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2003 Cattlemen's Day

Report of Progress 908

Kansas State University
Agricultural Experiment Station
and Cooperative Extension Service

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CONSUMER VALUATION OF STEAKS WITH DIFFERENT QUALITY ATTRIBUTES

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Summary

Determining needs and wants of consumers is important for the beef industry to reverse the downward trend in beef demand during the last two decades. This study used experimental auctions in conjunction with a survey to determine consumer preferences for beef steaks. Four experimental auctions were used to elicit consumers' maximum willingness to pay for five steak types: generic, guaranteed tender, "natural", USDA Choice, and Certified Angus Beef (CAB). Consumers indicated flavor and tenderness were the most important factors when eating steaks, but they believed there was only about a 50% chance a generic steak would adequately meet these criteria. Though some concern was shown for the safety of meat produced with growth hormones and oral antibiotics, less than half of the consumers in this study were willing to pay more for a "natural" steak than a generic steak. Participants were willing to pay substantially more for guaranteed tender, USDA Choice, and CAB steaks.

Introduction

Demand for beef declined precipitously from 1980 through 1998, with only recent modest increases. To reverse this trend, beef industry participants must offer consumers beef products that are appealing. Indeed, determining wants and needs of consumers is the first and most critical step towards revamping beef demand. Subsequent measures can then be taken to produce products that fulfill these desires.

Determining the needs and wants of consumers can be as simple as conducting a survey. However, past research has shown that surveys alone do not provide sufficient incentives to elicit responses consistent with actual behavior. Experimental auctions force consumers to "put their money where their mouth is," demanding real money from winners in exchange for auctioned goods. Because the research method uses real money, experiment participants tend to reveal their preferences more truthfully.

This study provides the beef industry with enhanced knowledge of consumers' needs and wants when consuming steaks. This knowledge will help in deciding appropriate strategies for producing and marketing beef to consumers.

Experimental Procedures

A series of steak auction experiments were conducted in the spring of 2002 in the meat lab at Kansas State University. Four different auction mechanisms were used to determine how much consumers value various ribeye steak attributes. A total of 258 randomly recruited Riley County residents completed the

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experiment. Participants were evenly split by gender and approximately 40% of them were college students.

Five different steaks were sold to participants using an auction: generic, "guaranteed tender", "natural", USDA Choice, and Certified Angus Beef (CAB). All steaks were fresh three-quarter pound ribeyes. Each steak was wrapped in clear plastic, backed with a styrofoam tray, and affixed with a plain white label displaying only its respective steak type. Each steak also displayed the USDA Federal Inspection sticker. The generic steak did not have a label, and participants were informed it was an unbranded and ungraded steak. The "guaranteed tender" steak had been tested using a shear-force test and was deemed to be tender. The "natural" steak was produced by an animal that was not fed antibiotics or given growth hormones. The USDA Choice steak met the requirements for that particular grade. The CAB steak was described as meeting standards for that branded program and the CAB specifications were provided to participants.

All participants completed a survey prior to bidding on steaks. The survey collected data on consumers' knowledge, perceptions, and preferences for beef. Steaks were sold in exchange for real money during the auctions and consumers were encouraged to examine the steaks beforehand, making the experience similar to everyday steak purchases in a grocery store.

Results and Discussion

Table 1 shows a summary of survey responses to particular buying, eating, and perception issues. Consumers indicated that they consider price, color, marbling, and external fat as important attributes when they buy beef steak. They indicated less concern with brands or labels. This stated preference is particularly interesting because when these same consumers used actual money to purchase steaks, they bid more for steak with a brand they were familiar with relative to others. Consistent with a large body of research, consumers rated flavor and tenderness most highly in their beef eating preferences. Overall, consumers did not feel particularly knowledgeable about beef production or slaughter practices. When asked about their perceptions regarding generic and USDA Choice and Certified Angus Beef steaks, consumers placed more trust and have higher expectations regarding labeled beef products.

Consumers were generally not concerned about safety of meat produced with growth hormones and subtherapeutic antibiotics. On average, respondents believed there was a 17% chance that they would become ill at some point in the future from consuming meat produced in this manner. Less than half of the consumers in this study were willing to pay a premium for a "natural" steak produced without the use of hormones over a generic steak (Figure 1).

The Certified Angus Beef program contends that meat from Angus cattle is inherently more tender and flavorful than other steaks due to the breed's high degree of marbling. Though consumers do not perceive a much greater chance the CAB steak would be tender compared to a USDA Choice steak, half of them were willing to pay a premium of $0.73 per pound or more for a CAB steak relative to a Choice steak (Figure 2). This indicates the CAB program has developed brand recognition and is able to command a higher price for its product.

Consumer perceptions about generic beef steaks are not encouraging, as they believe there is only about a 50% chance generic steak will provide a pleasant eating experience. When more information about steak is available, consumer perceptions improve markedly. Consumers in this study were willing to

pay about $1.60 per pound more for a USDA Choice steak than a generic steak. However, 55% of participants either did not know what grade of steak they buy or routinely purchased steak of less quality. Thus, a trusted brand will likely garner a consistent premium for its steak over generic steak if consumers are satisfied with its performance. Branding or labeling of beef products can improve consumer confidence and consumer demand, as evidenced by the Certified Angus Beef program. However, care should be taken to produce a consistent product that meets consumer requirements of adequate flavor, juiciness, and tenderness at a competitive price.

Table 1. Preferences, Perceptions, and Knowledge of Beef Consumers

Survey Topic	Average	Standard Deviation	Min	Max	Responses
Importance of Beef Buying Factors[a]					
Color	5.62	1.33	1	7	258
Brand (label)	3.41	1.55	1	7	258
USDA quality grade	5.05	1.50	1	7	258
External fat	5.36	1.47	1	7	258
Internal Fat (marbling)	5.48	1.25	1	7	258
Price	5.74	1.37	2	7	258
Importance of Beef Eating Factors[a]					
Safety	5.57	1.66	1	7	257
Juiciness	6.02	0.93	3	7	257
Flavor	6.44	0.79	3	7	257
Tenderness	6.37	0.82	2	7	257
Consistency	5.46	1.14	2	7	257
Doneness	5.52	1.34	1	7	257
Beef Production & Processing Knowledge[b]					
Beef production practices	3.25	1.78	1	7	256
USDA beef quality grading system	3.08	1.74	1	7	256
Beef slaughter practices	3.01	1.80	1	7	256
Food safety	4.31	1.71	1	7	256
Quality Perceptions					
Chance generic would be tender	45%	20%	0%	100%	255
Chance generic would be tasty[c]	50%	21%	0%	100%	253
Chance generic would cause illness[d]	17%	23%	0%	90%	233
Chance USDA Choice would be tender	77%	15%	20%	100%	233
Chance CAB would be tender	80%	16%	15%	100%	233

[a]Scale: 1=not important to 7=very important.
[b]Scale: 1=no knowledge to 7=very knowledgeable.
[c]Of adequate juiciness and flavor.
[d]Illness sometime in the future possibly due to added hormones and antibiotics.

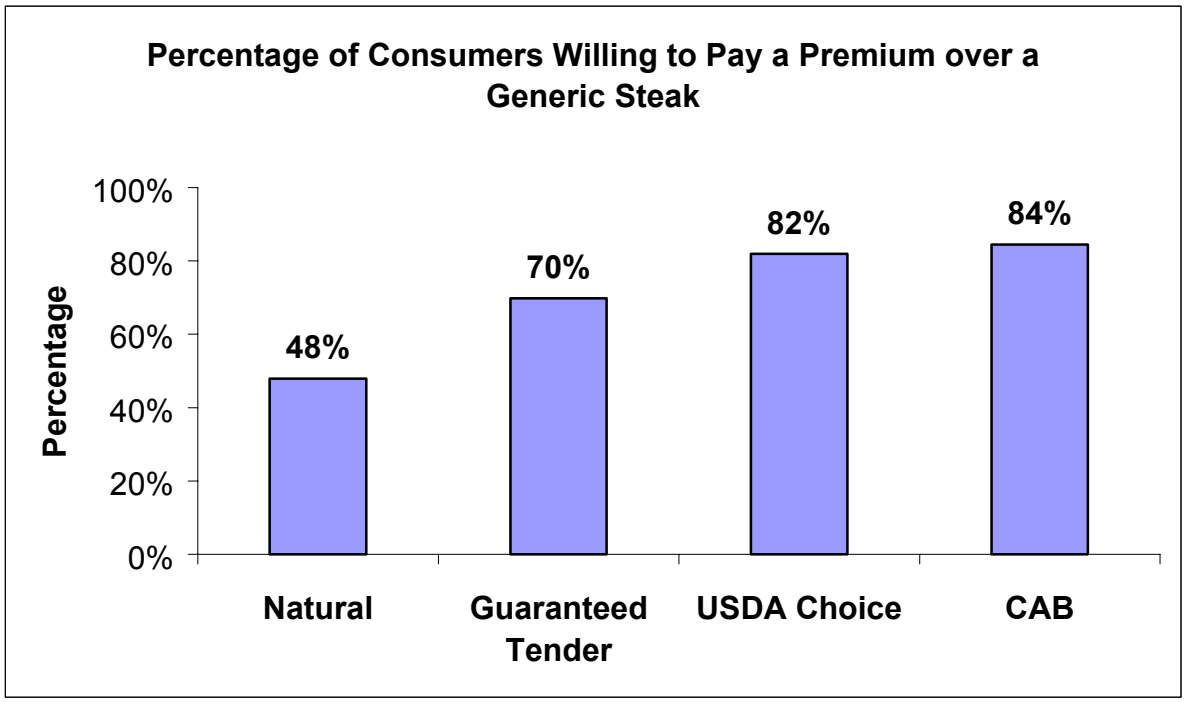

Figure 1. Steak Preference Rankings.

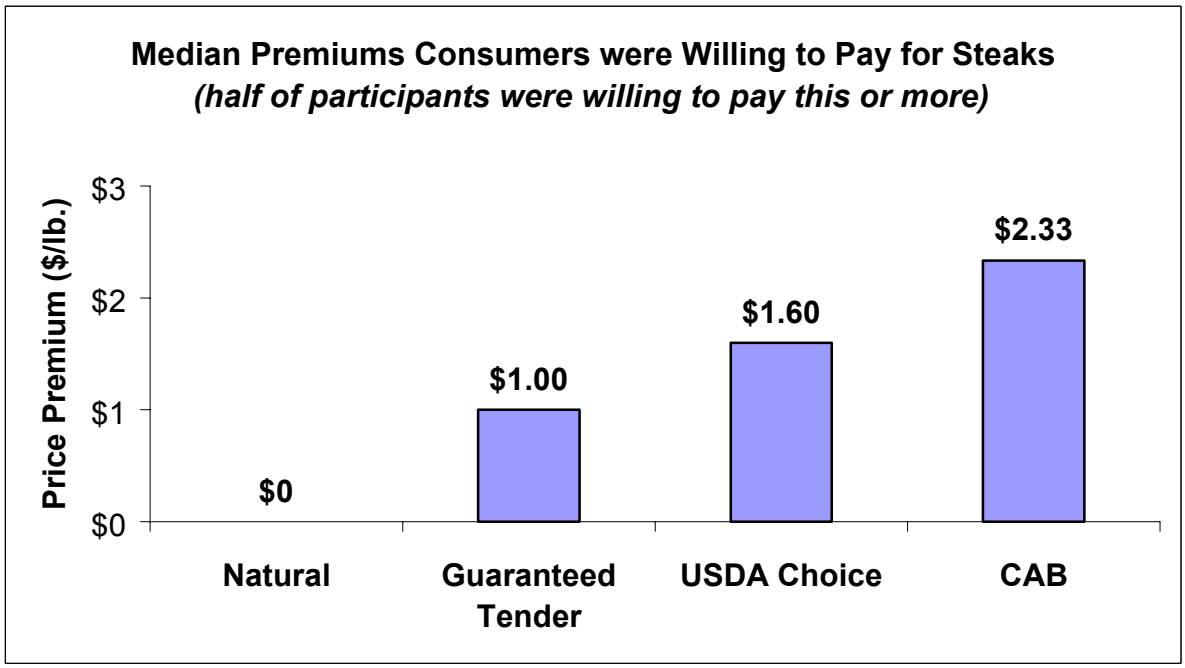

Figure 2. Median Steak Premium Estimates (Relative to the Generic Steak).

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MODELING OF COOKING STRIP LOIN AND OUTSIDE ROUND STEAKS IN A FORCED-AIR CONVECTION OVEN

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Summary

We used a forced-air convection oven to cook steaks from two muscles; strip loin (longissimus lumborum) and outside round (biceps femoris). We used a mathematical model to predict cooking time and temperature profiles for each steak. No differences ($P>0.05$) were found in cooking times between experimental and model values for either of the steaks. Modeled temperature profiles were consistently higher (except for the beginning of the cooking cycle) than the experimental values up to 65°C (150°F) in the cooking cycle for outside round steaks, whereas better agreement between experimental and modeled values was found for strip loin steaks. A highly positive linear relationship was found between experimental and modeled temperature histories for both strip loin ($R^2=0.99$) and outside round ($R^2=0.96$) steaks. The developed model should be useful for steak cooking, because the constant time to a given degree of doneness should increase consumer satisfaction by reducing variation in degree of steak doneness.

Introduction

Current practices in foodservice and restaurants do not rely on measurement of meat the temperature during cooking; rather, meat doneness is determined by visual observation. The problems associated with current practices are twofold: 1) the meat often is cooked to a higher endpoint temperature than intended, which results in customer dissatisfaction; or 2) the meat is cooked to a lower endpoint temperature than intended, which may cause food safety problems as well as customer dissatisfaction. Therefore, mathematical models have been used since the 1950's to predict cooking time or temperature profiles of meat during cooking. Earlier models were mostly based on predicting response variables such as cooking time, thermal conductivity, and beef tenderness from a measured property such as water content of the meat. Advances in computer technology have allowed scientists to develop computerized models. The objective of our study was to model cooking time and temperature profiles for oven roasting of beef strip loin or outside round steaks using a computerized mathematical model.

Experimental Procedures

In formulating the model, the following assumptions were made: 1) the steaks were homogenous and rectangular in shape; 2) the thermal conductivity, diffusivity, and heat capacity of the meat remain constant during the cooking cycle; 3) the heat transfer coefficient between hot air and meat remains constant; 4) heat transfer is considered for the thickness (x) and width (y) of the steaks; 5) energy required for melting of fat and protein denaturation is negligible; 6) the oven temperature is constant during the cooking cycle; and 7) evaporation of water is limited to the meat surface.

Cooking a steak in a forced-air convection oven includes a simultaneous heat and mass (mostly moisture) transfer in a continuously changing, complex porous structure. Therefore, both heat and mass transfer were used in

modeling the cooking process. We individually cooked each strip loin and outside round steak in a gas-fired forced-air convection oven (Model DFG-102 CH3, G.S. Blodgett Co., Burlington, VT) at 163°C (325°F) until the center temperature of each steak, which was monitored with copper-constantan thermocouples (Omega Engineering, Stamford, CT) every 30 seconds, reached 70°C (160°F). Temperature profiles for each steak were recorded by a Doric temperature recorder, which was interfaced to a computer. The time and temperature data were imported into a spreadsheet. Oven temperature was also monitored. Cooking loss on each steak was calculated. Cooking time for each steak was measured as the time elapsed between placing a steak in the oven and removing a steak from the oven. The heat and mass transfer program was compiled in Fortran 77 computer language and executed under UNIX, which enabled us to have an exceptional execution speed.

A paired-T test using PROC UNIVARIATE option of SAS (version 8.12, 2000) was performed to test the differences between experimental and modeled temperature profile and cooking time.

Results and Discussion

Cooking time. We found no differences (*P>0.05*) between experimental and modeled cooking times for strip loin steaks (Table 1). However, the variance was greater for experimental values. Pearson's correlation coefficient (r) was very high (0.93), indicating a positive linear relationship between experimental and modeled cooking times.

We also detected no difference (*P>0.05*) in cooking times between experimental and modeled values for outside round steaks (Table 1). Variances for experimental and modeled cooking times were similar. There was a strong positive linear relationship (r = 0.95) between the experimental and modeled cooking times. In general, greater variation in cooking times (both for experimental and modeled) was noted for outside round steaks than for strip loin steaks.

Temperature profiles. Our model closely predicted temperature profiles for strip loin steaks (Figure 1). However, investigating how our model fits at a specific degree of steak doneness (very rare = 55ºC (130°F); rare = 60ºC (140°F); medium rare = 65ºC (150°F); and medium = 70ºC (160°F)) is more important. The difference between predicted and experimental steak temperature was about 3ºC (5°F) for a very rare steak, and about 2ºC (4°F) for a rare steak, both of which might be considered relatively small. The difference between predicted and experimental steak temperature was almost 0ºC (0°F) for either a medium rare or medium steak.

We also looked at the differences between experimental and predicted temperature values every 1 minute for the entire cooking cycle. Interestingly, half of the time the paired T-test revealed significant differences between experimental and predicted values. However, the model was accurate after 9 minutes in the cooking cycle, as differences between experimental and predicted values became smaller (Table 3). Agreement between experimental and predicted values late in the cooking cycle is more important than near the beginning because a steak commonly will not be eaten before its temperature is more than 55°C (130°F).

Our model over-predicted the temperature of outside round steaks (Figure 2), especially between 5 and 10 minutes into the cooking cycle with differences as large as 11°C (20°F) between experimental and predicted values. As cooking proceeded, the difference between experimental and predicted values became smaller, especially after 12 minutes, which

corresponds to steak temperature of 65°C (medium rare). Thus, our model may not be applicable before this temperature. A paired T-test revealed predicted temperatures to be higher, which might restrict the use of the model. The use of modeling studies in meat cooking could minimize two costly problems, namely consumer dissatisfaction and food safety issues. Their success depends on more uniform, more highly controlled cooking.

Table 1. Experimental Versus Modeled Cooking Times for Strip Loin and Outside Round Steaks

	Strip Loin Steaks		Outside Round Steaks	
Steak #	Experimental	Modeled	Experimental	Modeled
	---------- Cooking time (minutes) ----------			
1	12.38	12.34	17.50	16.80
2	10.20	11.25	15.50	16.00
3	15.00	14.25	17.75	16.80
4	14.98	15.00	17.00	17.49
5	16.66	16.32	15.50	14.95
6	12.58	14.00	14.20	14.30
7	13.20	13.50	18.08	18.35
8	13.55	14.00	11.85	11.85
9	15.54	14.50	16.67	16.49
10	13.00	13.50	17.50	18.75

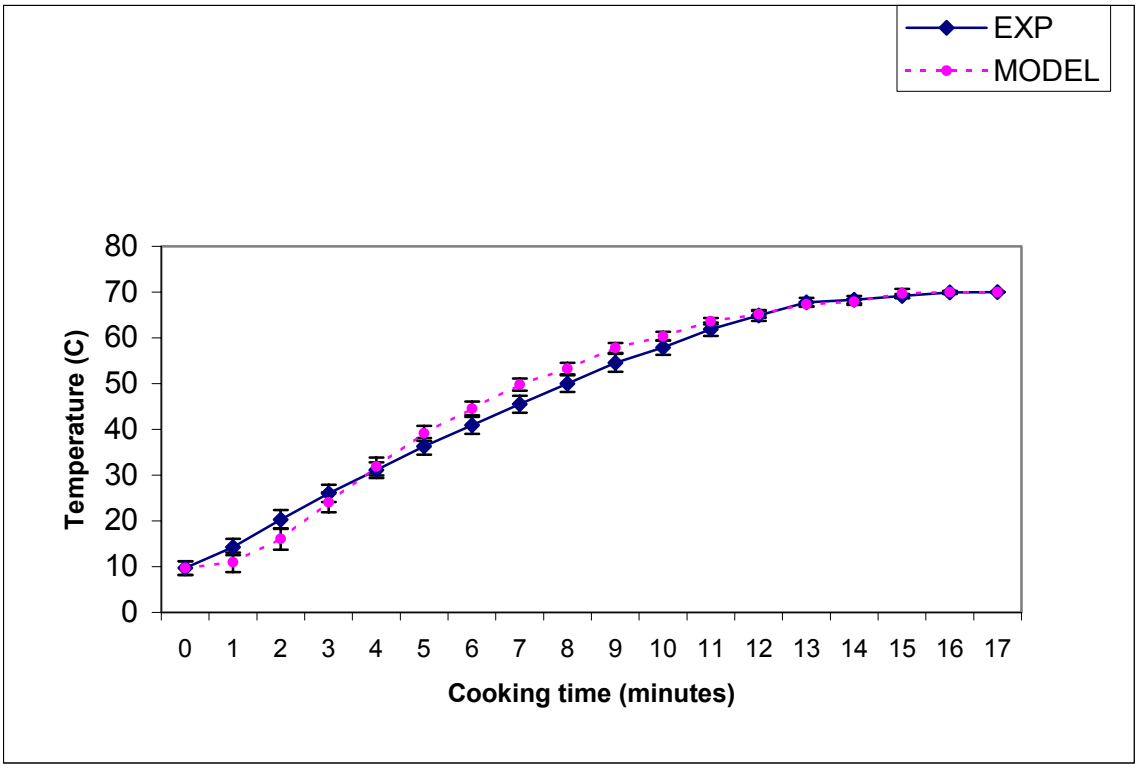

Figure 1. Experimental and Modeled Temperature Profiles for Strip Loin Steaks.

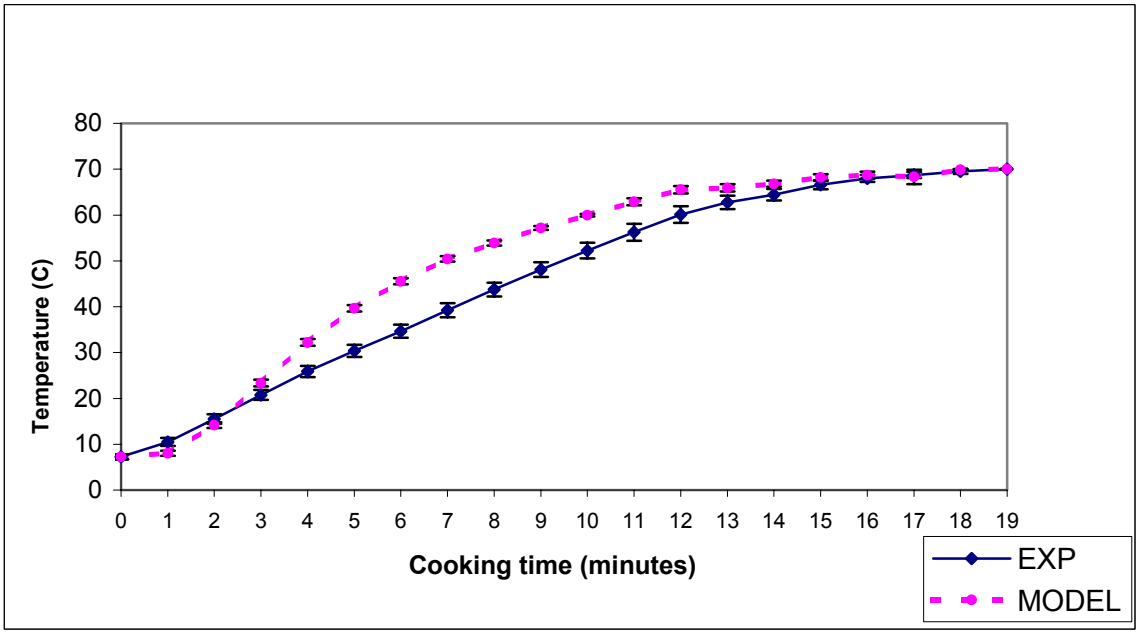

Figure 2. Experimental and Modeled Temperature Profiles for Outside Round Steaks.

MECHANICAL PROBES USED ON UNCOOKED STEAKS CAN PREDICT COOKED BEEF LONGISSIMUS TENDERNESS

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Summary

We investigated five mechanical probes, used on uncooked strip loin steaks at 2 days postmortem, to predict trained sensory panel (TSP) tenderness and Warner-Bratzler shear force (WBSF) of steaks aged 14 days. Twenty-nine USDA Select strip loins were evaluated with sharp needle, blunt needle, sharp blade, and blunt blade probes in parallel and perpendicular orientations to the length of the strip loin. A steak from each loin was also measured with a plumb bob probe in a parallel orientation and with a Miniscan for instrumental color. None of the perpendicular orientation measurements were correlated ($P>0.05$) to TSP tenderness. The sharp blade and sharp needle probe values from the perpendicular orientation were correlated to WBSF ($r=0.49$ and 0.37, respectively). Parallel measurements by the sharp needle, blunt needle, sharp blade, blunt blade, and plumb bob probes were correlated with TSP tenderness ($r=-0.77$, -0.40, -0.52, -0.57, and -0.53, respectively) and WBSF ($r=0.74$, 0.38, 0.60, 0.41, and 0.46). Instrumental color variables were not correlated ($P>0.05$) with TSP tenderness or WBSF. A regression equation for predicting TSP tenderness using the sharp needle probe resulted in R^2 of 0.74, while the equation predicting TSP tenderness from WBSF had an R^2 of 0.69. Equations using the sharp blade and plumb bob probe values in addition to L* values resulted in R^2 values of 0.45 and 0.56, respectively. The sharp needle, sharp blade, and plumb bob probes were successful in predicting trained sensory panel tenderness. However, the sharp needle probe was superior to the other mechanical probes.

Introduction

Tenderness is considered the most important palatability attribute of beef, and consumers are willing to pay a premium for tender beef. Participants in the Beef Strategies Workshop of the National Beef Quality Audit identified two of the top ten issues in the beef industry as inconsistency of carcasses and inadequate tenderness. Generally, marbling has been the primary factor used to segregate young beef carcasses into tenderness groups, yet marbling only accounts for a small amount of the variation in tenderness.

Researchers have developed numerous methods to predict beef tenderness. These include the Warner-Bratzler shear force (WBSF), Armour Tenderometer, Meat Animal Research Center Tenderness Classification System, and BeefCam. These methods have not predicted tenderness in an inexpensive, timely, and sufficiently accurate manner. In a previous study (2002 Cattlemen's Day), the sharp needle and plumb bob probe measurements were compared to trained sensory panel (TSP) tenderness and WBSF. The sharp needle and plumb bob probes were highly corre-

[1]Department of Statistics.

lated to TSP tenderness (r=-0.71 and -0.74, respectively) and to WBSF (r=0.78 and 0.67, respectively). The objective of this study was to investigate the use of these and other mechanical measures as well as objective color to predict beef tenderness.

Experimental Procedures

The sharp needle probe contains six, sharp needles fixed to a plate in two rows of three. The plumb bob probe is cone shaped with a diameter ranging from zero to 1.38 inches. The three new probes we developed were the blunt needle probe (similar to the sharp needle probe, except that each needle has a rounded point), the blunt blade probe (stainless steel, 0.06-inch thick and 1.6-inch wide with a rounded edge), and the sharp blade probe (similar to the blunt blade probe except that the edge is sharp with a 22^{o} angle).

Twenty-nine USDA Select strip loins from a commercial packing facility were transported to Kansas State University. The exterior fat was removed from each strip loin before it was evaluated by the probes. Each loin was assigned a random order of treatments.

Each probe was attached to the Instron Universal Testing Machine. The sharp needle, blunt needle, sharp blade, and blunt blade measured strip loins perpendicular to the long axis of the loin, at 2 days postmortem. The strip loins were then fabricated into four 2.5-inch sections for the sharp needle, blunt needle, sharp blade, and blunt blade probes and into three 1-inch steaks for the plumb bob probe, trained sensory panel (TSP) tenderness, and Warner-Bratzler shear force (WBSF). The steaks for TSP and WBSF were vacuum packaged and stored to 14 days postmortem. The sharp needle, blunt needle, sharp blade, and blunt blade probes penetrated 1.5 inches into the 2.5 inch sections and were used at four locations, twice perpendicular and twice parallel. The plumb bob probe penetrated 2.7 inches through the steaks in three locations. For each measurement, the peak force (kilograms) and total energy (Joules) required to penetrate the steak were measured by the Instron. The product of peak force and total energy (cross product) was also calculated and used in analysis.

Steaks assigned to plumb bob probe determination were allowed to bloom for at least 80 minutes before instrumental color measurements were obtained. Lightness of the steaks was depicted by L* values, redness with a* values, and yellowness with b* values. Four measurements of pH were recorded for each loin and averaged for analysis. Steaks assigned to TSP and WBSF were cooked to 160^{o}F. A trained six-member panel analyzed the TSP steaks for myofibrillar tenderness, juiciness, connective tissue amount, and overall tenderness, but only overall tenderness was used in this analysis. The WBSF steaks were chilled overnight at 33^{o}F before six to eight cores were taken parallel to the muscle fiber direction and sheared with the Warner-Bratzler attachment of the Instron. Correlations were determined and regression equations were calculated from the best combinations of probe and color measurements.

Results and Discussion

The correlation coefficients of peak force, total energy, and cross product variables of the five probes in both perpendicular and parallel orientations with trained sensory panel (TSP) tenderness and Warner-Bratzler shear force (WBSF) are presented in Table 1. Perpendicular measurements by mechanical probes were weakly correlated (P>0.05) to TSP tenderness. Blunt blade and blunt needle probe perpendicular measurements were also weakly correlated (P>0.05) to WBSF. Perpendicular peak force, total energy, and cross product measurements of the sharp blade probe were correlated to WBSF (r=0.40, 0.49, and 0.45, respectively). The peak force perpendicular measurements of the sharp needle probe were correlated to WBSF (r=0.37). We concluded

that probe measurements taken perpendicular to the length of the loin were not good predictors of tenderness and might be difficult to implement in plant operations.

In general, measurements taken parallel to the long axis of the loin were more consistently correlated to TSP tenderness and WBSF than the perpendicular orientation. In the parallel orientation, blunt blade, sharp blade, and sharp needle probes were all correlated ($P<0.05$) to TSP tenderness (Table 1). Total energy for the blunt needle probe was correlated ($r=-0.40$) to TSP tenderness, but its peak force and cross product were not ($P>0.05$). Eleven out of fifteen parallel probe variables were correlated ($P<0.05$) to WBSF. The blunt blade and blunt needle probes were weakly to moderately correlated (Table 1) to TSP tenderness and WBSF, and they were inferior to the sharp needle, sharp blade, and plumb bob probes in predicting TSP tenderness. The blunt needle and blunt blade probes were not good predictors of tenderness and were not considered further.

The correlation coefficients (Table 1) of the peak force, total energy, and cross product of the parallel sharp needle probe to TSP tenderness were r=-0.71, -0.71, and -0.77, respectively, and to WBSF were r=0.71, 0.74, and 0.74, respectively. The correlation coefficients of the peak force, total energy, and cross product of the parallel sharp blade probe to TSP tenderness were r=-0.38, -0.52, and -0.51, respectively, and to WBSF were r=0.35, 0.60, and 0.52, respectively. The correlation coefficients of the peak force, total energy, and cross product of the parallel plumb bob probe to TSP tenderness were r=-0.44, -0.53, and -0.50, respectively, and to WBSF were r=0.37, 0.46, and 0.44, respectively. The relationship of WBSF to TSP tenderness was r=-0.80. No color variable was correlated ($P>0.05$) to TSP tenderness or WBSF. Average pH values were correlated to TSP tenderness (r=-0.44) and WBSF (r=0.58).

Regression equations for predicting TSP tenderness from mechanical probe peak force, total energy, and cross product variables and L* values are presented in Table 2. For the sharp needle probe, the cross product was the most highly predictive as it accounted for 64% of the variation in TSP tenderness. The quadratic term of the cross product variable accounted for 74% of the variation in TSP tenderness, indicating that the sharp needle probe had a curvilinear relationship with TSP tenderness. The sharp needle probe regression equation had a R^2 (0.74) comparable to that of WBSF (R^2=0.69) for predicting TSP tenderness. The addition of instrumental color (L*) did not improve the predictive ability of the sharp needle probe equations. The sharp needle probe did not significantly alter the quality of the muscle during measurement.

A regression equation for predicting TSP tenderness from the total energy of the sharp blade probe had a R^2 value of 0.37, but the combination of total energy and L* values resulted in a R^2 of 0.43. The regression equation for predicting TSP tenderness from the quadratic term of the total energy resulted in an R^2 of 0.41, and L* accounted for an additional 4% of the variation in TSP tenderness. The sharp blade probe left marks on the uncooked steak, but these were not noticeable when the steaks were cooked.

A regression equation for predicting TSP tenderness from plumb bob probe total energy resulted in a R^2 of 0.52, and with the addition of L* values, the R^2 was 0.56. The plumb bob probe method leaves a steak unusable as a whole muscle product, but plumb bob steaks can still be used as cubed steaks or ground beef, retaining some value.

The sharp needle, sharp blade, and plumb bob probes have the potential to become online predictors of tenderness. In our study, the sharp needle probe was comparable to WBSF in predicting TSP tenderness. Although the

sharp blade and plumb bob probes were not as successful at predicting tenderness as the sharp needle probe, they still deserve further attention. Addition of color (L*) improved the regression equations for the sharp blade and plumb bob probes. The sharp needle, sharp blade, and plumb bob probes are more easily applied than WBSF as a useful tenderness evaluation tool, as they are used on uncooked strip loins at 2 days postmortem, rather than after aging and cooking.

Table 1. Correlation Coefficients of Blunt Blade, Blunt Needle, Sharp Blade, Sharp Needle, and Plumb Bob Probe Peak Force, Total Energy, and Cross Product (Peak Force x Total Energy) in Perpendicular and Parallel Orientations, Color Values (L*, a* and b*), and Average pH with Trained Sensory Panel (TSP) Tenderness and Warner-Bratzler Shear Force (WBSF)

Orientation	Probe	Variable	TSP	WBSF
Perpendicular	Blunt blade	Peak force	0.15	-0.14
		Total energy	0.04	-0.08
		Cross product	0.09	-0.09
	Blunt needle	Peak force	0.06	-0.03
		Total energy	0.18	-0.09
		Cross product	0.11	-0.04
	Sharp blade	Peak force	-0.10	0.40[a]
		Total energy	-0.20	0.49[a]
		Cross product	-0.14	0.45[a]
	Sharp needle	Peak force	-0.24	0.37[a]
		Total energy	-0.16	0.33
		Cross product	-0.17	0.34
Parallel	Blunt blade	Peak force	-0.43[a]	0.30
		Total energy	-0.57[a]	0.41[a]
		Cross product	-0.53[a]	0.38[a]
	Blunt needle	Peak force	-0.20	0.11
		Total energy	-0.40[a]	0.38[a]
		Cross product	-0.28	0.26
	Sharp needle	Peak force	-0.71[a]	0.71[a]
		Total energy	-0.71[a]	0.74[a]
		Cross product	-0.77[a]	0.74[a]
	Sharp blade	Peak force	-0.38[a]	0.35
		Total energy	-0.52[a]	0.60[a]
		Cross product	-0.51[a]	0.52[a]
	Plumb bob	Peak force	-0.44[a]	0.37[a]
		Total energy	-0.53[a]	0.46[a]
		Cross product	-0.50[a]	0.44[a]
	WBSF	Peak force	-0.80[a]	---
		Total energy	-0.77[a]	---
		Cross product	-0.80[a]	---
	L*		0.32	-0.26
	a*		0.04	-0.10
	b*		0.00	-0.07
	Average pH		-0.44[a]	0.58[a]

[a]$P<0.05$.

Table 2. Regression Equations for Predicting Trained Sensory Panel Tenderness from Sharp Needle, Sharp Blade, and Plumb Bob Probe and L* (Lightness) Values and Warner-Bratzler Shear Force

R^2	Equation
0.64	6.84 - 0.014(sharp needle cross product)
0.74	6.23 - 0.00007(sharp needle cross product)^2
0.37	7.29 - 0.023(sharp blade total energy)
0.43	4.12 - 0.021(sharp blade total energy) + 0.067(L*)
0.39	6.48 - 0.0015(sharp blade total energy)^2
0.45	3.37 - 0.00014(sharp blade total energy)^2 + 0.068(L*)
0.52	7.91 - 0.019(plumb bob total energy)
0.56	4.29 - 0.017(plumb bob total energy) + 0.076(L*)
0.69	8.51 - 0.74(Warner-Bratzler shear force)

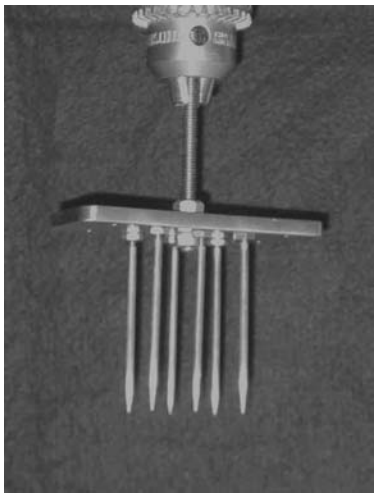

Figure 1. Sharp Needle Probe

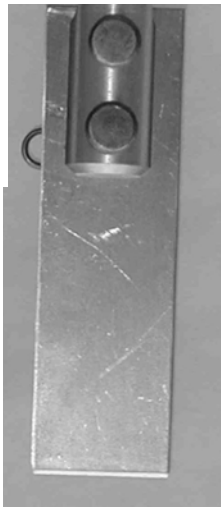

Figure 2. Sharp Blade Probe

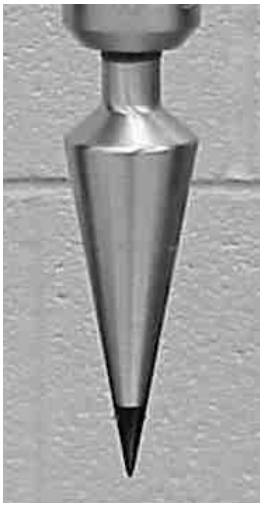

Figure 3. Plumb Bob Probe

EVALUATION OF MECHANICAL PROBES USED ON UNCOOKED STEAKS TO CLASSIFY BEEF LONGISSIMUS TENDERNESS

J. W. Stephens, J. A. Unruh, M. E. Dikeman, M. C. Hunt, T. E. Lawrence, and T. M. Loughin [1]

Summary

We pooled the mechanical probe data from two experiments to develop regression equations to predict beef longissimus tenderness. Fifty-three USDA Select strip loins were evaluated at 2 days postmortem with three mechanical probes to predict trained sensory panel (TSP) tenderness and Warner-Bratzler shear force (WBSF) of cooked steaks aged 14 days. The sharp needle, sharp blade, and plumb bob probes were correlated to TSP tenderness (r=-0.51, -0.45, and -0.35, respectively) and WBSF (r=0.56, 0.53, and 0.36, respectively). Regression equations developed from sharp needle, sharp blade, and plumb bob probe measurements and L* (lightness) values accounted for 49, 50, and 47% of the variation in TSP tenderness. The predicted values of equations were also used to classify the strips as tough or tender, and this classification was compared to the actual TSP tenderness classification. Of the steaks predicted to be tender by the equations using the sharp needle, sharp blade, and plumb bob probes and WBSF 88, 88, 84, and 87%, respectively, were actually tender according to TSP. The sharp needle, sharp blade, and plumb bob probe prediction equations were comparable to WBSF in classifying carcasses into sensory panel determined tenderness groups, and they were superior to WBSF in simplicity and cost.

Introduction

The beef industry needs to sort and market carcasses based on assurance of tenderness. Currently, marbling strongly influences industry marketing of carcasses due to its presumed influence on palatability, but the relationship of marbling to tenderness is low. Warner-Bratzler shear force (WBSF) is the most used objective method to measure tenderness, but is costly, time consuming, and difficult to fit into industry operations because it must be performed on cooked steaks. Sharp needle, sharp blade, and plumb bob probes were developed and evaluated in a previous study to predict cooked tenderness on uncooked, strip loin sections at 2 days postmortem. This study increased the number of observations relating sharp needle, sharp blade, and plumb bob probes and color variables to TSP tenderness.

Experimental Procedures

Fifty-three USDA Select strip loins were selected from a commercial processing facility and transported to Kansas State University. The exterior fat was removed from the strips before they were fabricated into two 2.5-inch sections and three 1-inch steaks. Two steaks were vacuum packaged and stored until 14 days postmortem for WBSF measurement and TSP evaluation.

[1]Department of Statistics.

The 2.5-inch sections were evaluated with the sharp needle and sharp blade probes attached to the Instron Universal Testing Machine. Each probe was used to penetrate the cut surface of the loineye section in medial and lateral locations, and the values were averaged for analysis. The Instron measured the peak force in kilograms and measured total energy required to penetrate the muscle in Joules. The product of peak force and total energy (cross product) was also studied as a variable to account for both peak force and total energy measurements. The remaining steak was used to measure instrumental color values of L* (lightness), a* (redness), and b* (yellowness) before evaluation with the plumb bob probe. The plumb bob probe was also attached to the Instron and was tested on each steak in three locations. A Sentron probe was used to measure pH on each loin.

The data were used to calculate the relationship of the probe measurements, color variables, and pH to trained sensory panel (TSP) tenderness and Warner-Bratzler shear force (WBSF). The best combinations of probe measurements and color values were used to calculate the regression equations and classify strips into tenderness groups. The predicted tenderness scores of 4.5 or higher were classified as tender and tenderness scores below 4.5 were classified as tough. These were compared to actual TSP scores, which were also used to classify the strips as tough or tender. When these agreed, the carcass was classified correctly.

Results and Discussion

The sharp needle probe peak force, total energy, and cross product were correlated to TSP tenderness (r=-0.53, -0.51, and -0.54, respectively) and WBSF (r=0.55, 0.56, and 0.56, respectively; Table 1). The sharp blade probe correlation coefficients of peak force, total energy, and cross product to TSP tenderness were -0.37, -0.45, and -0.45, respectively, and to WBSF were 0.33, 0.53, and 0.47, respectively. The correlation coefficients of the plumb bob probe peak force, total energy, and cross product to TSP tenderness were -0.44, -0.53, and -0.50, respectively, and to WBSF were 0.37, 0.46, and 0.44, respectively. No color variable was meaningfully correlated (P>0.05) to TSP tenderness or WBSF. Average pH values were correlated to TSP tenderness (r=-0.43) and WBSF (r=0.40). The correlation coefficient of TSP tenderness to WBSF was –0.69.

Sharp Needle Probe: The regression equation (Table 2) using the sharp needle cross product value (peak force x total energy) alone only accounted for 38% of the variation in TSP tenderness, while L* in combination with sharp needle cross product accounted for 49% of the variation in TSP tenderness. Of the loins that were predicted to be tender (tenderness>4.5) by the sharp needle probe and L* equation, 42 out of 48 (88%) were actually tender according to the TSP (Figure 1). However, of the loins predicted to be tough (tenderness<4.5), 3 out of 5 (60%) were actually tough. When the tenderness threshold of 5.5 was used to classify the loins, 25 of the 26 loins (96%) predicted to be tender were tender according to the TSP (tenderness>4.5).

Sharp Blade Probe: The equation from the pooled data using the sharp blade total energy alone accounted for 37% of the variation in TSP tenderness, while L* accounted for an additional 13% of the variation in TSP tenderness. Of the loins that were predicted to be tender (tenderness>4.5) by the sharp blade probe and L* equation, 44 out of 50 (88%) were actually tender according to the TSP (Figure 2). However, of the loins predicted to be tough (tenderness<4.5), 100% (3 out of 3) were actually tough. When the tenderness threshold of 5.5 was used to classify the loins, 21 of the 22 loins (95%) predicted to be tender were tender according to the TSP (tenderness>4.5).

Plumb Bob Probe: The equation from the pooled data calculated with the quadratic term of plumb bob total energy and L* accounted for 47% of the variation in TSP tenderness, and the equation using the linear term of the plumb bob total energy and L* accounted for 44% of the variation in TSP tenderness. Of the loins that were predicted to be tender (tenderness>4.5) by the plumb bob probe and L* equation, 43 out of 51 (84%) were actually tender according to the TSP (Figure 3). However, 1 of the 2 loins (50%) predicted to be tough (tenderness<4.5) was actually tough. When the tenderness threshold of 5.5 was used to classify the loins, 25 of the 26 loins (96%) predicted to be tender were tender according to the TSP (tenderness>4.5).

Warner-Bratzler Shear Force (WBSF): A regression equation using WBSF to predict TSP tenderness accounted for 58% of the variation in TSP tenderness. Of the loins that were predicted to be tender (tenderness>4.5) by the WBSF equation, 41 out of 47 (87%) were actually tender according to the TSP (Figure 4). However, of the loins predicted to be tough (tenderness<4.5), 3 of the 6 (50%) were actually tough. When the tenderness threshold of 5.5 was used to classify the loins, 20 of the 21 loins (95%) predicted to be tender were tender according to the TSP (tenderness>4.5).

The regression equations from the sharp needle, sharp blade, and plumb bob probes and L* values were comparable to those using WBSF at classifying carcasses into tenderness groups. The mechanical probes, which were superior to WBSF in simplicity and cost, have potential as on-line predictors of tenderness.

Table 1. Correlation Coefficients of the Sharp Needle, Sharp Blade and Plumb Bob Peak Force, Total Energy, and Cross Product (Product of Peak Force and Total Energy) Instrumental Color, and Average pH Values to Trained Sensory Panel (TSP) Tenderness and Warner-Bratzler Shear Force (WBSF) in the Pooled Data

Probe	Variable	TSP Tenderness	WBSF
Sharp needle	Peak force	-0.53[a]	0.55[a]
	Total energy	-0.51[a]	0.56[a]
	Cross product	-0.54[a]	0.56[a]
Sharp blade	Peak force	-0.37[a]	0.33[a]
	Total energy	-0.45[a]	0.53[a]
	Cross product	-0.45[a]	0.47[a]
Plumb bob	Peak force	-0.24	0.24
	Total energy	-0.35[a]	0.36[a]
	Cross product	-0.32[a]	0.33[a]
L*		0.43[a]	-0.15
a*		0.06	-0.08
b*		0.13	-0.06
Average pH		-0.43[a]	0.40[a]
WBSF		-0.69[a]	---

[a]P<0.05

Table 2. Regression Equations for Predicting Trained Sensory Panel Tenderness from the Sharp Needle, Sharp Blade, and Plumb Bob Probes and L* (Lightness) and Warner-Bratzler Shear Force

R^2	Intercept
0.38	6.25 - 0.0098 (sharp needle cross product)
0.49	1.92 - 0.0087 (sharp needle cross product) + 0.096(L*)
0.37	6.99 - 0.0216 (sharp blade total energy)
0.50	2.14 - 0.0196 (sharp blade total energy) + 0.106(L*)
0.47	0.82 - 0.00004 (plumb bob total energy) + 0.119(L*)
0.58	8.51 - 0.74 (Warner-Bratzler shear force)

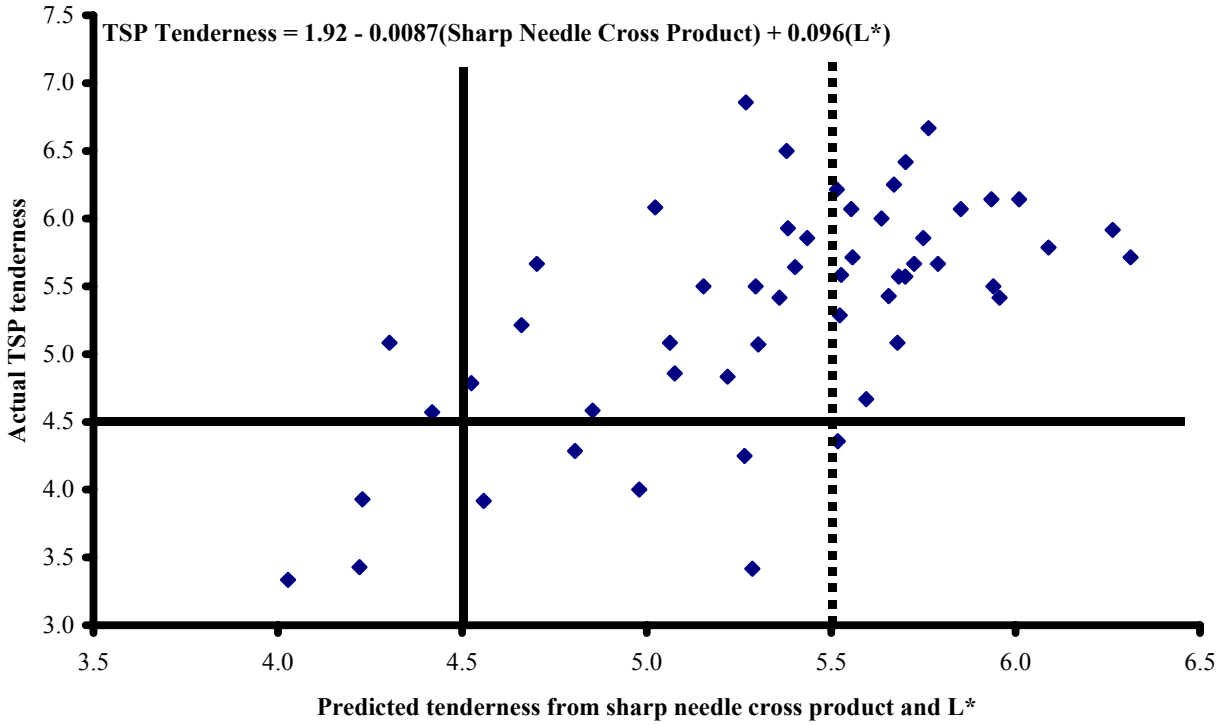

Figure 1. Classification of Longissimus Tenderness Based on 2-Day Postmortem Sharp Needle Probe and L* Prediction Equation Thresholds of 4.5 and 5.5 (4.0 = slightly tender, and 6.0 = moderately tender). Accuracy of Classification was Based Trained Sensory Panel (TSP) Ratings on Day 14 Postmortem.

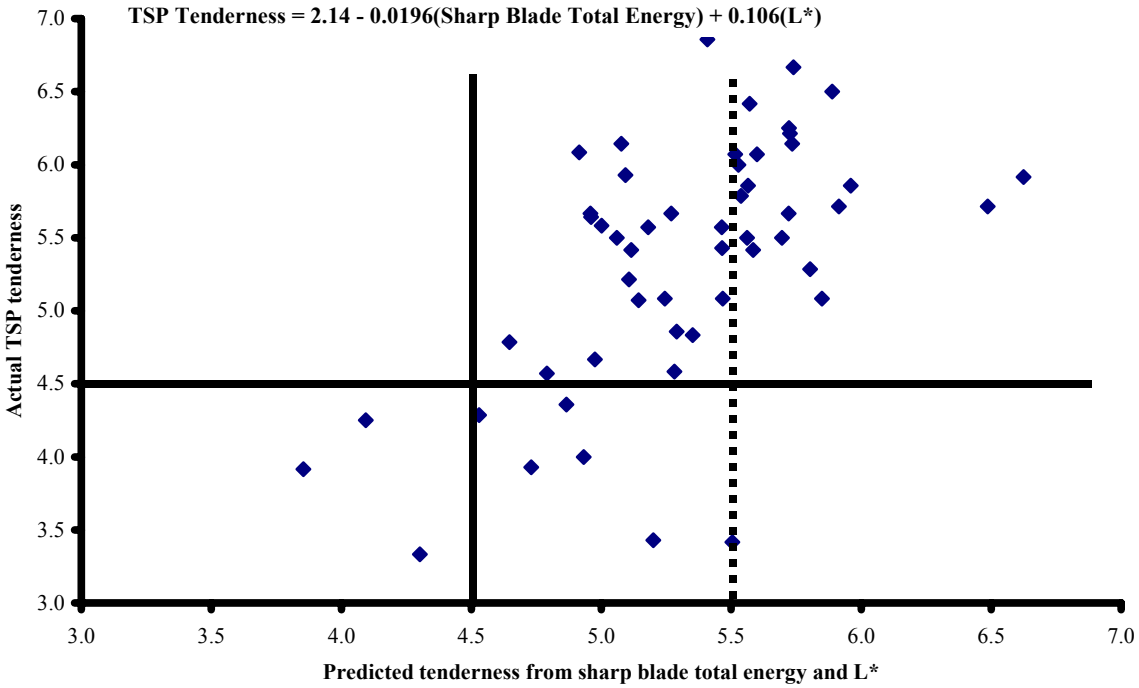

Figure 2. Classification of Longissimus Tenderness Based on 2-Day Postmortem Sharp Blade Probe and L* Prediction Equation Thresholds of 4.5 and 5.5 (4.0 = slightly tough, 5.0 = slightly tender, and 6.0 = moderately tender). Accuracy of Classification was Based Trained Sensory Panel (TSP) Ratings on Day 14 Postmortem.

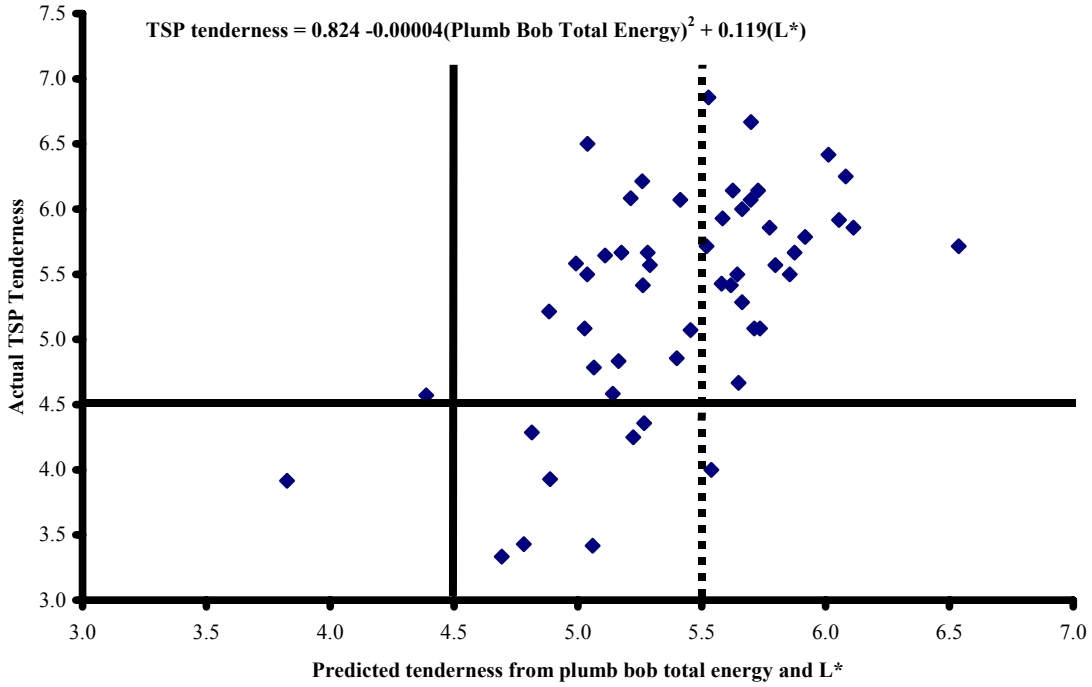

Figure 3. Classification of Longissimus Tenderness Based on 2-Day Postmortem Plumb Bob Probe and L* Prediction Equation Thresholds of 4.5 and 5.5 (4.0 = slightly tough, 5.0 = slightly tender, and 6.0 = moderately tender). Accuracy of Classification was Based Trained Sensory Panel (TSP) Ratings on Day 14 Postmortem.

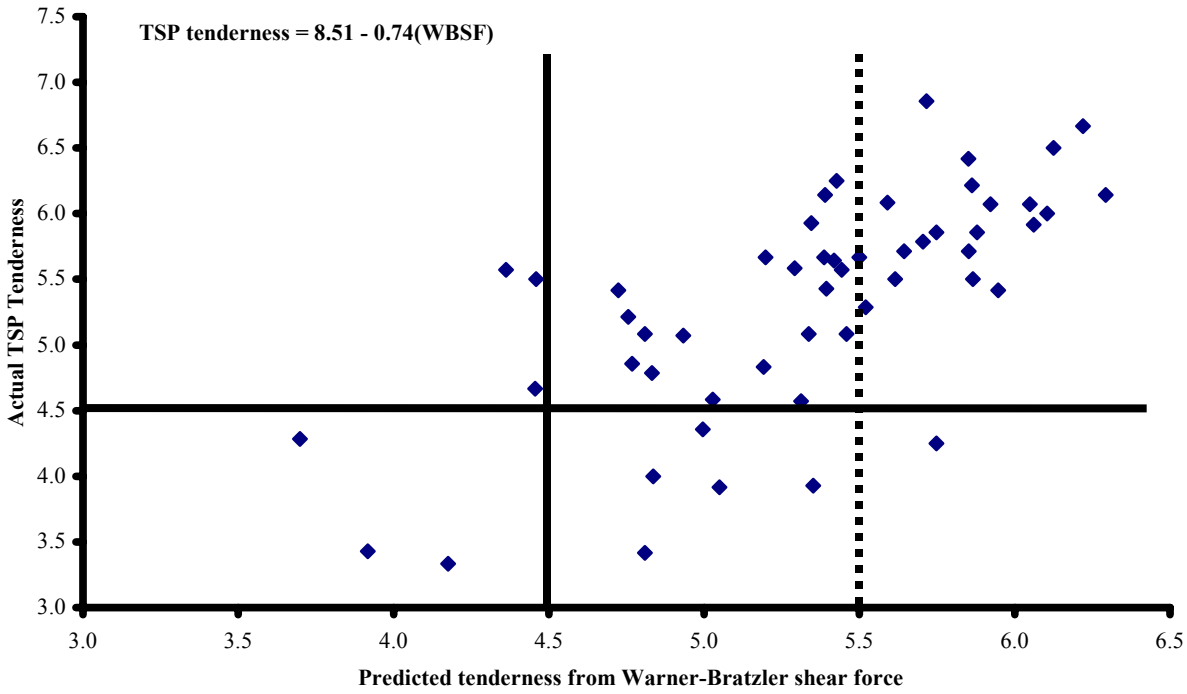

Figure 4. Classification of Longissimus Tenderness Based on 2-Day Postmortem Warner-Bratzler Shear Force (WBSF) Prediction Equation Thresholds of 4.5 and 5.5 (4.0 = slightly tough tough, 5.0 = slightly tender, and 6.0 = moderately tender). Accuracy of Classification was Based Trained Sensory Panel (TSP) Ratings on Day 14 Postmortem.

INVESTIGATION OF TENDERNESS MECHANISMS IN CALCIUM-ENHANCED MUSCLE

T. E. Lawrence, M. E. Dikeman, J. W. Stephens, E. Obuz, and J. R. Davis

Summary

We explored the mechanism(s) of calcium-induced tenderization in calcium-enhanced beef muscle. At 72 hours postmortem, we injected (9% by weight) beef strip loins (n=15) with 0, 0.05, 0.1, 0.2, or 0.4 *M* calcium chloride ($CaCl_2$) with and without 0.05 *M* zinc chloride ($ZnCl_2$), and they were then aged until 15 days postmortem. Warner-Bratzler shear force peak values indicated that addition of $ZnCl_2$ drastically inhibited tenderization; however, enhancement with $CaCl_2$ still tended to reduce shear values (P=0.07; 0.55 kg) when $ZnCl_2$ was present. In the absence of $ZnCl_2$, the 0.2 and 0.4 *M* $CaCl_2$ treatments were 18.9 and 32.1% more (P<0.05) tender than the no $CaCl_2$ treatment. These results suggest that both calcium-activated enzymatic activity and a non-enzymatic salting-in effect contributed to tenderization of calcium-enhanced muscle. However, the enzymatic mechanism reduced toughness 2.9 to 7.5 fold more than the non-enzymatic mechanism. Calcium-activated enzymatic degradation appears to be the major tenderization mechanism, and non-enzymatic salting-in of calcium ions appears to be a minor tenderization mechanism, even at high calcium concentrations.

Introduction

Muscle food research conducted during the past three decades showed that enhancement of fresh skeletal muscle with calcium ions resulted in the weakening and fragmentation of the myofibrillar component, thereby inducing meat tenderization. The majority of research suggests that the mode of tenderization is through the activation of calcium-dependent proteases occurring in skeletal muscle. In contrast, other research utilizing protease inhibitors suggests a non-enzymatic salting-in calcium effect causing protein solubilization. Chloride salts of calcium, barium, and magnesium destabilize proteins by increasing the electrostatic interactions between protein molecules and ionic solutions, thereby increasing protein solubility. With scientific evidence supporting both theories, both mechanisms possibly occur simultaneously in post-rigor muscle. In addition, these mechanisms have been investigated almost exclusively on normal calcium concentrations in postmortem muscle. Data are limited on the tenderization mechanisms at work in calcium-enhanced muscle. Therefore, the objective of this research was to inject a wide range of calcium concentrations into muscle with and without zinc ions (inhibitor of calpain enzyme activity) to determine if calcium induced tenderization is the result of calpain activity, a salting-in effect, or both.

Experimental Procedures

We selected beef strip loin subprimals (n=15) from USDA Standard carcasses from the fabrication line of a commercial processor and transported them at 0°C (32°F) to the Kansas State University Meat Laboratory. At 72 hours postmortem, a 1-inch-thick steak was cut from the center of each loin section and cooked immediately for Warner-Bratzler shear force evaluations. The remainder was cut transversely into four equal loin sections. We randomly allocated the 60 loin sections to one

of the following enhancement treatments, each in distilled water: (1) no $CaCl_2$; (2) 0.05 *M* $CaCl_2$; (3) 0.1 *M* $CaCl_2$; (4) 0.2 *M* $CaCl_2$; (5) 0.4 *M* $CaCl_2$ (6) 0.05 *M* $ZnCl_2$; (7) 0.05 *M* $CaCl_2$, + 0.05 *M* $ZnCl_2$; (8) 0.1 *M* $CaCl_2$ + 0.05 *M* $ZnCl_2$; (9) 0.2 *M* $CaCl_2$ + 0.05 *M* $ZnCl_2$; and (10) 0.4 *M* $CaCl_2$ + 0.05 *M* $ZnCl_2$. The pH of the solutions was 7.36, 9.08, 9.66, 9.91, 9.95, 6.75, 6.73, 6.62, 6.49, and 6.10, respectively. We injected (9% by weight) loin sections with their respective treatment, then vacuum packaged and stored them at 1°C (34ºF) until 15 days postmortem. At 15 days postmortem, we cut one 1-inch-thick steak from each loin section and cooked it immediately for shear force evaluation. We cooked steaks to an internal temperature of 70°C (158°F) on an electric belt grill set at 117°C (242°F), cooled them in a refrigerator for 24 hours at 1°C (34°F), then removed eight round cores (0.5 inch diameter) from each steak parallel to muscle fiber orientation. We sheared cores once through the center by a V-notch Warner Bratzler shear attachment connected to an Instron Universal Testing Machine and recorded the peak force required to shear each core.

Results and Discussion

All treatments containing $ZnCl_2$ had higher shear force ($P<0.05$) than those without $ZnCl_2$ (Figure 1). Within $ZnCl_2$ treatments, peak force decreased numerically when exogenous $CaCl_2$ was added. Treatments with $ZnCl_2$ and $CaCl_2$ tended to have lower shear values ($P=0.07$; 0.55 kg) than the $ZnCl_2$ only treatment. For treatments without $ZnCl_2$, peak force values decreased ($P<0.05$) as $CaCl_2$ concentration increased; treatments with $CaCl_2$ at 0.2 or 0.4 *M* were more tender ($P<0.05$) than the no $CaCl_2$ treatment.

Data in Figure 2 illustrate the reduction in Warner-Bratzler shear force from 72 hours (pre-enhancement) to 15 days postmortem (12 day post-enhancement) as a function of calcium concentration, regardless of level of calcium enhancement. Addition of $ZnCl_2$ resulted in less than 1.0 kg of reduction in Warner-Bratzler shear force. In comparison, enhancement without $ZnCl_2$ resulted in Warner-Bratzler shear force reductions of 1.5 to 3.4 kg. These data clearly illustrate that calcium-enhancement accelerates postmortem tenderization and that zinc retards tenderization. Similar to peak force values, treatments with $ZnCl_2$ and $CaCl_2$ tended ($P=0.06$; 0.60 kg) to have a larger reduction in shear values during aging than the $ZnCl_2$ only treatment, suggesting that minor non-enzymatic (salting in) tenderization occurs when exogenous calcium is added.

Non-enzymatic salting-in mechanism was responsible for approximately 30% of the improvement in tenderness from 72 hours to 15 days, whereas calcium-induced enzymatic activity was responsible for approximately 70% of the improvement. Results from adding the combination of $ZnCl_2$ and $CaCl_2$ to muscle suggest that the salting-in mechanism is responsible for small improvements in tenderness, but this is less than the improvement from activation of calcium-dependent proteases.

