of wastage collected by pen for the 5-day period was combined and subsampled for analysis. After the fifth day, feed remaining inside the ring feeders was collected and weighed. Individual bale core samples and alfalfa wastage combined by collection period were analyzed for dry matter, crude protein, and neutral detergent fiber.

Experiment 3

A total of 26 beef heifers (672 lb initial body weight) were used to evaluate the effect of free choice feeding of conventionally baled or precut alfalfa hay on heifer preference. Heifers were allotted by weight and breed to two pens. There were two ring feeders per pen (8-ft feeders); one contained the conventional treatment, and one contained the precut treatment. Unconsumed feed was collected and weighed every 2 days to calculate dry matter intake. Prior to the next 2-day period, feeders were moved within each pen so no carryover effect of feeder location would occur. Treatments were 4 × 4 ft conventional alfalfa bales and 4 × 4 ft precut alfalfa bales. During this study, all heifers were fed 13.3 lb of wet corn gluten feed daily. All bales were weighed individually prior to being placed in 8-ft ring feeders. Individual bale core samples were analyzed for dry matter, crude protein, neutral detergent fiber, and mold spore counts. At the end of the 2-day period, dry matter intake was calculated by subtracting orts from initial bale weight.

Data from all three experiments were analyzed with the MIXED procedures of SAS (SAS Institute, Inc., Cary, NC). Effects were declared significant at $P<0.05$ and regarded as tendencies at $P<0.10$.

Results and Discussion

In experiments 1 and 2, dry matter, crude protein, and neutral detergent fiber of bales differed between treatments (Table 1). The conventional treatment had greater dry matter (79.5% vs. 79.1%; $P<0.01$) and neutral detergent fiber (58.3% vs. 46.3%; $P<0.03$) than the precut treatment, but crude protein was greater (20.6% vs. 17.7%; $P<0.04$) in the precut treatment than in the conventional treatment. Initial body weights of heifers were similar (599 vs. 594 lb; $P=0.67$) for the conventional and precut alfalfa treatments (Table 2), as expected. Heifers consuming precut alfalfa had greater average daily gain than heifers consuming conventional alfalfa (3.02 vs. 2.49 lb/day; $P<0.01$). Calculated dry matter intake was not different between the precut and conventional treatments (12.3 vs. 11.5 lb/day; $P=0.70$). The reason for the greater gains of heifers in the precut alfalfa treatment is unknown, but the numerically greater intake

and better chemical composition (i.e., more protein and less fiber) of the precut treatment may have been contributing factors.

In experiment 2, there was no difference in alfalfa wastage (P>0.13) between treatments for day 1, 3, 4, and 5 (Table 3). Wastage for day 2 tended to be greater (P=0.10) for the precut treatment, but there was no overall difference (P>0.05). Previous research has demonstrated that up to 8.0% of dry matter can be wasted. Our data showed considerably less wastage (0.9% for conventional and 1.1% for precut), possibly because we evaluated different forage types. Dry matter and crude protein of orts were similar between treatments (P>0.90), but neutral detergent fiber was greater (P<0.02) in orts from conventional alfalfa bales (Table 4). In experiment 3, the precut treatment had greater dry matter (P<0.04) than the conventional treatment (Table 5) but less crude protein and neutral detergent fiber (P<0.04). These differences were surprising because bales were harvested from the same field only hours apart. Precut alfalfa bales in experiment 3 had greater mold counts, though it is unknown if these levels affected performance or eating preference.

In experiment 3, there was no difference in dry matter intake between the precut and conventional treatments (10.4 vs. 8.6 lb/day; P=0.48). Thus, type of alfalfa processing did not affect heifer consumption preference.

Implications

Feeding precut alfalfa bales increased heifer gains but did not affect forage wastage in ring feeders or eating preference compared with conventional alfalfa bales.

Table 1. Chemical analysis of alfalfa bales (experiments 1 and 2)

Item	Conventional	Precut
Dry matter, %	79.5	79.1
Crude protein, %	17.7	20.6
Neutral detergent fiber, %	58.3	46.3

Table 2. Effects of alfalfa bale type on heifer growth performance over 27 days (experiment 1)

	Alfalfa hay processing			
Item	Conventional	Precut	Probability, P<	SEM
Initial body weight, lb	599	594	0.67	30.2
Daily gain, lb	2.49	3.02	0.01	0.44
Forage dry matter intake[1], lb/day	11.5	12.3	0.70	4.0

[1] Estimated by subtracting orts and calculated wastage (determined in experiment 2) from initial bale weight.

Table 3. Effects of bale processing technique on hay wastage (experiment 2)

Item	Conventional	Precut	Probability, P<	SEM
Initial bale dry matter, lb	1106	1187	0.01	19.1
Hay dry matter wastage, lb				
Day 1	4.34	5.86	0.14	2.1
Day 2	2.56	5.22	0.10	3.6
Day 3	1.57	1.54	0.97	2.2
Day 4	0.99	0.52	0.16	0.7
Day 5	0.57	0.31	0.29	1.2
Total	10.03	13.47	0.30	6.3

Table 4. Chemical analysis of alfalfa orts remaining in the ring feeder (experiment 2)[1]

Item	Conventional	Precut	Probability, P<	SEM
Dry matter, %	78.1	78.6	0.90	3.9
Crude protein, %	20.0	20.1	0.96	1.0
Neutral detergent fiber, %	54.9	49.4	0.02	2.1

[1]Mean of six samples, each representing remaining alfalfa.

Table 5. Nutrient composition and intake of alfalfa hay by beef heifers (experiment 3)[1]

Item	Conventional	Precut	Probability, P<	SEM
Dry matter intake[2], lb/day	8.6	10.4	0.48	2.46
Nutrient analysis				
Dry matter, %	82.2	84.1	0.002	0.31
Crude protein, %	20.6	19.5	0.04	0.32
Neutral detergent fiber, %	54.5	50.8	0.01	1.21
Mold, spores/mg	10	64	0.04	16

[1] Five replicates per treatment.
[2] Calculated by subtracting weight of remaining orts from initial bale weight.

Round Bale Alfalfa Processing Method Does Not Influence Feeding or Mixing Characteristics in a Total Mixed Ration[1]

S.Q. Jones, J.M. DeRouchey, J.W. Waggoner, T.T. Marston, R.M. Breiner, and T.J. Kraus[2]

Introduction

Nutritionists and producers often assume that ingredients in a total mixed ration are uniformly mixed. However, many factors may affect ration homogeneity, including particle size, shape, and density and mixer discharge location. Forages are often ground prior to mixing in a total mixed ration to reduce variation in forage particle length. However, preprocessing forages while baling may facilitate particle length reduction and eliminate the need to grind forages prior to mixing. Objectives of this study were to determine the effects of forage processing method on uniformity and particle length of the total mixed ration at different discharge locations throughout mixing.

Experimental Procedures

Seventy-five bulls (697 lb initial body weight) were used to evaluate the effects of alfalfa hay processing method on total mixed ration uniformity at different mixer discharge locations. One field of alfalfa in northeast Kansas was swathed and raked in mid-July 2008. The three treatments were: 5 × 4 ft conventional alfalfa bales, 5 × 4 ft precut alfalfa gales, and 5 × 4 ft conventional alfalfa bales that were later tub ground. Precut bales were baled with a round baler equipped with serrated knives that cut the alfalfa into 3- to 8-in. sections as packer fingers moved the forage from the header to the baling chamber. No knives were present on the outer 6 in.; therefore, the ends and the perimeter of the bale were composed of full stem length forage, which maintained the structural integrity of the bale.

Prior to the start of the experiment, conventional bales were unrolled on a concrete slab, precut bales were broken apart by being raised approximately 16 ft with a tractor grapple fork and dropped onto concrete, and tub-ground bales were ground with a Haybuster H-1000 (DuraTech Industries International, Inc., Jamestown, ND) using a 2-in. screen.

Rations (Table 1) were prepared with a horizontal mixer (Forage Express; Roto-Mix, Dodge City, KS) and fed at an average of 2.33% (dry matter) of body weight for 15 days. Plastic containers (12 × 9 × 6 in.) were placed at the first, middle, and last third of the bunk line for collection of discharge location samples. Bale cores, discharge location samples, and refusals were analyzed for dry matter, crude protein, acid detergent fiber, and neutral detergent fiber. Diet particle length was determined by measuring the

[1] Appreciation is expressed to John Deer (Ottumwa, IA) for funding and use of tractors and baler and to Mark Cooksey of Roto-Mix (Scott City, KS) for technical support and donation of the mixer used in this study.

[2] John Deere, Ottumwa, IA.

geometric mean of the percentage of forage remaining on the top two screens (>12.7 mm), the overall geometric mean length, and geometric standard deviation.

Data were analyzed by using the MIXED procedure of SAS (SAS Institute, Inc., Cary, NC). Individual bale was the experimental unit. Main effects were declared significant at $P<0.05$ and regarded as tendencies at $P<0.10$. Contrasts were used to compare differences in bale processing method.

Results and Discussion

Average dry matter intake for the 15-day feeding period was 16.3 lb/animal each day. Average final body weight for the 15-day feeding period was 748 lb, and average daily gain was 3.3 lb/day. Diet samples from the beginning third and middle third of the mixer discharge had a smaller ($P=0.03$ and $P=0.07$, respectively) percentage of forage length of the total mixed ration (>12.7 mm) than samples from the last third of the mixer discharge (Tables 2 and 3). Additionally, diets containing tub-ground alfalfa had a smaller ($P=0.01$) percentage of forage length of the total mixed ration (>12.7 mm) than both the conventional and precut bale types. Samples taken from different discharge locations and bale types had similar ($P>0.23$) geometric mean lengths and standard deviations.

Chemical analysis revealed no ($P>0.80$) mixer discharge site by bale type interactions. Alfalfa processing method did not influence ($P>0.28$) dry matter and crude protein (Tables 4 and 5). There was no difference in acid detergent fiber ($P>0.17$) between samples from the first and middle third, but samples from the first third tended to have higher ($P=0.07$) neutral detergent fiber. Acid detergent fiber and neutral detergent fiber levels of feed samples from the last third of the mixer discharge were greater ($P=0.03$) than those of samples from the beginning third and similar ($P>0.44$) to those of samples from the middle third. Moreover, conventional bales had greater ($P=0.05$) neutral detergent fiber and tended to have a greater ($P=0.08$) percentage of acid detergent fiber than tub-ground bales.

Implications

There was more ingredient segregation in total mixed rations made from conventional or precut bales than in rations made with tub-ground forage. Precutting forages resulted in responses similar to those for conventionally baled forages at the dietary inclusion levels and conditions of this experiment.

Table 1. Ingredient composition of diet

Ingredient, % dry matter basis	
Alfalfa hay	60.00
Wet corn gluten feed	32.00
Steam-flaked corn	4.09
Premix[1]	3.91
Total	100.00
Calculated composition	
Dry matter, %	76.74
NE_m, Mcal/lb	0.67
NE_g, Mcal/lb	0.41
Crude protein, %	17.11
Calcium, %	1.25
Phosphorus, %	0.49

[1] Provided 1,500 IU/lb vitamin A; 10 IU/lb vitamin E; 0.3% salt; 0.1 ppm cobalt; 10 ppm copper; 0.5 ppm iodine; 60 ppm manganese; 0.25 ppm selenium; 60 ppm zinc; 30 g/ton Rumensin (Elanco Animal Health, Greenfield, IN); and 9 g/ton Tylan (Elanco Animal Health).

Table 2. Effects of alfalfa bale type on diet particle length[1]

	Bale type									
	Conventional			Precut			Tub ground			
Item	First third	Middle third	Last third	First third	Middle third	Last third	First third	Middle third	Last third	SEM
Fraction top two screens[2], %	19.9	21.4	26.1	15.6	17.5	23.7	3.7	2.6	5.6	3.08
Geometric mean length, mm	6.9	7.1	8.4	5.3	5.6	7.3	3.1	2.9	3.2	1.03
Geometric standard deviation, mm	4.5	5.1	6.1	4.0	4.3	5.7	2.9	2.8	2.9	0.42

[1] 45 samples of the complete diet were analyzed (ASAE Standard S424.1).
[2] Collected particles >12.7 mm.

Table 3. Probabilities of effects of alfalfa bale type on diet particle length[1]

	Probability, P<						
Item	First third vs. Middle third	First third vs. Last third	Middle third vs. Last third	Conventional vs. Precut	Conventional vs. Tub ground	Precut vs. Tub ground	Site × Type
Fraction top two screens[2], %	0.75	0.03	0.07	0.16	0.01	0.01	0.90
Geometric mean length, mm	0.83	0.96	0.79	0.50	0.28	0.68	0.91
Geometric standard deviation, mm	0.91	0.66	0.74	0.72	0.41	0.24	0.26

[1] 45 samples of the complete diet were analyzed (ASAE Standard S424.1).
[2] Collected particles >12.7 mm.

Table 4. Effects of alfalfa bale type and discharge site on total mixed ration composition[1]

	Bale type									
	Conventional			Precut			Tub ground			
Item, %	First third	Middle third	Last third	First third	Middle third	Last third	First third	Middle third	Last third	SEM
Dry matter	72.3	70.6	70.8	68.5	70.6	72.4	72.7	73.0	73.0	2.53
Crude protein	23.4	23.8	23.7	24.7	23.9	23.5	24.1	24.2	24.6	0.74
Acid detergent fiber	23.2	25.3	26.0	22.3	23.8	24.9	22.5	23.1	23.6	1.21
Neutral detergent fiber	39.8	42.6	42.1	39.9	41.1	42.2	39.2	39.8	40.3	1.07

[1] Chemical analyses of total mixed rations made from alfalfa hay processed by different methods and discharged from the mixer in the beginning, middle, and final third of each batch.

Table 5. Probabilities of effects of alfalfa bale type or discharge site on total mixed ration composition[1]

	Probability, P<						
Item, %	First third vs. Middle third	First third vs. Last third	Middle third vs. Last third	Conventional vs. Precut	Conventional vs. Tub ground	Precut vs. Tub ground	Site × Type
Dry matter	0.91	0.66	0.74	0.72	0.41	0.24	0.86
Crude protein	0.83	0.96	0.79	0.50	0.28	0.68	0.80
Acid detergent fiber	0.16	0.03	0.43	0.25	0.08	0.53	0.95
Neutral detergent fiber	0.07	0.03	0.71	0.63	0.05	0.14	0.85

[1] Probabilities (P-values) associated with feeding total mixed rations made from different alfalfa bale types and discharged from the mixer at the beginning, middle, or end of the mixer batch.

Botanical Composition of Diets Grazed by Beef Cows in the Kansas Flint Hills During Winter

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

Introduction

Analysis of microscopic plant fragments recovered from the gut of wild herbivores (i.e., microhistological analysis) has been used to estimate diet composition, but there is debate as to whether microhistological analysis of fecal samples is an appropriate method for characterizing diets of grazing beef cattle. Therefore, our goal was to determine whether this approach could effectively quantify the botanical composition of diets grazed by mature beef cows in the Kansas Flint Hills during winter.

Experimental Procedures

Mature, nonpregnant beef cows (n = 10; average initial weight = 1,150 lb) were maintained on a single, dormant, native tallgrass pasture at the Kansas State University Commercial Cow-Calf Unit. Approximately 95% of above-ground biomass on these pastures was composed of the following forage species: big bluestem, little bluestem, sideoats grama, blue grama, switchgrass, Indiangrass, lead plant, heath aster, dotted gayfeather, and purple prairie clover. Fecal samples were collected after a 30-day grazing period, cleaned, decolorized, and mounted on microscope slides.

Dried slides were evaluated with a compound microscope at 10x magnification. The microscope was equipped with a digital camera, and each slide field was photographed for comparison with standard slides. Twenty fields per slide were selected randomly from the entire slide view and used to measure the frequency with which plant fragments appeared. Plant fragments were identified by comparing their characteristics with standards prepared from pure stands of each plant. Plant fragment prevalence in slide fields was assumed to be equivalent to prevalence in fecal samples and in grazed diets on a dry matter basis.

Results and Discussion

Dietary composition data are shown in Table 1. Although cattle in this study were of the same class (i.e., mature cows) and age (i.e., 4 years), there were differences ($P<0.01$) among animals in the proportion of various range plants grazed. Only 3% of grass-plant fragments could not be positively identified as one of the six predominant grasses in the Flint Hills. A preference for sideoats grama and Indiangrass was apparent within this particular group of cattle.

A significant proportion of cow diets (32.32%) was composed of forbs despite the fact that the experiment was conducted on dormant winter range and most forbs were difficult to locate visually. Only 2.66% of forb fragments could not be identified as one of the four predominant forb species in the Flint Hills. Altogether, plant fragments that could not be positively identified composed 5.66% of the diet. We interpreted these data to mean that a relatively minor proportion of all plant fragments in fecal samples could not be classified according to plant species.

Implications

Microhistological characteristics of plant fragments recovered from fecal material were a viable means of identifying botanical fragments of forages grazed by mature cows during the winter in the Kansas Flint Hills. Approximately one third of the recognizable plant fragments were forbs.

Table 1. Identifiable botanical fragments in feces of beef cows that grazed Kansas Flint Hills range during winter

Species	Botanical composition, % of diet dry matter	SEM[1]	CV[1], %
Grasses			
Big bluestem	8.91	0.141	7.01
Little bluestem	8.07	0.127	6.97
Sideoats grama	15.06	0.128	3.76
Blue grama	8.88	0.107	5.34
Switchgrass	8.14	0.129	7.24
Indiangrass	12.95	0.135	8.54
Unidentified grasses	3.00	0.161	1.46
Forbs			
Lead plant	7.89	0.111	6.04
Heath aster	7.00	0.095	3.25
Dotted gayfeather	4.18	0.085	9.01
Purple prairie clover	13.26	0.124	4.14
Unidentified forbs	2.66	0.144	1.81

[1] SE, standard error of the mean for each individual grass species; CV, variation between grass species.

Wheat Gluten Films Prepared at High Temperature and Low pH Decrease Degradation by Rumen Microorganisms

K. Blaine and J.S. Drouillard

Introduction

Encapsulated amino acids, vitamins, and other nutrients are gaining popularity in the ruminant feed industry. The purpose of encapsulation is to provide protection from premature digestion in the rumen, making it possible to increase bioavailability of the core ingredient in the small intestine. Encapsulated products are more effective at delivering a targeted amount of a limiting nutrient than the traditional methods of heat or chemically treating protein, which result in an excess supply of other nutrients. The main limitation of feeding encapsulated products is cost. These products are expensive because of the cost of the film forming/encapsulating materials used. Wheat gluten is an inexpensive alternative and has natural film-forming capabilities.

Processing factors that influence the extent of degradation in the rumen and subsequent uptake in the post-ruminal digestive tract have not been fully elucidated. The objective of our research was to identify the initial processing conditions under which wheat gluten will provide sufficient protection from microbial degradation in the rumen. Temperature and pH, in particular, have a large effect on the final properties of the film because of their ability to alter the protein structure of the wheat gluten.

Experimental Procedures

We conducted an in vitro study to investigate effects of three pH levels (3.0, 5.0, and 7.5) and three temperature levels (104°F, 131°F, and 167°F) of the film-forming solution on final film stability in the rumen. An in vitro protein degradation assay was used to determine susceptibility of the protein-based film to degradation by ruminal microorganisms. Degradation of the films was measured after 0, 2, 4, 6, and 8 hours of fermentation.

Films were prepared by mixing wheat gluten (18% of the solution) into 100 mL of 95% ethanol and then slowly adding 50 mL of water. Glycerol was added at 1% as a plasticizing agent. The pH of film-forming solutions was appropriately adjusted with glacial acetic acid or 6 M ammonium hydroxide. The solutions were sheared for 5 minutes and then stirred and heated to the appropriate temperature under continuous reflux. Heated solutions were held at the appropriate temperature for 10 minutes and then centrifuged at 959 × *g* for 5 minutes at room temperature (68°F) to remove any remaining insoluble gluten. The supernatant was poured onto a Teflon-coated tray and allowed to dry at ambient air temperature. When dry, the films were subjected to a protein degradation assay to determine degradability under rumen conditions.

Results and Discussion

There was an interaction between pH and temperature ($P<0.01$); low pH (pH 3) and high temperature (167°F) films were most resistant to microbial degradation (Figure 1).

There was no interaction between temperature and time ($P>0.05$), but there was an interaction between pH and time ($P<0.01$) as well as a quadratic effect ($P<0.01$) of pH on degradability. Degradability values were smallest at pH 3 and largest at pH 5. The film prepared at pH 5 may be partially soluble in the rumen because the rumen pH is close to the pH used to prepare the film. Film formation at pH 7.5 was hindered by poor protein dispersion because the isoelectric region of wheat gluten is near pH 7.5. Poor film formation at the isoelectric region will compromise integrity of the film, making it more easily degraded by ruminal bacteria.

Film degradability decreased with increasing temperature ($P<0.01$); films manufactured at 167°F had the lowest degradability. The linear decrease of degradability with increased temperature of the film-forming solution may indicate increased cross-linking through covalent S-S bonds. The mechanism behind this may be that heated film-forming solutions denature wheat gluten proteins, thereby reducing existing S-S bonds and revealing previously unexposed SH groups. Upon drying, covalent S-S bonds formed by air oxidation cross-link protein molecules. This would contribute to the films' strength and resilience to microbial degradation.

Implications

Low pH and high processing temperatures yield encapsulating films that are substantially resistant to degradation by ruminal microorganisms. These films are inexpensive to produce and may be useful for encapsulating amino acids and vitamins to improve rumen bypass of these nutrients.

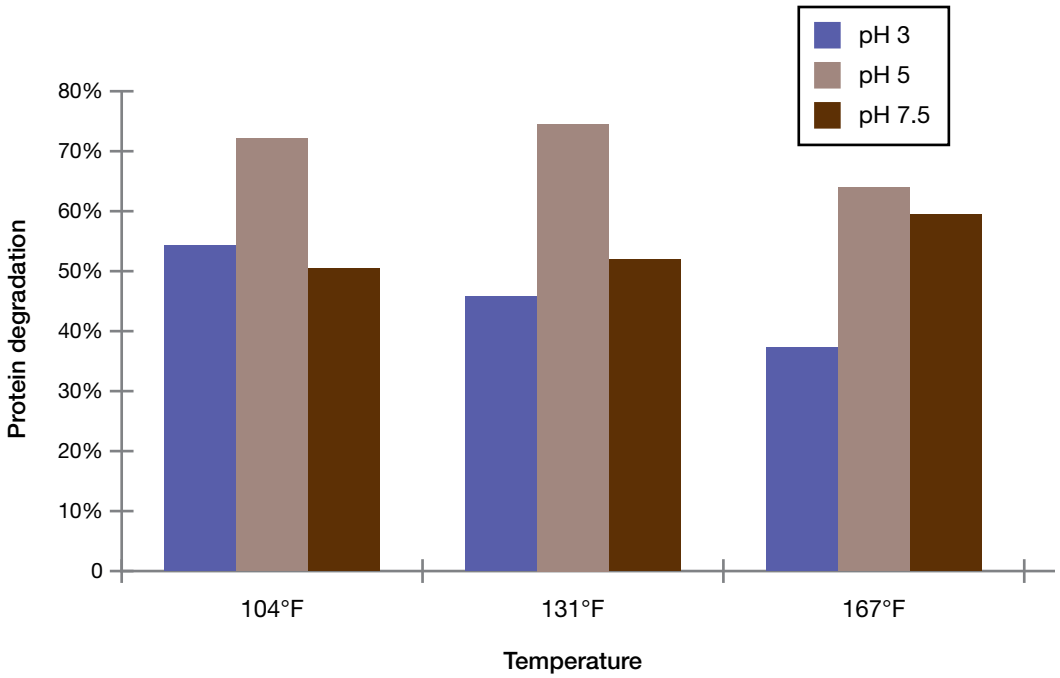


Figure 1. Protein degradation of films after 8 hours of ruminal fermentation.

Supplementing Fructose-Based Block Supplements to Forage-Fed Cattle Increases Capacity for Lactic Acid Metabolism

K.A. Miller, M.J. Quinn, and J.S. Drouillard

Introduction

Acidosis is one of the more important maladies afflicting cattle fed significant amounts of grain and has enormous economic impact for feedlots, dairies, and producers of seed stock. The highest incidence of acidosis occurs when animals are being transitioned from high-roughage diets to diets containing high levels of concentrates. When grain-based diets are consumed in excess, consumed too quickly, or fed without proper adaptation, digestive end products (organic acids) can accumulate within the rumen, resulting in acidosis. Lactic acid is one of the key organic compounds that accumulates under these conditions. Coupled with the animal's limited ability to metabolize lactate, accumulation of lactic acid in the rumen lowers ruminal pH and subsequently depresses feed intake. One means of preventing acidosis is to directly populate the rumen with lactate-utilizing bacteria. Alternatively, exposure to low levels of lactate (i.e., levels insufficient to harm the animal) may stimulate development of a population of lactate-utilizing bacteria. The objective of our study was to determine if supplementing low-moisture blocks made of high fructose corn syrup could increase ruminal lactate concentrations and subsequently stimulate growth of lactate-metabolizing bacteria. If successful, this could prove useful for adapting forage-fed cattle to grain-based diets.

Experimental Procedures

Blocks were manufactured by blending 24 lb of high fructose corn syrup (approximately 40% moisture) with 1 lb of vegetable oil. The mixture was placed into a steam-jacketed, scraped-surface kettle that was operated at atmospheric pressure and heated to a final temperature of approximately 250°F. The kettle then was subjected to vacuum for approximately 60 seconds, after which the dehydrated mixture was discharged into high-density polyethylene containers. Blocks were allowed to cool to room temperature and formed a solid, hardened mass. The blocks subsequently were broken into small fragments, weighed into 2-lb aliquots, and sealed in plastic bags until used.

Twelve ruminally cannulated heifers (1,179 lb) were fed a diet consisting of free-choice, long-stemmed prairie hay and loose salt. Heifers were weighed and assigned to individual feeding pens (5 × 12 ft) with slatted concrete floors. Each pen was equipped with a feeder and an automatic water fountain. Heifers were randomly allocated to one of two treatments (six heifers per treatment): control (no supplement) or block (2 lb per heifer daily of the fructose-based block supplement).

The study was conducted over a 3-day period. At approximately 7:00 a.m. each morning, a 2-lb aliquot of fructose block was administered via the ruminal cannula to heifers on the block treatment. On days 1 and 3 of the study, samples of ruminal digesta were removed from each animal via the ruminal cannula before feeding and at 30-minute intervals until 8 hours after feeding. Ruminal digesta samples were strained through

four layers of cheesecloth, pH was measured, and a sample was retained and frozen for analysis of lactic acid and volatile fatty acids. During the final collection of days 1 and 3, sterile anaerobic culture tubes containing 15 mL of a semi-defined lactate media were inoculated with 1 mL of strained ruminal fluid from each animal. The contents of each tube were homogenized using a vortex mixer, and absorbance (600 nm) was determined using a Spectronic-20 spectrophotometer. Culture tubes were placed into an incubator maintained at a temperature of 102°F for 24 hours. The tubes were removed from the incubator at hourly intervals throughout the 24-hour incubation period, and absorbance was measured. Changes in turbidity (associated with increased absorbance readings) were used as a measure of the proliferation of lactate-utilizing bacterial species.