Postmortem tenderization of muscle is a complex process. From our experiment, we conclude that at least two mechanisms contribute to tenderization in calcium-enhanced muscle. When longissimus muscle is injected with calcium ions at 72 hours postmortem, calcium-activated enzymatic activity and a non-enzymatic salting-in mechanism account for about 70% and 30%, respectively, of tenderization at 15 days postmortem.

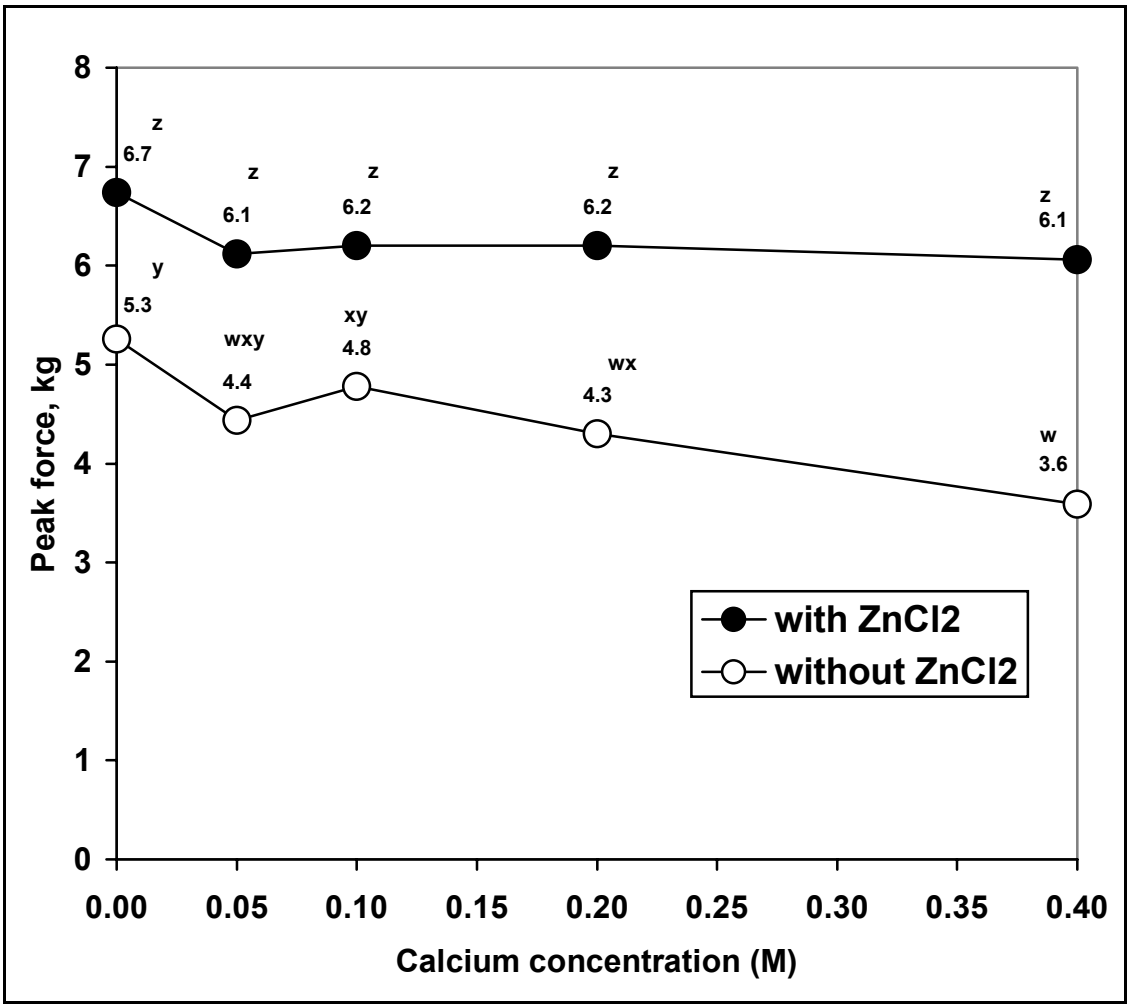

Figure 1. Warner-Bratzler peak shear force values of beef longissimus muscle enhanced with $CaCl_2$ with and without $ZnCl_2$ (SE=0.3). Means without a common superscript letter differ ($P<0.05$).

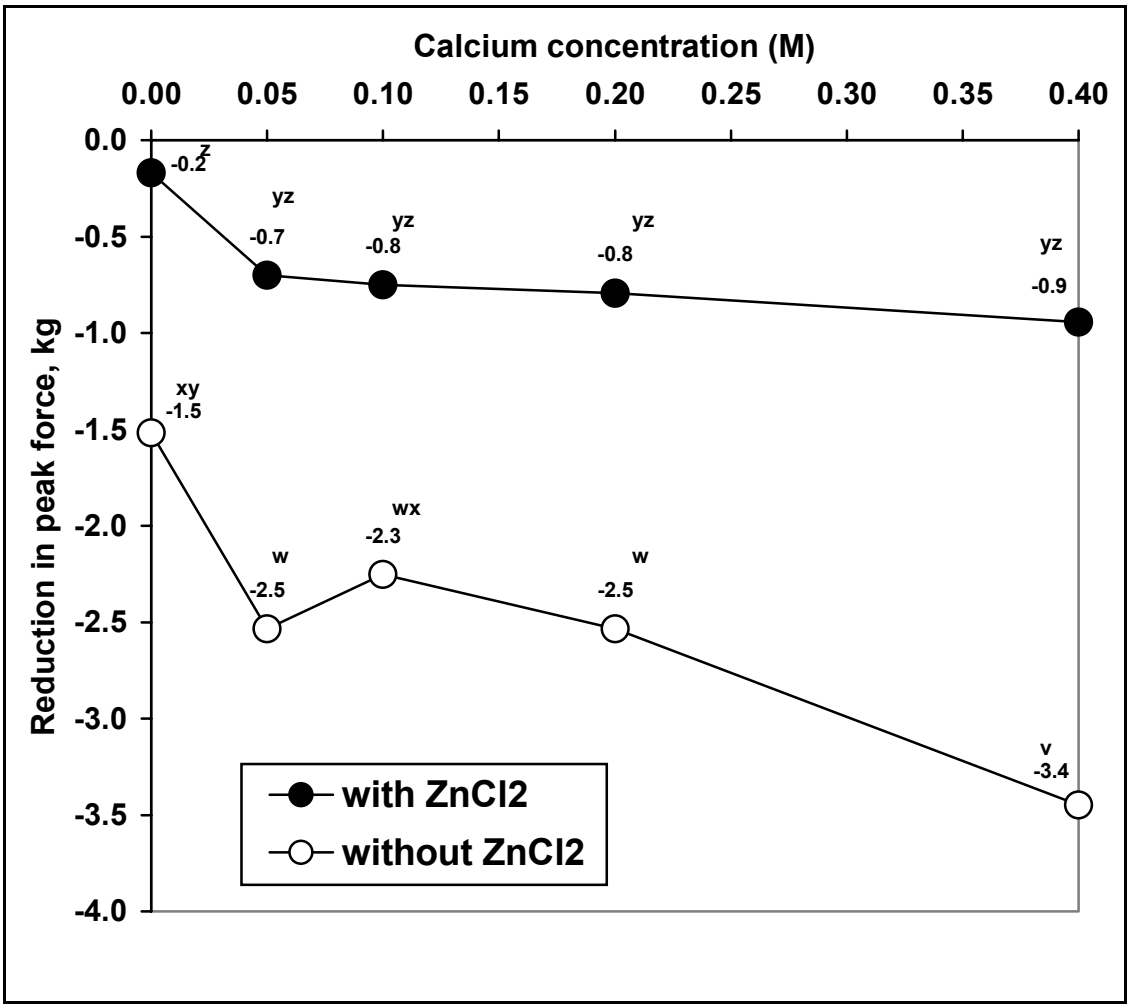

Figure 2. Reduction in Warner-Bratzler shear force values from 72 hours to 15 days post-mortem of beef longissimus muscle enhanced with $CaCl_2$ with and without $ZnCl_2$ (SE=0.4). Means without a common superscript letter differ ($P<0.05$).

Cattlemen's Day 2003

WARNER-BRATZLER SHEAR FORCE VALUES AND RANGES OF STEAKS FROM CATTLE OF KNOWN SIRES

M. E. Dikeman, E. J. Pollak[1], J. Taylor[2], S. Davis[2], T. Holm[3], S. Koontz[4], C. Gill[2], D. Moser, and E. A. Dressler[5]

Summary

Carcass data and Warner-Bratzler shear force (WBSF) data on strip loin steaks were collected from nearly 8,500 cattle in contemporary groups of progeny from the more popular sires in 14 different beef cattle breeds in the Carcass Merit Traits project funded by Beef Checkoff dollars, the breed associations, and MMI Genomics. In addition, trained sensory panel evaluations were conducted on over 2,500 strip loin steaks from contemporary groups of progeny from five sires included in the DNA marker validation component of the project. The correlation between WBSF and tenderness scored by the trained sensory panel was -0.82, indicating that as WBSF increased, tenderness scored by the sensory panel decreased. Our results showed that a WBSF value of ≥ 11.0 lb generally results in a sensory score of slightly tough or tougher. In this study, 22.8% of the cattle had WBSF values ≥ 11.0 lb and 26.3% had sensory scores of slightly tough or tougher. The phenotypic range of WBSF means for sires within breeds ranged from 1.9 to 6.6 lb. The phenotypic range of WBSF means across breeds was 8.9 lb, whereas the range among sires across breeds was a dramatic 14.4 lb. The phenotypic range for flavor intensity scores among sires within and across breeds was much smaller than for tenderness, with juiciness scores being intermediate. The 40 widely used sires that produced progeny with steaks that were unacceptable in tenderness in this study might be expected to be sires of several thousand bulls used in commercial herds. This demonstrates that seedstock producers should aggressively utilize sires that have genetics for tender meat.

Introduction

Consumers eat beef primarily for its desired flavor, but when they have a complaint about the palatability of beef, it usually is because of unacceptable tenderness. The National Beef Tenderness Study published in 1998 found that, except for the tenderloin, considerable variability occurred in tenderness, and significant percentages of nearly all beef cuts were unacceptable in tenderness. Tenderness generally is measured on the longissimus muscle (the main muscle in rib and strip loin cuts) because it has the most total value, and almost always is cooked by dry heat with the expectation that it will be tender, juicy, and flavorful. Recent market studies have shown that consumers are willing to pay more for beef of known tenderness. Although consumers are the ultimate judges of whether beef is desirable or undesirable in tenderness, Warner-Bratzler shear force (WBSF) is used as a highly repeatable and more economical

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method for measuring tenderness. Reviews of published literature on the genetic control of tenderness show that the heritability of WBSF is moderately high (29%) and that of marbling is high (38%), indicating that progress can be made through selection. However, selecting for tenderness or other palatability traits is expensive. With the availability of Expected Progeny Differences (EPDs) and(or) DNA marker-assisted selection, the beef cattle industry could make significant progress toward improving meat palatability through genetic selection. The American Simmental Association has published EPDs for WBSF for 120 of the most widely used Simmental and Simbrah sires. The Carcass Merit Traits project was an extensive 3½-year research project involving four universities, 13 beef cattle breed associations (14 breeds), and MMI Genomics. The project was funded with Beef Checkoff dollars, by participating breed associations, and MMI Genomics, and it was coordinated by the National Cattlemen's Beef Association (NCBA). The objectives of the project reported here were to:

1. Collect information and develop guidelines to aid in the development of EPDs for carcass merit traits.

2. Measure *longissimus lumborum* (strip loin steak) Warner-Bratzler shear force of contemporary groups of progeny from multiple sires within each breed.

3. Measure *longissimus lumborum* sensory attributes on a sample of contemporary groups of progeny from sires included in DNA marker validation.

4. Validate markers for the carcass traits of tenderness, marbling, and composition in different beef breeds.

Experimental Procedures

The 13 breed associations (14 breeds) provided approximately 8,500 AI progeny of the most widely used sires within their respective breeds, primarily from commercial cowherds. One or more reference sires of each breed was used in each test herd (to tie contemporary groups together within breeds). Beef Improvement Federation guidelines for sire evaluation were followed. The numbers of progeny from each breed were determined by the proportional numbers of registrations of the respective cooperating breeds. Each breed association was responsible for providing leadership for selection of sires; coordinating progeny testing; costs of synchronizing and mating cows; blood sampling; selection of feedlots and feedlot regimen, slaughter endpoint, and beef processing plants; carcass data collection; and the development of EPDs for their respective breed. Consequently, the breed associations funded approximately 50% of the total costs of the research project. The Beef Checkoff Program provided funds for shear force and sensory panel evaluation, graduate student assistantships, travel for carcass data collection, and one-half of the DNA analyses. MMI Genomics funded the other one-half of the cost of DNA analyses. Sires were compared only within breed and not across breeds. Breed identity was coded to prevent associations or breeders from comparing breeds. Dan Moser was the facilitator and liaison to the breed associations.

Each breed association was allocated a minimum of 10 sires plus additional sires based on the number of registrations for each respective breed. The range for the number of allocated sires for the different breed associations was from 10 to 54. Ten sires within each breed were designated as DNA sires, with a target of 50 progeny/sire. For the other sires within each breed, the target number of progeny/sire was 15. Carcass data and WBSF data were obtained on all progeny from all sires. For five of the DNA sires within each breed that were selected by the respective breed associations, trained sensory panel evaluations were conducted on their progeny. Prior to, or upon entering the feedlot, blood was obtained

and sent to both Clare Gill at Texas A&M University and to Tom Holm at MMI Genomics for analyses. Semen samples were also analyzed for the DNA sires. The DNA analyses were to validate the association of particular DNA markers with shear force, sensory panel traits, and carcass traits that were identified by Jerry Taylor and Scott Davis at Texas A&M University through the "Angleton" Genome Mapping project, which was funded by the Beef Checkoff, USDA-CSREES, and the Texas Agricultural Experiment Station.

A muscle sample from all progeny was obtained at slaughter for backup DNA analyses and verification of animal identity. Detailed carcass data were obtained. Additionally, one steak from the progeny of every sire and two steaks from DNA sires were obtained and shipped overnight to Michael Dikeman at Kansas State University for Warner-Bratzler shear force measurement. The extra steak from DNA sires was used for trained sensory panel evaluation. Steaks used to measure shear force were cooked at 14 days postmortem, whereas sensory panel steaks were frozen and later thawed for sensory panel evaluations.

The database maintained by John Pollak and researchers at Cornell University was secure and updated almost daily. The development of carcass, shear force, and sensory panel EPDs was the responsibility of the breed associations, although John Pollak conducted analyses for at least two breeds. The NCBA and breed associations own all carcass, shear force, and sensory panel data. The marker identities, genotypes produced by scoring the markers, and protocols for marker identification remain the property of Texas A&M University and NCBA. However, this information, as well as the phenotypic data, will be provided to the breed associations for their use in computing EPDs for related carcass merit traits.

Results and Discussion

The correlation between Warner-Bratzler shear force (WBSF) and trained sensory panel tenderness was -0.82, indicating that as WBSF increased (decreasing tenderness), there was a distinct corresponding decrease in sensory panel tenderness. This correlation is considerably higher than the average in the literature. Some research publications show that a WBSF value ≥10 lb results in a sensory panel score of slightly tough or tougher. However, our results show that a WBSF value of ≥11 lb generally resulted in a sensory panel tenderness score of slightly tough or tougher. Our analysis showed that 22.8% of the cattle in this study had WBSF values ≥11.0 lb and 26.3% had sensory panel tenderness scores of slightly tough or tougher. These steaks were aged to 14 days postmortem, were not mechanically tenderized, and were cooked to a medium degree of doneness (158°F). The steaks were from relatively young cattle that had been managed optimally. The phenotypic range of WBSF means for sires within breeds ranged from 1.9 lb in the least variable breed to 6.6 lb in the most variable breed (Table 1). Assuming a heritability estimate of 0.30 for tenderness, the genetic range for sires within breeds would be approximately 0.6 to 2.0 lb. The phenotypic range across breeds was large at 8.9 lb, whereas the range among all sires across all breeds was a dramatic 14.4 lb. These results indicate that there is considerable variation in WBSF of strip loin steaks from young cattle managed optimally.

On an 8-point scale with 8 being extremely tender and 1 being extremely tough, the range in sensory panel tenderness means for sires within breeds ranged from 0.56 in the breed with the least variation to 1.13 in the breed with the most variation (Table 2). The tenderness range across breeds was 2.55, whereas the range among all sires across all

breeds was 3.03. The range for sensory panel flavor scores for sires within breeds were quite small except for one breed (Table 3). The range for sensory panel juiciness scores (Table 4) for sires within breeds was larger than for flavor, but not as large as for tenderness. The rankings of breeds for sensory panel tenderness, flavor, and juiciness were not well related (Tables 2, 3, and 4).

If each of the 40 sires in this study that produced progeny with steaks that were unacceptable in tenderness were to sire 150 commercial bulls per year, that would be 6,000 bulls per year, or 18,000 bulls over three years (Table 5). If each of these commercial bulls produced 25 progeny per year, that would be 150,000 progeny per year plus an estimated 4,000 cull bulls and heifers from the 40 sires, or 154,000 progeny per year. Because loin eye and rib eye steaks from each carcass that are unacceptably tough could result in a negative eating experience for more than 50 consumers, as many as 7.5 million consumers could be impacted negatively per year, or more than 22 million in three years, unless effective mechanical tenderization and/or longer aging was used. Seedstock producers could improve tenderness genetically by aggressive discrimination against sires that are inferior for tenderness.

Table 1. WBSF Sire Ranges Within Breeds Ranked from Lowest to Highest WBSF*

Breed #1	3.45 lb
Breed #2	5.20 lb
Breed #3	3.74 lb
Breed #4	2.29 lb
Breed #5	2.79 lb
Breed #6	2.66 lb
Breed #7	4.32 lb
Breed #8	3.68 lb.
Breed #9	1.90 lb
Breed #10	3.99 lb
Breed #11	2.33 lb
Breed #12	6.62 lb
Breed #13	4.49 lb
Breed #14	6.41 lb

*Breed range = 8.09 lb; Range among all sires across all breeds = 14.44 lb.

Table 2. Sire Ranges for Sensory Panel Tenderness Scores Within Breeds Ranked from Most to least Tender Breed*

Breed #2	0.75
Breed #3	0.56
Breed #4	0.84
Breed #7	1.11
Breed #9	0.80
Breed #6	1.11
Breed #8	0.52
Breed #11	0.55
Breed #10	0.81
Breed #13	1.13
Breed #14	1.05

*Breeds within ≥100 progeny; Average tenderness score = 5.63; Breed range = 2.55; Range among all sires across all breeds = 3.03. Scale: 8 = extremely tender, 7 = very tender, 6 = moderately tender, 5 = slightly tender, 4 = slightly tough, 3 = moderately tough, 2 = very tough, 1 = extremely tough.

Table 3. Sire Ranges for Flavor Scores Within Breeds Ranked from Most to Least Flavorful Breed*

Breed #8	0.25
Breed #11	0.17
Breed #3	0.23
Breed #6	0.24
Breed #4	0.14
Breed #2	0.58
Breed #9	0.24
Breed #12	0.14
Breed #13	0.14
Breed #7	0.13
Breed #14	0.28

*Breeds with ≥100 progeny; Average flavor score = 5.54; Breed range = 0.45; Range among all sires across all breeds = 0.69. Scale: 8 = extremely intense, 7 = very intense, 6 = moderately intense, 5 = slightly intense, 4 = slightly bland, 3 = moderately bland, 2 = very bland, 1 = extremely bland.

Table 4. Sire Ranges for Juiciness Scores Within Breeds Ranked 1st to 12th*

Breed #12	0.21
Breed #6	0.38
Breed #9	0.31
Breed #2	0.70
Breed #8	0.40
Breed #11	0.28
Breed #4	0.38
Breed #7	0.36
Breed #3	0.31
Breed #13	0.27
Breed #14	0.70

*Breeds with ≥100 progeny; Average juiciness score = 5.63; Breed range = 0.67; Sire range = 1.12.

Table 5. Impact of 40 Sires with WBSF Values > 11.0 lb

- 40 sires → ≈400 progeny/sire/year → ≈150 bulls/sire/year
- 40 sires X 150 bulls/year → 6,000 bulls
- 6,000 bulls/year X 25 progeny/bull → ≈150,000 progeny/year
- 40 sires X 100 cull bulls or heifers → ≈4,000 year
- ≈154,000 progeny/year X 50 consumers → ≈7.5 million undesirable eating experiences
- ≈7.5 million X 3 years → ≈22.5 million undesirable eating experiences and no genetic progress would have been made

Cattlemen's Day 2003

HERITABILITY AND CORRELATION ESTIMATES OF WARNER-BRATZLER SHEAR FORCE AND MARBLING SCORE FROM ANGUS-, CHAROLAIS-, HEREFORD-, AND SIMMENTAL-SIRED CATTLE

J. A. Minick[1], M. E. Dikeman, E. J. Pollak[2], D. E. Wilson, and E. W. Dressler[3]

Summary

The objective of this study was to estimate heritabilities and genetic correlations for Warner-Bratzler shear force and marbling score of longissimus steaks from Angus-, Charolais-, Hereford-, and Simmental-sired cattle in the National Cattlemen's Beef Association (NCBA) coordinated Carcass Merit Traits Project funded with Beef Checkoff dollars. There were 700 Angus-sired steers, 691 Charolais-sired steers and heifers, 938 Hereford-sired steers, and 1,167 Simmental-sired steers and heifers in the study. Restricted maximum likelihood estimates of the genetic parameters were determined using a sire model with a sire/maternal grandsire relationship matrix. The heritabilities for Warner-Bratzler shear force and marbling score, respectively, were 0.35 and 0.36 for Angus, 0.43 and 0.26 for Charolais, 0.12 and 0.59 for Hereford, and 0.13 and 0.42 for Simmental. The genetic and phenotypic correlations between Warner-Bratzler shear force and marbling score, respectively, were -0.19 and -0.18 for Angus; -0.36 and -0.19 for Charolais; -0.47 and -0.23 for Hereford; and +0.64 and -0.11 for Simmental. The high positive genetic correlation between Warner-Bratlzer shear force and marbling score for Simmental sires indicates that as marbling increased Warner-Bratzler shear force increased (decreased tenderness). These results suggest that selection for increased marbling in the Simmental breed would actually have a detrimental effect on tenderness. Selection for Warner-Bratzler shear force in Angus and Charolais could result in improved in tenderness, but little progress would be expected in Hereford sired cattle. In general, selection for marbling score in these breeds would improve tenderness only minimally.

Introduction

Beef tenderness is a critical component of a good eating experience. Much recent research has focused on understanding tenderness. The literature reports heritabilities for Warner-Bratzler shear force that range from 0.02 to 0.53. The genetic and phenotypic correlations between Warner-Bratzler shear force and marbling score range from –1.00 to 0.45 and from -0.96 to -0.11, respectively. The National Cattlemen's Beef Association initiated a project in 1998 to study carcass merit in 15 breeds. The project was funded with Beef Checkoff dollars, the breed associations, and MMI Genomics. The objectives included developing methodology and procedures for collection of information for further development of expected progeny differences (EPDs) for carcass merit traits and measuring tenderness of the longissimus lumborum muscle (strip loin steaks) by Warner-Bratlzer shear force in contemporary groups of progeny of multiple

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sires within each breed. The data used in this study represent the Angus-, Charolais-, Hereford-, and Simmental-sired steers and heifers from that project. The objective of this analysis was to estimate heritabilities and genetic correlations for Warner-Bratzler shear force and marbling score in the four breeds.

Experimental Procedures

This study encompassed 700 yearling steers sired by 31 Angus bulls; 691 yearling steers and heifers sired by 32 Charolais bulls; 938 yearling steers sired by 47 Hereford bulls; and 1,167 yearling steers and heifers sired by 85 Simmental bulls. All were in the NCBA-coordinated Carcass Merit Traits project. The breed associations provided progeny of the more widely used sires within their respective breeds, primarily from commercial cowherds. One or more reference sires of each breed were used in a test herd, and 1996 Beef Improvement Federation guidelines for sire evaluation were followed. The selection of test herds, sires, feedlots and feedlot regimen, slaughter endpoint, and beef processing plants was at the discretion of each breed association.

Yield grade and quality grade data were collected by USDA personnel at 24 to 48 hours postmortem. A 1-inch thick steak was obtained from the longissimus lumborum muscle (strip loin steak) at the 13th rib region and shipped overnight to the Kansas State University Meat Laboratory. Steaks were vacuum packaged and aged for 14 days at 34°F.

Steaks were cooked at 325°F to an internal temperature of 158°F in a Blodget forced-air convection, gas oven and then cooled overnight before ½-inch diameter cores were removed and measured on an Instron Universal Testing Machine. The Warner-Bratzler shear force values for eight cores were averaged and used in statistical analyses.

In all breeds, age had an effect on marbling score ($P<0.02$) and these records were adjusted accordingly. Restricted maximum likelihood estimates of the genetic parameters were determined using a sire model that incorporated a sire/maternal grandsire relationship matrix. This model accounted for contemporary groups, which were derived from farm of origin, gender, and harvest date. Contemporary groups formed this way also accounted for season of birth and breed of dam. A two-trait analysis of Warner-Bratzler shear force and marbling score was performed.

Results and Discussion

The number of animals used and the genetic parameters for Warner-Bratzler shear force and marbling score are shown in Table 1. The heritabilities for Warner-Bratzler shear force were low to moderate and fell within the range of literature estimates. Heritabilities of Warner-Bratzler shear force in Hereford and Simmental were similar (0.12 and 0.13, respectively), whereas Angus and Charolais heritabilities for Warner-Bratzler shear force were somewhat higher (0.35 and 0.43, respectively). The spring 2002 Sire Summaries for the four breeds show heritabilities for marbling score and/or ultrasound percentage of intramuscular fat of 0.35 marbling score and 0.31% intramuscular fat for Angus; 0.30 marbling score for Charolais; 0.35% intramuscular fat for Hereford; and 0.35 marbling score for Simmental. The heritability for marbling score in our study for Hereford was somewhat higher than expected. This could be partially due to the fact that the American Hereford Association does not publish a marbling score EPD, but uses % intramuscular fat instead.

The genetic correlation between Warner-Bratzler shear force and marbling score in Charolais- and Hereford-sired cattle (–0.36 and –0.47, respectively) is similar to literature estimates of –0.25 to –0.55. The negative correlation indicates that more marbling is associated with less force required to shear steaks.

This correlation in Angus was somewhat smaller than expected (–0.19). Unlike the other breeds and most literature estimates, the genetic correlation between Warner-Bratlzer shear force and marbling score in Simmental was large and positive. The biological explanation for this is unknown; however, there is one published paper reporting a large positive genetic correlation (0.45) between Warner-Bratzler shear force and marbling score. The phenotypic correlation between Warner-Bratzler shear force and marbling score was similar for all breeds (–0.11 to –0.23) and agrees with literature estimates of –0.11. Direct selection could improve *longissimus* shear force-evaluated tenderness in Angus and Charolais. In Angus-, Charolais-, and Hereford –sired cattle, selection for increased marbling would be expected to result in a small improvement in tenderness, but in Simmental-sired cattle would be expected to result in decreased tenderness.

Table 1. Number of Animals, Heritability (h^2) for Warner-Bratzler Shear Force and Marbling Score[a], and Genetic Correlation (r_g) and Phenotypic Correlation (r_p) Between these Traits for Angus-, Charolais-, Hereford-, and Simmental-Sired Cattle

Item	Angus	Charolais	Hereford	Simmental
No. of cattle	700	691	938	1,167
Warner-Bratzler shear force h^2	0.35	0.43	0.12	0.13
Marbling score h^2	0.36	0.26	0.59	0.42
r_g	-0.19	-0.36	-0.47	0.64
r_p	-0.18	-0.19	-0.23	-0.11

[a]400 = slight, 500 = small.

RATE OF BLOOM OF BEEF LONGISSIMUS LUMBORUM: EFFECTS OF MUSCLE TEMPERATURE, AGE, AND OXYGEN EXPOSURE TIME

C. M. Trater and M. C. Hunt

Summary

Steaks from 12 loins were used to determine the best time and temperature combinations for blooming (development of a bright-red color) of the longissimus muscle at 2, 14, and 26 days postmortem. The lowest temperature (28°F) provided the fastest rate of bloom when the muscle was 2 days postmortem, and 30 minutes were needed to achieve 75% of final bloom color. For meat 14 days old, greater bloom occurred at 35 and 40°F than at 28°F. For meat 26 days old, rate of bloom was equal at all three temperatures. Thus, packers should bloom carcasses one-half hour at 28°F before presenting carcasses for grading, and retailers will need 30 to 40 minutes after cutting to achieve 75% of final bloom at 35° to 40°F.

Introduction

In packing plants, USDA graders assign quality grades to carcasses after the ribeye has been exposed to air. A fully bloomed or bright, cherry-red ribeye provides the best color for the grader, making it easier for the grader to see the carcass marbling and maturity. In packing plants, the time between carcass ribbing and when the grader views the ribeye is "bloom time." The amount of time the ribeye is exposed to air ultimately affects the carcass grade, but this varies from facility to facility because of plant design, product line speed, and number of cattle slaughtered per day. In addition, the temperature of the ribeye muscle during blooming may affect the rate of bright red color development. Other factors influencing the grade a carcass receives include lighting type and intensity at the grader's stand, occurrence and prevalence of "heat ring" or dark coarse area in the ribeye, and whether the carcasses were electrically stimulated.

When exposed to oxygen, freshly cut muscle myoglobin (deoxymyoglobin) converts to oxymyoglobin, which has a bright, cherry-red color. However, at higher muscle temperatures, enzymes naturally present in the muscle will be more active and will consume much of the available oxygen. Because the enzymes will compete with myoglobin for oxygen, the myoglobin takes longer to convert to oxymyoglobin. Therefore, at colder temperatures, meat should bloom faster because the competing enzyme activities are depressed and consume less oxygen.

In addition to time and temperature conditions, aging of meat can influence bloom rate. Previous research showed that: 1) Aged meat bloomed better, because enzymes were less active and the oxygen penetrated faster and deeper into the muscle, thus intensifying the oxymyoglobin color, and 2) Blooming occurs faster at lower temperatures, which further slows enzyme activity and increases the penetrability of oxygen into the meat surface. The rate of bloom following aging is important in retail situations, where the primal cuts are removed from vacuum packages and sliced into retail cuts for display. However, the superior bloom of aged meats is short term, as the color stability during display of aged meats is shorter than desirable.

The objective of this study was to evaluate the combined effects of bloom time, age, and meat temperature (28, 35, and 40°F) on the rate of bloom of beef loin (longissimus lumborum) at 2, 14, and 26 days postmortem.

Experimental Procedures

Beef short loins (n=18) were delivered at approximately 24 hours postmortem by Excel Corporation to the Kansas State University Meats Laboratory. Twelve loins were selected based on their pH and incoming temperature (Table 1). Each loin was divided into three portions (approximately 4 inches long). Each loin section was then assigned to one of three temperature treatments (28, 35, or 40°F), vacuum packaged, and stored overnight at that temperature for tempering and equilibration. At 2 days postmortem, loin sections were removed from the vacuum package and a 1-inch thick steak was cut to obtain a fresh-cut surface. The marbling (Table 1) was recorded for each loin using a fresh cut surface of the steak removed on day 2 from the most anterior section of the loin. The unused section of loin from each temperature treatment was then vacuum packaged again for storage at 35°F for 14 and 26 days.

The fresh-cut surface was scanned immediately (time 0) and at 5, 10, 15, 20, 30, 40, 50, and 60 minutes using a Miniscan^{TM} XE Plus (Hunterlab, Reston, Virginia). Three scans were taken at each time for spectral data from 400 to 700 nm using a 3-cm aperture. Percentage oxymyoglobin was calculated for each blooming time from the spectral data. For each sampling day, the Miniscan was calibrated, according to the manufacturer's guidelines, prior to the start of measuring meat color and then was recalibrated halfway into the experiment.

After 13 and 25 days of storage, the sections were placed into their treatment temperature to temper approximately 15 hours prior to subsequent blooming at 14 and 26 days. The loin sections were placed in three separate open top coolers maintained at the assigned temperatures.

Data were analyzed using the SAS System for Windows, with α=0.10. The design of the experiment was a split-plot with repeated measures. Temperature was used as a covariate to predict the rate of bloom at 28, 35, and 40°F.

Results and Discussion

Percentage oxymyoglobin is a good indicator of bloom rate, where the higher the percent oxymyoglobin, the better the bloom for the steaks. When all three temperatures are graphed for each time period (Figure 1), the effect of temperature becomes evident. At 2 days, the lowest temperature (28°F) had the fastest and 40°F had the slowest bloom rate. However, after 14 days of vacuum aging, blooming rate at the lowest temperature was the slowest and the highest temperature (40°F) had the fastest rate. As meat aged to 26 days, blooming rates were equal at all three temperatures.

Data in Figure 2 show effects of postmortem age on rate of bloom at three temperatures. At 28°F the 2-day-old steaks bloomed faster than steaks aged 14 or 26 days, which agrees with previous research. At the coldest temperature, enzymes were less active, allowing the muscle to utilize more of the oxygen to convert deoxymyoglobin to oxymyoglobin faster than at higher temperatures. However, very little difference was found between the three time periods at 35°F for rate of bloom of the steaks. At 40°F, 2-day-old steaks had the slowest rate of bloom, presumably because the enzymes are warm enough to compete with the myoglobin for oxygen and the greatest enzyme activity would be expected in 2-day-old

muscle. Therefore, the higher temperatures slow bloom at 2 days. For 14-day-old muscle, 40°F yielded the fastest rate of bloom, because aging the meat caused decreased enzyme activity. This allowed more of the oxygen to go straight to the muscle allowing it to bloom faster at 14 days and at 40°F.

To achieve the highest possible USDA quality grade and minimize the number of carcasses that need to be re-graded, a bright, cherry-red, bloomed color of the ribeye is essential. Our data show that a minimum of 20 minutes is needed to assure adequate bloom between beef carcass ribbing and when the grader evaluates the carcass. In addition, the colder the ribeye, the faster the bloom rate will be for 2-day-old carcasses. After 20 minutes at 28°F, approximately 65% of the pigment on the meat surface was converted to oxymyoglobin, and by 30 minutes about 75% was oxymyoglobin. We believe that 65 to 75% oxymyoglobin facilitates accurate grading and that these levels can be achieved fastest at meat temperatures of 28°F. Thus, for plants with good chill systems, the bloom time may be as short as 20 minutes. When ribeye temperatures are 35°F or above, longer bloom times will be needed. For retailers who deal with aged meat, 35 to 40°F appears adequate for blooming; however, colder temperatures will improve color stability compared with the warmer temperatures.

Table 1: pH, Marbling Score, and Quality Grade for Beef Strip Loins

Loin number	pH	Marbling score	Quality grade
1	5.5	Slight 70	Select
2	5.5	Slight 0	Select
3	5.5	Slight 40	Select
4	5.5	Small 60	Low Choice
5	5.5	Slight 80	Select
6	5.5	Traces 80	Standard
7	5.5	Small 70	Low Choice
8	5.6	Slight 80	Select
9	5.5	Modest 10	Average Choice
10	5.5	Small 40	Low Choice
11	5.6	Small 30	Low Choice
12	5.5	Slight 50	Select

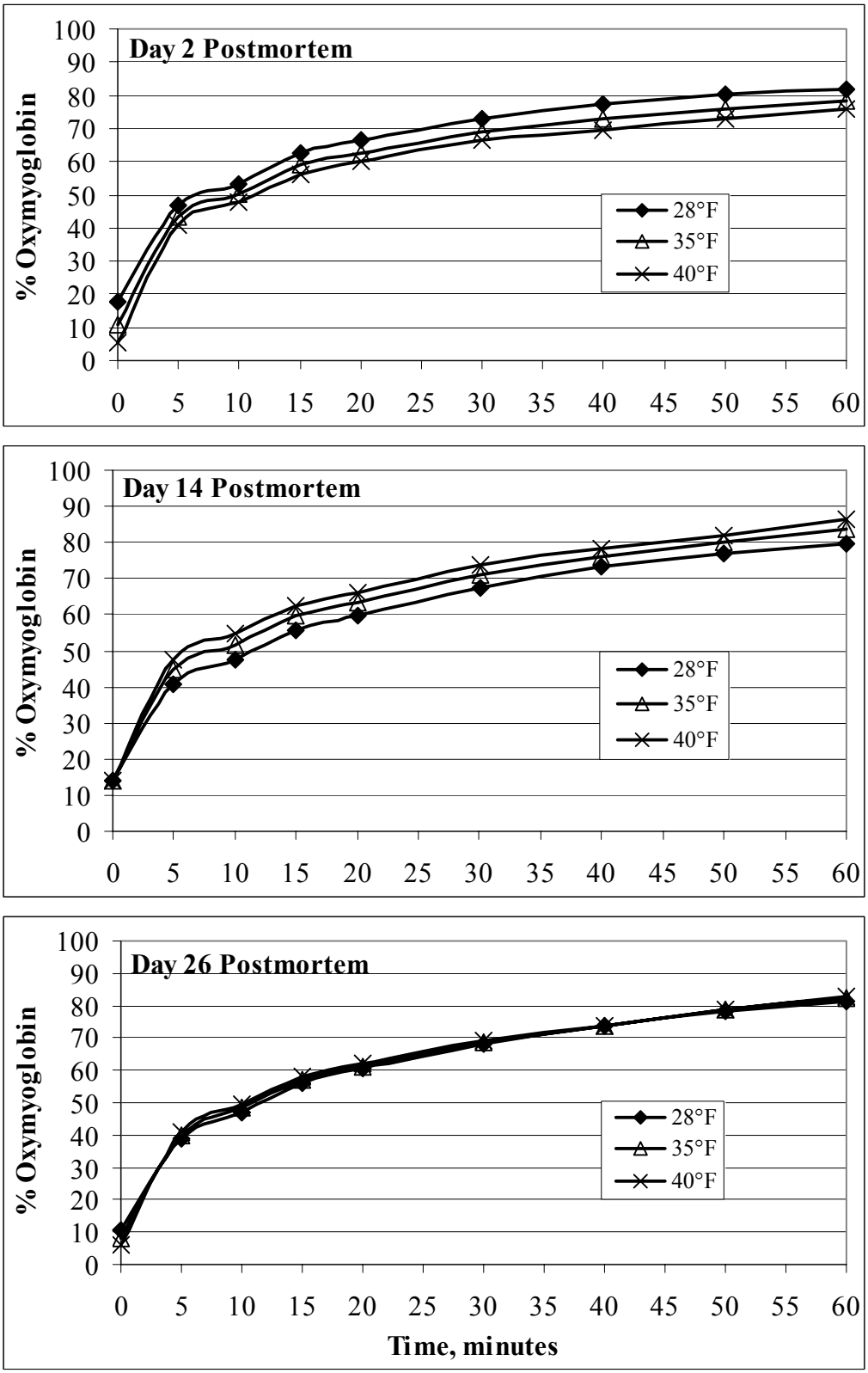

Figure 1. Estimated Percentage Oxymyoglobin in Longissimus Lumborum Held at 28, 35, or 40°F on Days 2, 14, and 26 Postmortem.

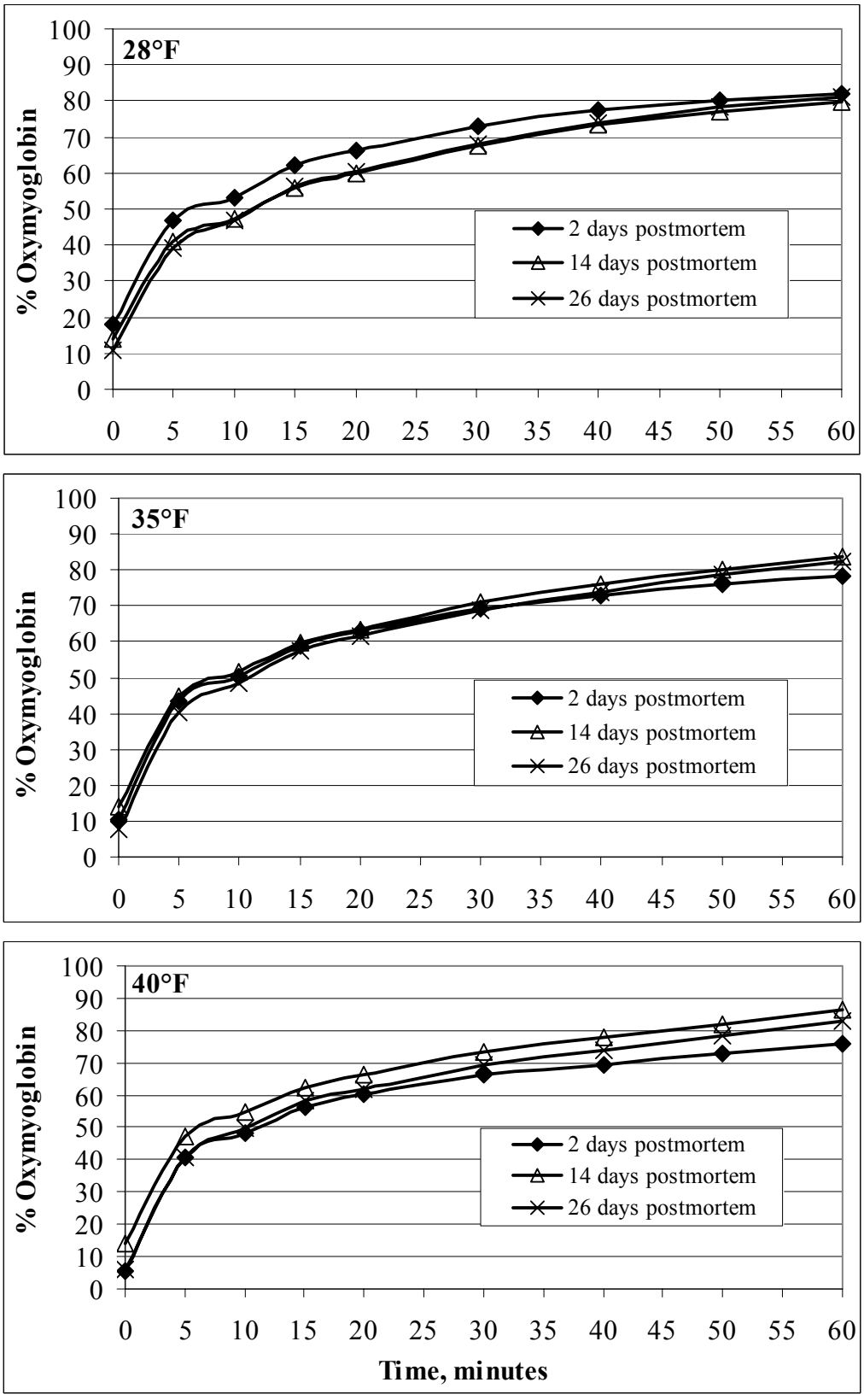

Figure 2. Estimated Percentage Oxymyoglobin in Longissimus Lumborum on Days 2, 14, and 26 Postmortem Held at 28, 35, or 40°F.

FACTORS CAUSING LIVERY FLAVOR IN BEEF STEAKS FROM THE CHUCK AND LOIN[1]

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Summary

The infraspinatus muscle (top blade) from the chuck clod, the gluteus medius muscle (top sirloin) from the sirloin, and the psoas major muscle (tenderloin) from the loin were obtained from 140 A- and B-maturity carcasses with either low-Slight or Small marbling and with either normal pH (5.7 or less) or high ultimate pH (6.0 or higher) to evaluate factors that could cause livery flavor in cooked beef. Muscles were aged for 7, 14, 21, or 35 days. A highly trained, flavor-profile sensory panel evaluated charbroiled steaks from these muscles. Approximately 8% of all sensory panelist judgments were scored to have some livery flavor. Numerous statistical interactions were found among traits, which made it difficult to make clear conclusions. In general, marbling and aging time had little direct effect on livery flavor, and livery flavor was not related to raw muscle lipid oxidation.

Introduction

Consumers primarily purchase beef because of its desirable flavor and texture. Consumers regard any beef eating experience where uncharacteristic or undesirable flavors are detected as an "unfavorable" eating experience. Purveyors have identified one such undesirable flavor as "livery", occurring primarily in top sirloin and tenderloin steaks. Reducing the incidence of "livery" flavor would benefit the beef industry, and information regarding prevention of "livery flavor" should help reduce unsatisfactory beef eating experiences.

Flavor problems are seldom reported to the retail markets where beef products are purchased. Although several researchers have reported the occurrence of livery flavor, essentially no research has been conducted to determine factors causing livery flavor development. This project was funded with Beef Checkoff dollars and coordinated by the National Cattlemen's Beef Association.

Experimental Procedures

Subprimal Selection. Beef chuck, shoulder clods; loin, top sirloin butts; and loin, full tenderloins were obtained from 140 carcasses from two commercial beef slaughter and processing facilities at six different sampling times. The infraspinatus, gluteus medius, and psoas major muscles were excised from each of the respective subprimals. Carcasses were selected to fit into two groups: carcasses of A-

[1]Appreciation is expressed to the Beef Checkoff for funding this project, National Cattlemen's Beef Association for coordination, and to Cryovac Sealed Air Corporation for providing packaging materials. The authors acknowledge the assistance of J.W. Stephens, J.R. Davis, S.L. Stroda, S. Lowak, and A. Jenkins.

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and B-maturity bone. Within maturity groups, two pH subgroups, pH of 5.7 or less (normal) and pH of 6.0 or greater (dark cutters) were selected. Ribeye muscle pH was measured at 24 to 48 hours postmortem. The carcasses also were selected for USDA marbling score of Slight^{00} to Slight^{50} or Small^{00} to Modest^{00} (Table 1). Due to the low incidence of B-maturity x high pH carcasses, we were unable to select an equal number of these carcasses. Subprimals were fabricated at 7 days postmortem, and the individual muscles of interest were removed. Steaks 1-inch thick were cut from the muscles, randomly assigned to an aging treatment (7, 14, 21, or 35 days), and vacuum packaged. The steaks assigned to the 7-day aging treatment were frozen at -40°F and stored until just prior to trained flavor-profile panel evaluations. The remaining steaks were aged at 36 to 39°F until either 14, 21, or 35 days postmortem. All steaks were then frozen and stored at -40°F until sensory panel evaluation.

Flavor-Profile Sensory Panel Evaluations. The **Plan** procedure of SAS was used to determine the treatments represented each day for the panel evaluations, to reduce any order bias. Steaks were thawed at 39°F for approximately 24 hours prior to trained flavor-profile sensory panel evaluations. The steaks were cooked on a Wells Model B-44 Electric Charbroiler and turned every 4 minutes until an internal temperature of 158°F was reached.

The highly trained flavor panel scored the cooked steaks using a 15-point scale, with 15 being most intense and 0 being none. The standards for each attribute were determined by the panelists and were used each time the panel met. Reference material for the livery flavor standard was generated by combining 80% lean ground beef with ground beef liver and cooking to 160°F. The panelists were provided reference standards with 1, 3, and 5% liver (by weight) during their evaluations that were assigned ratings of 1.5, 3.5, and 5.0, respectively.

After cooking, the steaks were cut perpendicular to the surface into cubes measuring 1.0 x 0.5 x 0.5 inch. Steaks were evaluated for the previously identified attributes and scored to the nearest 0.5 on the 15-point scale. Panelists were presented not more than 15 samples per session to minimize sensory fatigue and adaptation. The duration of each session was 1.5 hours, and panelists were allowed a 5-minute break after receiving one-half of the samples. The evaluations were conducted in an atmospherically controlled room with the temperature and humidity levels set at 70 ± 2°F and 55 ± 5%, respectively.

Statistical Analyses. The **Mixed** procedure of SAS was used to analyze all flavor profile data. The flavor panel data were analyzed in a split-plot design structure. The data were analyzed with maturity, marbling, pH, and muscle serving as whole plot fixed effects, and aging time as the subplot fixed effect. Interactions and main effects with $P<0.05$ were considered significant.

Results and Discussion

The percentage of total observations (9,397) rated as livery were: 0.4% rated as 0.5, 1.0% rated as 1.0, 2.9% rated as 1.5, 1.9% rated as 2.0, 1.2% rated as 2.5, 0.9% rated as 3.0, 0.8% rated as 3.5, 0.3% rated as 4.0, 0.1% rated as 4.5, 0.1% rated as 5.0. The three-way interaction for livery flavor suggests that neither marbling, maturity, nor aging time had a consistent effect on livery flavor (Table 2). There was a slight trend for muscles from A-maturity carcasses with small marbling to have less livery flavor and muscles from carcasses with B-maturity to have more livery flavor, but this was not a clear trend, and most samples scored 0 for livery flavor. Both the top sirloin and tenderloin steaks had a more

intense livery flavor ($P<0.05$) than the top blade, but the small numerical difference (0.07 on a 15-point scale) likely is of little practical importance (Table 3). The treatment combination of B-maturity, Slight marbling, and 35 days aging had more livery flavor ($P<0.05$) than any other, but its mean score of 0.47 on a 15 point scale is not a very strong indicator.

Livery flavor is a complex trait, its incidence is sporadic, and its cause(s) likely involve interactions among numerous traits. In general, marbling did not affect livery flavor.

Table 1. Distribution of Carcasses Sampled with Different Maturity, Marbling, and pH Combinations

No. of Carcasses	Maturity	USDA Marbling	pH
20	A	Slight	Normal
20	A	Small	Normal
20	A	Slight	High
20	A	Small	High
20	B	Slight	Normal
20	B	Small	Normal
8	B	Slight	High
12	B	Small	High

Table 2. Aging Time × Maturity × Marbling Interaction for the Livery Flavor Attribute

Aging Time	Maturity	Marbling	Livery Flavor*	Standard Error
7 days	A	Slight	0.17[c]	0.05
7 days	A	Small	0.18[c]	0.05
21 days	A	Small	0.21[bc]	0.05
35 days	A	Slight	0.21[bc]	0.05
7 days	B	Small	0.21[bc]	0.05
14 days	A	Slight	0.22[b]	0.05
14 days	B	Small	0.22[b]	0.05
35 days	A	Small	0.22[bc]	0.05
21 days	B	Slight	0.23[bc]	0.06
35 days	B	Small	0.24[bc]	0.05
14 days	A	Small	0.25[b]	0.05
21 days	A	Slight	0.25[bc]	0.05
21 days	B	Small	0.27[bc]	0.05
7 days	B	Slight	0.27[bc]	0.06
14 days	B	Slight	0.32[b]	0.06
35 days	B	Slight	0.47[a]	0.06

[abc]Means within a column not bearing a common superscript letter differ (P<0.05).
*0 = none, 15 = Most Intense.

Table 3. Muscle Effect on the Livery Flavor Attribute

Muscle	Livery Flavor*	Standard Error
Top Blade	0.20[b]	0.04
Top Sirloin	0.27[a]	0.04
Tenderloin	0.27[a]	0.04

[ab]Means within a column having different superscript letters differ (P<0.05).
*0 = none, 15 = Most Intense.

EFFECTS OF UNSATURATED FATTY ACIDS, LIPID OXIDATION, MYOGLOBIN, AND HEMOGLOBIN ON LIVERY FLAVOR VOLATILES IN BEEF STEAKS[1]

E. J. Yancey, M. E. Dikeman, J. S. Smith, K. A. Hachmeister, E. Chambers IV[2], P. Gadgil, G. A. Milliken[3], and E. Dressler[4]

Summary

Infraspinatus (top blade), gluteus medius (top sirloin), and psoas major (tenderloin) steaks were obtained from A- and B-maturity carcasses that had either a high (≥ 6.0) or normal (≤ 5.7) pH, and either slight or small marbling. The steaks were vacuum aged until either 7, 14, 21, or 35 days postmortem. The steaks were broiled and served to a highly trained flavor-profile sensory panel. Steaks with livery flavor were subjected to gas chromatography/mass spectrometry analyses for flavor compounds. Steaks aged until 7 or 35 days postmortem were analyzed for the 2-thiobarbituric acid reactive substances (TBARS) content to determine lipid oxidation and for myoglobin and hemoglobin concentrations. Thirteen different volatile compounds had greater amounts in steaks with livery flavor. Lipid oxidation of raw steaks was not related to livery flavor, but steak myoglobin concentration was related to livery flavor.

Introduction

Livery flavor is an off-flavor sometimes associated with beef. Livery flavor is objectionable to many consumers, and meat purveyors have received numerous complaints. Little research has been conducted on the volatiles responsible for livery flavor. Limited research has been conducted to determine if myoglobin and hemoglobin concentrations are related to the development of livery flavor. Therefore, the objectives of our study were to determine if pigment concentration, lipid oxidation, and fatty acid composition were related to livery flavor and to identify the volatile compounds that were related to livery flavor. This project was funded with Beef Checkoff dollars and coordinated by the National Cattlemen's Beef Association.

Experimental Procedures

Subprimal Selection. Beef chuck, shoulder clods; loin, top sirloin butts; and loin, full tenderloins were obtained from two commercial beef slaughter and processing facilities at six different sampling times. The infraspinatus, gluteus medius, and psoas major muscles were excised from each of the respective subprimals. Carcasses were selected to fit into two groups: 1) carcasses of A-maturity and 2) carcasses of B-maturity bone. These groups were further selected to be of two pH subgroups: 1) those having an ultimate pH of 5.7 or less and 2) those having a pH of 6.0 or greater (dark cutters). The carcasses also were

[1]Appreciation is expressed to the Beef Checkoff for funding this project, National Cattlemen's Beef Association for coordination, and to Cryovac Sealed Air Corporation for providing the packaging materials. The authors also acknowledge the contributions of J. W. Stephens, X. Wu, J. Fotso, J. R. Davis, S. L. Stroda, D. Trumble, and A. Jenkins to this project.

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selected to be of two marbling groups: 1) those having USDA marbling scores of Slight^{00} to Slight^{50} and 2) those having USDA marbling scores from Small^{00} to Modest^{00}. The subprimals were fabricated at 7 days postmortem, and the individual muscles of interest were removed from each subprimal. Steaks 1-inch thick were cut from the muscles, randomly assigned to an aging treatment (7, 14, 21, or 35 days), and vacuum packaged. Steaks were aged at 36 to 39°F until either 14, 21, or 35 days postmortem. All steaks were then frozen and stored at -40°F until analyses.

Quantification of Myoglobin and Hemoglobin. HPLC analyses were conducted on pulverized steak samples with a Hewlett-Packard Series II, 1090A HPLC. A 50 µL buffered volume of the filtered sample was injected into the HPLC instrument. Horse skeletal muscle myoglobin, bovine hemoglobin, sodium phosphate, and ammonium sulfate were used to make stock solutions containing varying levels of myoglobin and hemoglobin. The solutions were prepared using a 0.1 M sodium phosphate buffer, and these solutions were used to prepare standard curves.

Gas Chromatography/Mass Spectrometry. Steaks were cooked on a Wells B-44 charbroiler. Cooked samples that were found to be livery by the highly trained descriptive-flavor-profile sensory panel were frozen for later gas chromatography. Samples were divided into groups of either "extremely" livery (>2.0 on 15-point sensory scale), "moderately" livery (0.5-1.5), or control (0). These samples were frozen and used to identify which compounds contributed to livery flavor and to determine if amounts of some compounds increased as livery flavor increased.

Ten grams of frozen pulverized sample plus 40 mL of distilled water were steam distilled until a total of 8 mL had accumulated in a glass test tube. The distillate was then poured into a glass headspace vial, capped, and frozen until thawed for analysis. The samples were then placed in a water bath at 176°F and a 100 µm poly-dimethyl-sulfoxide fiber (Supelco, Bellefonte, PA) was inserted into the vial. The fiber was exposed to the headspace in the vial for 20 minutes. The fiber was then removed from the vial, and inserted through a septum into the Hewlett-Packard 5890 gas chromatography/mass spectrometer.

TBARS Analyses. Ten grams of pulverized sample was combined with 10 mL of 7.2% perchloric acid and 20 mL of cold distilled water. After blending, the sample mixture was filtered and the TBARS reagent added. The absorbance was read at 529.5 nm, and a standard equation was then used to determine the TBARS concentration.

Fatty Acid Profiles. Subcutaneous fat samples were taken from either the top sirloin butt or the shoulder clod of each carcass, frozen in liquid nitrogen and pulverized. A Shimadzu model GC-9AM gas chromatograph was used to analyze the samples. Proportions of 14:0, 16:0, 16:1, 18:0, 18:1, and 18:2 fatty acids were determined.

Statistical Analyses. The Correlation procedure of SAS was used to generate correlation coefficients and probablility values. Probablility values of less than 0.05 were considered significant.

Results and Discussion

Myoglobin and Hemoglobin. Myoglobin and hemoglobin levels were analyzed for correlations with sensory panel livery flavor intensity scores. Significant correlations involving myoglobin resulted for four treatment combinations (Table 1), although these correlations were somewhat low. However, myoglobin content of muscles may contribute to the intensity and incidence of livery flavor.

No correlations of hemoglobin with livery flavor were significant. No other published research has attempted to correlate pigment concentration with livery flavor.

Gas Chromatography/Mass Spectrometry. Table 2 contains a list of volatile compounds that frequently differed in concentration between samples that had livery flavor as rated by the trained flavor-profile sensory panel and those randomly selected that did not have livery flavor. Thirteen volatile compounds were in greater amounts in the samples that had livery flavor, whereas three were greater in selected samples that did not have a livery flavor. Other compounds (85) found in both livery and non-livery samples, were in proportions not different between sample types

Lipid Oxidation. As expected, longer aging time resulted in increased TBARS values ($P<0.05$; Table 3). However, the TBARS values for 35-day aged steaks were much lower than a level that could influence oxidative flavor. No significant ($P>0.05$) correlation existed between the sensory panel livery flavor attribute and TBARS values within any treatment combinations, possibly a result of very little variation in the low TBARS values.

Fatty Acid Profiles. Although some statistically significant correlation coefficients were identified (Table 4), no moderate or strong relationships were found. Even so, some unsaturated fatty acids may contribute to livery flavor in certain muscles.

Livery flavor was not strongly related to lipid oxidation. Muscle myoglobin concentration in some muscles may influence livery flavor. Thirteen different volatile compounds occur in greater amounts in samples with livery flavor. The undesirable livery off-flavor attribute is complex and likely affected by a number of muscle components, with no major contributor yet identified.

Table 1. Significant Correlation Coefficients ($P<0.05$) of the Livery Flavor Attribute with Myoglobin Concentration within Muscle, Aging Time, and Marbling

Muscle	Aging Time	Marbling	Pigment	Correlation Coefficient
Top sirloin	7 days	Slight	Myoglobin	0.34
Top blade	7 days	Slight	Myoglobin	0.28
Top blade	35 days	Slight	Myoglobin	0.35
Tenderloin	7 days	Small	Myoglobin	0.39

Table 2. Volatile Compounds Found to be Higher in Livery Samples versus Non-Livery Samples

Compound Name
(Compounds with higher concentrations in livery samples)
Hexanal
Butane, 1-(ethenylthio)
dl-Limonene
2-Octenal
Nonanal
2-Nonenal, (E)-
2-Decenal-[E]-
2,4-Decadienal, (E,E)-
2,4-Decadienal
2-Undecenal
Phenol, 2,6-bis(1,1-dimethylethyl)-4-methyl-
Pentan-1,3-Dioldiisobutyrate, 2,2,4-tryme
Tetradecanal
(Compounds with higher concentrations in non-livery samples)
Trans-2-Undecen-1-ol; or Dodecanol
Octadecanal or Hexadecanal
Octadecanal

Table 3. Aging Time Effects for 2-Thiobarbituric Acid (TBARS) Values from Steaks

Aging Time	TBARS Value (ppm)
7 days	0.06[b]
35 days	0.13[a]

[ab]Means within a column having different superscript letters differ (P<0.05).

Table 4. Significant Correlation Coefficients (P<0.05) of Livery Flavor Attribute with Fatty Acid Concentrations in Selected Muscle x Aging Time Combinations

Muscle	Aging Time	Fatty Acid[a]	Correlation Coefficient
Gluteus medius	7 days	18:1n9t	-0.20
Gluteus medius	14 days	18:1n9t	-0.20
Gluteus medius	14 days	18:1n9t	0.21
Gluteus medius	35 days	16:1	-0.19
Gluteus medius	35 days	17:1	-0.19
Psoas major	35 days	18:2n6c	-0.19

[a]n9t = carbon number 9 trans; n6c = carbon number 6 cis.

FLAVOR CHARACTERIZATION OF TOP BLADE, TOP SIRLOIN, AND TENDERLOIN STEAKS FROM A- AND B-MATURITY CARCASSES OF HIGH AND NORMAL pH

E. J. Yancey, M. E. Dikeman, K. A. Hachmeister, E. Chambers IV, G. A. Milliken, and E. Westcott

Summary

The infraspinatus muscle (top blade steak) from the chuck clod, the gluteus medius muscle (top sirloin steak) from the sirloin, and the psoas major muscle (tenderloin steak) from the loin were obtained from A- and B-maturity carcasses with either low-Slight or Small marbling and with either normal ultimate pH (5.7 or less) or high pH (6.0 or higher) to evaluate flavor profile characteristics. Muscles were aged for 7, 14, 21, and 35 days. A highly trained flavor-profile sensory panel evaluated charbroiled steaks from these muscles. Muscles from high pH (dark cutting) carcasses had less typical beef flavor identity and less brown roasted flavor than those from carcasses with normal pH. Top blade steaks had a more intense bloody/serumy flavor than top sirloin and tenderloin steaks. Aging steaks to 21 or 35 days postmortem increased the metallic flavor sensory characteristic. Top sirloin steaks had a more intense sour flavor than top blade or tenderloin steaks, and steaks from carcasses having a high pH were found to be more rancid than those from carcasses with normal pH. In general, high pH steaks and those aged longer than 21 days had less desirable flavor profiles than normal pH steaks and those aged only 14 days.

Introduction

Consumers primarily purchase beef because of its desirable flavor and texture. Researchers have characterized the palatability of high and normal pH and A- and B-maturity longissimus muscles, but no research has evaluated the effects of pH and maturity on the flavor attributes of top sirloin, tenderloin, or top blade steaks. Therefore, our project was designed to evaluate the effects of pH, maturity, marbling, and aging time on the flavor attributes of top blade, top sirloin, and tenderloin steaks. This project was funded with Beef Checkoff dollars and coordinated by the National Cattlemen's Beef Association.

Experimental Procedures

Subprimal Selection. Beef chuck, shoulder clods; loin, top sirloin butts; and loin, full tenderloins were obtained from two commercial beef slaughter and processing facilities at six different sampling times. Carcasses were selected to fit into two groups: 1) carcasses of

[1]Appreciation is expressed to the Beef Checkoff for funding this project, National Cattlemen's Beef Association for coordination, and to Cryovac Sealed Air Corporation for providing packaging materials. The authors would like to acknowledge the assistance of J. W. Stephens, J. R. Davis, S. L. Stroda, S. Lowak, and A. Jenkins.

[2]Department of Human Nutrition.

[3]Department of Statistics.

[4]National Cattlemen's Beef Association, Centennial, CO.

A-maturity bone and 2) carcasses of B-maturity bone. These groups were further selected to be of two pH subgroups: 1) those having an ultimate pH of 5.7 or less and 2) those having an ultimate pH of 6.0 or greater (dark cutters). Ribeye muscle pH was measured at 24 to 48 hours postmortem. The carcasses also were selected to be of two marbling groups: 1) those having USDA marbling scores of Slight^{00} to Slight^{50} and 2) those having USDA marbling scores from Small^{00} to Modest^{00}. Due to the low incidence of B-maturity x high pH carcasses, we were unable to select an equal number of these carcasses. The subprimals were fabricated at 7 days postmortem, and the top blade, top sirloin, and tenderloin were excised from each of the respective subprimals. Steaks 1-inch thick were cut from the muscles, randomly assigned to an aging treatment (7, 14, 21, or 35 days), and vacuum packaged. The steaks assigned to the 7-day aging treatment were placed in a freezer at -40°F until just prior to trained flavor-profile panel evaluations. The remaining steaks were aged at 36 to 39°F until either 14, 21, or 35 days postmortem, then frozen and stored at -40°F until sensory panel evaluation.

Flavor-Profile Sensory Panel Evaluations. The **Plan** procedure of SAS was used to determine the treatments represented each day for the panel evaluations in order to reduce any order bias that might be created during panelist evaluations. Steaks were thawed at 39°F for 24 hours prior to trained flavor-profile sensory panel evaluations. The steaks were cooked on a Wells Model B-44 Electric Charbroiler, and steaks were turned every 4 minutes until an internal temperature of 158°F was reached.