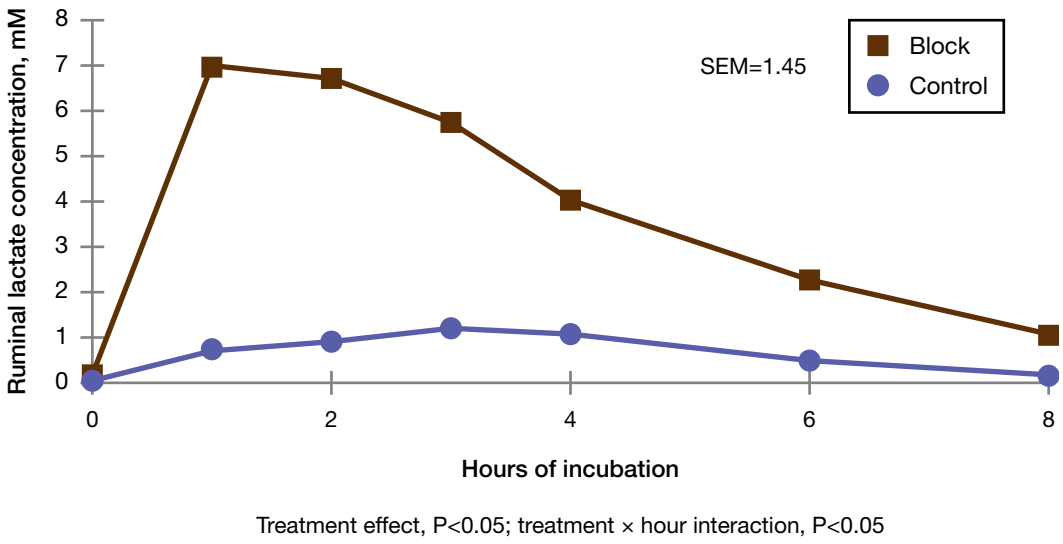
Results and Discussion

Compared with cattle fed the control diet, supplementation with fructose-based blocks increased ruminal lactate concentrations by nearly 6-fold (Figure 1; $P<0.05$). Peak differences occurred 1 to 3 hours after feeding the block and declined sharply thereafter. Peak concentrations of lactate were nearly doubled on day 3 compared with day 1 for supplemented heifers (data not shown), perhaps indicating that ruminal microorganisms adapt over a period of days by increasing the population of bacteria that synthesize lactate from fructose. Butyric acid, which is the primary end product associated with metabolism of lactate, was higher in supplemented cattle than in controls (Figure 2; $P<0.05$). Increases in butyric acid levels within the rumen are likely the direct result of lactic acid metabolism by ruminal bacteria. This is supported by the fact that increases in butyrate concentration seem to lag behind the changes in lactate concentrations. Propionate concentrations tended to be higher during the intermediate sampling points for cattle administered the block (Figure 3; Treatment × hour interaction, $P<0.05$). Supplementing fructose-based blocks resulted in modest, transient reduction in ruminal pH (Figure 4; Treatment × hour interaction, $P<0.01$), essentially reflecting the increased fermentative activity in supplemented heifers. Ruminal pH of supplemented heifers was lower than controls between 1 and 3 hours after administration of the block ($P<0.05$). At no point did pH decline to a level that would compromise fiber digestion.

Supplementing fructose blocks resulted in modest increases in turbidity of bacterial cultures (Figure 5) compared with cultures from control animals, revealing a greater capacity for supporting growth of lactic-acid-metabolizing bacteria. Additional days of supplementation may be warranted to further stimulate the proliferation of lactic-acid-utilizing bacteria.

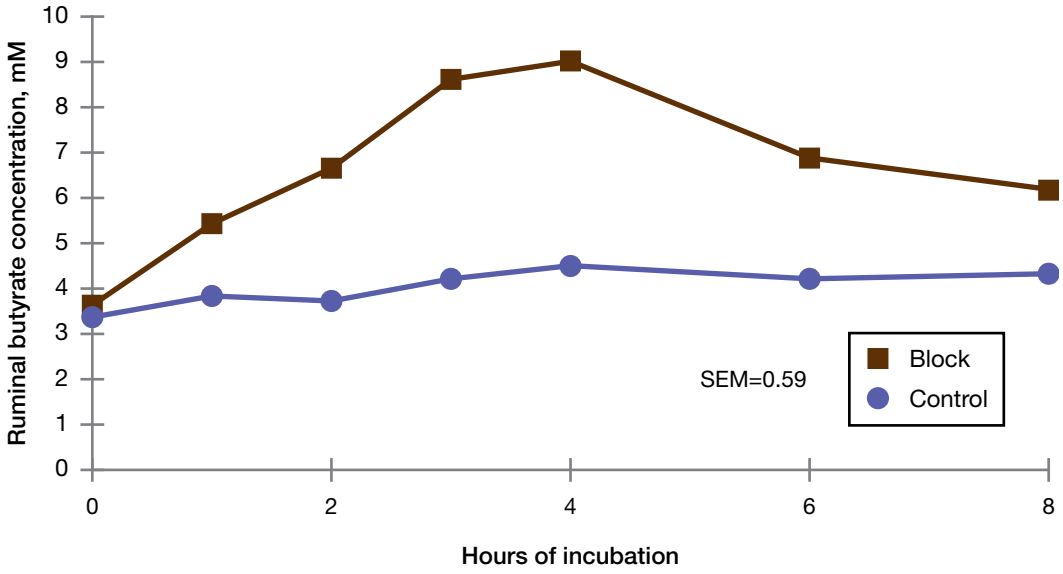
Implications

Feeding fructose-based block supplements increased lactic acid production in the rumen for a short period of time, allowing for establishment of a population of lactic-acid-metabolizing bacteria in the rumen. This research provides a basis for future development of management strategies aimed at preconditioning calves to avoid acidosis when grains are introduced into the diet.



Treatment effect, P<0.05; treatment × hour interaction, P<0.05

Figure 1. Ruminal lactate concentrations in heifers fed prairie hay with and without a fructose block supplement.



Treatment effect, P<0.05; treatment × hour interaction, P<0.01

Figure 2. Ruminal butyrate concentrations in heifers fed prairie hay with and without a fructose block supplement.

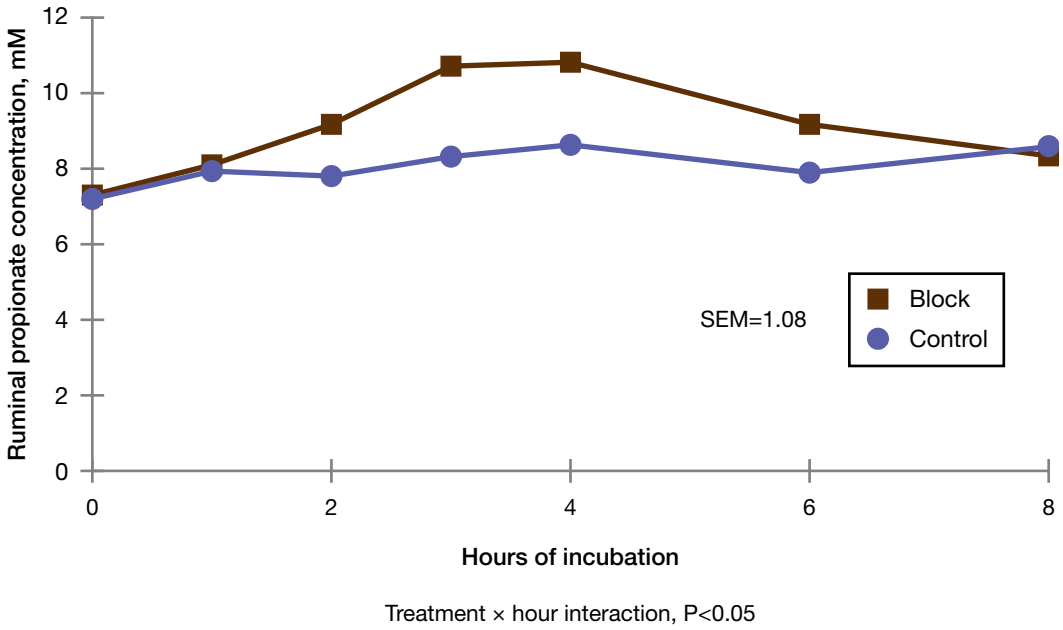


Figure 3. Ruminal propionate concentrations in heifers fed prairie hay with and without a fructose block supplement.

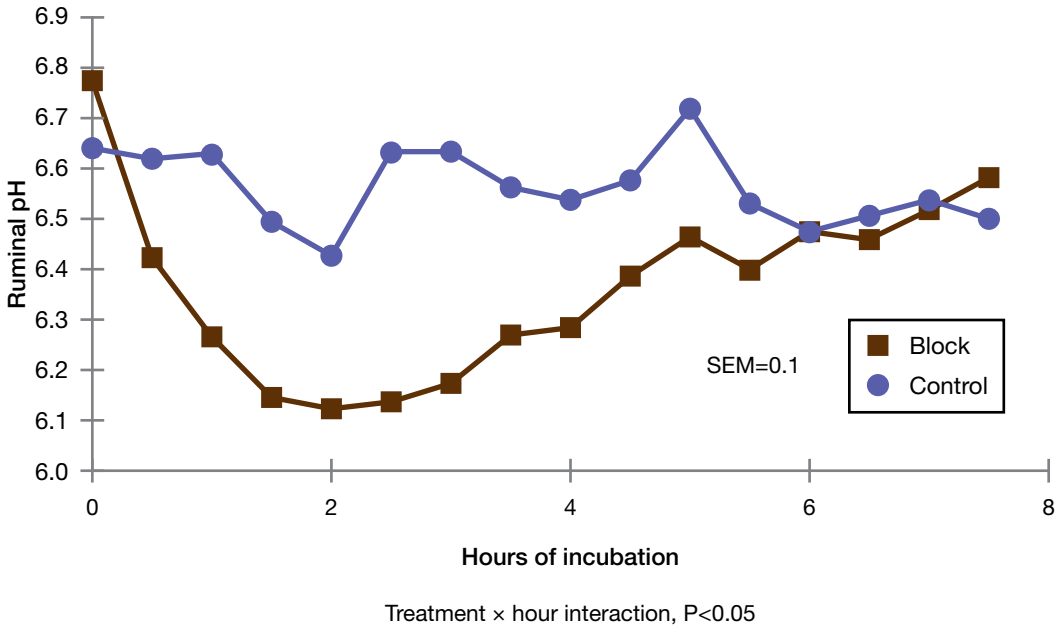


Figure 4. Ruminal pH in heifers fed prairie hay with and without a fructose block supplement.

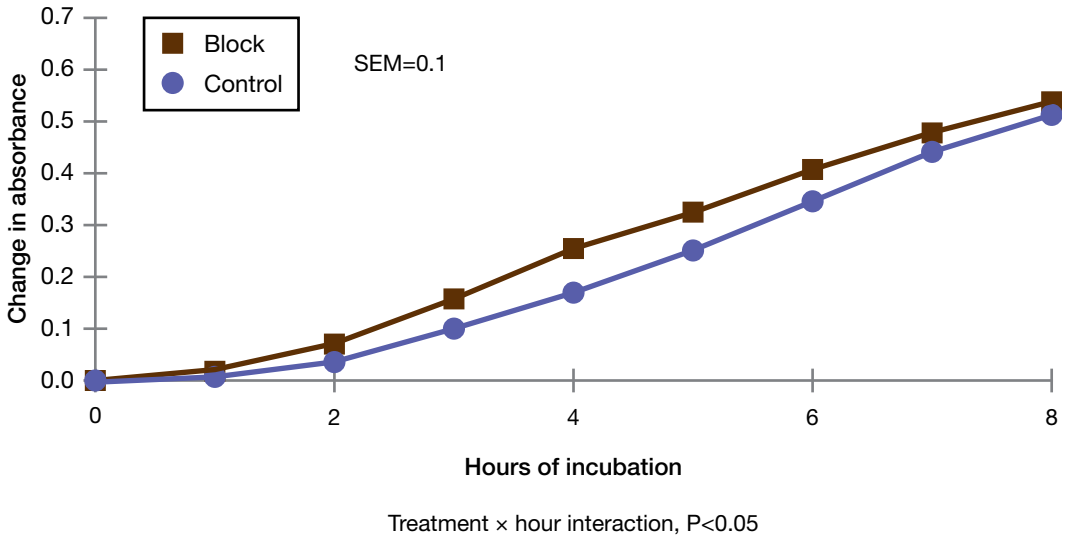


Figure 5. Change in turbidity (a measure of microbial growth) of ruminal cultures grown in lactic acid broth.

Effects of SmartLic Hi-Pro 40 Block Supplements on Ruminal Microbes in Cattle Fed Low-Quality Forages[1]

K.D. Derstein and J.S. Drouillard

Introduction

Dormant pastures and native grass hays often are deficient in protein and other nutrients needed to support optimum performance of beef cattle. These nutrients are essential for maintaining viable populations of symbiotic rumen microorganisms that digest the fiber in forages. When nutrient deficiencies occur, microbial populations in the rumen decrease, thereby limiting digestion of low-quality forages. This study was conducted to evaluate changes in rumen microbial populations and digestive activity when cattle consuming low-protein native grass hay are given access to high-protein, free-choice block supplements.

Experimental Procedures

Four ruminally fistulated steers were housed at the Kansas State University Beef Cattle Research Center in individual (10 × 12 ft) stalls. Steers had free-choice access to prairie hay (Table 1), loose salt, and water. Two of the four steers also had free-choice access to SmartLic Hi-Pro 40 block supplements. Blocks were weighed daily to determine the amount of supplement consumed by each steer. Animals were allowed a 10-day period to adapt to their respective diets before samples of ruminal fluid were obtained.

In situ Cellulose Disappearance

This experiment was performed to quantify differences in capacity for digestion of cellulose in each animal over a period of 14 and 24 hours using an in situ procedure. Cellulose filter papers were weighed, placed into nylon bags, and sealed. The bags were then placed into the rumen of each steer for 14 or 24 hours. At the end of the fermentation period, bags were rinsed in warm water and then placed into a drying oven and allowed to dry overnight. The dried cellulose papers were removed from the bags and weighed, and the percentage of digestion was recorded for each.

Microscopic Imaging

We used a scanning electron microscope to compare bacterial colonization of cellulose filter papers that were suspended in the rumens of cattle fed diets with and without the SmartLic Hi-Pro 40 blocks. Cellulose filter papers were placed into sealed nylon bags and incubated in the rumen of each steer for 10 or 14 hours. After incubation, bags were removed from the rumen and rinsed with warm water. Filter papers were removed from the bags and rinsed with alcohol to remove residual moisture. Filter papers were taken to the scanning electron microscopy laboratory, where a very thin layer of gold was applied to the surface of the papers to improve resolution of the microscopic images. Microscopic images of each filter paper were photographed to provide a visual assessment of differences in bacterial colonization of cellulose.

[1] The authors express their sincere appreciation to Dr. T.G. Nagaraja, Kent Hampton, Cheryl Armendariz, and all personnel at the Beef Cattle Research Center who assisted in this study.

Measuring Activity of Cellulose-Digesting Ruminal Microbes

Our goal in this part of the experiment was to quantify changes in capacity for cellulose digestion in the ruminal fluid from cattle fed diets with and without the SmartLic Hi-Pro 40 block supplements. Ruminal fluid was collected from each steer and filtered through four layers of cheesecloth. Small aliquots of the ruminal fluid were added to oxygen-free culture tubes that contained thin strips of cellulose paper. Tubes were then placed into an incubator and allowed to incubate for 21 days. After incubation, the tubes were removed, and the extent of digestion of the cellulose paper was estimated to determine capacity for cellulose digestion.

Protozoa Counts

Populations of ruminal protozoa were determined for cattle fed diets with and without the SmartLic Hi-Pro 40 block supplements. Unfiltered ruminal fluid was obtained from each steer and transported to the laboratory. Contents were then mixed with formalin, diluted with a glycerol buffer, and dyed. To count protozoa, the solution was thoroughly homogenized, and precisely 1 mL was placed into a counting chamber slide. Slides were viewed under a microscope, and the numbers of protozoa were counted for 20 different locations on each slide.

Results and Discussion

Composition of the prairie hay fed to steers in this study is shown in Table 1. It is typical of prairie hay produced in the Flint Hills region (i.e., low in protein and high in neutral detergent fiber). Intakes of prairie hay and the SmartLic Hi-Pro 40 supplement by steers are shown in Table 2. Feeding the SmartLic Hi-Pro 40 blocks increased hay consumption by steers ($P<0.10$). These increases in hay intake are consistent with our observations in other experiments and likely are due to improvements in forage digestion achieved by providing nutrients essential to the rumen microbial population.

Figure 1 illustrates changes in cellulose disappearance in the rumen with and without supplementation of SmartLic Hi-Pro 40 blocks. Feeding SmartLic Hi-Pro 40 blocks substantially increased cellulose digestion, resulting in a 3-fold increase in cellulose degradation after 24 hours of ruminal incubation. Figure 2 shows several scanning electron microscope images. These images reveal major differences in the surface characteristics of cellulose paper before and after 14 hours of incubation in the rumen. Image 2A is cellulose before incubation in the rumen. Figures 2B and 2C are images of cellulose papers that were incubated in the unsupplemented animals, and images 2D and 2E are from steers that had access to SmartLic Hi-Pro 40 blocks. The microscopic images illustrate that supplementation influences bacterial colonization of cellulose, ultimately leading to more extensive digestion.

Counts of ruminal protozoa populations are shown in Table 3. As expected, supplementation with SmartLic Hi-Pro 40 blocks substantially increased the number of protozoa in the rumen. Large effects of supplementation ($P<0.05$) were observed in two major groups of protozoa—Dasytrich and Isotricha. Total numbers of protozoa also were greater in the supplemented animals.

Implications

Results of our experiments illustrate that supplementing forage-fed cattle with SmartLic Hi-Pro 40 blocks can enhance fiber digestion by affecting viability of the rumen microbial population. Ultimately, these improvements in digestion lead to increases in animal performance.

Table 1. Composition of prairie hay

Component	% of dry matter
Dry matter	94.49
Crude protein	5.71
Calcium	0.61
Phosphorus	0.06
Potassium	0.94
Neutral detergent fiber	63.57

Table 2. Consumption of prairie hay and SmartLic Hi-Pro 40 block supplements

Dry matter intake, lb	Unsupplemented	SmartLic Hi-Pro 40	SEM
Prairie hay[1]	12.8	18.0	1.22
SmartLic Hi-Pro 40 block	0	2.6	0.35

[1] Treatments are different, P<0.10.

Table 3. Numbers of ruminal protozoa from cattle fed prairie hay with and without SmartLic Hi-Pro 40 block supplements

Protozoa/mL ruminal fluid	Unsupplemented	SmartLic Hi-Pro 40	SEM
Isotricha	1,067	2,280	815
Dasytricha[1]	4,609	9,315	345
Entodinium[1]	22,269	33,621	1,580
Ostracodinium	6,210	5,094	1,032
Metadinium	242	242	174
Epidinium	5,045	5,773	1,271
Total protozoa[1]	38,328	57,444	2,128

[1] Treatments are different, P<0.05.

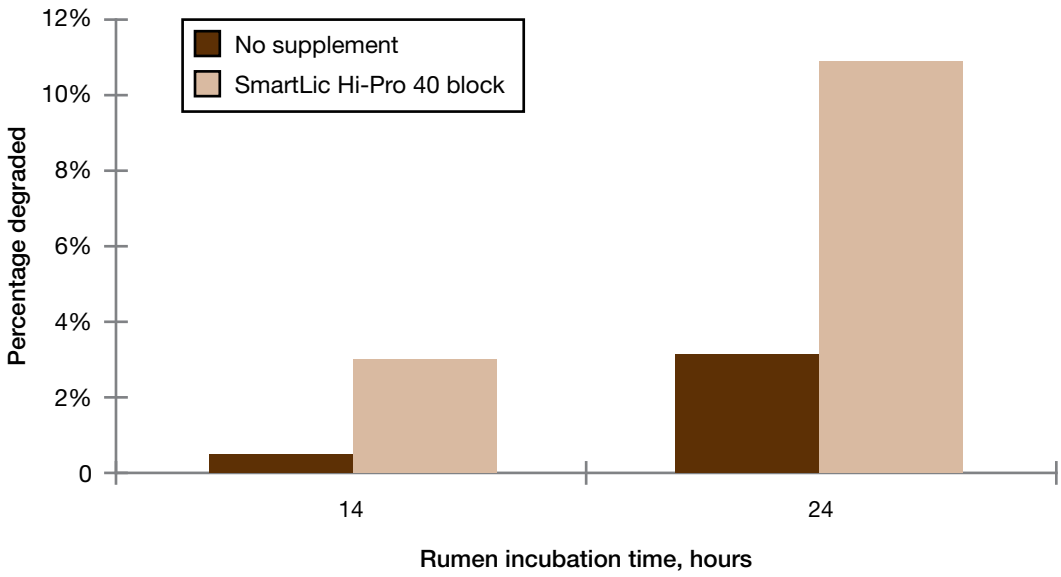


Figure 1. Disappearance of cellulose from nylon bags incubated in the rumens of steers fed prairie hay with and without SmartLic Hi-Pro 40 block supplements.

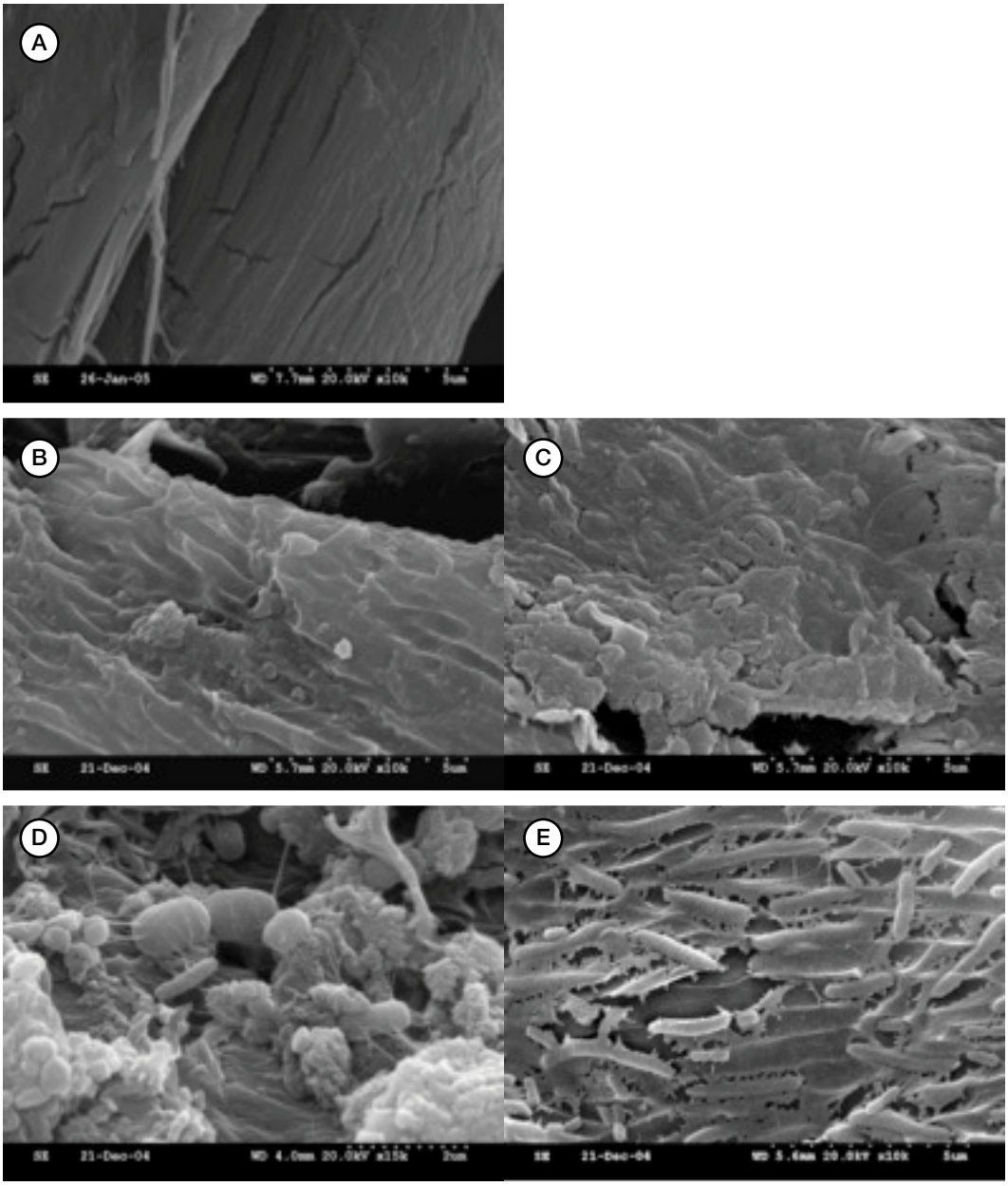


Figure 2. Scanning electron microscope images of cellulose before and after incubation in the rumens of steers fed prairie hay.
(A) cellulose paper before incubation in the rumen; (B and C) cellulose papers incubated for 14 hours in unsupplemented animals fed prairie hay; (D and E) images from animals fed prairie hay and supplemented with SmartLic Hi-Pro 40 blocks.

Initial Heifer Body Composition Has Little Impact on Response to Zilmax

L. Thompson, C. Schneider, G. Parsons, K. Miller, C. Reinhardt, and J. Drouillard

Introduction

Using a growth promotant at the correct time of finishing is critical for maximizing profit potential. Previous studies have shown that zilpaterol-HCl (Zilmax; Intervet/Schering-Plough Animal Health, Millsboro, DE) improves carcass characteristics. The objective of this study was to determine effects of prior body composition on subsequent changes in carcass weight, fatness, and muscle in heifers fed Zilmax so producers can introduce Zilmax at the level of finish that will result in the most desirable response. We hypothesized that fatter heifers use fat as the fuel for muscle growth.

Experimental Procedures

Crossbred heifers (n = 353; 941 ± 19.5 lb) were fed finishing diets consisting of a combination of steam-flaked corn and processed grain by-products with 3% alfalfa hay and 6% corn silage. Diets provided 300 mg monensin, 90 mg tylosin, and 0.5 mg melengestrol acetate per animal daily. Before initiation of the study, heifers were assigned randomly to experimental diets and pens within weight block. Cattle were placed into 1 of 48 concrete-surfaced pens; there were seven to eight animals per pen. Cattle were fed once daily and had free-choice access to feed and water.

Prior to feeding Zilmax, cattle were weighed, and ribeye area, rump fat thickness, and 12th rib fat thickness were measured by ultrasound. Average daily gains for individual heifers were calculated for the 66-day period preceding initiation of Zilmax feeding, and pre-Zilmax hot carcass weights were estimated by regression using ribeye area, rib fat thickness, and pre-Zilmax body weight. Zilmax was added to finishing diets at 7.56 g/ton (dry matter basis) beginning 23 days before harvest and withdrawn for the final 3 days on feed. Heifers were slaughtered at a commercial abattoir, where carcass data were collected.

Regression formulas were developed to estimate the effects of the means of pre-Zilmax body weight, rump fat thickness, rib fat thickness, ribeye area, and average daily gain on subsequent post-Zilmax changes in 12th rib fat thickness, yield grade, ribeye area, and carcass average daily gain.

Results and Discussion

The following formulas were used to estimate the relationship between initial carcass measurements and changes in fatness or carcass weight that developed during the Zilmax feeding period:

Change in 12th rib fat thickness (in inches) = (0.43 × rump fat) – 0.08 ($R^2 = 0.09$, $P<0.01$).

Change in carcass average daily gain (lb/day) = (0.007 × pre-Zilmax body weight) – (0.18 × ribeye area) – 3.67
(R^2 = 0.13, P<0.01). This formula is shown in Figure 1.

Yield grade change = (2.21 × rump fat) + (0.002 × pre-Zilmax body weight) – (0.10 × pre-Zilmax average daily gain) – (0.11 × ribeye area) – 2.16
(R^2 = 0.28, P<0.01).

The following formulas illustrate that increases in ribeye areas were more pronounced in leaner, heavier heifers that started with smaller ribeyes:

Change in ribeye area (square inches) = 6.88 – (0.68 × ribeye area) – (2.06 × rump fat) – (2.96 × rib fat) + (0.004 × pre-Zilmax body weight) + (0.26 × pre-Zilmax average daily gain)
(R^2 = 0.58, P<0.01).

Change in carcass efficiency = (-0.67 × ribeye area) – (2.07 × rump fat) – (2.93 × rib fat) + (0.004 × pre-Zilmax body weight) + (0.26 × pre-Zilmax average daily gain) + 6.91
(R^2 = 0.58, P<0.01).

Implications

Feeding Zilmax can be an effective management tool for feedlot operators. This study suggests that benefits of Zilmax are similar for lean and fat heifers. Carcass gain efficiency is also similar for lean and fat heifers. Feeding Zilmax to fatter heifers does not elicit a better response that would justify costs of the extended feeding period. Zilmax should be fed to heifers with a typical degree of finish because degree of fatness does not drive the Zilmax response. Formulas from this study may help predict changes in carcass composition when feeding Zilmax to heifers.

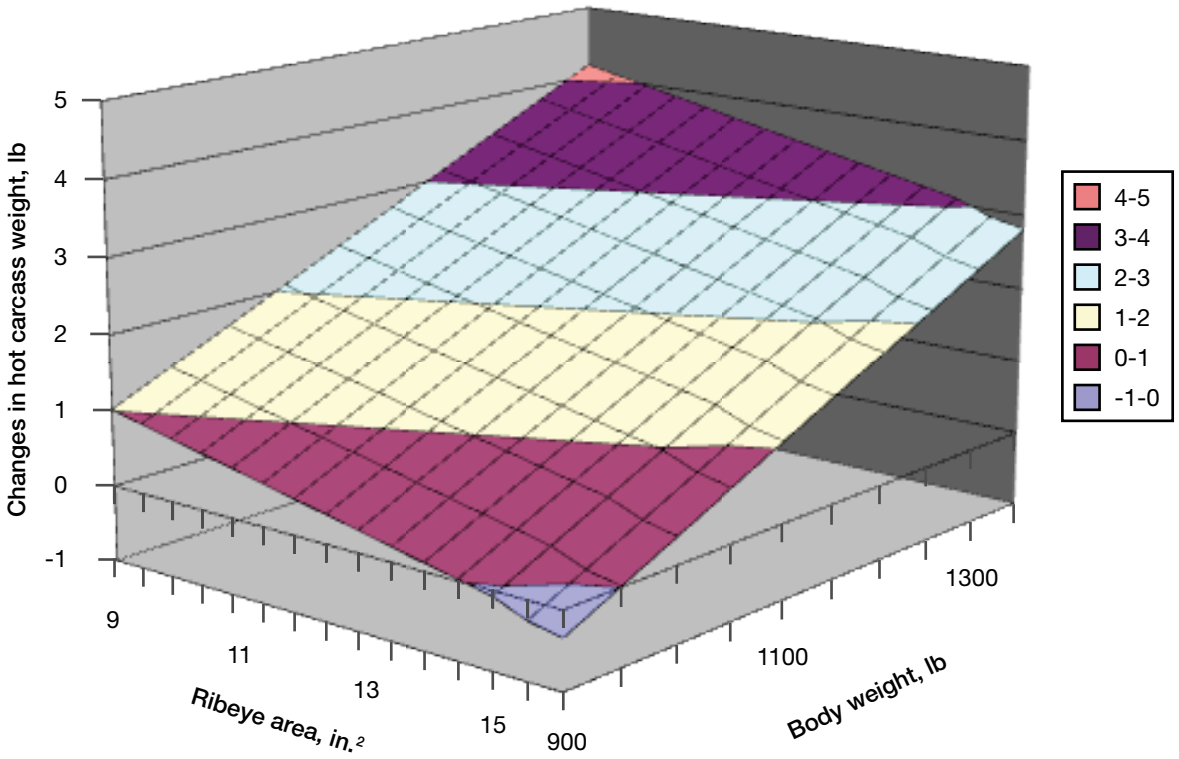


Figure 1. Changes in hot carcass weight as affected by ribeye size and live body weight of feedlot heifers.

Effects of Extended Zilpaterol-HCl Withdrawal on Performance and Carcass Traits of Finishing Beef Heifers

G.L. Parsons, B.E. Depenbusch, C.D. Reinhardt, D.A. Yates[1], J.P. Hutcheson[1], and J.S. Drouillard

Introduction

Zilpaterol-HCl (Zilmax; Intervet/Schering-Plough Animal Health, Millsboro; DE) is an orally active β_2-adrenergic agonist that is approved for use in feedlot cattle at the rate of 7.56 g/ton of diet dry matter for the final 20 to 40 days on feed. The minimum withdrawal time for Zilmax is 3 days. Zilmax increases hot carcass weight and dressing percentage, primarily as a result of increasing lean muscle mass and decreasing body fat. Zilmax also decreases marbling and increases shear-force values (i.e., less tender) of steaks. This study was conducted to determine whether the benefits of Zilmax would be retained with longer withdrawal times while overcoming undesirable effects on shear force and marbling.

Experimental Procedures

Crossbred heifers (n = 450; initial body weight = 1,025 ± 59 lb) were blocked into two groups on the basis of initial body weight. A total of 54 feedlot pens were used. Partially covered concrete pens, uncovered concrete pens, and dirt-surfaced pens were used in this study. Replicates within weight blocks were balanced according to pen type. Treatments were arranged in a 2 × 3 factorial arrangement. Factors were Zilmax (0 or 7.56 g/ton diet dry matter; Table 1) and withdrawal times of 3, 10, or 17 days. Zilmax was fed for 20 days. Cattle were fed free choice once daily and had access to clean, fresh water from a municipal source. Within weight block, Zilmax was initiated on the same day so all cattle would have a similar degree of fatness at the start of Zilmax feeding.

On the morning of shipment, cattle were weighed and then transported to Tyson Fresh Meats in Holcomb, KS. Paired groups of control and Zilmax-fed cattle were harvested on the same day. Animal performance measurements included average daily gain, dry matter intake, and feed:gain. Hot carcass weight and liver abscess were collected immediately following harvest. After a 48-hour chill, USDA yield and quality grades; percentage of kidney, pelvic, and heart fat; 12th rib fat thickness; ribeye area; marbling score; and lean color score were recorded for each carcass. Dressing percentage was calculated as hot carcass weight divided by shrunk final body weight.

Loins were collected from 15 animals per treatment on each harvest day. Approximately equal numbers of USDA Choice and Select loin sections were retained from each treatment. The loins were wet aged in vacuum-packaged bags for 7, 14, and 21 days after harvest. Steaks were cut and frozen at each aging time to terminate the aging process, and frozen steaks stored until shear-force measurements were made. To determine shear force, loin steaks were cooked in an oven to an internal temperature of

[1] Intervet, Inc., Millsboro, DE.

160°F. Cooked steaks were allowed to cool overnight in a refrigerator. Six core samples were drilled from each steak, and shear-force values were determined with an Instron machine (Instron, Norwood, MA).

Results and Discussion

Zilmax had no effect ($P>0.64$) on final body weight, average daily gain, or feed intake of heifers (Table 2) but tended to improve feed efficiency ($P<0.11$). Zilmax increased hot carcass weights by 27, 17, and 11 lb following 20 days of feeding and withdrawal times of 3, 10, and 17 days, respectively (Table 3). Dressing percentages were greater ($P<0.01$) for heifers fed Zilmax. Ribeye areas increased with Zilmax feeding ($P<0.01$). Zilmax did not affect 12th rib fat thickness, but fat thicknesses increased with extended withdrawal times ($P<0.03$), presumably because heifers were fed longer. Increased withdrawal times resulted in less kidney, pelvic, and heart fat ($P<0.01$). There were no differences ($P=0.96$) in liver abscesses were noted.

Zilmax improved USDA yield grades when withdrawn for 3 or 10 days, but improvements were no longer evident after 17 days of withdrawal (Zilmax × withdrawal time, $P=0.06$; Table 4). Zilmax decreased ($P<0.05$) the percentage of yield grade 3 carcasses.

Zilmax decreased marbling scores ($P<0.01$; Table 5), and these negative effects were partially overcome with extended withdrawal times ($P=0.04$). Zilmax increased the percentage of cattle grading USDA Standard and Select and decreased the percentage of carcasses grading USDA Choice ($P<0.10$). Improvements in carcass quality were achieved by extending the posttreatment withdrawal time.

Heifers fed Zilmax had increased shear-force values ($P>0.01$; Table 6), but increasing Zilmax withdrawal times had no effect ($P=0.31$) on shear-force values. Previous research indicated that shear-force values became acceptable by wet aging steaks for 14 days or longer. In this study, steaks from Zilmax-treated heifers showed greater (aging × Zilmax, $P<0.05$) improvements in shear-force values than steaks from control heifers as wet aging time increased.

Implications

Feeding Zilmax increased hot carcass weights and dressing percentage but decreased marbling scores and increased shear-force values of loin steaks. The effects of Zilmax were less pronounced with longer withdrawal times. Aging loins for 14 days or more resulted in acceptable tenderness.

Table 1. Ration composition (% of diet dry matter)

	Treatments	
Ingredient, %	Control	Zilmax
Steam-flaked corn	80.5	80.5
Alfalfa hay	6.0	6.0
Corn steep liquor	8.0	8.0
Control supplement[1]	3.3	---
Zilmax supplement[2]	---	3.3
Feed additive premix[3]	2.23	2.23

[1] Control supplement was formulated to provide 0.1 ppm cobalt; 10 ppm copper; 0.6 ppm iodine; 60 ppm manganese; 0.25 ppm selenium; 60 ppm zinc; 1,200 IU/lb vitamin A; and 10 IU/lb vitamin E in the total diet dry matter.

[2] Zilmax supplement was formulated to provide 0.1 ppm cobalt; 10 ppm copper; 0.6 ppm iodine; 60 ppm manganese; 0.25 ppm selenium; 60 ppm zinc; 1,200 IU/lb vitamin A; 10 IU/lb vitamin E; and 7.56 g/ton zilpaterol-HCl in the total diet dry matter.

[3] Feed additive premix was formulated to provide 300 mg Rumensin (Elanco Animal Health; Greenfield, IN), 90 mg Tylan (Elanco Animal Health), and 0.5 mg MGA (Pfizer Animal Health; New York, NY) per heifer daily in a ground corn carrier.

Table 2. Effects of Zilmax and extended withdrawal times on performance of finishing heifers

	3-day withdrawal		10-day withdrawal		17-day withdrawal			P-values[1]		
Item	Control	Zilmax	Control	Zilmax	Control	Zilmax	SEM	Zilmax	Withdrawal	W × Z
Initial weight, lb	1029	1035	1032	1032	1032	1031	57.94	0.68	0.99	0.73
Pre-Zilmax weight, lb	1187	1191	1194	1184	1190	1189	8.83	0.81	0.99	0.74
Final weight, lb	1215	1229	1241	1243	1268	1265	19.04	0.64	0.01	0.72
Average daily gain, lb	2.81	2.95	2.91	2.97	2.98	2.97	0.17	0.54	0.75	0.81
Feed intake, lb	19.05	18.98	19.47	18.63	19.30	19.02	0.92	0.16	0.91	0.50
Feed:Gain	6.78	6.43	6.69	6.27	6.47	6.41	0.28	0.11	0.74	0.71

[1] W × Z, Interaction between withdrawal and Zilmax.

Table 3. Effects of Zilmax and extended withdrawal times on carcass characteristics of finishing heifers

	3-day withdrawal		10-day withdrawal		17-day withdrawal			P-values[1]		
Item	Control	Zilmax	Control	Zilmax	Control	Zilmax	SEM	Zilmax	Withdrawal	W × Z
Carcass weight, lb	775	803	798	815	798	815	7.6	0.01	0.01	0.54
Dressing percentage	63.78	65.34	64.34	65.56	64.34	65.56	0.72	0.01	0.13	0.70
Backfat, in.	0.43	0.44	0.46	0.40	0.46	0.40	0.06	0.16	0.03	0.34
Kidney, pelvic, and heart fat, %	2.13	2.25	2.00	1.98	2.00	1.98	0.06	0.57	0.01	0.33
Ribeye area, sq. in.	13.7	14.8	13.6	14.6	13.6	14.6	0.59	0.01	0.25	0.64
Liver abscess, %	3.17	2.22	4.29	5.40	4.29	5.40	0.96	0.96	0.43	0.90

[1] W × Z, Interaction between withdrawal and Zilmax.

Table 4. Effects of Zilmax and extended withdrawal times on USDA yield grade of finishing heifers

	3-day withdrawal		10-day withdrawal		17-day withdrawal			P-values[1]		
Item	Control	Zilmax	Control	Zilmax	Control	Zilmax	SEM	Zilmax	Withdrawal	W × Z
USDA yield grade	2.3	2.16	2.46	2	2.37	2.38	0.18	0.02	0.23	0.06
Yield grade 1, %	13.2	22.9	11. 5	27.3	18.0	8.9	0.05	0.17	0.45	0.04
Yield grade 2, %	45.5	42.8	40.2	46.3	31.6	47.9	0.08	0.18	0.73	0.27
Yield grade 3, %	38.9	29.7	38.8	25.1	47.2	39.0	0.08	0.05	0.19	0.90
Yield grade 4 and 5, %	2.4	4.6	9.5	1.3	3.1	4.2	0.04	0.41	0.69	0.07

[1] W × Z, Interaction between withdrawal and Zilmax.

Table 5. Effects of Zilmax and extended withdrawal times on USDA quality grade of finishing heifers

	3-day withdrawal		10-day withdrawal		17-day withdrawal			P-values[1]		
Item	Control	Zilmax	Control	Zilmax	Control	Zilmax	SEM	Zilmax	Withdrawal	W × Z
Marbling score	457	404	466	445	459	442	11	0.001	0.04	0.14
Standard, %	0	1.6	0	0	0	2.8	0.01	0.08	0.38	0.38
Select, %	31.1	54.1	23.2	28.3	27.8	29.7	0.05	0.03	0.01	0.11
Choice, %	64.0	44.3	75.2	71.8	69.1	67.4	0.05	0.07	0.01	0.20
Upper 2/3 choice, %	38.0	18.4	47.4	43.0	33.0	42.8	0.05	0.33	0.02	0.05
Prime, %	5.0	0.1	1.7	0.18	3.3	0.1	0.02	0.01	0.53	0.53

[1] W × Z, Interaction between withdrawal and Zilmax.

Table 6. Effects of Zilmax, withdrawal time, and postmortem aging on shear-force values of loin steaks

	3-day withdrawal		10-day withdrawal		17-day withdrawal			P-values[1]				
Item	Control	Zilmax	Control	Zilmax	Control	Zilmax	SEM	Z	W	A	Z × A	Z × W × A
Shear force, lb												
7-day aged	7.54	8.40	8.03	9.70	8.20	9.79	0.14	0.001	0.31	0.001	0.054	0.8
14-day aged	6.62	7.30	7.01	8.04	7.01	8.53	0.14	0.001	0.31	0.001	0.054	0.8
21-day aged	8.13	9.55	6.20	7.21	6.28	7.11	0.14	0.001	0.31	0.001	0.054	0.8

[1] Z, Zilmax; W, Withdrawal time; A, Aging.

Effect of Nitrogen Supplementation and Zilpaterol-HCl on Urea Recycling in Steers Consuming Corn-Based Diets[1]

D.W. Brake, E.C. Titgemeyer, and M.L. Jones

Introduction

Cattle have the innate ability to recycle nitrogen absorbed post-ruminally back to the rumen as endogenously synthesized urea. Urea returning to the rumen provides an additional opportunity for ruminal microbes to benefit from nitrogen absorbed post-ruminally. Urea recycling may provide a significant benefit to cattle when protein requirements of ruminal microbes are high or when large amounts of the dietary protein escape ruminal degradation.

Zilmax (Intervet/Schering-Plough Animal Health, Millsboro, DE) is the brand name for zilpaterol-HCl, an orally active β-adrenergic agonist approved as a feed additive for beef cattle in the United States. Orally active β-adrenergic agonists repartition nutrients from lipid accretion toward skeletal muscle growth. When fed during the final 20 to 40 days on feed, Zilmax has been shown to increase average daily gain and feed efficiency of cattle consuming corn-based diets and has been shown to either have little effect on or slightly reduce dry matter intake. This repartitioning of nutrient use in Zilmax-fed cattle clearly increases net protein deposition.

As use of ethanol fermentation coproducts (e.g., distillers grains) increases in finishing cattle diets, dietary nitrogen available to ruminal microflora may be reduced compared with that available from traditional sources of supplemental protein. Urea recycling may be more important when finishing cattle consume supplemental proteins with low ruminal degradability. The goal of our study was to better quantify the amount of urea recycled in growing cattle fed corn-based diets supplemented with different sources of protein with or without Zilmax.

Experimental Procedures

Two sets of six steers were blocked into pairs on the basis of pretrial voluntary feed intake and used in two replicates of similarly designed trials conducted at different times. Within each replicate, three steers (one randomly selected from each blocked pair) were fed 60 mg/day zilpaterol-HCl (1.25 g/day Zilmax) throughout the trial, and the remaining 3 steers received no Zilmax. Thus, the Zilmax treatment was provided in a randomized block design.

Within each group of three steers receiving the same Zilmax treatment, steers were used in a 3 × 3 Latin square concurrent with an identical Latin square involving the group of three steers receiving the other Zilmax treatment. Treatments within each square were three corn-based diets: control (9.6% crude protein), urea (12.4% crude protein), or dried distillers grains with solubles (13.7% crude protein).

[1] This project was supported by National Research Initiative Competitive Grant no. 2007-35206-17848 from the USDA Cooperative State Research, Education, and Extension Service.

Steers were housed in metabolism crates to allow for total collection of urine and feces. Steers were fed twice daily in equal amounts at 12-hour intervals. The amount of feed offered was near voluntary intake for each individual steer prior to the experiment.

Intake, digestion, and nitrogen balance were measured for all treatments. Urea that was composed of heavy isotopic nitrogen (^{15}N) was infused intravenously to measure urea kinetics.

Results and Discussion

Effects of Diet

Nitrogen intake (Table 1) was greatest with dried distillers grains with solubles (176 g/day), intermediate with urea (161 g/day), and least with the control (120 g/day). These differences were expected. Additions of supplemental nitrogen as dried distillers grains with solubles increased (72 g/day) nitrogen retention compared with the control (37 g/day), and urea was intermediate (61 g/day). Increases in response to dried distillers grains with solubles probably represent responses to increases in metabolizable protein supply.

Urea production was numerically greater for dried distillers grains with solubles (193 g/day) than for the control (141 g/day) or urea (138 g/day). Digestive tract entry of urea (recycling) also was also was numerically greater for dried distillers grains with solubles (151 g/day) than for urea (101 g/day) or the control (111 g/day).

Cattle fed dried distillers grains with solubles tended ($P=0.16$) to capture more recycled urea in ruminal microbes than cattle fed the other diets (data not shown).

Effects of Zilmax

Dry matter intake of steers fed Zilmax was greater ($P<0.01$) than that of steers not fed Zilmax (8.5 vs. 6.6 kg/day, respectively). Differences in dry matter intake were due to unexpected greater refusals by steers not receiving Zilmax compared with steers receiving Zilmax (27% vs. 7%, respectively) rather than to differences in the amount of feed offered. Differences in intake due to Zilmax were not expected and are contrary to results of previous research. Zilmax increased ($P<0.01$) nitrogen intake (171 vs. 134 g/day). Increases in nitrogen intake in response to Zilmax were not expected but were proportional to the increase in dry matter intake.

No measureable effects of Zilmax were observed for urea kinetics. Zilmax unexpectedly increased intakes in our experiment, and it is difficult to separate the effects of Zilmax from those of increased intakes. Interestingly, Zilmax had no effects on urea production or recycling of urea to the digestive tract despite the greater nitrogen intake of steers fed Zilmax. Similar research demonstrated that increases in nitrogen intake lead to increases in urea production and urea recycling in cattle. Zilmax repartitions nitrogen such that more nitrogen is directed to lean tissue accretion (i.e., muscle growth). Our initial hypothesis was that increases in nitrogen retention in response to Zilmax would lead to less catabolism of amino acids, less urea production, and less urea recycling to the digestive tract. In light of the greater nitrogen intake of Zilmax-fed cattle and the lack of change in urea produced and recycled to the digestive tract, it is possible that the effects of nitrogen intake and Zilmax counteracted one another in this experiment.

Implications

Understanding the effects of β-adrenergic agonists, such as Zilmax, on nitrogen recycling will allow nutritionists to formulate diets that more closely match the nutrient needs of finishing cattle. Appropriately matching dietary nutrients with cattle's requirements may prevent costly overfeeding of nitrogen and wasteful nitrogenous excretions.

Table 1. Effects of nitrogen supplementation and dietary zilpaterol-HCl (Zilmax) on intake, digestion, and nitrogen retention in steers consuming corn-based diets supplemented with no protein (Control), dried distillers grains with solubles (DDGS), or urea

	Zilmax			No Zilmax				P-value		
Item	Control	DDGS	Urea	Control	DDGS	Urea	SEM	Zilmax	Diet	Interaction
Dry matter intake, lb/day	18.8	18.8	18.6	14.2	14.3	15.2	1.1	<0.01	0.76	0.61
Dry matter digestion, %	77.4	77.4	76.4	76.2	79.1	77.8	2.4	0.80	0.65	0.62
Nitrogen intake, g/day	138	198	177	102	155	145	11	<0.01	<0.01	0.79
Nitrogen retained, g/day	49	87	75	26	57	47	17	0.05	0.10	0.97
Urea production, g nitrogen/day	156	169	134	126	217	142	52	0.80	0.36	060
Urea recycling, g nitrogen/day	126	132	109	97	169	93	47	0.94	0.39	0.58

Urea Recycling in Beef Cattle Fed Prairie Hay-Based Diets[1]

E.A. Bailey, E.C. Titgemeyer, KC Olson, D.W. Brake, D.E. Anderson, and M.L. Jones

Introduction

Maximizing utilization of native rangeland is an important aspect of the cow/calf phase of beef production. Native rangeland is often of poor quality (less than 7% crude protein). Protein content of the rangeland is important because nitrogen is a key growth factor used by ruminal microbes. Without adequate nitrogen, the ruminal ecosystem will not operate at peak efficiency, which subsequently reduces the supply of nutrients to the animal.

Historically, producers have provided supplemental nutrients to their cattle to achieve maximum performance. Both supplemental protein and energy have been provided to cattle consuming low-quality forage with varying levels of success. Typically, supplemental energy without adequate protein reduces fiber digestion by cattle. On the other hand, supplemental protein consistently improves overall performance.

Previous research has established that cattle conserve nitrogen in the body through urea recycling. This process allows cattle to preserve nitrogen when forage quality is not adequate. Research quantifying urea recycling and how it is affected by supplemental protein and energy in cattle fed low-quality forage is sparse.

Objectives of this experiment were to determine the impacts of supplemental protein and energy on forage intake, digestion, and urea kinetics in growing beef cattle.

Experimental Procedures

Six Angus-cross steers (initial body weight 470 lb) were used in a metabolism trial to measure the effects of supplemental energy and protein on intake, digestion, and urea kinetics. The steers were ruminally and duodenally cannulated. The trial was conducted as a 6 × 6 Latin square with treatments in a 3 × 2 factorial arrangement. The energy treatments were: (1) no supplemental energy, (2) 600 g of glucose dosed ruminally once daily, and (3) 480 g of volatile fatty acids (40% acetate, 30% propionate, and 30% butyrate) infused over 8 hours daily. Casein (120 or 240 g) was dosed once daily as the degradable intake protein supplement. The steers were given ad libitum access to low-quality prairie hay (5.8% crude protein).

Each period was 14 days long. The first 9 days were used for adaptation to treatments. During the next 4 days, total fecal and urine collections were used to assess digestion and urea kinetics. Ruminal and duodenal collections occurred over the final day of each period. Labeled urea was infused intravenously from day 10 through 14 of each period to provide a means of measuring urea kinetics.

[1] This project was supported by National Research Initiative Competitive Grant no. 2007-35206-17848 from the USDA Cooperative State Research, Education, and Extension Service.

Results and Discussion

Forage intake, digestion, and urea kinetics are shown in Table 1. The volatile fatty acid infusion decreased ($P<0.01$) forage intake by 27%. Decreases in forage intake due to glucose (7%) and increases due to increasing casein (4.5%) were not significant.

Glucose decreased total tract neutral detergent fiber digestibility ($P<0.01$), and the depression in response to supplemental glucose tended to be greater at the low level of casein. Providing supplemental energy to cattle without sufficient protein can have detrimental effects on forage digestion. Ruminal microbes that ferment glucose compete for nutrients with microbes that digest fiber. When a large amount of a readily useable substrate (glucose) is provided, glucose-digesting microbes grow quickly and consume large amounts of ruminally available nitrogen. Thus, energy supplementation can exacerbate protein deficiencies, limit productivity of fiber-digesting microbes, and depress fiber digestion. Producers should be conscious of the protein content of the diet before providing supplemental energy to avoid depressing forage digestion.