The highly trained flavor profile panel used a 15-point scale for evaluations, with 15 being most intense and 0 being none. The standards for each attribute were determined by the panelists, and reference samples were used each time the panel met. Panelists used 80% lean ground chuck cooked to 160°F as the standard for both beef flavor identity and the brown roasted attribute. This standard was rated as a 10.5 for beef flavor identity and a 10.0 for brown roasted flavor. Strip loin steaks (USDA Select) were used as the standard for the bloody/serumy and metallic attributes. The steaks were cooked on the charbroiler to an internal temperature of 140°F. This standard was rated as a 5.5 for the bloody/serumy attribute and a 4.0 for the metallic attribute. Dole brand canned pineapple juice was also used for the metallic attribute and was rated as a 6.0. Crisco vegetable oil that had been heated in a microwave oven for 3 minutes and cooled was used as the rancid reference and was rated a 7.0. Two citric acid solutions were used for a sour reference; 0.015% solution and 0.025% solution were rated as 1.5 and 2.5, respectively.

After cooking, the steaks were cut into cubes measuring 1.0 x 0.5 x 0.5 inch perpendicular to the surface. Steaks were scored to the nearest 0.5 on the 15-point scale. Panelists were presented not more than 15 samples per session to minimize sensory fatigue and adaptation. The duration of each session was 1.5 hours, and panelists were allowed a 5 minute break after receiving one-half of the samples. The evaluations were conducted in an atmospherically controlled room.

Statistical Analyses. The **Mixed** procedure of SAS was used to analyze all flavor panel data. The flavor panel data were analyzed in a split-plot design structure, with carcass as the whole plot and steak as the subplot. Maturity, marbling, pH, and muscle served as whole plot fixed effects, and aging time served as the subplot fixed effect. Interactions and main effects with probability values of less than 0.05 were considered significant.

Results and Discussion

In general, carcasses with normal pH had more intense beef flavor identity than carcasses with high pH. The tenderloin had greater beef flavor identity than the top sirloin, and both had greater beef flavor identity than the top blade, especially for carcasses with high pH. When considering all muscles from carcasses with high pH, those from B-maturity had more perceptible beef flavor identity than those from A-maturity.

The tenderloin from carcasses with normal pH had a more intense ($P<0.05$) beef flavor identity than all other treatment combinations. Muscles from carcasses with high pH generally had the least beef flavor identity, especially for the top blade. The effect of aging on beef flavor identity was very inconsistent.

The tenderloin from carcasses with high pH had a more intense ($P<0.05$) brown roasted flavor than the top blade from carcasses with high pH. In general, the brown roasted flavor attribute was more intense ($P<0.05$) for muscles from carcasses with normal pH. The top blade from carcasses of high pH had the least intense brown roasted flavor, especially after the 35-day aging period. The effect of marbling was inconsistent on brown roasted flavor.

Muscle-ranked from most to least ($P<0.05$) in intense bloody/serumy flavor were: top blade, tenderloin and top sirloin. Marbling had an inconsistent effect on bloody/serumy flavor intensity. The high pH, B-maturity carcasses had more intense ($P<0.05$) bloody/serumy flavor than the other pH × maturity combinations. In general, bloody/serumy flavor intensity decreased as aging time increased. The least intense bloody/serumy flavor was for muscles from A-maturity carcasses that had been aged 35 days.

Aging muscles for 21 or 35 days generally resulted in increased metallic flavor compared to aging only 7 or 14 days, but the differences were small. pH had an inconsistent effect on metallic flavor. The top sirloin had more intense metallic flavor ($P<0.05$) than the top blade and tenderloin, but the small numerical differences are not of practical importance.

The top sirloin generally had a more intense sour flavor than the tenderloin, and the top blade had the least intense ($P<0.05$) sour flavor. Muscles from carcasses with high pH had increased sour flavor for the tenderloin but decreased sour flavor for the top sirloin. Sour flavor generally increased with longer aging, but the effect of pH on sour flavor was different for longer aging than it was for shorter aging. The sour attribute would be expected to increase over time due to the growth of lactic acid bacteria within the vacuum package. However, the magnitudes of these differences were too small to be of practical importance. Maturity had an inconsistent effect on the sour flavor attribute.

Rancid flavor was more intense ($P<0.05$) for muscles from carcasses with high pH than for muscles from carcasses with normal pH. The high pH of the muscle was probably more favorable for the growth of microorganisms that break down lipids, and these organisms could have been responsible for the higher rancid flavor scores associated with steaks from high pH carcasses. The top blade had the most intense ($P<0.05$) rancid flavor and the top sirloin had the least intense ($P<0.05$) rancid flavor. Rancid flavor was more intense for A-maturity than for B-maturity top blade, but this was not true for the top sirloin and tenderloin.

As aging time increased, rancid flavor increased ($P<0.05$) for muscles from carcasses with both normal and high pH. The combina-

tion of small marbling and high pH resulted in the most ($P<0.05$) rancid flavor and, in general, muscles from carcasses with high pH and high marbling had more rancid flavor than those from carcasses with normal pH. The polyunsaturated fatty acids and phospholipids would be expected to autoxidize over time, which could have contributed to the increase in the rancid flavor attribute detected by the sensory panelists.

INHIBITION OF HETEROCYCLIC AMINE FORMATION IN BEEF PATTIES WITH ADDED SPICES AND INGREDIENTS

S. Hinojosa Verdin, K. A. Hachmeister, and J. S. Smith

Summary

Heterocyclic amines (HCAs) are compounds present at part per billion levels in fried, grilled, broiled, barbecued and smoked meats. Most of these compounds are highly mutagenic, as demonstrated by the Ames test using *Salmonella typhimurium*. They also are carcinogenic in rodents and non-human primates following high dosage and long term oral administration. For decades, researchers have focused on inhibiting the production of these carcinogens. This research investigates the effects of natural antioxidants in spices or other ingredients on the reduction of heterocyclic amines formation when beef patties are cooked. The term "spice" in this paper includes herbs. Ground beef patties combined with different levels of added spices or ingredients were cooked at 375°F (5 minutes each side) or 400°F (7.5 minutes each side). Extracted HCAs were then analyzed using reversed-phase High Performance Liquid Chromatography (HPLC) with UV-Visible and fluorescence detectors. Of the spices used, basil added at 0.5% was most effective in decreasing HCAs. Of all the ingredients, food starches showed the best inhibition when added at 5% as they reduced MelQx, harman, and norharman forms of HCA at both 375°F and 400°F.

Introduction

In 1977, extremely high mutagenic activity was reported in grilled beef and fish, which led to the discovery of the heterocyclic amines (HCAs). Further studies found that HCAs were produced in meat and other protein rich products. Recently, MelQx, IQ, MelQ and PhlP, four of the most dangerous HCAs, were nominated by the National Toxicology Program to be included on the 10th and 11th Reports of Carcinogens. HCAs have been related to colon, breast, and prostate cancer in numerous studies.

HCAs can be divided into two groups: the amino-carbolines or pyrolysis products, and the amino-imidazo-azaarenes (AIAS). The amino-carboline HCAs are formed by the pyrolysis of amino acids and proteins, but the exact mechanism is still unknown. Their formation is not dependent on creatin(in)e precursors, and therefore they may be present in foods of vegetative origin. The AIAS are formed at ordinary cooking temperatures. These compounds are extremely mutagenic compared to the amino-carbolines and are more commonly and easily formed during cooking.

The levels of HCAs can be reduced by preventing the Maillard browning reaction intermediates from reacting with creatinine. The use of antioxidants as free radical scavengers have stabilized intermediates from the Maillard browning reaction, therefore reducing the HCAs.

Some naturally occurring antioxidants found in spices can decrease levels of HCAs. Mustard and green tea have decreased the level of MelQx in beef. Rosemary, thyme, sage, garlic, and cherry tissue have decreased MelQx, IQ, MelQ, and PhlP when applied on the surface of beef steaks. Until now, no stud-

ies have assessed the effect of these spices when formulated into beef patties prior to cooking. This study measured inhibition of heterocyclic amines by adding certain spices or other ingredients to ground beef.

Experimental Procedures

Fine ground (1/8-inch plate) beef (20% fat) from the Meat Lab at Kansas State University was mixed manually with spices or other ingredients in batches of 25 lb for every level of added spice. Spice levels were 0.5 and 5% and ingredient levels were 2.5 and 5%. The spices (and herbs) included basil, garlic, ginger, onion, oregano, rosemary, sage, thyme, and turmeric. Dried plums were also included at 3 and 10%. Other ingredients included modified food starches (B990 and Firmtex), corn syrup solids (M200), rolled oat blend, whey protein isolate, whey protein concentrate, soy protein isolate, and soy protein concentrate. Patties were formed using patty molds to dimensions of 0.6 inch thick and 4 inches in diameter and weighing from 3.7 to 4.0 ounces. The 10 patties formed per level of spice were crust frozen on aluminum trays for 20 minutes at –40°F to facilitate handling, then packaged. Control samples without spices were prepared in a similar manner. Samples were stored at 0°F prior to cooking.

The samples were cooked on a Teflon® covered electric grill with temperature controller (Toastmaster, Denver, CO). A temperature profile of the grill surface was obtained prior to cooking in order to validate that the patties were all cooked under the same conditions. Three patties of each added level of spices or ingredients were cooked at the same time for each temperature. Two temperatures were used: 375°F (5 minutes each side), and 400°F (7.5 minutes each side). The griddle was cleaned between spices or ingredients to avoid interferences. After cooking, the patties were cooled to room temperature, then ground completely using a Micro-Mill.

All ground patties were stored at 0°F prior to extraction with 9 to 1 methanol:ammonium hydroxide and subsequent analysis. The extract was dried under pressure with N_2 and suspended with 25 µl of methanol. Eight µl of the sample was injected using a 20 µl loop into a Hewlett-Packard 1090 A, series II HPLC (Palo Alto, CA) fitted with a photodiode array UV-visible detector and a programmable fluorescence detector. Data were then analyzed using an HP ChemStation. Separation was achieved with a silica-based reversed-phase TSK-Gel ODS-80TM column (25 cm × 4.6 cm, 5 µm, 80 Å; Toso Haas, Montgomeryville, PA). The mobile phase consisted of three solvents: solvent A, 0.01 M triethylamine (pH 3.2); solvent B, 0.01 M triethylamine (pH 3.6); solvent C, acetonitrile. The gradient profile was linear, and the program was 0-10 minutes, 5-15% C in A; 10-10.1 minutes, exchange of A with B; 10.1-10 minutes, 15-25% C in B; 20-30 minutes, 25-55% C in B, followed by 15 minutes for column equilibration.

The standards for polar HCAs (MelQ and PhlP) and nonpolar HCAs (harman and norharman) were obtained from Toronto Research Chemicals (Toronto, Canada).

Results and Discussion

Recovery of compounds calculated by the spiking of samples was 59.5% for MelQx, 73.1% for PhlP, 51.0% for norharman, and 43% for harman. Of the spices used, basil added at 0.5% was most effective in decreasing HCAs. At 0.5%, basil decreased MelQx and PhlP, while having no effect ($P>0.05$) on the co-mutagenics harman and norharman. Onion did not inhibit HCAs, but increased norharman and MelQx when used at 5% in

patties cooked at 400°F, and increased harman and PhlP at both levels of addition. Dried plums were not very effective either, as they increased MelQx and PhlP when added at 10%, and increased harman and norharman at 3% and 10%. Rosemary and sage, recognized as remarkably active antioxidant spices (actually herbs), were not the most effective, suggesting that inhibition does not totally depend on the antioxidant activity of the ingredient but on its molecular conformation.

Cattlemen's Day 2003

EFFECT OF INFORMATION AND INFORMATION SOURCE ON CONSUMER PREFERENCE FOR FOOD IRRADIATION

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Summary

The effect of consumer information about food irradiation and the source of the information was studied through a survey mailed to 400 residents each of Manhattan and Topeka, Kansas. Two-thirds of the surveys contained a brochure providing answers to frequently asked questions about irradiation, one-third did not. Half of the informational brochures were altered to suggest they were from industry, half from the government. The survey questioned consumer choice between irradiated and non-irradiated ground beef patties, with price differentials from 10 cents/lb to 40 cents/lb costlier for irradiated patties. A greater price differential resulted in less preference for irradiated beef patties. The informational brochure increased the choice of irradiated patties, with that from a "government source" rather than an "industry source" being more effective (57% compared to 51%).

Introduction

Studies have shown a positive effect on consumer acceptance from providing additional information about irradiation. Negative information will reduce acceptance levels, and the impact of negative information about the process can dominate effects of positive pro-irradiation information. Because most people are still unfamiliar with irradiation (only 48% of a sample of 10,780 adults had heard of the process), providing information to consumers is critical to the market success of irradiated foods.

While the effects of information on acceptance are fairly well established, less attention has been given to effects related to source of information. For example, does it matter if industry or government provides the information? If consumers perceive information provided by the irradiation industry to be less reliable, public health benefits associated with irradiation justify public expenditures to inform consumers about the process.

The goal of this study was to investigate whether identical brochures from two sources, industry and government, would have a similar effect on consumer acceptance of irradiated hamburger.

Experimental Procedures

A survey was mailed to 400 residents of Manhattan, Kansas and 400 residents of Topeka, Kansas on April 15, 2002 with a follow-up mailing to non-respondents on May 24. The survey included questions about beef purchases, the respondent's knowledge of and attitude toward food irradiation, and demographics.

One-third of respondents received no information about food irradiation except for a brief statement of its effect on food-borne pathogens. For the remaining two-thirds, the

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survey included a brochure providing answers to frequently asked questions about irradiation. The leaflet was developed by Dr. Christine Bruhn, Director, Center for Consumer Research at the University of California, Davis. The brochures were altered to suggest that half were from an industry source using the wording "Based on information provided by the food irradiation industry," and the other half from a government source using the wording "Based on information provided by the Food and Drug Administration and the United States Department of Agriculture."

The preference question in the survey asked consumers to choose between irradiated and non-irradiated hamburger patties. The wording was*: "If your local food store sold hamburger patties which had been treated by irradiation to control Salmonella, E. coli and other food-borne bacteria, would you buy non-irradiated hamburger patties at $1.69 per pound or irradiated hamburger patties at $‹‹PRICE›› per pound?* The "PRICE" for the irradiated patties varied between a 10 cent/lb premium and a 40 cent/lb premium across four versions of the survey. The price for non-irradiated patties was $1.69/lb in all surveys.

Results

After allowing for 38 undelivered surveys, the overall response rate was 57%, with 215 and 216 surveys returned from Manhattan and Topeka, respectively.

Information about irradiation influenced attitudes toward the process. Thirty-two percent of respondents who did not receive an information brochure reported a positive attitude toward irradiation. Of those who received the "industry" brochure, 66% reported a positive attitude, while 76% of those who received the "government" brochure reported a positive attitude.

As expected, the proportion of consumers choosing irradiated patties decreased as the price of irradiated patties increased. At a premium of 10 cents/lb, 59% of the respondents chose the irradiated patties. When the premium was raised to 40 cents/lb, the proportion choosing irradiated fell to 36%.

Providing information about irradiation impacted choices. When averaged across the four price levels, irradiated patties were chosen by 57% of individuals receiving government information, by 51% of those receiving industry information, but only by 39% of individuals who received no information. Government information was more effective than industry information at the lower and higher prices, but had a similar impact at mid-range prices.

EFFICACY OF BUFFERED SODIUM CITRATE ALONE AND IN COMBINATION WITH SODIUM DIACETATE AGAINST *LISTERIA MONOCYTOGENES* ON BEEF FRANKS

E. Ceylan, M. Hajmeer, and J. L. Marsden

Summary

We assessed the antimicrobial efficacy of buffered sodium citrate alone and in combination with sodium diacetate against *L. monoyctogenes* on beef frank samples stored at 39°F. Initial inoculum level of *L. monocytogenes* was 1.5 log colony forming units (CFU)/cm^2. After 6 weeks of incubation at 39°F, the pathogen reached 5.4 log CFU/cm^2 in the control sample, but was 1.2 log CFU/cm^2 and 0.85 log CFU/cm^2 in samples treated with 1% buffered sodium citrate alone and in combination with 0.1% sodium diacetate, respectively. Use of buffered sodium citrate and the combination of buffered sodium citrate and sodium diacetate should improve safety of ready to eat foods by controlling *L. monoc*ytogenes during storage.

Introduction

Extending shelf life and assuring safety of meat and poultry products is a high priority. Buffered sodium citrate is a combination of citric acid and sodium citrate. The USDA Food Safety and Inspection Service has permitted the use of buffered sodium citrate since June 24, 1996 in cured and uncured meat and poultry products. Sodium citrate, a salt of citric acid, is approved as a generally recognized safe compound by the Food and Drug Administration. It occurs as a natural compound in fruits and has few limitations for use in food.

Buffered sodium citrate, IONAL™, inhibits microbial growth and retains flavor. It is especially effective a low initial microbial count. IONAL increases ionic strength in the system, which allows better water holding capacity, lower water activity, and less purge in meat and poultry products. It increases shelf life and maintains organoleptic characteristics of meat and poultry for a long period of time during storage. The recommended usage level of IONAL is 1.0 to 1.3%. Its antimicrobial activity increases as product pH decreases.

Listeria monocytogenes has been associated with a variety of foods and is designated as a zero tolerance organism in ready-to-eat foods. *Listeria monocytogenes* is Gram-positive, motile with flagella, psychrotrophic, and nonsporeforming. It has been associated with raw milk, pasteurized milk, cheeses, ice cream, vegetables, fermented sausages, raw and cooked poultry, raw meats, and raw and smoked fish. *Listeria monocytogenes* has been isolated from soil, leaf litter, sewage, silage, dust, and water. Its abundance in the environment and ability to grow at temperatures as low as 37°F can cause a serious bacterial infection, listeriosis, in refrigerated and ready to eat foods. Listeriosis has been implicated in approximately 2,500 cases and an estimated 50 fatalities each year. Multistate outbreaks of listeriosis were reported by the Centers for Disease Control and Prevention and the outbreaks caused by consumption of deli turkey meat and hot dogs.

We evaluated the antimicrobial effect of 1% buffered sodium citrate (IONAL) alone and in combination with 0.1% sodium diacetate against *L. monocytogenes* on beef frankfurters during refrigerated storage.

Experimental Procedures

Culture preparation. *Listeria monocytogenes* cultures (ATCC 13932, ATCC 49594, ATCC 43256, ATCC 51414 and ATCC 7647) were obtained from the American Type Culture Collection (Atlanta, GA). Cultures were grown in Brain Heart Infusion broth at 35°C for 24 hours and kept at 39°F until use. Each culture was then transferred from the stock collection and grown at 95°F for 24 hours. Equal volume of each culture was transferred into a sterile test tube to make a mixture of 5 strains of *L. monocytogenes*. Serial dilutions of this mixture were made using 0.1% peptone water (Difco Laboratories, Detroit, MI) and inoculated onto the beef frankfurter samples.

Preparation of beef frank samples. Commercial beef franks were purchased from a local grocery store. The average surface area and weight of beef franks were determined prior to the experiment (n=5). Single beef frank samples were placed into a vacuum packaging bag. Each bag was inoculated with the *L. monocytogenes* mixture. Samples were surface treated using 1% buffered sodium citrate or 1% buffered sodium nitrate + 0.1% sodium diacetate. Control samples (no antimicrobial treatment) were inoculated only with *L. monocytogenes*. Samples were vacuum packaged, kept at 39°F, and analyzed weekly. *Listeria monocytogenes* count was determined using Tryptic Soy Agar (Difco Laboratories, Detroit, MI) incubated at 95°F for 24 hours. Experiments were repeated three times.

Results and Discussion

The average surface area and weight of beef franks were 91 cm^2 and 44.8 g, respectively. Initial inoculum level of *L. monocytogenes* was 1.5 log CFU/cm^2. After 6 weeks of incubation at 35°F, the pathogen reached a 5.4 log CFU/cm^2 in control samples, but was only 1.2 log CFU/cm^2 and 0.85 log CFU/cm^2 in samples treated with 1% IONAL, and the combination of 1% IONAL and 0.1% sodium diacetate, respectively. These results show the potential bacteriostatic and/or bactericidal effect of 1% IONAL and the combination of 1% IONAL and 0.1% sodium diacetate against *L. monocytogenes*. Combining 1% IONAL and 0.1% sodium diacetate might also induce sublethal injury, which would reduce of the number of *L. monocytogenes* on beef frank samples.

POST-PROCESS STEAM PASTEURIZATION OF PACKAGED FRANKFURTERS COMBINED WITH ACID/BUFFER TREATMENTS FOR CONTROL OF *LISTERIA MONOCYTOGENES*

A. L. Reicks, H. Thippareddi, R. K. Phebus, J. L. Marsden, and C. L. Kastner

Summary

The efficacy of a saturated steam-based post-process pasteurization system to reduce/eliminate *Listeria monocytogenes* on frankfurters was evaluated. Frankfurters were packaged individually or in a single layer format (4 per package, touching). Samples were surface treated with 2% lactic acid, 4% lactic acid, 2% buffered sodium citrate, or 2% buffered sodium lactate, vacuum packaged, and steam pasteurized to end-point surface temperatures of 160, 170 or 180°F using a Townsend Post-Process Pasteurization system (formerly Stork-RMS Protecon). Pasteurization of inoculated single layer franks to surface end point temperature targets of 160, 170, and 180°F resulted in *L. monocytogenes* reductions ($P<0.05$) of 0.92, 1.44 and 2.89 log colony forming units (CFU)/frank, respectively. Greater reductions in *L. monocytogenes* populations were observed for individually packaged frankfurters with 2.32, 4.62 and 6.52 log CFU/frank reductions at target surface end point temperatures of 160, 170, and 180°F, respectively. No differences ($P>0.05$) were noted between various surface acid treatments applied. Post-process pasteurization of frankfurters (in-package) using the saturated-steam-based Townsend system was effective in reducing numbers of *L. monocytogenes*.

Introduction

Listeria monocytogenes, an important foodborne pathogen, may be present on a variety of foods including coleslaw, raw vegetables, milk, and poultry. Most recently, outbreaks have involved ready-to-eat meats such as hot dogs and lunch meats. Even though these ready-to-eat products are free of *L. monocytoge*nes when exiting the cooker, further handling and packaging of the meats may lead to re-contamination of product surfaces.

Post-process pasteurization can eliminate *L. monocytogenes* by exposing the product (in-package) to steam, which thermally destroys the bacteria. Other means of destroying bacteria include the use of acid or buffer treatments as product washes prior to packaging. Treatment of ready-to-eat meats using various acid and buffer treatments in conjunction with post-process pasteurization may provide additional assurance to consumers of a safe product, even if contaminated after initial heat processing. The objective of this research was to quantify *L. monocytogenes* reductions on packaged frankfurters using the Townsend system and to determine if organic acid pre-treatment of products enhanced the thermal effectiveness of this system.

Experimental Procedures

Inoculum preparation. A five-strain cocktail of *L. monocytogenes* [108 M, 109, serotype 4c ATCC, serotype 3 ATCC, and H7738 (food outbreak strain)] was used. The cultures were maintained on Tryptic Soy Agar (Difco, Detroit, MI) slants at 39°F. Fresh cultures of the inoculum were prepared from the slants by transferring the cultures to 5 mL of Tryptic Soy Broth (Difco, Detroit, MI) and incubating at 95°F for 24 hours. After incubation, 1 mL of fresh culture was transferred into centrifuge bottles containing 100 mL Tryptic Soy Broth and further incubated at 95°F for 18

hours. Cultures were then centrifuged, resuspended with 50 mL of 0.1% peptone water (Difco, Detroit, MI), and centrifuged again. The remaining pellet was resuspended with 10 mL peptone water. All strains were combined aseptically in a sterile bottle to form a five-strain cocktail of *L. monocytogenes*.

Product inoculation. Beef, pork, and turkey frankfurters were obtained from a local retail store and stored at 39°F until treatment and pasteurization. Frankfurter packages were opened and individual surfaces were blotted dry with a paper towel. The products were mist inoculated in a bio-containment chamber. A 1-hour attachment period was provided. Inoculated products were treated and vacuum-packaged individually (1 per package) or in a single layer (4 per package) format.

Acid/buffer treatment. Inoculated franks [except controls (no wash treatment, no heat)] were treated using a spray washer developed by Kansas State University. The treatments tested were 2% lactic acid, 4% lactic acid, 2% buffered sodium citrate, and 2% buffered sodium lactate at 20 psi.

Post-pasteurization treatment. The franks were aseptically vacuum-packaged and pasteurized to target product sub-surface temperatures of 160, 170, and 180°F. Temperature was measured between the two middle frankfurters for single layer frankfurters, which is the slowest heating surface. For the individually packaged frankfurters, sub-surface (1 mm from the surface) temperature was used to measure the target temperature. At a pasteurization chamber temperature of 205°F, times for surfaces of individually packaged frankfurters to reach 160, 170, and 180°F were 38, 58, and 96 seconds, respectively. Pasteurization times of 4 minutes 14 seconds, 5 minutes 4 seconds, and 6 minutes and 2 seconds, were required for single layer franks to attain temperatures of 160, 170, and 180°F, respectively. After pasteurization, the franks were chilled in an ice water bath for 15 minutes before sampling.

Sampling. The entire frank from the individual packaged product or one frank from the two middle franks in the single layer package was aseptically transferred to a filter stomacher bag. Each sample was homogenized in a stomacher (Tekmar Co., Cincinnati, OH) with 50 mL of 0.1% sterile peptone water for 2 minutes. Samples were serially diluted using 9 mL peptone blanks and plated on Modified Oxford Agar (Oxoid Ltd., Basingstoke, Hampshire, England) and Tryptose Phosphate Agar (Difco, Detroit, MI). Plates were incubated at 95°F for 48 hours. Colonies were counted and reported at $\log_{10}$ CFU/frank.

Results and Discussion

Individually packaged frankfurters. Pasteurization of franks to target surface end point temperatures of 160, 170, and 180°F resulted in 2.32, 4.62, and 6.52 log CFU/frank reductions ($P<0.05$) of *L. monocytogenes*, respectively. The various acid and buffer treatments applied to the franks did not reduce *L. monocytogenes* ($P>0.05$) populations on the surface of the franks beyond the steam pasteurization effect. Larger reductions in *L. monocytogenes* on frankfurters were achieved using an individual frankfurter format compared to the single layer (touching franks) format, and shorter pasteurization times were required for the individually packaged product.

Single layer frankfurters. Acid treatment alone of frankfurters resulted in approximately 0.7 log reductions in surface *L. monocytogenes* ($P<0.05$), and no interaction between the wash treatment and target temperature was observed. Pasteurization of inoculated franks to target end-point temperatures of 160, 170, and 180°F resulted in *L. monocytogenes* reductions of 0.92, 1.44 and 2.89 log CFU/frank.

Listeria monocytogenes, a fairly acid tolerant organism, can grow at pH 4.6. The antimicrobial action of organic acids in order of increasing effectiveness previously was reported as acetic>citric>lactic>malic acids. Incorporation of some type of organic acid treatment, especially lactic or acetic, was expected to provide additional safety for frankfurters and reduce the risk of *L. monocytogenes* growth. However, this did not prove true in this experiment.

Risk of *L. monocytogenes* on frankfurters can be reduced by post-process, in-package pasteurization to eliminate *L. monocytogenes* surface recontamination of ready-to-eat products. The steam based post-process pasteurization system alone or in combination with a wash treatment is effective in reducing *L. monocytogenes* populations on surfaces of frankfurters and can be used as a critical control point in the manufacture of frankfurters and similar ready-to-eat meat products. This system was more effective on an individually packaged frank compared to franks packaged in a single layer.

CONTROL OF *LISTERIA MONOCYTOGENES* IN READY-TO-EAT MEATS USING CETYL PYRIDINIUM CHLORIDE

M. Singh, H. Thippareddi, R. K. Phebus, J. L. Marsden, and C. L. Kastner

Summary

Cetyl Pyridinium Chloride (CPC) spray using variable application temperatures, pressures, and times was evaluated for its effectiveness in reducing *Listeria monocytogenes* inoculated on the surfaces of commercial frankfurters and Polish sausage. Frankfurters and Polish sausage were inoculated with a five-strain cocktail of *L. monocytogenes* (101M, 109, 108M, serotype 4c ATCC, and serotype 3 ATCC) and subjected to no treatment, CPC treatment, and CPC followed by water treatment. CPC (1%) was applied to the frankfurters and Polish sausage by spraying in a cabinet using all combinations of 77, 104, and 131°F spray temperatures; 20, 25, and 35 psi spray pressures; and 30, 40, and 60 second times of exposure. No individual effect ($P>0.05$) of any particular application temperature, pressure, or time on the reduction of *L. monocytogenes* was observed. Hardness and color of the product was not affected when treated with 1% CPC. From initial inoculum levels of 8.20 log colony forming units (CFU)/gram, 1% CPC reduced *L. monocytogenes* by 1.19 to 2.39 log CFU/gram.

Introduction

Listeria monocytogenes has emerged as an important and deadly food-borne pathogen that causes a high rate of hospitalization and death. Food-borne transmission of *L. monocytogenes* has been implicated in human outbreaks of listeriosis involving consumption of coleslaw, raw vegetables, milk, and Mexican style cheese. Consumption of *L. monocytogenes* contaminated turkey frankfurters was implicated in listeriosis in an immunocompromised woman. Consumption of undercooked chicken and uncooked frankfurters has been epidemiologically linked to an increased risk of listeriosis.

Listeria species are gram positive, asporogenous coccobacilli that are motile when cultured at 68 to 77°F. While their optimal temperatures for growth are between 86 and 99°F, *Listeria* can grow over a temperature range of 34 to 113°F, which makes the organism a potential food safety concern in refrigerated foods. Organic acids such as acetic, lactic, citric, and propionic have been used as antimicrobial agents in food products. Another antimicrobial used as a sanitizer/disinfectant is Cetyl Pyridinium Chloride (CPC), commercially known by the name of CECURE (Safer Foods Corporation, North Little Rock, Arkansas). CECURE is 40% active CPC. CPC is an active ingredient in mouthwashes and is a quaternary ammonium compound.

This study was designed to examine the efficacy of CPC as a post-process decontaminant for ready-to-eat meats and to optimize its application parameters for use in frankfurters and Polish sausage.

Experimental Procedures

A five-strain cocktail of *L. monocytogenes* (101M, 109, 108M, serotype 4c ATCC, and serotype 3 ATCC) was used. Cultures were maintained separately on Tryptic Soy Agar (Difco, Detroit, MI) slants at 39°F. Fresh cultures for the inoculum were prepared by inoculating the cultures into Tryptic Soy Broth

(Difco, Detroit, MI) and incubating at 95°F for 24 hours. Fresh cultures (1 ml) were transferred into centrifuge bottles containing 100 ml Tryptic Soy Broth and further incubated at 95°F for 20 hours. Cultures were then centrifuged, resuspended with 50 ml of 0.1% peptone water (Difco, Detroit, MI), and recentrifuged. The resultant pellet was resuspended with 10 ml of peptone water. A cocktail was prepared by mixing the five cultures in a sterile bottle.

Product preparation and inoculation. Frankfurters (8 in a pack) and Polish sausage (16 in a pack) obtained from a local grocery store were stored at 39°F before removal from the packages. They were placed onto butcher paper and individually dried with blotting paper. The top of each frankfurter and Polish sausage was wrapped with parafilm to avoid contamination while handling. The inoculum was sprayed onto the surface of the wrapped product by "misting" in a "bio-containment" chamber. After inoculation, products were held for 30 minutes in a laminar flow cabinet to allow attachment of *L. monocytogenes*.

Three frankfurters/Polish sausages were assigned to each treatment. The treatments included all combinations of three levels of each application parameter; spray temperature (77, 104, 131°F), spray pressure (20, 25, and 35 psi), and time of exposure to CPC (30, 40, and 60 seconds). For the microbiological shelf life evaluation, the products were inoculated with two different inoculum levels; high (10^9 cfu/ml) and low (10^2 to 10^3 cfu/ml).

CPC was prepared to a concentration of 1% by adding 25 ml of concentrated CPC to 1 liter of distilled water. The pH of the CPC was 5.2, and the temperature of water used to prepare the solution was 77°F. A spray washer (Kansas State University, Manhattan) was used to apply the treatments (1.6 L per minute at 20 psi) onto the product. Sets of three frankfurters/Polish sausages were considered as one sample. The treatments were applied for 30, 40, or 60 seconds. Two types of treatments for each set of spray combinations were used: 1) CPC only and 2) CPC followed by water wash. The inoculated product intended for microbiological shelf life evaluation was vacuum packed in sets of three per package after treating them with 1% CPC at 20 psi, 77°F, and 30 seconds of exposure to CPC. The treated product for shelf life evaluation was stored at 32°F and 39°F for 1, 2, 3, 4, and 6 weeks. Non-inoculated product was treated similarly as the inoculated product and stored for 1, 2, 3, 4, and 6 weeks at 32°F and 39°F in a simulated retail display. For each treated sample, a parallel control (non-treated) sample was also stored under similar conditions. The frankfurters/Polish sausages were then removed for microbial analysis to determine residual *L. monocytogenes* population. A Texture Profile Analyzer was used to determine the hardness of the shelf life samples.

Microbial sampling. Treated sets of three frankfurters/Polish sausages were removed from the spray cabinet and placed into sterile stomacher bags that contained pre-poured 1% peptone diluent to make a 1:1 dilution. Before sampling, the top parafilm wrapping was removed. Each sample was homogenized in a stomacher (Tekmar Co., Cincinnati, OH) for 2 minutes. The samples from the shelf life evaluation were removed from vacuum packages and placed into sterile stomacher bags for homogenizing in a stomacher for 2 minutes.

Microbiological enumeration. Samples were serially diluted in peptone water and spiral plated onto Modified Oxford Agar (Oxoid Ltd., Basingstoke, Hampshire, England) and Tryptose Phosphate Agar (Difco, Detroit, MI). The plates were incubated at 100°F for 24 hours. Enumeration was performed by counting black colonies on Modified Oxford Agar

and white colonies on Trypose Phosphate Agar (used for recovery of injured cells).

Results and Discussion

Treatment of frankfurters/Polish sausages with 1% CPC and 1% CPC followed by water wash resulted in reductions of 1.19 and 2.39 log CFU/gram of *L. monocytogenes*, respectively, from initial levels of 8.20 log CFU/gram when enumerated on Modified Oxford Agar. Increasing the spray pressure of CPC from 20 psi to 35 psi, or extending the time of exposure from 30 seconds to as long as 60 seconds did not result in additional reductions ($P>0.05$) of *L. monocytogenes*. Similarly, spray temperature did not affect numbers of *L. monocytogenes*.

The main objective of this study was to optimize parameters of application of CPC onto the surface of ready-to-eat meat products like frankfurters. Exposure time, spray pressure, and temperature of spray used in this study did not influence reduction of *L. monocytogenes*. However, the effectiveness of 1% CPC against *L. monocytogenes* and its potential use as an antimicrobial rinse on frankfurters was documented.

Because no difference ($P>0.05$) was observed between treatment parameters; 20 psi, 77°F, and 30 seconds of exposure to CPC was selected for treating the product for shelf life studies. These treatments with 1% CPC did not affect the hardness of the frankfurters stored for 6 weeks.

EVALUATION OF CONSUMER REHEATING METHODS FOR DESTRUCTION OF *LISTERIA MONOCYTOGENES* IN FRANKFURTERS

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Summary

The USDA Food Safety and Inspection Service has issued a "zero tolerance" for *Listeria monocytogenes* in ready-to-eat meat and poultry products. The Food Safety and Inspection Service recommends that consumers "Reheat [hotdogs] until steaming" to reduce the risk of listeriosis. We evaluated *L. monocytogenes* survival on inoculated frankfurters after reheating using common, in-home consumer practices. Frankfurters were inoculated with a six-strain mixture of *L. monocytogenes* to an initial level of approximately 10^7 colony forming units (CFU)/gram. Eight inoculated franks for each treatment were cooked using boiling water, a conventional electric oven, or a microwave oven. *L. monocytogenes* recovery was calculated after plating on Modified Oxford Agar and Tryptose Phosphate Agar. *L. monocytogenes* reductions were 3.2 $\log_{10}$ CFU/gram on franks microwaved with or without water for 60 seconds or cooked in a conventional electric oven at 500°F for 2 or 5 minutes. Franks cooked in boiling water for 30 and 60 seconds achieved reductions of 4.3 and 4.9 $\log_{10}$ CFU/gram, respectively. Franks wrapped in a paper napkin and microwaved for 60 seconds resulted in a 6.8 $\log_{10}$ CFU/gram reduction, the most effective consumer reheating protocol.

Introduction

Listeria monocytogenes is the major microbiological risk in ready-to-eat meat products. Fifty-three percent of vacuum packaged processed meat samples were contaminated with *L. monocytogenes*. Ineffective sanitizing procedures to eliminate biofilm-entrapped *L. monocytogenes* from frankfurter contact surfaces during processing and production facility environmental contamination are major causes of *L. monocytogenes* product recontamination.

USDA-Food Safety and Inspection Service has had a "zero tolerance" for *L. monocytogenes* in ready-to-eat products and began testing for the pathogen in 1987. However, outbreaks associated with hot dogs and deli meats in the fall of 1998 and spring of 2000 prompted the agency to advise plants to reconsider their HACCP plans relative to *L. monocytogenes* control. Several processing techniques developed to decontaminate frankfurters and deli meats prior to or immediately after final packaging include use of antibacterial peptides, antilisterial bacteria and/or competitive exclusion, organic acid treatments, high-pressure processing, and post-packaging treatments such as microwaves, hot water or steam, and gamma irradiation.

Although some methods were effective against *L. monocytogenes*, they are not widely accepted and some affect organoleptic qualities of the products. USDA recommends that consumers reheat hotdogs until steaming to prevent listeriosis, but consumer reheating practices for frankfurters have not been scientifically validated as to their effectiveness against *L. monocytogenes*.

Experimental Procedures

Six *L. monocytogenes* strains were grown independently under aerobic conditions in 5 ml Tryptic Soy Broth, transferred to 100 ml Tryptic Soy Broth, and incubated for 24

hours at 37°C. Cell pellets were resuspended in 60 ml of 0.1% peptone water after centrifuging the cultures.

All-beef frankfurters (approximately 0.9-inch diameter by 4.7 inches long) were purchased at two local supermarkets over an 8-month period. They contained 17 grams of fat and 640 milligrams of sodium per 57 gram serving. Franks were deposited with sterile tongs into a cooking rack, leaving empty places between franks. Franks were mist inoculated inside a sealed plexiglass chamber with the six-strain mixture (9 $\log_{10}$ CFU/ml) to achieve 7 $\log_{10}$ CFU/gram product. Eight inoculated franks were placed into Cryovac B 540 barrier bags and vacuum packaged. Sealed bags containing the inoculated franks were shrunk by exposing them to water at 176°F for 2 seconds. The packages were stored at 41°F for 1 week prior to simulated consumer cooking treatments.

Survival of *L. monocytogenes* was evaluated by randomly assigning each of eight inoculated and vacuum packaged franks to one of the following consumer cooking protocols:

1. No treatment control.

2. Place one frank in boiling water, cover container and remove it from heat; let stand 30 seconds.

3. Place one frank in boiling water, cover container and remove it from heat; let stand 60 seconds.

4. Place one frank in a small microwave-safe dish and heat on high for 60 seconds in a 1000-watt microwave oven.

5. Wrap one frank in a paper napkin and place it in a small microwave-safe dish and heat on high for 60 seconds.

6. Place one frank in ½ cup water in a small microwave safe dish and heat on high for 60 seconds.

7. Cook one frank for 2 minutes in a conventional oven preheated to 500°F.

8. Cook one frank for 5 minutes in a conventional oven preheated to 500°F.

Frankfurters' surface temperature and the internal temperature at 0.4 inches in depth, were measured from the frankfurter middle length and recorded before and after treatments using a type T thermocouple (Omega Engineering, Standford, CT) attached to a digital thermometer (Model HH23, Omega Engineering, Standford, CT).

Each heat-treated frank and the control was prepared, serially diluted in peptone water, and spiral plated onto Modified Oxford Agar and Tryptose Phosphate Agar (Buffered peptone and Bacto™ agar, Difco, Detroit, MI). Plates were enumerated after 24 hours incubation at 100°F, and the bacterial population was reported on a per gram basis. The USDA-Food Safety and Inspection Service *L. monocytogenes* enrichment procedure was followed for the samples where bacterial growth was not seen after 24 hours incubation on agar plates.

Results and Discussion

The inoculated frankfurters stored at 41°F for 1 week had a *L. monocytogenes* population of 7.3 $\log_{10}$ CFU/gram. Before treatments, the frankfurters had a surface temperature of 44°F and an internal temperature of 40°F. In general, the lowest *L. monocytogenes* reductions were observed when franks were reheated in a conventional oven for 2 minutes, microwaved in water for 60 seconds, or cooked in a conventional oven for 5 minutes. Bacterial reductions of 0.41, 0.68, and 1.00 $\log_{10}$ CFU/gram,

respectively, were observed using these protocols. Frankfurters microwaved in water reached a surface and an internal temperature of 96 and 72°F, respectively, and the water temperature was 111°F at the end of the 60-second treatment. When franks were cooked in a microwave oven for 60 seconds (without water), a 3.2 $\log_{10}$ CFU/gram *L. monocytogenes* reduction was observed. The surface and internal temperatures were 174 and 194°F, respectively. When franks were immersed in boiling water, followed by removing the container from the heating source, and kept for 30 and 60 seconds (treatments 2 and 3), bacterial reductions of 4.3 and 4.9 $\log_{10}$ CFU/gram, respectively, were achieved. The surface temperatures were 107 and 127°F and the internal temperatures were 50 and 59°F, respectively. The highest bacterial reduction, 6.9 $\log_{10}$ CFU/gram, was observed in franks wrapped with a paper napkin and microwaved for 60 seconds. With this treatment, surface and internal temperatures of 202 and 169°F, respectively, were observed.

The paper napkin likely entrapped the steam produced during microwaving of the product, keeping it in contact with the contaminated frankfurter surface, thus raising its surface temperature from 44 up to 202°F in 60 seconds. This procedure could easily be utilized by consumers. Reheating franks in a conventional oven for up to 5 minutes at 500°F was ineffective in destroying *L. monocytogenes*. Commonly, consumers place unwrapped franks into a microwave for a short reheating cycle. This protocol was only moderately effective at reducing surface contamination, as was placement of franks into boiling water for short periods.

Cattlemen's Day 2003

ANTIMICROBIAL EFFECT OF BUFFERED SODIUM CITRATE, ALONE OR COMBINED WITH SODIUM DIACETATE, ON TOTAL AEROBIC COUNT OF GROUND BEEF STORED AT 39°F

E. Ceylan and J. L. Marsden

Summary

We studied the antimicrobial efficacy of buffered sodium citrate and a combination of buffered sodium citrate and sodium diacetate on natural aerobic microflora of ground beef stored at 39°F. For non-treated control and 1% buffered sodium citrate, total aerobic count gradually increased from 4.2 log colony forming units (CFU)/gram initially to 9.0 and 8.7 log CFU/gram, respectively, after 10 days. Both treatments reached the spoilage index number of 7.0 log CFU/gram after 5 days. A combination of 1% buffered sodium citrate and 0.1% sodium diacetate resulted in a total aerobic count of 5.9 log CFU/gram (below the spoilage index) after 10 days of storage at 39°F. Combined 1% buffered sodium citrate and 0.1% sodium diacetate suppressed growth of aerobes and increased the shelf life of ground beef stored at 39°F.

Introduction

Meat is highly perishable. Ground meat has a large surface area that favors growth of aerobic microflora during storage. Extended shelf life and greater safety of meat and poultry products are critical needs. Buffered sodium citrate is a combination of citric acid and sodium citrate. The USDA Food Safety and Inspection Service permits the use of buffered sodium citrate, effective June 24, 1996, in cured and uncured meat and poultry products. Sodium citrate, a salt of citric acid, is approved as a generally recognized safe compound by the Food and Drug Administration. It occurs as a natural compound in fruits and has few limitations for use in food.

Buffered sodium citrate (IONAL™) inhibits microbial growth and retains flavor and is especially effective when a low initial microbial count occurred. IONAL increases ionic strength in meat products and allows better water holding capacity, lower water activity, and less purge in meat and poultry products. It increases shelf life and maintains organoleptic characteristics of meat and poultry over long storage. The recommended usage level of IONAL is 1.0 to 1.3%. Its antimicrobial activity increases as pH decreases.

Fresh meats can be contaminated during handling and processing. Grinding meat increases surface area and favors the growth of microorganisms. Meat provides nutrients required for the growth of microorganisms. Intrinsic and extrinsic parameters in combinations provide a "hurdle effect" for controlling the growth of microorganisms in foods. This study evaluated the antimicrobial effect of 1% buffered sodium citrate (IONAL) alone or in combination with 0.1% sodium diacetate against natural microflora of ground beef.

Experimental Procedures

Ground beef (20% fat), purchased from a local retail store, was divided into three equal parts. The first part was designated as a control sample (no antimicrobial agents added).

The second part was mixed with 1% buffered sodium citrate, and the third with a combination of 1% buffered sodium citrate and 0.1% sodium diacetate. Samples were placed into commercial ground beef bags and stored at 39°F. Total aerobic counts were performed daily from randomly selected subsamples. These samples were homogenized and diluted using 0.1% peptone water (Difco Laboratories, Detroit, MI). Enumeration of total aerobic bacteria of samples was performed on Tryptic Soy Agar plates incubated at 95°F for 24 hours. Experiments were repeated three times.

Results and Discussion

For control and 1% IONAL treatment, the total aerobic count gradually increased from the initial level of 4.2 log CFU/gram to 9.0 and 8.7 log CFU/gram, respectively, after 10 days of storage. Both treatments reached the spoilage index number of 7.0 log CFU/gram, on the 5th day of storage. The combined 1% IONAL and 0.1% sodium diacetate resulted in a total aerobic count of 5.9 log CFU/gram, which was below the spoilage index after 10 days of storage at 39°F. The combination of 1% IONAL and 0.1% sodium diacetate suppressed the growth of total aerobic bacteria and increased the shelf life of ground beef.

EFFECTS OF DRIED PLUM MIXTURES ON TOTAL AEROBIC GROWTH IN UNCOOKED GROUND BEEF

L. K. Thompson and D.Y.C. Fung

Summary

Spices and plant components are being used more often in food products as natural antimicrobials. Dried plums are effective antimicrobials against foodborne pathogens including *Escherichia coli* O157:H7. The objective of this experiment was to determine the ability of dried plum mixtures to increase the shelf life of ground beef at refrigeration temperatures. Ground beef (80% lean) was mixed with 6% dried plum mixtures and stored at 45°F. Ground meat containing any of the seven dried plum mixtures remained at the initial total aerobic count of 6 log CFU/gram after 13 days compared to 8.5 log CFU/gram at 13 days for controls (without dried plum).

Introduction

The greater surface area of ground meat enables increased natural flora, particularly psychrotrophic spoilage organisms. One approach for controlling spoilage organisms is to use natural food ingredients. Approved food additives with dual function as antioxidants and antimicrobials, such as phenolic antioxidants, spices, flavoring agents, phosphates, and lactates, are potentially beneficial and allow a lower amount and fewer types of food additives to be used. They also eliminate the need for toxicological studies to establish the safety of the additive. Secondary components of many spice plants are powerful antimicrobials. For example, garlic and cinnamon have reduced *E. coli* O157:H7 in liquid media and ground beef.

Commercial prunes and prune extracts contain phenolics, such as hydroxycinnamates, neochlorogenic acid, and chlorogenic acid, which can inhibit the oxidation of low-density lipoproteins. Dried plum puree at 3% worked equally well as some chemical antioxidants to prevent warmed-over flavor caused by lipid oxidation in precooked pork sausage. This study dealt with the effects of dried plum on aerobic plate counts in uncooked ground beef.

Experimental Procedures

Dried plum mixtures used in this experiment were USDA prune puree, classic prune concentrate, plum juice, lighter bake powder, lighter bake puree, prune puree without potassium sorbate, and prune powder with maltodextrin.

Ground beef (80% lean) purchased from a local grocery store on the day that the experiment was initiated was separated into 211.5-gram samples. Dried plum mixtures were added at 6% for each of the seven different dried plum mixtures. Samples without added dry plum mixtures served as the control. Samples of 25 grams each were placed into sterile filter stomacher bags and held at 45°F for testing at 0, 1, 3, 5, 7, 9, 11, and 13 days.

At appropriate test times, sterile 0.1% peptone water was added to the samples, and then samples were stomached. Samples were diluted and spread plated onto Tryptic Soy Agar plates. The plates were then incubated for 48 hours at 95°F, and colony forming units (CFU) were enumerated.

Results and Discussion

All samples had an initial aerobic bacterial load of about 6 log CFU/gram and grew very little by 24 hours. From day 3 until day 13, the control sample with no added dried plum mixture steadily increased to 8.5 log CFU/gram while the other samples had static growth and remained at an aerobic count of approximately 6 log CFU/gram. The ground beef sample without any dried plum mixture also exhibited an off-odor after 9 days. Samples with dried plum mixture had no off-odor at day 13.

Dried plum mixtures were effective at controlling aerobic bacteria on ground beef (80% lean) stored at 45° F.

EFFECTS OF CASTRATION AGE AND A GROWTH IMPLANT DURING SUCKLING ON WEANING AND PRECONDITIONED WEIGHTS

T. T. Marston, D. A. Llewellyn, L. C. Hollis, and J. W. Homm

Summary

Crossbred Angus calves (n=141) were used to determine the effect of castration age and implant on weaning and preconditioned weights. Calf treatments consisted of: early castration at 90 days of age with no growth implant, early castration with a growth implant (Synovex C) at 90 days of age, or late castration at weaning (226 days of age). All calves completed a preconditioning program that consisted of timely vaccinations (21 days prior and at weaning) and a 28-day, post-weaning feeding period. Steers that were early castrated/implanted had weaning weights similar to those of bull calves, and both groups weighed 15 lb more than their early castrated/no implant contemporaries. However, 28 days after weaning the early castrated/implanted steers weighed 20 lb more than either the early castrate/no implant or late castrated steers. Our data indicate that early castration in combination with a suckling phase implant produces the greatest amount of saleable weight along with the most flexibility in marketing options.

Introduction

Cow/calf producers have several options for selling their calves. Traditionally, calves have been sold either at weaning, after a growing period, or retained until slaughter. The initiation of a preconditioning program can create a new marketing opportunity. Most preconditioning programs require vaccinations and boosters for bovine respiratory diseases, clostridials, treatment for internal and external parasites, as well as dehorning and castration. The more stringent programs will also require calves to be held for 30 to 45 days after weaning. The timing of castration and implementation of an implant program may affect selling weight. Therefore, the objective of this trial was to determine the effect of different castration ages in combination with a growth implant on calf weights at weaning and after preconditioning.

Experimental Procedures

One hundred forty-one spring-born (average birth date = March 4), Angus crossbred calves were used in this experiment. Calves were blocked by dam age and then randomly assigned to treatments. The three treatments were: 1) castrated in early June with no implant, 2) castrated in early June and implanted with Synovex® C (Fort Dodge), and 3) castrated mid-October on the day of weaning. Calves in the early castrated/ no implant and early castrated/ implanted treatments were approximately 90 days of age when castrated, whereas late castrated calves averaged 226 days of age at time of castration. Dates of castration were used to simulate typical branding and weaning ages of the calves. Calves were allowed to freely nurse their dams throughout the summer with no creep feed. Three weeks prior to weaning, all calves were weighed and injected with Cattlemaster 4® (Pfizer) and Fortress 7® (Pfizer). Calves were weighed, received a booster vaccination of Cattlemaster 4, and were treated with Dectomax® Pour-on (Pfizer) on the day of weaning. After weaning, calves were fed round bales of brome hay free choice and hand-fed 5 pounds/day of a pelleted, commercial starter feed for 28 days. During the first 5 days after weaning, the

hand-fed supplement was top dressed with Aueromycin® (Alpharma) at a rate of 5 grams chlortetracycline per calf daily.

Results and Discussion

Descriptions of the calves and results are summarized in Table 1. Summer health of the calves was excellent and was reflected by their summer weight gains. Between the June and September weigh dates the average calf gain of all calves was 2.46 lb/day. The early castrated/ no implant calves gained slower ($P<0.01$) while suckling their mothers than did early castrated/ implanted and late castrated calves (2.37 lb/day, 2.53 lb/day, and 2.53 lb/day, respectively). Our data indicates that a single implant given during the suckling phase will produce a positive weight gain response when compared to non-implanted steer calves and that the weight gain of castrated, implanted calves will mirror intact bull calf performance.

Average gain of all calves (1.61 lb/day) during the 21 days from first vaccination to weaning dates was less than the previous summer period. This is probably the result of several factors, including decreasing dam milk production and maturing forages. Regardless, no differences in rate of gain were noted between treatments ($P>0.94$) during this short period of time. If calves were to be marketed directly off their dams, early castrated/ implanted and late castrated calves would have had greater pay weights than their early castrated/ no implant contemporaries. Previous reports suggest that the price of bull calves would be $5 to $6/cwt less than of comparable steer mates. These price discounts would have made our late castrated calves the least valuable at weaning time. Market prices would dictate the necessary price adjustments cow/calf producers would need to compensate for the weight difference between early castrated/ no implant and early castrated/ implanted calves (See Table 2).

The weather following weaning was cool, damp, and cloudy for the first 2-week period. All calves readily ate the commercial starter feed by the third day. At 28 days after weaning, early castrated/ implanted steers weighed more than either early castrated/ no implant or late castrated steers. Average daily gains during the post-weaning period were similar ($P=0.22$) between early castrated/ implanted (1.72 lb/day) and early castrated/ no implant (1.52 lb/day) steers and both were greater ($P<0.01$) than late castrated (1.16 lb/day). This difference in rate of gain erased any weight advantage late castrated calves had over their contemporaries at weaning time.

Cow/calf producers that desire marketing flexibility should consider early castration and implanting suckling calves if maximum pounds of saleable product are desirable.

Table 1. Description of Calves

	Treatments		
	Early Castration		Late
Item:	No implant	Implant	Castration
No. of calves	60	40	41
Average birth date	March 9	March 2	March 2
Average castration age, days	87 ± 18	94 ± 19	226 ± 16
Weight, lb			
June	304 ± 38	311 ± 37	317 ± 42
September 2	530 ± 3	545 ± 4	544 ± 4
October 15	564 ± 5	580 ± 5	578 ± 5
November 12	606 ± 4	628 ± 4	611 ± 4

Table 2. Market Price Adjustments Needed to Compensate for Differences in Weaning Weight or Weight 28 Days After Weaning Between Early Castrated/No Implant and Early Castrated/Implanted Steer Calves

	Price Adjustment[a], $/cwt	
Anticipated market price	Sell at Weaning	Sell after Preconditioning
$105/cwt	+2.90	+3.79
$100/cwt	+2.76	+3.50
$95/cwt	+2.62	+3.33
$90/cwt	+2.48	+3.15
$85/cwt	+2.34	+2.98
$80/cwt	+2.21	+2.80

[a]The additional price that would need to be received to justify not implanting early-castrated calves.

EFFECTS OF PREGNANCY IN FEEDLOT HEIFERS ON PERFORMANCE AND CARCASS CHARACTERISTICS

G. L. Bishop, J. R. Brethour, T. T. Marston, and T. E. Lawrence

Summary

Sixty-eight, spring-born, yearling heifers were raised, estrous synchronized, artificially inseminated once, and then finished at the Kansas State University Western Kansas Agricultural Research Center at Hays to determine the effects of pregnancy status on feedlot performance and carcass traits. To achieve a common endpoint at slaughter, heifers were allotted to one of two slaughter dates to achieve a backfat measurement of 0.5 inch. Therefore, both open and pregnant heifers were slaughtered at either 105 or 147 days (fetal age averaged 174 days for the pregnant heifers). Initial weight, rate of gain, and final weight were similar between open and pregnant heifers ($P>0.36$). Dressing percentage and ribeye area were lower ($P<0.05$) for pregnant than open heifers. Hot carcass weight tended ($P=0.13$) to be greater for open heifers. No differences between treatment groups were observed for fat thickness, percentage kidney, pelvic, and heart fat, yield grade, marbling score, or maturity score ($P>0.16$). However, even though only small differences were recorded in carcass weights, yield grades, and quality grades, their impact on carcass value and cattle feeding profits may be important.

Introduction

There are unique challenges associated with finishing heifers. There are several options for management of the pregnant feedyard heifer including: diagnosis of pregnancy at or soon after arrival and subsequent treatment with an abortifacient to end pregnancy; treatment of all heifers to terminate pregnancy; or shipping heifers prior to calving. There may be costs associated with aborting heifers beyond the initial cost of diagnosis and treatment of pregnancy. The objective of this study was to conduct an initial investigation of the effects of mid-term pregnancy on growth rate and carcass characteristics in yearling heifers.

Experimental Procedures

Sixty-eight, spring-born, yearling heifers were raised and fed at the Kansas State University Western Kansas Agricultural Research Center at Hays. Prior to the feeding period, the heifers were estrous synchronized and artificially inseminated upon observation of standing heat. Heifers were classified as open (n=43) or pregnant (n=25) based on ultrasound diagnosis 60 days after breeding. Heifers were immediately placed on feed and provided a common diet. No growth implants were given. The finishing diet consisted of feeding 10 lb/heifer daily of corn silage (as fed), finely ground grain sorghum ad libitum, and a supplement (Table 1).

Table 1. Composition of the Supplement Used in the Finishing Diet

Ingredient	Pounds per heifer daily
Soybean meal	0.51
Urea	0.11
Ammonium sulfate	0.11
Trace mineral/vitamin premix	0.11
Limestone	0.22
Sodium chloride	0.07

In an effort to harvest heifers at a common backfat endpoint (0.5 inch), ultrasonic estimates of backfat were used to assign heifers within each pregnancy status into two harvest groups (105 and 147 days on feed). All pregnancies were visually confirmed at the abattoir.

Results and Discussion

Table 2 shows the feedlot performance of the heifers. Initial weight was not different for open or pregnant heifers. During the initial 90 days on feed, the open heifers had greater gains than their pregnant contemporaries ($P<0.01$). However, live weight recorded just prior to slaughter revealed no effects of pregnancy status on live selling weight or overall average daily gain.

An intermediate ultrasound estimate of marbling score and 12th rib fat thickness was taken after 90 days on feed. No difference was noted in back fat between the open and pregnant heifer ($P>0.44$), but pregnant heifers tended ($P<0.21$) to have more intramuscular fat than the open heifers at that time.

Final carcass characteristics are presented in Table 3. Dressing percent was 2.3 percentage units lower ($P<0.01$) for pregnant heifers. Because the reduction in dressing percent is directly related to fetal age, it would be anticipated that the decrease observed in this trial would continue to increase in magnitude as the heifers were fed to heavier weights and longer term pregnancies.

Pregnant heifers tended to have lighter carcasses ($P=0.13$). Although not statistically significant, the reduction in carcass weight of 22 lb could result in significantly less revenue in marketing systems that pay according to dressed weight.

Ribeye muscle area was greater in open heifers ($P<0.05$). No differences were observed in 12th rib fat thickness; percent kidney, heart, and pelvic fat; and calculated yield grade. In each case, pregnant heifers had numerically greater values, suggesting fatter carcasses, although these differences were not statistically significant ($P=0.17$). Neither marbling nor maturity scores were different due to pregnancy in this trial ($P>0.16$). However, there were slight differences in the distribution of USDA quality grades that favored the pregnant heifers (Table 4).

Table 4 describes the distribution of yield and quality grades for open and pregnant heifers. If sold on a value-based marketing grid, open heifers would have benefited from a greater percentage of carcasses falling within yield grades 1 and 2 (63% vs. 43%). There was no difference between groups in the percentage of carcasses falling into the heavily discounted yield grade 4 category. These results indicate that although actual measured backfat thickness may not be different, the cutability (yield grade) as assigned by USDA graders may favor carcasses of open heifers.

Table 2. The Effects of Pregnancy on Feedlot Heifer Performance

	Pregnancy Status			
Item:	Open	Pregnant	Standard Error	P-value
No. of heifers	43	25		--
Starting weight, lb	915	920	11.0	0.85
Gain (first 90 days), lb/day	3.30	3.08	0.07	0.01
Final weight, lb	1276	1287	15.2	0.65
Overall weight gain, lb	361	368	6.4	0.45
Overall daily gain, lb/day	2.86	2.86	0.04	0.43

Table 3. Carcass Traits of Pregnant and Open Feedlot Heifers

	Pregnancy Status			
Item	Open	Pregnant	Standard Error	P-value
Hot carcass yield, %	62.6	60.3	0.24	0.01
Hot carcass wt, lb	799	777	9.9	0.13
Ribeye area, inch^2	13.9	13.3	0.22	0.05
12th rib fat thickness, inch	0.54	0.56	0.03	0.45
Kidney, pelvic, and heart fat, %	2.15	2.28	0.05	0.28
USDA Yield grade	2.85	3.07	0.11	0.17
Marbling score[a]	5.97	6.26	0.24	0.45
Maturity score[b]	1.75	1.69	0.024	0.16

[a]Marbling score scale: 5.00=Small^{00}, 6.00=Modest^{00}.
[b]Maturity scale: 1.00=A^{00}, 2.00=B^{00}.

Table 4. Distribution of Yield and Quality Grades of Pregnant and Open Feedlot Heifers

	Pregnancy Status	
USDA standards	Open	Pregnant
Yield grade	---------- % ----------	
1	7	0
2	56	40
3	33	56
4	4	4
Quality grade		
Prime	12	16
Upper 2/3 of Choice	25	28
Lower 1/3 of Choice	40	36
Select	21	20
Standard	2	0

RELATIONSHIPS AMONG CHAROLAIS SIRE EXPECTED PROGENY DIFFERENCES AND ACTUAL PROGENY PERFORMANCE IN COMMERCIAL HERDS

S. C. Clark, D. W. Moser, and R. E. Williams

Summary

Data on Charolais-sired calves were analyzed to evaluate progeny performance related to sire expected progeny differences (EPD) in a large data set of commercial crossbred cattle in several herds across the United States. The traits analyzed were birth weight (n=3,554) and weaning weight (n=3,604) of crossbred progeny from nationally evaluated sires. Birth weight EPD and weaning weight EPD were evaluated as predictors of crossbred performance. Random regression coefficients were estimated for progeny birth weight on sire birth weight EPD of 1.03±0.09 lb/lb of birth weight EPD, and for progeny weaning weight, 0.66±0.11 lb/lb of weaning weight EPD. Published sire birth weight EPD and weaning weight EPD were averaged and weighted on published accuracy. The average weighted sire birth weight EPD was 0.86 lbs and weaning weight EPD was 16.06 lbs, with an average accuracy of 0.79 and 0.75, respectively. Correlations for effect of sire in commercial herds with published sire birth weight and weaning weight EPD were 0.59 and 0.39, respectively. Sire birth weight EPD and weaning weight EPD were positively related to actual progeny performance. Therefore, selection based upon sire EPD should result in change of crossbred progeny performance. This further validates use of EPD as a selection tool for birth weight and weaning weight in commercial herds. However, weaning weight response was lower than expected, possibly a result of management practices in commercial herds compared to purebred herds.

Introduction

Commercial beef cattle producers are encouraged to use genetic information to select sires to improve performance in their herds. To do this, they rely on expected progeny differences (EPD), which enhance the accuracy of selection decisions by establishing an evaluation of the relative genetic value of a sire within a breed. Today, EPD are widely used and successfully implemented into commercial beef cattle enterprises.

The sire evaluations currently taking place in the beef industry by most breed associations are based on purebred progeny performance. Therefore, sire EPD comparisons are only applicable within a particular breed. However, the environment of purebreds may differ from that of crossbred cattle. In the seed purebred enterprise, the environment may be superior to their commercial counterpart's environmental conditions. Therefore, it is worthwhile to evaluate sire progress for commercial use through crossbred progeny.

Large numbers of actual data under true commercial production conditions in the United States have not been examined. The purpose of this study was to evaluate progeny performance and sire EPD in a large data set of commercial crossbred calves in several herds across the United States using Charolais sires.

Experimental Procedures

The carcass database of the American-International Charolais Association (AICA, Kansas City, MO) was obtained for analysis to provide information on progeny dam breeds, herds, sires, birth weight, and weaning weight records that were collected from 1988 to 2001. The sires used in the study were used in 31 cooperator herds that consisted of commercial crossbred females. The herds were used for carcass data collection only. Therefore, the data used in this analysis were independent of those used in the AICA growth trait EPD calculations.

The final data set consisted of birth weight records on 3,554 animals and weaning weights on 3,604 animals. There were 224 sires with progeny data from 31 herds. The contemporary group for the progeny measurements was defined as animals born in the same year and raised in the same environment. There were 56 contemporary groups used in the data set. Finally, the carcass database was merged to the sire EPD database to provide sire birth weight EPD and weaning weight EPD records that were collected on Charolais sires enrolled in the AICA evaluation program by AICA members. The sires used in the data set had an average weighted sire birth weight EPD of 0.86 lbs and weaning weight EPD of 16.06 lbs, with an average accuracy of 0.79 and 0.75, respectively. The published sire birth weight and weaning weight EPDs were weighted on published accuracy.