Neither supplemental energy nor increased casein significantly affected the amount of urea produced in the body or recycled to the gut. However, gut entry (recycling) of urea as a percentage of total urea production was decreased by casein ($P=0.01$) and increased by provision of glucose ($P=0.05$). Supplemental volatile fatty acids had no effect on the proportion of total urea production that was recycled to the gut. We observed differences between glucose and volatile fatty acid treatments because there were fundamental differences between the treatments. Glucose was provided as an energy source for ruminal microbes, whereas volatile fatty acids were provided as an energy source for the animal only. Ruminal microbes produce volatile fatty acids as end products of their metabolism; thus, they have no use for the supplemented volatile fatty acids. Increased urea recycling with supplemental energy is a function of increased microbial activity in the rumen and the subsequent increased demand for nitrogen. Nitrogen is a critical growth factor for ruminal microbes. Providing additional casein ameliorates the deficiency, explaining the lower proportion of urea production that was recycled to the rumen at the 240 g/day casein level.

Duodenal flows of nitrogen represent the amount of protein (amino acids) that is available to the animal and represent the sum of microbial protein synthesis in the rumen and dietary protein that is not degraded (bypass protein). Increasing casein tended to increase duodenal nitrogen flow ($P=0.15$), but there was not an energy effect. Microbial nitrogen was increased by increasing casein ($P=0.04$), demonstrating that the low level of supplementation (120 g/day of casein) did not meet the microbial requirement. As part of our urea kinetics measurements, we quantified the amount of recycled urea that was incorporated into microbial nitrogen. Providing additional casein tended to decrease microbial capture ($P=0.08$), particularly when glucose was supplemented. Glucose significantly increased the amount of microbial capture of recycled urea ($P=0.01$), mostly at the lower level of casein supplementation, because of an increased need for nitrogen in the rumen facilitated by increased activity of glucose-digesting bacteria.

Implications

Cattle have the ability to recycle nitrogen to the rumen and to use this mechanism as a means of meeting ruminal nitrogen requirements. Providing supplemental energy to cattle consuming low-quality forage can be detrimental to forage digestion when protein is deficient. Increasing protein ameliorated the negative impact of supplemental glucose on forage digestion. Thus, producers may be able to provide supplemental energy to their cattle if they are mindful of the protein content in the total diet.

Table 1. Effects of degradable intake protein (DIP) and energy [glucose (GLC) or volatile fatty acid (VFA)] supplementation on intake, digestion, urea kinetics, and microbial flow in growing steers fed low-quality forage

	120 g/d DIP			240 g/d DIP				P-value		
Item	Control	GLC	VFA	Control	GLC	VFA	SEM	DIP	Energy	DIP × Energy
Organic matter intake, lb/day										
Forage	8.2	8.2	6.6	9.3	8.1	6.4	0.9	0.42	0.01	0.27
Total	8.4	9.7	7.7	9.9	9.7	7.9	0.9	0.19	0.01	0.27
Total tract digestibility, %										
Organic matter	56.0	55.1	62.6	55.7	60.2	59.4	2.1	0.75	0.04	0.09
Neutral detergent fiber	54.0	44.1	53.2	52.9	49.5	50.2	2.5	0.81	0.01	0.12
Urea kinetics, g/day of nitrogen										
Production	39	68	61	55	45	63	12	0.89	0.39	0.15
Gut entry (Recycled)	32	65	54	43	37	48	12	0.38	0.32	0.16
% of total production	83	93	86	77	82	76	4	0.01	0.05	0.65
Duodenal flow, g/day of nitrogen										
Total nitrogen	56	59	51	72	67	59	10	0.15	0.55	0.85
Microbial nitrogen	37	38	33	54	45	41	7	0.04	0.39	0.68
Microbial nitrogen from recycled urea	7.7	15.4	7.7	8.7	8.2	6.6	1.9	0.08	0.02	0.03
% of total microbial nitrogen	20.7	40.5	24.1	16.2	18.1	16.1	3.8	0.01	0.01	0.01

Effect of Nitrogen Supplementation on Urea Recycling in Steers Consuming Corn-Based Diets[1]

D.W. Brake, E.C. Titgemeyer, M.L. Jones, and D.E. Anderson

Introduction

Nitrogen absorbed in the small intestine of cattle can be recycled to the rumen and incorporated into microbially synthesized amino acids. This is an advantage when dietary protein is low or when ruminally available nitrogen is limited by poor ruminal protein degradation.

In a survey, consulting feedlot nutritionists reported that 83% of their clients used ethanol coproducts in finishing diets. Ruminal availability of nitrogen in dried distillers grains with solubles is low (i.e., 25% of total nitrogen). Thus, urea recycling may be of greater relative importance when distillers grains are used to supplement protein to cattle.

The goals of our study were to better predict the amount of urea recycled by growing cattle fed corn-based diets supplemented with dried distillers grains with solubles or urea and quantify use of recycled urea by ruminal microbes.

Materials and Methods

Six ruminally and duodenally fistulated steers of British breeding were used in two concurrent 3 × 3 Latin squares. Treatments were three corn-based diets: control (10.2% crude protein), urea (13.3% crude protein), and dried distillers grains with solubles (14.9% crude protein). Treatments delivered dried distillers grains with solubles and urea at inclusion rates similar to those used commonly in corn-based diets fed to finishing cattle. Dried distillers grains with solubles was selected as a supplemental protein source because of its relatively high undegradable intake protein content. Urea was selected as a supplemental nitrogen source that is completely ruminally degradable.

Steers were housed in metabolism crates to allow total collection of urine and feces. Steers were fed twice daily in equal amounts. A temporary indwelling catheter was placed into an ear vein for infusion of $^{15}N^{15}N$-urea to allow measurement of urea recycling.

Results and Discussion

Intake, Digestibility, and Nutrient Flow

Dry matter intake did not differ among treatments ($P \geq 0.18$) but was numerically less when steers consumed urea.

[1] This project was supported by National Research Initiative Competitive Grant no. 2007-35206-17848 from the USDA Cooperative State Research, Education, and Extension Service.

Total tract dry matter digestibility tended (P=0.11) to be greatest for urea, least for the control, and intermediate for dried distillers grains with solubles. Increased dry matter digestibility may be explained by urea stimulating microbial fermentation, although ruminal digestion of dry matter was not different among treatments (P=0.81). Numerically lower dry matter intake for the urea treatment may have contributed to its greater total tract dry matter digestibility compared with other treatments.

As expected, protein intake increased with increasing crude protein concentration in the diet (P<0.01). Steers consumed the greatest amount of protein when fed dried distillers grains with solubles, the least amount of protein when fed the control diet, and an intermediate amount when fed urea. Ruminally undegraded intake protein was numerically greatest for dried distillers grains with solubles, although microbial crude protein flowing to the intestine did not differ (P=0.81) among treatments.

Nitrogen retention (i.e., lean tissue deposition) was greater (P=0.02) for steers fed dried distillers grains with solubles than for steers fed the control diet or urea. This treatment effect may have been a response to an increasing metabolizable protein supply. Other researchers have observed that young cattle benefit from increases in metabolizable protein.

Urea Recycling

Urea production was greater (P=0.09) for dried distillers grains with solubles than for the control, but urea production in the urea treatment was not different from that in the dried distillers grains with solubles or control treatments. Urea recycling to the digestive tract did not differ among treatments (P=0.25), but there were large numerical differences that corresponded to the pattern of urea production. The dried distillers grains with solubles treatment yielded the numerically greatest microbial capture of endogenously produced (83 g/day), the control treatment produced the least (39 g/day), and the urea treatment was intermediate (57 g/day).

The percentage of microbial crude protein derived from urea recycling was greater (P=0.10) for dried distillers grains with solubles than for urea or the control. As the proportion of ruminally undegraded dietary protein increased, ruminal microbes may have incorporated more nitrogen from recycled urea. Previous research reported that urea recycling increased when intake of ruminally undegraded intake protein increased.

Microbial Capture of Endogenously Produced Urea

Urea production (percentage of protein intake) was numerically greater for dried distillers grains with solubles (83%) than for urea (73%). Steers fed dried distillers grains with solubles captured (P=0.10) a greater proportion of their microbial crude protein from recycled urea (35%) than steers fed urea (22%) or the control (17%). Ruminal microbes are more dependent on urea recycling to meet their needs for nitrogen when ruminally undegraded intake protein is provided to cattle. Previous research at Kansas State University reported similar increases in the amount of recycled urea captured by ruminal microbes when ruminally undegraded protein was supplemented.

Implications

Improved estimates of urea recycling by cattle consuming corn-based diets will lead to more precise diet formulation and less nitrogen excretion.

Table 1. Effect of nitrogen supplementation on urea recycling in steers consuming corn-based diets supplemented with no protein (Control), dried distillers grains with solubles (DDGS), or urea

	Diets				
Item	Control	DDGS	Urea	SEM	P-value
Dry matter intake, lb/day	13.6	13.6	12.7	1.3	0.18
Ruminal dry matter digestion, %	40.6	37.5	42.7	8.4	0.81
Total tract dry matter digestion, %	78.8	79.1	80.5	1.6	0.11
Nitrogen intake, g/day	99[a]	151[b]	123[c]	12	<0.01
Nitrogen retained, g/day	41[a]	67[b]	47[a]	7	0.02
Undegraded intake protein, g/day	51	97	67	18	0.12
Urea production, g/day of nitrogen	52[a]	118[b]	86[ab]	17	0.09
Urea recycling, g/day of nitrogen	39	83	57	17.1	0.25
Microbial nitrogen, g/day of nitrogen	95	84	83	16	0.81
Ruminal microbial capture of recycled urea					
grams of nitrogen/day	17	30	18	6.4	0.28
% of total microbial nitrogen	17[a]	35[b]	22[a]	5.3	0.10

Means in the same row with common superscript letters are not different (P>0.05).

Effects of Supplemental Protein and Energy on Digestion and Urea Kinetics in Beef Cattle[1]

E.A. Bailey, E.C. Titgemeyer, KC Olson, D.W. Brake, D.E. Anderson, and M.L. Jones

Introduction

Previous research at Kansas State University has shown that providing supplemental energy when protein is deficient will cause a decrease in digestion of low-quality forage. Our project examined the effects of supplemental glucose on low-quality forage intake and digestion. Urea recycling is a mechanism by which cattle preserve nitrogen when faced with a deficiency. Young, growing cattle receiving sufficient protein recycle large amounts of nitrogen to the rumen. Our goal was to explore the effects of providing supplemental energy and protein to cattle that are on the downward side of their growth curve. Specifically, we measured intake, digestion, and urea kinetics in these animals.

Experimental Procedures

Six Angus-cross steers (initial body weight = 908 lb) were used in a metabolism trial to measure the effect of supplemental energy and protein on intake, digestion, and urea kinetics. The animals were ruminally and duodenally cannulated. The trial was conducted as a 4 × 4 Latin square with two extra steers per period. Supplemental energy treatments were a control (no supplemental energy) or 1,200 g glucose dosed ruminally once daily. Casein (240 or 480 g) was dosed once daily as a degradable intake protein supplement. The steers were given ad libitum access to low-quality prairie hay (4.7% crude protein). Each 14-day period consisted 9 days for adaptation to treatments, 4 days for fecal and urine collection, and 1 day for ruminal and duodenal sample collection. Doubly labeled urea was infused intravenously from day 10 through day 14 of each period to allow measurement of urea kinetics.

Results and Discussion

Forage intake, digestion, and urea kinetics are shown in Table 1. Glucose reduced forage intake by 18% ($P<0.01$), but casein supplementation did not change ($P=0.69$) forage intake. Glucose depressed ($P<0.01$) total tract digestion of neutral detergent fiber. Providing supplemental energy to cattle without sufficient dietary protein had detrimental effects on forage digestion. When a large amount of a readily useable substrate (glucose) was provided, glucose-digesting microbes grew quickly and consumed large amounts of ruminally available nitrogen. Thus, energy supplementation can exacerbate protein deficiencies, limit productivity of fiber-digesting microbes, and depress fiber digestion. To avoid depressing forage digestion, producers should be conscious of the protein content of the diet before providing supplemental energy.

The amount of urea produced by the body increased 50% ($P=0.03$) as casein increased from 240 to 480 g/day. The amount of urea recycled to the gut numerically increased by

[1] This project was supported by National Research Initiative Competitive Grant no. 2007-35206-17848 from the USDA Cooperative State Research, Education, and Extension Service.

25% as casein increased (P=0.30). The proportion of urea production that was recycled to the gut decreased (P<0.01) as casein increased. When more nitrogen was available in the rumen, the animal was less reliant on urea recycling to optimize performance of ruminal microbes. Glucose supplementation did not change (P=0.70) urea production or the amount of urea recycled to the gut (P=0.91); however, the proportion of urea production recycled to the gut numerically increased (P=0.25) when glucose was supplemented.

Total nitrogen flow to the duodenum increased as casein increased in glucose-supplemented steers but not in control steers. A similar pattern was observed for microbial nitrogen flow to the duodenum. The amount of recycled urea captured by ruminal microbes was less (P=0.07) for the treatment providing no supplemental energy and 480 g of casein. This likely occurred because ruminal microbes were receiving an excess of available nitrogen. Increasing casein decreased (P=0.02) the percentage of total microbial nitrogen derived from recycled urea. In contrast, supplemental glucose tended to increase (P=0.18) the percentage of microbial nitrogen derived from recycled urea. This reflected an increased need for nitrogen in the ruminal environment when energy supply was increased.

Implications

Supplemental glucose decreased forage intake and digestibility. Increasing casein altered urea kinetics by increasing urea production, but the proportion of urea nitrogen recycled to the gut decreased. Cattle continue to recycle urea even when they receive sufficient amounts of nitrogen to meet their requirements.

Table 1. Effects of degradable intake protein (DIP) and glucose supplementation (1.2 kg/day) on intake, digestion, urea kinetics, and microbial flow in mature steers fed low-quality forage

	240 g/day DIP		480 g/day DIP			P-value		
Item	Control	Glucose	Control	Glucose	SEM	DIP	Energy	DIP × Energy
Organic matter intake, lb/day								
Forage	9.7	7.5	9.0	7.9	0.7	0.69	0.01	0.19
Total	10.1	10.6	10.1	11.2	0.7	0.39	0.08	0.19
Total tract digestibility, %								
Organic matter	55.7	60.0	55.6	60.9	1.6	0.78	0.01	0.70
Neutral detergent fiber	53.9	43.4	48.8	43.1	2.1	0.09	0.01	0.12
Urea kinetics, g/day of nitrogen								
Production	88	86	137	125	21	0.03	0.70	0.77
Gut entry (Recycled)	74	76	94	93	21	0.30	0.91	0.99
% of total production	81	85	67	73	5	0.01	0.25	0.84
Duodenal flow, g/day of nitrogen								
Total nitrogen	73	56	70	79	6	0.06	0.43	0.02
Microbial nitrogen	49	40	55	59	5	0.01	0.55	0.11
Microbial nitrogen from recycled urea	18.7	18.0	7.3	18.3	3.1	0.06	0.10	0.05
% of total microbial nitrogen	39.3	46.2	13.7	29.4	7.7	0.02	0.18	0.54

Beta Acid Extracts of Hops Have a Modest Effect on Ruminal Metabolism and Apparent Total Tract Digestibility by Steers Fed High-Concentrate Diets[1]

S. Uwituze, J.M. Heidenreich, J.J. Higgins, and J.S. Drouillard

Introduction

Hops have been used for centuries to control bacterial contamination in beer production. Today, alpha acids are extracted from hops for use in flavoring beer, leaving residues that are rich in beta acids. Beta acid fractions of hops can selectively inhibit specific ruminal Gram-positive bacteria that are responsible for major digestive disturbances, such as acidosis and bloat, and have a chemical structure similar to that of ionophores used in feedlot production. Use of ionophores improves efficiency of feed utilization and decreases the incidence of digestive disturbances that are a major cause of morbidity and mortality in cattle feeding operations. The objectives of this study were to evaluate the effect of beta acid extracts of hops on ruminal fermentation and diet digestibility in cattle fed high-concentrate diets and determine response to different doses of beta acid extracts of hops.

Experimental Procedures

Ruminally cannulated crossbred Angus steers (n = 14; 900 ± 17.5 lb body weight) were used to evaluate the effects of beta acid extracts derived from hops on ruminal fermentation and apparent total tract digestibility of feedlot diets. Treatments were a control (no additive or beta acid extracts of hops); Rumensin (Elanco Animal Health, Greenfield, IN) fed at 300 mg/day; and beta acid extracts of hops fed at 10, 80, 160, 240, or 300 mg/day (approximately 1, 8, 16, 24, and 30 ppm, respectively, of diet dry matter). Rumensin and beta acid extracts of hops were ruminally dosed once daily immediately before feeding.

Steers were housed in individual slatted-floor pens equipped with individual feed bunks and water fountains that allowed free access to feed and clean water. The basal diet was based on steam-flaked corn and contained (dry basis) 10% alfalfa hay and 15% dried distillers grains (Table 1). The diet was mixed, proportioned, and delivered to each pen once daily at 8:00 a.m. Each morning before feeding, unconsumed feed was weighed and dried to determine actual dry matter intake. Four experimental periods were used, each consisting of a 21-day adaptation phase followed by a 3-day collection phase; there were two steers per treatment during each period. Starting 96 hours before the collection phase of each period, chromic oxide (10 g) in gelatin capsules (Torpac Inc., Fairfield, NJ) was placed into the rumen before feeding each day to estimate total fecal output. Ruminal digesta samples were collected at 2-hour intervals to cover 24 hours after feeding during the collection phase of each period and used to determine ruminal pH and ruminal concentrations of ammonia and volatile fatty acids. Fecal samples were collected simultaneously, composited by animal within each period, and used to deter-

[1] The authors acknowledge M.K. Shelor for his technical contributions during this experiment.

mine total tract digestibilities of dry matter, organic matter, starch, neutral detergent fiber, crude protein, and crude fat.

Results and Discussion

Neither Rumensin nor beta acid extracts of hops affected ruminal pH ($P>0.20$) or ruminal concentrations of acetate, propionate, and butyrate and the acetate:propionate ratio ($P>0.50$). Likewise, lactate concentration was not affected ($P>0.30$) by Rumensin or beta acid extracts of hops, but steers dosed with Rumensin tended ($P=0.12$) to have lower ruminal pH than the control group. Cattle that received beta acid extracts of hops tended ($P=0.11$) to have higher ruminal ammonia concentrations than steers fed Rumensin. Isobutyrate concentration in steers fed beta acid extracts of hops was higher ($P=0.03$) than that in control group steers but was not different ($P=0.26$) from that in the Rumensin-fed group. Feeding beta acid extracts of hops also resulted in numerically higher concentrations of isovalerate and valerate relative to the control group.

It is possible that the beta acid extracts are enhancing ruminal protein degradation or reducing bacterial uptake of recycled urea nitrogen. In situations in which ruminal nitrogen requirements are not being met, this effect could be useful and potentially reduce the need for supplemental nitrogen in feedlot diets.

There were no effects ($P>0.20$) of Rumensin or beta acid extracts of hops on intake or total tract digestibility of dry matter, organic matter, starch, crude protein, or crude fat (Table 2). However, several animals that were previously fed 300 mg/day of beta acid extracts of hops indulged themselves in subsequent feeding periods, leading to digestive disturbances and very low feed intake. As a result, data from the 300 mg/day treatment was not included in statistical analysis of dose titration. Dose titration up to 240 mg/day of beta acid extracts of hops had no effect ($P>0.20$) on ruminal fermentation characteristics or diet digestibility.

Implications

Beta acid extracts of hops acids have modest biological activity in the rumen, and this activity might have commercial application.

Table 1. Diet composition of cannulated steers dosed with or without Rumensin or beta acid extracts of hops

Ingredients	% Dry matter
Steam-flaked corn	64.8
Corn dried distillers grains	15.0
Alfalfa hay	9.7
Corn steep liquor	6.3
Supplement[1]	1.9
Premix	2.2
Analyzed composition, %	
Dry matter	83.1
Crude protein	13.7
Ether extract	4.1
Neutral detergent fiber	9.8
Calcium	0.63
Phosphorus	0.45
Potassium	0.68

[1] Formulated to provide 1,000 IU/lb vitamin A; 10 IU/lb vitamin E; 0.3% salt, 0.70% calcium; 0.70% potassium; 0.1 ppm cobalt; 10 ppm copper; 0.15 ppm iodine; 60 ppm manganese; 0.25 ppm selenium; and 60 ppm zinc.

Table 2. Digestion characteristics of ruminally cannulated steers dosed with or without Rumensin or beta acid extracts of hops

	Treatments							
			Beta acid level, mg/day					
Item	Control	Rumensin	10	80	160	240	300	SEM
Intake, lb/day								
Dry matter	19.03	18.11	18.38	18.53	19.93	20.44	18.20	0.56
Organic matter	18.11	17.24	17.43	17.57	18.96	19.43	17.19	0.53
Starch	10.35	9.82	9.99	10.04	10.83	11.10	9.85	0.30
Neutral detergent fiber	2.98	2.83	2.87	2.89	3.14	3.20	2.85	0.09
Crude protein	2.61	2.48	2.52	2.54	2.74	2.81	2.48	0.08
Crude fat	0.79	0.75	0.75	0.77	0.83	0.83	0.75	0.02
Apparent total tract digestibility, %								
Dry matter	77.4	77.6	81.2	78.5	75.4	79.1	76.6	3.16
Organic matter	79.4	80.2	84.0	80.7	78.5	82.2	79.6	2.93
Starch	99.8	99.7	99.8	99.7	99.6	99.8	99.7	0.06
Neutral detergent fiber[1]	39.8	49.5	48.2	43.6	37.0	44.5	40.0	6.37
Crude protein	73.0	73.5	77.1	73.9	70.6	75.4	73.3	3.23
Crude fat	88.7	88.9	92.1	88.9	89.0	90.9	90.8	1.38

[1] Control vs. Rumensin, P=0.06; Control vs. beta acid, P>0.3; Beta acid vs. Rumensin, P=0.07.

Effects of Crude Glycerin on Ruminal Metabolism and Diet Digestibility of Flaked-Corn Finishing Diets

G.L. Parsons and J.S. Drouillard

Introduction

Expansion of the biodiesel industry has increased supplies of crude glycerin available for livestock feeding. Catalyzed reactions between methanol and triglycerides from vegetable oils, such as soybean oil, yield biodiesel and a coproduct, crude glycerin. Approximately 10% of the weight of soybean oil used to produce biodiesel becomes glycerin. Limited work has been conducted to understand metabolism of glycerin in ruminant livestock. In previous studies at Kansas State University, feeding crude glycerin at 8% or less of the diet improved cattle performance. Subsequent laboratory experiments indicated that low levels of glycerin may improve ruminal fermentation. This study was conducted to determine whether adding low levels of glycerin to feedlot diets could affect diet digestibility.

Experimental Procedures

Crossbred steers (n = 9; 1,373 ± 176 lb) fitted with ruminal cannulae were used to conduct a replicated, complete block experiment with three treatments and nine observations per treatment. Treatments consisted of steam-flaked corn diets containing 0%, 2%, and 4% crude glycerin (dry matter basis). Steers had ad libitum access to finishing diets fed once daily. Diets contained 6% alfalfa hay and provided 14% crude protein, 0.7% calcium, and 0.7% potassium (Table 1). Periods consisted of a 10-day acclimation phase followed by a 3-day collection phase. Chromic oxide (10 g/day) was used as an indigestible marker to estimate total fecal output and was dosed intraruminally prior to feeding each day beginning 7 days before the sampling phase. Starting on day 11 of each period, ruminal digesta were collected throughout a 3-day collection phase. Collection times were: day 1 at 0, 6, 12, 18 and 24 hours postfeeding; day 2 at 2, 8, 14, and 20 hours postfeeding; and day 3 at 4, 10, 16 and 22 hours postfeeding. Digesta were removed from the rumen via the ruminal cannulae and strained through eight layers of cheesecloth. Ruminal fluid was analyzed for volatile fatty acid profiles, pH, and ammonia concentration. Apparent total tract digestibilities were calculated for various nutrients.

Results and Discussion

Dry matter intake was similar among treatments (Table 2). Fecal output was 2.7, 2.8, and 2.8 lb/day when glycerin was fed at 0%, 2%, and 4%, respectively ($P>0.74$). Apparent total tract digestibilities of dry matter, organic matter, starch, crude protein, and crude fat were similar for cattle fed different levels of crude glycerin ($P>0.51$). Apparent total tract digestibilities of neutral detergent fiber were 60%, 52%, and 48% for cattle fed 0%, 2%, and 4% glycerin, respectively (linear effect, $P<0.01$; Table 2). No treatment-by-time interactions were observed for ruminal parameters (Table 3; $P>0.27$). Feeding glycerin linearly increased ruminal pH from 5.61 in control steers to 5.67 and 5.73 when glycerin was added at 2% and 4%, respectively ($P<0.06$; Figure 1). Butyr-

ate and valerate concentrations decreased as crude glycerin increased in the diet (linear effect; P<0.03), and acetate concentrations also decreased with increasing glycerin concentrations (linear effect; P=0.06). When fed at low levels in finishing diets, glycerin appears to alter fiber digestion but has little impact on other diet components.

Implications

Glycerin can be feed to finishing cattle without significantly altering digestibilities of most nutrients. However, changes that occur in volatile fatty acid profiles may relate to changes in fiber digestion.

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

	Crude glycerin, %		
Ingredient, %	0	2	4
Steam-flaked corn	82.6	80.2	77.8
Corn steep liquor	5.7	5.7	5.7
Alfalfa hay	5.9	5.9	5.9
Soy-based crude glycerin[1]	0.0	2.0	4.0
Soybean meal	0.37	0.80	1.20
Limestone	1.45	1.45	1.45
Urea	1.15	1.14	1.14
Salt	0.28	0.29	0.28
Mineral premix[2]	0.35	0.34	0.34
Feed additive premix[3]	2.2	2.2	2.2

[1] Methanol content of glycerin was <0.01%.
[2] Formulated to provide 0.1 ppm cobalt; 10 ppm copper; 0.6 ppm iodine; 60 ppm manganese; 0.25 ppm selenium; 60 ppm zinc; 1,200 IU/lb vitamin A; and 10 IU/lb vitamin E.
[3] Feed additive premix was formulated to provide 300 mg monensin and 90 mg tylosin daily in a ground corn carrier.

Table 2. Apparent total tract digestibility of diets containing 0%, 2%, or 4% crude glycerin

	Crude glycerin, %				P-value	
Item	0	2	4	SEM	Linear	Quadratic
Feed intake, lb/day	17.7	17.5	17.7	0.86	0.99	0.76
Fecal output, lb/day	2.7	2.8	2.8	0.37	0.51	0.76
Apparent total tract digestion						
Dry matter, %	84.9	84.1	84.2	1.3	0.57	0.69
Organic matter, %	87.6	87.0	86.7	1.0	0.51	0.96
Neutral detergent fiber, %	60.4	51.8	48.1	3.6	<0.01	0.47
Starch, %	99.6	99.7	99.6	0.11	0.93	0.44
Crude protein, %	78.8	80.3	79.0	1.5	0.90	0.34
Crude fat, %	90. 9	91.6	90.4	1.3	0.81	0.27

Table 3. Ruminal concentrations of volatile fatty acids and ammonia in steers fed 0%, 2%, or 4% of diet dry matter as crude glycerin

	Crude glycerin, %				P-value	
Item	0	2	4	SEM	Linear	Quadratic
Volatile fatty acids, m*M*						
Total volatile fatty acids	120	116	116	4.7	0.23	0.31
Acetate	52.8	50.7	50.1	1.60	0.06	0.56
Propionate	50.8	48.7	50.7	3.50	0.76	0.32
Acetate:Propionate ratio	1.16	1.20	1.14	0.14	0.68	0.25
Butyrate	14.4	13.5	12.5	1.05	0.03	0.99
Isobutyrate	0.88	0.85	0.84	0.05	0.34	0.92
Valerate	5.45	4.85	3.74	0.73	<0.01	0.52
Isovalerate	2.25	1.85	2.35	0.37	0.80	0.20
Ammonia, m*M*	7.99	7.80	7.67	1.33	0.72	0.97

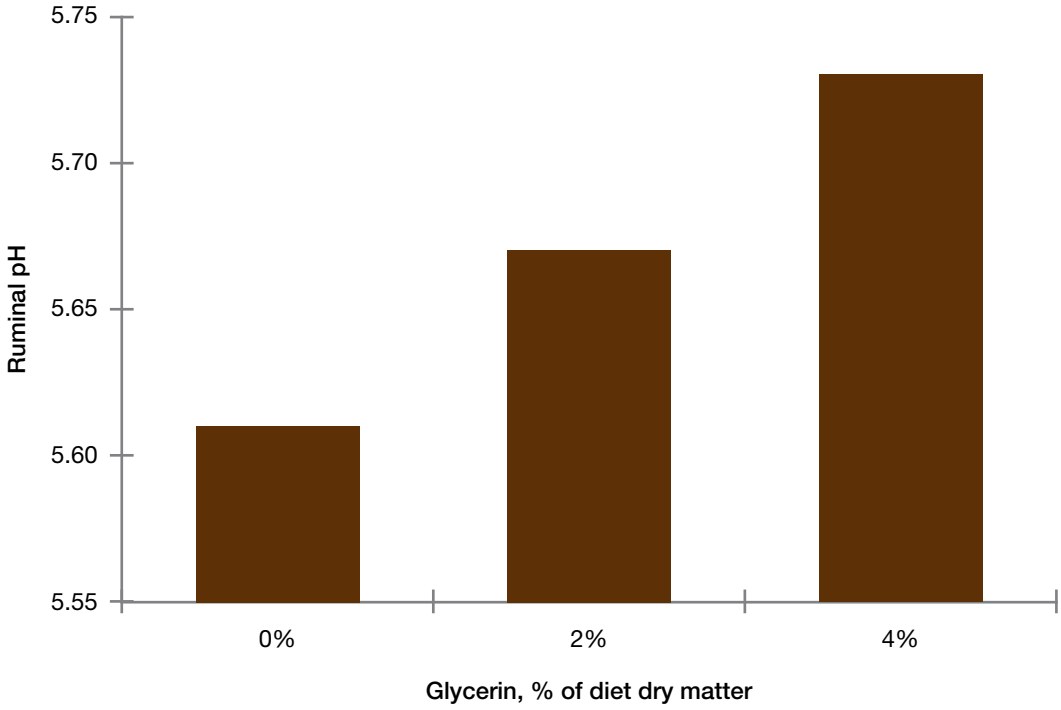


Figure 1. Effects of glycerin level on ruminal pH.

Dried Distillers Grains Supplemented at Different Frequencies to Stocker Heifers Grazing Late-Season Flint Hills Native Pastures

M.P. Epp, D.A. Blasi, W.L. Metzen, and B.E. Oleen

Introduction

Wetter-than-normal summer grazing seasons can produce excessive forage beyond what the typical Flint Hills double-stock harvest rate can remove. These late-summer native grasses do not contain adequate protein to sustain economical gains for stocker cattle, but producers can extend the grazing season by using a protein-based supplement to generate economically feasible rates of gain. Use of dried distillers grains as a supplementation program can help promote overall productivity during the fall grazing season. However, the drawback is the potential high labor input for supplement delivery. Delivering supplements at reduced frequencies per week may be able to sustain daily gains of stocker cattle while reducing labor costs associated with supplement delivery.

Experimental Procedures

One 72-day grazing period was conducted at the Kansas State University Beef Stocker Unit starting September 1, 2009, to determine the response to various frequencies of dried distillers grains supplementation of heifers grazing Flint Hills native grasses. All cattle were sourced from a local sale barn 12 days prior to the study, vaccinated for clostridial and respiratory diseases, dewormed, and fed a high-roughage diet free choice. To obtain a more uniform group of animals, cattle with extreme high or low weights or cattle that exhibited signs of prior illness, lameness, or poor disposition were removed from the pool of cattle eligible for the experiment.

Cattle were randomized and stratified by weight to obtain an equal stocking rate per paddock. The stocking rate per paddock was approximately 63 lb/acre. There were three treatment groups and three replications (paddocks) per treatment group. All cattle were fed dried distillers grains at a daily rate of 0.33% body weight (dry matter basis), but the dried distillers grains were delivered at one of three frequencies: every day, every other day, or every third day. On the basis of predicted gains of 1.5 lb/head daily, dried distillers grains supplementation was increased every 2 weeks during the grazing period. All cattle were hand-fed in bunks located in each pasture. Forage samples were collected at three different times during the grazing study from four different pastures and submitted to a commercial laboratory for nutrient analysis.

Performance data were analyzed by using the MIXED model procedure of SAS (SAS Institute, Inc., Cary, NC). Data were arranged in a randomized complete block design, and pasture was the experimental unit for growth outcomes as affected by treatment. In the model, fixed effects were treatment and pasture, and random effects were pasture × treatment, pasture, and animal.

Results and Discussion

Average daily gain was not different among the treatment groups (Table 1). Cattle fed dried distillers grains every other day or every third day gained at essentially the same rate as cattle supplemented daily during the 72-day grazing period that was initiated in September 2009.

Crude protein and energy content of the clipped forage collected from the four paddocks declined at a marked rate over this study (Table 2).

Implications

If adequate grass resources are available in late summer, producers can reduce labor costs by supplementing dried distillers grains to cattle every second or third day and still achieve performance that is similar to feeding dried distillers grains daily.

Table 1. Performance of stocker heifers fed dried distillers grains (DDG) at a daily rate of 0.33% of body weight (dry basis) at different frequencies while grazing Flint Hills native grasses in late summer and fall

	DDG supplementation frequency				
Item	Daily	Every other day	Every third day	SEM	P-value
No. of pastures	3	3	3		
No. of cattle	17	17	17		
DDG[1], total lb fed	508	507	501		
Initial weight, lb	620	622	614	8.7	>0.54
Final weight, lb	727	728	715	10.1	>0.38
Average daily gain, lb	1.51	1.49	1.43	0.15	>0.71

[1] DDG nutrient content: 90% dry matter, 30% crude protein.

Table 2. Fall 2009 nutritional quality of native pastures at the Kansas State University Beef Stocker Unit

	Pasture 3			Pasture 7			Pasture 13			Pasture 17		
	Sampling date			Sampling date			Sampling date			Sampling date		
Item	8/31	9/29	11/2	8/31	9/29	11/2	8/31	9/29	11/2	8/31	9/29	11/2
Nutrient composition												
Dry matter, %	38.3	36.3	73.4	44.3	40.4	72.9	43.0	44.2	80.27	41.2	43.9	77.3
Crude protein, %	6.8	4.9	3.1	5.3	4.7	3.1	5.3	4.7	3.04	6.3	4.2	2.5
Soluble crude protein, % of crude protein	28.8	25.0	25.0	40.6	25.0	25.0	25.0	25.0	25.0	38.3	25.0	25.0
Fat, %	2.4	2.5	2.1	1.8	2.4	2.5	1.9	1.8	2.5	2.4	1.9	2.3
Acid detergent fiber, %	36.0	36.4	40.4	34.3	36.4	41.1	33.8	37.5	37.7	36.0	40.3	42.0
Neutral detergent fiber, %	64.6	62.2	68.2	62.4	62.1	69.3	61.4	63.9	64.1	62.3	68.3	70.7
Calculated analysis												
Net energy maintenance, Mcal/cwt	58.0	52.3	49.6	50.8	51.9	46.5	52.7	47.3	49.2	56.9	50.0	49.6
Net energy gain, Mcal/cwt	32.1	26.8	24.4	25.5	26.5	21.5	27.2	22.2	24.0	31.1	24.2	24.4
Total digestible nutrients, %	59.0	55.3	53.6	54.4	55.1	51.6	55.6	52.1	53.3	58.3	53.9	53.6
Calcium , %	0.38	0.82	0.43	0.47	1.03	0.97	0.83	0.84	1.24	0.56	0.47	0.47
Phosphorus, %	0.12	0.07	0.04	0.10	0.13	0.06	0.09	0.07	0.04	0.11	0.08	0.05
Magnesium, %	0.20	0.23	0.14	0.24	0.24	0.17	0.10	0.09	0.11	0.23	0.19	0.14
Potassium, %	1.16	0.69	0.11	1.12	0.65	0.25	0.83	0.67	0.12	1.09	0.66	0.19
Sulfur, %	0.12	0.08	0.05	0.11	0.09	0.07	0.08	0.07	0.07	0.10	0.07	0.05
Iron, ppm	178.57	209	153	234.29	291	263	238.37	216	175	---	174	118
Manganese, ppm	41.29	38	36	16.51	17	21	37.15	49	53	---	32	40
Copper, ppm	11.35	14	11	11.35	12	10	11.35	13	13	---	13	10
Zinc, ppm	29.93	38	34	32.00	35	43	28.89	33	39	---	30	30
Molybdenum, ppm	---	1	1	3.10	2	1	1.03	1	1	---	1	1
Cobalt, ppm	---	1	1	3.10	1	1	---	1	1	---	1	1
Selenium, ppm	---	0.05	0.04	---	0.03	0.03	---	0.02	0.03	---	---	0.03

High Sulfur Content in Distillers Grains Alters Ruminal Fermentation and Diet Digestibility in Beef Steers

S. Uwituze, G.L. Parsons, K.K. Karges[1], M.L. Gibson[1], L.C. Hollis, and J.S. Drouillard

Introduction

Requirements for elemental sulfur in feedlot diets have been established to be approximately 0.15% with a maximum upper threshold of 0.40% of diet dry matter. Feeding ethanol fermentation by-products, such as distillers grains with solubles, that are high in sulfur can result in dietary sulfur levels that exceed the recommended maximum. Previous studies indicated that dietary sulfur influenced the site and extent of fiber and protein digestion. The objective of this study was to evaluate ruminal fermentation characteristics and diet digestibility when 30% (dry matter basis) dried distillers grains with solubles with various levels of sulfur was incorporated into finishing diets based on steam-flaked corn or dry-rolled corn.

Experimental Procedures

Twelve ruminally cannulated crossbred steers were used in a metabolism study and fed one of four experimental diets: (1) dry-rolled corn with high sulfur (0.65%), (2) dry-rolled corn with moderate sulfur (0.42), (3) steam-flaked corn with high sulfur (0.65%), or (4) steam-flaked corn with moderate sulfur (0.42). The moderate sulfur level was achieved by using individual ration ingredients, whereas the high sulfur level was attained by mixing sulfuric acid with dried distillers grains with solubles.

Steers were assigned randomly to experimental diets. Diets were fed free choice and formulated to contain similar amounts of crude protein (Table 1). Weights of fresh feed offered to steers and feed refusals were recorded daily. Steers were housed in individual slatted-floor pens with a total area of 60 ft^2. Pens were equipped with individual feed bunks and water fountains.

Two 15-day experimental periods, each consisting of a 12-day diet adaptation phase and a 3-day sample collection phase, were used to assess intake and diet digestion. Beginning 7 days before sample collection, steers were dosed daily via ruminal cannulae with 10 g of chromic oxide, which was used as an indigestible marker to estimate total fecal output. Collection times for fecal and ruminal digesta samples were 0, 6, 12, and 18 hours after feeding on day 1; 2, 8, 14, and 20 hours after feeding on day 2; and 4, 10, 16, and 22 hours after feeding on day 3.

Ruminal pH was measured immediately after samples were collected from the rumen. Concentrations of ruminal ammonia, volatile fatty acids, and lactate in digesta samples were measured. Fecal samples were composited for each animal and period and used to

[1] Dakota Gold Research Association, Sioux Falls, SD.

estimate total fecal output and total tract digestibilities of dry matter, organic matter, neutral detergent fiber, crude protein, starch, and crude fat.

Animal health was monitored daily. One animal on the steam-flaked corn with high sulfur treatment exhibited symptoms related to polioencephalomalacia during the experiment and was removed from all analyses.

Results and Discussion

There were no interactions ($P>0.10$) between grain processing method and dietary sulfur level with respect to feed intake or diet digestibility (Table 2). Feeding high dietary sulfur decreased ($P=0.04$) neutral detergent fiber intake and tended to be associated with lower intake of dry matter and organic matter ($P=0.08$), crude protein ($P=0.06$), crude fat ($P=0.08$), and starch ($P=0.09$).

Steers fed high dietary sulfur had greater apparent total tract digestibility of dry matter ($P=0.04$) and fat ($P=0.03$) than steers fed diets containing moderate dietary sulfur, but dietary sulfur level had no effect on digestibility of other nutrients (Table 2). Conversely, dietary sulfur level did not affect ($P\geq0.17$) the actual amount digested (lb/day), suggesting that differences in the percentage of total tract digestibility were related to feed intake rather than sulfur level. Steers fed diets with high dietary sulfur consumed less feed and, consequently, had a greater percentage of diet digestibility than steers fed diets with moderate dietary sulfur.

Ruminal pH was greater ($P<0.01$) in cattle fed high dietary sulfur than in those fed moderate dietary sulfur (Figure 1). This may be attributable to two factors: lower ($P<0.05$) volatile fatty acid concentrations (Figure 2) resulting from less feed intake and greater ($P<0.01$) ruminal ammonia concentrations (Figure 3).

There were interactions ($P<0.05$) between grain processing method and dietary sulfur levels with respect to acetate and propionate concentrations. Steers fed dry-rolled corn with high dietary sulfur had the least acetate concentration, but sulfur level did not affect acetate concentration when steam-flaked corn was fed. Conversely, propionate concentration was least in cattle fed steam-flaked corn with high sulfur but greatest in cattle fed steam-flaked corn with low sulfur. Despite this interaction, there was also a substantial impact of sulfur level ($P<0.01$) on propionate concentration. Steers fed high-sulfur diets had a lower ($P=0.02$) propionate concentration than steers fed moderate-sulfur diets.

Data from a finishing study in which animals were fed the same diets used this study (Table 1) indicated that cattle fed high-sulfur diets had greater ruminal concentrations of hydrogen sulfide than cattle fed moderate-sulfur diets. High dietary sulfur level negatively affected propionate concentration. Thus, it is conceivable that some free hydrogen ions that could be used to produce propionate were shifted to production of hydrogen sulfide.

Steers fed high-sulfur diets had greater ($P<0.01$) ruminal ammonia concentrations than steers fed low-sulfur diets, especially when dry-rolled corn was fed (interaction, $P<0.01$). Protein-digesting bacteria likely grew better at greater pH. Previous studies

showed that cattle fed dry-rolled corn had greater ruminal pH than cattle fed steam-flaked corn. It is probable that feeding high dietary sulfur either enhanced ruminal protein degradation or reduced bacterial uptake of recycled urea nitrogen.

Implications

Feeding distillers grains containing high levels of dietary sulfur decreased intake and altered ruminal fermentation and diet digestibility. This may have reduced energetic efficiency of the diet by producing more undesirable hydrogen sulfide and less propionate. Overall, this could have compromised growth performance of feedlot cattle.

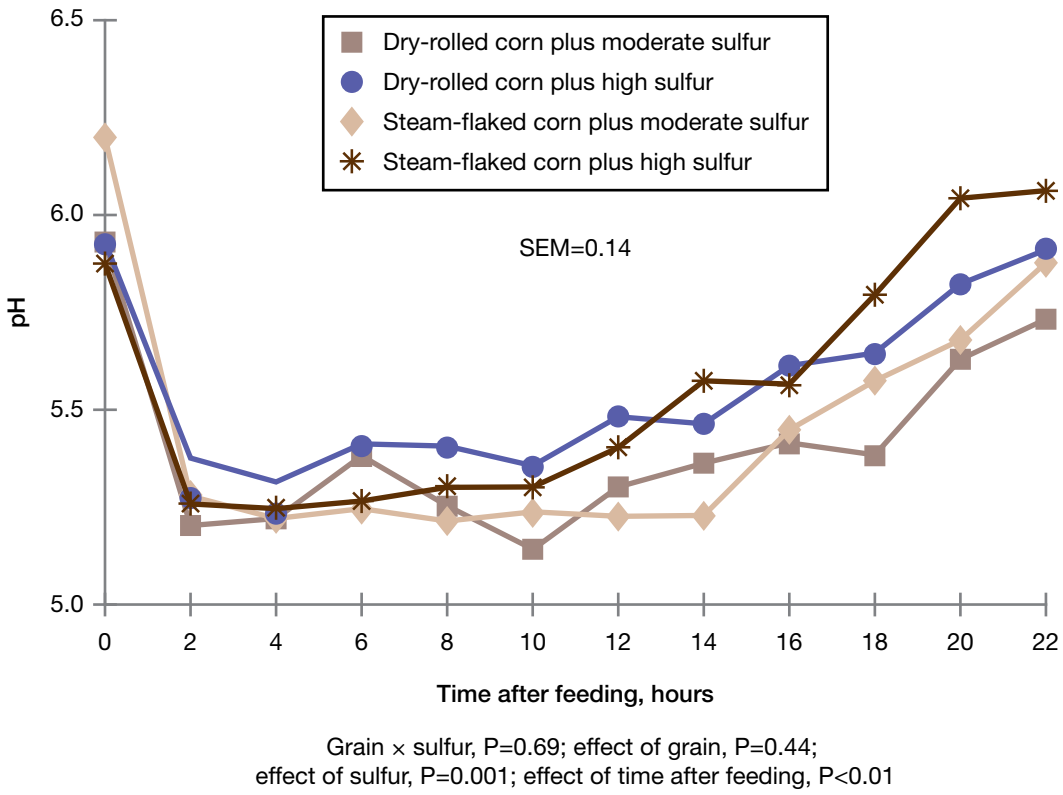
Table 1. Composition of finishing diets based on steam-flaked corn or dry-rolled corn containing dried distillers grains with moderate or high sulfur concentrations

	Dry-rolled corn		Steam-flaked corn	
Item	Moderate sulfur	High sulfur	Moderate sulfur	High sulfur
Ingredients, % dry matter				
Steam-flaked corn	---	---	51.1	50.6
Dry-rolled corn	51.3	50.8	---	---
Dried distillers grains with high sulfur	---	30.4	---	30.6
Dried distillers grains with low sulfur	29.9	---	30.1	---
Alfalfa hay	8.6	8.6	8.6	8.6
Cane molasses	6.2	6.2	6.2	6.2
Supplement[1]	4.0	4.0	4.0	4.0
Analyzed composition, %				
Dry matter	87.2	86.6	84.1	83.4
Starch	38.3	38.4	38.8	38.9
Crude protein	15.6	15.4	15.2	15.0
Crude fat	5.8	5.8	5.8	5.8
Neutral detergent fiber	12.6	12.2	12.5	12.1
Calcium	0.7	0.7	0.7	0.7
Phosphorus	0.4	0.4	0.4	0.4
Potassium	0.7	0.7	0.7	0.7
Sulfur	0.42	0.65	0.42	0.65

[1] Formulated to provide 300 mg/day Rumensin and 90 mg/day Tylan (Elanco Animal Health, Greenfield, IN); 1,000 IU/lb vitamin A; 10 IU/lb vitamin E; 10 ppm copper; 60 ppm zinc; 60 ppm manganese; 0.5 ppm iodine; 0.25 ppm selenium; and 0.15 ppm cobalt.

Table 2. Digestion characteristics in ruminally cannulated crossbred steers fed steam-flaked corn or dry-rolled corn diets containing dried distillers grains with moderate or high sulfur concentrations

	Dry-rolled corn		Steam-flaked corn			P-values		
Item	Moderate sulfur	High sulfur	Moderate sulfur	High sulfur	SEM	Grain processing	Sulfur level	Grain × Sulfur level
No. of steers	6	5	6	5				
Feed intake, lb/day								
Dry matter	14.82	13.07	15.11	13.71	2.00	0.59	0.08	0.85
Organic matter	13.97	12.32	14.30	12.96	1.89	0.55	0.08	0.85
Starch	5.68	5.02	5.87	5.34	0.77	0.46	0.08	0.85
Neutral detergent fiber	1.99	1.63	1.91	1.62	0.28	0.77	0.04	0.77
Crude protein	2.31	2.01	2.30	2.06	0.31	0.95	0.06	0.85
Crude fat	0.86	0.76	0.88	0.80	0.12	0.59	0.08	0.86
Apparent total tract digestibility, %								
Dry matter	70.1	76.1	76.6	79.9	2.1	0.03	0.04	0.59
Organic matter	73.5	78.5	78.8	81.8	2.1	0.06	0.08	0.61
Starch	90.2	96.4	99.2	99.6	2.1	0.02	0.14	0.19
Neutral detergent fiber	15.3	21.3	18.4	27.3	6.1	0.37	0.16	0.75
Crude protein	76.4	77.1	77.6	81.9	2.0	0.13	0.18	0.32
Crude fat	91.6	92.4	90.6	94.3	0.8	0.08	0.03	0.14



Grain × sulfur, P=0.69; effect of grain, P=0.44;
effect of sulfur, P=0.001; effect of time after feeding, P<0.01

Figure 1. Ruminal pH in cannulated crossbred steers fed finishing diets based on steam-flaked corn or dry-rolled corn containing dried distillers grains with moderate or high sulfur concentrations.

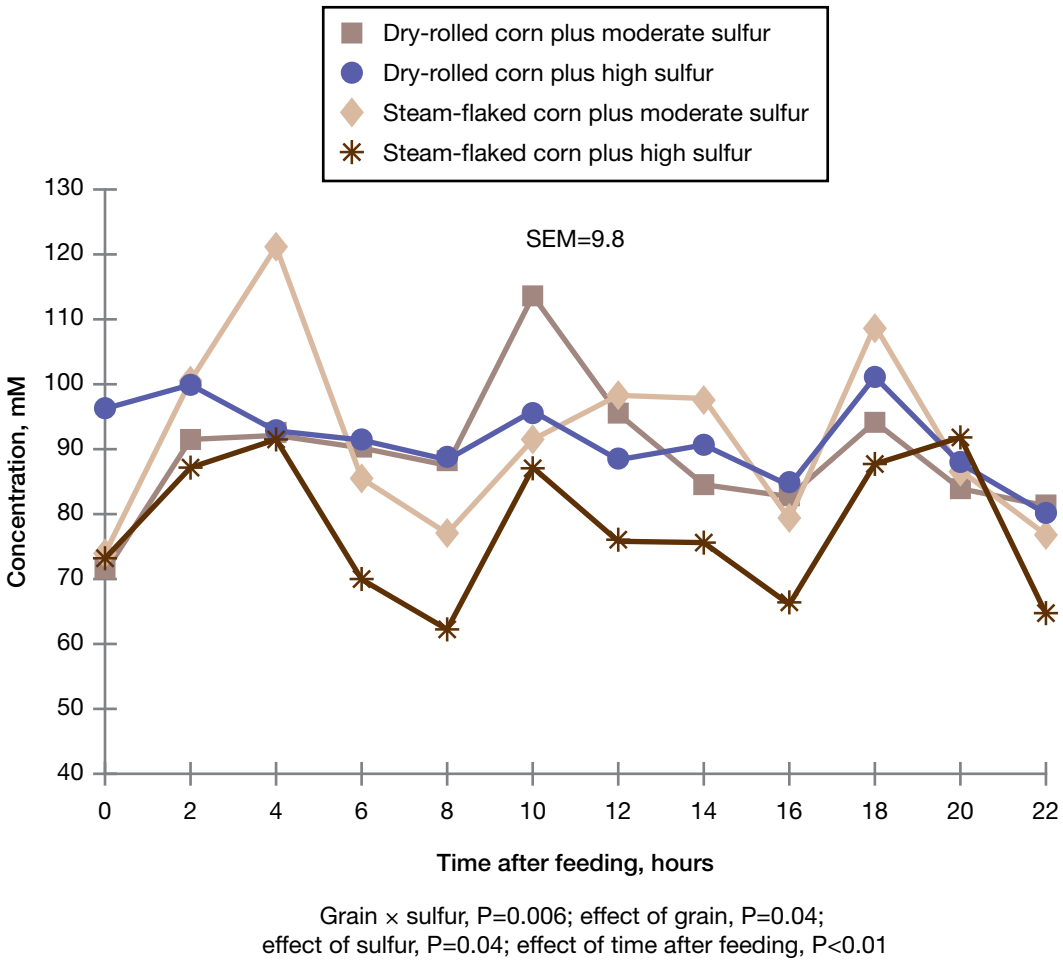


Figure 2. Total volatile fatty acid concentrations in cannulated crossbred steers fed finishing diets based on steam-flaked corn or dry-rolled corn containing dried distillers grains with moderate or high sulfur concentrations.