The data were analyzed by the mixed procedure in SAS. The statistical model used for birth weight included a fixed effect of contemporary group and a random effect of sire birth weight EPD. The same model was used for WW, substituting weaning weight EPD for birth weight EPD. This model calculated a random regression coefficient for birth weight and weaning weight on sire EPD.

A second analysis was performed to estimate effect of sire. The statistical model used for birth weight and weaning weight included a fixed effect of contemporary group and a random effect of sire. Correlations weighted on number of progeny were obtained between effect of sire and published sire EPD for both birth weight and weaning weight, weighted on accuracy.

Results and Discussion

The means and standard deviations of the progeny and the means and standard deviations of sire birth weight and weaning weight EPD are summarized in Table 1.

The random regression coefficient for progeny birth weight on sire EPD was 1.03 ± 0.09 lb/lb of birth weight EPD, indicating that for each pound of birth weight EPD, you would expect 1.03 lb of actual birth weight. The regression of progeny weaning weight on sire EPD was 0.66 ± 0.11 lb/lb of weaning weight EPD. Therefore, for each pound of weaning weight EPD, you would expect only 0.66 lb of actual weaning weight.

Sire birth weight EPD was positively related to actual progeny performance, suggesting that prediction of birth weight based on published Charolais sire EPD agrees closely with the theoretical value of 1.0 lb/lb of EPD. Therefore, selection based on birth weight EPD should, on average, be effective and consistent with theoretical expectation. However, sire EPD differences for weaning weight were not completely expressed. This may be a result of environmental differences, such as nutritional and management differences between commercial and purebred herds. For instance, the purebred herds have a greater level of labor input and different nutritional programs than their counterparts in the commercial herds. Managers of purebred herds may provide superior management compared to man-

agers in commercial herds. For example, earlier detection and treatment of sick calves may occur in purebred herds versus commercial herds due to the smaller number of cattle, thus improving growth rates in purebred herds relative to commercial herds. Therefore, the genetic potential for weaning weight may not have been fully expressed in the crossbred progeny in our study due to differences in nutrition and management. Thus, commercial producers should expect less response than suggested by sire weaning weight EPD. Overall, selection based upon sire EPD should result in change of crossbred progeny performance. This provides commercial producers with a valuable selection tool for birth weight and weaning weight and further validates use of EPD as a selection tool for birth weight and weaning weight in commercial herds.

Positive correlations were obtained for effect of sire with sire birth weight and weaning weight EPD. Weighted correlations for effect of sire with published sire birth weight and weaning weight EPD were 0.59 and 0.39, respectively. For our study, random mating was assumed. The moderate birth weight to low weaning weight correlations could be a result of not including dam effects. Dams might have contributed different genetics to their progeny and their ability to produce milk could have varied. This could cause a difference in performance among progeny and affect the correlations for effect of sire with sire birth weight EPD or weaning weight EPD.

Table 1. Numbers of Sires and Progeny Evaluated, Means and Standard Deviations

Item	Number of Records	Mean	Standard Deviation
Progeny:			
Birth weight, lb	3,554	88.42	12.56
Weaning weight, lb	3,604	501.00	110.39
Sire:			
Birth weight EPD, lb	224	0.91	2.51
Weaning weight EPD, lb	224	15.37	12.32

GENETIC RELATIONSHIPS OF BODY CONDITION SCORE WITH CARCASS TRAITS IN LIMOUSIN CATTLE

D. R. Eborn and D. W. Moser

Summary

Field data from the North American Limousin Federation was used to determine the heritability and genetic correlations of body condition score (BCS) with carcass traits. Carcass traits included carcass weight, ribeye area, fat thickness, intramuscular fat, and % kidney, pelvic, and heart fat, and all were estimated to be lowly to moderately heritable (0.14 to 0.34). Heritability of BCS was 0.19. Favorable correlations existed between ribeye area and carcass weight (0.50), ribeye area and BCS (0.60), and carcass weight and BCS (0.28). Unfavorable correlations existed among ribeye area and intramuscular fat (-0.40), carcass weight and intramuscular fat (-0.23), and intramuscular fat and BCS (-0.64). These results suggest that selection for BCS should be effective and would result in some favorable changes in ribeye area and carcass weight but with unfavorable change in marbling.

Introduction

With the opportunity of increased profit through value-based marketing and with the availability of carcass expected progeny differences (EPDs), there is more selection pressure on carcass traits than ever before. Carcass traits have been reported to be from moderately to highly heritable, and selection for specific carcass endpoints has been effective. Another trait of concern for cow-calf producers is BCS. Body condition score at calving has been shown to be a good predictor of the interval to first estrus and days to pregnancy. Maintenance requirements of mature cows also change according to body condition.

We estimated the heritability and genetic correlations of BCS with carcass traits to examine how BCS is affected by carcass trait selection.

Experimental Procedures

Field data and pedigree information was obtained through the North American Limousin Federation, Englewood, CO. A total of 19,506 BCS for 12,493 cows, recorded at calf weaning on a 1 to 9 scale (1=emaciated, 9=extremely fat), were included in the analyses. The effects accounted for in the BCS model included fixed contemporary group, random animal, and repeat record, and scores were adjusted for year of age. Contemporary groups were designated by the calf's weaning weight contemporary group. All cows older than 12 years of age were placed in one age class and recorded as 12 years of age. Both linear and quadratic terms were included for age adjustments. Records on 4,326 animals were used in the carcass trait analyses. The model for carcass traits included the effects for fixed contemporary group, random animal, and a linear adjustment for days of age. Contemporary group designation included weaning weight, contemporary group, gender, and date of slaughter. Summary statistics for BCS and each carcass trait are presented in Table 1. A derivative-free restricted maximum likelihood algorithm was used to estimate variance and co-variance. Heritabilities and genetic correlations were obtained by single- and pairwise trait analyses, respectively.

Results and Discussion

Estimates of heritabilities and genetic correlations are presented in Table 2. Traits were lowly to moderately heritable (0.14 to 0.34). Ribeye area had the highest heritability estimate of 0.34, which is in agreement with reported estimates in other studies. Carcass weight (0.14) and intramuscular fat (0.15) heritabilities were lower than previously reported estimates and may reflect a Limousin breed difference. Fat thickness exhibited a moderate heritability of 0.24 and heritability for kidney, pelvic, and heart fat was 0.16. A heritability of 0.19 for BCS is in agreement with other estimates and suggests that modest genetic changes for body condition are possible through selection. Favorable carcass correlations were observed between carcass weight and ribeye area (0.50), carcass weight and kidney, pelvic, and heart fat (-0.23), ribeye area and fat thickness (-0.19), and ribeye area and kidney, pelvic, and heart fat (-0.51). Selection to increase carcass weight would be expected to increase ribeye area and decrease kidney, pelvic, and heart fat, selection to increase ribeye area would be expected to decrease fat thickness and kidney, pelvic, and heart fat. Some unfavorable genetic correlations also exist among carcass traits; the negative correlations of intramuscular fat with carcass weight (-0.23) and with ribeye area (-0.40) suggest that selection to increase muscling or weight would lower intramuscular fat. The correlation between fat thickness and intramuscular fat tended to be a negative correlation but was not significant. Favorable positive correlations were found between carcass weight and BCS (0.28) and ribeye area and BCS (0.60). A strong unfavorable correlation was obtained for BCS with intramuscular fat (-0.64), which indicates that selection for increased BCS would result in decreased marbling. This relationship was not expected.

These results suggest that carcass traits and BCS are lowly to moderately heritable and would respond to selection, but both unfavorable and favorable changes in carcass traits will result. Selection for growth and muscling would lower intramuscular fat. Selection to increase carcass weight and ribeye area would increase BCS, selection to increase BCS would decrease intramuscular fat, and selection for higher or lower BCS would not affect carcass fat thickness.

Table 1. Summary Statistics for Body Condition Score and Carcass Traits in Limousin Cattle

Trait	Average	Standard deviation	Minimum	Maximum
Cow age, year	5.7	2.7	2.0	12.0
Body condition score[a]	5.4	1.2	1.0	9.0
Carcass age, day	494.4	61.0	365.0	708.0
Carcass weight, lb	772.5	88.7	600.0	1000.0
Ribeye area, inch^2	14.5	2.0	9.1	22.8
Fat thickness, inch	0.40	0.19	0.05	1.20
Intramuscular fat score[b]	5.20	2.10	2.00	10.90
Kidney, pelvic, and heart fat, %	2.3	0.7	0.5	5.0

[a]1 = Emaciated, 5 = Moderate, 9 = Extremely Fat.
[b]2 = Practically Devoid, 5 = Small, 10 = Abundant.

Table 2. Heritabilities and Genetic Correlations for Body Condition Score (BCS) and Carcass Traits in Limousin Cattle[a]

	BCS	Carcass weight	Ribeye area	Fat thickness	Intramuscular fat[b]	KPH, %
BCS	0.19					
Carcass weight	0.28	0.14				
Ribeye area	0.60	0.50	0.34			
Fat thickness	-0.04	0.09	-0.19	0.24		
Intramuscular fat	-0.64	-0.23	-0.40	-0.14	0.15	
KPH, %	0.16	-0.23	-0.51	0.53	-0.20	0.16

[a]Heritabilities are listed on the diagonal and genetic correlations are listed below the diagonal. Heritability standard errors range from 0.02 to 0.05. Carcass trait correlation standard errors range from 0.12 to 0.20. BCS and carcass trait correlation standard errors can not be estimated.
[b]Kidney, pelvic, and heart fat.

RELATIONSHIPS BETWEEN LIVE ANIMAL ULTRASOUND PREDICTED INTRAMUSCULAR FAT AND SHEAR FORCE IN FED CATTLE

L. D. Keenan, D. W. Moser, D. R. Eborn, and T. T. Marston

Summary

Approximately 280 Simmental- and Hereford-sired feedlot steers were ultrasonically evaluated for intramuscular fat deposition using CPEC and Critical Vision, Inc. (CVI) ultrasound systems. Warner-Bratzler shear force measurements were taken on steaks from the 13th rib region. Differences between CPEC and CVI ultrasound and actual marbling measurements were corrected for bias and identified as CPEC deviation and CVI deviation. Correlation coefficients and linear models were used to determine if shear force values were associated with amount of intramuscular fat predicted by the ultrasound systems. Correlation coefficients of CPEC deviation and CVI deviation with shear force were 0.18 and 0.15, respectively. This indicates that animals overestimated for marbling by ultrasonic measures had a tendency to have higher shear force values. However, when the data were evaluated with linear models, which take many variables into account, we found that animals with ultrasound marbling predictions higher than the actual carcass marbling score were not associated with higher shear force values. Thus, animals with a higher marbling prediction are not associated with an unfavorable increase in shear force values. Selecting animals for increased marbling through ultrasound evaluation should have neither a favorable nor unfavorable effect on tenderness.

Introduction

Real-time ultrasound has proven to be an accurate tool in the prediction of intramuscular fat in beef cattle. This information can be used in the selection and genetic evaluation of breeding animals. Ultrasonic evaluation of carcass traits in breeding animals can be used to reduce the cost of sire progeny testing programs or eliminate the bias associated with feeding only culled animals for carcass data collection.

Consumers have identified tenderness as the foremost characteristic in determining meat acceptability. Marbling and tenderness are not highly related. Intramuscular fat often explains only 5% of the variation in tenderness. It has yet to be determined whether ultrasound systems used to predict intramuscular fat can distinguish between connective tissue and intramuscular fat. It would be detrimental to consumer acceptance of beef to mistakenly identify connective tissue as intramuscular fat through ultrasound evaluation and to classify those individuals as being superior. The objective of our study was to determine if tenderness is negatively affected in animals with higher amounts of intramuscular fat determined through ultrasound.

Experimental Procedures

Ultrasound measurements were taken on one group of Simmental-sired (n=136) and one group of Hereford-sired (n=148) feedlot steers. Two commercially available ultrasound systems were used to scan the cattle for intramuscular fat. The two systems used were CPEC, Oakley, KS (developed by Kansas State University, Hays) and Critical Vision, Inc., Atlanta, GA (developed by Iowa State University). Ultrasound images were taken with an Aloka 500V system outfitted with a 17-cm, 3.5-MHz transducer. An ultrasound technician scanned each steer with both sys-

tems over the 12th to 13th rib site. The CPEC system estimated the marbling score on-site. Images from the Critical Vision machine were sent to the Centralized Ultrasound Processing lab in Ames, IA for analysis of intramuscular fat.

Visual evaluation of fat thickness was utilized to determine harvest date, which was used to define contemporary groups. The Simmental-sired cattle were harvested at IBP, Inc., in Emporia, KS on 29, 35, 69, 75, 79, and 85 days after scanning. The Hereford cattle were harvested at Excel Corp. in Ft. Morgan, CO in one group 17 days after scanning. Each carcass was evaluated for 12th rib fat thickness, longissimus muscle area, weight, and marbling score by a commercial data collector. Steaks were removed from the 13th rib region of the hindquarter from each carcass and promptly shipped to Kansas State University where the standard protocol for aging and shear force evaluation was followed to determine tenderness of the steaks.

CVI's prediction for percent intramuscular fat (%IMF) was converted to the standard USDA marbling score using:

Marbling score = [(749.81 + 67.197 * %IMF – 1.172 * %IMF²) /100]-5 where Slight^{40} = 4.4; Slight^{50} = 4.5; Small^{00} = 5.0; Modest^{10} = 6.1; etc. CPEC predicts actual marbling score directly, so no conversion was needed. CPEC and CVI deviation from actual marbling (CPEC deviation and CVI deviation) were calculated by subtracting marbling score from CPEC or CVI then mathematically correcting for bias due to unknown error.

Pearson correlation coefficients were calculated among all variables (CPEC, CVI, CPEC deviation, CVI deviation, contemporary group, fat thickness, longissimus muscle area, marbling score, shear force, and weight). Two linear models accounting for breed, CPEC deviation or CVI deviation, marbling score, shear force, and the interaction of breed with shear force were developed using the GLM procedure of SAS.

To evaluate the utility of including both systems in determining actual marbling score, three linear models were developed, each accounting for contemporary group. Two models consisting of variables CVI, contemporary group, and their interaction, or CPEC, contemporary group, and their interaction were developed to compare to a model consisting of contemporary group, CVI, CPEC, contemporary group x CVI interaction, and contemporary group x CPEC interaction.

Results and Discussion

Simple descriptive statistics are presented in Table 1. The correlation for CPEC with shear force was the only correlation of interest that was not significantly different from zero (Table 2). The correlation for CVI with shear force was negative. Thus, as predicted marbling increased, there was a decrease in shear force. The two most noteworthy statistics in Table 2 are the positive correlations of CPEC deviation and CVI deviation with shear force ($P<0.01$). This indicates that animals that were overestimated for intramuscular fat with CPEC and CVI were associated with an increase in shear force. To further evaluate these relationships, other factors were taken into account by using the GLM procedure of SAS. When marbling score, shear force, breed, and breed x shear force interaction effects were accounted for in their relationship with CPEC deviation and CVI deviation, shear force and breed x shear force did not significantly affect ($P>0.05$) CPEC deviation or CVI deviation. All other effects were significant ($P<0.001$). Thus, animals that were evaluated as having a higher percentage of intramuscular fat were not associated with an unfavorable increase in shear force values. Therefore, it appears that selecting for increased intramuscular fat in cattle through ultrasound evaluation should have neither a favorable nor unfavorable effect on tenderness.

Our data are not sufficient to accurately compare the two ultrasound systems because ether extractable fat data were not collected. Previous studies found that the two ultrasound systems did not differ in predicting ether extractable fat. R^2 values, which describe the percent of variation in marbling that can be explained by the ultrasound estimate of marbling, were evaluated on models in order to compare the accuracy of predicting marbling score using one ultrasound system as compared to both ultrasound systems. We found that using both systems (R^2=0.47) as opposed to one (R^2=0.44 and 0.42, for CPEC and CVI, respectively) does not increase the accuracy of predicting marbling score enough to justify the additional costs and time of using both ultrasound systems to predict intramuscular fat.

Table 1. Descriptive Statistics

Variable	Average	Standard Deviation	Minimum	Maximum
Warner-Bratzler shear force	9.51	1.47	6.47	13.86
Fat thickness, inch	0.53	0.22	0.08	1.20
Longissimus muscle area, inch²	13.15	1.36	9.90	16.60
Marbling score	5.07	0.73	3.70	8.00
CPEC	4.53	0.56	3.21	6.21
CVI	4.52	0.39	3.70	5.72
CPEC Deviation	-0.54	0.84	-2.96	1.44
CVI Deviation	-0.55	0.64	-2.75	0.85

Table 2. Pearson Correlation Coefficients and Statistical Significance of Variables

	Fat Thickness	Longissimus Muscle Area	Marbling Score	CPEC	CVI	CPEC Deviation	CVI Deviation
Warner-Bratzler	0.17	-0.2	-0.25	-0.06	-0.23	0.18	0.15
Shear Force	<0.01	<0.01	<0.01	0.31	<0.01	<0.01	<0.01
Fat		-0.28	-0.12	0.18	-0.22	0.23	-0.002
Thickness		<0.01	0.04	<0.01	<0.01	0.97	0.97
Longissimus			0.24	-0.09	0.23	-0.27	-0.14
Muscle Area			<0.01	<0.01	<0.01	<0.01	0.02
Marbling				0.18	0.48	-0.75	-0.84
Score				<0.01	<0.01	<0.01	<0.01
CPEC					0.35	0.52	0.02
					<0.01	<0.01	0.72
CVI						-0.18	0.07
						<0.01	0.27
CPEC Deviation							0.75
							<0.01

ESTIMATES OF PARAMETERS BETWEEN DIRECT AND MATERNAL GENETIC EFFECTS FOR WEANING WEIGHT AND GENETIC EFFECTS FOR CARCASS TRAITS IN CROSSBRED CATTLE[1]

R. K. Splan[2], L. V. Cundiff[3], M. E. Dikeman, and L. D. Van Vleck[4]

Summary

Estimates of heritabilities and genetic correlations were obtained from weaning weight records of 23,681 crossbred steers and heifers, and carcass data of 4,094 crossbred steers using REML applied to animal models. Direct and maternal heritabilities for weaning weight were 0.14 and 0.19, respectively. The genetic correlation between direct and maternal weaning weight was negative (-0.18). Heritabilities for carcass traits of steers were moderate to large (0.34 to 0.60). Genetic correlations between direct genetic effects for weaning weight and carcass traits were small, except with hot carcass weight (0.70), ribeye area (0.29) and adjusted fat thickness (0.26). Genetic correlations of maternal genetic effects for weaning weight with direct genetic effects for carcass traits were**:** hot carcass weight (0.61), retail product percentage (-0.33), fat percentage (0.33), ribeye area (0.29), marbling score (0.28), and adjusted fat thickness (0.25). These results indicate that maternal genetic effects for weaning weight may be correlated with genetics for propensity to fatten in steers. Selection for only direct weaning weight would be expected to increase carcass weight and ribeye area and slightly decrease marbling and retail product percentage. Selection for either increased maternal or direct weaning weight would be expected to result in increased carcass weight, ribeye area, and fat thickness, but would not be expected to affect tenderness.

Introduction

Recently, the beef industry has moved toward value-based marketing to satisfy consumer preferences for meat quality. Breed associations have responded by incorporating carcass EPDs into annual sire evaluations, in addition to EPDs previously calculated for growth and reproductive traits.

Selection for genetic improvement in several traits is most effective when relationships among the traits selected are known. An estimate of maternal genetic ability for weaning weight has been included in breed evaluation programs for some time, but its relationship to carcass characteristics is relatively unknown. Correlations between total genetic effects for weaning weight and some economically important carcass traits have, in some cases, been

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[1]This article was derived from a research paper published in the Journal of Animal Science. Data were derived from Cycles I-IV of the Germ Plasm Evaluation research program conducted under the leadership of Dr. Larry V. Cundiff at the Roman L. Hruska U.S. Meat Animal Research Center, Clay Center, NE. Dr. Michael E. Dikeman was a collaborator on the carcass and meat data collection.

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estimated to be favorable and may represent opportunities for increased productivity. If genetic antagonisms exist, however, they may compromise selection response and reduce profitability. The objective of this study, therefore, was to estimate correlations among direct and maternal genetic effects for weaning weight and direct genetic effects for carcass and meat traits in beef cattle.

Experimental Procedures

Data were obtained from Cycles I-IV of the Germ Plasm Evaluation project at the Roman L. Hruska U. S. Meat Animal Research Center, Clay Center, NE. Calves in Cycle I (born 1970 to 1972) resulted from AI matings of Hereford, Angus, Jersey, South Devon, Limousin, Charolais, and Simmental sires to Hereford and Angus dams. Cycle II calves (born 1973 to 1974) resulted from mating Hereford, Angus, Red Poll, Brown Swiss, Gelbvieh, Maine Anjou, and Chianina sires to Hereford, Angus, Red Poll and Brown Swiss dams. Cycle III calves (born 1975 to 1976) resulted from AI matings of Hereford, Angus, Brahman, Sahiwal, Pinzgauer, and Tarentaise bulls to Hereford and Angus dams. Cycle IV calves (born 1986 to 1990) resulted from AI matings of Angus, Hereford, Longhorn, Piedmontese, Charolais, Salers, Galloway, Nelore, and Shorthorn bulls to Hereford and Angus dams.

The F_1 heifers were managed to calve at 2 years of age. Heifers born in Cycle I were bred by AI to Hereford, Angus, Holstein, South Devon, and Brahman sires. Cycle II heifers were mated by AI to Hereford, Angus, Brahman, and Santa Gertrudis sires. In the final two cycles, all heifers were bred by natural service to Red Poll sires. Females older than 2 years were subsequently bred by natural service to Simmental sires. Weaning weights (n=23,681) (adjusted to 205 days) included both F_1 males and females, as well as calves of F_1 females.

After weaning, steers were allocated to replicated pens and fed in groups by sire breed. A postweaning adjustment period of 25 to 40 days was followed by an average of 262 days on feed. Each year, steers were serially slaughtered in three or four groups over a period of 56 to 84 d. After a 24-hour chill, ribeye area; kidney, pelvic, and heart fat percentage; adjusted fat thickness, and marbling score were determined. For Cycles I - III (1970 to 1976), carcass sides were processed at K-State; for Cycle IV, sides were processed at the U.S. Meat Animal Research Center. Processing resulted in boneless, closely trimmed retail cuts, fat trim, and bone. Ribeye steaks were aged for 7 days, frozen, later thawed, and cooked for Warner-Bratzler shear force tests.

Table 1 shows the summary statistics for weaning weight and carcass traits. The multiple-trait, derivative-free, residual-maximum likelihood suite of programs applied to animal models was used for analyses of all traits.

Results and Discussion

Estimates of heritability and direct-maternal correlation for weaning weight are shown in Table 2. The estimate of direct heritability for weaning weight was slightly less than expected, though not outside the range of values reported in the literature (0.14 to 0.58). The estimate of maternal heritability was only slightly greater than the estimate for direct heritability. Estimates of heritability for carcass traits, and direct and maternal genetic correlations with weaning weight are shown in Table 3. Estimates of heritability for carcass traits were moderate to large. Estimates between direct and maternal weaning weight and percentage retail product were negative (-0.12 and -0.33, respectively).

Estimates of genetic correlations for direct and maternal effects of weaning weight with adjusted fat thickness were moderate and positive (0.26 and 0.25, respectively), suggesting

that as weaning weight increases, adjusted fat thickness will also increase. Estimates of genetic correlations between kidney, pelvic, and heart fat percentage and the direct and maternal genetic effects for weaning weight were relatively small and positive. The genetic correlation between direct effect of weaning weight and marbling score was slightly negative (-0.12), whereas the genetic correlation for the maternal effect for weaning weight and direct effect for marbling score was positive (0.28). These results suggest that selection for direct weaning weight may result in a slight decrease in marbling score, but selection for maternal weaning weight would result in increased marbling.

Near-zero estimates of genetic correlations were found between direct and maternal effects of weaning weight and Warner-Bratzler shear force, suggesting that selection for weaning weight will not have an effect on meat tenderness. Selection for increased direct genetic value for weaning weight would be expected to increase hot carcass weight, fat percentage, adjusted fat thickness, ribeye area, and kidney, pelvic, and heart fat percentage. At the same time, it would be expected to decrease retail product percentage, bone percentage and marbling score, and to have almost no effect on Warner-Bratzler shear force. Selection for maternal milk, or maternal effects on weaning weight, may lead to positive correlated responses in hot carcass weight, fat percentage, adjusted fat thickness, ribeye area, marbling score, and kidney, pelvic, and heart fat percentage; a negative correlated response in retail product percentage; and almost no effect on Warner-Bratzler shear force. Genetic correlations of direct and maternal effects on weaning weight with carcass traits were generally similar. Only for marbling score were the relationships with direct and maternal effects on weaning weight different. Genetic correlations between maternal effects of weaning weight and carcass traits were moderate for carcass traits involving fat percentage (0.33), retail product percentage (-0.33), and marbling score (0.28).

To meet consumer demands for quality beef, seedstock breeders and commercial producers need to consider not only the traditional traits of growth, maternal ability and production efficiency in their selection decisions, but also carcass traits. Carcass traits, including tenderness, can be improved through selection because of the moderate to high heritability of the traits. Selection for either increased maternal or direct weaning weight would be expected to result in increased carcass weight, ribeye area, and fat thickness. Selection for only maternal weaning weight would also be expected to result in increased carcass fat percentage and marbling, and decreased retail product percentage. Selection for only direct weaning weight would be expected to slightly decrease marbling and retail product percentage. Selection for either increased maternal or direct weaning weight would not be expected to affect tenderness.

Table 1. Summary Statistics for Weaning Weight and Carcass Traits

Trait	n	Mean[a]	SD[a]
Weaning weight, lb	23,681	403.70	67.70
Hot carcass weight, lb	4,088	664.50	90.50
Retail product percentage, %	3,708	68.70	4.10
Fat percentage, %	3,708	18.42	4.72
Bone percentage, %	3,704	12.88	1.07
Ribeye area, inch^2	4,094	11.39	1.40
Adjusted fat thickness, inch	4,091	0.48	0.29
Kidney, pelvic, and heart fat, %	3,707	3.95	1.13
Marbling score	3,696	5.29	1.00
Warner-Bratzler shear force, lb	3,705	9.15	3.37

[a]Unadjusted means and standard deviations
[b]Small^{29} = 5.29.

Table 2. Estimates of Direct (h^2_d) and Maternal (h^2_m) Heritabilities and Genetic Correlation ($r_{d,m}$) Between Direct and Maternal Weaning Weight

Parameter	Estimate
h^2_d	0.14
h^2_m	0.19
$r_{d,m}$	-0.18

Table 3. Estimates of Direct Heritability (h^2) and Direct (r_d) and Maternal (r_m) Genetic Correlations with Weaning Weight

Trait	H^2	r_d	r_m
Hot carcass weight	0.49	0.70	0.61
Retail product percentage	0.58	-0.12	-0.33
Fat percentage	0.49	0.14	0.33
Bone percentage	0.48	-0.13	-0.08
Ribeye area	0.58	0.29	0.29
Adjusted fat thickness	0.46	0.26	0.29
Kidney, pelvic, and heart fat	0.60	0.17	0.19
Marbling score	0.35	-0.12	0.28
Warner-Bratzler shear force	0.34	0.05	-.06

Cattlemen's Day 2003

CHANGES IN FED CATTLE MARKETING METHODS: SURVEY RESULTS

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Summary

Significant changes in fed cattle marketing methods have occurred over time. This report summarizes a survey conducted to determine current and intended marketing practices of cattle feeders. Use of marketing agreements has increased over time. In 1996, 23% of cattle fed by survey respondents were sold under some type of marketing agreement. This increased to 52% in 2001 and was expected to increase to 65% by 2006. Use by cattle feeders of cash live and carcass weight pricing is expected to decline, and grid pricing is expected to increase substantially over time. The percentage of cattle that survey respondents marketed using cash markets declined from 82% in 1996 to 53% in 2001, and it is expected to be only 33% by 2006. Grid pricing increased from 16% of marketings in 1996 to 45% in 2001, and this is expected to reach 62% by 2006. Respondents indicated a strong desire to have grid base prices tied to boxed beef or retail markets, but a slightly less strong desire to have base prices negotiated.

Introduction

The fed cattle marketing environment has changed dramatically over the last decade. Increased use of various pricing methods, including value-based pricing, price grids, formula pricing, marketing agreements, and alliances, have displaced the once dominant negotiated cash live and dressed weight fed cattle trade. Recent evolution away from cash negotiated trade suggests a new center of fed cattle price discovery is probable.

Changes in fed cattle marketing methods and resulting impacts on price and other market information have recently brought numerous policy proposals to the forefront. Certainly, the change from voluntary to mandatory price reporting in fed cattle and wholesale boxed beef markets is one notable example of a policy change intended to address producer concerns about availability of reliable and representative price information and terms of trade. Recent proposals intended to prohibit various forms of beef processor ownership and control of fed cattle are examples of policy issues motivated by changes occurring in fed cattle markets.

To gain a better understanding of the nature of recent and expected changes occurring in fed cattle marketing and pricing methods, a survey of cattle feeders located in the southern plains and corn belt region was undertaken. The primary objectives summarized here were: 1) to determine the extent of recent and future expected changes in cattle feeder use of marketing agreements and alliances, 2) to quantify how cattle pricing methods are changing over time, and 3) to determine feedlot manager attitudes regarding fed cattle marketing and pricing issues.

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Experimental Procedures

To accomplish the objectives of this study, a survey was conducted in March 2002 of cattle feedlots located in Kansas, Iowa, Texas, and Nebraska. Overall, 1501 feedlots were surveyed, and 316 returned useable responses (21% response rate). Consistent with the types of feeding companies located in each respective state, smaller yards with less than 5,000 head annual marketings were mostly in Iowa (96% of Iowa respondents) followed by Nebraska (39% of Nebraska respondents). Kansas and Texas respondents tended to be more represented by feeding companies that marketed more than 5,000 head per year and several companies that marketed in excess of 100,000 head in 2001.

Results and Discussion

Survey results revealed substantial changes occurring in the way fed cattle are marketed. In 1996, marketing agreements and alliances were uncommon with only 25% of respondents indicating that they had marketed at least some cattle under a marketing agreement without an alliance, while 11% had marketed cattle under an alliance; a total of 30% had been involved in one or both types of marketing agreements (Figure 1). In 1996, the average percentage of each respondent's fed cattle that were marketed under an agreement without an alliance was 9% and with an alliance was 4%. However, larger operations were more likely to participate in marketing agreements, so 14% of total fed cattle were marketed in a marketing agreement and 8% in a marketing alliance in 1996. Both alliance and marketing agreement participation increased by 2001, with alliances increasing to 45% of respondents marketing at least some cattle in an alliance, which represented an estimated 27% of fed cattle marketed. Overall, marketing agreements in 2001 represented 52% of estimated cattle marketed by survey respondents. Alliances and marketing agreements were expected to increase in 2006 to approximately 65% of fed cattle marketed by respondents (Figure 1).

Cattle feeders indicated that the most important reasons they were entering into marketing agreements was that such arrangements enabled them to acquire quality and yield grade premiums as well as obtain detailed carcass data. Detailed data are necessary to provide cattle feeders with important information to identify problem areas and make appropriate adjustments. For those that were involved in an agreement of some type in 2001, the third most important motive was securing a buyer for their cattle. The least important motive, especially for those in current agreements, was that the producer was pressured by a packer to enter into an arrangement. This suggests the decision to enter into an agreement is something producers make on their own volition.

The vast majority of survey respondents used the cash market for at least some of their fed-cattle marketings. However, the trend was clearly downward over time, declining from 97% of respondents using the cash market (live and/or carcass weight) in 1996 to 70% expected in 2006. The percentage of respondents using grid pricing for at least some of their fed-cattle marketings increased dramatically from 23% in 1996 to 88% in 2001; 88% also indicating they planned to market at least some fed cattle using grids in 2006.

The percentage of fed cattle marketed using various methods suggests increasing use of grid marketing and reduced use of live or carcass-weight pricing. In 1996, the average number of fed cattle that respondents marketed using live or carcass weight was 90%, which declined to 55% in 2001 and was expected to decline to only 36% by 2006. Use of grids increased from 8.1% of average re-

spondent cattle in 1996 to 44% in 2001 and to an expected 60% by 2006. Weighted by respondents' 2001 fed-cattle marketings, the percentage of cattle priced using grids increased from 16% in 1996 to 45% in 2001 and to 62% expected by 2006 (Figure 2).

Related to these changes in marketing practices, cattle feeders have also developed concerns about declining cash market trade and they hold a variety of opinions about how best to deal with these changes. Respondents generally agreed that base prices in grids should be tied to boxed beef or retail prices and somewhat agreed that negotiated base prices in grids are preferred to formula prices. Survey respondents also tended to agree that reduced trading in the cash market would be harmful to the beef industry. This is particularly interesting because cash trade appears likely to continue to decline in the future.

The question evoking the most polar responses from cattle feeders was whether beef packers should be banned from owning or feeding cattle. Feeders frequently responded with three scores of 1 (strongly disagree), 5 (neutral), or 9 (strongly agree). Overall, respondents tended to feel that packers should not be allowed to feed cattle. The most common response was a 9 (48% of respondents) and the second most common was a 5 (15% of respondents). Further, this issue had considerable regional diversity. Feeders located in Iowa agreed most strongly (average score of 7.7, with 60% giving a response of 9). In contrast, cattle feeders in Kansas and Texas were neutral with average scores of 5.4 and 5.2, respectively. However, Kansas and Texas producers were somewhat divided, with the most common responses by producers located in each state being 1, 5, and 9. There was a tendency for producer feelings regarding this issue to be related to feeding operation size. Larger cattle feeding operations were considerably more inclined on average to disagree (though not unanimously as all feedlot size categories included responses ranging from 1 to 9) that packer feeding or ownership should be banned relative to smaller operations. Thus, the geographic dispersion in response appears related to operation size.

Respondents generally did not feel that packers should be prevented from contracting or forming marketing agreements with cattle feeders (average response 4.8). Similarly, respondents generally felt that packers should not be prevented from contracting or forming agreements with retailers (average response 4.2).

Results of this survey document the extent to which use of cash fed-cattle markets is expected to continue to decline over time. A dilemma presents itself because at the same time as cash fed-cattle markets are declining, survey respondents indicate concerns that reduced cash fed-cattle trade is harmful to the industry. It is not surprising, therefore, that respondents prefer to have base prices in grids tied to boxed beef or retail markets. Dwindling volume of cash trade may make this necessary. However, most grid base prices are tied to plant average or local cash market prices and respondents expect these to continue to be important sources of base prices in the future. As the cash fed-cattle market volume declines, concerns about how representative plant average and local cash-market prices may be is likely to increase. Cattle feeders and beef packers together need to find other sources of base prices than cash fed-cattle prices or plant averages. If they do not, momentum for policies attempting to force various marketing or pricing methods upon the industry are possible at some point in the future.

Respondents indicated that grid pricing and marketing agreements have enabled producers to obtain greater information regarding

carcass quality and yield grades and to secure associated premiums and discounts. Such pricing and marketing arrangements obviously are valued by the survey respondents or they would not indicate such large anticipated increases in future use. Such pricing methods clearly benefit the industry by improving the flow of quality information from processors to producers. Therefore, it is imperative that policies do not inhibit value-based pricing and information-sharing networks, or much of the progress made to date could be jeopardized.

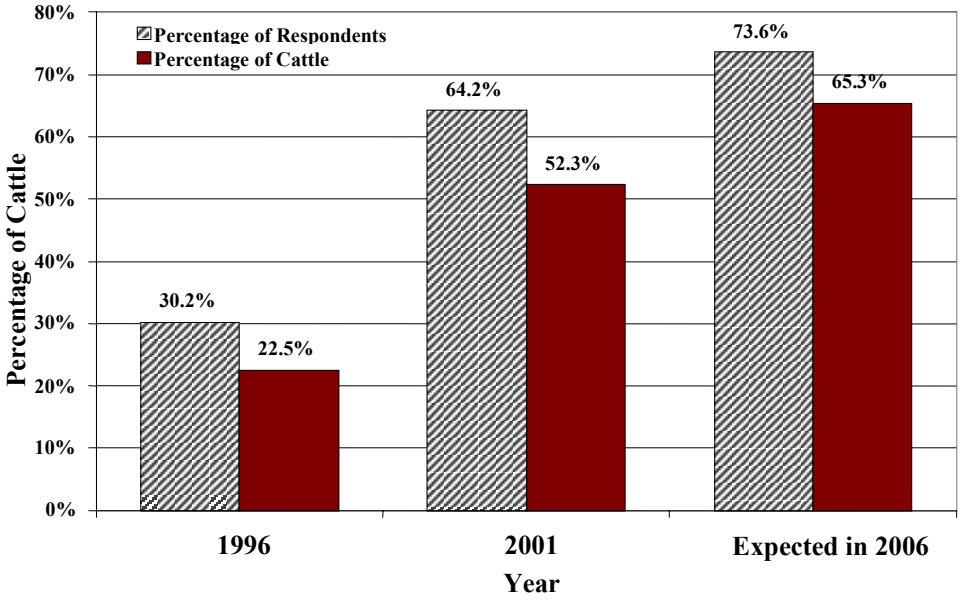

Figure 1. Percentage of Respondents and Estimated Weighted-Average Percentage of Cattle Marketed Under Marketing Agreements, by Year.

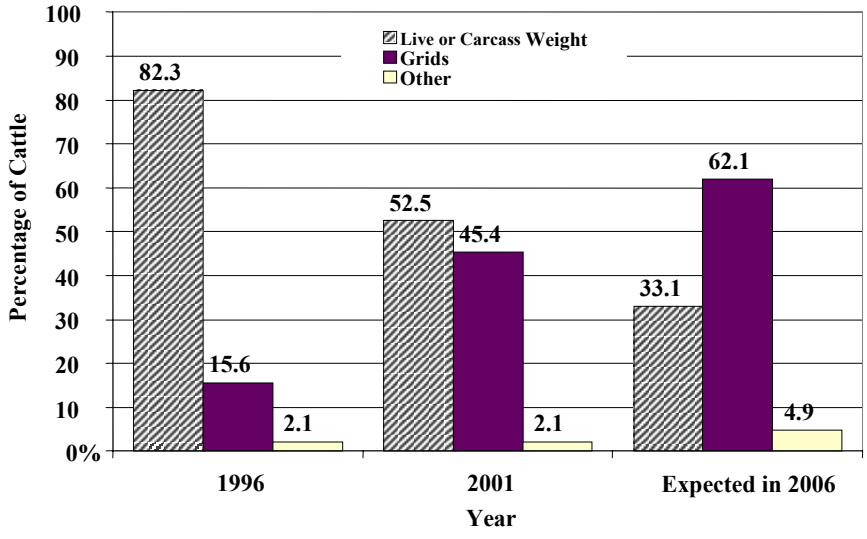

Figure 2. Weighted-Average Percentage of Respondents Fed Cattle Marketed Using Live or Carcass Weight, Grids, and Other Pricing Methods, by Year.

CATTLE FEEDER PERCEPTIONS OF MANDATORY PRICE REPORTING

T. Schroeder[1], S. Grunewald[1], and C. Ward[2]

Summary

Livestock price reporting mandated by the USDA was designed to increase available price data with the intent of providing producers with information to facilitate price discovery. Has the program been effective at accomplishing this goal? This study determined how cattle feeders, a primary target of the program, feel about mandatory price reporting effectiveness. This study reports results from a survey of cattle feeding companies located primarily in Kansas, Nebraska, Texas, and Iowa. Results indicate a diversity of opinions regarding the effectiveness of mandatory price reporting. On average, producers are neutral to slightly negative regarding the value of mandatory price reporting. Some of the dissatisfaction was associated with excessive or unrealistic expectations. Feedlot size, amount of custom feeding, and the percentage of cattle sold by the feedlot to its largest buyer had little systematic relationship to the manager's perceptions regarding the usefulness of mandatory price reporting. In contrast, feedlot location and feedlot manager opinions about market structure were related to their opinions regarding mandatory price reporting.

Introduction

Providing timely, reliable, and relevant livestock market information is an important function of the USDA. In April 2001 the USDA launched the Livestock Mandatory Reporting Act of 1999. This new information reporting law was enacted to directly address a perceived need to provide more market information to livestock producers in light of substantial changes that have occurred in livestock market structure and marketing institutions. The primary purpose of mandatory reporting was to enhance livestock market information that would allow producers to better determine prevailing prices, conditions, and arrangements pertinent to the marketing process. The Mandatory Reporting Act was a stark contrast in the process of collecting information compared to previous voluntary reporting methods used by the USDA Agricultural Marketing Service to report livestock prices and sales.

The livestock mandatory price reporting policy proposal was strongly contested by the packing industry, but supported by producers. The purpose of this study was to assess cattle feeder perceptions regarding the effectiveness of mandatory price reporting for fed cattle. This policy is scheduled for review by USDA and, therefore, having a better understanding of its effectiveness and problems would be valuable as modifications to the policy are considered.

Experimental Procedures

To discern cattle feeder perceptions regarding mandatory price reporting, a survey was conducted in March 2002 of cattle feed-

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lots located in Kansas, Iowa, Texas, and Nebraska. Overall, 1501 feedlots were surveyed and 316 returned useable responses (21% response rate). Response rates by state were 152/970 in Iowa (16%), 50/131 in Kansas (38%), 66/250 in Nebraska (26%), and 48/150 in Texas (32%).

The questionnaire asked for feedback on the usage of mandatory price reports, and whether the new reports have enhanced feedlot negotiations with packers for base prices, quality premiums and discounts, and cash prices. The questionnaire also asked where the operation is located, cattle ownership, how prices are negotiated, and marketing arrangements. Opinion questions were answered using a scale of 1 (strongly disagree) through 9 (strongly agree).

Statistical models were used to determine how feedlot size, location, marketing methods, custom feeding practices, and feedlot manager opinions about market structure issues were related to feedlot manager perceptions regarding three issues: 1) whether mandatory price reporting is benefiting the beef industry; 2) whether information has increased regarding regional/national daily fed cattle cash prices, base prices used in grid pricing, premiums/discounts used in grid pricing, and boxed beef prices; and 3) whether mandatory price reporting has enhanced producer ability to negotiate cash prices, base prices or formulas, or grid premiums/discounts with packers.

The average feedlot respondent marketed approximately 18,300 head in 2001 with a standard deviation of more than 36,000 head. The respondents included large yards as well as many smaller yards (54% of respondents marketed less than 2,500 head).

Results and Discussion

Producers were split in their opinion regarding whether mandatory reporting was benefiting the beef industry. About 9% were at the upper limit strongly agreeing (response of a 9) and 22% at the lower limit strongly disagreeing (response of a 1) (Figure 1). Statistically significant factors ($P<0.10$) related to manager perceptions mandatory reporting feedlot location and the manager's perception of whether large packers should be broken into smaller packers, whether packers should be allowed to feed cattle, and whether summary reports are timely enough for decision making needs.

Cattle feeders located predominantly in Kansas and Texas were prone to most strongly disagree that mandatory reporting was benefiting the industry relative to those located in Iowa. The probability that a respondent answered this question with a response of 1 (strongly disagree), was 0.30 for Kansas feedlots and 0.15 for Iowa firms. However, overall regional differences in response to this issue were subtle. Managers that are more concerned about beef packer concentration and cattle ownership by packers or contracting are more likely to feel mandatory price reporting is beneficial to the industry.

Only a few variables explaining cattle feeders' thoughts regarding whether information on fed cattle cash prices, base prices, grid premiums and discounts, and boxed beef prices had increased were statistically significant ($P<0.10$) (see Figure 2 for response distribution). As the opinion that captive supplies depress cash market prices increases, respondents were less likely to agree that more information is available as a result of mandatory reporting. Respondents that felt timeliness of daily summary reports was adequate were more likely to agree that mandated reporting has resulted in increased information. This indicates that some cattle feeder dissatisfaction with mandatory reporting is related to inadequate timeliness of reports. Cattle feeders that felt packers should not be allowed to feed cattle were more likely to respond that information had increased with mandatory reporting. The only other statistically signifi-

cant variable was that cattle feeders located primarily in Nebraska were less likely to strongly disagree that information had increased.

A major motivation of producers supporting mandatory price reporting was that cattle feeders felt increased information available to them regarding non-cash terms of trade could provide them increased leverage in the price discovery process. However, 38% of cattle feeder respondents indicated that they strongly disagreed (response of 1) that mandatory price reporting had helped them negotiate more effectively with beef packers (Figure 3). Like other opinions regarding mandatory reporting, there was considerable variability across respondents. Three factors were statistically significant ($P<0.10$) in explaining differences in respondents' opinions regarding the effectiveness of mandatory reporting to enhance their negotiations with packers. Feedlot location, opinions that the manager had about breaking up large beef processors, and opinions regarding timeliness of reports were statistically significant. Cattle feeders located in Kansas and Texas held stronger opinions that mandatory reporting had not enhanced their ability to negotiate terms of trade with beef processors than those located in Iowa; there was more than 0.70 probability of observing a response of 1 (strongly agree) for feedyards located in Kansas and Texas relative to 0.56 for Iowa firms. However, when responses of 1 through 3 were combined, the cumulative response was similar across all four regions. Cattle feeders that thought large processors should be broken up and that reports are timely enough for decision making needs were more likely to agree that their ability to negotiate has improved. Again, part of the sentiment that price negotiating leverage of feeders had not been enhanced was attributable to concerns regarding timeliness of reports.

Mandatory price reporting of beef and fed cattle was designed to improve information available to cattle producers to facilitate the price discovery process. It was supported by producer organizations but not supported by the beef processing industry. The answer to the question, "Has mandatory reporting accomplished its intended goal?" depends on who answers the question. Overall, many producers may have had unrealistic expectations regarding what the Act was to accomplish. Approximately 75% of survey respondents moderately to strongly agreed that mandatory price reporting was not as beneficial as they expected. With just under half of fed cattle being sold on a non-cash basis and not being reported, producers may have felt increased reporting of these prices would reveal information they could use in price discovery. Results of this survey suggest it did not.

This is not necessarily a condemnation of mandatory reporting. Not revealing information can be, in itself, useful information. That is, if mandatory price reporting did not reveal that non-cash marketings were receiving different terms of trade than what was being reported under voluntary reporting, the perception that "special deals" were being made is not correct.

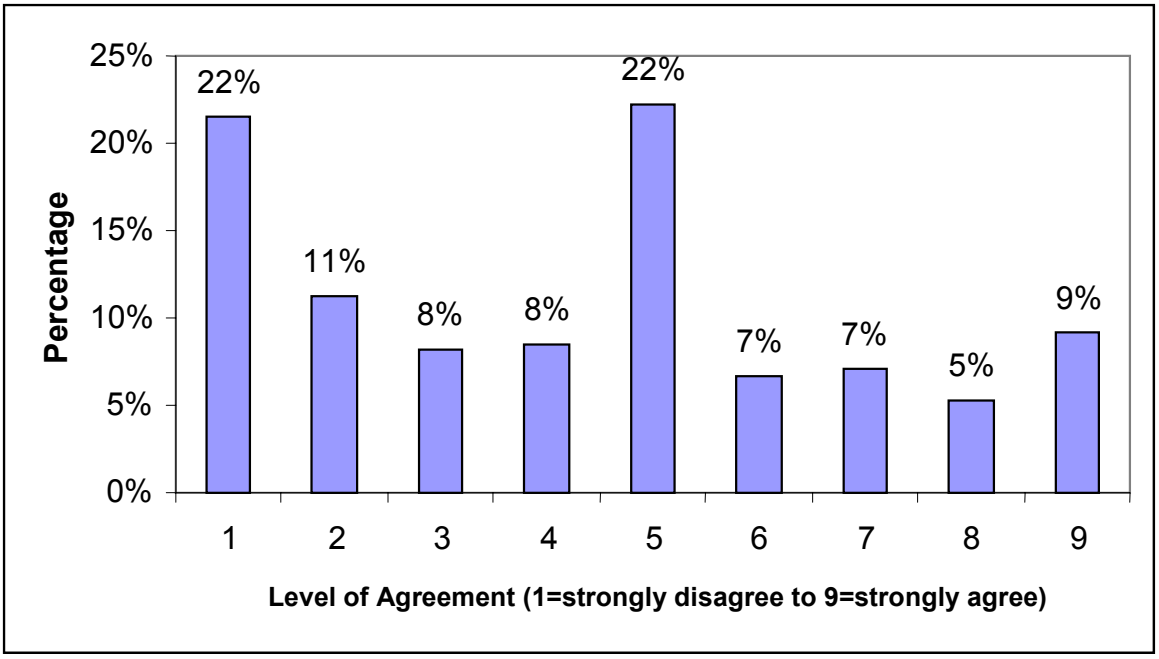

Figure 1. Survey Response Distribution to Statement: ***Mandatory Price Reporting is Benefiting the Beef Industry.***

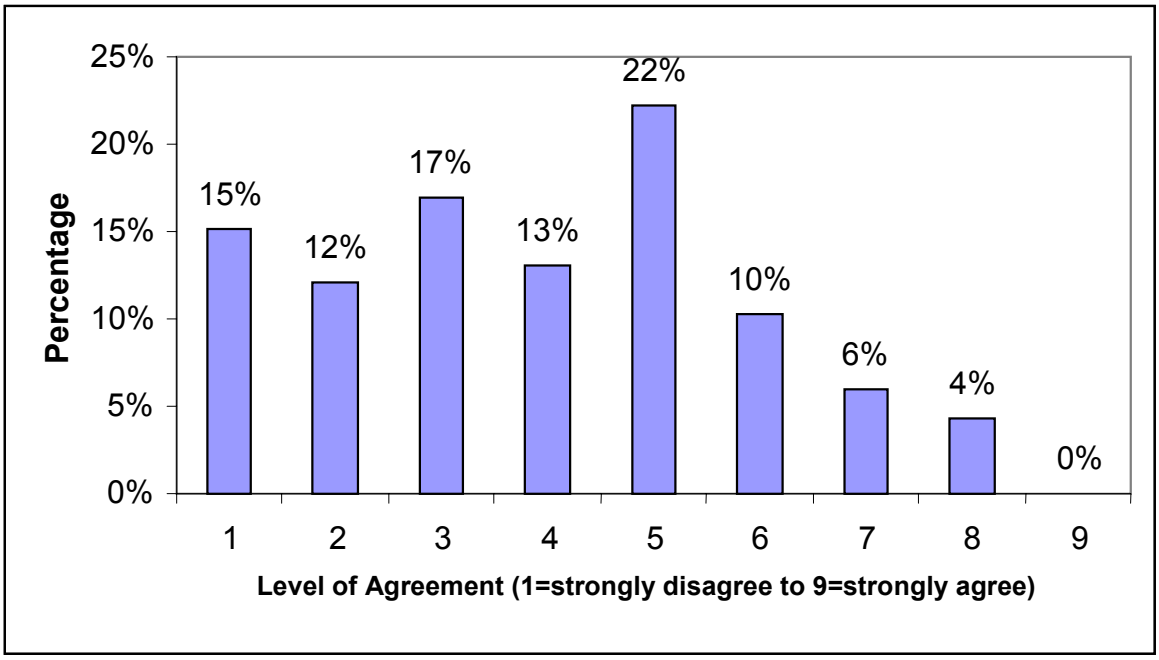

Figure 2. Survey Response Distribution to Statement: ***Information on Regional/National Daily Fed Cattle Cash Prices, Base Prices Used in Grid Pricing, Premiums/Discounts Used in Grid Pricing, and Boxed Beef Prices has Increased.***

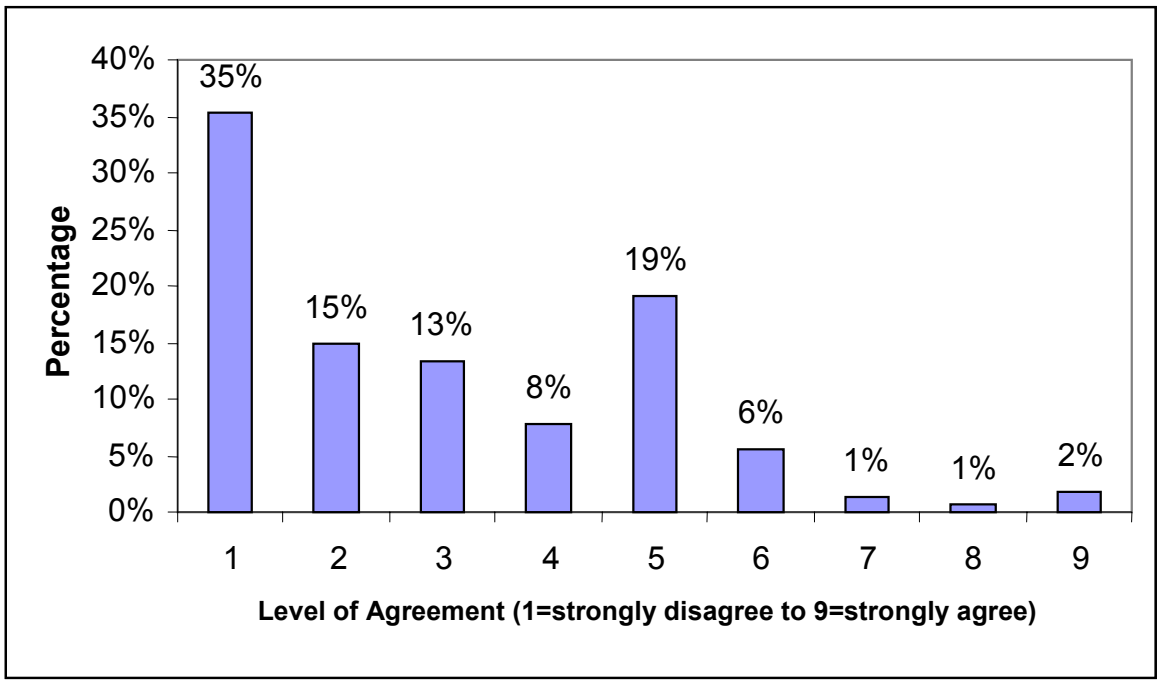

Figure 3. Survey Respondent Distribution to Statement: ***MPR has Enhanced My Ability to Negotiate Cash Prices, Base Prices or Formulas, Grid Premiums/Discounts with Packers*****.**

Cattlemen's Day 2003

ESTIMATING THE IMPACT OF ANIMAL HEALTH AND DEATH LOSS ON ECONOMIC PERFORMANCE OF FEEDLOT CATTLE

M. Irsik [1] and M. Langemeier [2]

Summary

This study examined the impacts of animal health and death loss on the economic performance of feedlot cattle. Using data from two feedlots in western Kansas, the impact of animal health on economic performance was quantified. Death loss and the percentage of animals treated significantly impacted feed conversion, average daily gain, and cost of gain. Feed conversion for a pen of cattle was found to increase by 0.27 lb feed/lb gain and daily gain decreased by 0.08 lb/day for each percentage point increase in death loss. An increase in death loss from 1% to 2% increased cost of gain by $2.29/100 lb gain.

Introduction

The cattle feeding industry is a capital intensive, high-risk business that relies heavily on economies of scale to minimize costs and maximize returns. Profit margins for fed cattle are often small and variable while losses can be large. One of the tools cattle feeders can utilize in managing economic risk is to continually evaluate or estimate the performance of cattle currently on feed as well as those being purchased.

There are numerous variables that impact the performance of feedlot cattle. Some variables are more easily managed than others. Examples of variables that are easier to manage are purchase weight, origin of cattle, type of cattle, genetic makeup, and background. Other variables, such as animal health, are more difficult to control. This study focused on the impact of animal health and death loss on economic performance of feedlot cattle.

Experimental Procedures

Feedlot data pertaining to head count, gender, death loss, number of cattle treated, date in, date out, days of feed, weight in, weight out, gain per head, feed conversion (dry matter basis), average daily gain, cost of gain, feed consumption per head (dry matter basis), ration cost, non-feed cost, origin, and background were collected from customer closeouts for two western Kansas commercial feedlots. Data were collected for steers, heifers, and mixed pens of cattle placed on feed from August 2000 through January 2001. The total number of pens was 673 (53,890 cattle).

Regression analysis was used to examine the impact of death loss on feed conversion, average daily gain, and non-feed cost. Non-feed cost included the cost of medicine to treat cattle, processing, metaphylaxis, yardage, association dues, and insurance. The non-feed cost model was used to investigate the portion of cost of gain not accounted for by feed. Independent variables included in the feed conversion, average daily gain, and non-feed cost regressions included death loss, average in

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weight, average out weight, and dummy variables for gender of cattle in the pen, quarter of the year in which cattle were closed out, origin of the cattle, background of the cattle, and feedlot. Death loss was expected to be positively related to feed conversion (feed/gain) and non-feed cost, and negatively related to average daily gain.

A spreadsheet was utilized to examine the impact of animal health on cost of gain. This spreadsheet incorporated information from the feed conversion, average daily gain, and non-feed cost regressions. Ration cost was held at the average level for the study period to estimate cost of gain.

The percentage of animals treated was regressed on death loss to examine the impact of animals treated on death loss. A positive relationship between these two variables was expected.

Results and Discussion

Table 1 provides summary statistics for the data collected. Average death loss and percentage of animals treated were 2.30% and 13.62%, respectively. The percentage of animals treated was expressed as a percentage of cattle received and included cattle retreated. Average feed conversion, daily gain, and cost of gain were 6.67 lb feed/lb gain, 3.24 lb/day, and $53.20/100 lb gain, respectively.

The estimated regression coefficient for death loss in the feed conversion regression model was 0.27 ($P<0.01$). Thus, for every percentage point increase in death loss, holding all other independent variables constant, feed conversion for a pen of cattle increased by 0.27 lb feed/lb gain. Table 2 illustrates estimated feed conversion levels for death loss ranging from 1% to 10%.

The estimated regression coefficient for death loss in the average daily gain regression model was 0.08 ($P<0.01$). Thus, average daily gain for a pen of cattle decreased by 0.08 lb/day for each percentage point increase in death loss, when holding the other independent variables constant. Table 2 contains average daily gain estimates for death loss ranging from 1% to 10%.

Each percentage point increase in death loss resulted in a $1.00 per head increase in non-feed cost. Table 2 illustrates costs of gain for death loss ranging from 1% to 10%. These results reveal the sensitivity of fed cattle economic performance to changes in death loss. For a 2% death loss, feed conversion was 6.79 lb feed/lb gain, average daily gain was 3.17 lb/day, and cost of gain was $54.05/100 lb gain. For a 4% death loss, feed conversion was 7.32 lb feed/lb gain, average daily gain was 3.02 lb/day, and cost of gain was $58.51/100 lb gain. The higher cost of gain was due to a higher feed conversion level (which led to higher feed cost), a lower average daily gain, and higher non-feed cost.

Results of the regression examining the relationship between death loss and percentage of animals treated revealed a significant relationship ($P<0.01$). The estimated regression coefficient for percentage of animals treated was 0.14. Thus, for every percentage point increase in the percentage of animals treated, death loss increased by 0.14 percentage points, which results in an increase in feed conversion and cost of gain, and a decline in average daily gain.

Table 1. Summary Statistics for Fed Cattle Closeouts, August 2000 to January 2001

Variable	Unit	Average	Standard Deviation
Cattle per pen	No.	80	41
Death loss	%	2.30	3.83
Animals treated	%	13.62	17.76
Days of feed	No.	148.43	29.17
In weight	lb	756.33	113.63
Out weight	lb	1256.95	107.32
Gain per head	lb	500.62	77.40
Feed conversion	lb feed/lb gain	6.67	1.60
Feed consumption	lb/day	21.05	2.87
Average daily gain	lb/day	3.24	0.61
Cost of gain	$/cwt	53.20	15.66
Ration cost	$/ton	143.83	3.73
Added cost	$/head	22.57	8.81
Steers	%	49.33	50.03
Heifers	%	32.69	46.94
Mixed	%	17.98	38.43
First quarter	%	23.63	42.51
Second quarter	%	19.02	39.27
Third quarter	%	25.56	43.65
Fourth quarter	%	31.80	46.60
Kansas origin	%	36.26	48.11
Oklahoma origin	%	8.77	28.30
Texas origin	%	4.31	20.32
Southeast origin	%	45.02	49.79
Northeast origin	%	5.65	23.10
Sale barn	%	51.56	50.01
Preconditioned	%	18.87	39.16
Grass Background	%	25.41	43.57
Wheat Background	%	4.16	19.98
Feedlot 1	%	69.84	45.93
Feedlot 2	%	30.16	45.93

Table 2. Impact of Death Loss on Fed Cattle Performance

Death Loss	Feed Conversion (lb feed/lb gain)	Average Daily Gain (lb/day)	Cost of Gain ($/100 lb)
1%	6.52	3.25	51.76
2%	6.79	3.17	54.05
3%	7.05	3.09	56.18
4%	7.32	3.02	58.51
5%	7.59	2.94	60.87
6%	7.86	2.86	63.26
7%	8.12	2.78	65.68
8%	8.39	2.71	67.85
9%	8.66	2.63	70.32
10%	8.93	2.55	72.85

IMPROPER DOSING USING AVERAGE CATTLE WEIGHTS

L. C. Hollis, D. A. Blasi, M. F. Spire[1], and J. J. Higgins[2]

Summary

A retrospective analysis of 6,231 head of stocker and feeder cattle comprising 24 separate lots was conducted to evaluate the extent and degree of improper dosing that would have occurred in individual animals if all animals in each lot were treated with a single dosage level of a pharmaceutical product based upon the average weight of the lot. Nine hundred forty-six head would have been overdosed by 10% or more, while 831 head would have been underdosed by 10% or more. Four hundred thirty-eight head would have been overdosed by 15% or more, while 366 head would have been underdosed by 15% or more. Two hundred and four head would have been overdosed by 20% or more, while 128 would have been underdosed by 20% or more. Ninety-eight head would have been overdosed by 25% or more, while 35 head would have underdosed by 25% or more.

Introduction

Most vaccines are designed so that a fixed dose of vaccine is administered irrespective of the size of the animal. Most pharmaceutical products are designed so that the dose to be administered varies based upon the weight of the animal. When utilizing pharmaceuticals, livestock producers commonly treat animals as a group based upon the average weight of the group, rather than determining individual weights and adjusting the dosage for each animal accordingly. As a result, some animals in the group are properly dosed, while lighter weight animals in the group are overdosed and heavier weight animals are underdosed. The degree to which improper dosing occurs depends upon the degree of weight variation within the group.

Overdosing lighter weight animals may lead to toxicity problems or require extended withdrawal times prior to harvest. Another obvious consequence is money wasted needlessly on excess product cost per animal.

Underdosing heavier weight animals may lead to lack of efficacy of the product involved. Underdosing anthelmintics may result in cattle that still retain a significant worm burden and have poorer performance than anticipated. Underdosing antimicrobials may lead to poor treatment response, including repulls, chronics, or even death losses. Underdosing with these classes of products has potentially far greater economic loss than the expense of excess product typically associated with overdosing.

Experimental Procedures

To develop a feel for the extent and degree of improper dosing that occurs in the beef cattle industry, individual weights previously collected from 6,231 head comprising 24 lots of stocker and feeder cattle involved in field studies at Kansas State University were evaluated. The average in-weight of each lot was calculated, and individual in-weights of

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[2]Department of Statistics.

animals in the lot were compared to the average for the lot. When the actual weight of the individual was less than the average weight of the lot, the degree of overdosing was calculated. When the actual weight of the individual was greater than the average weight of the lot, the degree of underdosing was calculated.

Results and Discussion

Assuming that the average weight of each lot was used to determine the dosage of either an anthelmintic or a metaphylactic antimicrobial treatment for all animals in the lot, the extent and degree of potential individual animal improper dosing was calculated (Figure 1). Of the 6,231 head involved, 15.2% (946 head) would have been overdosed by 10% or more; 7.0% (438 head) overdosed by 15% or more; 3.3% (204 head) overdosed by 20% or more; and 1.6% (98 head) overdosed by 25% or more. Over 13.3% (831 head) would have been underdosed by 10% or more; 5.9% (366 head) underdosed by 15% or more; 2.1% (128 head) underdosed by 20% or more; and 0.6% (35 head) underdosed by 25% or more.

While the biological significance of improper dosing was not measured directly in these field studies, product-specific dose titration studies have previously shown that underdosing can contribute to lack of efficacy of dose-dependent products such as anthelmintics and antimicrobials.

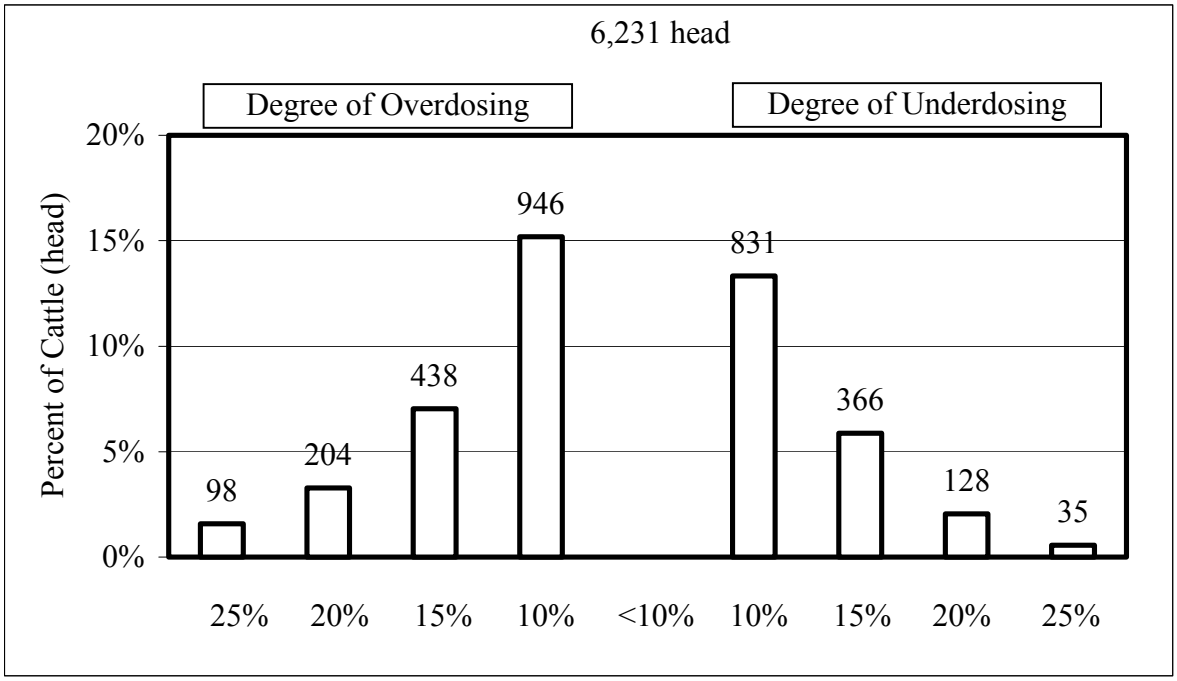


Figure 1. Overdosing and Underdosing Using Average In-Weights.

Cattlemen's Day 2003

TIMED ARTIFICIAL INSEMINATION IN YEARLING BEEF HEIFERS: 7-11 COSYNCH VS. COSYNCH

A. W. Thompson, C. D. Holladay, D. R. Eborn, and D. M. Grieger

Summary

Previous research demonstrated that an estrus-synchronization program using a short period of melengestrol acetate (MGA) feeding in conjunction with a Cosynch protocol was effective in synchronizing estrus in postpartum beef cows. The objective of our study was to test this synchronization protocol (7-11 Cosynch) in yearling beef heifers in comparison to a Cosynch protocol. Fifty-eight commercial beef replacement heifers were assigned randomly to two protocols: Cosynch (n=29) and 7-11 Cosynch (n=29). Beginning on day 1, heifers in the 7-11 Cosynch protocol were fed MGA (0.5 mg/heifer daily) for 7 days. On day 7, the last day of MGA feeding, the heifers on the 7-11 Cosynch protocol received an injection of $PGF_{2\alpha}$. On day 11 all 58 heifers received an injection of GnRH (100 μg). On day 18, all 58 heifers were injected with $PGF_{2\alpha}$. On day 20, all of the heifers received a 100 μg dose of GnRH by injection and were artificially inseminated. Ultrasonography was used to determine pregnancy status 29 days after breeding. A greater percentage ($P<0.01$) of heifers were pregnant after the 7-11 Cosynch treatment (67%) than after the Cosynch treatment (31%). This study demonstrates the potential of achieving acceptable pregnancy rates using timed artificial insemination in yearling beef heifers.

Introduction

The use of artificial insemination (AI) is limited in the beef industry due to the added costs, labor, time, and the additional skills required. Application of estrus-synchronization protocols has reduced the time required for using AI, making it a feasible option for some producers. Most protocols require estrus detection, but in recent years timed AI protocols for cows have yielded acceptable results, further reducing the time requirement for AI. However, the timed AI protocols designed for cows do not always provide satisfactory results when applied to heifers.

A common protocol for synchronizing estrus in heifers is to feed melengestrol acetate (MGA) for 14 days at a rate of 0.5 mg/heifer daily. Heifers then receive an injection of $PGF_{2\alpha}$ 17 to 19 days after MGA feeding and are inseminated according to observed estrus. This synchronization system is effective but requires 31 to 33 days from the initiation of MGA feeding to the beginning of AI.

Recently, another protocol (7-11 Synch) for heifers was tested with a shorter, 7-day, MGA feeding period combined with the Select-Synch protocol. Although this protocol yielded good synchrony and conception rates in heifers, this synchronization system still requires labor for detection of estrus.

The present study was designed to determine whether the 7-11 Synch system could be modified for timed AI of heifers.

Experimental Procedures

A group of 58 yearling heifers (Angus x Hereford) from the Kansas State University Cow-Calf Unit were used in this study. Blood

was collected 11 days before the experiment as well as on days 1 and 18 and subsequently analyzed for concentrations of progesterone to determine whether each heifer had achieved puberty. Heifers were blocked by weight and pubertal status and assigned to one of two protocols. One group (7-11 Cosynch; n=29) were fed MGA (0.5 mg/heifer daily; Pharmacia Animal Health, Kalamazoo, MI) in combination with a Cosynch protocol (Figure 1). The control group (Cosynch) received the traditional Cosynch protocol (Figure 1).

Heifers in the 7-11 Cosynch group were individually fed a grain sorghum carrier containing MGA for 7 days starting on day 1. On the last day of MGA feeding, the heifers were injected with 25 mg (i.m.) of $PGF_{2\alpha}$ (Estrumate, Schering-Plough Animal Health, Kenilworth, NJ). The Cosynch group was fed the carrier without MGA for the first 7 days. Thereafter, all of the heifers were fed only the carrier throughout the end of the trial. On day 11, all heifers received 100 μg (i.m.) of gonadotrophin-releasing hormone (GnRH; Cystorelin, Merial, Iselin, NJ). Then, on day 18, all heifers received an injection of $PGF_{2\alpha}$. All heifers were injected with GnRH (100 μg) and artificially inseminated on day 20. Semen from two sires was distributed equally between the two treatments.

Results and Discussion

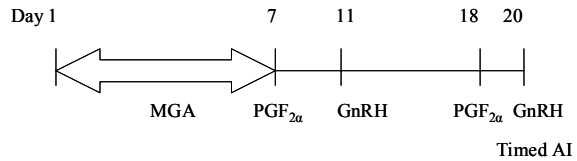
Ultrasonography was used to determine pregnancy status at 29 days after timed AI. In total, 28 of 58 (48%) heifers were pregnant. In the 7-11 Cosynch group 19 of 29 (67%) heifers were confirmed pregnant. In contrast, only 9 of 29 (31%) heifers in the Cosynch group conceived. Even with this small number of heifers, pregnancy rates differed ($P<0.01$) between the two treatments.

No difference in pregnancy rates was detected between sires. Seven heifers were nonpubertal at the beginning of the trial. At day 18, four heifers still were not cycling. Two of the three heifers that began cycling during the treatment were confirmed pregnant.

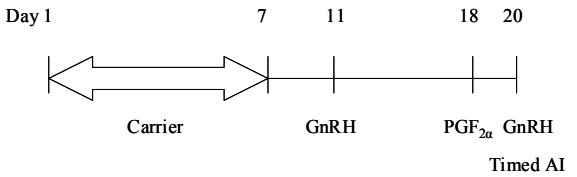
A great opportunity exists to use AI in the beef industry, but this advantage requires a greater input of time and labor. The present study indicates that short-term MGA feeding combined with the Cosynch protocol may yield acceptable pregnancy rates with timed AI in yearling beef heifers.

Acceptable pregnancy rates obtained from timed AI protocols may allow more producers to use AI and thereby benefit from superior genetics at costs comparable to purchasing bulls.

7-11 Cosynch



Cosynch



Cattlemen's Day 2003

COMPARISON OF BREEDING SYSTEM COSTS FOR ESTRUS-SYNCHRONIZATION PROTOCOLS PLUS ARTIFICIAL INSEMINATION VERSUS NATURAL SERVICE

S. K. Johnson, S. L. Fogleman, and R. Jones

Summary

Breeding system costs were estimated for natural service and various estrous synchronization plus artificial insemination (AI) systems. Cost per pregnancy was lower for natural service than AI; however, for the large herd size the difference was small for some synchronization systems examined. When the value of an AI-sired calf at weaning was included as $25 greater than a natural service sired calf, several synchronization systems had lower breakeven prices than natural service. Assuming skilled labor could be obtained, systems that involved more heat detection time were more profitable than strict timed insemination systems. Producers that can obtain greater returns from AI-sired calves will find synchronization of estrus and AI valuable tools to increase profitability of their operation.

Introduction

To incorporate desired genetics into cattle breeding programs, producers have an increasing number of options available for synchronization of estrus or ovulation and artificial insemination (AI). Low-cost production continues to be essential for survival in the beef industry. Understanding the costs of producing pregnancies via various methods and their associated value is very important. For some, the need to do more than turn a bull out with the cows is sufficient analysis for them not to consider AI. Others will take a broader view of the issue and may find that AI is a tool that can improve profitability.

This paper examines the costs associated with producing pregnancies via natural service and various estrous synchronization systems. Some parts of the process are relatively easy to assign costs and make comparisons; whereas, for others, assigning economic values is much more difficult. As always, to make the most informed decisions, each producer must know costs of production for their own operation.

Cost of Natural Service

Understanding the costs associated with natural service breeding is a good place to begin. The original purchase price, bull to cow ratio, and years of use are all important factors that affect breeding costs. Table 1 shows annual bull ownership costs and estimated costs per pregnancy for a range of bull purchase prices ($1,500 to $3,000) and bull to cow ratios (1:15 to 1:50). For reference, the American Angus Association reported the average price of Angus bulls sold for fiscal years 2000 and 2001 were $2,292 and $2,267, respectively. Annual bull costs were calculated using Kansas Cow-Calf Enterprise Budget cost estimates made by Fogleman and Jones in 2001. Additional assumptions included the use of each bull for four breeding seasons; 10% death loss; 9% interest rate; and a 94% pregnancy rate. Annual feed costs for cow herds vary by as much as $200 per cow and this same variability is expected in feed costs for bulls. Increasing annual feed costs by $100 increased cost per pregnancy by $7.41 for a low bull to cow ratio (15 cows/year) and $2.22 for heavy bull use (50 cows/year).

Producers who use breeding pastures with carrying capacities less than the serving capacity of the bull (bull to cow ratio), will increase cost per pregnancy. Conversely, cost per pregnancy will be reduced if highly fertile bulls are identified and exposed to more females compared to more conservative recommendations.

Table 1. Annual Bull Costs ($) Based on Purchase Price and Associated Cost per Pregnancy

Purchase price	1,500.00	1,700.00	2,000.00	2,300.00	2,500.00	3,000.00
Salvage value	860.00	860.00	860.00	860.00	860.00	860.00
Summer pasture	104.13	104.13	104.13	104.13	104.13	104.13
Crop residue	7.50	7.50	7.50	7.50	7.50	7.50
Hay	90.61	90.61	90.61	90.61	90.61	90.61
Protein, mineral	25.00	25.00	25.00	25.00	25.00	25.00
Labor	50.00	50.00	50.00	50.00	50.00	50.00
Vet	21.00	21.00	21.00	21.00	21.00	21.00
Repairs	31.00	31.00	31.00	31.00	31.00	31.00
Misc.	7.00	7.00	7.00	7.00	7.00	7.00
Interest	15.13	15.13	15.13	15.13	15.13	15.13
Total variable	351.37	351.37	351.37	351.37	351.37	351.37
Depreciation on equipment	12.39	12.39	12.39	12.39	12.39	12.39
Depreciation on bull	160.00	210.00	285.00	360.00	410.00	535.00
Interest on bull	212.40	230.40	257.40	284.40	302.40	347.40
Death loss	15.00	17.00	20.00	23.00	25.00	30.00
Total fixed	399.79	469.79	574.79	679.79	749.79	924.79
Total cost/year	751.16	821.16	926.16	1,031.16	1,101.16	1,276.16
Purchase price	1,500.00	1,700.00	2,000.00	2,300.00	2,500.00	3,000.00
Cows Exposed Per Year	Cost per pregnancy					
15	53.27	58.24	65.69	73.13	78.10	90.51
20	39.96	43.68	49.26	54.85	58.57	67.88
25	31.96	34.94	39.41	43.88	46.86	54.30
30	26.64	29.12	32.84	36.57	39.05	45.25
35	22.83	24.96	28.15	31.34	33.47	38.79
40	19.98	21.84	24.63	27.42	29.29	33.94
50	15.98	17.47	19.71	21.94	23.43	27.15

Cost of Synchronization of Estrus Plus AI

The partial budget in Table 2 gives an overview of cost differences between an AI program and natural service. Compared to natural service, increased costs of an AI program included synchronization products, labor for synchronization of estrus and AI, time for planning, and perhaps improvements in facilities. Decreased returns include income from the sale of cull bulls because fewer bulls will be needed. Depending on the size and management of the operation, costs could be decreased by having fewer bulls to purchase, maintain, and keep out of trouble, less time and labor for calving in a shorter calving season, and less calving assistance from high-accuracy, low-calving-difficulty bulls. Income will increase as a result of more older, heavier calves at weaning. Producers with good marketing skills also will increase returns from a more uniform calf crop and by producing offspring with genetics that are in demand. If replacement heifers are generated from within the herd, long-term benefits may accrue from selection for traits such as milk production or longevity. The beneficial items in our budget (i.e., improved genetics, more concentrated calving season) are much more difficult to value, and some might not be captured by producers without additional marketing efforts. Nevertheless, in a marketplace that is increasingly value driven, the opportunity to capture this genetic value will expand in the future.

An example of the potential value of improved genetics is in Table 3. Boxed beef values from Angus sires with 10 or more carcass data records are illustrated. The carcass value was $206 per head greater for sires grouped in the top 10% than the bottom 10% for carcass value. It is clear that a few more dollars could be invested in breeding costs to produce a product worth $206 more at harvest. Because the industry has been selling commodity cattle based on average values for so long, it is difficult for many producers to market calves so that they are paid for the true value of the genetics produced. Currently, these value differences are more readily observed at harvest than weaning, but the trend is toward identifying and rewarding known genetics earlier in the production process. Excellent marketing is one of four keys for high returns on assets for cow/calf enterprises in the Northern Great Plains. As the beef industry continues to shift from a commodity market to a value-based market, differences in costs and returns for various breeding systems may be more readily calculated. If the cost per pregnancy is higher for a particular method of breeding, what are the chances those costs can be recouped achieving higher marketing returns on the superior genetics?

Table 2. Partial Budget for Synchronization of Estrus Plus AI

Budget Effect	Source	Budget Effect	Source
Increased returns	Heavier calves (earlier average birth date) Improved genetics (calves and replacement females) Uniformity of calf crop (fewer sires could be used, total breeding season could be shorter)	Decreased returns	Fewer cull bulls to sell
Decreased costs	Fewer bulls to purchase and maintain Less labor for more concentrated calving season More predictable calving ease	Increased costs	Planning and management for synchronization of estrus and AI Synchronization products and supplies Labor Improved facilities?

Table 3. Average Boxed Beef Values For Angus Sires With 10 Or More Carcass Data Records*

Trait	Top 10%	Bottom 10%	Difference
No. of progeny	2728	1751	
No. of sires	109	110	
% Prime	7.7	0.7	+7.0
% CAB	47.4	0.7	+46.7
% Choice & above	93.7	48.1	+45.6
% Select	6.1	35.0	-28.9
% Standard	0.2	16.9	-16.7
% Yield grades 1 and 2	60.0	38.2	+21.8
% Yield grades 4 and 5	1.4	18.2	-16.8
Carcass price/cwt	$110.19	$94.15	$16.04
Carcass value	$822.27	$616.36	**$205.91**

*Source: Angus Beef Bulletin, January 2000.

Whole herd cost of pregnancy

To evaluate breeding costs under different breeding systems, estimates of the hours of labor required for various synchronization systems were obtained from a survey of beef producers using AI in Nebraska in 1988. From that survey, regression equations were estimated for total labor hours required for various AI programs.

Nonsynchronized program:
$TM = 19 + 0.036(CD)$ $R^2 = 0.83$

Lutalyse synchronization program:
$TM = 2.65\ (CD)^{0.5}$ $R^2 = 0.60$

SyncroMate-B synchronization program:
$TM = 2.53\ (CD)^{0.5}$ $R^2 = 0.87$

TM = Total hours of labor required for AI program
C = Total number of cows and heifers being bred AI
D = Total number of days in AI program

The equation for the SyncroMate-B system was used for all the estrous synchronization systems in this report. Breeding systems were evaluated for various herd sizes. Breeding herds of 35, 116, and 348 head allowed for culling of nonpregnant and physically impaired cows to yield 30-, 100-, and 300-head calving herds. For the current model, costs were estimated over a range of AI-pregnancy rates. Pregnancy rate was multiplied by number of cows, and the product was divided by an average conception rate of 70% to get the number of cows in estrus. Cows and heifers not pregnant to AI were exposed to bulls for the remainder of the breeding season. Pregnancy rate for the total breeding season was 94%. The number of bulls required for clean-up was calculated based on the outcome of the AI program. One bull was used per 30 nonpregnant females. Variable and fixed costs for AI are shown in Table 4. The annual interest rate charged for cash costs was 9%. The labor rate used was $10.77 per hour. Annual bull costs ($2,000 purchase price) were $926 per bull as illustrated in the Table 1. Budget items from the partial budget in Table 2 that are not accounted for in this model include value of AI-sired replacement heifers, more concentrated calving season,

more predictable calving ease, and any facility improvements.

Table 4. Artificial Insemination Costs

Item	Cost per unit
Semen	$13.00/straw
Prostaglandin $F_{2\alpha}$	$2.00/dose
GnRH	$4.00/dose
CIDR	$8.00/dose
Supplies	%0.50/insemination
Fixed costs[a]	$176.30

[a]Semen tank, carrying case, pipette gun, thaw box, and liquid nitrogen.

Costs per pregnant female calculated in this model reflect both AI and natural service pregnancies. In this case, pregnancy rate to AI impacts the cost per pregnant female in two ways. As AI pregnancy rate is reduced without changing the number of bulls required for natural service, cost per pregnancy actually decreases because of lower costs for semen and interest for a system involving heat detection and AI. Although this reduction means fewer AI-sired calves, the impact of that reduction depends on how well the producer capitalizes on the genetic value of the calves and is not reflected in the cost per pregnant female. When pregnancy rate increases to a point where the operation can get along with one less bull, then the reduced bull costs significantly lower costs per pregnancy with little change in the pregnancy rate. As seen in Table 5, an additional bull for natural service adds from $8.27 per pregnant female for herds of 100 head and only $2.61 for herds of 300 head. As the AI pregnancy rate increases, the percentage of costs due to semen expense increases and those attributed to the bull decrease. At what might be considered typical AI pregnancy rates, approximately 50%, bull costs easily represent the largest share of costs followed by semen costs. The importance of annual bull costs to the total cost of the breeding system is further emphasized with bulls with a higher initial purchase price. The percentage of total costs attributed to bulls reflects how bull costs change based on the number of cows pregnant to AI. In reality, a decision on how many bulls to place with the cows after AI must be made before knowing the AI pregnancy rate. Successfully identifying bulls that can reliably service more than the 30 cows would be extremely valuable. If four rather than five bulls are used for the 300-cow herd when the pregnancy rate is 65%, the cost per pregnant female is reduced $2.83.

A better evaluation of breeding systems would be to account for the proportion of pregnancies from AI or natural service in each system. To do this, calves with AI sires were assigned a value of $25 per head greater than those born to natural service. The AI sired calves would be on average 10 days older and 20 lb heavier at weaning, thus increasing the return at weaning by $20, if the additional weight is worth $1/lb. An extra $5 per calf was assigned for "genetic" value. This is a fairly conservative estimate compared to the $25 per head bonus for calves that fit the Laura's Lean specifications (genetic and management requirements) and an average of $10 to 15 per head bonus on carcass performance. For this model, calves sired by AI sires were valued at $525 per head, and natural service sired calves were valued at $500 per head. To compare breeding system costs and returns, a standardized production scale was generated. Breeding system costs per exposed female were reduced for any increased revenue from AI-sired calves and expressed as a 500-lb equivalent, weaned-calf, breeding cost per hundred pounds (cwt). A weaned calf crop of 82% was assumed.

Table 5. Effect of Changing Pregnancy Rate on Breeding Cost per Pregnant Female in a Select Synch Protocol

Calving herd size	AI pregnancy rate (%)	No. of bulls for natural service	Breeding cost ($) per pregnancy	Proportion (%) of total cost attributed to:			
				Bulls	Semen	Labor	Treatments
100	75	1	42.06	20	37	19	15
100	74	2	50.33	34	30	16	13
100	55	2	46.08	37	24	18	14
100	49	2	44.74	36	22	18	14
100	48	3	53.01	48	19	15	12
300	66	4	38.29	30	35	12	17
300	65	5	40.90	35	33	11	16
300	57	5	39.11	36	30	12	16
300	56	6	41.72	41	28	11	15
300	55	6	41.49	41	27	11	15
300	49	6	40.15	42	25	12	16
300	48	7	42.76	46	23	11	15

Breeding system costs and the standardized cost per cwt for various breeding systems assuming equivalent AI pregnancy rates (50%) are in Table 6. Breeding system costs per pregnant female were least for natural service followed by MGA + PGF and MGA-Select or Select Synch (depending on herd size); CO-Synch + CIDR was most expensive. On a standardized production scale, 500-lb equivalent weaned-calf breeding cost per cwt, several systems have costs nearly equal to or less than natural service. These include MGA + PGF, MGA Select, and Select Synch for all herd sizes and include 7-11 Synch, CIDR + PGF7, and CIDR + PGF8 for a herd size of 300. So, decisions based strictly on cost and not the returns generated by those costs, may be erroneous. Systems with the highest standardized cost per cwt involve CIDRs and/or timed AI. The difference in cost per cwt between MGA + PGF and natural service was $2.23/cwt and $1.71/cwt, for herd sizes of 300 and 30, respectively. The difference in cost per cwt between natural service and MGA + PGF indicates the amount the breakeven price for weaned calves would need to change to account for differences in breeding system costs and number of AI pregnancies. Therefore, the weaning breakeven price must be $2.23/cwt greater for a natural service breeding system than one using MGA + PGF to generate equal returns with all else being equal. The CO-Synch+CIDR system standardized cost per cwt was $2.63 and $2.66 more than natural service for herd sizes of 30 and 300, respectively. The common factors among those systems with the lowest standardized costs seem to be low treatment costs, heat detection and estrus AI, and relatively higher labor costs. A comparison in this manner assumes that additional labor to facilitate the heat detection and AI is either readily available or can be hired. If competent help can be hired to complete the task, then that would seem to be the most economical method to use. Some cannot or will not hire outside help, in which case the opportunity cost of the time spent on AI may be perceived to be too great compared to other farming or ranching activities.

In comparing a timed AI system such as CO-Synch to Select Synch where cows are inseminated after an observed estrus, the standardized costs per cwt are less with the Select Synch system, and the difference is greatest

for the largest herd size. Therefore, although in most cases estrus-AI may produce more pregnancies with less cost, timed AI may allow a producer who would not have considered AI if heat detection was necessary to use AI. This situation may occur because of herd size, a pasture too large for efficient heat detection, or unavailability of labor. This type of producer may have a greater ability to recover the additional cost of timed AI in the value received for the genetics produced.

A further examination of the Select Synch and CO-Synch systems at varying labor and semen costs is shown in Table 7. At low semen costs and high labor costs, the differences in cost per cwt between CO-Synch and Select Synch are rather small and range from $0.32 to $0.05 per cwt. For a herd size of 30, the breeding costs per cwt are less for CO-Synch than Select Synch at low semen costs and medium to high labor costs and at the highest semen and labor costs at an AI pregnancy rate of 60%. For a herd size of 300, there are no combinations where the costs are less for CO-Synch. Averaged across all herd sizes and AI pregnancy rates, and at the highest labor cost, the standardized cost for Select Synch is $0.79/cwt less than CO-Synch, and this increases to $1.61/cwt at low labor costs. At the lowest semen cost, averaged across all herd sizes and AI pregnancy rates, the advantage of Select Synch over CO-Synch is only $0.45 and increases to $1.96/cwt at high semen costs.

Pregnancy rates to AI will vary based on a variety of factors and the effect of changing pregnancy rate on the standardized cost per cwt was calculated within each system (Table 8). Notice that for a herd size of 30 using CO-Synch, the cost per pregnant female remains the same despite differences in AI pregnancy rates. This is because all animals are treated and inseminated, one bull is still needed for clean up and total number of cows pregnant at the end of the entire breeding season is similar. The benefit of more AI pregnancies is reflected in the standardized production scale.

Table 8 allows a comparison of systems at different AI pregnancy rate outcomes. For example, if heat detection is problematic and reduces the pregnancy rate to 40% in a Select Synch system, then the pregnancy rate to timed AI in the CO-Synch system must be between 50 and 60% to yield similar costs per cwt for a herd size of 300. In larger herds where heat detection may really present a challenge, this could easily be true.

Comparing Select Synch to Select Synch + CIDR, the CIDR allows for two fewer days of heat detection and should increase pregnancy rates over Select Synch, particularly in anestrous cows. However, even at a 60% pregnancy rate for the Select Synch + CIDR, the cost per cwt is still less for a Select Synch system yielding a 40% pregnancy rate. MGA-Select requires one additional injection of GnRH and one more day of labor than MGA + PGF. Costs per cwt for MGA + PGF at a 40% pregnancy rate are slightly less than a 50% pregnancy rate with MGA + Select (300 head). CO-Synch and MGA-CO-Synch have very similar costs and returns, because there is little added cost with the MGA-CO-Synch in this model. This is based on the assumption that there is no additional labor cost to deliver the MGA, and the MGA carrier is part of the normal ration. A comparison of giving PGF on the day before CIDR removal (CIDR + PGF7) or at CIDR removal (CIDR + PGF8) indicates that the CIDR + PGF8 system reduces cost from $0.90 to $0.28 per pregnant female for herd sizes of 30 to 300, respectively, and reduces cost per cwt $0.21 to $0.07.

Economies of scale are evident in these results, but breeding costs are just part of the picture. Both Kansas SPA and Farm Management databases indicate that small herds are just as likely to be profitable as large herds.

Pregnancy rates to AI

The costs and returns based on various AI pregnancy rates and estrous synchronization systems have been shown. The question then becomes, what pregnancy rate can be expected from various systems? Age, body condition, and days postpartum will all impact the proportion of cows cycling at the onset of the breeding season and thus the pregnancy rate to AI. AI-pregnancy rates will vary widely for the same synchronization system. Table 9 depicts ranges in pregnancy rates that might be expected during a 5-day AI period or a single timed AI (CO-Synch and Ovsynch). The value under the "typical" column is a conservative estimate that might be used for planning in well-managed herds with optimal conditions.

Exercise caution when evaluating field reports of pregnancy rates from various systems. In some cases, only part of the herd (mature or early calving cows) was studied. This may be a wise and practical way to implement an AI program, but the results will likely be better than when the entire herd is synchronized. The method of determining AI pregnancies also may be misleading. To ensure clear distinction between AI and natural service pregnancies, a common research practice is to wait at least 10 days after AI before turning out bulls for clean-up in order to make an accurate early pregnancy diagnosis (30 to 40 days after first AI).

It is clear that reliable estrous synchronization systems exist that generate AI pregnancy rates of 50% or more with a single timed AI. Producers who refine their management in preparation for the breeding season, identify highly fertile bulls for both AI and natural service, and have a gradually increasing percentage of cows calving early will find even better results over time.

Conclusions

Although costs of a breeding system are important, a system that can be implemented correctly and efficiently within a given production environment may be equally important. The duration or complexity of a system may make it a bad choice for certain situations even though it looks good on paper. The model described here does not account for such things as the likelihood that the proper treatment will be given on the correct day or that the facilities are adequate to allow detection of estrus and sorting of breeding females and their calves.

Results indicate that synchronization systems that involve considerable animal handling and heat detection can generate a return greater than natural service. Given all the demands on the operators of today's cow-calf herds, hiring highly skilled, specialized people to apply estrous synchronization systems and AI makes good sense. Particularly for someone just starting an estrous synchronization program, experienced help may be worth a lot to the success of a program. The planning required to schedule help is a problem for some, but should be a priority.

Much research has been done to improve pregnancy rates to timed AI. If labor is available and heat detection is feasible, cost analyses indicate that AI after estrus rather than timed AI should produce greater returns per cwt. Some timed AI systems have standardized costs similar to natural service at a 50% pregnancy rate and lower costs at 60% depending on herd size. For producers who can further capitalize on increased returns for AI-sired calves, this benefit should be even greater.

Table 7. 500 lb Equivalent Weaned Calf Breeding Costs per cwt for a Herd Size of 100 at Various Labor and Semen Costs

System	Preg. Rate (%)	Semen cost ($)								
		$3/unit			$13/unit			$23/unit		
		Labor Cost ($/hour)								
		5.77	10.77	15.77	5.77	10.77	15.77	5.77	10.77	15.77
CO-Synch	40	8.35	8.85	9.34	11.01	11.50	12.00	13.67	14.16	14.66
CO-Synch	50	5.89	6.38	6.88	8.55	9.04	9.54	11.20	11.70	12.20
CO-Synch	60	5.37	5.87	6.37	8.03	8.53	9.02	10.69	11.19	11.68
Select Synch	40	7.31	8.17	9.03	8.83	9.68	10.54	10.34	11.20	12.06
Select Synch	50	4.98	5.84	6.70	6.88	7.74	8.60	8.78	9.63	10.49
Select Synch	60	4.60	5.46	6.31	6.87	7.73	8.59	9.15	10.01	10.87

Table 9. Pregnancy Rates (%) to a 5-Day AI Period or a Single Timed Insemination*

	Heifers		Cows	
	Range	Typical	Range	Typical
MGA + PGF	40-70	60	40-60	55
MGA Select	40-65	60	40-65	60
MGA CO-Synch*			45-65	60
Select Synch	40-65	50	25-55	45
CO-Synch*	-		30-55	50
CO-Synch+CIDR*	-		+ 0 –15	
Ovsynch*	-		50-57	50
CIDR + PGF	35-60		35-60	45
7-11 Synch	30-55		35-65	
2 × PGF	30-65	50	20-45	40

Table 6. Breeding System Costs and 500 lb Equivalent Weaned Calf Breeding Cost per cwt

	Days worked	Preg. rate (%)	Total labor hours			No. of bulls			Cost ($) per pregnancy			500 lb equivalent weaned calf breeding cost ($) per cwt					
			Herd size														
			30	100	300	30	100	300	30	100	300	30	Diff[a]	100	Diff[a]	300	Diff[a]
System*																	
Natural Service						2	4	12	**56**	**34**	**34**	**12.91**	-	**7.79**	-	**7.79**	-
Select Synch	9	50	45	82	142	1	2	6	67	45	40	12.75	0.16	7.74	0.05	6.68	1.11
7-11 Synch	8	50	42	77	133	1	2	6	69	47	43	13.15	(0.25)	8.23	(0.44)	7.22	0.57
CIDR+PGF7	8	50	42	77	133	1	2	6	71	49	45	13.62	(0.71)	8.69	(0.90)	7.69	0.10
CIDR+PGF8	7	50	40	72	125	1	2	6	70	49	44	13.41	(0.51)	8.58	(0.79)	7.62	0.17
Hybrid Synch**	7	50	40	72	125	1	2	6	72	51	47	14.01	(1.11)	9.18	(1.39)	8.22	(0.43)
MGA Select	7	50	40	72	125	1	2	6	66	45	40	12.48	0.42	7.65	0.14	6.69	1.10
Select Synch+CIDR	7	50	40	72	125	1	2	6	74	53	49	14.48	(1.57)	9.64	(1.85)	8.68	(0.90)
MGA + PGF	6	50	37	67	116	1	2	6	60	39	35	11.20	1.71	6.47	1.32	5.56	2.23
CO-Synch	3	50	26	47	82	1	2	6	70	51	48	13.41	(0.51)	9.04	(1.25)	8.32	(0.53)
CO-Synch + CIDR	3	50	26	47	82	1	2	6	79	60	57	15.54	(2.63)	11.17	(3.38)	10.45	(2.66)
MGA-CO-Synch	3	50	26	47	82	1	2	6	70	51	48	13.55	(0.64)	9.18	(1.39)	8.45	(0.66)

*Descriptions of these systems are shown in Figure 1.

**Assumes 40% of cows bred based on observed estrus (no GnRH at AI)

[a]Diff=difference between natural service and breeding system, $/cwt

Table 8. Breeding System Costs ($) and 500 lb Equivalent Weaned Calf Breeding Cost ($) per Cwt at Various AI Pregnancy Rates

	Days worked	Preg. rate (%)	No. of bulls			Cost ($) per pregnancy			500 lb equivalent weaned calf breeding cost ($) per hundred					
			Herd size											
System			30	100	300	30	100	300	30	Diff[a]	100	Diff[a]	300	Diff[a]
Natural Service			2	4	12	**56**	**34**	**34**	**12.91**	**-**	**7.79**	**-**	**7.79**	**-**
CO-Synch	3	40	1	3	7	70	59	50	13.93	(1.02)	11.50	(3.71)	9.48	(1.70)
	3	50	1	2	6	70	51	48	13.41	(0.51)	9.04	(1.25)	8.32	(0.53)
	3	60	1	2	5	70	51	45	12.90	0.01	8.53	(0.74)	7.16	0.63
MGA-CO-Synch	3	40	1	3	7	70	60	51	14.06	(1.15)	11.64	(3.85)	9.62	(1.83)
	3	50	1	2	6	70	51	48	13.55	(0.64)	9.18	(1.39)	8.45	(0.66)
	3	60	1	2	5	70	51	45	13.03	(0.12)	8.66	(0.87)	7.29	0.50
CO-Synch+ CIDR	3	40	1	3	7	79	68	60	16.06	(3.15)	13.63	(5.84)	11.61	(3.82)
	3	50	1	2	6	79	60	57	15.54	(2.63)	11.17	(3.38)	10.45	(2.66)
	3	60	1	2	5	79	60	54	15.03	(2.12)	10.65	(2.87)	9.28	(1.49)
MGA/PGF	6	40	1	3	7	58	46	36	11.20	1.71	8.41	(0.63)	6.21	1.58
	6	50	1	2	6	60	39	35	11.20	1.71	6.47	1.32	5.56	2.23
	6	60	1	2	5	62	42	35	11.20	1.71	6.46	1.33	4.91	2.88
MGA Select	7	40	1	3	7	63	51	41	12.49	0.42	9.60	(1.81)	7.34	0.45
	7	50	1	2	6	66	45	40	12.48	0.42	7.65	0.14	6.69	1.10
	7	60	1	2	5	68	47	40	12.48	0.43	7.65	0.14	6.04	1.75
CIDR+PGF8	7	40	1	3	7	67	55	45	13.42	(0.51)	10.53	(2.74)	8.27	(0.48)
	7	50	1	2	6	70	49	44	13.41	(0.51)	8.58	(0.79)	7.62	0.17
	7	60	1	2	5	72	51	44	13.41	(0.50)	8.58	(0.79)	6.97	0.82
Select Synch+CIDR	7	40	1	3	7	72	60	50	14.48	(1.57)	11.59	(3.80)	9.34	(1.55)
	7	50	1	2	6	74	53	49	14.48	(1.57)	9.64	(1.85)	8.68	(0.90)
	7	60	1	2	5	77	56	49	14.48	(1.57)	9.64	(1.85)	8.03	(0.24)
Hybrid Synch	7	40	1	3	7	72	60	50	14.53	(1.62)	11.64	(3.85)	9.38	(1.60)
	7	50	1	2	6	72	51	47	14.01	(1.11)	9.18	(1.39)	8.22	(0.43)
	7	60	1	2	5	72	51	44	13.50	(0.59)	8.67	(0.88)	7.06	0.73
7-11 Synch	8	40	1	3	7	66	53	43	13.16	(0.25)	10.18	(2.39)	7.87	(0.08)
	8	50	1	2	6	69	47	43	13.15	(0.25)	8.23	(0.44)	7.22	0.57
	8	60	1	2	5	71	49	42	13.15	(0.24)	8.23	(0.44)	6.57	1.22
CIDR+PGF7	8	40	1	3	7	68	55	45	13.62	(0.71)	10.64	(2.85)	8.34	(0.55)
	8	50	1	2	6	71	49	45	13.62	(0.71)	8.69	(0.90)	7.69	0.10
	8	60	1	2	5	73	51	44	13.62	(0.71)	8.69	(0.90)	7.04	0.75
Select Synch	9	40	1	3	7	65	51	41	12.75	0.16	9.68	(1.90)	7.33	0.45
	9	50	1	2	6	67	45	40	12.75	0.16	7.74	0.05	6.68	1.11
	9	60	1	2	5	69	47	40	12.75	0.16	7.73	0.06	6.03	1.76

[a]Diff=difference between natural service and breeding system, $/cwt

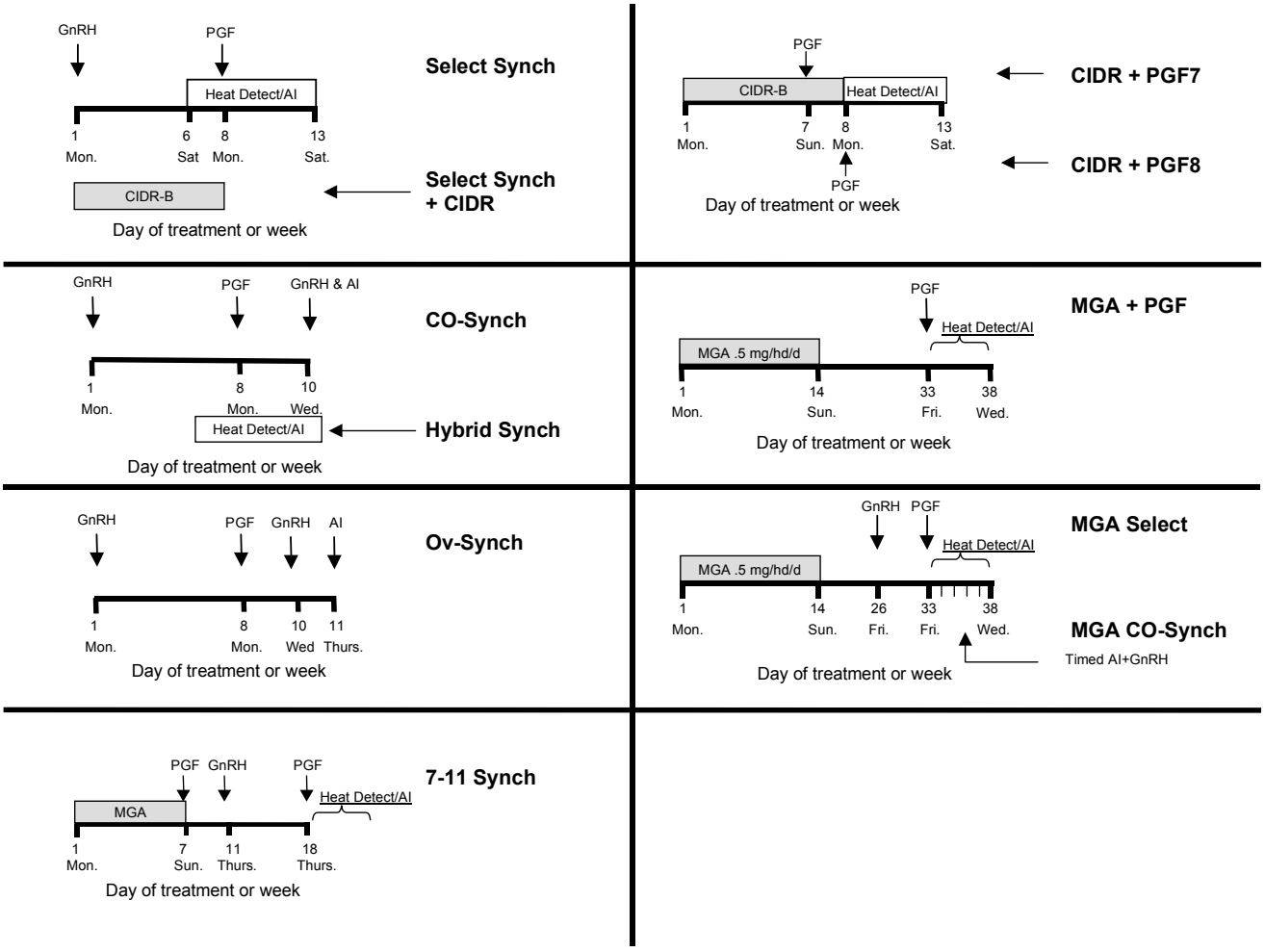


Figure 1. Diagram of Systems For Synchronization of Estrus Included in Cost Analysis.

Cattlemen's Day 2003

FORAGE PRODUCTION FROM TALLGRASS PRAIRIE BURNED ANNUALLY IN AUTUMN, WINTER, OR SPRING

E. G. Towne[1]

Summary

Aboveground biomass production was measured on upland and lowland prairie in replicated, ungrazed watersheds at the Konza Prairie Biological Station (Manhattan, KS) that were burned annually for seven years in either autumn (November), winter (February), or spring (April). Average grass and forb biomass did not significantly differ among burn seasons on either topographic site, although production fluctuated considerably over years. Results of this study contrast with many of the conventional views of how tallgrass prairie vegetation responds to seasonal fire.

Introduction

Fire is an integral component of tallgrass prairie. For more than 7,000 years vegetation has been influenced by anthropogenic burning practices. Intentional burning in autumn and late winter was a frequent ritual of most indigenous Indian tribes. After the influx of transient cattle to the Kansas Flint Hills in the late 1800s, pastures were burned annually in February or March to improve livestock gains. Traditional burn season shifted gradually to mid- or late-April, because fire at that time favored the warm-season perennial grasses that are the mainstay of livestock grazing. In addition, burning tallgrass prairie at times other than late spring has been discouraged because of reputed adverse effects on vegetation productivity. Current perceptions of how tallgrass prairie responds to fire at times other than late spring are based
either on small-plot studies or from single-burn events. Because topographic location, soil texture, and climatic factors can affect forage production, long-term large-scale studies are needed to test conventional generalizations on how prairie vegetation responds to season of fire. In addition, fire season is often mistakenly blamed for the adverse effects from concentrated livestock grazing in pastures that have been partially burned by wildfires. Therefore, the objectives of this study were to assess biomass changes from annual burning in different seasons in large, ungrazed, replicated watersheds.

Experimental Procedures

The study was conducted on Konza Prairie Biological Station on six ungrazed watersheds that were burned annually in either autumn (late-November), winter (mid-February), or spring (late-April). Burning began in autumn 1993, with the same two watersheds being burned in the same season throughout the study. At the end of each growing season, aboveground biomass production was measured by clipping twenty, 20 × 50 cm quadrats on both upland and lowland sites in each watershed. Vegetation in the plots was clipped at ground level, separated into graminoid, forb, and woody components, oven-dried at 60°C,

[1]Division of Biology.

and weighed. Biomass production was analyzed as a repeated measures split-split plot, with burn season as the whole plot factor, topographic position as the subplot, and year as the sub-subplot.

Results and Discussion

Average grass biomass for the 7-year period was not different among burn seasons on either upland (P=0.96) or lowland (P=0.41) sites, although production fluctuated considerably over time (Figure 1). On upland sites, autumn burning did not significantly reduce grass production in any year compared to spring burning, and winter burning reduced (P=0.001) grass production only once (24% in 1999). In contrast, both autumn and winter burning increased (P<0.01) grass production 22% and 28%, respectively, above spring burning in 1995. In all other years, grass production was similar among burn seasons on the upland sites. Precipitation during the growing season was above normal in both 1995 and 1999, but timing of rainfall events likely was responsible for the different response patterns to season of burn. Precipitation in May was 2.8 times above normal in 1995, and April precipitation was 2.9 times above normal in 1999.

On lowland sites, interannual fluctuations of grass production were more erratic among burn seasons than on the upland sites. Winter burning produced higher (P<0.05) grass biomass than spring burning in three of the seven years (1994, 1995, and 1996), and autumn burning produced higher grass biomass than spring burning in two years (1995 and 1996). In contrast, spring burning increased (P=0.01) grass production above autumn burning only once (1998), and produced more (P<0.05) biomass than winter burning twice (1998 and 1999).

Average forb production did not significantly differ among burn seasons, although production was almost always lowest in response to spring burning on both topographic sites (Figure 2). Fluctuations in forb production apparently responded to precipitation patterns, but there was no significant trend towards increased forb biomass through time with repeated autumn or winter burning. Woody biomass (including leadplant) averaged 15 lbs/acre on uplands and 56 lbs/acre on lowlands, and it did not change through time from burning in any season. Although burning suppresses woody species by removing accumulated top growth, seven years of annual fire in autumn, winter, or spring did not eliminate any shrub species.

Interactions between burn seasons and years suggest that biomass production was likely mediated by climatic factors (e.g., temperature, precipitation amounts, or precipitation distribution patterns) that affected soil moisture availability. Burning tallgrass prairie during winter or early spring has been discouraged because bare ground that is exposed for extended periods potentially could increase surface runoff and evaporation losses, thereby lowering soil moisture and subsequent grass production. However, we saw no evidence of this in the production data collected, even though precipitation during the growing season was below normal in five of seven years of this study (which would, presumably, exacerbate these effects).

The results of this long-term study contrast with many of the conventional views of how tallgrass prairie vegetation responds to seasonal fire, and they challenged traditional recommendations that burning should only occur in late spring. Opposition to autumn, winter, or early spring burning may trace back to anti-burn campaigns in earlier decades and inferences extrapolated from other ecosystems. Annual burning of tallgrass prairie at times other than late spring is apparently a sustainable option that does not sacrifice forage production.

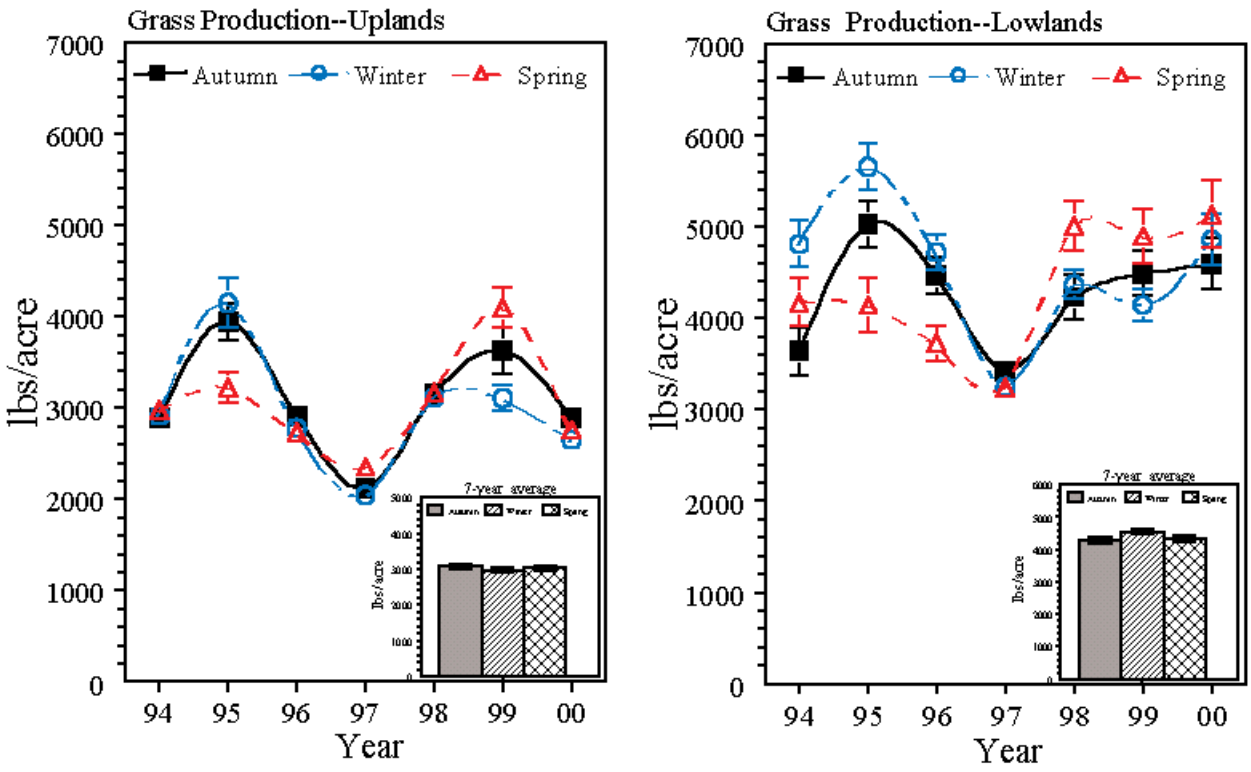


Figure 1. Grass Production from Autumn, Winter, or Spring Burning on Upland and Lowland Sites from 1994 to 2000.

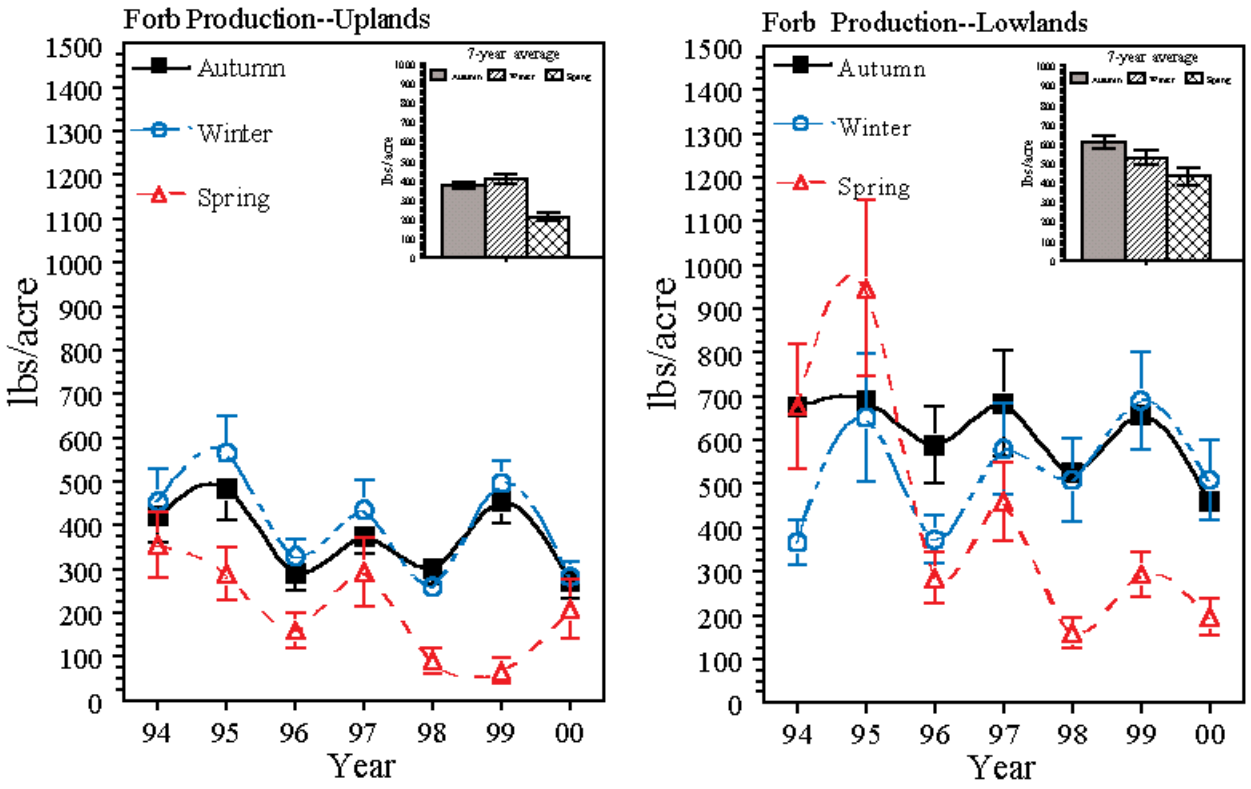


Figure 2. Forb Production from Autumn, Winter, or Spring Burning on Upland and Lowland Sites from 1994 to 2000.

INTERSEEDING LESPEDEZA INTO CRABGRASS PASTURE VERSUS ADDITIONAL NITROGEN FERTILIZATION ON FORAGE PRODUCTION AND CATTLE PERFORMANCE

L. W. Lomas, J. L. Moyer, F. K. Brazle, and G. L. Kilgore

Summary

A total of 160 steers grazed 'Red River' crabgrass pastures that were either fertilized with additional nitrogen (N) or interseeded with lespedeza during the summers of 1998, 1999, 2000, and 2001. Wheat was also grazed in 1999, 2000, and 2001 prior to crabgrass emergence. Legume cover, forage dry matter production, grazing steer performance, and subsequent feedlot performance were measured. Available forage dry matter and grazing steer performance were similar between pastures of crabgrass fertilized with additional N and those interseeded with lespedeza in 1998, 1999, and 2000. In 1999, finishing feed intake, finishing gain and ribeye area were higher ($P<0.05$) for steers that grazed pastures with lespedeza. In 2001, wheat grazing gain, overall grazing performance, finishing gain, and overall performance (grazing + finishing) were higher ($P<0.05$) for steers that grazed pastures fertilized with additional N. Total grazing gain per acre (wheat + crabgrass) was similar between pastures fertilized with additional N and those interseeded with lespedeza and averaged 304, 452, and 406 lb/acre in 1999, 2000, and 2001, respectively. In conclusion, the crabgrass wheat double-crop system produced satisfactory cattle performance with grazing gains being similar ($P>0.05$) between pastures fertilized with additional N and those interseeded with lespedeza. Therefore, economics rather than cattle performance would likely determine which option a producer might select. This study will be continued for three additional grazing seasons with no additional crabgrass being seeded to determine whether crabgrass will voluntarily re-seed itself sufficiently to sustain the system.

Introduction

Cattlemen in southeastern Kansas, eastern Oklahoma, and western Arkansas need high quality forages to complement grazing of tall fescue. Complementary forages are especially needed during the summer months when fescue forage production declines and animal performance is reduced by the endophyte typically found in most fescue grown in this region. Crabgrass could fill this niche by providing high-quality forage for summer grazing. A high level of nitrogen (N) fertilization is required for crabgrass. Adding a legume could reduce the amount of N fertilizer required, enhance the utilization of crabgrass, and extend grazing of high-quality forage in late summer. The purpose of this study was to evaluate the effect of interseeding lespedeza into crabgrass pastures on forage availability, grazing stocker steer performance, and subsequent feedlot performance.

Experimental Procedures

Pastures. Korean lespedeza was no-till seeded on April 14 and 15, 1998 at 15 lb/acre on five of ten 4-acre pastures that had been seeded with Red River crabgrass during the summer of 1997. An additional 2 lb/acre of crabgrass seed was broadcast at this time on all 10 pastures. The ground had been worked previously and planted to wheat in the fall of 1997, after the crabgrass had set seed. The wheat was cut for hay in mid May of 1998. All pastures

received 50 lb of N/acre on May 26, 1998 at the time of crabgrass emergence, and an additional 50 lb of N/acre was applied to the five pastures without lespedeza in early August. In 1998, all pastures were clipped on July 6 to a height of approximately 7 inches and mowed for hay on August 17 to control weeds.

'Jagger' hard red winter wheat was planted in the same 10 pastures where crabgrass had been previously grown on October 15, 1998, September 22, 1999, and September 28, 2000 at a rate of 106 lb/acre using a no-till drill. The wheat was planted for grazing in 1999, 2000, and 2001, respectively. Korean lespedeza was no-till seeded on April 7, 1999 at the rate of 19.5 lb/acre; March 15, 2000 at the rate of 18.3 lb/acre; and March 27, 2001 at the rate of 15 lb/acre on the same five pastures that had been seeded with lespedeza during 1998. An additional 2 lb/acre of crabgrass seed was broadcast each year immediately prior to planting lespedeza. All pastures received 68-34-34 lb/acre of N-P_2O_5-K_2O on November 19, 1998; 46 lb of N/acre on March 26, 1999; 48.5 lb of N/acre on May 28, 1999; 77-44-44 lb/acre of N-P_2O_5-K_2O on October 12, 1999; 56 lb of N/acre on May 23, 2000; 71-41-41 lb/acre on November 17, 2000; and 51 lb of N/acre on May 17, 2001. An additional 50 lb of N/acre was applied to pastures without lespedeza on July 16, 1999, July 17, 2000, and July 11, 2001.

Available forage was determined at the initiation of grazing and during the season with a disk meter calibrated for crabgrass and for wheat. One exclosure (15 to 20 square feet) was placed in each pasture. Total production for a grazing period was estimated from three readings per exclosure, and available forage was determined from three readings near each cage. Lespedeza canopy coverage was estimated from the percentage of the disk circumference that contacted a portion of the canopy.

Cattle. In 1998, 40 mixed-breed steers with an initial weight of 702 lb were weighed on consecutive days, stratified by weight, and allotted randomly to the 10 pastures on June 23 to graze crabgrass. In 1999, 2000, and 2001, 50 mixed-breed steers with initial weights of 639 lb, 600 lb, and 554 lb, respectively, were weighed on consecutive days, stratified by weight, and allotted randomly to the 10 pastures on March 30, 1999, March 9, 2000, and March 22, 2001 to graze out wheat and then graze crabgrass. Cattle were weighed on consecutive days when the wheat was nearly completely grazed out and crabgrass had sufficient growth to provide sufficient grazing for the cattle. This weight was used as the ending weight of the wheat grazing phase and the beginning weight of the crabgrass grazing phase. In 1999, cattle grazed wheat from March 30 until May 26 (57 days) and then grazed crabgrass from May 26 until September 1 (98 days). In 2000, cattle grazed wheat from March 9 until May 9 (61 days) and then grazed crabgrass from May 9 until September 6 (120 days). In 2001, cattle grazed wheat from March 22 until May 17 (56 days) and then grazed crabgrass from May 17 until September 6 (112 days). Cattle were treated for internal and external parasites prior to being turned out to pasture and later were vaccinated for protection from pinkeye. Steers had free access to commercial mineral blocks that contained 12% calcium, 12% phosphorus, and 12% salt. In 1998, all pastures were grazed continuously for 98 days at a stocking rate of 1.0 head/acre until grazing was terminated and steers were weighed on September 28 and 29. In 1999, pastures were stocked initially with 1.2 head/acre until August 17, when a steer closest to the pen average weight was removed from each pasture as available forage became limited because of below average rainfall. In 2000 and 2001, a steer closest to the pen average weight was removed from each pasture at the end of the wheat phase. Pastures were then stocked at l.0 head/acre until grazing was terminated and

steers were weighed on August 31 and September 1, 1999; September 5 and 6, 2000; and September 5 and 6, 2001. Pastures were mowed and harvested for hay on September 14, 2000, May 15, 2001, and September 10, 2001 to remove residual forage after grazing.

Following the grazing period, cattle were shipped to a finishing facility and fed a diet of 80% ground milo, 15% corn silage, and 5% supplement (dry matter basis). Cattle that were grazed in 1998, 1999, 2000, and 2001 were fed for 142, 114, 128, and 119 days, respectively. Steers were implanted with Synovex S® on days 0 and 84 of the finishing period. Cattle were slaughtered in a commercial facility at the end of the finishing period, and carcass data was collected.

Results and Discussion

Pastures. Available forage dry matter for 1998 through 2001 is presented in Figure 1. In 1998, available forage was similar between pastures that received additional N fertilizer and those that were interseeded with lespedeza. However, dry matter decreased dramatically for both treatments after mid-August, following mowing for hay coupled with below normal precipitation. Legume coverage averaged 4.7% in pastures interseeded with lespedeza and 1.3% in those that received additional N fertilization. Three pastures were eliminated from the analysis because they contained significant amounts of volunteer ladino clover.

In 1999, available forage dry matter was not significantly different ($P<0.05$) between treatments overall or at any time during the growing season. Available forage dry matter from wheat decreased ($P<0.05$) after April 27 to a low of 660 lb/acre on July 20, then increased somewhat during the crabgrass phase by September 2.

In 2000, available forage dry matter was not significantly different ($P<0.05$) between treatments overall or at any time during the growing season. Available forage dry matter from wheat decreased ($P<0.05$) after April 27 to a low of 1160 lb/acre on June 6, then dry matter increased to its maximum on August 10.

In 2001, available forage dry matter was not significantly different ($P>0.05$) between treatments overall or at any time during the growing season. Available forage dry matter decreased ($P<0.05$) after April 19 to a low of 1160 lb/acre on June 14, then increased through August 10.

Available forage dry matter appeared lower in much of 1999 compared to the other three years. Forage dry matter availability patterns also differed markedly in 1998, when the maximum amount of forage occurred early in the season, whereas the maximum in 2000 and 2001 occurred late in the season. These differences were likely due to a higher initial stocking rate and grazing wheat prior to crabgrass in 2000 and 2001. In 1999, forage availability was relatively low throughout the season, which may be attributed, at least in part, to uneven rainfall distribution and thinner stands of crabgrass and lespedeza. Lespedeza canopy coverage peaked at 10% on August 18, 1998; 5.8% on July 20, 1999; 18% on July 12, 2000; and 19% on August 9, 2001 (Figure 2).

Cattle Performance. Performance of steers that grazed crabgrass pastures either fertilized with additional N or interseeded with lespedeza are shown in Table 1. In 1998, grazing gains, subsequent feedlot performance, and overall performance were similar between pastures with lespedeza and those that received an extra application of N; grazing gains were 1.23 and 1.27 lb/head daily, respectively. Cattle should have been removed from pastures 2 weeks earlier in 1998 to achieve maximum gains.

In 1999, grazing gains were again similar between pastures with lespedeza and those that received an extra application of N. Gains during the wheat phase averaged 2.22 and 2.26

lb/head/day; during the crabgrass phase, 1.30 and 1.25 lb/head/day; and overall, gains averaged 1.64 and 1.62 lb/head/day for pastures interseeded with lespedeza and fertilized with additional N, respectively. Crabgrass gains in 1999 likely were limited by below normal precipitation during the summer months. During the finishing phase, steers that previously grazed pastures interseeded with lespedeza had higher ($P<0.05$) feed consumption, higher gains ($P<0.05$), and larger ($P<0.05$) ribeye areas than those that grazed pastures fertilized with additional N. Because feed efficiency was similar ($P>0.05$) between treatments, the difference in finishing gain was due primarily to the difference in feed intake. Overall performance from the beginning of the grazing phase through the end of the finishing phase was similar ($P>0.05$) between treatments.

During all phases in 2000, grazing gains were again similar between pastures with lespedeza and those that received an extra application of N. Gains during the wheat phase averaged 3.09 and 3.18 lb/head/day for pastures with lespedeza and fertilized with additional N, respectively. During the crabgrass phase, gains averaged 1.74 and 1.82 lb/head/day; and overall, gains averaged 2.19 and 2.28 lb/head/day for pastures interseeded with lespedeza and fertilized with additional N, respectively.

In 2001, steers that grazed pastures fertilized with additional nitrogen had higher ($P<0.05$) wheat grazing gains and overall grazing gains (wheat + crabgrass) than those that grazed pastures interseeded with lespedeza. Gains during the wheat phase averaged 2.56 and 3.11 lb/head/day for pastures with lespedeza and fertilized with additional N, respectively. During the crabgrass phase, gains averaged 1.72 and 1.99 lb/head/day; and overall, gains averaged 2.00 and 2.36 lb/head/day for pastures interseeded with lespedeza and fertilized with additional N, respectively. Finishing gains, overall performance, hot carcass weight, and fat thickness were greater ($P<0.05$) for steers that grazed nitrogen-fertilized pastures than those that grazed pastures interseeded with lespedeza.

Grazing performance averaged over 1999, 2000, and 2001 is presented in Table 2. Daily gain and gain per acre were similar ($P>0.05$) during the wheat phase, crabgrass phase, and overall for steers that grazed pastures fertilized with additional N and those interseeded with lespedeza. Finishing gain and overall gains (grazing + finishing) were also similar ($P>0.05$) between treatments.