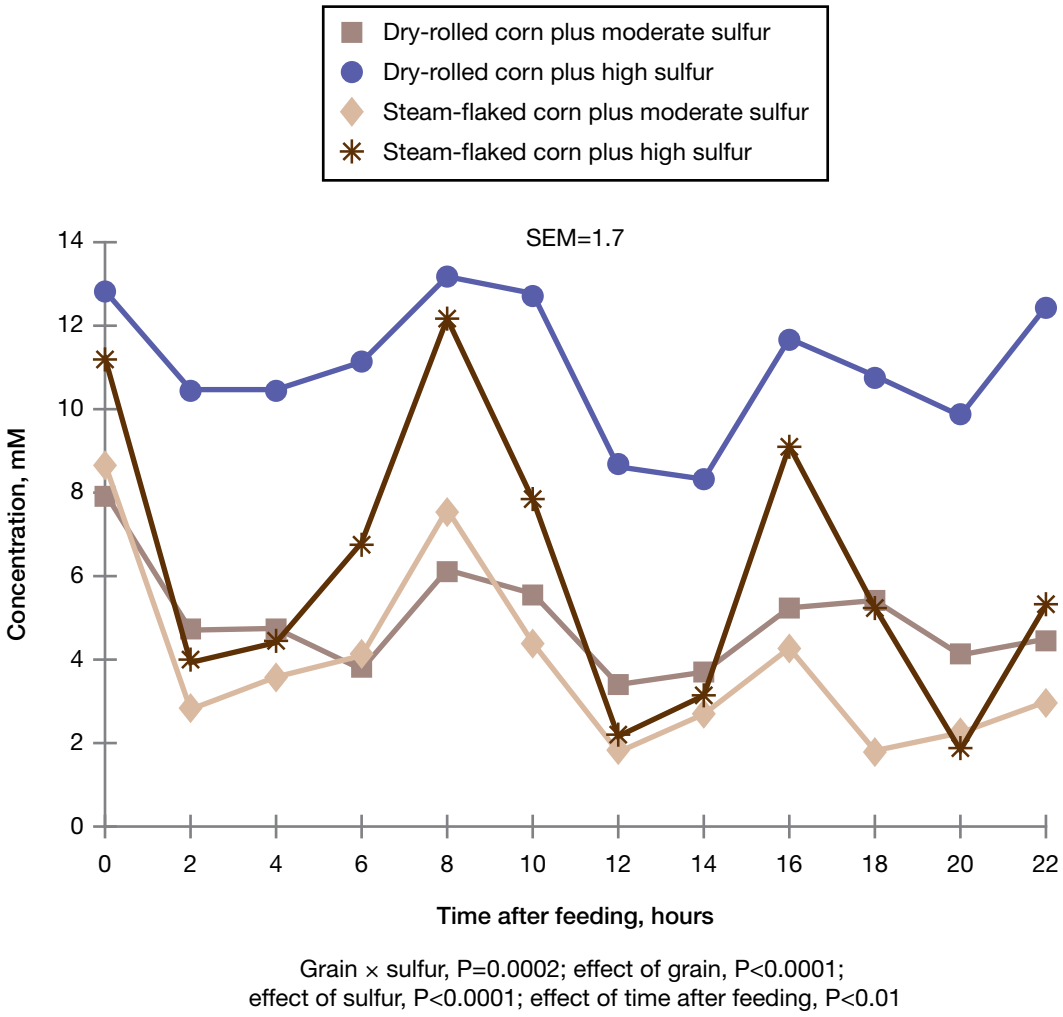


Figure 3. Ammonia concentrations in cannulated crossbred steers fed finishing diets based on steam-flaked corn or dry-rolled corn containing dried distillers grains with moderate or high sulfur concentrations.

High Sulfur Content in Distillers Grains with Solubles May Be Deleterious to Beef Steer Performance and Carcass Quality

S. Uwituze, G.L. Parsons, C.J. Schneider, K.K. Karges[1], M.L. Gibson[1], L.C. Hollis, and J.S. Drouillard

Introduction

Distillers grains with solubles are becoming an increasingly important staple of cattle diets because of rapid expansion of the fuel ethanol industry. Sulfuric acid often is used in ethanol production processes to clean and control the pH of fermenters. Consequently, distillers grains with solubles can occasionally contain high sulfur concentrations. Within the rumen, sulfur is converted to hydrogen sulfide gas by ruminal microbes. Hydrogen sulfide is eructated from the rumen and subsequently aspirated into the lungs; excess amounts of hydrogen sulfide can cause polioencephalomalacia (brainers). Polioencephalomalacia is characterized by increased respiration, decreased feed intake, listlessness, muscular incoordination, progressive blindness, and necrosis of brain tissue. Elevated sulfur levels also may have deleterious effects on cattle growth performance and carcass characteristics. The objective of this study was to evaluate effects of sulfur content in dried distillers grains with solubles on ruminal gas concentrations, feedlot performance, and carcass characteristics of finishing steers fed diets based on steam-flaked corn or dry-rolled corn.

Experimental Procedures

Crossbred yearling steers (n = 80; 904 ± 6 lb initial weight) were fed diets based on steam-flaked or dry-rolled corn. All diets included 30% dried distillers grains with solubles (dry matter basis) and contained (dry matter basis) a moderate (0.42%) or high (0.65%) dietary sulfur level. The four experimental diets were: dry-rolled corn with high sulfur, dry-rolled corn with moderate sulfur, steam-flaked corn with high sulfur, and steam-flaked corn with moderate sulfur. The 0.42% sulfur level was obtained from the sulfur content of ration ingredients, and the 0.65% level was attained by adding sulfuric acid to dried distillers grains with solubles before mixing rations.

On arrival at the feedlot, steers were allowed free access to ground alfalfa hay and municipal water. One day after arrival, steers were individually weighed and implanted with Revalor 200 (Intervet, Inc., Millsboro, DE) and received Phoenectin pour-on IVX (Animal Health, St. Joseph, MO), Bovishield – 4 (Pfizer Inc., New York, NY), and Fortress – 7 (Pfizer Inc.). Steers were assigned randomly to experimental diets and pens within weight block. Steers were housed in one of four barns containing 20 individual partially covered concrete pens per barn; each pen measured 5 × 19.8 ft. Steers were moved up stepwise to the finishing diets (Table 1) through four gradual step-up diets, each fed for 5 days. Animals were evaluated daily for symptoms of polioencephalomalacia. On day 28 of the study, one animal fed steam-flaked corn with high sulfur presented symptoms of polioencephalomalacia including blindness. This animal was

[1] Dakota Gold Research Association, Sioux Falls, SD.

removed from the study and treated. No other animals experienced any health-related problems. Three animals were fed the wrong diet for approximately 1 week as a result of a clerical error. Data from all three misfed animals and the sick animal were excluded from analysis.

On days 69, 83, 90, 97, and 104, ruminal gas samples were collected from ruminal gas cap and analyzed for hydrogen sulfide concentrations. Steers were weighed every 14 days, and final live weights were measured on day 140 before steers were shipped to a commercial abattoir in Holcomb, KS. Carcass weights and incidence of liver abscesses were recorded at slaughter, and other carcass characteristics were measured following a 48-hour chill.

Results and Discussion

There were no interactions ($P \geq 0.15$) between grain processing method and dietary sulfur level for growth performance or carcass characteristics. Feeding high levels of sulfur decreased dry matter intake ($P < 0.01$), average daily gain ($P < 0.01$), and final body weight ($P < 0.01$) but had no effect ($P = 0.25$) on feed efficiency (Table 2). Steers fed diets containing high sulfur had 9% less dry matter intake and gained 13% less daily compared with their counterparts fed diets with moderate sulfur. Steers fed high sulfur were 4.3% lighter than steers fed moderate sulfur.

Grain processing method had no effect ($P = 0.30$) on average daily gain, but steers fed dry-rolled corn had greater ($P < 0.01$) dry matter intake than steers fed steam-flaked corn. Conversely, cattle fed steam-flaked corn tended ($P = 0.07$) to have better feed efficiency, and diets based on steam-flaked corn provided more ($P < 0.01$) dietary net energy for maintenance and net energy for gain than diets based on dry-rolled corn. High sulfur decreased ($P < 0.01$) hot carcass weight by 4.3%; decreased kidney, pelvic, and heart fat by 16.2% ($P < 0.01$); and tended ($P = 0.13$) to decrease marbling score (Table 2). Cattle fed high sulfur yielded carcasses with lower ($P = 0.04$) yield grades than carcasses from cattle fed moderate sulfur content. There were no differences among treatments with respect to dressing percentage, fat thickness over the 12th rib, ribeye area, liver abscesses, or USDA quality grades (Table 2). Grain processing method had no effects ($P > 0.15$) on carcass characteristics.

Cattle fed high sulfur had greater ($P < 0.01$) concentrations of hydrogen sulfide in the ruminal gas cap than cattle fed moderate sulfur (Figure 1), and hydrogen sulfide was inversely related ($P < 0.01$) to average daily gain ($r = -0.42$), dry matter intake ($r = -0.43$), and feed efficiency ($r = -0.20$). Production of hydrogen sulfide may compromise energy efficiency, resulting in poorer growth performance and lower marbling scores. Additionally, hydrogen sulfide gas is a causative factor in sulfur-induced polioencephalomalacia.

Implications

Feeding distillers grains that are high in dietary sulfur may increase the concentration of hydrogen sulfide in the ruminal gas cap, which may decrease intake and compromise growth performance, carcass characteristics, and health of feedlot cattle regardless of the grain processing method used.

Table 1. Composition of finishing diets based on steam-flaked corn or dry-rolled corn containing dried distillers grains with moderate or high dietary sulfur (S) concentrations

	Dry-rolled corn		Steam-flaked corn	
Item	0.42% S	0.65% S	0.42% S	0.65% S
Ingredients, % of dry matter				
Steam-flaked corn	---	---	51.1	50.6
Dry-rolled corn	51.3	50.8	---	---
Dried distillers grains with high sulfur	---	30.4	---	30.6
Dried distillers grains with moderate sulfur	29.9	---	30.1	---
Alfalfa hay	8.6	8.6	8.6	8.6
Cane molasses	6.2	6.2	6.2	6.2
Supplement[1, 2]	4.0	4.0	4.0	4.0
Analyzed composition, % of dry matter				
Dry matter	87.2	86.6	86.5	83.4
Starch	38.3	38.4	38.8	38.9
Crude protein	15.6	15.4	15.2	15.0
Crude fat	5.8	5.8	5.8	5.8
Neutral detergent fiber	12.6	12.2	12.5	12.1
Calcium	0.7	0.7	0.7	0.7
Phosphorus	0.4	0.4	0.4	0.4
Potassium	0.7	0.7	0.7	0.7
Sulfur	0.42	0.65	0.42	0.65

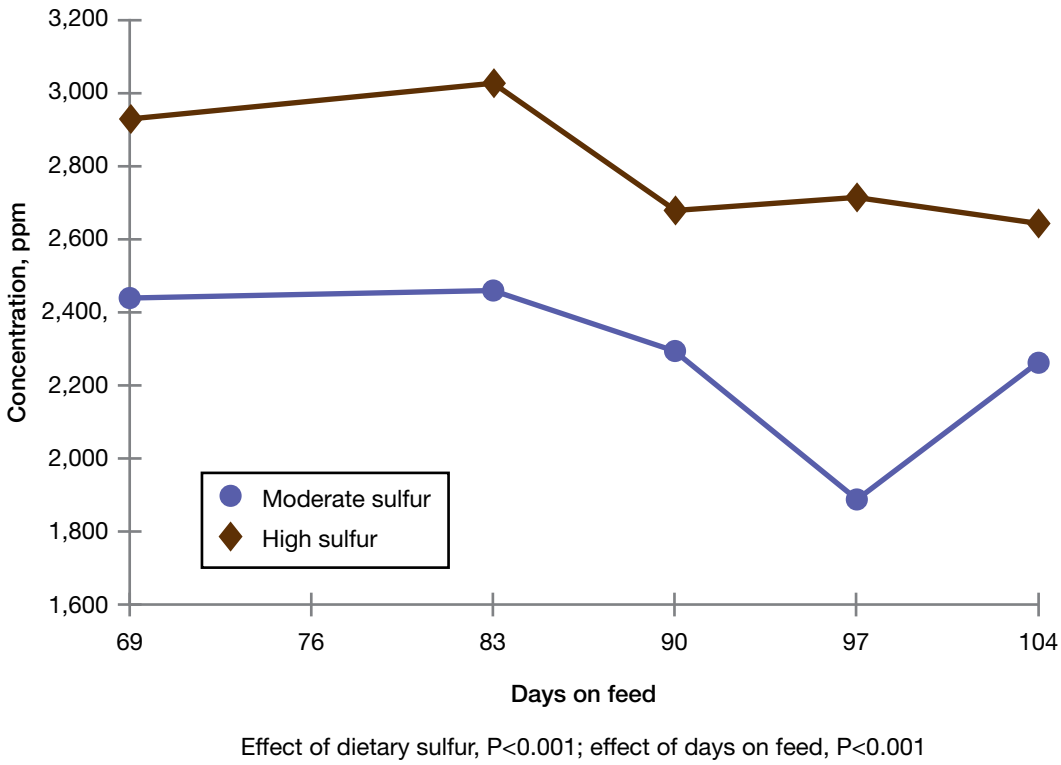
[1] Formulated to provide 300 mg/day Rumensin (Elanco Animal Health, Greenfield, IN); 90 mg/day Tylan (Elanco Animal Health); 1,000 IU/lb vitamin A; 10 IU/lb vitamin E; 10 ppm copper; 60 ppm zinc; 60 ppm manganese; 0.5 ppm iodine; 0.25 ppm selenium; and 0.15 ppm cobalt.

[2] Zilmax (Intervet/Schering-Plough Animal Health, Millsboro, DE) was fed the last 21 days at 7.56 g/ton (dry matter basis) with a 3-day withdrawal period.

Table 2. Growth performance and carcass characteristics of steers fed finishing diets based on steam-flaked corn or dry-rolled corn containing dried distillers grains with moderate or high dietary sulfur (S) concentrations

	Dry-rolled corn		Steam-flaked corn			P-values[1]		
	0.42% S	0.65% S	0.42% S	0.65% S	SEM	G	S	G × S
Number of steers	18	19	20	19	---	---	---	---
Growth performance								
Days on feed	140	140	140	140	---	---	---	---
Initial weight, lb	903	902	905	904	6	0.15	0.43	0.59
Final weight[2], lb	1409	1334	1374	1330	24	0.34	<0.01	0.46
Average daily gain, lb/day	3.61	3.09	3.35	3.04	0.16	0.30	<0.01	0.48
Dry matter intake, lb/day	23.5	21.6	21.3	19.2	0.59	<0.01	<0.01	0.97
Feed:Gain	6.41	6.94	6.33	6.29	0.28	0.07	0.25	0.27
Diet NE_m, Mcal/100 lb	103.4	100.7	109.8	109.3	2.3	<0.01	0.50	0.63
Diet NE_g, Mcal/100 lb	72.1	69.9	77.6	77.6	1.8	<0.01	0.50	0.61
Carcass characteristics								
Hot carcass weight, lb	896	847	873	845	16	0.34	<0.01	0.45
Dressed yield, %	66.1	65.4	65.1	65.5	0.40	0.19	0.61	0.15
Ribeye area, sq. in.	14.4	14.3	14.8	14.6	0.32	0.19	0.51	0.91
12th rib fat, in.	0.64	0.54	0.40	0.58	0.18	0.58	0.82	0.41
Kidney, pelvic, and heart fat, %	1.88	1.45	1.76	1.60	0.12	0.82	<0.01	0.24
Liver abscess[3], %	5.9	0	15.0	0	5.4	---	---	---
Marbling score[4]	SL^{94}	SL^{82}	Sm^{3}	SL^{69}	16	0.91	0.13	0.48
Yield grade	2.34	2.00	2.15	1.79	0.19	0.23	0.04	0.95
Choice, %	41.2	31.6	50.0	31.6	12.0	0.70	0.23	0.70
Select, %	52.9	57.9	25	57.9	11.9	0.23	0.10	0.23
Standard, %	5.9	10.5	25	10.5	8.3	0.23	0.54	0.23

[1] G, Effect of grain processing method; S, Effect of dietary sulfur level; G × S, interaction between grain processing method and dietary sulfur level.
[2] Final weight was calculated by dividing carcass weight by a common dressing percentage (63.5%).
[3] Chi-square test = no treatment effect (P=0.15).
[4] SL, Slight; Sm, Small. Numbers indicate degrees of marbling (0 to 99) within a marbling score.



Effect of dietary sulfur, P<0.001; effect of days on feed, P<0.001

Figure 1. Effect of days on feed on ruminal hydrogen sulfide concentration in steers fed finishing diets containing dried distillers grains with moderate or high dietary sulfur concentrations.

FlaxLic Supplementation Improves Growth Performance of Angus Bulls

A.C. Pesta and J.S. Drouillard

Introduction

Nutrition can affect bull fertility. Omega-3 fatty acids such as alpha linolenic, eicosapentaenoic, and docosahexaenoic acids can affect motility and morphology of sperm. Flaxseed is an excellent source of alpha linolenic acid and has been shown to increase tissue concentrations of both alpha linolenic acid and eicosapentaenoic acid, which are involved in synthesis of important reproductive hormones. Flax can be difficult to transport, process, and store, but the FlaxLic block (New Generation Feeds, Belle Fourche, SD) is stable and easy to handle, contains high levels of omega-3 fatty acids, and may be a useful supplement for developing beef bulls. In a previous study at Kansas State University, feeding FlaxLic blocks to developing bulls for 61 days prior to breeding soundness examinations increased rate of gain and percentages of motile and normal sperm.

The FlaxLic block is a high-density, low-moisture product that resists heat and humidity. Blocks of this type typically are made with molasses. One of our study objectives was to determine whether corn steep liquor, when combined with molasses and subjected to high process temperatures (248°F to 284°F), could partially substitute for molasses with no significant change in block integrity or animal performance.

Experimental Procedures

Yearling Angus bulls (n = 120; initial body weight = 1,115 lb) were assigned randomly to three treatment groups: control (forage-based diet), FlaxLic (control diet with free access to FlaxLic), and corn steep block (control diet with free access to an alternative block formulation in which a portion of the molasses was replaced by corn steep liquor).

The control diet consisted of 61% chopped hay, 26% corn silage, 9% wheat middlings, and 3% supplement on a dry matter basis. Bulls were fed free choice for 70 days. Daily feed consumption was monitored using the GrowSafe electronic monitoring system (GrowSafe Systems, Ltd., Airdrie, Alberta, Canada). The 60-lb supplement blocks for the FlaxLic and corn steep block treatments were placed in GrowSafe feeders for the designated pen. One pen of 40 bulls was used for each treatment.

Identification number, treatment allocation, initial body weight, and final body weight for each bull were recorded. Feed and block consumption were also recorded. Blood samples were drawn from all bulls on day 14 of the trial and again at the end of the trial. Blood serum was analyzed via gas chromatography to determine long-chain fatty acid concentrations.

A veterinarian performed breeding soundness examinations on a randomly selected population of bulls from each treatment at the beginning and end of the trial. Semen

samples were evaluated for sperm motility, sperm morphology, and long-chain fatty acid composition.

Results and Discussion

Supplementation with FlaxLic and the corn steep block increased serum concentrations of alpha linolenic acid (Table 1). Concentrations of alpha linolenic acid and arachidonic acid in semen were decreased ($P<0.05$) by FlaxLic but not by the corn steep block compared with the control (Table 1). Excess arachidonic acid can lead to oxidation and loss of sperm motility. We speculated that the observed shift in fatty acid concentration may have improved semen quality. Conversely, supplementation with FlaxLic and the corn steep block had no effect on the percentages of normal or motile sperm compared with the control diet (Table 2). Similarly, breeding soundness examination results were similar among treatment groups.

The FlaxLic treatment increased ($P<0.05$) average daily gain (Table 3) and improved ($P<0.05$) gain efficiency compared with the control and corn steep block treatments. Differences in performance between the block formulations indicated that certain ingredients, such as corn steep liquor, may be unsuitable for use in processes that use high temperatures, such as block manufacturing.

Implications

Feeding FlaxLic or the corn steep block did not alter breeding soundness in spite of increased amounts of key fatty acids in semen. However, FlaxLic increased growth performance and efficiency. Substituting 15% corn steep liquor for molasses had a negative effect on nutritional value of the corn steep block. We speculated that corn steep liquor proteins may have been damaged when combined with sugars and subjected to high processing temperatures.

Table 1. Serum and semen fatty acid concentrations in yearling Angus bulls fed a forage-based diet (Control) and supplemented with FlaxLic or a corn steep liquor block

Fatty acid, µg/g	Control	FlaxLic	Corn steep block	SEM
Blood serum fatty acids				
Linoleic acid (omega-6)	479.7	486.7	455.1	17.52
Alpha linolenic acid (omega-3)	126.4[a]	146.8[b]	140.3[ab]	5.1
Arachidonic acid (omega-6)	4.75	4.86	4.55	0.61
Eicosapentaenoic acid (omega-3)	5.69	6.39	7.14	0.66
Docosahexaenoic acid (omega-3)	5.69	5.54	5.02	0.45
Total fatty acids	1237	1276	1212	37
Semen fatty acids				
Linoleic acid (omega-6)	28.48	37.25	34.62	3.68
Linolenic acid (omega-3)	11.93[a]	7.28[b]	8.86[ab]	1.08
Arachidonic acid (omega-6)	4.20[a]	2.36[b]	3.08[ab]	0.52
Eicosapentaenoic acid (omega-3)	1.94	2.08	2.13	0.52
Docosahexaenoic acid (omega-3)	213.4	163.1	181.2	22.9
Total fatty acids	489.6	419.9	437.8	39.6

Means in a row with common superscript letters are not different (P>0.05).

Table 2. Breeding soundness and semen attributes of yearling Angus bulls fed a forage-based diet (Control) and supplemented with FlaxLic or a corn steep liquor block

Item	Control	FlaxLic	Corn steep block	SEM
Sperm motility, %	51.3	51.9	50.5	2.16
Normal sperm, %	79.7	80.7	79.5	1.15

Table 3. Performance data of yearling Angus bulls fed a forage-based diet (Control) and supplemented with FlaxLic or a corn steep liquor block

Item	Control	FlaxLic	Corn steep block	SEM
Dry matter intake, lb	26.8[a]	25.7[b]	25.52[b]	0.17
Daily gain, lb	2.93[a]	3.27[b]	2.73[a]	0.06
Feed:gain	9.16[a]	7.91[b]	9.14[a]	0.22

Means in a row with common superscript letters are not different (P>0.05).

Effects of *Morinda citrifolia* on Growth Performance and Health of High-Risk Calves

L.R. Hibbard, D A. Blasi, R.G. Godbee, M.P. Epp, B. Oleen, and KC Olson

Introduction

Bovine respiratory disease continues to be the most costly disease affecting productivity and profitability in the stocker segment. Long-acting injectable antimicrobials are presently used to reduce the incidence and severity of bovine respiratory disease. However, future use of antimicrobial treatment may be significantly curtailed in light of an increasing negative perception of antibiotic usage in food animals by consumers and governmental agencies. Consequently, preconditioning and enhanced nutrition programs that may include nutraceuticals could become more prevalent. MorindaMax (Morinda International, Provo, UT) is a natural product manufactured from the *Morinda citrifolia* fruit (i.e., Noni). Published literature suggests this plant extract has a broad range of immune-enhancing effects, including antibacterial, anti-inflammatory, analgesic, antioxidant, and anti-tumor effects.

Experimental Procedures

A 42-day receiving study was conducted at the Kansas State University Beef Stocker Unit during March 2009 to evaluate dry matter intake and health parameters of high-risk stocker calves receiving *Morinda citrifolia*. All cattle were sourced from an order buyer in Tennessee, and cattle were received over 3 consecutive days (one load per day). Upon arrival, all calves were weighed, tagged, mass medicated with Excede (Pfizer Animal Health, New York, NY) at 1.5 mL/100 lb body weight and palpated for gender (bull or steer). Calves were then given ad libitum access to long-stem prairie hay and water overnight. The following day, calves were vaccinated against clostridial and respiratory diseases and dewormed, and bulls were surgically castrated. Each load was blocked by arrival date and randomly assigned to one of three treatments for a total of 24 pens. Castrated bulls were equally distributed among the eight pens within each load. Cattle were weighed and revaccinated 14 days after initial processing and weighed again following the 42-day feeding period. Calves were stepped up using three sequential growing diets ranging from 29% to 36.5% concentrate. Diets were fed twice daily, and one of the following treatments was top-dressed on the delivered feed for 10 days starting on day 2 after arrival: water at 4 oz/head per day (control), MorindaMax at 2 oz/head per day (low), or MorindaMax at 4 oz/head per day (high).

Cattle were observed daily for symptoms of bovine respiratory disease and injury (scrotal infections, lameness, etc.) by personnel blinded to treatments. Following a moratorium of 3 days post-metaphylaxis, calves were pulled and treated for respiratory disease as needed. Calves determined to need treatment were given Baytril (Bayer Animal Health, Shawnee Mission, KS) at 5 mL/100 lb body weight as a first treatment, Nuflor (Intervet/Schering-Plough Animal Health, Millsboro, DE) at 6 mL/100 lb body weight as a second treatment, and Bio-Mycin 200 (Boehringer Ingelheim, Ridgefield, CT) at 4.5 mL/100 lb body weight as a third treatment, if needed.

Bunks were checked twice daily, and feed was delivered in amounts sufficient to result in slick bunks both morning and afternoon. Calves were fed their respective diets at approximately 7:00 a.m. and 3:00 p.m. daily for 55 days.

Daily dry matter intake, gains, and feed efficiencies were determined for each pen of calves. Health records were used to determine the number of animals treated and percentage of death loss.

Performance and health data were analyzed by using the random effects MIXED model procedure of SAS (SAS Institute, Inc., Cary, NC). Data were arranged in a randomized incomplete block design; pen served as the experimental unit for growth and health outcomes as affected by treatment. In the model, fixed effects were treatment, load, and gender, and random effects were load × treatment, pen, and animal ID. Percentages of bovine respiratory disease morbidity and mortality were tested by using the Chi Square test, and differences were declared significant at $P<0.05$.

Results and Discussion

Performance and health results are presented in Table 1. Overall, all cattle performed exceedingly well, and there was little to no health challenge from bovine respiratory disease. There were no significant differences between treatments in the percentage of steers treated once, twice, or three times for bovine respiratory disease ($P>0.05$). There were no significant differences in daily gain ($P=0.81$), daily dry matter intake ($P=0.34$), or feed efficiency ($P=0.80$) between the three treatments. Although there was a slight numerical increase in daily feed intake for MorindaMax treatment groups (low and high) relative to the control treatment, there were only subtle numerical differences in average daily gain and feed efficiency between the three treatment groups.

Implications

The low level of bovine respiratory disease (as revealed by morbidity and mortality rates) was likely not sufficient to adequately test this feed additive.

Table 1. Effect of MorindaMax on growth performance and health of calves

Item	Control[1]	Low	High	SEM[2]	P-value
Pens	8	8	8	---	---
Animals on trial	92	94	94	---	---
Days on feed	42	42	42	---	---
Initial weight, lb	488	486	486	---	---
Final shrunk weight, lb	617	610	614	---	---
Day 1 to 13					
Dry matter intake, lb/day	10.3	10.2	10.5	0.29	0.56
Daily gain, lb/day	3.11	3.12	3.23	0.14	0.81
Feed efficiency	3.21	3.22	3.12	0.13	0.86
Day 1 to 27					
Dry matter intake, lb/day	13.2	13.2	13.6	0.29	0.48
Daily gain, lb/day	3.35	3.35	3.43	0.14	0.79
Feed efficiency	3.78	3.79	3.79	0.12	0.99
Day 1 to 42					
Dry matter intake, lb/day	15.2	15.0	15.7	0.32	0.34
Daily gain, lb/day	3.52	3.39	3.48	0.14	0.81
Feed efficiency	4.18	4.26	4.25	0.10	0.80
Health status					
Morbidity by treatment group, % of experimental treatment[3]					
First treatment, %	10.64	12.77	8.51	---	0.68
Second treatment, %	3.19	8.51	3.19	---	0.19
Third treatment, %	1.06	3.19	0	---	0.33
Miscellaneous morbidity, % of experimental treatment	5.32	3.19	2.13	---	0.62
Miscellaneous morbidity, retreatment, %	0	2.13	0	---	0.33
Mortality, %	0	0	0	---	---

[1] Control, basal diet with 4 oz water per day applied for each animal; Low, MorindaMax at 2 oz/head per day top-dressed on feed; High, MorindaMax at 4 oz/head per day top-dressed on feed. All treatments applied on days 1 to 10.