Although there was no difference ($P>0.05$) in grazing performance between cattle that grazed pastures fertilized with additional N and those that grazed pastures interseeded with lespedeza, grazing performance varied significantly ($P<0.05$) between years. Daily gains from grazing wheat ranged from 2.24 lb/day in 1999 to 3.14 lb/day in 2000. Wheat grazing gains were higher ($P<0.05$) in 2000 and 2001 than in 1999. Gain per acre from grazing wheat ranged from 160 lb in 1999 to 239 lb in 2000. Performance of cattle that grazed crabgrass improved with time. This may be attributed to improvement in crabgrass stands. Daily gains from grazing crabgrass ranged from 1.25 lb per day in 1998 to 1.85 lb per day in 2001. Daily gains were higher ($P<0.05$) in 2000 and 2001 than in 1998 and 1999. Gain per acre from grazing crabgrass ranged from 123 lb in 1998 to 213 lb in 2000. Gain per acre was higher ($P<0.05$) in 2000 and 2001 than in 1998 and 1999. Overall grazing performance (wheat + crabgrass) also improved with time. Overall daily gains and gain per acre were higher ($P<0.05$) in 2000 and 2001 than in 1999. Overall daily gain ranged from 1.63 lb in 1999 to 2.24 lb in 2000 and overall gain per acre ranged from 304 lb in 1999 to 452 lb in 2000.

In conclusion, grazing performance was similar from wheat + crabgrass pastures fertilized with additional N and those interseeded

with lespedeza. Both treatments produced satisfactory cattle performance which tended to improve each successive grazing season. This study will be continued for at least three more grazing seasons with no additional crabgrass being seeded to determine if the crabgrass will voluntarily re-seed itself sufficiently to sustain the system.

Table 1. Effects of Interseeding Legumes vs. Nitrogen Fertilization on Performance of Steers Grazing Wheat-Crabgrass Pastures, Southeast Agricultural Research Center

	1998		1999		2000		2001	
Item	Nitrogen	Lespedeza	Nitrogen	Lespedeza	Nitrogen	Lespedeza	Nitrogen	Lespedeza
Grazing Phase - Wheat								
No. of days	-	-	57	57	61	61	56	56
No. of head	-	-	15	20	15	20	15	20
Initial weight, lb	-	-	639	639	600	600	554	554
Ending weight, lb	-	-	768	766	794	789	727	697
Gain, lb	-	-	129	127	194	189	174	144
Daily gain, lb	-	-	2.26	2.22	3.18	3.09	3.11[a]	2.56[b]
Gain/acre, lb	-	-	161	158	242	236	218	180
Hay production, lb/acre	-	-	-	-	-	-	1563	1660
Grazing Phase – Crabgrass								
No. of days	98	98	98	98	120	120	112	112
No. of head	12	16	12[c]	16[c]	12	16	12	16
Initial weight, lb	702	702	772	766	786	785	729[a]	697[b]
Ending weight, lb	827	823	895	893	1005	994	952[a]	889[b]
Gain, lb	124	121	122	128	218	208	223	192
Daily gain, lb	1.27	1.23	1.25	1.30	1.82	1.74	1.99	1.72
Gain/acre, lb	124	121	142	145	218	208	223	192
Hay production, lb/acre	-	-	-	-	605	605	666	838
Overall Grazing Performance (Wheat + Crabgrass)								
No. of days	-	-	155	155	181	181	168	168
Gain, lb	-	-	251	254	412	397	397[a]	336[b]
Daily gain, lb	-	-	1.62	1.64	2.28	2.19	2.36[a]	2.00[b]
Gain/acre, lb	-	-	303	304	460	444	440	372
Finishing Phase								
No. of days	142	142	114	114	128	128	119	119
No. of head	12	16	12	16	12	16	12	16
Starting weight, lb	827	823	895	893	1005	994	952[a]	889[b]
Final weight, lb	1253	1239	1350	1400	1421	1388	1428[a]	1323[b]
Gain, lb	426	416	456[a]	507[b]	416	394	476[a]	434[b]
Daily gain, lb	3.00	2.93	4.00[a]	4.45[b]	3.25	3.08	4.00[a]	3.65[b]
Daily dry matter intake, lb	26.3	26.9	29.7[a]	33.3[b]	30.1	29.2	27.4	25.1
Feed/gain	8.77	9.18	7.42	7.49	9.25	9.53	6.85	6.88
Hot carcass weight, lb	764	756	794	824	835	830	845[a]	784[b]
Dressing %	61.0	61.0	58.8	58.8	58.8	59.8	59.2	59.2
Backfat, inch	0.36	0.34	0.60	0.54	0.58	0.65	0.56[a]	0.42[b]
Ribeye area, inch^2	12.8	13.1	12.3[a]	13.2[b]	13.6	13.5	13.5	13.1
Yield grade	2.6	2.4	3.5	3.0	3.2	3.4	3.2	2.7
Marbling score	SM[16]	SM[43]	SM[46]	SM[93]	MT[15]	MT[16]	MT[30]	MT[26]
% Choice	65	75	67	92	75	100	100	94
Overall Performance (Grazing + Finishing Phase)								
No. of days	-	-	269	269	309	309	287	287
Gain, lb	-	-	708	761	821	788	874[a]	768[b]
Daily gain, lb	-	-	2.64	2.83	2.65	2.55	3.05[a]	2.68[b]

[a,b]Means within a row within the same year with the same letter are not significantly different (P<0.05).
[c]Pastures were stocked with 1.2 steers per acre for 83 days and then 1 steers per acre for the final 15 days.

Table 2. Effects of Additional Nitrogen Fertilization and Interseeding Lespedeza on Performance of Steers Grazing Wheat-Crabgrass Pastures, Southeast Agricultural Research Center (1999, 2000, 2001)

	Treatment	
Item	N Fertilization	Lespedeza
Grazing Phase – Wheat		
Daily gain, lb	2.85	2.62
Gain/acre, lb	207	191
Grazing Phase – Crabgrass		
Daily gain, lb	1.69	1.59
Gain/acre, lb	194	182
Overall Grazing Performance (Wheat + Crabgrass)		
Daily gain, lb	2.09	1.94
Gain/acre, lb	401	373
Finishing daily gain, lb	3.75	3.73
Overall daily gain (grazing + finishing), lb	2.78	2.69

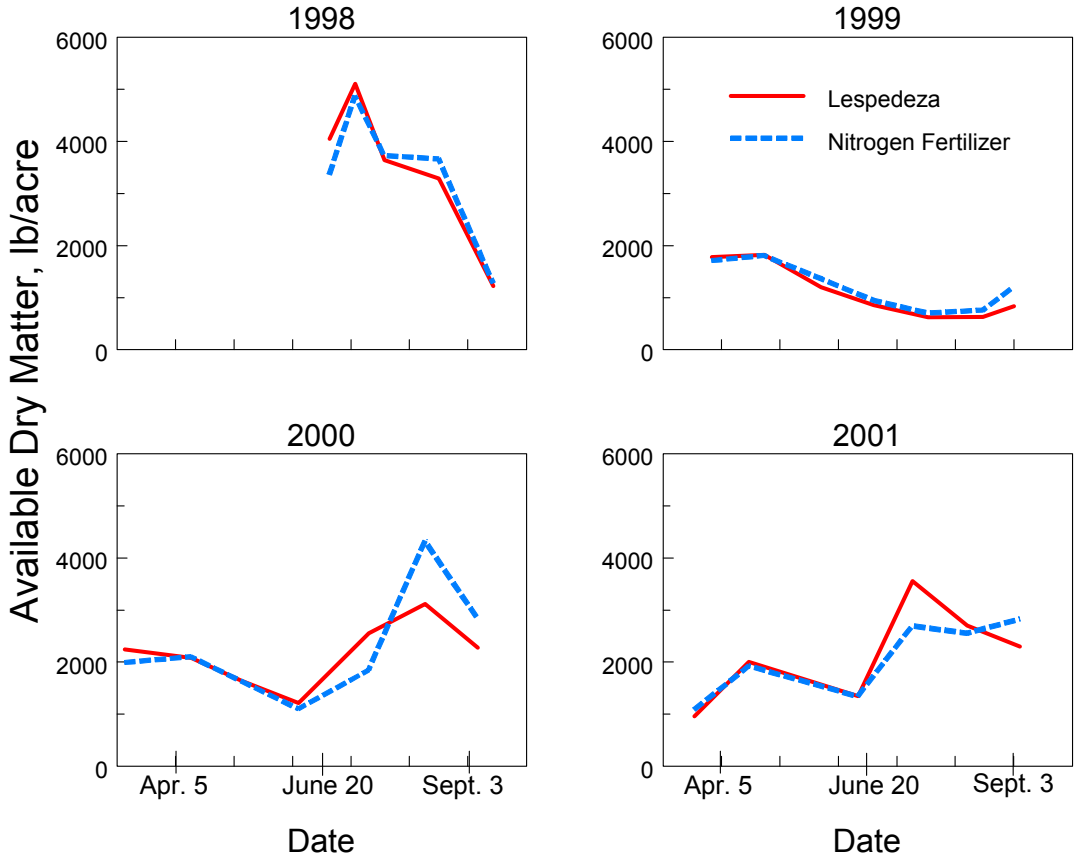


Figure 1. Available Forage in Wheat and Crabgrass Pastures, 1998-2001, Southeast Agricultural Research Center.

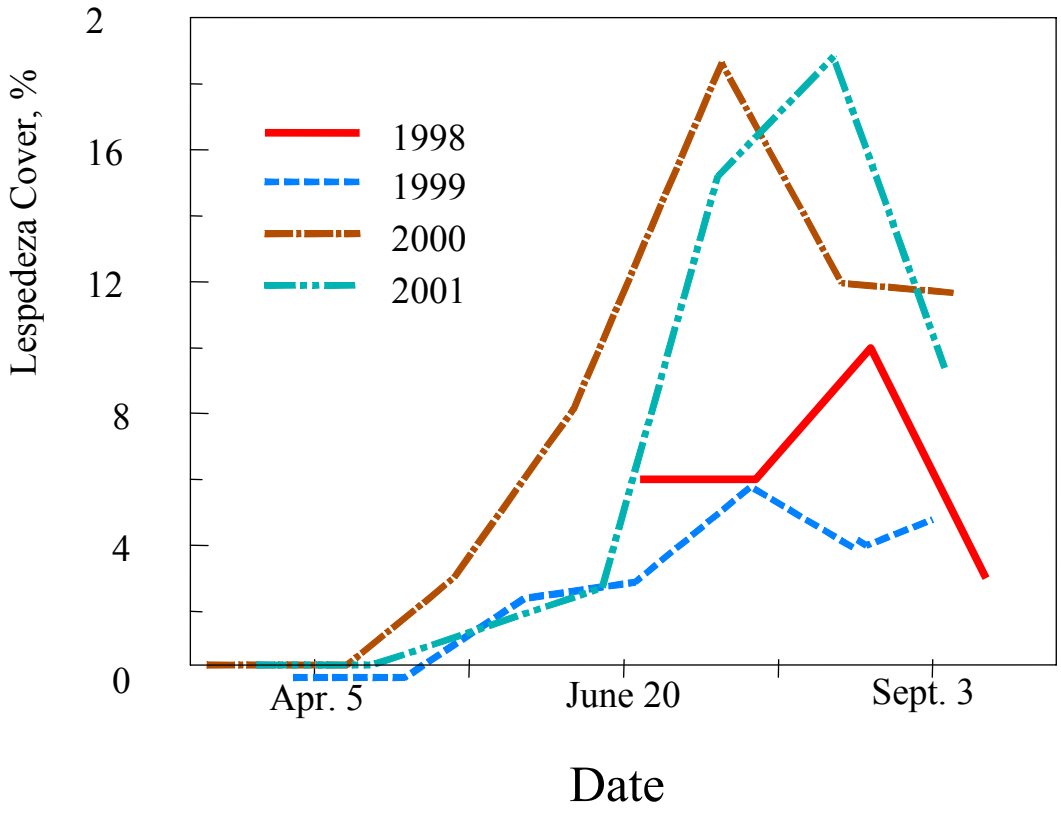


Figure 2. Lespedeza Canopy Cover in Wheat and Crabgrass Pastures, 1998-2001, Southeast Agricultural Research Center.

Cattlemen's Day 2003

ENERGY SUPPLEMENTATION OF STEERS GRAZING EARLY-SEASON, NATIVE RANGE: EFFECTS ON GRAZING AND SUBSEQUENT FINISHING PERFORMANCE AND CARCASS MERIT[1]

S. P. Montgomery, D. A. Blasi, R. L. Packard[2], J. C. Forcherio[3], and R. R. Scott[3]

Summary

Crossbred beef steers (n = 328, initially 495 lb) were used to determine the effects of energy supplementation on grazing and subsequent finishing performance of steers grazing early-season, native range. Treatments consisted of either no supplemental energy or access to feeders containing a free choice, grain-based energy supplement. On the first day of the grazing period, steers were weighed and randomly allotted among eight pastures, providing four replications per treatment. Stocking density was 34% higher for supplemented than for unsupplemented pastures. At the end of the grazing period, steers were transported to a commercial feedlot and allowed ad libitum access to a common finishing diet for an average of 171 days. Supplement intake averaged 5.4 ± 1.1 lb/day (dry matter basis) or approximately 0.90% of body weight during the grazing period. Supplementation increased ($P<0.01$) grazing period gains from 1.47 to 2.20 lb/day. Supplementation also increased ($P<0.01$) ribeye area, back fat, and rump fat at the end of the grazing period. Supplementation did not affect subsequent finishing performance or carcass merit, but it reduced ($P<0.01$) time required for finishing by 18 days. Energy supplementation of steers grazing early-season, native range resulted in more pounds of gain per acre due to improved grazing performance as well as a 34% increase in stocking density.

Introduction

Providing supplemental energy to stocker cattle grazing early-season, native range increases grazing period gains without negatively affecting subsequent finishing performance. However, due to high forage quality, gain efficiencies of energy supplements fed to stocker cattle during the grazing period may be marginal. Energy supplementation of stocker cattle grazing winter wheat pasture allows for increased stocking densities and weight gains and, therefore, greater gain efficiencies per acre. Our objective was to evaluate the effects of energy supplementation on the performance of stocker cattle grazing early-season, native range at an increased stocking density and subsequent effects on finishing performance and carcass characteristics.

Experimental Procedures

Three hundred twenty-eight preconditioned crossbred beef steers of Southeast origin initially weighing 495 ± 35 lb were used. Real time ultrasound measurements of ribeye area, rib fat, and rump fat of steers were obtained 6 days prior to the steers' arrival in

[1]Sincere appreciation is expressed to the Cargill Ranch of Medicine Lodge, KS for their cooperation.
[2]Collingwood Grain, Pretty Prairie, KS.
[3]Purina Mills, St. Louis, MO.

Kansas. Upon arrival in Kansas, steers were implanted with Component TE-G® and allowed ad libitum access to a receiving diet consisting of grass hay and 5.1 lb (as fed) of a pelleted commercial receiving supplement for 10 days.

The grazing period was initiated on April 27 and terminated on August 3, 2002. On day one of the grazing period, steers were weighed and randomly allotted among eight pastures, providing four pastures per treatment, with pasture serving as the experimental unit. The predominant grass species in pastures were big bluestem (*Andropogon gerardii*) and little bluestem (*Andropogon scoparius*). Treatments consisted of no supplement or access to covered self-feeders containing a mixture of Accuration® and dry-rolled corn provided free choice. Stocking density was 34% higher for supplemented pastures.

Composition of the Accuration concentrate is shown in Table 1. Supplement intake was controlled by manipulating the percentage of Accuration concentrate and dry-rolled corn over the grazing period. Accuration in the total supplement was increased by approximately 10% each time feeders were refilled in order to limit consumption. Dry matter inclusion rates of Accuration were 40% of the total supplement at the beginning of the grazing period and 80% at the end of the grazing period. Supplement intake was targeted for 0.65 to 0.90% of body weight on a dry matter basis. Supplement intake was measured weekly using a portable weighing system to weigh each self-feeder and its entire contents in the pasture. A commercial mineral mixture was provided free choice to all steers, and mineral feeders were weighed throughout the grazing period to measure mineral intake.

On days 55 and 97, steers were weighed and real time ultrasound measurements were again taken with the data representing interim and final grazing period measurements, respectively. At the conclusion of the 97-day grazing period, steers were transported approximately 200 miles to a commercial feedlot facility in western Kansas.

Table 1. Composition of Accuration Added to Dry-Rolled Corn to Provide the Energy Supplement Offered Free Choice to Steers During the Grazing Period

Nutrient	%
Dry matter	87.5
	% of Dry Matter
Crude protein	22.9
Crude fat	5.7
Acid detergent fiber	10.4
Calcium	1.1
Phosphorus	1.1
Salt	5.7
Total digestible nutrients, calculated	76.0
NEm, Mcal/lb, calculated	0.87
NEg, Mcal/lb, calculated	0.54

Steers received a Ralgro® implant within 24 hours of arrival at the feedlot and were fed a common finishing diet for an average of 171 days. Each pasture of steers was finished in a separate feedlot pen. The final finishing diet contained 52% high-moisture corn, 32% steam-flaked sorghum, 3% sorghum silage, 3% fat, and 10% of a commercial protein supplement, and it was provided once daily for ad libitum consumption. On day 81 of the finishing period, steers were implanted with Component TES®. Visual appraisal of steers was used to determine marketing date of each pen, at which time steers were transported to a commercial slaughter facility where carcass data were collected following a 36-hour chill. Final body weight was calculated by dividing

hot carcass weight by a common dressing percentage of 65.39%.

Forage quantity was estimated by hand clipping forage inside 40 quadrats of 2.7 square feet randomly distributed in pastures on April 25 and May 25. Grass clippings were obtained approximately every 14 days throughout the grazing period. Grass clippings were dried at 55°C for 48 hours, ground through a 1-mm screen, and analyzed for dry matter, crude protein, and acid detergent fiber.

Results and Discussion

Intakes of the energy supplement by steers during the grazing period averaged 5.4 ± 1.1 lb/day (dry matter basis) and corresponded to approximately 0.90% of body weight, with little variation among periods (Table 2). This suggests that increasing the ratio of Accuration to dry-rolled corn successfully limited intake to targeted levels (Figure 1) in spite of a decline in forage quality due to increasing forage maturity (Figure 2). Energy- supplemented cattle consumed less ($P<0.01$) free choice mineral during the grazing period. Energy supplementation increased ($P<0.01$) grazing period gains of steers. Interestingly, gains for both the control and supplemented steers were greater during the latter part of the grazing period. This increase in gain may partially be the result of an increase in gastrointestinal tract fill caused by increasing forage maturity and subsequent fiber content, which would reduce forage digestibility and passage rate. Energy supplemented steers tended ($P<0.09$) to demonstrate greater weight loss due to shrink during transportation to the feedlot.

Energy supplementation tended ($P<0.09$) to increase forage quantity measured in pastures following 30 days of grazing (Table 2), even though stocking density was increased by 34%. This effect on pasture forage quantity suggests that energy supplementation reduced forage intake by the steers. Energy supplementation increased ($P<0.01$) ribeye area, rib fat, and rump fat during the grazing period (Table 3). Such effects are attributed to increased energy intake of supplemented steers, which would allow for increased deposition of protein and fat during the grazing period. Energy supplementation did not affect subsequent finishing performance or carcass merit (Table 4); however, energy supplementation did reduce ($P<0.01$) the amount of time required during the finishing period by 18 ± 3 days.

Energy supplementation of stocker cattle grazing early-season, native range can be inefficient if stocking rates are not increased. In our study, energy supplementation of stocker cattle grazing early-season, native range allowed for stocking density to be increased by 34% while increasing grazing period average daily gain. When evaluating the economic effectiveness of the supplementation program that we tested, producers should consider pasture and supplementation costs (direct and indirect) in addition to the buy-sell margin of the cattle.

Table 2. Grazing Performance of Steers Offered no Supplement (Control) or Allowed Free Choice Access to a Grain-Based Energy Supplement (Energy) While Grazing Early–Season, Native Range

Item	Control	Energy	SEM	P-value[a]
No. of steers	140	188	-	-
No. of pastures	4	4	-	-
Initial weight, lb	495	495	0.26	0.82
Final weight, lb	638	706	11.2	0.01
Stocking density, acres/steer	5.9	4.3	-	-
Forage quantity, lb dry matter/acre				
April 25	155	229	158	0.75
May 25	1059	1367	122	0.09
Supplement intake, lb/day dry matter				
day 1 to 55	-	5.0	0.61	-
day 56 to 97	-	5.6	0.39	-
day 1 to 97	-	5.4	0.50	-
Supplement intake, % of body weight				
day 1 to 55	-	0.93	0.005	-
day 56 to 97	-	0.87	0.011	-
day 1 to 97	-	0.89	0.008	-
Mineral intake, oz/day				
day 1 to 55	1.4	0.5	0.26	0.04
day 56 to 97	3.1	1.0	0.27	< 0.01
day 1 to 97	2.4	0.7	0.27	0.01
Daily gains, lb				
day 1 to 55	1.17	1.87	0.16	0.02
day 56 to 97	1.91	2.60	0.12	0.01
day 1 to 97	1.47	2.20	0.11	0.01
Supplement conversion[b]				
day 1 to 55	-	7.5	1.6	-
day 56 to 97	-	9.9	1.6	-
day 1 to 97	-	8.0	1.6	-
Off truck weight, lb[c]	607	662	12.5	0.02
Shrink, %	4.9	6.1	0.41	0.09

[a]Probability that effects observed were due to random chance.
[b]Calculated as supplement intake on a dry matter basis divided by increase in daily gains.
[c]Body weight upon arrival at feedlot.

Table 3. Real Time Ultrasound Measurements of Steers Offered No Supplement (Control) or Allowed Free Choice Access to a Grain-Based Energy Supplement (Energy) While Grazing Early–Season, Native Range

Item	Control	Energy	SEM	P-value[a]
No. of steers	140	188	-	-
No. of pastures	4	4	-	-
Ribeye area, inch^2				
day (-16)	6.2	6.2	0.01	0.15
day 56	6.9	7.7	0.13	0.01
day 97	7.0	7.9	0.13	0.01
Rib fat, inch				
day (-16)	0.06	0.06	0.001	0.28
day 56	0.08	0.09	0.002	0.01
day 97	0.08	0.10	0.003	0.01
Rump fat, inch				
day (-16)	0.07	0.07	0.001	0.29
day 56	0.10	0.11	0.003	0.02
day 97	0.10	0.14	0.005	0.01

[a]Probability that effects observed were due to random chance.

Table 4. Finishing Performance of Steers Offered no Supplement (Control) or Allowed Free Choice Access to a Grain-Based Energy Supplement (Energy) While Grazing Early–Season, Native Range

Item	Control	Energy	SEM	P-value[a]
No. of steers	140	188	-	-
No. of pens	4	4	-	-
Initial weight, lb	623	684	11.9	0.01
Final weight, lb[b]	1272	1272	10.8	0.98
Dry matter intake, lb/day	21.1	21.3	0.35	0.90
Average daily gain, lb	3.61	3.61	0.051	0.95
Gain:feed	0.170	0.170	0.002	0.95
Days on feed	180	162	2.5	0.01
Hot carcass weight, lb	832	832	7.0	0.99
Dressing percent[c]	65.7	65.1	0.25	0.15
Ribeye area, inch^2	12.7	12.9	0.17	0.38
Fat thickness, inch	0.72	0.67	0.020	0.16
Yield grade 1, %	1	2	0.8	0.49
Yield grade 2, %	10	12	2.9	0.65
Yield grade 3, %	76	72	4.0	0.53
Yield grade 4 & 5, %	13	14	2.7	0.77
Marbling score	Small^{75}	Small^{93}	8.3	0.19
USDA Prime, %	3	7	1.3	0.09
USDA Choice, %	84	73	4.9	0.16
USDA Select, %	13	20	4.9	0.33

[a]Probability that effects observed were due to random chance.
[b]Calculated as hot carcass weight ÷ common dressing percent of 65.39%.
[c]Dressing percent = hot carcass weight ÷ (live weight × 0.96).

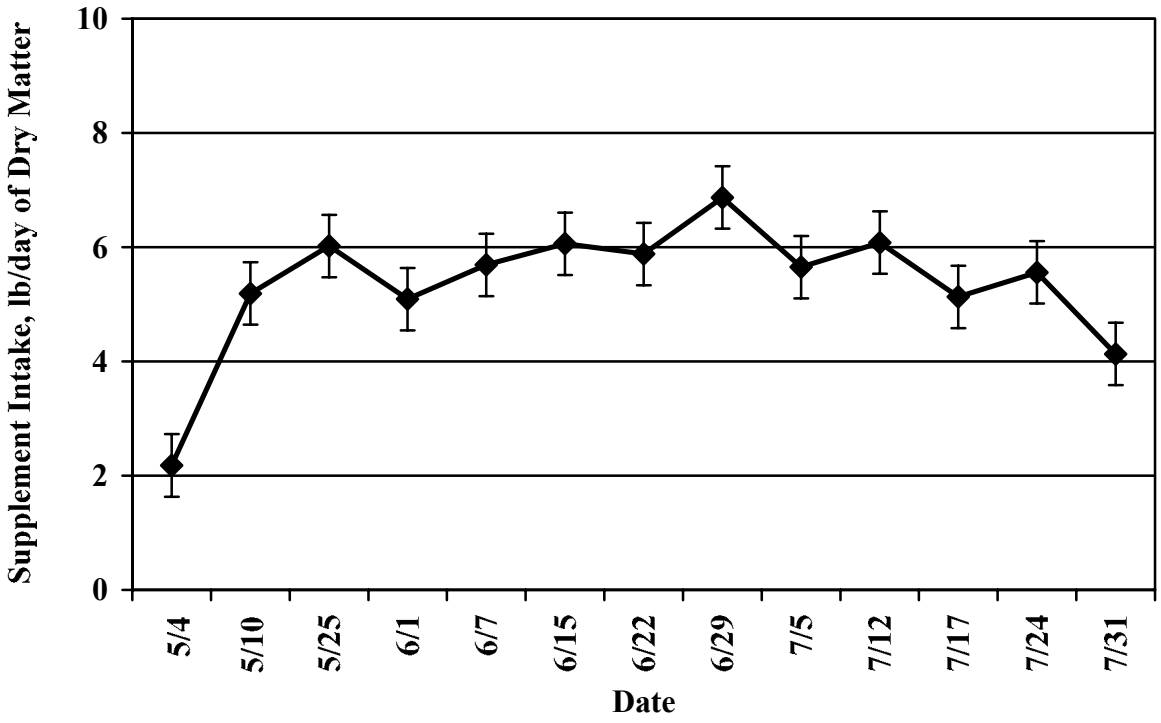


Figure 1. Intake Throughout the Grazing Period of a Free-Choice Grain-Based Energy Supplement by Steers Grazing Early-Season, Native Range.

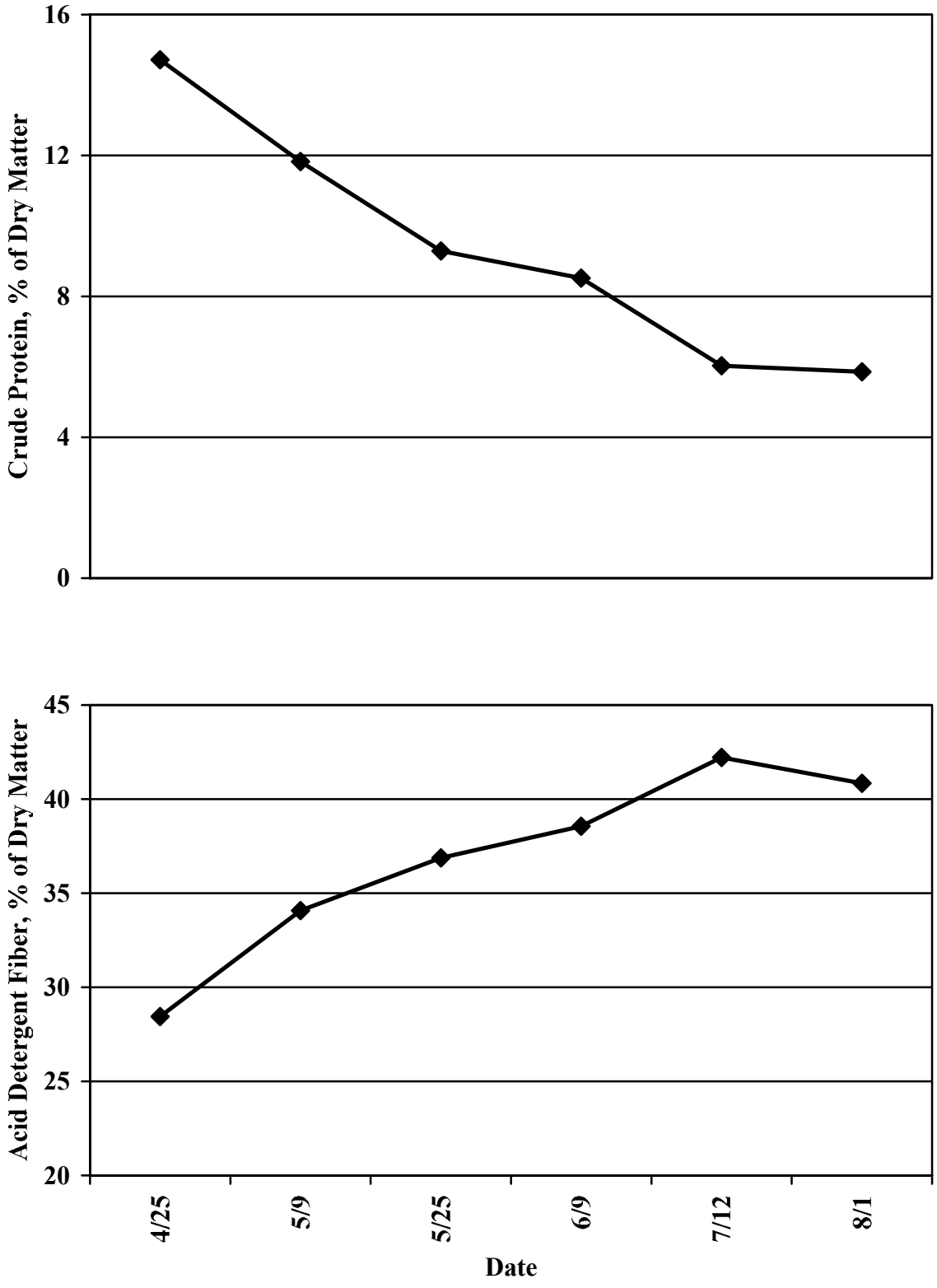


Figure 2. Crude Protein and Acid Detergent Fiber Content of Forage Sampled from Pastures During the Grazing Period.

Cattlemen's Day 2003

INFLUENCE OF LOW-LEVEL SUPPLEMENTATION WITH A HIGH-PROTEIN FEED ON PERFORMANCE OF BEEF COWS GRAZING TALLGRASS-PRAIRIE RANGE DURING THE FALL

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Summary

An experiment was conducted to evaluate the effect of hand feeding a limited quantity of a high-protein supplement during the fall grazing period on cow and calf performance. The time of initiation of supplementation was also evaluated. One-hundred thirty-six multiparous, pregnant, spring-calving cows grazing native range were assigned to supplementation treatments. Control cows received no fall supplementation. Supplemented cows received 0.14% of body weight per day (1.5 lbs per day) of a high-protein supplement (40% crude protein, as-fed basis) approximately 2 months before and after weaning (Aug 15 to Dec 14; weaning = Oct 15) or only after weaning (Oct 15 to Dec 14). Supplement was fed 3 days per week (Monday, Wednesday, and Friday) and was prorated to deliver the designated daily amount. All cows received 4 lbs per day of the same supplement during the winter (Dec 14 until calving in early March). Fall and cumulative winter performance (body condition score and body weight) indicated that providing a limited amount of a high-protein supplement during the fall supplementation period can increase cow body condition and body weight, and in some cases, subsequent calf performance. Fall supplementation did not significantly affect the proportion of cows cycling prior to the breeding season or subsequent pregnancy rate.

Introduction

Forage quality in most of the western United States declines during the late summer and fall and is quite low as the plants reach vegetative maturity. This is especially true in the tallgrass-prairie regions that are dominated by C4 grass species. Previous research at Kansas State University has demonstrated that cattle grazing low-quality tallgrass prairie respond very positively to supplementation with ruminally degradable protein (the protein available to rumen microbes) and that the greatest efficiency is achieved from the first increments of supplemental protein. The nutrient requirements of spring-calving cows are typically lowest during the fall and it has been demonstrated that the efficiency of metabolizable energy use to promote body condition gain is greater during late lactation than during the dry period. Together, these factors may provide a unique opportunity to realize efficient range cow weight and body condition gains prior to entering the winter grazing season. This could be important for the maintenance of reproduction in beef cows in poor body condition and also could moderate subsequent winter supplement dependency by building mobilizable reserves during a period when such reserves are established efficiently. Therefore, the objective of our study was to evaluate the impact of delivering limited quantities of a hand-fed, high-protein supplement during the fall grazing period on fall and subsequent winter beef cow performance. The provision of supplement prior to weaning versus after weaning was also evaluated to determine if performance differences existed due to the time of initiation of supplementation.

Experimental Procedures

An experiment was conducted from August 15, 2001 through the beginning of the 2002 summer grazing season that used 136 mature, pregnant, spring calving Hereford x Angus cows. The treatments were as follows: 1) control with no fall supplementation; 2) fall supplementation during the entire fall grazing period, both before and after weaning (August 15 to December 14); 3) fall supplementation beginning after weaning (October 15 to December 14). Initial body weights of the cows and calves and body condition scores of the cows (1 to 9 scale) were recorded on August 14, 2001 and repeated approximately every 60 days and within 48 hours of calving. Additional body weight and condition scores of the cows and calf weights (for the 2002 calf crop) were collected at the beginning of the summer grazing season. Treatments were randomly assigned to 12 fall pastures of tallgrass prairie with 3 replications per treatment. Four groupings of the treatment/fall pasture combinations were then assigned to one of four winter pastures of tallgrass prairie (each fall treatment was represented in each winter pasture). The cattle were stratified by body condition score and pair weight and assigned to one of the three fall supplementation treatments. The pastures varied in size from 60 to 100 acres; therefore, the randomization procedure was designed to allow a consistent number of cows across treatments and a stocking rate of approximately 7.5 acres per cow/calf pair.

All fall-supplemented cows received 0.14% of their average initial body weight per day (as-fed basis) in supplement during their designated supplementation period, and all treatment groups received 4 lbs/day of the same 40% crude protein supplement in meal form during the winter grazing period (December 15 to calving). The supplement used throughout the experiment was comprised of approximately 52% cottonseed meal, 30% soybean meal, 15% sunflower meal, 2.5% molasses, and 0.5% grease. All supplementation occurred 3 days per week (Monday, Wednesday, and Friday) and was prorated to deliver the designated daily amount. To ensure that only cows consumed the supplement fed during the period before weaning, calves were separated from their dams before bunk feeding the supplement. During the entire fall period, all cows were fed as groups in their respective pastures. On supplementation days during the winter period, cows within each of the four pastures were separated into their respective treatment groups and bunk fed their allotment of supplement. Adequate forage was available in all pastures during the course of the study, and the approximate quality of the forage available in those pastures was characterized. Five samples, randomly distributed throughout each of the experimental pastures, were collected in each time period (total samples = 160) utilizing 1.08 square foot frames (Table 1). A commercial mineral mix was provided free choice to all cattle throughout the experiment. To evaluate the effect of fall supplementation on subsequent reproductive performance, two blood samples were collected from the tail vein of each cow prior to the breeding season (May 10, 2002 and May 20, 2002) and assayed for progesterone levels to determine whether cows were cycling prior to the breeding season. Pregnancy was confirmed by rectal palpation on September 12, 2002.

Results and Discussion

Cows receiving supplement prior to weaning tended (P=0.16; Table 2) to increase in body condition a bit more than nonsupplemented cows. This observation was corroborated by a higher (P=0.03; Table 3) weight gain in that group. However, weight change in calves (Table 4) nursed by these cows during this period was not different (P=0.33) from the calves nursed by nonsupplemented cows. All cows lost body condition during the period after weaning (October 15 to December 14) even though weight gain was positive (due to growth in the products of conception).

Cows receiving fall supplementation lost less (P=0.02) body condition and gained more (P=0.02) weight than the control cows. Cumulative weight and body condition scores were affected as well. Weight and body condition change between the two supplemented groups was not significantly different during the period after weaning, which suggests that neither compensation nor adaptation (i.e., adaptation to having been supplemented previously) were important under these circumstances.

In contrast, at calving the cows receiving fall supplementation tended (P=0.12) to be only slightly heavier with no significant differences in body condition score when compared to the control cows. This suggests that the cows that were not supplemented during the fall exhibited some ability to compensate for the earlier nutritional restriction. No significant differences in calf birth weights were observed among the treatments for the 2002 calf crop. However, calves produced by cows that had received supplementation during the previous fall gained faster (P=0.03) than calves from control cows during the period from birth until the start of the summer grazing season (May 20). Likewise, calves from cows that had been supplemented both before and after weaning gained faster (P=0.02) than those calves whose dams only received supplement during the period after weaning. No significant differences were observed among treatments in either the proportion of cows that were cycling prior to the breeding season or in the number of cows that ultimately became pregnant.

In conclusion, feeding beef cattle a limited amount of a high-protein supplement during the fall period can elicit positive changes in body weight and body condition scores, particularly during the period after weaning. Similarly, this practice also may positively affect the performance of calves born to these dams. However, it also appears that cows that do not receive fall supplementation have some potential to compensate during the winter if they are appropriately supplemented during that period. It seems likely that low-level fall supplementation would have greatest applicability in cows that enter the fall grazing season in a compromised state of body condition.

Table 1. Forage Chemical Composition

	Nutrient[a]			
Item	Organic Matter	Crude Protein	Neutral Detergent Fiber	Acid Detergent Fiber
Tallgrass-prairie range	---------- % of the Dry Matter ----------			
September 25	89.3	5.48	68.4	46.5
December 10	89.7	3.45	74.0	52.4
February 28	90.5	3.33	74.4	53.7

[a]From analysis of hand clipped samples.

Table 2. Influence of Low-Level Fall Supplementation on Beef Cow Body Condition Scores

		Supplementation			Statistical Comparisons (P-values[b])		
Item	Control	Before and After Weaning	After Weaning Only	SEM[c]	Before Weaning vs None	Before and After vs After	Control vs Supplement
No. of cows	46	44	46				
Body condition score[a]							
Initial	4.77	4.76	4.76	0.018			
Change before weaning, Aug 14-Oct 15	0.42	0.51	0.31	0.075	0.16	NA	NA
Change after weaning, Oct 15-Dec 14	-0.44	-0.09	-0.11	0.089	NA	0.86	0.02
Cumulative changes							
Aug 14-Dec 14	-0.02	0.42	0.20	0.108	NA	0.19	0.04
Aug 14-Calving	-0.15	-0.01	-0.05	0.087	NA	0.75	0.30
Dec 15-Cavling	-0.14	-0.43	-0.25	0.103	NA	0.25	0.15
At calving[d]	4.60	4.75	4.70	0.086	NA	0.74	0.28

[a]Body condition score: 1 = emaciated; 9 = obese.
[b]NA = not applicable. Statistical comparison under consideration was not applicable to the designated period.
[c]SEM = standard error of the mean.
[d]Average calving date = March 7, 2002.

Table 3. Influence of Low-Level Fall Supplementation on Beef Cow Body Weights

		Supplementation			Statistical Comparisons (P-values[a])		
Item	Control	Before and After Weaning	After Weaning Only	SEM[b]	Before Weaning vs None	Before and After vs After	Control vs Supplement
No. of cows	46	44	46				
Body weight, lb							
Initial	1078	1083	1083	6.1			
Change before weaning, Aug 14-Oct 15	98	115	86	6.8	0.03	NA	NA
Change after weaning, Oct 15-Dec 14	30	60	67	9.3	NA	0.63	0.02
Cumulative changes							
Aug 14-Dec 14	128	176	153	14.1	NA	0.30	0.08
Aug 14-Calving	7	32	18	6.3	NA	0.16	0.05
Dec 15-Cavling	-122	-143	-135	8.9	NA	0.52	0.16
At calving[d]	1087	1116	1100	8.9	NA	0.29	0.12

[aN]A = not applicable. Statistical comparison under consideration was not applicable to the designated period.
[b]SEM = standard error of the mean.
[c]Average calving date = March 7, 2002.

Table 4. Influence of Low-Level Fall Supplementation on Calf Body Weight and Cow Reproductive Performance

		Supplementation			Statistical Comparisons (P-values[b])		
Item	Control	Before and After Weaning	After Weaning Only	SEM[c]	Before Weaning vs None	Before and After vs After	Control vs Supplement
2001 Calf Crop							
No. of calves	46	44	46				
Initial weight, lb	406	405	409	6.8			
Weight gain before weaning, lb, Aug 14-Oct 15	133.0	141.8	137.8	4.9	0.33	NA	NA
2002 Calf Crop							
Calf birth weight, lb	90.4	90.4	88.2	1.3	NA	0.12	0.74
Calf weight on May 20, lb	233.7	247.0	235.9	2.8	NA	0.02	0.09
Calf weight gain, birth-May 20, lb	144.6	155.7	147.1	2.0	NA	0.02	0.03
Reproductive performance							
No. of cows	40	40	42				
Cows in estrous prior to May 20[c], %	85	87	93				
Cows pregnant on Sept 12[d], %	100	95	98				

[a]NA = not applicable. Statistical comparison under consideration was not applicable to the designated period.
[b]SEM = standard error of the mean.
[c]Chi-Square, P = 0.52.
[d]Chi-Square, P = 0.35.

Cattlemen's Day 2003

INFLUENCE OF LOW-LEVEL FALL PROTEIN SUPPLEMENTATION ON FORAGE INTAKE, DIET DIGESTION, AND SELECTION BY BEEF STEERS GRAZING TALLGRASS-PRAIRIE RANGE

D. A. Llewellyn, R. C. Cochran, T. T. Marston, C. G. Farmer, and T. A. Wickersham

Summary

This study evaluated the effect on forage utilization of providing a limited quantity of a high-protein (40% crude protein) supplement to beef cattle grazing tallgrass prairie during the fall. Sixteen ruminally fistulated beef steers were randomly assigned to one of two treatments (fall supplementation or no fall supplementation), which were evaluated for their effect on forage intake and digestion during September and November. Within each treatment, four steers were used for measuring diet selection (by ruminal evacuation) and four were used for determining diet digestion (by total fecal collection). Data from both groups were used to calculate forage intake. Steers were individually fed a high-protein supplement at a rate of 0.14% of body weight/day (as-fed basis; 0.80 lb/day during September and 0.99 lb/day during November) but prorated and delivered only three days per week. Quality of diet selected decreased as season progressed (decreased protein and increased fiber) and, as a result, forage intake and digestion was significantly lower during the late fall period. Neither diet selection nor forage intake were significantly influenced by fall supplementation; however, supplemented steers digested their total diet to a greater extent.

Introduction

Previous research conducted at Oklahoma State University demonstrated that providing a limited amount of a high-protein supplement during the late summer period can be effective in eliciting efficient weight gains in stocker cattle grazing native range. It seems logical that a similar response might be observed in cattle grazing tallgrass prairie during the fall period. If cows are in poor body condition during the fall, such a practice may be beneficial in preparing cows for entering the winter period. The performance benefits that are realized by protein supplementation are often mediated by increases in forage intake and digestion. Therefore, the objective of our experiment was to determine if providing a limited quantity of a high-protein supplement during the early or late fall has an effect on forage intake, diet digestion, and the quality of the diet selected by steers grazing tallgrass-prairie range.

Experimental Procedures

Sixteen ruminally fistulated Hereford x Angus steers were utilized in a two-period experiment (average initial starting weight in period 1 and period 2 = 571 and 706 lbs, respectively). Each period lasted 21 days and the respective starting dates were September 17, 2001 and November 26, 2001. During each period steers grazed a single 68-acre pasture of tallgrass prairie (Table 1). Forage availability was abundant during both periods. Steers were weighed at the beginning of each period, blocked by weight, and randomly assigned to one of two treatments: 1) fall supplementation, 2) no fall supplementation. Within each treatment, four steers were used for measuring diet selection (by ruminal

evacuation) and four steers were used for estimating diet digestion (by total fecal collection). Steers remained on the same treatments and were used for the same collection activities throughout the experiment. Supplemented steers received a 40% crude protein supplement (as-fed basis; supplement composition was about 52% cottonseed meal, 30% soybean meal, 15% sunflower meal, 2.5% molasses, and 0.5% grease) in meal form at a daily rate of 0.14% of body weight measured at the beginning of each period (as-fed basis; this feeding level was commensurate that the amount fed in a companion study which monitored beef cow performance). The desired daily quantity was prorated for delivery three times per week (Monday, Wednesday, and Friday). On these days, steers were gathered in the morning and individually fed the prorated amount. Each collection period consisted of a 15-day adaptation (days 1 through 15), a 6-day fecal collection (days 16 through 21), and a 4-day diet collection (days 18 through 21). Diet selection samples were analyzed for dry matter and organic matter, crude protein, neutral detergent fiber (NDF), and acid detergent fiber (ADF). The selected forage, feces, and supplement were analyzed for acid detergent insoluble ash for use as an internal maker for calculation of digestibility. Indirect calculation of forage intake was derived from equations utilizing calculated digestibility and measured fecal output.

Results and Discussion

The effect of supplementation treatment on diet selection was not dependent on the period in which selection was measured (i.e., September versus November). Supplementation treatment did not affect (P=0.62) the percentage of crude protein in the diet selected although the amount of crude protein in the diet selected declined (P<0.01) during late fall (Table 2). Compared to the crude protein concentration in the standing forage, steers selected a diet with higher crude protein content. This also has been observed in other grazing studies. Neither measure of dietary fiber (NDF and ADF) in the selected forage was significantly affected by the supplementation treatments evaluated. However, both NDF (P=0.08) and ADF (P<0.01) tended to increase with advancing season. Also, steers selected diets with less fiber (i.e., higher quality) than that present in the standing forage.

The response of steers to supplementation treatment in terms of the effect on forage intake or digestion was not significantly dependent on the period in which these characteristics were measured. Forage and total organic matter intakes (i.e., consumption of both forage and supplement) were not affected by supplementation (P=0.61 and P=0.94, respectively; Table 3). However, each of these was significantly lower (P=0.02) during the late fall period. Total diet digestion also was significantly lower (P=0.02) during the late fall. In contrast to forage intake, diet digestion tended (P=0.06) to be greater for supplemented compared with nonsupplemented steers, and most of this difference was due to a difference between treatments during the November sampling period. Digestion of low-quality forage diets is often restricted by lack of ruminally available protein. Providing a source of ruminally available protein provides nutrients that enable ruminal microbes to degrade forage fiber. The supplement fed in this study was both highly digestible itself, as well as an excellent source of ruminally available protein. Thus, the observed trends for improved digestion may have reflected both of these aspects. Digestible organic matter intake is a product of total intake and digestion and is a good integrated measure of how a treatment affects forage use. In our study, digestible organic matter intake was not different (P=0.60) between supplementation treatments but was lower (P=0.01) during late fall than early fall.

In conclusion, provision of limited quantities of a high-protein supplement to steers grazing native range during the late summer and fall tended to improve digestion but had little effect on the quality of diet selected or forage intake. Changes in diet selection and digestion were consistent with decreasing forage quality.

Table 1. Chemical Composition of Available Pasture Forage

	Nutrient			
Sampling Date	Organic Matter	Crude Matter	Neutral Detergent Fiber	Acid Detergent Fiber
	---------- % of Dry Matter ----------			
September 25	89.3	5.8	66.6	46.3
December 7	90.1	2.9	71.9	50.6

[a]From analysis of hand clipped samples.

Table 2. Influence of Low-Level Fall Protein Supplementation on Quality of Diet Selected by Grazing Steers

	September		November			Statistical Comparisons (P-values)		
Item	Fall Supplement	No Supplement	Fall Supplement	No Supplement	SEM[a]	Supplement	Period	Supplement x Period
Organic matter	85.7	85.6	86.2	85.5	1.21	0.70	0.88	0.79
---------- % of forage organic matter ----------								
Crude protein	9.5	9.3	6.4	6.1	0.43	0.62	<0.01	0.91
Neutral detergent fiber	75.0	77.1	79.4	80.1	2.21	0.32	0.08	0.71
Acid detergent fiber	43.7	46.0	49.9	51.2	1.47	0.22	<0.01	0.69

[a]Standard error of the mean; n = 4.

Table 3. Influence of Low-Level Fall Protein Supplementation on Organic Matter Intake and Digestibility in Grazing Steers

	September		November			Statistical Comparisons (P-values)		
Item	Fall Supplement	No Supplement	Fall Supplement	No Supplement	SEM[a]	Supplement	Period	Supplement x Period
Organic intake, % of body weight daily								
Forage	1.97	2.07	1.69	1.79	0.15	0.61	0.02	0.97
Supplement[b]	0.12	—	0.12	—				
Total	2.09	2.07	1.81	1.79	0.15	0.94	0.02	0.97
Digestible organic matter	1.09	1.07	0.92	0.84	0.07	0.60	0.01	0.70
Total tract digestion, %								
Organic matter	52.2	51.8	50.6	46.7	1.1	0.06	0.02	0.17

[a]Standard error of the mean; n = 4.

Cattlemen's Day 2003

THE RELATIVE VALUE OF RUMINALLY DEGRADABLE AND UNDEGRADABLE PROTEIN ON THE UTILIZATION OF LOW-QUALITY PRAIRIE HAY BY STEERS

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Summary

An experiment was performed to investigate the impact of providing six levels of ruminally degradable protein (RDP; protein that is available to ruminal microbes) in combination with two levels of ruminally undegradable protein (RUP; protein that is not available to the ruminal microbes, but can be digested directly by cattle) on the intake and digestion of low-quality prairie hay. Twelve steers were provided unlimited access to low-quality prairie hay (5.3% crude protein and 71.7% neutral detergent fiber) throughout the trial. To simulate dietary RUP, casein was infused abomasally once daily at either 0 or 0.087% of body weight. To simulate dietary RDP, casein was infused ruminally once daily at 0, 0.029, 0.058, 0.087, 0.116, or 0.145% of body weight. As provision of RDP increased, forage intake and fiber digestion increased. Supplementing with RUP alone increased forage intake but not fiber digestion, although the intake response was not as large as providing the same amount of RDP. In conclusion, RUP is less efficient than RDP in stimulating forage intake and digestion.

Introduction

Low-quality forage typically limits beef production because of its low crude protein content (less than 7% crude protein), which limits the amount of nitrogen available to ruminal microbes. Research at Kansas State University and other research institutions has consistently demonstrated that supplementing low-quality forage with feeds rich in crude protein increases the utilization of the forage resource and improves livestock performance. However, protein can be classified into two broad categories: ruminally degradable protein (RDP; also known as degradable intake protein or DIP) and ruminally undegradable protein (RUP; also known as undegradable intake protein or UIP). Ruminally degradable protein is the fraction of the protein consumed by the animal that has the potential to be degraded by ruminal microbes and subsequently used in the synthesis of microbial crude protein and in the fermentation of carbohydrates. Inadequate RDP decreases microbial protein production and ruminal fermentation; this has the potential to decrease feed intake and ultimately animal performance. Ruminally undegradable protein is the portion of the dietary protein that is not degraded and is available for digestion and absorption in the gastric stomach and intestines only by the host animal, similar to the way protein is available to humans. Even so, the potential exists for nitrogen from the RUP to be recycled to the rumen and used by ruminal microbes.

Typically, the goal of supplementing low-quality forages is to address the deficiency of nitrogen in the rumen, which is accomplished most directly with RDP. However, except for non-protein nitrogen sources such as urea, essentially all supplements and forages contain both RDP and RUP. For example, the protein in tallgrass-prairie hay is about 50% degradable and 50% undegradable, whereas the protein in soybean meal is about 70% degradable and 30% undegradable. Therefore, fed cattle received both RDP and RUP. The objective of this study was to investigate how the provision of RUP might affect the impact of sup-

plemental RDP on the consumption and digestion of low-quality forage offered to steers.

Experimental Procedures

Twelve Angus × Hereford steers (average initial body weight = 796 pounds) with ruminal fistulas were used to evaluate the impact of increasing level of supplemental RDP in combination with one of two levels of supplemental RUP. Provision of supplemental RDP was simulated by ruminally infusing casein. Casein was chosen because of its relatively high protein content (95.3% crude protein) and because it is both highly degradable in the rumen and highly digestible in the intestines. This latter point allowed us to use casein to simulate RUP supplementation without having to confound the experiment by using a different protein source as our RUP source. By infusing casein directly into the abomasum (i.e., postruminal infusion), we bypassed the ruminal microbes and, thereby, simulated the appearance of RUP in the gastric stomach and intestines. The RDP was provided daily at 0, 0.029, 0.058, 0.087, 0.116, and 0.145% of initial body weight. These levels were selected based on previous research conducted at Kansas State University and were expected to significantly increase total digestible organic matter intake (which is a sum of the total amount of feed consumed and digested by the animal, and is a good integrated measure of how a treatment affects forage utilization). The RUP was infused daily postruminally at 0 and 0.087% of initial body weight. The 0.087% level was selected to provide sufficient RUP to elicit a potential effect on total digestible organic matter intake and yet small enough to make abomasal infusions feasible.

Steers were given free-choice access to low-quality, tallgrass-prairie hay (Table 1) throughout the experiment. A two period crossover design was used. Each period of the experiment was divided into five phases: 1) 10-day adaptation to the provision of supplemental protein; 2) 7-day measurement of hay intake and digestibility (with continued provision of supplemental protein); 3) 3-day ruminal sampling period (with continued provision of supplemental protein); 4) 10-day depletion (no treatment infusions were administered, intake measurements continued); 5) 7-day measurement of hay intake (no treatment infusions were administered). Steers received their protein supplements at 6:30 each morning and were fed their hay shortly thereafter. Total fecal collection was used to determine diet digestion. During the 3-day ruminal sampling period a ruminal fermentation profile was conducted to determine ammonia concentrations and ruminal pH.

Table 1. Chemical Composition of Tallgrass-Prairie Hay and Casein

	Tallgrass-Prairie Hay	Casein
	- % of Dry Matter -	
Organic Matter	94.9	96.5
Crude Protein	5.3	95.3
Ruminally Degradable Protein[1]	49.0	-
Neutral Detergent Fiber	71.7	-
Acid Detergent Fiber	46.9	-
Acid Detergent Insoluble Ash	6.8	-

[1]Percent of crude protein.

Results and Discussion

Forage and total digestible organic matter intakes (Table 2) as a percent of initial body weight increased in proportion to the increasing provision of supplemental RDP (linear; $P<0.05$). An interaction between RDP and RUP ($P=0.08$) can be explained by the greater response to supplementation with a low level of RDP when no supplemental RUP was provided. Large increases in intake with the first

increments of RDP were observed when no RUP was provided, but provision of RDP in the presence of supplemental RUP resulted in relatively small increases. This difference in forage and total digestible organic matter intake with RUP supplementation may be explained by the alleviation of a severe nitrogen deficiency via the recycling of RUP, which would render the response to the first increments of RDP supplementation smaller. Increased intake of forage and total digestible organic matter is a commonly observed response when low-quality forage is supplemented with protein. A large portion of this increase can be attributed to the improvement in the amount of nitrogen available to the ruminal microbes.

Supplementing with RUP also increased the total digestible organic matter intake (Table 2; $P<0.05$). The digestion of the organic matter in the supplement itself can account for a portion of this increase. However, a portion of the response was also due to the effect of RUP supplementation on forage intake. When no supplemental RDP was provided, supplementation with RUP increased the intake of forage by about 34%. As noted above, we suspect that some of this increase was due to the recycling of nitrogen to the rumen from the blood of the animal, which would have addressed a portion of the ruminal nitrogen deficiency. However, we observed little difference between these groups in the ruminal events that one would expect to occur (i.e., increased ruminal ammonia and fiber digestion) if nitrogen recycling was solely responsible for the effect on intake. Failure to observe increases in fiber digestion may be the result of increased passage rate (associated with increased intake) masking the effect of nitrogen recycling on fiber digestion. Additionally, small increases in ruminal N supply from recycling may not have been detectable due to rapid utilization by the ruminal microbes in the face of a significant ruminal nitrogen deficiency. Alternatively, RUP may have elicited a more direct effect on the animal's intake control mechanisms. Regardless, as RDP supplementation increased, the positive effect of RUP was less apparent.

When comparing the two treatments that provided the same amount of protein (0.087% of body weight) but in the two different forms (i.e., as RDP or RUP), we observed that the total digestible organic matter intake was increased 77% with RDP supplementation alone but only 50% with RUP supplementation alone. This indicates that RDP supplementation is likely to be more efficient than RUP supplementation at stimulating an overall increase in the intake and digestion of low-quality forage.

Provision of supplemental RDP increased (linear; $P<0.01$) organic matter and forage fiber (i.e., neutral detergent fiber) digestion (Table 3). Such increases in digestion are largely attributable to providing the ruminal microbes with a source of nitrogen. Increased levels of ruminally available nitrogen have been shown to increase ruminal fermentation of low-quality forage. Supplementation with RUP resulted in significant increases ($P<0.01$) in organic matter digestion; however, fiber digestion was not increased. Much of the increase in organic matter digestion in response to RUP is attributable to the digestion of the casein itself. The failure to observe a change in fiber digestion with the provision of supplemental RUP highlights the question posed above regarding the importance of nitrogen recycling versus other modes of action in eliciting the positive effect on forage intake observed for this treatment.

Measurements of ruminal metabolites can provide valuable information regarding how supplements bring about improvements in the utilization of low-quality forage. Ruminal pH is of concern because low pH (less than 6.2) can depress fiber fermentation. The provision of either supplemental RDP or RUP failed to significantly influence ruminal pH and the average ruminal pH was greater than 6.2 for all

treatments (Table 3). In general, low-quality forage consumption has been associated with low levels of ruminal ammonia, which limits microbial activity. Supplementation with RDP increased ruminal ammonia (Table 3) and may explain a large portion of the increase in forage utilization. However, RUP supplementation in this study did not significantly increase ruminal ammonia.

Supplementation of low-quality forages with a large portion of the supplemental protein as RDP should bring about the greatest increases in forage intake and digestion. While the ability of RUP to contribute to increased forage utilization should not be overlooked, protein supplementation to cattle eating low-quality range forage should focus on the delivery of RDP.

Table 2. Effect of Supplemental Ruminally Degradable and Undegradable Protein on Forage Intake and Total Digestible Organic Matter Intake in Beef Steers Fed Low-Quality Prairie Hay

		Intake, % of initial body weight daily	
RDP level[a]	RUP level[b]	Forage	Total Digestible Organic Matter Intake
0	0	1.57	0.66
0.029	0	2.06	0.87
0.058	0	2.21	1.10
0.087	0	2.36	1.17
0.116	0	2.33	1.19
0.145	0	2.19	1.22
0	0.087	2.11	0.99
0.029	0.087	2.13	0.99
0.058	0.087	2.37	1.26
0.087	0.087	2.10	1.14
0.116	0.087	2.45	1.40
0.145	0.087	2.32	1.31
SEM[c]		0.15	0.084
P – values[d]			
RDP: Linear		0.04	<0.01
RDP: Quadratic		0.15	0.17
RDP: Cubic		0.89	0.79
RUP		0.06	<0.01
RDP × RUP		0.08	0.07

[a]Ruminally degradable protein level, crude protein/day expressed as a % of body weight.
[b]Ruminally undegradable protein level, crude protein/day expressed as % of body weight.
[c]For n = 2.
[d]Probability that responses to treatments of the magnitudes observed were due to random chance.

Table 3. Effect of Supplemental Ruminally Degradable and Undegradable Protein on Digestibility and Ruminal Fermentation Characteristics by Steers Consuming Low-Quality Prairie Hay

		Total tract digestibility, %			
RDP level[a]	RUP level[b]	Organic Matter	Neutral Detergent Fiber	pH	Ammonia, m*M*
0	0	44.8	47.1	6.71	0.33
0.029	0	44.4	46.6	6.59	0.52
0.058	0	50.9	53.7	6.53	1.17
0.087	0	50.1	51.9	6.46	2.67
0.116	0	51.6	55.3	6.46	7.78
0.145	0	54.3	55.3	6.48	5.45
0	0.087	47.2	46.5	6.62	0.91
0.029	0.087	46.5	48.5	6.60	1.08
0.058	0.087	53.2	55.2	6.54	2.83
0.087	0.087	52.7	54.4	6.33	3.30
0.116	0.087	55.8	56.2	6.36	6.30
0.145	0.087	53.3	52.6	6.62	6.50
SEM[c]		1.3	1.5	0.093	0.72
P - values[d]					
RDP: Linear		<0.01	<0.01	0.11	< 0.01
RDP: Quadratic		0.27	0.03	0.12	0.28
RDP: Cubic		0.37	0.32	0.28	0.01
RUP		<0.01	0.49	0.49	0.25
RDP × RUP		0.09	0.50	0.43	0.41

[a]Ruminally degradable protein level, crude protein/day expressed as a % of body weight.
[b]Ruminally undegradable protein level, crude protein/day expressed as % of body weight.
[c]For n = 2
[d]Probability that responses to treatments of the magnitudes observed were due to random chance.

Cattlemen's Day 2003

EFFECT OF SUPPLEMENTAL CARBOHYDRATE TYPE AND AMOUNT OF RUMINALLY DEGRADABLE PROTEIN ON UTILIZATION OF TALLGRASS-PRAIRIE HAY BY BEEF STEERS

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Summary

This experiment determined the impact of type of supplemental carbohydrate and amount of supplemental ruminally degradable protein (RDP) on intake and digestion of prairie hay. Fourteen ruminally fistulated beef steers were supplemented with one of two carbohydrates (corn starch or the simple sugar glucose) at 0.30% of body weight and one of seven levels of ruminally degradable protein (RDP; 0, 0.015, 0.051, 0.087, 0.123, 0.159, or 0.195% of body weight). Two additional steers served as controls (non-supplemented steers, i.e., no carbohydrate or RDP supplementation). Forage intake and digestion were substantially improved by increasing amounts of supplemental RDP. Supplemental carbohydrate with insufficient supplemental RDP depressed fiber digestion although carbohydrate type did not alter the digestion response or forage intake. In conclusion, when supplementing cattle eating low-quality forage, it is important to ensure that the supplement contains adequate RDP. The impact of the supplement on forage use should not differ greatly between starch (e.g., cereal grains) and sugar (e.g., molasses) as the main carbohydrate source.

Introduction

Supplementing cattle eating low-quality forage with feedstuffs rich in ruminally degradable protein increases forage intake and digestion. However, even in feedstuffs with high concentrations of protein, typically more than half of the feed is something other than protein. The largest contributor to this remaining portion is usually carbohydrate (e.g., starch, sugar, or fiber). Some research indicates that supplementing cattle eating low-quality forage with feedstuffs rich in starch (such as cereal grains) may negatively impact forage intake and digestion. However, previous research conducted at Kansas State University raised questions about whether the negative effects of supplemental carbohydrate are specific to starch and whether the responses elicited by different carbohydrates might depend on the amount of supplemental ruminally degradable protein fed. In particular, given the widespread use of molasses-based supplements (which contain high concentrations of sugars), we wondered whether sugar would have a different effect than starch on forage utilization and how each of these might respond to different levels of ruminally degradable protein. Therefore, an experiment was conducted to evaluate the influence of both of these factors (i.e., carbohydrate type and level of supplemental ruminally degradable protein) on low-quality forage utilization.

Experimental Procedures

Sixteen ruminally fistulated beef steers (body weight = 485 lb), each given free-choice access to tallgrass-prairie hay (Table 1), were used in a two-period crossover experiment. Fourteen steers were supplemented with either corn starch or a simple sugar (dextrose, a form of the simple sugar glucose) at 0.30% of body weight and one of seven levels of ruminally degradable protein (RDP; 0, 0.015,0.051, 0.087, 0.123, 0.159, or 0.195% of

body weight). Two additional steers served as controls (non-supplemented steers, i.e. no carbohydrate or RDP supplementation). Each experimental period lasted 24 days (14 days of adaptation) and included periods for measuring intake and fecal output and for monitoring ruminal fermentation. Offered and refused hay was weighed to measure feed intake, and intake was used in conjunction with fecal measurements to calculate organic matter and fiber (i.e., neutral detergent fiber) digestibilities.

Results and Discussion

Forage intake increased (Figure 1; linear, $P<0.01$) as increasing amounts of supplemental RDP were fed. Similarly, the total amount of digestible feed consumed (digestible organic matter intake, which includes that from both forage and supplement) responded positively to increasing supplemental RDP, although the rate of increase in intake slowed somewhat at the highest levels of RDP supplementation (quadratic, $P<0.05$). The type of supplemental carbohydrate did not affect forage ($P=0.37$) or digestible organic matter ($P=0.44$) intake.

Forage fiber and organic matter (i.e., forage plus supplement) digestion were substantially improved (Figure 2; linear, $P<0.05$) by providing increasing amounts of supplemental RDP. Although the rate of improvement in fiber digestion tended (quadratic, $P=0.08$) to decrease at the highest levels of RDP supplementation. When compared with the non-supplemented cattle, fiber digestion was depressed by about 23% when supplemental carbohydrate was fed without any supplemental RDP. However, when adequate supplemental RDP was fed, fiber digestion was similar to or slightly higher than that observed in the non-supplemented cattle. Supplemental carbohydrate type did not significantly alter the effect on digestion. Ruminal pH averaged between 6.1 to 6.8 (data not shown) across treatments, suggesting that differences in fiber digestion are unlikely to be adequately explained by changes in pH alone. The positive effect of supplemental ruminally degradable protein appears to be primarily due to the provision of nutrients that are commonly deficient in low-quality forages, particularly RDP (nitrogen). Protein supplementation also increases the concentration of branched chain volatile fatty acids, which serve as growth factors for some fiber-digesting microbes and, as a result, may stimulate ruminal fiber digestion.

In conclusion, when supplementing low-quality forages, it is important to ensure that supplements provide an adequate quantity of RDP. However, results from this study suggest that little difference in forage utilization would be likely for supplements that differ solely on the basis of the presence of starch (as would be found in cereal grains) versus glucose (as would be found in molasses) as the dominant carbohydrate source.

Table 1. Chemical Composition of Forage and Supplements

Item	Organic Matter	Neutral Detergent Fiber	Acid Detergent Fiber	Crude Protein	Ruminally Degradable Protein
	----------% of Dry Matter ----------				% of Crude Protein
Prairie hay	94.5	76.2	40.4	5.1	56.9
Supplement component					
Casein	97.1	-	-	94.2	100
Starch	100	-	-	-	-
Dextrose	100	-	-	-	-

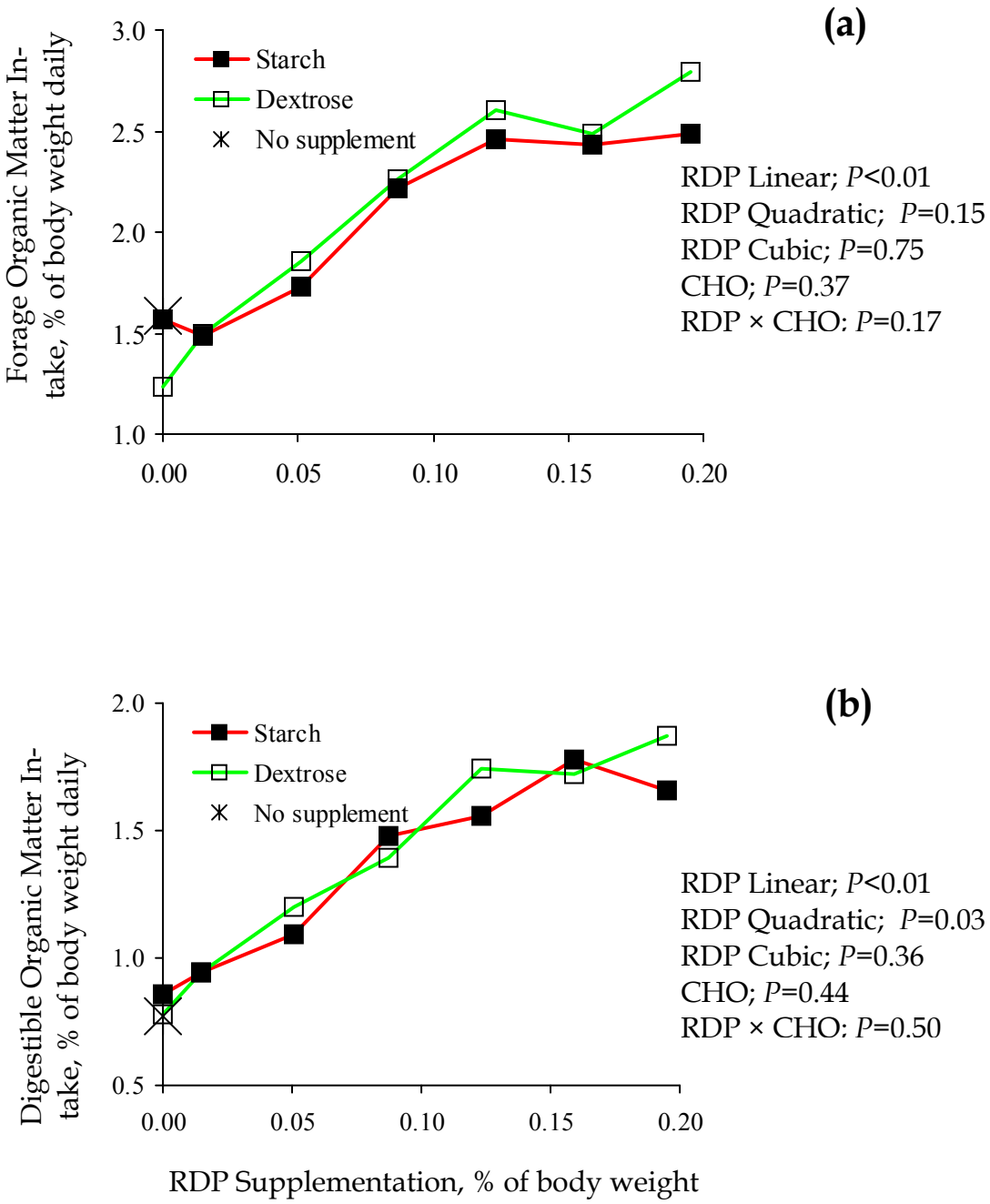

Figure 1. Intake of Forage Organic Matter (a) and Total Digestible Organic matter (b) by Beef Steers Supplemented with Increasing Levels of Rumen Degradable Protein (RDP) and Two Carbohydrate Types (CHO).

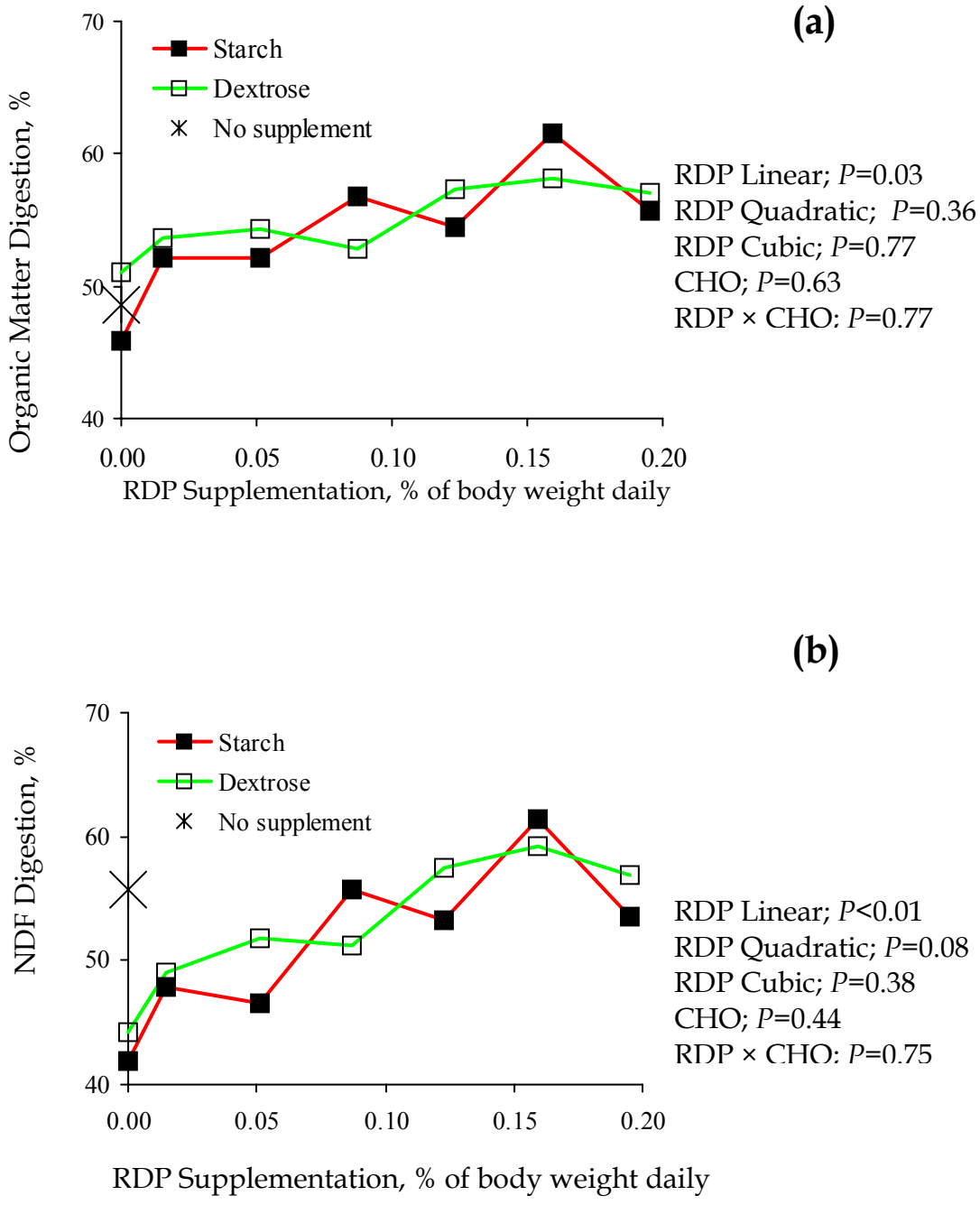

Figure 2. Digestion of Organic Matter (a) and Neutral Detergent Fiber (NDF) (b) by Beef Steers Supplemented with Increasing Levels of Rumen Degradable Protein (RDP) and Two Carbohydrate Types (CHO).

Cattlemen's Day 2003

EFFECT OF FEEDING CONVENTIONAL OR HIGH-MOISTURE, STEAM-FLAKED CORN TO FINISHING HEIFERS

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Summary

Finishing heifers were fed diets containing either conventional (18% moisture) or high-moisture (36% moisture) steam-flaked corn. Increasing moisture concentration in flakes increased starch availability ($P<0.01$), but feeding heifers high-moisture flakes decreased ($P<0.05$) dry matter intake and average daily gain compared to heifers fed conventional flakes. Feeding heifers high-moisture flakes also numerically reduced hot carcass weight and ribeye area, but caused ($P<0.01$) heifers to deposit more fat over their 12th rib. Extreme levels of moisture in flaked corn improve starch availability but do not appear to increase heifer performance or carcass value. The interaction between moisture and flake density needs further evaluation.

Introduction

Many feedlots equipped with steam-flaking mills apply moisture to corn prior to steaming to aid in the flake manufacturing process. Moisture levels of grain are closely monitored and altered to improve consistency of the final product, reduce fine particles, and decrease equipment maintenance.

Moisture is also an essential component of starch gelatinization. Without adequate moisture, starch gelatinization is incomplete. For complete gelatinization of starch to occur, moisture must accompany starch in a ratio of at least 2:1. Moisture concentration of corn prior to flaking generally ranges from 16 to 24%. Improving the gelatinization of starch by increasing the moisture content of corn prior to flaking may result in improvements in cattle performance. Our objective was to evaluate the performance of heifers fed steam-flaked corn-based diets containing flakes of 18 or 36% moisture.

Experimental Procedures

Crossbred beef heifers (n=96; 859 lb) were used in an 82-day finishing experiment. Heifers were randomly allocated to pens and stratified by pen weight to two treatments (8 heifers per pen, 6 pens per treatment). Heifers were implanted with Revlor-H® on day 1 and adapted to the final finishing diets within 15 days. Final finishing diets provided 300 mg Rumensin®, 90 mg Tylan®, and 0.5 mg MGA® per heifer daily.

Heifers were allowed ad libitum access to diets that contained approximately 73% steam-flaked corn (dry matter basis, Table 1). Dietary treatments consisted of steam-flaked corn that was prepared to contain 18% (conventional) or 36% moisture (high-moisture). The high-moisture steam-flaked corn was made by combining 1000 lb of whole corn (89% dry matter) and 380 lb of water. Corn was mixed periodically and tempered overnight to allow for sufficient uptake of moisture. Both conventional and high-moisture corn were steam conditioned for 45 minutes in a 96-cubic foot steam chest and subsequently flaked to 26 lb/bushel using an 18-inch × 24-inch Ferrel-Ross flaker. Electrical load on the flaker during production of both high-moisture and conventional flakes was measured using an ammeter. Flake samples were analyzed for

enzyme (amyloglucosidase) susceptibility to estimate starch availability.

Average daily gain and feed efficiencies were calculated using final weights estimated as hot carcass weight divided by a common dressing percentage (63%).

Results and Discussion

Electrical load on the flaker was not different for the two sources of corn. The average loads placed on the flaker were 27.6 and 28.2 amps when flaking the high-moisture and conventional corn sources, respectively. We thought that increasing the moisture concentration of corn might reduce the electrical use by the flaker. Because added moisture will increase flake density and both sources of grain were processed to common flake densities, the high-moisture corn was likely processed to a greater extent than the conventional corn. Thus, the roll tension on the flaker was likely tighter when the high-moisture corn was processed, which could mask any advantages that moisture might have on reducing electrical use by the flaker.

Performance and carcass characteristics are summarized in Table 2. Feeding heifers high-moisture flakes compared to conventional flakes decreased ($P<0.05$) dry matter intake and average daily gain. Feed efficiencies were similar ($P=0.82$) between both groups of heifers, but lower gains resulted in numerically lighter carcasses for heifers fed high-moisture flakes. Increasing the moisture concentration of flakes also increased starch availability (Table 1; $P<0.01$). The high availability of starch may have caused sub-acute acidosis in the heifers fed the high-moisture flakes and depressed their feed intake. Despite the reduction in average daily gain, heifers fed the high-moisture flakes were fatter over the 12th rib, tended ($P=0.11$) to have more USDA yield grade 3 carcasses, and tended ($P=0.13$) to have smaller ribeye areas than heifers fed conventional flakes. The higher availability of starch for heifers fed the high-moisture flakes may have altered digestion and(or) meal patterns and, thus, changed systemic hormones that regulate glucose clearance in body tissues, resulting in energy partitioning towards adipose accretion rather than muscle deposition.

Again, it should be noted that both the conventional and high-moisture flaked corn were processed to a common flake density (26 lb/bushel). If other processing factors are held constant, increasing the moisture concentration of flaked corn will cause flake density to increase. Therefore, the high-moisture flakes were likely processed to a greater degree than the conventional flakes, and moisture level may be confounded with flake density in our trial. Assuming that only moisture caused the observed differences in this trial may be incorrect due to the impact of moisture on flake density. Further research is necessary regarding the interaction of moisture content and flake density.

Table 1. Experimental Diets (% of Dry Matter)

Ingredient	Conventional Flakes	High-moisture Flakes
Steam-flaked corn, 18% moisture	73.3	-
Steam-flaked corn, 36% moisture	-	72.9
Wet corn gluten feed	9.7	9.8
Alfalfa hay	5.9	6.0
Tallow	3.1	3.1
R-T-MGA premix[1]	2.4	2.6
Soybean meal	2.1	2.1
Limestone	1.7	1.7
Urea	1.0	1.0
Potassium chloride	0.4	0.4
Sodium chloride	0.3	0.3
Vitamin/trace mineral premix[2]	0.1	0.1
Nutrient, analyzed		
Dry matter, %	77.2	65.4
Crude protein, % of dry matter	14.6	14.6
Calcium, % of dry matter	0.8	0.8
Phosphorus, % of dry matter	0.3	0.3
Starch availability of flaked corn	56.8	72.0

[1]Formulated to provide: 300 mg Rumensin, 90 mg Tylan, and 0.5 mg MGA per heifer daily.
[2]Vitamin/trace mineral premix formulated to provide (total diet dry matter): 1000 IU/lb Vitamin A, 0.13 ppm cobalt, 0.63 ppm iodine, 60 ppm manganese, 0.25 ppm selenium, 60 ppm zinc, 10 ppm thiamin, 10 ppm copper, and 2.5 ppm iron.

Table 2. Performance and Carcass Characteristics of Heifers Fed Finishing Diets Based on Steam-flaked Corn Containing 18 or 36% Moisture

Item	Conventional Flakes	High-moisture Flakes	SEM	P-value
No. of heifers	48	48		
No. of pens	6	6		
Initial weight, lb	855	862	14	0.73
Final weight, lb	1172	1154	16	0.45
Dry matter intake, lb/day	18.9	17.6	0.34	0.05
Average daily gain, lb	3.28	3.01	0.08	0.05
Gain:feed	0.173	0.171	0.0050	0.82
Hot carcass wt, lb	711	702	5.3	0.58
Dressing percentage	63.2	63.3	0.23	0.64
Ribeye area, square inches	13.0	12.4	0.26	0.13
Kidney, pelvic, & heart fat, %	2.45	2.49	0.054	0.65
Back fat thickness, inches	0.51	0.57	0.010	<0.01
USDA yield grade 1, %	13	8	3.7	0.45
USDA yield grade 2, %	33	27	4.6	0.36
USDA yield grade 3, %	46	56	4.2	0.11
USDA yield grade 4, %	8	8	3.5	1.00
Marbling score	Slight^{259}	Slight^{262}	6.8	0.80
USDA Choice, %	23	25	6.2	0.82
USDA Select, %	67	71	5.3	0.59
USDA Standard, %	10	4	4.0	0.30
Liver abscesses, %	2.1	2.1	2.1	1.00

Cattlemen's Day 2003

EFFECT OF PROCESSING VARIABLES ON CHARACTERISTICS OF STEAM-FLAKED CORN

J. J. Sindt, J. S. Drouillard, S. P. Montgomery, and E. R. Loe

Summary

We evaluated tempering moisture concentration, addition of a surfactant to improve moisture uptake, steam conditioning time, and flake density to determine their impact on characteristics of steam-flaked corn. Increasing steam conditioning time from 20 to 40 minutes or adding a surfactant during tempering did not increase final flake moisture concentration, but moisture content of flaked corn was linearly increased by increasing tempering moisture concentration. Addition of Grain Prep® surfactant during tempering decreased ($P<0.05$) the amount of moisture lost during flaking. Flake durability was increased by increasing tempering moisture concentration, but only if corn was steamed for 40 minutes (tempering moisture × steam time interaction; $P<0.10$). Decreasing flake density linearly increased both starch availability ($P<0.01$) and flake durability ($P<0.05$). In this experiment, tempering moisture concentration had the largest impact on flake moisture content, and flake density was the most influential variable altering flake durability and starch availability.

Introduction

Steam-flaking is a common method of processing grain for cattle fed in confinement. Feedlot mill operators, cattle feeders, and nutritionists emphasize the importance of flake quality, which often is measured in terms of consistency of flake thickness, moisture level, durability, and degree of starch gelatinization.

Moisture is commonly added to whole corn prior to steaming to aid in the flake manufacturing process by reducing mill electrical consumption, to allow steam conditioning to "cook" the corn rather than to transfer moisture, and to reduce fines during flaking. There is little data available about either preprocessing conditions involving moisture application to corn or methods that impact quality attributes of flakes. Our goal was to characterize how some of the variables involved with the steam-flaking process alter flake quality, which we quantified in terms of flake durability and susceptibility of starch to fermentation.

Experimental Procedures

The variables used in this experiment were tempering moisture level (6, 10, or 14% moisture), addition of a surfactant to increase moisture uptake (0 or 0.09 oz of Grain Prep® surfactant/gallon of added water, providing for 2.2 oz of surfactant/ton of flaked corn, considering 10% water added), steam conditioning time (20 or 40 minutes), and flake density (28, 26, or 24 lb/bushel) in a 3×2×2×3 factorial arrangement of treatments. The surfactant was provided by Agrichem, Inc., Ham Lake, MN.

Whole shelled corn (11% moisture) was weighed into 1-gallon glass jars (n=12; 4.5 lb each) and 6, 10, or 14% water by weight containing 0 or 0.09 oz/gallon of Grain Prep surfactant was added. Jars containing corn samples were immediately placed on a mechanized rotary device to allow for continuous contact of moisture and corn and were tempered for 2 hours. After tempering, samples were steam conditioned for 20 or 40 minutes in a pilot steam table under atmospheric pres-

sure. Following steam conditioning, samples were flaked to a common bushel weight. This procedure was repeated three times daily to obtain samples with flake densities of 28, 26, and 24 lb/bushel and replicated over 3 days to obtain triplicate representation of each treatment. Samples were collected following tempering, steam conditioning, and flaking and were frozen daily. Tempered, steamed, and flaked samples were analyzed for moisture after completion of the study. To estimate starch availability, flaked corn samples (ground to pass through 1-mm screen) were incubated *in vitro* for 3 hours, and total gas production was measured. Additionally, flaked samples (0.55 lb) were placed into a multi-chambered rotary box tester and tumbled for 10 minutes with (modified) or without (unmodified) ½ inch hexagonal nuts. Tumbling flakes with the hexagonal nuts was thought to simulate a more aggressive handling/mixing procedure to better understand how the different variables affect the resiliency of the flakes. The percentage of flakes retained on a 0.37-inch screen was measured to estimate flake durability.

Results and Discussion

The effects of tempering moisture level and surfactant on dry matter of whole corn samples are presented in Table 1. As expected, increasing tempering moisture concentration linearly increased corn moisture concentration ($P<0.0001$). However, tempering with Grain Prep did not alter corn moisture concentration ($P=0.36$). Tempering moisture concentration was the only tested variable that affected steamed corn moisture content. Like tempering, moisture concentration of corn after steam conditioning was not increased by Grain Prep. Surfactants are thought to increase the rate or amount of water that penetrates the corn kernel. In our experiment, moisture uptake was not improved by adding a surfactant to the water during the tempering process. Moisture concentration of flaked corn was increased ($P<0.0001$) by increasing water concentration during tempering. Grain Prep ($P=0.38$), steam time ($P=0.17$), and flake density ($P=0.86$) did not alter moisture content of flaked corn. However, addition of Grain Prep during tempering increased ($P<0.05$) moisture gain during flaking.

We expected a longer steam time to increase flake moisture content but this was not the case. Longer conditioning times (40 vs 20 minutes) may not further increase moisture content when corn is previously tempered with at least 6% moisture. Moisture gain in corn can be accomplished via tempering or steaming and either can substitute for the other. When less moisture is applied during tempering more moisture can be accumulated during steam conditioning, and when greater quantities of moisture are applied during tempering, less moisture will be taken up via steam. Adequate quantities of moisture (>6% added) may allow for the steam to more thoroughly and efficiently "cook" the starch rather than to transfer moisture to the starch.

By more thoroughly "cooking" the grain prior to flaking, gelatinization of starch should be increased. However, gas production (Table 2; a measure of starch availability) was not altered by tempering moisture ($P=0.62$), Grain Prep ($P=0.31$), or steam time ($P=0.33$). Decreasing flake density linearly increased ($P<0.01$) gas production during a 3-hour *in vitro* incubation.

Steaming the corn longer (40 vs 20 minutes) did improve flake durability (Table 3), but only if tempering moisture concentration increased (tempering moisture × steam time interaction; $P<0.10$). Additionally, decreasing flake density linearly increased ($P<0.05$) durability of flakes, and Grain Prep addition to water during tempering slightly increased ($P<0.05$) the amount of flakes retained on a 0.37-inch screen after modified tumbling (Table 4). Improving flake durability by decreasing flake density is likely explained by the production of larger diameter flakes that are

retained to a greater degree on the 0.37-inch screen.

Flake moisture content was most affected by tempering moisture concentration. Increasing moisture concentration of corn prior to flaking improved flake durability when corn was steamed for at least 40 minutes. In our experiment, a commercial surfactant did not alter moisture content, but it did increase moisture gain during flaking, and it also marginally increased flake durability. Decreasing flake density increased starch availability and increased flake durability. Flake density was the most influential factor that affected laboratory estimates designed to measure differences in flake quality and feeding value.

Table 1. Effect of Processing Variables on Moisture Concentration of Tempered, Steamed, or Flaked Corn Samples. Corn Samples Were Tempered with 6, 10, or 14% Water and 0 or 0.09 oz/gallon of Grain Prep Surfactant for 2 Hours, Steam Conditioned for 20 or 40 Minutes, and Flaked to Densities of 28, 26, or 24 lb/Bushel. No Interactions Existed Among Treatments

Item	Initial Corn Moisture, %	Moisture Gain during Tempering, %	Tempered Corn Moisture, %	Moisture Gain during Steaming,. %	Steamed Corn Moisture, %	Moisture Gain during Flaking, %	Flaked Corn Moisture, %
Tempering moisture, %							
6	11.0	6.2	17.2	5.6	22.8	-0.3	22.6
10	11.0	10.4	21.4	4.7	26.1	-0.1	26.1
14	11.0	13.9	24.9	2.5	27.4	-0.4	26.8
SEM		0.31	0.31	0.47	0.47	0.67	0.63
P-value, linear effect		<0.0001	<0.0001	<0.0001	<0.0001	0.87	<0.0001
Grain Prep, oz/gallon[a]							
0.00	11.0	10.2	21.2	4.6	25.8	-0.8	25.0
0.09	11.0	10.1	21.1	4.0	25.1	0.3	25.3
SEM		0.30	0.30	0.39	0.39	0.62	0.61
P-value		0.36	0.36	0.25	0.16	<0.05	0.38
Steam time, minutes							
20	11.0	10.2	21.2	4.0	25.2	-0.3	24.9
40	11.0	10.1	21.1	4.6	25.7	-0.2	25.4
SEM		0.30	0.30	0.39	0.39	0.62	0.61
P-value		0.49	0.49	0.29	0.42	0.93	0.17
Flake density, lb/bushel							
28	11.0	10.2	21.2	4.2	25.4	-0.1	25.3
26	11.0	10.2	21.2	4.0	25.2	-0.1	25.1
24	11.0	10.1	21.1	4.7	25.8	-0.6	25.0
SEM		0.33	0.33	0.48	0.48	0.67	0.65
P-value		0.78	0.78	0.57	0.72	0.66	0.86

[a]To provide 2 oz of Grain Prep/ton of flaked corn.

Table 2. Effect of Processing Variables on Gas Produced During a 3-Hours In Vitro Fermentation of Flaked Corn. Corn Samples Were Tempered with 6, 10, or 14% Water and 0 or 0.09 oz/gallon of Grain Prep Surfactant for 2 Hours, Steam Conditioned for 20 or 40 Minutes, and Flaked to Densities of 28, 26, or 24 lb/bushel. No Interactions Existed Among Treatments

Item	Gas Volume, mL
Tempering moisture, %	
6	76.4
10	74.9
14	76.8
SEM	1.8
P-value	0.62
Grain Prep, oz/gallon	
0.00	75.2
0.09	76.9
SEM	1.6
P-value	0.31
Steam time, minutes	
20	75.2
40	76.9
SEM	1.6
P-value	0.33
Flake density, lb/bushel	
28	66.9
26	72.2
24	89.0
SEM	2.3
P-value, linear effect	<0.01

Table 3. Durability of Flaked Corn Samples After Tumbling With (Modified) or Without (Unmodified) Six Hexagonal, 0.5-inch Nuts for 10 Minutes in a Multi-Chambered Durability Tester. Flaked Corn Samples Were Tempered with 6, 10, or 14% Water and Steam Conditioned for 20 or 40 Minutes

	Steam Time	
Item	20 Minutes	40 Minutes
Unmodified	---------- % retained on 0.37 inch screen ----------	
Tempering moisture, %		
6	43.7	44.6
10	46.3	51.4
14	45.2	54.4
SEM	4.4	4.4
Tempering moisture × steam time interaction, $P<0.05$.		
Modified		
Tempering moisture, %		
6	8.2	11.8
10	17.3	20.4
14	17.1	25.2
SEM	3.2	3.2
Tempering moisture × steam time interaction, $P<0.10$.		

Table 3. Durability of Flaked Corn Samples After Tumbling With (Modified) or Without (Unmodified) Six Hexagonal, 0.5-inch Nuts for 10 Minutes in a Multi-Chambered Durability Tester. Flaked Corn Samples Were Tempered with 0 or 0.09 oz/gallon of Grain Prep Surfactant for 2 Hours and Flaked to Densities of 28, 26, or 24 lb/bushel

Item	Unmodified	Modified
Grain Prep, oz/gallon	---------- % retained of 0.37 inch screen ----------	
0.00	47.2	15.6
0.09	48.0	17.7
SEM	4.2	3.0
P-value	0.58	<0.05
Flake density, lb/bushel		
28	45.9	14.2
26	45.8	15.2
24	51.1	20.6
SEM	4.3	3.4
P-value, linear effect	<0.05	<0.01

Cattlemen's Day 2003

HIGH MOISTURE TEMPERING OF CORN BEFORE FLAKING: EFFECTS ON BACTERIAL CONTAMINATION FROM HOUSEFLIES AND FECAL SHEDDING IN FINISHING CATTLE

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Summary

Tempered and non-tempered steam-flaked corn samples along with total mixed rations containing either tempered or non-tempered steam-flaked corn were exposed to flies and the environment for 21 hours. Exposure to flies and the environment increased ($P<0.05$) generic *E. coli*, non-*E. coli* coliforms, total coliforms, and total plate count for the steam-flaked corn samples independent of tempering. Tempering corn before steam-flaking increased total plate counts. Exposure to the environment and flies did not significantly ($P>0.05$) alter microbial counts of total mixed rations regardless of tempering (Table 1). Generic *E. coli* coliforms were greater in total mixed rations when the corn was tempered, both before and after exposure to flies and the environment ($P<0.05$). Similarly, total microbial plate counts were higher in steam-flaked corn samples when the corn was tempered ($P<0.05$). A significant increase in response to grain tempering was also noted in non-*E. coli* coliforms and total microbial plate counts for the total mixed ration samples after exposure (Table 1).

Following the initial experiments, 96 finishing beef steers were used to evaluate the effects of tempering steam-flaked corn on acid-resistant *E. coli* and total fecal coliforms. On day 56 of the feeding period, fecal samples were collected and analyzed for total and acid-resistant *E. coli* and coliforms. No significant treatment difference was observed in the total fecal coliforms ($P>0.05$), but acid-resistant (pH 2) non-*E. coli* and total fecal coliforms (Table 2) were lower in feces of cattle fed the tempered grain than those fed non-tempered grain.

Introduction

Visual observations at the Beef Cattle Research Center suggest that houseflies (*Musca domestica*) have an affinity for tempered steam-flaked corn as compared to non-tempered steam-flaked corn. High moisture tempering of whole shelled corn prior to flaking resulted in significantly higher moisture content (37%) of the flaked corn as compared to industry standards (20%). The end product of the tempering process that attracts the flies is not known. Recent research indicates that houseflies are a common carrier of pathogens such as *Salmonella* and *Escherichia coli* (*E. coli*) O157:H7. Considering both issues, one might conclude that tempering steam-flaked corn may attract more flies and pathogens resulting in higher number of food-borne pathogens shed by the cattle. We hypothesized that the tempered steam-flaked corn would have higher levels of *E. coli* coliforms and that the cattle receiving the tempered total mixed ration would shed higher numbers of fecal coliforms.

Experimental Procedures

Trial 1

High moisture tempering of the whole shelled corn was achieved by mixing corn with water in a stationary mixer periodically for 24 hours. The tempered corn was then

flaked to a bulk density of 26 lb/bushel resulting in final moisture content of 37%. Non-tempered whole shelled corn was also flaked to the same bulk density as the tempered steam-flaked corn samples. To determine initial bacterial counts, 250-gram aliquots of tempered and non-tempered corn were sampled directly from the steam flaker following completion of the flaking process and immediately refrigerated. An additional 70 lb sample of each corn treatment was acquired and left exposed to the environment and flies for the next 21 hours, samples were then aseptically mixed completely and thoroughly by hand. Random grab samples were used to acquire a 250-gram aliquot, which was refrigerated prior to enumeration of microbial populations. Samples of the total mixed ration were taken directly from the unloading chute of the feed truck mixer following mixing of the ration. Samples of the total mixed rations were collected and refrigerated immediately in order to determine the initial bacterial counts. Five pounds of each of the tempered and non-tempered rations were also exposed to the environment and flies for 21 hours. Samples were then serially diluted in 0.1% peptone water and plated onto both Petrifilm™ and Tryptic Soy Agar petri plates. All plates were incubated for 48 hours at 37°C and enumerated.

Trial 2

Twelve pens with eight steers each received total mixed rations containing either tempered or non-tempered steam-flaked corn. Fecal samples were collected on day 56 of the feeding period. Composite pen samples made using fecal grab samples from individual animals were mixed thoroughly and refrigerated. Fecal samples from each pen were adjusted to pH 2 or 7 for 15 minutes to ascertain total and acid-resistant coliforms and *E. coli.* The pH 2 samples were then neutralized to pH 7 with 1 M NaOH. Serial dilutions were made and plated on Petrifilm. The plates were incubated for 48 hours at 37ºC and enumerated.

Results and Discussion

Trial 1

Generic *E. coli* coliforms, total coliforms, and total plate counts were all numerically higher for the tempered steam-flaked corn samples than for their non-tempered counterparts (Table 1). Non-*E. coli* coliforms, generic *E. coli* coliforms, total coliforms, and total plate counts were all numerically higher for the tempered total mixed rations than for their non-tempered counterparts (Table 1). Exposure to flies and environment significantly increased non-*E. coli* coliforms, generic *E. coli*, total coliforms, and total plate counts for the tempered and non-tempered steam-flaked corn samples ($P<0.05$). Exposure of tempered and non-tempered total mixed rations did not significantly change the microbial counts. Higher background microbial counts of the other ingredients in the ration are probably the reason the differences were not significant.

Trial 2

According to the data from Trial 1, cattle fed the tempered ration would consume more microorganisms than the cattle receiving the non-tempered ration. This is in agreement with our original hypothesis. The pH 7 fecal coliforms shed by the cattle were not significantly different between the rations containing tempered and non-tempered steam-flaked corn (Table 2). However, contrary to our hypothesis cattle receiving the non-tempered rations actually shed more acid-resistant coliforms than the cattle fed the rations containing the tempered steam-flaked corn (Table 2).

Competitive exclusion organisms and/or changes in the ruminal environment would be possible causes for the significant differences in the shedding of acid-resistant coliforms. Possibly the higher moisture contents of the tempered rations fostered the growth of competitive organisms that reduced the acid-

resistant coliforms. Perhaps less substrate was passed on to the large intestine of the cattle fed the ration containing tempered steam-flaked corn resulting in less substrate for the proliferation of acid resistant coliforms.

Table 1. Bacterial Counts in Steam-Flaked Corn and Total Mixed Rations Before (Initial) and After (Final) Environmental Exposure (Trial 1)

Steam-Flaked Corn	Initial	Final
Non-*E. coli* coliforms	------- Log_{10} colony forming units/gram -------	
Non-Tempered	0.47	2.65†
Tempered	0.20	2.32†
Generic *E. coli*		
Non-Tempered	0.20	2.00†
Tempered	0.87	3.19†
Total coliforms		
Non-Tempered	0.20	2.44†
Tempered	0.88	3.33†
Total Plate Count[a]		
Non-Tempered	3.86	5.49†
Tempered	5.78*	8.19*†
Total Mixed Ration		
Non-*E. coli* coliforms		
Non-Tempered	3.22	3.05
Tempered	4.07	4.67*
Generic *E. coli*		
Non-Tempered	1.88	2.16
Tempered	3.46*	4.03*
Total coliforms		
Non-Tempered	3.26	3.16
Tempered	4.19	4.76
Total Plate Count[a]		
Non-Tempered	7.02	6.44
Tempered	7.63	8.60*

[a]Total aerobic fastidious and non-fastidious microorganisms.
*Value for tempered product is significantly greater than value for corresponding non-tempered product ($P<0.05$).
†Value after exposure is significantly greater than value for corresponding initial value ($P<0.05$).

Table 2. Fecal Coliform Levels from Steers Receiving Total Mixed Rations Containing Either Tempered or Non-tempered Steam-Flaked Corn (Trial 2)

Fecal Coliforms	Non-tempered	Tempered	P-value[a]
Total Coliforms (pH 7)	---- Log_{10} colony forming units/gram ----		
E. coli	6.29	6.18	0.70
Non-*E. coli*	5.60	5.57	0.96
Total	6.45	6.33	0.80
Acid-resistant Coliforms (pH 2)			
E. coli	1.33	0.85	0.09
Non-*E. coli*	2.29	0.85	0.01
Total	2.49	0.85	0.002

[a]Probability that differences of the magnitude observed were due to random chance.

EFFECTS OF SUPPLEMENTAL PROTEIN REMOVAL ON TOTAL AND ACID-RESISTANT *E. COLI,* TOTAL COLIFORMS, AND PERFORMANCE IN FINISHING STEERS

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Summary

Fifty-four crossbred finishing steers were used to measure the effects of reducing supplemental protein (nitrogen) on feedlot performance and fecal shedding of acid-resistant *Escherichia coli* and total coliform bacteria. A control diet (15.0% crude protein; high protein) was compared to a low protein diet (8.9% crude protein; low protein) from which supplemental nitrogen sources (urea and soybean meal) were removed for the last 8 days of the feeding period. Fecal *E. coli* and coliform populations were measured prior to harvest. Removal of supplemental nitrogen from feedlot cattle diets did not substantially reduce populations of acid-resistant fecal *E. coli* and coliforms. Fecal pH tended to be lower ($P=0.11$) and the molar percentage of fecal isobutyrate and valerate were lower ($P<0.05$) for steers receiving low protein diets, but total fecal volatile fatty acid concentrations were not affected by dietary treatment. Dry matter intake tended to be lower ($P<0.10$) for steers fed low protein diets, whereas daily gains, feed:gain, final weights, dressing percentages, and carcass characteristics were similar for cattle fed low and high protein diets.

Introduction

The Centers for Disease Control estimates that about 74,000 cases of illness due to enterohemorrhagic *E. coli* O157:H7 occur annually in the United States. Cattle are a principal reservoir of *E. coli*, and ground beef is the major source of transmission. The disease can cause diarrhea, hemorrhagic colitis, and/or kidney damage that eventually may result in hemolytic uremic syndrome. *E. coli* O157:H7 is known to resist the human gastric barrier and proliferate in the lower gastrointestinal tract. The survival of *E. coli* in the human gastrointestinal tract may be enhanced by preconditioning bacteria to acidic conditions prior to infection. Development of acid resistance by *E. coli* may be induced by protein(s) that exist in high grain diets of ruminants. It has been documented that the presence of protein in culture medium confers acid resistance to *E coli*. Decarboxylation of protein elevates pH in the micro-environment surrounding the organism, thus enabling it to survive in harsh acidic environments. Increases in local pH may reduce the susceptibility of *E. coli* to the acidity of the human gastric defense system. Previous research at Kansas State University indicated a tendency for lower populations of fecal *E. coli* and coliforms capable of surviving a pH 2 acid shock when supplemental nitrogen was removed from the diet for 48 hours. In commercial cattle feeding operations, precise slaughter dates can be difficult to predict, making short-term reductions in pathogen shedding management intensive. Extending that time by reducing protein levels in finishing cattle diets one or two weeks prior to shipping, without sacrificing performance, could help reduce the risks of *E. coli* contamination prior to and during harvest. This approach would be more manageable for commercial operations, allowing for greater flexibility in marketing of fed cattle. In addition, lower feed costs can be expected with the reduction of dietary protein during this period. The objective of this experiment

was to measure the effects of removing supplemental nitrogen from finishing diets on generic *E. coli* and coliform populations 8 days prior to harvest while examining resulting cattle performance and carcass characteristics.

Experimental Procedures

Fifty-four crossbred steers were used in this experiment. Steers were housed in open lot, dirt-floor pens with fence-line waters that were cleaned twice weekly. Steers were adapted to a common high-concentrate, flaked corn-based finishing diet and allowed *ad libitum* access to feed for 12 days. On day 13, fecal grab samples were collected to establish baseline *E. coli* and coliform populations. Then, steers were provided diets (Table 1) with 15.0% crude protein (high protein) or 8.9% crude protein (low protein). High protein diets contained supplemental urea and soybean meal, whereas urea and soybean meal were replaced with steam-flaked corn in the low protein diets. On day 21, final fecal *E. coli* and coliform populations were measured for both groups of cattle. Upon arrival at the laboratory, fecal samples were combined with a citrate buffer (pH 7 or 2) for determination of total and acid-resistant *E. coli* and coliforms. Samples were serially diluted, plated onto *E. coli*/coliform Petrifilm™, incubated at 35°C for 24 hours, and enumerated. Steers were harvested on day 22. Animal performance and carcass traits were evaluated in each group to quantify effects of short-term removal of supplemental protein. Five steers of different breeds and similar finish were selected from the high protein treatment to participate in a market steer judging event after the final fecal sampling period. Bacterial counts from these five animals were used in the final analysis of the data, but unfortunately performance and carcass characteristics were not obtained from these animals.

Results and Discussion

Removal of supplemental protein from finishing cattle diets did not significantly affect populations of total and acid-resistant fecal *E. coli* and coliforms (Table 2). Previous research at Kansas State University indicated that when supplemental nitrogen was removed from finishing cattle diets, populations of fecal *E. coli* and coliforms dropped within the initial two days after removal, but tended to be higher at later sampling times. The data suggests that the microflora inhabiting the lower gastrointestinal tract of cattle may adapt to the nitrogen deficit over time. In the present study, the relatively small change in bacterial populations (3.06 to 2.75 log colony forming units/gram wet feces for acid-resistant *E. coli* and 3.18 to 2.84 colony forming units/gram wet feces for acid-resistant coliforms) following removal of supplemental protein may indicate that protein (nitrogen) is either nonessential as a mechanism for development of acid resistance, or that the microflora were able to adapt to this change within the 8-day period prior to the final sampling. Eliminating or reducing the adaptation of the bacteria may aid in the management of *E. coli*.

Fecal pH tended to be slightly lower for steers fed low protein diets (Table 3; $P = 0.11$). The molar percentages of fecal isobutyrate and valerate were lower ($P < 0.05$) for steers receiving low protein diets, but total fecal volatile fatty acid concentrations were not affected by dietary treatment. Dry matter intake also tended to be lower ($P<0.10$) for steers fed low protein diets, but average daily gain, feed:gain, final weights, dressing percentages, and carcass characteristics were unaffected by diet (Tables 4 and 5). Because performance was not affected by dietary treatment, the data suggests that there may be additional economic incentives to removing supplemental nitrogen in finishing diets to reduce feed costs. Additional large scale

studies analyzing cost of gain and performance are warranted.

Populations of fecal *E. coli* and coliforms, performance, and carcass characteristics were not significantly affected by removal of supplemental nitrogen from finishing cattle diets 8 days prior to harvest.

Table 1. Composition of Experimental Diets (% of Dry Matter)

Item	High Protein[a]	Low Protein[b]
Steam-flaked corn	75.67	81.08
Alfalfa hay	5.78	5.77
Cane molasses	4.88	4.89
Soybean meal, 52% crude protein	4.37	-
Tallow	4.11	4.11
RT premix[c]	2.27	2.26
Urea	1.22	-
Limestone	1.34	1.38
Sodium chloride	0.30	0.30
Potassium chloride	0.02	0.18
Vitamin/trace mineral premix[d]	0.04	0.04
Crude protein, analyzed	15.0	8.9

[a]High Protein = 15.0% crude protein.
[b]Low Protein = 8.9% crude protein.
[c]RT premix = provided 33.3 grams/ton Rumensin® and 10 grams/ton Tylan® in a ground corn carrier.
[d]Formulated to provide (total diet dry matter): 1,200 IU/lb vitamin A, 0.1 ppm cobalt, 0.5 ppm iodine, 50 ppm manganese, 0.3 ppm selenium, 50 ppm zinc, and 8.3 ppm copper.

Table 2. Effect of Diet and Buffer Treatment on Fecal *E. coli* and Coliforms

	Treatment		
Item	High Protein[1]	Low Protein[2]	SEM
Fecal *E. coli*[a]	------$\log_{10}$ colony forming units/gram wet feces-----		
Buffer treatment			
pH 2	3.06	2.75	0.37
pH 7	5.93	5.87	0.36
Fecal Total Coliforms[a]			
Buffer treatment			
pH 2	3.18	2.84	0.37
pH 7	5.95	5.95	0.37

[1]High Protein = 15.0% crude protein.
[2]Low Protein = 8.9% crude protein.
[a]Detection limit = 1.18 $\log_{10}$ colony forming units/gram wet feces.

Table 3. Effects of Supplemental Nitrogen 8 Days Prior to Slaughter on Fecal pH and Volatile Fatty Acid Proportions

	Treatment		
Item	High Protein[1]	Low Protein[2]	SEM
Fecal pH	6.81	6.66	0.08
Total volatile fatty acids, m*M*	78.7	75.8	5.51
Acetate:propionate	3.96	3.57	0.26
	---------- m*M* ----------		
Acetate	53.3	49.9	3.61
Propionate	14.2	15.1	1.75
Butyrate	7.3	7.6	0.81
Isobutyrate	0.87[a]	0.45[b]	0.16
Valerate	0.95[a]	0.74[b]	0.08
Isovalerate	2.21	1.93	0.17

[1]High Protein = 15.0% crude protein.
[2]Low Protein = 8.9% crude protein.
[a,b]Means with different superscript differ ($P<0.05$).

Table 4. Effects of Removing Supplemental Protein 8 Days Prior to Slaughter on Performance in Finishing Steers

	Treatment[1]		
Item	High Protein[2]	Low Protein[3]	SEM
No. of steers	22	27	
Live weight			
day 1	1092	1122	39
day 13	1145	1177	40
day 21	1163	1188	42
Carcass adjusted live weight [a]			
day 21	1161	1192	46
Dry matter intake, lbs/day			
day 1 to 13	19.78	19.94	0.63
day 13 to 21	20.75[d]	19.31[e]	0.76
Gain, lbs/day			
day 1 to 13	4.42	4.58	0.32
day 13 to 21	2.25	1.38	0.31
Carcass adjusted gain, lbs/day [b]			
day 13 to 21	2.00	1.88	0.68
Feed:gain			
day 1 to 13	4.48	4.35	0.47
day 13 to 21	9.2	14.0	4.1
Carcass adjusted feed:gain [c]			
day 13 to 21	10.4	10.3	9.6

[1]Steers were placed onto a common diet on day 1. Starting on day 13, initial baseline *E coli*/coliform populations were obtained. Low protein steers were switched to a diet containing no supplemental protein (soybean meal or urea) or non-protein nitrogen; High protein cattle were left on the initial diet. Steers were fed for eight days, final *E. coli*/coliform populations were obtained, then harvested on day 22.
[2]High protein = 15.0% crude protein
[3]Low protein = 8.9% crude protein
[a]Carcass adjusted live weight = carcass weight ÷ common dressing percent of 61.74%.
[b]Carcass adjusted gain = (adjusted live weight – initial weight) ÷ days on feed.
[c]Carcass adjusted gain:feed = adjusted daily gain ÷ dry matter intake.
[d,e]Means with different superscript differ (P<0.10).

Table 5. Effects of Removing Supplemental Protein 8 Days Prior to Slaughter on Carcass Traits of Finishing Steers

	Treatment		
Item	High Protein[1]	Low Protein[2]	SEM
No. of steers	22[a]	27	
Hot carcass weight, lb	717	736	28
Dressing percent, %[b]	61.6	61.9	0.66
Yield grade	2.52	2.30	0.17
Back fat, inches	0.41	0.36	0.04
Kidney, pelvic & heart fat, %	2.06	2.18	0.08
Ribeye area, square inches	11.61	12.40	0.55
USDA quality grade, %			
Choice or Prime	22.2	37.0	11.4
Select	64.8	59.3	5.3
Standard	13.0	3.7	7.6

[1]High Protein = 15.0% crude protein.
[2]Low Protein = 8.9% crude protein.
[a]Five steers were removed after day 21 prior to harvest.
[b]Dressing percent = hot carcass weight ÷ live weight before shrink.

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PERFORMANCE AND CARCASS CHARACTERISTICS OF YEARLING STEERS AND HEIFERS FED AGRADO™ THROUGHOUT THE FINISHING PERIOD

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Summary

A finishing experiment was conducted at a commercial feedlot facility in Larned, Kansas, using 3,295 yearling steers and heifers to evaluate effects of Agrado™ addition to finishing diets. Agrado (ethoxyquin) is a dietary anti-oxidant that protects against oxidative loss of critical vitamins and prevents rancidity and unpalatable odors. Supplementing finishing diets of yearling steers and heifers with 150 ppm Agrado had no measurable effects on growth performance or carcass characteristics.

Introduction

Previous research has indicated that cattle performance may be improved by the inclusion of the antioxidant Agrado™ (ethoxyquin) into cattle diets. Recently, experiments have reported slight improvements in rate and efficiency of gain in cattle fed Agrado for 28 days prior to harvest. Other studies have noted reductions in morbidity, mortality, and treatment costs when cattle were fed Agrado. Research suggests improvements in performance in cattle supplemented with Agrado may be due to an increase in organic matter digestion. Additionally, Agrado may also alter fermentation patterns and contribute to a healthier gut mucosa, as well as decrease oxidation during digestion and absorption.

Currently, information is limited regarding the efficacy of grade supplementation throughout the finishing phase. Our objective was to assess the impact of Agrado supplementation on performance and carcass characteristics of finishing steers and heifers.

Experimental Procedures

Steers (n=1780; 745 lb initially) and heifers (n=1515; 679 lb initially) were transported from winter cereal pastures to a commercial feedlot in Larned, Kansas. Upon arrival, cattle were eartagged, implanted with estrogenic implants, vaccinated against common viral and clostridial diseases, and treated for internal and external parasites.

Cattle within each load were split into two groups based on order of processing, such that even-numbered cattle were placed into one group and odd-numbered cattle were placed into another. Groups were placed into feedlot pens averaging approximately 165 animals per pen. Cattle were sorted by gender (steers and heifers) and blocked by date of arrival. A total of five replications of steers and five replications of heifers were used (20 pens total).

Dietary treatments consisted of 0 or 150 ppm of dietary Agrado (as-fed basis), which was included into the finishing diet (Table 1) by using a micro ingredient machine. Agrado was provided by Solutia, Inc., St. Louis, MO. Cattle were adapted to the final finishing diet within 20 days after arrival. Heifers were reimplanted with a trenbolone acetate implant and steers were reimplanted with a combination trenbolone acetate/estradiol implant approximately 50 to 70 days after arrival. Cattle were fed for an average of 131 days. Pens of cattle were shipped to a commercial abattoir in Emporia, Kansas when they achieved an estimated 12th rib fat thickness of 0.40 inch. An equal number of pens from each treatment were shipped on each slaughter date.

Data obtained for each pen of cattle included weight gain, feed intake, feed efficiency, carcass weight, dressing percentage, USDA quality grade, USDA yield grade, incidence and severity of liver abscess, and incidence of dark cutting beef.

Table 1. Composition of Experimental Diets (DM Basis)

	Agrado	
Item	0	150 ppm
Steam-flaked corn	64.0	64.0
Wet distiller's grains	14.0	14.0
Mixed silage	6.0	6.0
Wheat middlings	6.0	6.0
Liquid supplement[a]	5.3	5.3
Tallow	2.7	2.7
Corn screenings	2.0	2.0
Agrado	-	+[b]
Nutrient, calculated		
Crude protein	15.2	15.2
Calcium	0.73	0.73
Phosphorus	0.40	0.40

[a]Provided 30 g/ton Rumensin, and 10 g/ton Tylan to complete diet (dry matter basis).
[b]Provided 150 ppm ethoxyquin (as-fed basis).

Results and Discussion

Supplementation of Agrado to yearling steers and heifers at 0 or 150 ppm in finishing diets resulted in similar dry matter intakes, average daily gains, and feed efficiencies (Tables 2 and 3). Carcass weights were essentially the same for control and Agrado-supplemented steers and heifers ($P>0.90$), but dressing percentage was lower for Agrado-supplemented heifers than for controls (64.0 vs. 64.3%, respectively; $P<0.05$). However, these differences can be attributed to the slightly higher number of pregnancies among Agrado-supplemented heifers compared to controls (2.2 vs 0.8%, respectively). Percentages of USDA Prime, Choice, Select, and Standard carcasses were not influenced by Agrado supplementation. Furthermore, percentages of USDA Yield Grade 1, 2, 3, 4, and 5 carcasses were similar for control and Agrado-supplemented groups.

Responses to antioxidants are likely dependent on degree of stress and the nutritional background of the cattle. The yearling steers and heifers used in this experiment were healthy, low health-risk cattle that previously grazed high-quality annual cereal pastures, perhaps limiting the potential for response to antioxidant supplementation.

Table 2. Finishing Performance and Carcass Characteristics of Heifers Fed Diets Containing 0 or 150 ppm Agrado

	Agrado			
Item	0	150 ppm	SEM	P-value
No. of heifers	758	757	-	-
No. of pens	5	5	-	-
Average days on feed	128	128	-	-
Initial weight, lb	680	677	4.0	0.61
Final weight, lb	1126	1133	4.6	0.33
Dry matter intake, lb/day	20.24	20.64	0.28	0.34
Average daily gain, lb	3.49	3.56	0.06	0.38
Feed:gain	5.82	5.82	0.04	0.97
Dressing percentage	64.32	64.03	0.07	0.03
Hot carcass weight, lb	725	726	2.9	0.94
USDA Yield grade 1, %	16.1	14.0	2.1	0.49
USDA Yield grade 2, %	27.5	30.4	1.4	0.17
USDA Yield grade 3, %	47.8	46.8	2.3	0.77
USDA Yield grade 4, %	7.7	8.0	1.0	0.82
USDA Yield grade 5, %	0.8	0.7	0.27	0.91
USDA Prime, %	2.1	1.5	0.63	0.53
USDA Choice, %	49.2	53.2	4.3	0.52
USDA Select, %	44.0	40.0	3.7	0.47
USDA Standard, %	3.2	3.8	0.55	0.51
Dark cutter, %	0.8	0.8	0.57	1.00
Liver abscess, %	6.0	7.8	1.4	0.38

Table 3. Finishing Performance and Carcass Characteristics of Steers Fed Diets Containing 0 or 150 ppm Agrado

	Agrado			
Item	0	150 ppm	SEM	P-value
No. of steers	890	890	-	-
No. of pens	5	5	-	-
Average days on feed	133	133	-	-
Initial weight, lb	742	747	3.4	0.42
Final weight, lb	1248	1247	6.5	0.92
Dry matter intake, lb/day	20.94	21.15	0.14	0.31
Average daily gain, lb	3.85	3.82	0.02	0.36
Feed:gain	5.45	5.55	0.05	0.22
Dressing percentage	64.35	64.44	0.18	0.72
Hot carcass weight, lb	803	804	5.4	0.91
USDA Yield grade 1, %	15.5	19.5	2.8	0.34
USDA Yield grade 2, %	35.9	36.9	2.4	0.76
USDA Yield grade 3, %	39.8	37.6	3.2	0.63
USDA Yield grade 4, %	8.5	5.8	1.0	0.11
USDA Yield grade 5, %	0.2	0.2	0.09	0.95
USDA Prime, %	0.8	0.5	0.26	0.42
USDA Choice, %	35.7	37.8	2.1	0.50
USDA Select, %	56.0	54.8	1.7	0.63
USDA Standard, %	7.1	6.4	1.2	0.66
Dark cutter, %	0.1	0.0	0.12	0.42
Liver abscess, %	10.4	8.6	1.2	0.32

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EFFECT OF FULL-FAT CORN GERM AND VITAMIN E ON FINISHING PERFORMANCE AND CARCASS CHARACTERISTICS OF BEEF HEIFERS

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Summary

Eight hundred eighty-eight crossbred beef heifers weighing 837 lb were used in a 105-day finishing study to evaluate full-fat corn germ as a lipid source and added vitamin E in finishing diets containing steam-flaked corn. Treatments were arranged in a 2 × 4 factorial and consisted of finishing diets formulated to provide no added fat (Control), 4% tallow (Tallow), or 10% or 15% full fat corn germ on a dry matter basis (10%FFG and 15%FFG, respectively) with or without 2000 IU of additional vitamin E per heifer daily. No fat × vitamin E interaction was detected. Fat addition decreased ($P<0.01$) dry matter intake and tended ($P<0.09$) to improve gain efficiency, but marbling score and the number of carcasses grading USDA Choice were decreased by fat additions ($P<0.01$). Tallow and 10%FFG yielded similar finishing performance and carcass characteristics. Increasing full fat corn germ led to linear decreases ($P<0.05$) in dry matter intake, average daily gain, final body weight, and hot carcass weight, as well as marbling score and the number of carcasses grading USDA Choice. Gain efficiency was increased by addition of full fat corn germ at 10% of the diet, but not at 15% of the diet. Addition of full fat corn germ to the diet tended (linear, $P<0.06$) to decrease the incidence of liver abscesses. Addition of vitamin E did not affect finishing performance ($P>0.12$). This study suggests that full fat corn germ can serve as a supplemental lipid source for finishing cattle. Responses to 10% full fat corn germ were similar to those obtained when an equal amount of fat from tallow was incorporated into the diet.

Introduction

Full-fat corn germ is a byproduct of corn wet milling and traditionally has been used for corn oil production. Full-fat corn germ contains approximately 45% lipid and 12% crude protein on a dry matter basis and has been used successfully as a fat source in finishing diets containing dry-rolled corn. Vitamin E is a fat-soluble vitamin that serves as an antioxidant, is involved in lipid metabolism, and has been shown to increase the shelf life of red meat. Our objectives were to evaluate the effects of full-fat corn germ as a lipid source in finishing diets containing steam-flaked corn as well as the effects of added vitamin E in finishing diets containing various concentrations of added fat on finishing performance and carcass characteristics.

Experimental Procedures

Eight hundred eighty-eight crossbred beef heifers weighing 837 lb were processed over 8 days. Processing included vaccination against respiratory and clostridial diseases and implanting with Revelor H®. Immediately following processing, heifers were randomly assigned to dirt-surfaced pens so that each pen contained between 14 and 23 heifers each, depending on pen size. Pen served as the experimental unit, and pens were blocked by date of implanting. Dietary treatments (Table 1) consisted of finishing diets formulated to provide no added fat (Control), 4% tallow

(Tallow), or 10% or 15% full fat corn germ on a dry matter basis (10%FFG and 15%FFG, respectively) with or without 2000 IU of additional vitamin E per heifer daily. Treatments were assigned randomly to pens within each block. A total of 48 pens were used, providing six pens per treatment. Heifers were maintained on the control diet until all heifers were processed, upon which time heifers were weighed and their respective dietary treatments were initiated. Diets were fed once daily and were offered for ad libitum consumption. At the end of the 105-day finishing period, each pen of heifers was weighed and transported to a commercial slaughter facility. Hot carcass weights and the incidence of liver abscesses were recorded at time of slaughter. Other carcass traits were measured following a 24-hour chill.

Results and Discussion

The effects of fat addition and full-fat corn germ on finishing performance and carcass characteristics are shown in Table 2. Fat addition decreased ($P<0.01$) dry matter intake and tended ($P<0.09$) to improve gain efficiency when compared to Control, although marbling score and the percentage of carcasses grading USDA Choice were decreased ($P<0.01$) in response to supplemental fat. Whether this was an effect of decreased feed intake or an effect of fat on marbling is not known. Tallow and 10%FFG yielded similar finishing performance and carcass characteristics, suggesting that including full-fat corn germ at 10% in finishing diets can effectively replace 4.2% tallow as a fat source. Increasing full fat corn germ decreased dry matter intake (linear, $P<0.01$), daily gains (linear, $P<0.03$), final body weight (linear, $P<0.02$), hot carcass weight (linear, $P<0.02$), as well as marbling score (linear, $P<0.01$) and the number of carcasses grading USDA Choice (linear, $P<0.01$). Gain efficiency was improved when 10% full fat corn germ was added to the diet, but this benefit was lost when it was added at 15% of the diet (quadratic, $P<0.03$). Increasing full fat corn germ tended (linear, $P<0.06$) to reduce the incidence of liver abscesses. Decreases in liver abscesses could be a result of decreased feed intake, or possibly some antimicrobial property of full-fat corn germ that suppressed the growth of bacteria responsible for liver abscesses.

The addition of vitamin E did not affect finishing performance, but it did marginally increase ($P<0.04$) the number of carcasses grading USDA Select and decrease ($P<0.05$) the number of carcasses grading USDA Standard (Table 3). This effect on carcass quality might have been due to the anti-oxidant property of vitamin E.

This study suggests that full fat corn germ can serve as a supplemental fat source for finishing cattle. Responses were similar to those obtained when an equal amount of fat from tallow was incorporated into the diet. Furthermore, providing finishing cattle an additional 2,000 IU of vitamin E daily does not affect finishing performance but may marginally affect carcass characteristics.

Table 1. Experimental Diets (% of Dry Matter)

	Treatment			
Item	Control	Tallow	10%FFG	15%FFG
Steam-flaked corn	48.6	43.6	38.8	33.9
Wet corn gluten feed	35.2	35.2	35.2	35.2
Alfalfa hay	4.1	4.1	4.1	4.1
Full-fat corn germ	-	-	10.5	15.7
Tallow	-	4.2	-	-
Corn steep liquor	8.0	8.0	8.0	8.0
Dehulled soybean meal	2.0	2.8	1.3	1.0
Limestone	1.7	1.7	1.7	1.7
Salt	0.30	0.30	0.30	0.30
Vitamin/mineral premix[a]	0.10	0.10	0.10	0.10
RTM premix[b]	+	+	+	+
Crude protein, analyzed	16.2	16.2	16.3	16.3
Crude fat, calculated	3.2	7.0	7.7	10.0

[a]Formulated to provide 0.1 ppm cobalt, 10 ppm copper, 0.6 ppm iodine, 0.2 ppm iron, 60 ppm manganese, 0.3 ppm selenium, 60 ppm zinc, 1,000 IU/lb vitamin A, and either no vitamin E or 2,000 IU of vitamin E daily.

[b]Fed at 0.44 lb per heifer daily (dry matter basis) and provided 300 mg/day Rumensin®, 90 mg/day Tylan®, and 0.5 mg/day melengestrol acetate.

Table 2. Finishing Performance and Carcass Characteristics of Heifers Fed Diets Containing No Added Fat (Control), 4% Tallow (Tallow), or 10 and 15% Full fat Corn Germ (10%FFG and 15%FFG, respectively)

	Treatment					Contrast[a]			
Item	Control	Tallow	10%FFG	15%FFG	SEM	1[b]	2[c]	3[d]	4[e]
Number of heifers	220	222	224	222	-	-	-	-	-
Number of pens	12	12	12	12	-	-	-	-	-
Initial weight, lb	826	826	822	822	6.6	0.76	0.70	0.67	0.91
Final weight, lb[f]	1130	1130	1131	1106	6.3	0.25	0.88	0.02	0.04
Dry matter intake, lb/day	19.5	18.6	18.7	18.0	0.17	< 0.01	0.76	< 0.01	0.37
Average daily gain, lb	2.84	2.83	2.88	2.65	0.053	0.34	0.54	0.03	0.02
Gain:feed	0.146	0.152	0.154	0.147	0.0026	0.09	0.62	0.47	0.03
Hot carcass weight, lb	725	724	725	709	4.0	0.25	0.88	0.02	0.04
Dressing percentage[g]	64.3	64.3	64.3	63.9	0.16	0.63	0.83	0.19	0.12
Fat thickness, inch	0.54	0.56	0.57	0.52	0.017	0.77	0.79	0.58	0.09
Longissimus muscle area, inch^2	13.6	13.5	13.5	13.4	0.15	0.71	0.73	0.58	0.95
Kidney, pelvic, & heart fat, %	2.4	2.3	2.4	2.4	0.03	0.35	0.06	0.33	0.13
Liver abscesses, %	8.6	8.3	4.1	3.4	2.00	0.15	0.15	0.06	0.70
Yield grade 1, %	8	13	11	11	2.2	0.11	0.58	0.23	0.60
Yield grade 2, %	35	30	23	37	3.8	0.21	0.17	0.79	0.01
Yield grade 3, %	48	43	50	43	3.7	0.52	0.14	0.49	0.25
Yield grade 4, %	9	12	15	8	2.1	0.19	0.42	0.83	0.02
Yield grade 5, %	0	2	1	1	0.5	0.12	0.24	0.41	0.54
Marbling score[h]	Sl^{95}	Sl^{67}	Sl^{78}	Sl^{62}	5.3	< 0.01	0.13	< 0.01	0.40
USDA Prime, %	1	1	1	0	0.4	0.19	1.00	0.13	0.83
USDA Choice, %	42	30	35	30	3.3	0.01	0.29	0.01	0.55
USDA Select, %	54	60	56	60	3.1	0.19	0.43	0.25	0.88
USDA Standard, %	3	9	8	10	1.8	0.03	0.45	0.02	0.62
Dark cutters, %	0	0.3	0.6	1.3	0.63	0.15	0.68	0.07	0.83

[a]Probability that effects observed were due to random chance.
[b]1 = Control vs. fat.
[c]2 = 10%FFG vs. Tallow.
[d]3 = Linear effect of full fat corn germ.
[e]4 = Quadratic effect of full fat corn germ.
[f]Final weight = hot carcass weight ÷ common dressing percentage of 64.10%.
[g]Calculated as hot carcass weight ÷ (live weight × 0.96).
[h]Sl = Slight.