[2] Standard errors of the least squares mean, n = 11 or 12.

[3] Morbidity data reflect respiratory data only. Miscellaneous morbidity data reflects infected scrotums, pink eye, skeletal problems, or any other medical issue needing treatment. No mortality was observed.

Effects of Feeding Low Levels of Crude Glycerin With or Without Other By-Products on Performance and Carcass Characteristics of Feedlot Heifers[1]

C.J. Schneider, G.L. Parsons, K.A. Miller, L.K. Thompson, and J.S. Drouillard

Introduction

Expansion of the renewable fuels industries has increased availability of by-products that are well suited for use as cattle feed. Glycerin is among the principal by-products of biodiesel production, comprising approximately 10% (by weight) of the soybean oil that is used to manufacture soy-based diesel fuel. Our previous research evaluated effects of including between 0% and 16% glycerin in flaked-corn finishing diets and revealed that optimal growth performance was achieved with 2% glycerin addition. Our laboratory experiments have suggested that even lower levels of glycerin may be effective at stimulating digestion. Therefore, the objective of this study was to evaluate effects of low levels of glycerin in the diet on performance and carcass characteristics of finishing cattle. Furthermore, because distillers grains and other by-products are increasingly common in feedlot rations, we opted to evaluate glycerin in corn-based finishing diets as well as in diets that consisted of a combination of corn grain, distillers grains, and soybean hulls.

Experimental Procedures

Crossbred heifers (n = 295; 941 ± 19.5 lb) were fed grain-based finishing diets containing 0%, 0.5%, or 2% crude glycerin or diets containing by-products with 0% or 2% crude glycerin. In by-product-based finishing diets, 25% soybean hulls and 15% wet distillers grains replaced corn and soybean meal. Diets primarily consisted of dry-rolled corn for the first 37 days of the feeding period and then gradually transitioned to diets based on steam-flaked corn. All diets contained 3% alfalfa hay and 6% corn silage and provided 300 mg Rumensin (Elanco Animal Health, Greenfield, IN), 90 mg Tylan (Elanco Animal Health), and 0.5 mg MGA (Pfizer Animal Health, New York, NY) per heifer daily. Heifers also were fed Zilmax (Intervet/Schering-Plough Animal Health, Millsboro, DE) at 7.56 g/ton for 21 days before harvest.

Incoming cattle were allowed free access to ground alfalfa hay and were processed within 24 hours of arrival. During processing, heifers were identified with an individual ear tag, individually weighed, implanted with Revalor 200 (Intervet/Schering-Plough), vaccinated with Bovi-Shield-IV and Fortress-7 (Pfizer Animal Health), injected with Micotil (Elanco Animal Health), and drenched with Safe-Guard (Intervet/Schering-Plough) for internal parasites. Four weeks after initial processing, cattle were revaccinated with Bovi-Shield-IV. Prior to initiation of finishing treatments, cattle were fed a series of step-up rations to gradually adapt them to their final finishing rations (Table 1).

[1] Funding provided by the Kansas Soybean Commission Checkoff.

Cattle were stratified by body weight and randomly assigned (within strata) to 40 pens containing seven to eight animals per pen; there were eight pens per treatment. Pens were partially covered and had solid concrete surfaces (392 ft^2). Feed bunks provided no less than 12 linear in. of bunk space per animal, and fence line water fountains were shared between two adjacent feedlot pens.

Weight of each pen of heifers was determined at the beginning of the experiment and immediately prior to slaughter. After 89 days on feed, cattle were transported to a commercial abattoir in Holcomb, KS, and harvested. Carcass weights and incidence of liver abscesses were recorded on the day of harvest, and USDA quality grade; USDA yield grade; marbling; 12th rib fat thickness; ribeye area; and kidney, pelvic, and heart fat were recorded after a 48-hour chilling period.

Results and Discussion

Addition of glycerin to grain-based diets caused a linear ($P=0.04$) decrease in dry matter intake (Table 2). However, there were no differences in dry matter intake between the 0.5% and 2% glycerin levels in grain-based diets. Feeding both 0.5% and 2% glycerin in grain-based diets tended to cause a 3.5% decrease (0.5%, $P=0.06$; 2%, $P=0.07$) in daily dry matter intake compared with the control steam-flaked corn diet. Similar glycerin effects on dry matter intake were not observed when glycerin was fed in a by-product diet (Table 2). Feeding 2% glycerin in a by-product diet increase ($P<0.01$) daily dry matter intake 11.1% compared with feeding 2% glycerin in a grain-based diet. The addition of by-products without glycerin increased ($P<0.01$) daily dry matter intake by 5.3% compared with the control steam-flaked corn diet. Collectively, the addition of by-products, with or without glycerin, increased ($P<0.01$) dry matter intake compared with grain-based diets (Table 2). The carcass-adjusted feed-to-gain ratio also was poorer ($P<0.01$) as a result of adding by-products to the diet. There were no differences ($P>0.2$) among treatments with respect to average daily gain, feed-to-gain ratio, and final body weight.

Glycerin added to grain-based diets had a linear tendency ($P=0.058$ for overall F test and $P=0.03$ for contrast) to decrease the percentage of carcasses that graded USDA Choice or higher (Table 2). Consequently, glycerin fed in grain-based diets caused a linear increase ($P=0.02$) in the percentage of carcasses that graded USDA Select. Similarly, the addition of by-products had a tendency ($P=0.058$ for overall F test and $P=0.02$ for contrast) to decrease the percentage of carcasses that graded USDA Choice or higher and increase ($P=0.02$) the percentage of carcasses that graded USDA Select (Table 2). There were no differences ($P>0.3$) among treatments in hot carcass weight; dressed yield; loin muscle area; 12th rib fat thickness; marbling score; USDA yield grade; liver abscess prevalence; or kidney, pelvic, and heart fat.

Implications

Adding low levels of glycerin reduced dry matter intake in grain-based diets but had no effect on dry matter intake in diets containing by-products. Unlike previous studies, adding glycerin to the diet did not improve performance.

Table 1. Composition of steam-flaked corn-based finishing diets containing low levels of crude glycerin and diets containing by-products with or without crude glycerin fed to yearling heifers

	Grain-based diets			By-product-based diets	
Ingredients, % dry matter	0% Glycerin	0.5% Glycerin	2% Glycerin	0% Glycerin	2% Glycerin
Steam-flaked corn	80.7	80.1	78.3	45.6	44.2
Soybean hulls	---	---		25.0	25.0
Wet distillers grains	---	---		15.0	15.0
Corn silage	6.0	6.0	6.0	6.0	6.0
Soybean meal	4.4	4.5	4.8	---	0.4
Alfalfa hay	3.0	3.0	3.0	3.0	3.0
Crude glycerin	---	0.5	2.0	---	2.0
Supplement[1]	5.9	5.9	5.9	4.4	4.4
Analyzed composition, %					
Dry matter	76.1	76.2	76.3	64.6	64.7
Neutral detergent fiber	13.5	13.4	13.3	29.8	29.6
Crude protein	14.4	14.4	14.4	14.1	14.1
Calcium	0.7	0.7	0.7	0.9	0.9
Phosphorus	0.3	0.3	0.3	0.4	0.4
Potassium	0.8	0.8	0.8	0.9	0.9

[1] Formulated to provide 300 mg/day Rumensin; 90 mg/day Tylan; 1,000 IU/lb vitamin A; 10 IU/lb vitamin E; 10 ppm copper; 60 ppm zinc; 60 ppm manganese; 0.5 ppm iodine; 0.25 ppm selenium; and 0.15 ppm cobalt. Zilmax was fed for 21days before harvest at the rate of 7.56 g/ton of diet dry matter followed by a 3-day withdrawal period.

Table 2. Performance and carcass characteristics of yearling heifers fed finishing diets based on steam-flaked corn containing 0%, 0.5%, or 2% glycerin or diets containing by-products with 0% or 2% glycerin

	Grain-based diets			By-product-based diets			Contrast P-values[1]	
Item	0% Glycerin	0.5% Glycerin	2% Glycerin	0% Glycerin	2% Glycerin	SEM	Glycerin Effect	By-product Effect
Initial weight, lb	942	941	942	943	939	19.51		
Final weight[2], lb	1240	1222	1214	1215	1220	18.80		
Dry matter intake, lb/day	19.5[a]	18.7[a]	18.8[a]	20.5[b]	20.9[b]	0.40		<0.01
Average daily gain, lb/day	2.95	2.7	2.56	2.56	2.87	0.15		
Feed:Gain	6.58	6.92	7.30	7.16	7.89	0.38		
Carcass-adjusted feed:gain	5.81	5.92	6.73	6.73	6.56	0.01		<0.01
Hot carcass weight, lb	787	776	771	772	775	11.94		
Dressing percentage	65.4	65.7	65.9	64.5	66.1	0.01		
Ribeye area, sq in.	14.3	14.2	13.9	13.8	14.1	0.21		
12th rib fat thickness, in.	0.5	0.5	0.5	0.55	0.47	0.03		
Kidney, pelvic, and heart fat	2.1	2.0	2.1	2.0	2.1	0.08		
Liver abscess prevalence, %	3.3	1.8	3.3	3.3	5.4	2.52		
Marbling[3]	Sm 50	Sm 30	Sm 20	Sm 30	Sm 30	13.12		
USDA yield grade	2.1	2.0	2.1	2.2	2.1	0.10		
USDA quality grade, %								
Premium Choice	26.1	16.4	15.2	18.8	20.3	0.74		
Choice or greater	80	65	66	60	61	0.06		0.02
Select	12	26	27	34	32	0.04		0.01
Standard	8	9	7	6	7	0.44		

Within a row, means without common superscripts are different (P<0.05).

[1] Contrasts protected by an overall F-test (P<0.10).

[2] Final body weight was calculated as hot carcass weight divided by a common dressing percentage of 63.5%.

[3] Sm, Small amount of marbling as determined by USDA grader.

Supplementing Feedlot Steers and Heifers with Zilmax Increases Proportions of Strip Loin, Chuck Clod, and Top Sirloin Steaks Exceeding Warner-Bratzler Shear Force Thresholds, Whereas Aging Moderates This Effect

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Introduction

Ractopamine hydrochloride (Elanco, Greenfield, IN) and Zilmax (zilpaterol hydrochloride; Intervet/Schering-Plough, Millsboro, DE) are β-adrenergic agonists approved in the United States and several other countries to increase growth rate, improve efficiency of feed utilization, and increase carcass meat yield. Zilmax has been shown to improve feed efficiency by 26% and increase hot carcass weight, longissimus muscle area, and meat yield. However, a few studies have shown that Zilmax significantly increased Warner-Bratzler shear force values (decreased tenderness).

The objectives of our research were to determine the effects of supplementing feedlot diets of steers and heifers with Zilmax for 0, 20, 30, or 40 days before harvest and the subsequent effects of 7, 14, and 21 days of aging on tenderness of steer and heifer *Longissimus lumborum* (from strip loins) and heifer *Triceps brachii* (from chuck clods) and *Gluteus medius* (from top sirloin butts) muscles.

Experimental Procedures

Out of 2,300 steers and 2,400 heifers from a larger study, 117 steers and 132 heifers were selected for the current study. These cattle were British and British × Continental crossbreds. In the large study, steers and heifers were blocked by initial weight into six blocks of four pens, and each pen contained one treatment. Zilmax was fed daily at a concentration of 7.56 g/ton on a 100% dry matter basis. One pen in each block received no Zilmax (control), and the other pens received Zilmax for 20, 30, or 40 days followed by a 3-day withdrawal before slaughter. Steers were slaughtered in two groups, and all heifers were slaughtered at a later date in two groups at the same plant. The first half of each gender was slaughtered at a weight acceptable to a typical feedyard and by visual appraisal of finish, with the target of approximately 60% Choice and a maximum of 15% yield grade 4 and 5 carcasses. We randomly selected carcasses of steers and heifers

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from the larger study to be A maturity and to approximately equally represent USDA Choice and Select quality grades and yield grades 1+, 2-, 2+, 3-, 3+, and 4.

Steer and heifer strip loins, chuck clods, and top sirloin butts were received at the Kansas State University Meat Laboratory from Tyson Fresh Meats at 7 days postmortem. The muscles were received in four different shipments according to slaughter date. The strip loins were then cut into nine uniform, 1.0-in. thick steaks containing only the *Longissimus* muscle. Three of the steaks were individually vacuum packaged for Warner-Bratzler shear force determinations, and the remaining six were sent to the Texas Tech University Meats Laboratory for consumer sensory analysis. Steaks that were to be used for 14- and 21-day Warner-Bratzler shear force determinations were aged in vacuum at 4°F for an additional 7 or 14 days and then frozen until tenderness evaluation. On the last two shipment days, heifer shoulder clods and top sirloins were obtained, and the *Triceps brachii* and *Gluteus medius* muscles, respectively, were removed and cut into 1.0-in.-thick steaks and aged until 14 and 21 days postmortem as described for the *Longissimus* muscle.

The three types of steaks were in frozen storage for 2 to 4 months, depending on the date of fabrication, thawed, and then only one muscle type was cooked per day. Between 30 and 120 steaks were cooked and sheared each time; the 7-, 14- and 21-day aged treatments each represented approximately one third of the steaks each day. Steaks were cooked on a Next Grilleration George Foreman Digital Grill (conduction cookery) to a medium degree of doneness (158°F). Cooked steaks were chilled overnight, and then six 0.5-in. cores were obtained for Warner-Bratzler shear force measurements.

The experimental design for the effect of Zilmax treatment on Warner-Bratzler shear force was a randomized complete block design with a split-plot. There were six blocks, each containing four pens for both steers and heifers. The blocking factor was initial animal weight, and each pen contained one treatment. The whole-plot treatment factor was Zilmax at feeding levels of 0 (controls), 20, 30, and 40 days. Heifer and steer data were analyzed separately because they were from different sources and harvested at different times. Analyses were done using the MIXED procedure in SAS (SAS Institute Inc., Cary, NC). The main effects of treatment and aging and their interactions were tested using a significance level of 0.05. The design for testing a threshold level of Warner-Bratzler shear force was the same as for testing the effect of Zilmax treatment on Warner-Bratzler shear force; analyses were done using the GENMOD procedure of SAS with binomial distribution and the logit-link function.

Results and Discussion

There was no ($P>0.05$) treatment-by-aging interaction for steer *Longissimus* muscle Warner-Bratzler shear force; therefore, Zilmax treatment main effects are shown in Figure 1. The 20-day Zilmax treatment increased ($P<0.05$) Warner-Bratzler shear force of steaks 1.1 lb compared with controls. Steaks from 20-day Zilmax steers had 1.76 lb less ($P<0.01$) Warner-Bratzler shear force than steaks from 40-day Zilmax steers. Although steer and heifer data were analyzed separately, *Longissimus* muscles from heifers averaged about 1.1 lb higher Warner-Bratzler shear force than those from steers. There were no treatment-by-aging interactions ($P>0.05$) for Warner-Bratzler shear force of heifer *Longissimus* or *Triceps brachii* muscles. The Zilmax treatment and aging

means for these two heifer muscles are also shown in Figure 1. *Longissimus* steaks from control heifers had >2.4 lb less (P<0.05) Warner-Bratzler shear force than steaks from 30- and 40-day Zilmax heifers. *Triceps brachii* steaks from 20-, 30-, and 40-day Zilmax heifers had higher (P<0.05) Warner-Bratzler shear force than steaks from control heifers, but there were no (P<0.05) differences among the 20-, 30-, and 40-day Zilmax treatments.

There was a treatment-by-aging interaction (P<0.05) for Warner-Bratzler shear force of heifer *Gluteus medius* muscles (Figure 2). The Warner-Bratzler shear force of *Gluteus medius* muscles from 20-day Zilmax heifers was not different (P>0.05) from that of controls after 7 days of aging or from the 30- or 40-day Zilmax treatments after 14 and 21 days of aging. After 21 days of aging, Warner-Bratzler shear force of *Gluteus medius* muscles from 40-day Zilmax heifers was higher (P<0.05) than that of controls by 1.1 lb.

The *Gluteus medius* Warner-Bratzler shear force means for the 30- and 40-day Zilmax treatments decreased (P<0.05) from 7 to 14 days of aging, but no treatment decreased (P>0.05) from 14 to 21 days (Figure 2). Means for the 30- and 40-day Zilmax treatments were higher than those for controls and the 20-day Zilmax treatment after 7 days of aging and higher than those for controls at 14 and 21 days of aging.

As the aging time of heifer *Longissimus* muscle increased from 7 to 14 to 21 days, Warner-Bratzler shear force decreased (P<0.01) from 11.5 to 9.5 to 8.6 lb, respectively. The Warner-Bratzler shear force of heifer *Triceps brachii* muscle decreased (P<0.01) to a lesser extent from 9.7 to 9.0 to 8.6 lb as aging increased from 7 to 14 to 21 days, respectively. For heifer *Guteus medius* muscles, the 30-day Zilmax treatment generally had the greatest response to aging, but the 20-day Zilmax treatment had no response (Figure 2).

Published research specifies Warner-Bratzler shear force values that might correspond to unacceptable tenderness as perceived by consumers. The value of 10.1 lb often is used as a threshold value, and we also used this value. The percentages of steaks that exceed the threshold value might be more important than treatment means. Table 1 shows the percentages of steer *Longissimus* steaks that exceeded the threshold of 10.1 lb for the combinations of Zilmax treatment and aging. The percentage of steaks from the 20-day Zilmax treatment aged at least 14 days that exceeded the threshold is very low (10%). As expected, the percentage of steaks from the 40-day Zilmax treatment aged only 14 days that were above the threshold value was relatively high (37%). These percentages were higher (P<0.05) than those for the control and 20-day Zilmax treatment.

Table 1 shows the percentages of heifer *Longissimus* muscle steaks that exceed the threshold of 10.1 lb for the combinations of treatment and aging. These data clearly show that a high percentage (79%) of steaks from all Zilmax treatments aged for 7 days exceeded threshold levels. The percentages of steaks aged 14 days that exceeded the 10.1-lb threshold were higher (P<0.05) for the 30- and 40-day Zilmax treatments than for the control and 20-day Zilmax treatments. After 21 days of aging, the percentages of steaks from the control and 20-day Zilmax treatments that exceeded the 10.1-lb threshold were not different (P>0.05) from those of steaks from the 30- and 40-day Zilmax treatments.

For heifer *Triceps brachii* muscle, 18% of steaks from the 20- and 30-day Zilmax treatments exceeded the 10.1-lb threshold after 21 days of aging. For the heifer *Gluteus medius* muscle, aging steaks for 14 or 21 days still resulted in 45% of steaks from the 20-day Zilmax treatment exceeding the 10.1-lb threshold (Table 1). The difference in percentages between steaks from the control and 20-day Zilmax treatments was significant ($P<0.05$). Interestingly, there was little difference in the percentage of steaks exceeding the 10.1-lb threshold between the 20-, 30-, and 40-day Zilmax treatments after 21 days of aging (39% to 48%). Given that 20% of G*luteus medius* steaks from control cattle exceeded the 10.1-lb threshold after 21 days of aging, tenderness of heifer *Gluteus medius* muscle is problematic, especially for Zilmax-treated cattle.

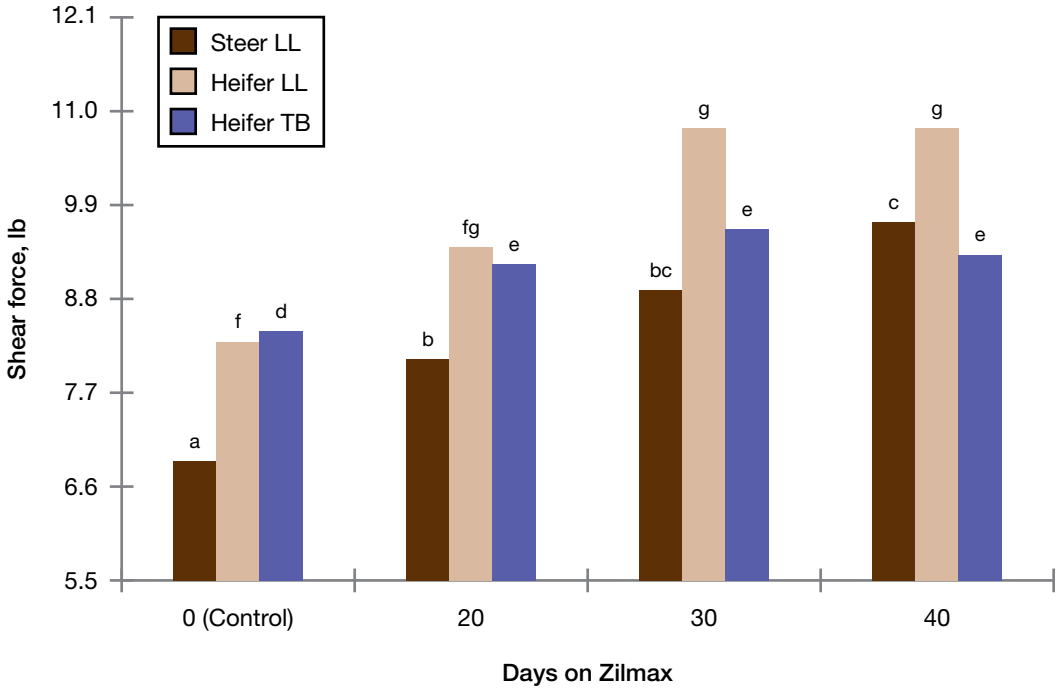
There were no differences ($P>0.05$) in the percentage of intramuscular fat for any muscle among the control or Zilmax treatments. However, the percentage of intramuscular fat of steer *Longissimus* muscle tended ($P=0.06$) to decrease as Zilmax treatment increased from the control to 40 days (data not shown). Percentage of intramuscular fat had little effect on tenderness. Furthermore, none of the correlations within Zilmax treatments among Warner-Bratzler shear force values of different muscles from heifers at different aging times were significant ($P>0.10$; data not presented). The low, nonsignificant correlations among the muscle-by-aging treatment combinations suggest that increases or decreases in Warner-Bratzler shear force for any of the three muscles might not relate to increases or decreases in Warner-Bratzler shear force of other muscles from the same animal aged for the same amount of time.

Implications

Beneficial effects of supplementing feedlot diets with Zilmax to capitalize on growth and carcass composition must be balanced with negative effects on tenderness. When Zilmax is fed to benefit growth and carcass composition, only 20 days of supplementation coupled with 21 days of aging is recommended.

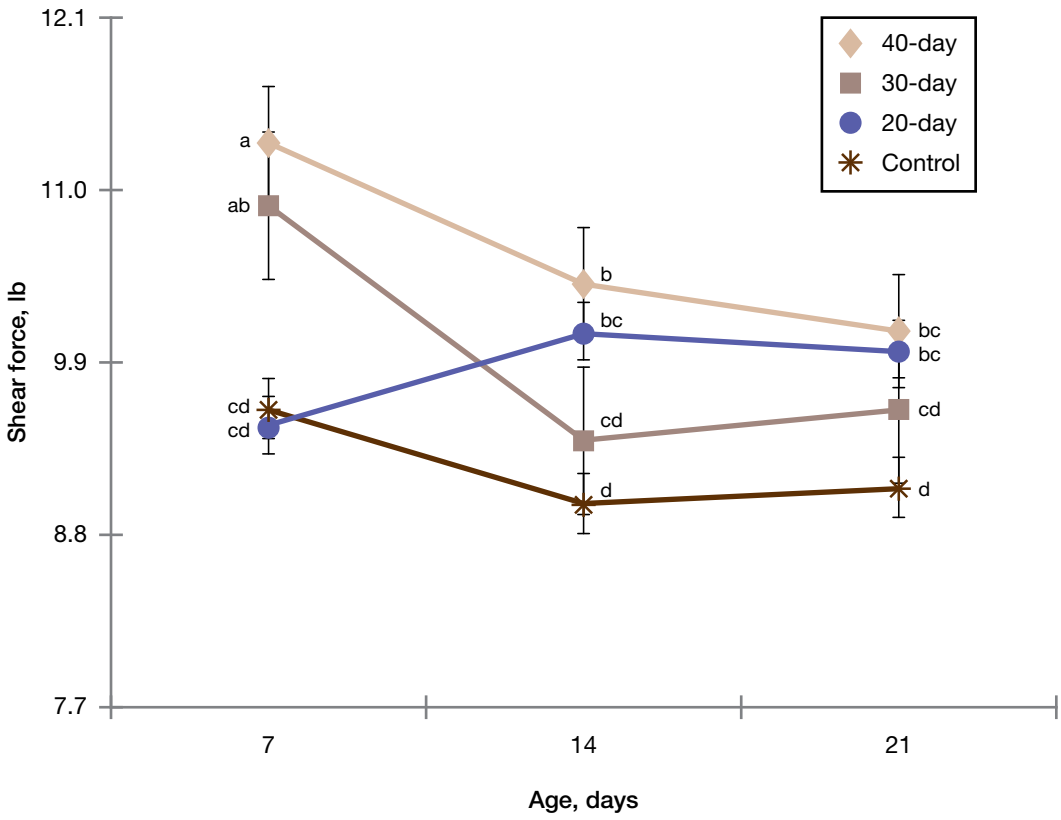
Table 1. Percentages of steer *Longissimus* and heifer *Longissimus*, *Gluteus medius* and *Triceps brachii* steaks aged for 7, 14, or 21 days that exceeded the 10.1-lb Warner-Bratzler shear force threshold

Muscle	Zilmax treatment	7-day aging	14-day aging	21-day aging
Steer *Longissimus*	control	6.9	6.9	0.0
	20-day	10.2	10.3	6.7
	30-day	35.1	20.9	12.8
	40-day	46.6	36.1	25.9
Heifer *Longissimus*	Control	40.4	22.8	15.2
	20-day	66.5	20.9	17.4
	30-day	77.9	54.3	33.1
	40-day	79.1	56.4	28.3
Heifer *Triceps brachii*	Control	11.8	2.9	0.0
	20-day	30.1	17.5	17.5
	30-day	55.9	23.7	17.6
	40-day	41.9	30.0	22.2
Heifer *Gluteus medius*	Control	43.4	23.4	20.0
	20-day	41.1	44.5	44.5
	30-day	63.0	26.4	38.5
	40-day	55.6	55.6	47.5



Within muscle, means without a common letter differ (P<0.05).

Figure 1. Effect of Zilmax treatment on Warner-Bratzler shear force of steer and heifer *longissimus lumborum* (LL) and heifer *triceps brachii* (TB) muscles.



Means without a common letter differ (P<0.05).

Figure 2. Interaction between aging and Zilmax treatment on Warner-Bratzler shear force of heifer *Gluteus medius* muscle.

Needle-Free Injection Enhancement of Beef Strip Loins with Phosphate and Salt Has Potential to Improve Yield, Tenderness, and Juiciness but Harm Texture and Flavor[1]

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Introduction

Meat tenderness is the most important palatability attribute affecting consumers' overall eating experience. Injection enhancement and blade tenderization have long been used to improve this important trait. Injection enhancement has been shown to improve tenderness, juiciness, color stability, and cooking yield, but not all solutions have been adequately evaluated. Thus, there is a need to conduct research on the effectiveness of common enhancement solutions. We published results from an extensive study comparing a solution of phosphate, salt, and rosemary with a solution of calcium lactate and rosemary injected by using traditional needle injection. There were no differences in Warner-Bratzler shear force values between treatments, but trained panelists scored steaks enhanced with calcium lactate and rosemary to be less tender and juicy than steaks enhanced with phosphate, salt, and rosemary. However, steaks enhanced with the phosphate solution had a higher incidence of metallic and salty off-flavors, a darker initial color, and more color deterioration. Because needle-free injection enhancement is relatively similar to traditional needle-injection enhancement with regard to food safety, it should be evaluated for its effects on meat color, instrumental tenderness, sensory traits, and yields.

Objectives of this research were to determine the effects of injection method (needle-free vs. needle injection) and solution (calcium lactate vs. phosphate solution) on meat color, instrumental tenderness, sensory traits, pump yield, and cooking loss of beef *Longissimus lumborum* muscles.

Experimental Procedures

Experiment 1

Beef *Longissimus* muscles (n = 15) from USDA Select, A-maturity carcasses were obtained from a commercial abattoir at 2 days postmortem and stored at 4°F until 9 days postmortem. Fat was trimmed to 0.13 in., and each loin was halved and then assigned randomly to one of two injection treatments: needle or needle-free. A Plexiglas template with holes spaced 0.38 in. apart was used to space the injection sites for needle-free injection. In the needle-free treatment, the dorsal and ventral sides of the strip loins were injected at 25 psi. Needles on the needle injector were spaced 0.70 × 1.0 in. apart. The injector was set to achieve a desired pump yield of 12% by injecting from the fat side only. A solution containing 2.2% salt, 4.4% sodium tri-polyphosphate,

[1] This research was funded in part by beef and veal producers and importers through their $1-per-head checkoff and was produced for the Cattlemen's Beef Board and state beef councils by the National Cattlemen's Beef Association.

and 1.5% potassium lactate was used for injection. After injection, each muscle section was allowed to drain for 30 minutes before a final weight was taken.

After injection, four steaks (1.0-in. thick) were cut from the anterior end of each muscle section. Two of these steaks were placed on separate Styrofoam trays, covered with polyvinyl chloride film, and placed into simulated retail display for visual color evaluation. The remaining two steaks were vacuum packaged; one was stored at 4°F for 4 days until it was used for *Longissimus* slice shear force measurement, and the other was frozen for sensory analysis. Steaks used for visual color evaluation were displayed under continuous fluorescent lighting for 5 days at 4°F. Trained visual color panelists (n = 8) evaluated initial color on day 0 of display and display color and surface discoloration on days 1 to 5 of display.

On day 13 postmortem, shear force steaks were cooked in a forced-air convection oven set at 325°F to an internal temperature of 158°F and allowed to cool for 2 minutes at room temperature before a 0.4-in.-thick, 2.0-in.-long slice was removed from the lateral end of each steak parallel to the muscle fibers and sheared perpendicular to the muscle with an Instron Universal Testing Machine. Eight trained panelists evaluated steaks. Steaks were thawed overnight, cooked to 158°F, sliced into 1.0 × 0.5 × 0.5 in. samples, and served warm to panelists. Panelists also recorded verbal descriptors for abnormal texture, such as "slick," "rubbery," or "mushy."

Experiment 2

For each of two replications on 2 separate days, 15 beef *Longissimus* muscles from strip loins from USDA Select, A-maturity carcasses were obtained at 2 days postmortem and stored at 4°F until 5 days postmortem. Fat was trimmed to 0.13 in., and each strip loin was halved. Then, the halves were assigned randomly to one of four treatments: needle injected with the same calcium lactate solution used in experiment 1, (2) needle-free injected with the same calcium lactate solution, (3) needle injected with the same phosphate solution used in experiment 1, or (4) needle-free injected with the same phosphate solution. Injection enhancement, slice shear force, and sensory panel evaluation conducted as in experiment 1.

Display color and discoloration data were analyzed as a split-plot design using the mixed model procedure (PROC MIXED) of SAS (SAS Institute, Inc., Cary, NC). Sensory, cooking loss, pump yield, and slice shear force data were analyzed using analysis of variance (ANOVA) in the PROC MIXED procedure in SAS.

Results and Discussion

Experiment 1

There was considerable variation in pump yield for both injection methods; however, there was a trend ($P=0.08$) toward higher pump yields for the needle-free treatment. Treatment had no effect ($P>0.05$) on initial color scores at day 0. However, needle-injected steaks were darker on day 1 of display but not after day 1. As expected, discoloration scores indicated that steaks from both treatments had increasing amounts of discoloration as day of display increased ($P<0.0001$); the greatest increase occurred after day 3.

Slice shear force values showed that all steaks were tender, but steaks from loins injected using the needle-free technology (17.0 lb) were more tender (P<0.05) than those from loins injected with the traditional needle injector (22.27 lb). The trend (P=0.08) toward higher pump yields for the needle-free treatment could have played a role in the greater tenderness of the needle-free steaks.

Loins injected with the needle-free device had lower cooking loss percentages (P<0.05) than loins injected with the needle injector, perhaps because there was a trend (P=0.08) toward higher pump yields with the needle-free treatment. It is logical that any increase in distribution of the enhancement solution throughout the meat that happened with needle-free injection could have reduced cooking losses.

Myofibrillar tenderness, juiciness, connective tissue amount, and overall tenderness were not different (P>0.05) between treatments. Steaks from the needle-free treatment had less (P<0.05) beef flavor intensity than steaks from the needle treatment (3.6 vs. 4.9; Figure 1). Panelists also reported greater (P<0.05) off-flavor scores in the needle-free treatment (3.9) than in the needle treatment (5.1). The most common off-flavors were salty, soapy, livery, and metallic. These off-flavor descriptors were reported fairly evenly for both treatments; the primary difference was that intensity of the off-flavors was greater for the needle-free treatment. The soapy descriptor was used almost exclusively for steaks in the needle-free treatment. The salty off-flavor was the most common descriptor, and almost every sample in both treatments received that descriptor. A few comments from panelists indicated that steaks in the needle-free treatment had a slick, mushy texture.

Experiment 2

The needle-free loins injected with the phosphate solution had higher (P<0.05) pump yields than loins in all other treatment combinations. There was no difference (P>0.05) between needle and needle-free treatments when the calcium lactate solution was used. Neither needle nor needle-free loins injected with the calcium lactate solution had pump yields that differed from those of the needle-injected loins injected with the phosphate solution.

Steaks injected with the phosphate solution had lower (P<0.05) slice shear force values than steaks injected with the calcium lactate solution, but there were no differences (P>0.05) in slice shear force between needle and needle-free treatments, which contradicts results from experiment 1. There was no difference (P>0.05) in cooking loss between needle and needle-free injection for loins injected with calcium lactate; however, loins injected with calcium lactate had a higher (Figure 2, P<0.05) cooking loss than loins injected with the phosphate solution.

Panelists did not detect differences (P>0.05) between needle and needle-free treatments for myofibrillar tenderness, juiciness, beef flavor intensity, connective tissue amount, and overall tenderness. However, the needle-injected steaks had fewer (P<0.05) off-flavors. Salty was the most common off-flavor, and it was far more common to loins injected with the phosphate solution, which contained 2.2% salt. Texture scores were higher (P<0.05) for needle-injected steaks, meaning that panelists perceived the texture of needle-injected steaks to be closer to that of normal, nonenhanced steaks. The most common descriptors for abnormal texture were mealy, gelatin, crunchy, slick, or mushy.

The gelatin descriptor was more common among steaks enhanced with the phosphate solution, whereas steaks enhanced with the calcium lactate solution more commonly received a mealy texture descriptor.

Myofibrillar tenderness, juiciness, connective tissue amount, and overall tenderness were scored lower ($P<0.05$) for loins enhanced with the calcium lactate solution than for loins enhanced with the phosphate solution (Figure 3). Steaks enhanced with calcium lactate had a lower ($P<0.05$) incidence of off-flavors and a more normal texture.

Implications

Literature comparing needle-free injection enhancement with traditional needle injection enhancement was, until now, not available. Enhancement with needle-free vs. needle injection did not have a detrimental effect on meat color and resulted in reduced cooking loss. However, needle-free injection resulted in more off-flavor intensity, with the soapy descriptor being exclusive to the needle-free treatment. Abnormal textures described as slick or mushy were also associated with needle-free steaks. Enhancement with the phosphate solution resulted in greater myofibrillar and overall tenderness, juiciness, and cooking yield with less connective tissue but also caused more abnormal texture, described as gelatin, and more off-flavor intensity, with common descriptors of salty or livery. Additional research needs to be conducted to develop a prototype needle-free injector with multiple injection tips to allow a more direct comparison of needle and needle-free injection with or without enhancement solutions.

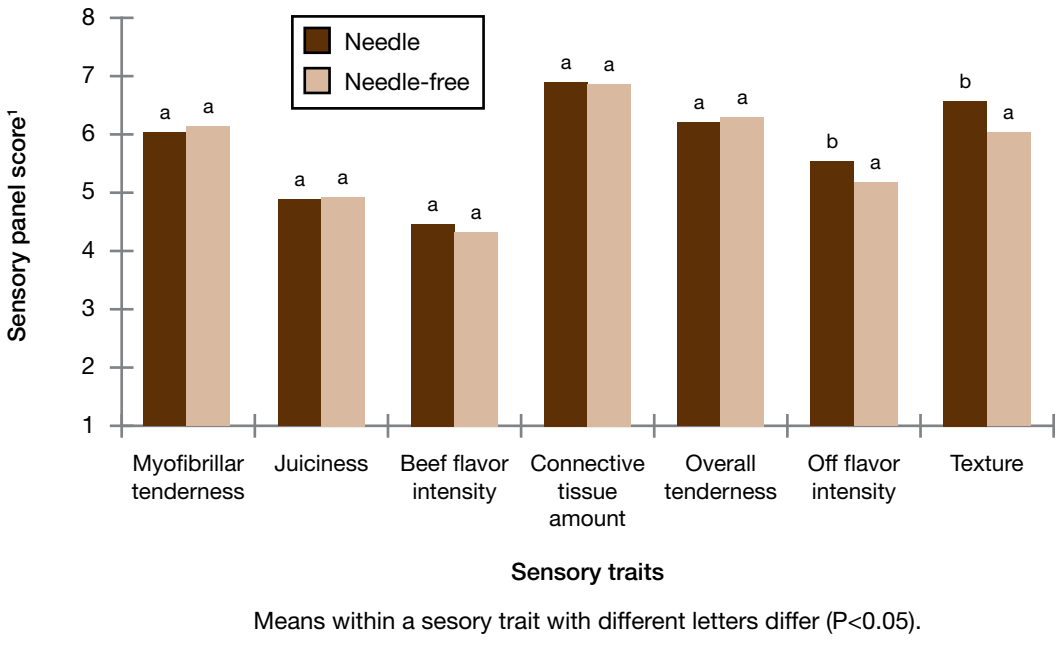

Figure 1. Trained sensory panel scores for *Longissimus lumborum* steaks injected with a needle or needle-free method (experiment 1).

[1] Myofibrillar and overall tenderness scale: 1 = extremely tough, 4 = slightly tough, 8 = extremely tender; Juiciness scale: 1 = extremely dry, 4 = slightly dry, 8 = extremely juicy; Beef flavor intensity scale: 1 = extremely bland, 4 = slightly bland, 8 = abundant; Connective tissue amount scale: 1 = abundant, 4 = moderate, 8 = none; Off-flavor intensity scale: 1 = abundant, 4 = moderate, 8 = none; Texture scale: 1 = extremely abnormal, 4 = slightly abnormal, 8 = extremely normal.

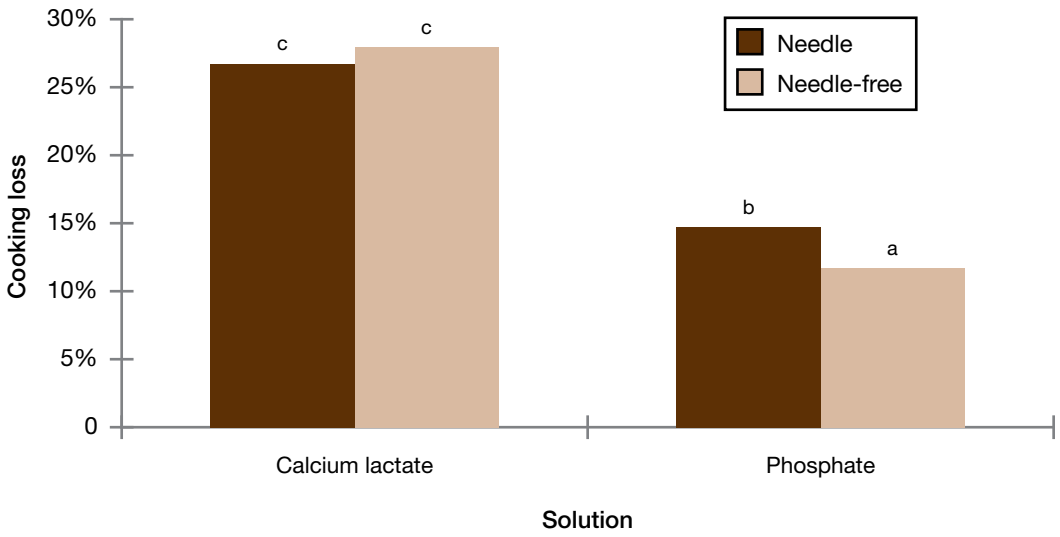

Figure 2. Cooking loss for *Longissimus lumborum* steaks injected with a calcium lactate or phosphate solution with a needle or needle-free method (experiment 1).

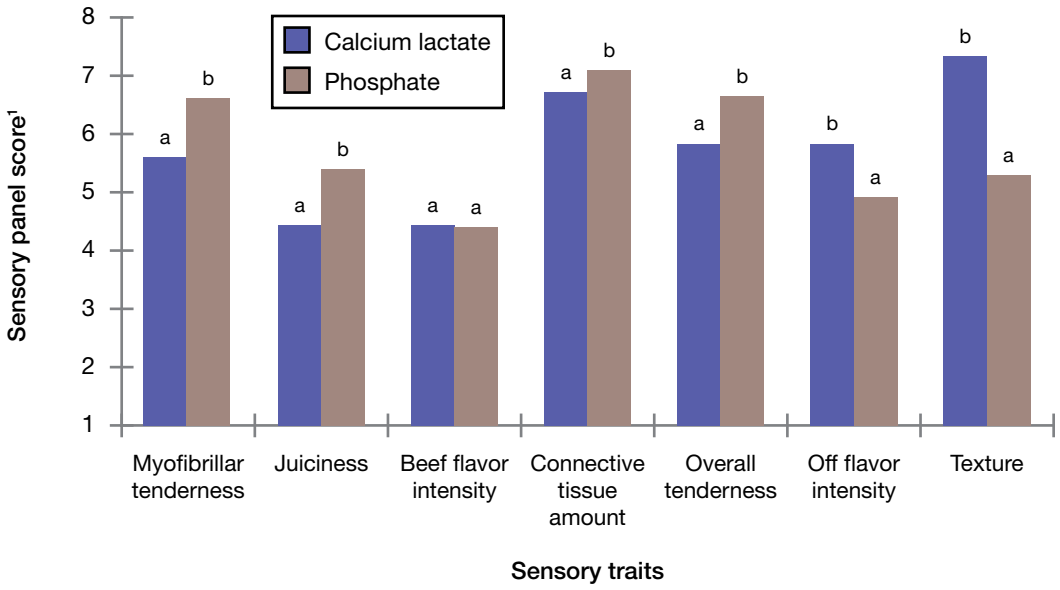

Figure 3. Trained sensory panel scores for *Longissimus lumborum* steaks injection enhanced with a calcium lactate or phosphate solution (experiment 2).

[1] Myofibrillar and overall tenderness scale: 1 = extremely tough, 4 = slightly tough, 8 = extremely tender; Juiciness scale: 1 = extremely dry, 4 = slightly dry, 8 = extremely juicy; Beef flavor intensity scale: 1 = extremely bland, 4 = slightly bland, 8 = abundant; Connective tissue amount scale: 1 = abundant, 4 = moderate, 8 = none; Off-flavor intensity scale: 1 = abundant, 4 = moderate, 8 = none; Texture scale: 1 = extremely abnormal, 4 = slightly abnormal, 8 = extremely normal.

Packaging Systems and Storage Times Serve as Post-Lethality Treatments for *Listeria monocytogenes* on Whole Muscle Beef Jerky

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Introduction

Following several outbreaks involving *Listeria monocytogenes* in ready-to-eat meat and poultry products, the United States Department of Agriculture Food Safety and Inspection Service required that processors of these products implement post-processing intervention strategies for controlling *L. monocytogenes*. The USDA defines a post-lethality treatment as a process that reduces *L. monocytogenes* by at least 1 log. Research has shown that packaging can generate a 1 log *L. monocytogenes* reduction following 1 or more weeks of storage at room temperature. The objective of our study was to determine the effect of packaging system and storage time on reducing *L. monocytogenes* on shelf-stable whole muscle jerky.

Experimental Procedures

Whole muscle beef jerky was cut into 1.6 × 1.6 inch pieces, dipped into a five-strain *L. monocytogenes* cocktail, and dried at room temperature for 1 to 2 hours to allow water activity to reach its original level prior to inoculation. Inoculated pieces of jerky were then packaged in one of four packaging systems: heat sealed, heat sealed with oxygen scavenger, nitrogen flushed with oxygen scavenger, and vacuum. Packages were then stored at room temperature for 24, 48, and 72 hours and 30 days to determine whether storage time and packaging system had any effect on reduction of *L. monocytogenes*.

Packaged jerky was sampled at 0, 24, 48, and 72 hours after packaging and after 30 days of ambient temperature storage to determine *L. monocytogenes* population reductions. Prior to microbiological sampling, the atmosphere of each packaging treatment was measured to determine the oxygen concentration. Three replications were conducted for this study, and each replication consisted of duplicate samples.

Results and Discussion

Following 24 hours of storage, the heat sealed with oxygen scavenger and vacuum packaging treatments both achieved a 1 log reduction of *L. monocytogenes* (Figure 1). The heat sealed and nitrogen flushed with oxygen scavenger packaging treatments did not achieve the 1 log reduction until 48 hours after packaging. At 72 hours post-packaging, the nitrogen flushed with oxygen scavenger treatment was less effective than the other packaging treatments, but it still achieved the required 1 log reduction of *L. monocytogenes*. After 30 days of room temperature storage, *L. monocytogenes* was reduced by more than 3.5 log CFU/0.39 in.^{2} for all packaging treatments. At all times, oxygen content was less than 0.01% for the heat sealed with oxygen scavenger, vacuum, and nitrogen flushed with oxygen scavenger packaging treatments.

[1] Oberto Sausage Company, Kent, WA.

Implications

Using the heat sealed with oxygen scavenger and vacuum packaging treatments in conjunction with a 24-hour storage time prior to shipping reduced *L. monocytogenes* populations by 1 log, and all packaging treatments reduced *L. monocytogenes* populations by at least 1 log after 48 hours of storage. Small and large beef jerky processing facilities can use any of these packaging systems in conjunction with a storage time of at least 48 hours as *L. monocytogenes* post-lethality control treatments.

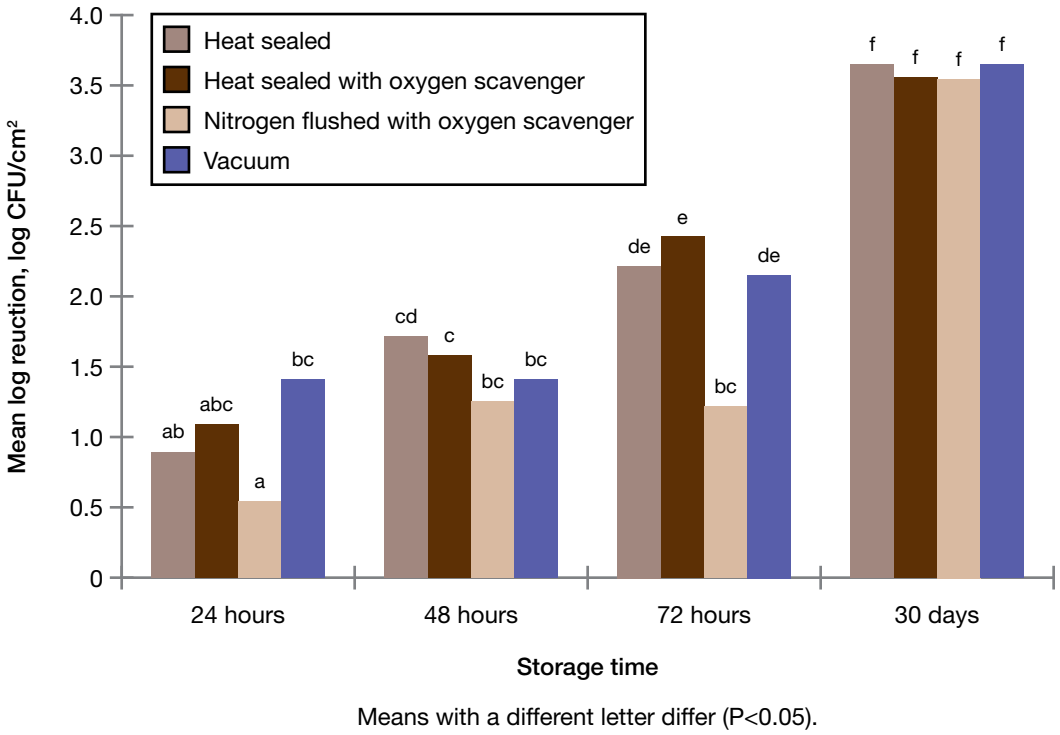


Figure 1. Mean log reduction of *Listeria monocytogenes* on beef jerky packaged in different packaging systems and stored at room temperature.

Packaging Systems and Storage Times Serve as Post-Lethality Treatments for *Listeria monocytogenes* on Kippered Beef Steaks

A. Lobaton-Sulabo, K. Uppal[1], K. Getty, E. Boyle, N. Harper, B. Barry[1], and J. Higgins

Introduction

Following several outbreaks involving *Listeria monocytogenes* in ready-to-eat meat and poultry products, the United States Department of Agriculture Food Safety and Inspection Service required that processors of these products implement post-processing intervention strategies for controlling *L. monocytogenes*. The USDA defines a post-lethality treatment as a process that reduces *L. monocytogenes* by at least 1 log. Research has shown that packaging can generate a 1 log *L. monocytogenes* reduction following 1 or more weeks of storage at room temperature. The objective of our study was to determine the effect of packaging system and storage time on reducing *L. monocytogenes* in shelf-stable kippered beef steak.

Experimental Procedures

Kippered beef steaks were obtained from a commercial supplier. Steak strips were dipped in a five-strain *L. monocytogenes* cocktail for 1 minute and then allowed to dry until the water activity of the inoculated product was roughly equivalent to the starting water activity of 0.83. Inoculated samples were then packaged in one of four treatments: heat sealed, heat sealed with oxygen scavenger, nitrogen flushed with oxygen scavenger, and vacuum. Packaged inoculated treatments were stored at room temperature and evaluated for *L. monocytogenes* after 0, 24, 48, and 72 hours. Three replications were conducted for this study, and each replication consisted of duplicate samples.

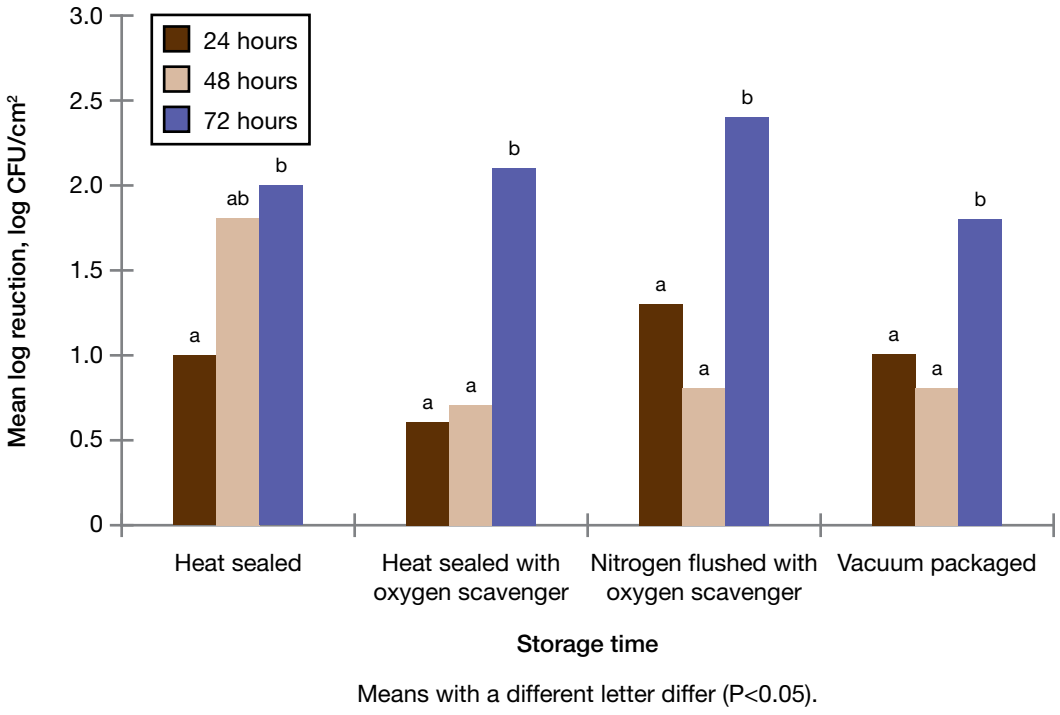
Results and Discussion

A 1 log reduction of *L. monocytogenes* was observed after 24 hours for all packaging treatments except heat sealed with oxygen scavenger, which had only a 0.6 log reduction (Figure 1). After 48 hours of storage, *L. monocytogenes* reductions were inconsistent for all treatments and ranged from <1.0 log reduction for the heat sealed with oxygen scavenger, nitrogen flushed with oxygen scavenger, and vacuum packaging treatments to >1.5 log reduction for the heat sealed treatment. After 72 hours of ambient temperature storage, log reductions for all packaging treatments ranged from 1.7 to 2.4.

Implications

Kippered beef steak processors could use a storage time of 24 hours prior to shipping in combination with heat sealed, nitrogen flushed with oxygen scavenger, or vacuum packaging treatments to reduce *L. monocytogenes* populations by at least 1 log. However, processors should be encouraged to hold packaged product for a minimum of 72 hours to enhance the margin of safety for *L. monocytogenes* control.

[1] Oberto Sausage Company, Kent, WA.



Means with a different letter differ (P<0.05).

Figure 1. Mean log reductions of *Listeria monocytogenes* on kippered beef steaks packaged in different packaging systems and stored at room temperature.

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