Table 3. Finishing Performance and Carcass Characteristics of Heifers Fed Diets Containing No Additional Vitamin E or 2,000 IU of Added Vitamin E Per Heifer Daily

	Treatment			
Item	No Vitamin E	Added Vitamin E	SEM	P-value[a]
Number of heifers	448	440	-	-
Number of pens	24	24	-	-
Initial weight, lb	824	824	4.8	0.98
Final weight, lb[b]	1120	1128	4.6	0.18
Dry matter intake, lb/day	18.6	18.8	0.12	0.42
Average daily gain, lb	2.76	2.84	0.039	0.12
Gain:feed	0.148	0.151	0.0019	0.18
Hot carcass weight, lb	718	723	2.9	0.18
Dressing percentage[c]	64.1	64.3	0.12	0.43
Fat thickness, inch	0.55	0.55	0.012	0.91
Longissimus muscle area, inch^2	13.4	13.6	0.11	0.41
Kidney, pelvic, & heart fat, %	2.4	2.4	0.02	0.37
Liver abscesses, %	7.8	4.5	1.45	0.10
Yield grade 1, %	12	10	1.6	0.39
Yield grade 2, %	30	33	2.8	0.56
Yield grade 3, %	44	47	2.7	0.40
Yield grade 4, %	13	9	1.5	0.09
Yield grade 5, %	1	1	0.4	0.72
Marbling score[d]	Sl^{78}	Sl^{73}	3.8	0.36
USDA Prime, %	1	0	0.3	0.32
USDA Choice, %	36	33	2.4	0.31
USDA Select, %	54	61	2.3	0.04
USDA Standard, %	9	6	1.3	0.05
Dark cutters, %	0.2	0.8	0.45	0.33

[a]Probability that effects observed were due to random chance.
[b]Final weight = hot carcass weight ÷ common dressing percentage of 64.10%.
[c]Calculated as hot carcass weight ÷ (live weight × 0.96).
[d]Sl = Slight.

Cattlemen's Day 2003

COMPARISON OF DRIED FULL-FAT CORN GERM AND TALLOW IN FINISHING FEEDLOT DIETS FOR HEIFERS

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Summary

A trial was conducted using 588 finishing beef heifers (705 lb initially) to compare tallow and dried full-fat corn germ as supplemental energy sources. Pens of 20 to 50 heifers were fed finishing diets containing 1) tallow or 2) corn germ. The tallow diet contained (dry basis) 46% steam-flaked corn, 35% wet corn gluten feed, 3% alfalfa hay, 1.5% soybean meal, and 4% tallow. The corn germ diet contained 41% steam-flaked corn, 35% wet corn gluten feed, 3% alfalfa hay, and 10% corn germ. Diets provided 300 mg monensin, 90 mg tylosin, and 0.5 mg MGA per heifer daily and were fed ad libitum once daily for 110 days. Gains of 2.99 lb/day for tallow and 2.95 lb/day for corn germ were not different (P>0.30), but dry matter intake tended to be greater for cattle fed corn germ than for those fed tallow (P=0.10; 16.7 vs 16.4 lb/day, respectively). Consequently, cattle fed germ were 3.4% less efficient than cattle fed tallow (P<0.04). Hot carcass weight was not different (P>0.40) between treatments. Cattle fed corn germ had more carcasses grading prime (P=0.03), more carcasses grading average choice or higher (P<0.05), and tended to have more marbling (P=0.08) than cattle fed tallow. Incidence of liver abscesses was higher (P<0.02) for cattle fed corn germ than for those fed tallow (4.8% vs 1.8%, respectively). These results indicate that corn germ is a suitable substitute for tallow in finishing rations.

Introduction

Fat is commonly added to finishing diets to increase energy density and to improve efficiency of gain in feedlot cattle. Corn germ is a high-fat byproduct produced by the corn wet milling industry during the production of sweeteners and(or) fuel ethanol. Use of liquid fats such as tallow is limited to operations with special equipment such as heated tanks and pump systems. In contrast, corn germ is easily handled using conventional bins and auger systems. Corn germ also can be stored for an extended period of time without the risk of oxidative rancidity, due to its low moisture content. Corn germ contains between 46 and 54% fat, and 12 to 15% protein on a dry matter basis (Table 1) The objective of this study was to compare tallow and dried full-fat corn germ as supplemental energy sources on performance and carcass characteristics of finishing cattle.

Experimental Procedures

Five hundred eighty-eight crossbred heifers (705 ± 8 lb initially) housed in 16 pens of 20 to 50 heifers each were blocked by previous treatment (MGA or no MGA in the receiving diet) and randomly allocated to finishing diets containing 1) tallow or 2) corn germ. Diets were fed ad libitum once daily, and the amount of feed offered was determined by a 7:00 a.m. feed call so that only traces remained each day. Heifers were

[1]Minnesota Corn Processors, Marshall, MN.

implanted with Revalor-H and transitioned to their respective experimental diet. The corn germ was added to diets in amounts to provide the same amount of fat as the tallow, and it additionally replaced 4.7% steam-flaked corn and 1.5% soybean meal such that diets contained the same levels of protein (Table 2). Diets were formulated to provide 300 mg monensin, 90 mg tylosin, and 0.5 mg MGA per heifer daily. On day 100, 25% of the cattle from each treatment were shipped for slaughter. The remaining cattle were shipped on day 130. Cattle were slaughtered at a commercial abattoir in Emporia, KS, and carcass data were obtained following a 24-hour chill.

Table 1. Ingredient Composition

	Ingredient	
Item	Tallow	Corn Germ
Dry matter, %	99.9	96.1
Crude protein, %	0.0	12.8
Calcium, %	0.0	0.03
Phosphorus, %	0.0	0.33
Crude fat, %	99.9	45.0
F.O.B. cost per ton[1], $	340	285

[1]As of 1/8/03.

Results and Discussion

Table 3 summarizes the performance and carcass characteristics of cattle fed finishing diets containing tallow or dried full-fat corn germ. Gains of 2.99 lb/head for tallow and 2.95 lb/head for corn germ were not different (P>0.30), but dry matter intake tended to be greater for cattle fed corn germ than for cattle fed tallow (P=0.10; 16.7 vs 16.4 lb/day, respectively). Consequently, cattle fed germ were 3.4% less efficient than cattle fed tallow (P=0.04). Hot carcass weight was not different (P>0.40) between treatments. Cattle fed corn germ had more carcasses grading prime (P=0.03), more carcasses grading average choice or higher (P=0.04), and tended to have more marbling (P=0.08) than cattle fed tallow. The incidence of liver abscesses was higher (P=0.01) for cattle fed corn germ than for cattle fed tallow (4.8% vs 1.8%, respectively). Our results indicate that when priced appropriately corn germ is a suitable substitute for tallow as a supplemental energy source in finishing diets. For operations that are not equipped to handle liquid fat, corn germ may be an effective means of incorporating supplemental fat into the diet.

Table 2. Experimental Diets (Dry Matter Basis)

	Treatment	
Ingredient, %	Tallow	Corn Germ
Steam-flaked corn	46.2	41.4
Wet corn gluten feed	35.0	35.0
Alfalfa hay	3.0	3.0
Steep liquor	8.1	8.1
Tallow	4.1	-
Corn germ	-	10.3
Soybean meal	1.5	-
Vitamin/mineral premix[1]	1.6	1.6
R-T-MGA premix[2]	2.5	2.5
Crude protein, analyzed	12.8	12.9
Cost per ton, $[3]	78.8	75.0

[1]Formulated to provide 1660 IU/lb vitamin A, 10 IU/lb vitamin E, 0.13 ppm Co, 0.63 ppm I, 60 ppm Mn, 0.30 ppm Se, and 60 ppm Zn.
[2]Formulated to provide 300 mg monensin, 90 mg tylosin, and 0.5 mg MGA per heifer daily.
[3]As of 1/8/03.

Table 3. Performance and Carcass Characteristics of Heifers Fed Tallow or Dried Full-Fat Corn Germ

	Treatment			
Item	Tallow	Corn Germ	SEM	*P*-value
Number of heifers	285	303	-	-
Number of pens	8	8	-	-
Initial weight, lb	707	702	8.2	0.66
Final weight, lb	1047	1038	7.9	0.41
Daily gain, lb	2.99	2.95	0.03	0.33
Feed intake, lb/day	16.37	16.72	0.14	0.10
Feed:gain	5.47	5.67	-	0.04
Liver abscesses, %	1.9	4.8	0.73	0.01
Carcass weight, lb	676	670	5.1	0.42
Dressing, %	64.6	64.3	0.16	0.17
Ribeye area, inch^2	11.79	11.79	0.17	0.99
12th rib fat thickness, inch	0.54	0.55	0.01	0.80
Kidney, pelvic, & heart fat, %	2.45	2.50	0.03	0.19
Marbling score	Small30	Small49	7.0	0.08
Prime, %	2	6	1.1	0.03
Choice, %	71	66	2.5	0.18
Average Choice or greater, %	14	21	2.1	0.04
Select, %	27	27	2.7	0.98
Yield grade 1, %	3	3	0.9	0.96
Yield grade 2, %	24	25	3.1	0.83
Yield grade 3, %	55	55	2.2	0.93
Yield grade 4 & 5, %	18	17	1.8	0.78

Cattlemen's Day 2003

COMPARISON OF CONCENTRATED SEPARATOR BYPRODUCT AND CANE MOLASSES FOR FINISHING HEIFERS

E. R. Loe, J. S. Drouillard, T. J. Kessen, S. P. Montgomery, J. N. Pike, J. J. Sindt, and M. J. Sulpizio

Summary

We compared concentrated separator byproduct (CSB) to cane molasses on feedlot performance and carcass merit of 394 crossbred yearling beef heifers fed for 148 days. Sugar beet molasses undergoes a process in which approximately half of the sugar is removed, concentrating protein and mineral in CSB. Compared with cane molasses, CSB has more crude protein, ash, and moisture. Two diets based on steam-flaked corn containing either CSB or cane molasses at 5% (dry matter basis) of the diet were fed. Feedlot performance was similar between heifers fed the two diets (P>0.23). Apparent dietary concentrations of net energy for gain (NE_g), calculated from performance, were similar (P=0.21) for the CSB and cane molasses diets. The apparent NE_g for cane molasses and CSB were not statistically different (P=0.20); the NE_g concentrations of cane molasses and CSB were 0.21 and 0.50 ± 0.15 Mcal/lb, respectively. Carcass characteristics were similar between diets. Based on our data, CSB and cane molasses have a similar feeding value and energy content in beef finishing diets that are based on steam-flaked corn.

Introduction

Concentrated separator byproduct is a liquid byproduct derived through chromatographic separation of sucrose from beet molasses, reducing the concentration of sucrose by half. Reduced sucrose and increased moisture and ash have fueled the thought that CSB is inferior to cane molasses as an energy source. Inherent in this assumption is the undocumented expectation that relatively small differences in sugar content will yield measurable differences in animal performance. Unfortunately, these characterizations of CSB do not take into consideration some of its potentially valuable attributes. Relative to cane molasses, CSB contains higher levels of crude protein and potassium, both of which must be supplemented in finishing cattle diets. Additionally, CSB contains relatively high levels of betaine, which is altogether absent from cane molasses.

Previous studies at Kansas State University have evaluated betaine as a supplement for finishing cattle diets. Resulting improvements in gain, efficiency, and carcass attributes were small to moderate, but were relatively consistent and economically significant. Given the small differences in carbohydrate content, as well as the relatively low dietary inclusions of cane molasses and CSB in finishing diets, it seems unlikely that differences in sugar content of the two products would result in measurable differences in animal performance. However, improvements due to betaine supplementation are, in fact, possible. Nutrient analyses of cane molasses and CSB are listed in Table 1.

Our objective was to compare performance during the finishing period and carcass characteristics of beef heifers fed diets containing either CSB or cane molasses.

Experimental Procedures

Crossbred yearling heifers (n = 394; 658 ± 4 lb initially) were fed for 148 days. The heif-

ers were allocated to 24 feedlot pens. Twelve pens were fed a diet containing CSB; 12 pens were fed a diet containing cane molasses. Diet compositions and actual nutrient levels are listed in Table 2. Both diets were formulated to provide a minimum 14% crude protein, 0.7% calcium, 0.3% phosphorus, 0.7% potassium, 300 mg/heifer monensin daily, 90 mg/heifer tylosin daily, and 0.5 mg/heifer melengestrol acetate daily. During processing heifers were vaccinated against viral (Bovishield-IV®) and clostridial (Fortress-7®) diseases, implanted with Component EH®, treated for internal and external parasites with Eprinex® pour-on, and administered a metaphylactic dose of Micotil®.

The statistical design of this study was a randomized complete block design with a 2 × 2 factorial arrangement of treatments; factors were CSB or cane molasses and high or low blood glucose measured at arrival. Data related to blood glucose is not presented, but blood glucose did not interact with diet to affect any criteria.

Cattle were blocked by initial glucose concentrations and allotted to feedlot pens at random. Feedlot pen served as the statistical unit. Pens of heifers were weighed at the beginning of the experiment and immediately before shipping to a commercial slaughterhouse in Emporia, Kansas. Treatment differences were evaluated by analysis of variance using the General Linear Models procedure of SAS.

Results and Discussion

There was no effect of dietary treatment on feedlot performance (P>0.23; Table 3). Using feedlot performance, apparent dietary NE_g values were calculated and no difference occurred between diets containing CSB or cane molasses (P=0.21). The NE_g for cane molasses and CSB were 0.21 and 0.50 Mcal/lb (P=0.20), respectively. These NE_g values are based on feedlot performance and, because gains were identical, the numerical difference between the NE_g values for CSB and cane was a result of the slight difference in feed intake. Carcass characteristics of heifers fed diets containing CSB and cane molasses are listed in Table 3 and were similar between diets.

Based on the findings of this experiment, the feeding value of CSB is similar to that of cane molasses when included at 5% (dry matter basis) in diets based on steam-flaked corn. Dependent on price and availability, CSB is a suitable replacement for cane molasses in finishing cattle diets.

Table 1. Analyzed Nutrient Concentration of Cane Molasses and Concentrated Separator Byproduct

Item, %	Cane Molasses	Concentrated Separator Byproduct
Dry matter	70.7	65.4
	----------Dry matter basis----------	
Crude protein	6.3	21.9
Calcium	1.19	0.47
Phosphorus	0.04	0.03
Potassium	5.3	10.2
Ash[a]	13.3	30.3

[a]Ash content of cane molasses and concentrated separator byproduct are tabular values.

Table 2. Diet Composition, % of Dry Matter

Ingredient	CANE	CSB[a]
Steam-flaked corn	76.7	77.2
Ground alfalfa hay	8.1	8.0
Cane molasses	5.0	–
Concentrated separator byproduct	–	5.3
Soybean meal	4.0	3.1
Tallow	3.2	3.2
Limestone	1.3	1.5
Urea	1.3	1.3
Salt	0.3	0.3
Premix [b]	0.1	–
Premix [c]	–	0.1
Nutrient [d]		
Crude protein	15.2	15.9
Calcium	0.78	0.74
Phosphorus	0.24	0.24
Potassium	0.66	0.90

[a]Concentrated separator byproduct.
[b]Formulated to provide 1200 IU/lb vitamin A, 50 ppm Zn, 50 ppm Mn, 8.3 ppm Cu, 0.5 ppm I, 0.3 ppm Fe, 0.25 ppm Se, 0.1 ppm Co, 33.3 grams/ton Rumensin, 10 grams/ton Tylan, and 0.5 mg/heifer melengestrol acetate daily.
[c]Formulated to provide 1200 IU/lb vitamin A, 51 ppm Zn, 50 ppm Mn, 9.4 ppm Cu, 4.5 ppm Fe, 0.5 ppm I, 0.25 ppm Se, 0.1 ppm Co, 33.3 grams/ton Rumensin, 10 grams/ton Tylan, and 0.5 mg/head melengestrol acetate daily.
[d]From analysis of ingredients.

Table 3. Finishing Performance and Carcass Characteristics of Yearling Heifers Fed Diets Containing Either Cane Molasses (CANE) or Concentrated Separator Byproduct (CSB)

Item	CANE	CSB	SEM	P [a]
Dry matter intake, lb/day	17.9	17.6	0.2	0.24
Initial body weight, lb	659	656	3.8	0.54
Final body weight, lb[b]	1125	1122	9.3	0.81
Average daily gain, lb[c]	3.15	3.15	0.06	0.99
Feed:Gain	5.70	5.58	–	0.24
Net energy for gain, Mcal/lb [d]				
Diet	0.73	0.74	0.01	0.21
Ingredient, Cane or CSB	0.21	0.50	0.15	0.20
Hot carcass weight, lb	714	712	5.9	0.81
Dress, %	63.9	64.0	0.1	0.50
Longissimus muscle area, inch^2	13.3	13.3	0.1	0.90
12th rib fat thickness, inches	0.49	0.51	0.02	0.53
Kidney, pelvic, & heart fat, %	2.37	2.45	0.06	0.34
Yield grade 1, %	18.8	12.7	2.5	0.10
Yield grade 2, %	31.4	38.6	3.6	0.17
Yield grade 3, %	40.7	38.1	2.8	0.53
Yield grades 4 & 5, %	9.1	10.6	2.4	0.65
Marbling score	Slight 71	Slight 77	7.1	0.54
USDA Choice, %	40.1	45.5	4.3	0.39
USDA Select, %	52.8	43.6	4.2	0.13
USDA Standard, %	6.0	8.8	1.4	0.17
Liver abscesses, %	1.5	2.1	0.8	0.61
Dark cutters, %	0.5	1.5	0.7	0.29

[a]Probability that the observed response is not due to random chance.
[b]Calculated as hot carcass weight ÷ 63.5% dress.
[c]Calculated using carcass adjusted final weight.
[d]Calculated from heifer performance using the NRC (1984) equations and the method of substitution.

Cattlemen's Day 2003

RELATIONSHIP OF BLOOD GLUCOSE CONCENTRATION AT ARRIVAL TO PERFORMANCE AND CARCASS CHARACTERISTICS OF BEEF HEIFERS

E. R. Loe, J. S. Drouillard, T. J. Kessen, S. P. Montgomery, J. N. Pike, J. J. Sindt, and M. J. Sulpizio

Summary

Crossbred yearling heifers (n = 394) were used to compare the effect of high or low blood glucose measured at arrival on feedlot performance and carcass characteristics. A blood sample was collected when heifers arrived at the Beef Cattle Research Center, and heifers were sorted into two groups: high or low blood glucose. The mean blood glucose concentration of the heifers was 57 ± 2 mg/dL in the low group and 78 ± 2 mg/dL in the high group. Heifers that had low blood glucose at arrival consumed more feed (P=0.02), tended to have increased final bodyweight and rate of gain (P<0.10), had increased backfat thickness (P<0.05), and tended to have heavier hot carcass weights and fewer standard carcasses (P<0.10) compared with heifers that had high blood glucose at arrival.

Introduction

During the period of time from weaning to placement in a feedyard, cattle are exposed to many stressors. Being moved in and out of sale barns; shipped long distances; and hauled into a new environment are some factors that cause stress. One of the stress responses is for an animal to mobilize glucose from body tissue, which increases the concentrations of glucose and lactate in the blood. Previous research at K-State has shown that plasma glucose is related to feedlot performance, carcass weight, longissimus muscle area, and fat thickness. However, documentation of the effect of sorting incoming cattle on the basis of blood glucose concentration measured from a single blood sample taken after arrival is lacking. Our objective was to determine the effect of sorting cattle into low or high blood glucose groups, based on incoming blood glucose concentrations, on feedlot performance and carcass characteristics.

Experimental Procedures

A total of 394 crossbred yearling heifers (658 ± 4 lb initial body weight) were sorted based on their blood glucose concentration and fed for 174 days (148 days on the finishing diet). Information relative to previous nutrition and management of these heifers was not known. The heifers were allocated to 24 feedlot pens, 12 pens of high blood glucose heifers and 12 pens of low blood glucose heifers. Diet composition and actual nutrient levels are listed in Table 1. The diet was formulated to provide a minimum 14% crude protein, 0.7% calcium, 0.3% phosphorus, 0.7% potassium, 300 mg/heifer monensin daily, 90 mg/heifer tylosin daily, and 0.5 mg/heifer melengestrol acetate daily. Heifers were fed between 9:00 and 11:00 a.m. daily, except on weigh days when cattle were fed after being weighed.

Heifers were shipped 655 miles from Cameron, TX to Manhattan, KS arriving in Manhattan at approximately 4:00 a.m. and unloaded between 6:15 and 7:30 a.m. Initial processing commenced at approximately 10:00 a.m. During initial processing a blood sample was taken via jugular venipuncture, and heifers were vaccinated against viral (Bovishield-IV®) and clostridial (Fortress-7®) diseases, implanted with Component EH®, treated for internal and external parasites with

Eprinex® pour-on, and administered a metaphylactic dose of Micotil®.

The concentration of glucose in the blood sample at initial processing was used for characterizing heifers as having either low or high blood glucose. A mean blood glucose concentration was calculated within each receiving group. Cattle that had blood glucose concentrations above the mean blood glucose concentration (66 mg/dL) were sorted into the high blood glucose group and cattle that had blood glucose concentrations below 66 mg/dL were sorted into the low blood glucose group. Nine days prior to slaughter, heifers were weighed and a blood sample was collected; this sample is referred to as the "final" blood sample. On the day of the final blood sampling, blood samples were collected between 7:05 a.m. and 3:17 p.m.; heifers were not fed until body weight was measured and a blood sample was obtained.

Blood and plasma glucose and lactate concentrations were measured using a YSI 2300 STAT plus (YSI Inc., Yellow Springs, OH). After measuring blood glucose and lactate, the blood was centrifuged for 15 minutes at 2000 × *g* using a Centra-GP8R centrifuge (Thermo-IEC, Needham Heights, MA). Plasma was stored frozen for later analysis. Concentration of glucose and lactate in the blood and plasma were measured from the initial sample; only the plasma glucose and lactate concentrations were measured in the final sample.

In this study, treatments were arranged as a 2 × 2 factorial; factors were dietary concentrated separator byproduct or cane molasses and high or low blood glucose. There were no interactions between diet and glucose, and only blood glucose data is presented in this paper. The diet listed in Table 1 represents the average composition of the two diets that were fed.

Feedlot pen constituted the statistical unit. Each pen of heifers was weighed at the beginning of the experiment and immediately before shipping to a commercial slaughterhouse in Emporia, KS. Treatment differences were evaluated by analysis of variance using the General Linear Models procedure of SAS.

Table 1. Diet Composition[a], % of Dry Matter

Ingredient	Inclusion Level
Steam-flaked corn	77.0
Ground alfalfa hay	8.0
Cane molasses/concentrated separator byproduct	5.2
Soybean meal	3.5
Tallow	3.2
Limestone	1.4
Urea	1.3
Salt	0.3
Premix [b]	0.1
Nutrient [c]	
Crude protein	15.6
Calcium	0.76
Phosphorus	0.24
Potassium	0.78

[a]Diet represents the average of two diets that were fed.
[b]Formulated to provide 1200 IU/lb vitamin A, 51 ppm Zn, 50 ppm Mn, 8.7 ppm Cu, 2.4 ppm Fe, 0.5 ppm I, 0.25 ppm Se, 0.1 ppm Co, 33.3 grams/ton Rumensin, 10 grams/ton Tylan, and 0.5 mg/heifer melengesterol acetate.
[c]From analysis of ingredients.

Results and Discussion

Initial and final blood glucose concentrations are listed in Table 2. The initial blood sample was taken the day the cattle arrived at the Beef Cattle Research Center and the final blood sample was taken 9 days prior to slaughter. The heifers that were categorized as having high blood glucose at arrival maintained a higher level of blood glucose throughout the feeding period ($P<0.01$). The lactate concentration was greater in heifers

with high initial blood glucose concentrations than in those with low initial blood glucose concentrations (P<0.01).

Feedlot performance and carcass characteristics of heifers with either low or high blood glucose concentrations are shown in Table 3. Heifers that were categorized as having low blood glucose ate 4% more feed (P=0.02) and tended to gain at a faster rate (P=0.09). Feed efficiency was similar between these two groups (P=0.82). Heifers with low arrival blood glucose had more 12th rib back fat (P<0.05) and tended to have heavier carcass weights and less standard carcasses (P<0.10).

Cattle with lower blood glucose concentrations at arrival maintained a lower circulating glucose concentration throughout the feeding period. Furthermore, better feedlot performance was observed for heifers that had low initial blood glucose concentrations. The reason for the high or low concentrations of circulating glucose at arrival is not known because we did not have any background information on the heifers. If the high levels of glucose measured in the blood and plasma in the initial sample are due to higher stress on those individuals during shipping and receiving, the high level of circulating glucose maintained after 165 days on feed could stem from reduced insulin sensitivity, which would reduce tissue uptake of glucose.

These data demonstrate that cattle with low levels of circulating glucose have greater feedlot performance and carcass fat accretion compared to cattle with high levels of circulating glucose.

Table 2. Blood and Plasma Glucose and Lactate Levels of Yearling Heifers with Low or High Blood Glucose at Arrival Sampled at Arrival (Initial) and 9 Days Prior to Slaughter (Final)

	Low Glucose	High Glucose	SEM	P [a]
Initial glucose				
Blood, mg/dL	57.1	78.0	2.4	<0.001
Plasma, mg/dL	95.6	117.5	3.2	<0.001
Final glucose				
Plasma, mg/dL	113.9	139.0	6.2	0.01
Initial lactate				
Blood, mmol/L	3.79	5.70	0.31	<0.001
Plasma, mmol/L	6.80	9.02	0.47	0.003
Final lactate				
Plasma, mmol/L	4.91	6.22	0.35	0.01

[a]Probability that the observed response is not due to random chance.

Table 3. Finishing Performance and Carcass Characteristics of Yearling Heifers with Low Blood Glucose or High Blood Glucose at Arrival

Item	Low Glucose	High Glucose	SEM	P [a]
Dry matter intake, lb	18.1	17.4	0.2	0.02
Initial body weight, lb	660	655	3.8	0.41
Final body weight, lb[b]	1136	1111	9.3	0.07
Average daily gain, lb[c]	3.22	3.08	0.06	0.09
Gain:Feed	0.178	0.177	0.002	0.82
Hot carcass weight, lb	721	705	5.9	0.07
Dress, %	63.8	64.2	0.1	0.07
Longissimus muscle area, inch^2	13.4	13.3	0.1	0.42
12th rib fat thickness, inches	0.52	0.47	0.02	0.05
Kidney, pelvic, & heart fat, %	2.44	2.38	0.06	0.47
Yield grade 1, %	13.7	17.9	2.5	0.25
Yield grade 2, %	35.0	35.1	3.6	0.98
Yield grade 3, %	39.2	39.5	2.8	0.95
Yield grades 4 & 5, %	12.1	7.6	2.4	0.19
Marbling score	Slight 79	Slight 68	7.1	0.30
USDA Choice, %	43.8	41.8	4.3	0.75
USDA Select, %	48.5	47.9	4.2	0.92
USDA Standard, %	5.6	9.2	1.4	0.08
Liver abscesses, %	1.5	2.1	0.8	0.61
Dark cutters, %	1.0	1.0	0.7	0.95

[a]Probability that the observed response is not due to random chance.
[b]Calculated as hot carcass weight ÷ 63.5% dress.
[c]Calculated using carcass adjusted final weight.

RUMINAL AMMONIA LOAD DOES NOT AFFECT HISTIDINE UTILIZATION IN GROWING STEERS

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Summary

Fermentation of dietary protein in the rumen leads to ammonia absorption, which could impair amino acid utilization in cattle. Our study was conducted to determine the effects of rumen ammonia load on histidine utilization. Six ruminally cannulated Holstein steers (318 lb) housed in metabolism crates were used in a 6 × 6 Latin square design. Treatments were arranged as a 3 × 2 factorial and included: 0, 1.5, or 3 grams/day L-histidine infused abomasally; and 0 or 80 grams/day urea infused ruminally to supply a metabolic ammonia load. As expected, urea infusions increased rumen ammonia and plasma urea concentrations. No change in nitrogen retention, a measure of lean tissue growth, occurred in response to urea. Retained nitrogen increased with histidine supply, and the maximal response occurred with 1.5 grams/day of histidine, suggesting that this amount was near the supplemental requirement. Our research revealed that increases in ammonia load did not demonstrate a metabolic cost in terms of whole body protein deposition, regardless of whether histidine was limiting. Thus, although an excess protein supply may not be economically efficient or environmentally friendly, it does not appear to directly penalize animal performance.

Introduction

Intestinal supply of amino acids, the building blocks of protein, must meet animal requirements in order to optimize lean muscle growth. Restriction of a single dietary essential amino acid may limit growth. Previous research indicated that with our experimental model we can create a histidine deficiency in calves that is useful for studying factors that affect the efficiency of amino acid use.

In ruminants, ammonia is produced within the rumen as a result of fermentation of dietary protein. This ammonia subsequently is absorbed through the rumen wall and transported to the liver where it is detoxified. There is some evidence suggesting that ammonia detoxification may contribute to the inefficient use of dietary amino acids. This is because ammonia is detoxified to urea in the liver, and amino acids can be consumed metabolically during the process of urea synthesis. However, other research suggests that amino acid use for the synthesis of urea from ammonia is not quantitatively important. Our study was conducted to determine if an increased ammonia load has a negative impact on protein deposition when histidine is the most limiting amino acid.

Experimental Procedures

Six ruminally cannulated Holstein steers averaging 318 lb were used in a 6 × 6 Latin square to determine effects of rumen ammonia load on utilization of histidine. Steers were housed in metabolism crates and fed 5.5 lb/day (dry matter basis) of a basal diet containing 83% soybean hulls, 7.6% wheat straw, 4% molasses, 5% minerals/vitamins, and 0.4% urea.

To insure that histidine was the first limiting amino acid for lean tissue deposition, all steers received abomasal infusions that con-

tained 250 grams/day amino acids, which supplied adequate amounts of all essential amino acids except histidine, and 300 grams/day glucose. Vitamin B-6, folic acid, and vitamin B-12 also were supplemented to all steers to ensure that they were not limiting. All steers also received ruminal infusions that contained 180 grams/day acetate, 180 grams/day propionate, and 45 grams/day butyrate to supply energy without increasing microbial protein supply. Treatments were continuously infused, arranged as a 3 × 2 factorial, and included: 0, 1.5, or 3 grams/day L-histidine infused abomasally; and 0 or 80 grams/day urea infused ruminally to supply a metabolic ammonia load. The two infusions were continuously supplied by a peristaltic pump through tubing that passed through the rumen cannula with one line terminating in the rumen and one in the abomasum.

Experimental periods were 6 days, with 2 days for adaptation to treatment and 4 days for total fecal and urinary collection to allow measurement of nitrogen retention, a measure of lean tissue deposition. Rumen fluid was collected 2, 4, and 6 hours after feeding to determine rumen ammonia concentration. Blood samples were collected from the jugular vein 5 hours after feeding on day 6 of each period for plasma urea analysis.

Results and Discussion

Nitrogen balance data are presented in Table 1. Retained nitrogen increased linearly ($P<0.01$) with histidine supplementation, indicating that the control steers were histidine deficient. Nitrogen retention leveled off between 1.5 grams/day and 3 grams/day supplemental histidine, indicating that 1.5 grams/day was near the steers' requirements for growth.

Urea infusions increased ($P<0.01$) rumen ammonia from 8.6 to 19.7 m*M*. Increases in rumen ammonia concentration show that the non-protein nitrogen was hydrolyzed in the rumen to ammonia. Plasma urea concentrations increased from 2.7 to 5.1 m*M* when urea was infused, also indicating that an increased ammonia load was achieved through the urea treatment.

Due to the nitrogen infused as urea, total nitrogen intake increased for steers receiving 80 grams/day urea. Fecal nitrogen was similar among all treatments, which suggests that the extra nitrogen infused as urea was absorbed. No change in nitrogen retention occurred in response to urea, nor was there a histidine by urea interaction for nitrogen retention. As a result, our study indicates that an increased ammonia load did not change how efficiently the calves used histidine for growth. Increased ruminal ammonia concentrations did not negatively impact animal performance. Despite the lack of effect on growth, feeding of diets that yield a large ammonia load may not be economically efficient or environmentally friendly.

The maximal response to histidine occurred with 1.5 grams/day supplementation, suggesting that this amount was near the requirement. By using the difference between nitrogen retention for 0 and 1.5 grams/day supplementation, efficiency of histidine deposition in lean tissue can be calculated. Grams of nitrogen retained can be converted to grams of crude protein retained per day and from this we can calculate the amount of histidine retained (2.5 grams of histidine/100 grams of crude protein). In our study, steers deposited an additional 0.98 grams of histidine for each 1.5 grams that were supplemented, which equates to an efficiency of deposition of supplemental histidine of 65%, a value near that used by several models for prediction of cattle performance.

In our experiment with growing steers, increases in the ammonia load did not demonstrate a metabolic cost in terms of whole body protein deposition, regardless of whether histidine was limiting.

Table 1. Effect of Supplemental Histidine and Urea on Nitrogen Balance of Growing Steers

	No Urea			80 grams/day Urea			
Nitrogen, grams/day	No His	1.5 His[1]	3 His[1]	No His	1.5 His[1]	3 His[1]	SEM
Total intake	87.8	89.4	91.3	124.7	127.4	127.6	
Fecal	15.0	15.5	15.3	15.0	15.4	15.4	0.8
Urinary[ab]	41.7	37.9	37.8	77.6	72.4	72.2	2.2
Retained[a]	31.1	35.9	38.2	31.8	39.6	39.8	1.9

[1]1.5 His = 1.5 grams/day histidine; 3 His = 3 grams/day histidine.

[a]Linear effect of histidine level ($P<0.01$).

[b]Effect of urea level ($P<0.01$).

Cattlemen's Day 2003

EFFECTS OF FLAX SUPPLEMENTATION AND A REVALOR-S IMPLANT ON CIRCULATING INSULIN-LIKE GROWTH FACTOR 1 (IGF-1) AND MUSCLE IGF-1 mRNA LEVELS IN FINISHING CATTLE

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Summary

Sixteen crossbred steers weighing 875 lb were used to evaluate the effects of a 5% ground flaxseed supplement and a combined trenbolone acetate/estradiol (TBA/E_2) growth promoting implant, Revalor-S®, on both circulating insulin-like growth factor-1 (IGF-1) and local muscle IGF-1 mRNA concentrations. Steers were randomly assigned to one of four treatments: . 1) Flax/Implant, 2) No Flax/ Implant, 3) Flax/No Implant, 4) No Flax/No Implant. Serum was harvested from blood collected via jugular venipuncture on day 0 (before implantation or flax addition), 14, and 28. Muscle biopsy samples were obtained from the *longissimus* muscle on days 0, 14, and 28. Implanted steers had 52 and 84% higher ($P<0.05$) circulating IGF-1 levels than non-implanted steers on days 14 and 28, respectively. Cattle fed diets without flax had higher levels of muscle IGF-1 mRNA than cattle fed diets with flax on day 28 (4.4-fold, $P<0.01$). Our data support that the administration of a combined TBA/E_2 growth promotant increases circulating IGF-1 and local muscle IGF-1 mRNA concentrations in finishing cattle. However, this increase in muscle IGF-1 mRNA appears to be attenuated by the addition of a dietary flax supplement.

Introduction

Growth promoting implants containing both trenbolone acetate (TBA) and estradiol (E_2) are known to increase insulin-like growth factor-1 (IGF-1) levels in circulation as well as IGF-1 mRNA levels in the muscle of finishing cattle. IGF-1 is a very important growth factor for skeletal muscle growth because it stimulates muscle cell proliferation, differentiation, and protein synthesis. Flaxseed is a source of alpha-linolenic acid, which is an omega-3 polyunsaturated fatty acid. Additions of dietary omega-3 fatty acids have been shown to increase cell membrane fluidity, which may enhance the ability of IGF-1 to bind to its receptor in muscle tissue, thus potentiating IGF-1 actions in muscle. There is potential for additive or synergistic effects on muscle growth when growth promotants that increase both circulating IGF-1 and muscle IGF-1 mRNA concentrations are used in conjunction with feedstuffs high in omega-3 fatty acids. The objective of our study was to determine how circulating IGF-1 and muscle IGF-1 mRNA levels are affected by a 5% ground flaxseed supplement and administration of a combined TBA/E_2 implant, Revalor-S.

Experimental Procedures

Sixteen crossbred steers weighing 875 lb were stratified by weight and randomly assigned to one of four treatments: 1) Flax/Implant, 2) No Flax/Implant, 3) Flax/No Implant, 4) No Flax/No Implant. Steers were allowed ad libitum access to a 92% concentrate diet supplied once daily (Table 1). Serum was harvested from blood samples collected by jugular venipuncture on days 0 (before implantation and flax addition), 14, and 28 and were stored for subsequent analysis of circulating IGF-1. Muscle biopsy samples were obtained from the *longissimus dorsi* on

days 0, 14, and 28 using a Bergstrom biopsy needle. Total RNA was isolated from the muscle samples, and real-time quantitative polymerase chain reaction (PCR) was used to evaluate IGF-1 gene expression.

Results and Discussion

Flax supplementation had no significant effect on circulating IGF-1 levels in finishing steers (Figure 1). Implanted steers had 52 and 84% greater ($P<0.05$) circulating IGF-1 levels than their non-implanted counterparts on days 14 and 28, respectively (Figure 1). Cattle that were not supplemented with flax had higher (4.4 fold, $P<0.01$) levels of muscle IGF-1 mRNA on day 28 than those that received the flax supplement. On day 28, implanted steers had 2.4-fold higher ($P<0.01$) muscle IGF-1 mRNA levels than non-implanted steers (Figure 2). Our data was consistent with other research findings and demonstrates that the administration of a TBA/E_2 growth promotant, Revalor-S, increased circulating IGF-1 and muscle IGF-1 mRNA levels in finishing cattle.

Flax supplementation had no effect on circulating IGF-1 levels, and it led to lower muscle IGF-1 mRNA levels on day 28 (Figure 2). It is possible that the addition of flax to the diet increased the sensitivity of the muscle tissue to systemic IGF-1, which could, in turn, cause the level of muscle IGF-1 gene expression to be down-regulated. It is also possible that the alpha-linolenic acid in the flax supplement had direct effects on muscle IGF-1 gene expression. It is not possible to discern from our data whether dietary addition of flax has a direct or indirect effect on muscle IGF-1 mRNA levels. However, our data still offer useful information toward the ultimate goal of understanding how dietary additions of omega-3 fatty acids and the use of anabolic steroid implants impact muscle growth of finishing cattle.

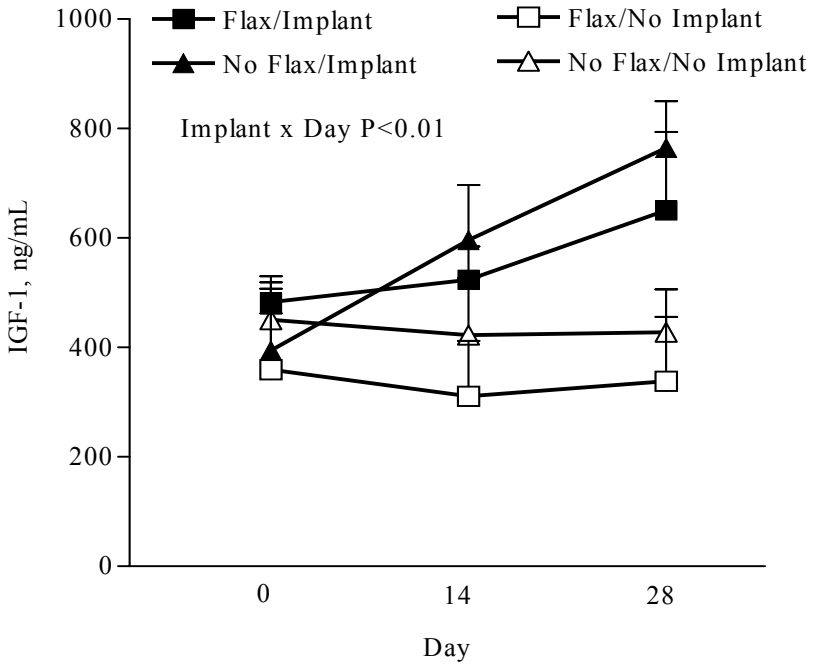

Figure 1. Effect of Flax Supplementation and a Revalor-S Implant on Circulating IGF-1 Levels of Finishing Cattle.

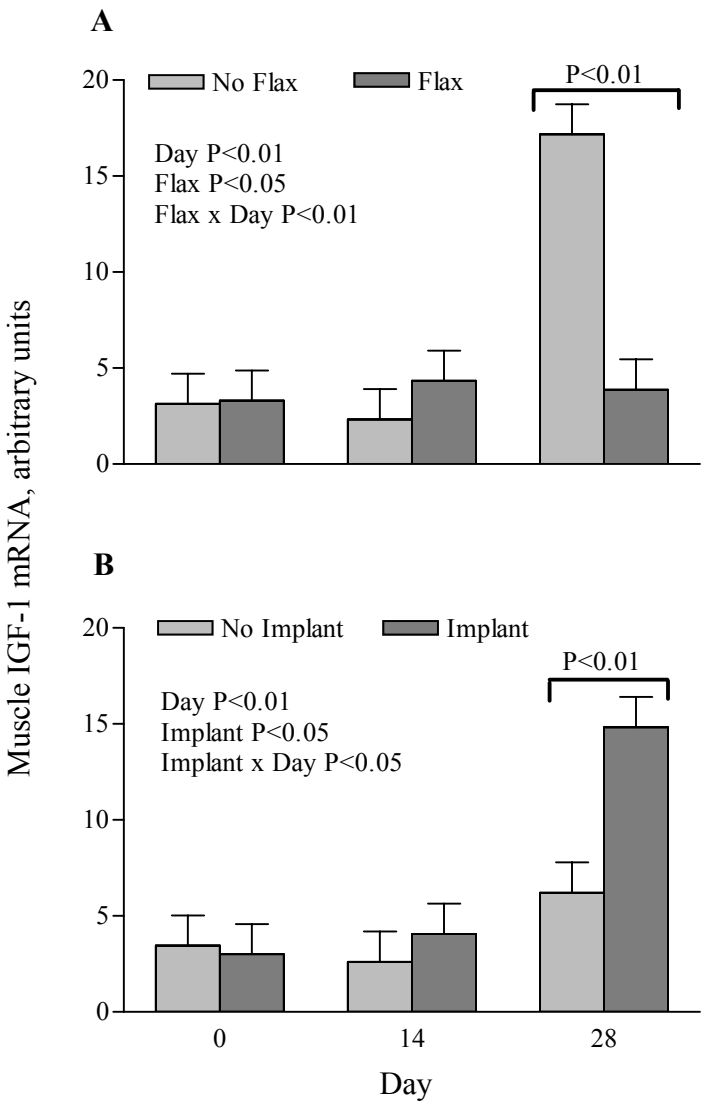

Figure 2. Effects of Flax Supplementation (Panel A) and a Revalor-S Implant (Panel B) on Muscle IGF-1 mRNA Levels of Finishing Cattle.

Table 1. Experimental Diets

	Treatments	
Ingredient	Flax	No Flax
	---------- % of Dry Matter ----------	
Steam-flaked corn	77.5	81.9
Corn steep liquor	5.9	5.9
Alfalfa hay	8.0	8.0
Flaxseed, ground	5.1	—
Vitamin/trace mineral premix[a]	3.6	4.2
	---------- lb per Steer Daily ----------	
Rumensin/Tylan premix[b]	0.5	0.5

[a]Vitamin/trace mineral premix formulated to provide (total diet dry matter): 1,500 IU/lb vitamin A, 835 IU/lb vitamin E, 0.2 ppm cobalt, 13 ppm copper, 75 ppm manganese, 0.30 ppm selenium, 75 ppm zinc, and 78 ppm iodine.
[b]Provided 300 mg Rumensin and 90 mg Tylan per steer daily.

Cattlemen's Day 2003

EFFECTS OF MGA IN RECEIVING DIETS ON HEALTH, PERFORMANCE, AND CARCASS CHARACTERISTICS

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Summary

A trial was conducted using 723 crossbred heifers (468 lb initially) to evaluate the effects of including melengestrol acetate (MGA) in receiving diets on growth performance, morbidity, mortality, and carcass characteristics. Treatments were: 1) MGA included in the receiving diet at a rate of 0.5 mg per heifer daily or 2) no MGA in the receiving diet. Diets were fed once daily and contained 42% steam-flaked corn, 45% alfalfa hay, 6% steep liquor, and 2% tallow; monensin and tylosin were included. Receiving diets were fed for 35 days. After 35 days MGA was fed to all heifers, and cattle were stepped up to common finishing diets. Cattle exhibiting clinical signs of bovine respiratory disease (BRD) were treated with Excenel (1 ml/100 lb body weight) for 3 days. Animals requiring follow-up treatment received the same therapy. Cattle pulled a third time received oxytetracycline (4.5 ml/100 lb body weight) and Predef (5 ml/heifer). Initial respiratory pulls (73.9% for MGA and 77.3% for no MGA), re-treatments, and death loss were not different (P>0.40) during the first 35 days. The number of heifers requiring a third antibiotic treatment tended (P=0.09) to be higher for heifers not receiving MGA. Average daily gain (deads out) for the first 35 days tended to be higher for heifers fed MGA (P=0.06), but dry matter intake and feed efficiency were not different between treatments (P>0.17). Gain throughout the 220-day feeding period was 2.6% higher for cattle fed MGA during the receiving phase (P=0.05). Overall, feed intake and feed efficiency were not different (P>0.50) between treatments, but heifers fed MGA during the initial receiving period tended to have heavier carcass weights (P=0.13). No differences were detected in quality grade, yield grade, or marbling (P>0.23). Feeding MGA during the initial 35 days after arrival may improve gain and carcass weights.

Introduction

Bovine respiratory disease (BRD) has enormous economic impact on the cattle industry as a result of its effects on labor cost, antibiotic treatment, feed efficiency, and carcass value. BRD is seldom the result of a single factor, but rather a result of a variety of environmental stresses that facilitate invasion of the lungs by opportunistic pathogenic bacteria such as the gram-negative *Pasteurella multocida* and *Pasteurella haemolytica*. Gram-negative bacterial infections are characterized by the animal's reaction to components of the bacterial cell wall, frequently resulting in elevated body temperatures and production of pro-inflammatory cytokines. Cytokines are protein mediators produced by immune cells in response to a foreign antigen. Cytokines play an important role in immune function, but excess or prolonged production may be deleterious to epithelial tissue. The pro-inflammatory cytokines, which include tumor necrosis factor-alpha, have been implicated as having inhibitory effects on feed consumption, glucose regulation, and glycogen synthesis. Suppressing the release of pro-inflammatory cytokines may be beneficial to the well-being and future productivity of disease challenged animals.

Studies conducted with other animal species have successfully suppressed production of tumor necrosis factor-alpha through administration of exogenous progesterone compounds, thus increasing appetite and weight gain. We hypothesized that melengestrol acetate (MGA), a synthetic progesterone commonly used to suppress estrus in feedlot heifers, may have application in receiving cattle to improve growth performance and health. Our objective was to determine the effects of adding MGA to receiving diets fed to pre-pubertal heifer calves on morbidity, mortality, and growth performance throughout the feeding period, as well as carcass characteristics. This paper summarizes our observations during the initial 35 days following arrival and overall performance at the feedlot.

Experimental Procedures

Seven hundred twenty-three crossbred heifers were transported from Missouri and Kentucky sale barns to the KSU Beef Cattle Research Center in Manhattan, KS. They were placed into pens upon arrival, given free access to water and hay, and processed within 24 hours after arrival. Average weight at initial processing was 468 ± 5 lb. Cattle were identified with uniquely numbered ear tags, individually weighed, and given injections of 4-way viral (Bovishield 4) and 7-way clostridial (Fortress-7) vaccines. Implanting was delayed to avoid hormone interactions with MGA. Cattle were allotted to 12 pens of 46 to 53 head each, and 10 pens of 13 to 14 head each. Pens of heifers were randomly assigned to two treatments: 1) no MGA, or 2) 0.5 mg MGA per heifer daily included in the diet for the first 35 days. A second dose of Fortress-7 was given 7 to 10 days after initial processing.

Initial diets contained 60% concentrate, utilizing steam-flaked corn as the primary energy source (Table 1). The amount of feed offered was determined by a 7:00 a.m. feed call so that only traces of feed remained each day. The entire daily ration for each pen was delivered by approximately 8:00 a.m. each day. Excess residual feed was removed from the bunk to prevent spoilage and was weighed and accounted for in calculating feed intake. On day 21, heifers were transitioned to a 97% concentrate finishing ration containing a mixture of steam-flaked corn and wet corn gluten feed using a series of five steps.

On day 35, MGA was added to all diets, and cattle were individually weighed and implanted with Ralgro. On approximately day 95 cattle were individually weighed, reimplanted with Revalor-H, and then were reallocated equally across treatments to a finishing trial in which diets contained 4.0% tallow or 10% corn germ. Thirteen chronic animals were removed from the study at this point. Cattle were slaughtered in two groups. On approximately day 195, 25% of the cattle from each treatment were shipped for slaughter. The remaining cattle were shipped at approximately day 223. Cattle were slaughtered at a commercial abattoir in Emporia, KS, and carcass data were obtained following a 24-hour chill.

Cattle that exhibited clinical signs of respiratory disease, including depression, lethargy, anorexia, coughing, rapid breathing, and nasal and(or) ocular discharge were treated with a subcutaneous injection of Excenel at the rate of 1 ml/100 lb body weight for 3 days. Cattle were placed into sick pens and then returned to their original pen following treatment. Cattle pulled for a relapse were treated in the same manner. Cattle requiring a third treatment were given oxytetracycline at 6 ml/100 lb body weight and PreDef 2x at 5 ml/heifer one time and returned to their pen.

Results and Discussion

Table 2 summarizes the performance, mortality, and morbidity of heifers during the 35-day receiving trial. MGA tended to increase daily gains (P=0.06), which accounts for the differences in body weight at day 35

(540.5 and 525.8 lbs respectively, *P*=0.07) calculated on a deads-out basis (only animals sent to slaughter). Incidence of respiratory disease treatments was not affected by MGA (*P*=0.41). Likewise, the number of heifers requiring a second antibiotic treatment was not affected (*P*=0.44), but feeding MGA did tend (*P*=0.09) to reduce the number of heifers requiring three treatments for BRD. Death loss was not different between treatments (*P*=0.98). Cattle continued to experience mortality after day 35 with a 15.8 and 17.7% mortality rate for cattle fed MGA and no MGA, respectively (*P*=0.62) for the entire feeding period (Table 3).

Performance throughout the entire feeding period (receiving plus finishing on a deads-out basis) and carcass characteristics are shown in Table 3. Daily gain throughout the entire receiving and finishing period tended to be increased by feeding MGA in the receiving period (*P*=0.05) thus increasing hot carcass weight (679 and 667 lbs, *P*=0.13). However, feed intake and feed efficiency were not affected by feeding MGA during the receiving phase. The percentage of carcasses grading USDA Choice and Prime and USDA yield grades were not different between treatments (*P*>0.50).

Heifers in this study experienced a high incidence of respiratory challenge and mortality, thus leading to relatively poor performance for both treatments during the receiving period. Including MGA in diets of heifers immediately after arrival in the feedlot may be an effective means of reducing chronicity, as indicated by reductions in the number of heifers pulled for BRD three times, and of improving subsequent finishing performance. Further studies utilizing MGA in diets of lightweight receiving heifers are necessary to determine if results can be repeated with more moderate disease challenges.

Table 1. Experimental Diets (% of Dry Matter) Fed During the 35-Day Receiving Period

	Treatment	
Ingredient	MGA	No MGA
Steam-flaked corn	42.0	42.0
Alfalfa hay	45.4	45.4
Steep liquor	6.1	6.1
Tallow	2.0	2.0
Soybean meal	3.6	3.6
Vitamin/mineral premix[1]	0.4	0.4
R-T-MGA premix[2]	2.5	-
R-T premix[3]	-	2.5
Crude protein, analyzed	17.0	17.0

[1]Formulated to provide 1500 IU/lb vitamin A, 20 IU/lb vitamin E, 0.1 ppm Co, 0.6 ppm I, 60 ppm Mn, 0.25 ppm Se, 60 ppm Zn, and 10 ppm Cu.

[2]Rumensin/Tylan/MGA premix was fed in a ground corn carrier and provided 300 mg monensin, 90 mg tylosin, and 0.5 mg MGA per heifer daily.

[3]Rumensin/Tylan premix was fed in a ground corn carrier and provided 300 mg monensin and 90 mg tylosin per heifer daily.

Table 2. Health and Performance During the 35-Day Receiving Period for Heifers Fed No MGA or 0.5 mg MGA per Heifer Daily

	MGA in Receiving Diet			
Item	0.5 mg/day	0	SEM	*P*-value
1st Treatment, %	73.9	77.3	2.87	0.41
2nd Treatment, %	40.6	44.4	3.45	0.44
3rd Treatment, %	20.9	29.5	3.42	0.09
Dead, %	9.8	9.9	2.41	0.98
Performance[1]				
Initial weight, lb	470.9	467.9	4.90	0.70
End weight, lb	540.5	525.8	6.29	0.07
Daily gain, lb	2.00	1.66	0.12	0.06
Feed intake, lb/day	8.76	8.13	0.32	0.17
Feed:gain	4.39	4.89	-	0.28

[1]Deads out basis.

Table 3. Performance Throughout the Receiving and Finishing Period and Carcass Traits for Heifers Fed No MGA or 0.5 mg MGA per Heifer Daily During the 35-Day Receiving Period

	MGA in Receiving Diet			
Item	0.5 mg/day	0	SEM	*P*-value
Performance[1]				
End weight, lb	1051.5	1033.2	7.86	0.12
Daily gain, lb	2.78	2.71	0.02	0.05
Feed intake, lb/day	14.16	13.97	0.24	0.59
Feed:gain	5.09	5.14	-	0.69
Dead, %	15.8	17.7	2.57	0.62
Carcass trait				
Carcass weight, lb	678.6	666.9	5.10	0.13
Dressing, %	64.7	64.3	0.20	0.09
Rib eye area, in^2	11.91	11.67	0.17	0.31
12th rib fat thickness, in	0.55	0.54	0.01	0.82
Kidney, pelvic & heart fat, %	2.50	2.46	0.03	0.32
Marbling score	Small41	Small38	7.0	0.81
Prime, %	4.1	3.2	1.1	0.55
Choice, %	67.7	69.3	2.5	0.66
Avg. Choice or greater, %	17.4	17.2	2.1	0.94
Select, %	27.2	26.1	2.7	0.79
Yield grade 1, %	2.5	4.2	0.9	0.23
Yield grade 2, %	26.8	21.5	3.1	0.25
Yield grade 3, %	53.7	56.5	2.2	0.38
Yield grade 4 & 5, %	17.1	17.9	1.8	0.76

[1]Deads out basis.

Cattlemen's Day 2003

EFFECT OF MELENGESTROL ACETATE (MGA) ON CULTURED BOVINE MUSCLE SATELLITE CELL PROLIFERATION AND DIFFERENTIATION

E. K. Sissom, J. P. Kayser, A. T. Waylan, J. D. Dunn, and B. J. Johnson

Summary

Melengestrol acetate (MGA) increases growth rate and inhibits estrus in feedlot heifers. Little is known of MGA's effect on skeletal muscle growth and differentiation. The purpose of this trial was to investigate the potential direct effects of MGA on cultured bovine muscle satellite cell proliferation and differentiation. Satellite cells isolated from yearling cattle were used to assess the effect of MGA in a dose titration (0, 1 n*M*, 10 n*M*, 100 n*M*, 1 μ*M*, 10 μ*M*, and 100 μ*M*) study on [^{3}H]-thymidine incorporation. Likewise, satellite cell cultures were allowed to differentiate, and nuclei were stained at 168 hours to determine the effect of MGA (10 n*M* and 100 μ*M*) addition during the first 48 hours on extent of differentiation and absolute myotube nuclei number. MGA addition resulted in a dose-dependent decrease ($P<0.05$) in DNA synthesis as measured by [^{3}H]-thymidine incorporation. MGA addition (10 n*M*) did not significantly alter the extent of differentiation or myotube nuclei number at 168 hours in culture even though this concentration reduced DNA synthesis. However, 100 μ*M* MGA addition significantly ($P<0.05$) reduced both fusion percentage and myotube nuclei number as compared to control cultures. These data suggest MGA addition at concentration between 10 nM and 100 μ*M* affected bovine muscle cell proliferation and differentiation. A better understanding of these effects will increase our knowledge of bovine muscle growth and development.

Introduction

Melengestrol acetate (MGA) is an orally active, synthetic progestogen that has been fed to feedlot heifers in the United States for over 30 years. MGA has been shown to be efficacious at increasing growth rate and inhibiting estrus in feedlot heifers. While many of the well-documented benefits of MGA have been attributed to the latter, very little information exists in relation to potential direct effects that this progestogen may have on skeletal muscle growth and metabolism, in particular to muscle satellite cell proliferation and differentiation. Satellite cells have been shown to be critically important in supporting postnatal muscle growth. Satellite cells provide the important DNA necessary to support increased muscle hypertrophy during postnatal growth. Satellite cells fuse with existing fibers and, in so doing, contribute their nuclei to the fiber. It has been estimated that approximately 60 to 90% of the DNA in a mature muscle fiber originates from satellite cells. Thus, satellite cell proliferation and subsequent fusion into muscle fibers to provide DNA required for muscle growth may be a critical rate limiting step for muscle growth. Increasing either the rate of satellite cell proliferation or the number of proliferating satellite cells could enhance the extent and efficiency of muscle growth in beef cattle. The purpose of this trial was to investigate the potential direct effects of MGA on cultured bovine muscle satellite cell proliferation and differentiation.

Experimental Procedures

Bovine Satellite Cell Isolation. Satellite cell isolation was conducted using standard laboratory procedures. Cattle were sacrificed by bolting followed by exsanguination. Using sterile techniques, approximately one pound of the semimembranosus muscle was removed and transported to the cell culture laboratory. Subsequent procedures were conducted in a sterile field under a tissue culture hood. After removal of connective tissue, the muscle was passed through a sterile meat grinder. The ground muscle was incubated with 0.1% pronase in Earl's Balanced Salt Solution (EBSS) for 1 hour at 37°C with frequent mixing. Following incubation, the mixture was centrifuged at 1500 x g for 4 minutes, the pellet was suspended in phosphate buffered saline (PBS: 140 m*M* NaCl, 1 m*M* KH_2PO_4, 3 m*M* KCl, 8 m*M* Na_2HPO_4), and the suspension was centrifuged at 500 x g for 10 minutes. The supernatant was centrifuged at 1500 x g for 10 minutes to pellet the mononucleated cells. The PBS wash and differential centrifugation were repeated two more times. The resulting mononucleated cell preparation was suspended in cold (4°C) Dulbecco's Modified Eagle Medium (DMEM) containing 10% fetal bovine serum (FBS) and 10% (v/v) dimethylsulfoxide (DMSO) and frozen. Cells were stored frozen in liquid nitrogen.

[^{3}H]Thymidine Incorporation. Bovine satellite cells were plated for measuring thymidine incorporation. Culture plates were pre-coated with reduced growth factor basement membrane matrigel diluted 1:10 (v/v) with DMEM. Cells were plated in DMEM containing 10% FBS and incubated at 37°C, 5% CO_2 in a water-saturated environment. Plating density for cells was empirically established so that all cultures were 25 to 50% confluent after the incubation period. This ensured that cell proliferation rate was not affected by contact inhibition. In the first set of experiments, 48 hours after plating the bovine satellite cells in 10% FBS/DMEM, cultures were rinsed three times with serum-free DMEM, and the appropriate levels of MGA (0, 1 n*M*, 10 n*M*, 100 n*M*, 1 μ*M*, 10 μ*M*, and 100 μ*M*) were added in 2% bovine serum (BS)/DMEM. This range spans both the physiological and pharmacological dose of MGA *in vivo*. In the second set of experiments, appropriate MGA levels were added to the cultures immediately following the plating of the cells to give final concentrations similar to those used in the first set of experiments. At 48 hours, cultures were rinsed three times with serum-free DMEM, and 2% BS/DMEM was added. For both sets of experiments, at 72 hours, cultures were rinsed three times with serum-free DMEM and [^{3}H]-thymidine was added to each well. Cells with [^{3}H]-thymidine were incubated at 37°C, 5% CO_2 in a water-saturated environment for 3 hours. After incubation period, satellite cells were rinsed three times with cold serum-free DMEM to wash off free [^{3}H]-thymidine. Cold 5% trichloroacetic acid (TCA) was added to every well and incubated overnight at 4ºC. The following day, cells were rinsed two times with cold TCA to remove any remaining unincorporated [^{3}H]-thymidine. The precipitated cell material was dissolved in 0.5 mL of 0.5 *M* NaOH by vigorously shaking the plates for 30 minutes at 37°C. The NaOH suspensions were transferred quantitatively into scintillation vials containing 10 mL of scintillation cocktail and counted in a scintillation counter. All treatments were measured in triplicate.

Markers of differentiation. Bovine satellite cells were plated as previously described to be used for differentiation studies. MGA (0, 10 n*M*, 100 μ*M*) was added to the cultures immediately following plating of the cells. At 48 hours, cultures were rinsed three times with serum-free DMEM and 10% FBS/DMEM was added. At 96 hours, cells were rinsed three times with serum-free DMEM, and 3% horse

serum/1.5 μg/mL BSA-Linoleic Acid/DMEM fusion media was added. After approximately 120 hours in culture, cells fused into multinucleated myotubes and were stained using Hoechst 33342 stain. The stained nuclei were visible under blue fluorescent light, at which time, digital photos were taken of random fields in each well to determine extent of differentiation (fusion percentage; defined as myotube nuclei/total nuclei). Treatments were measured in duplicate.

Results and Discussion

MGA was added to bovine satellite cell cultures at concentrations that spanned 1 n*M* to 100 μ*M* (supraphysiolgical). Little information is available as to the blood level of MGA in heifers fed the approved dose. MGA addition to cultured bovine satellite cells resulted in a dose-dependent decrease in DNA synthesis as measured by [^{3}H]-thymidine incorporation (Figure 1). [^{3}H]-Thymidine incorporation of bovine satellite cells was not affected ($P>0.05$) by the addition of 1 n*M* MGA. However, the addition of 10 n*M*, 100 n*M*, and 1 μ*M* MGA to cultures of proliferating bovine satellite cells reduced [^{3}H]-thymidine incorporation 27, 25, and 28%, respectively, compared to the control. Additionally, MGA doses of 10 and 100 μ*M* further reduced [^{3}H]-thymidine incorporation 50 and 57%, respectively, compared to control cultures.

The effect of MGA addition on the extent of muscle satellite cell differentiation was also assessed. Based on results of the [^{3}H]-thymidine incorporation experiments, we chose 10 n*M* and 100 μ*M* MGA addition to assess these potential effects. MGA addition at a level of 10 n*M* did not significantly alter ($P<0.05$) the extent of differentiation as estimated by fusion percentage (Table 1). Similarly, there was no difference in the absolute number of myotube nuclei when 10 n*M* of MGA was supplemented (Table 1). However, the addition of 100 μ*M* MGA significantly reduced ($P<0.05$) both fusion percentage and myotube nuclei number when compared to control cultures (Table 1).

Taken together, our data suggest that MGA-supplemented cultures (10 n*M*) can partially overcome the MGA-dependent decrease in DNA synthesis early in the proliferation stages as demonstrated by reduction in [^{3}H]-thymidine incorporation and achieve similar myotube nuclei number and fusion percentage at 168 hours. However, this was not the case for those cultures treated with supraphysiological doses (100 μ*M*). Additional research investigating the mechanism of MGA at the cellular level will increase our understanding of MGA's role in improving performance of feedlot heifers.

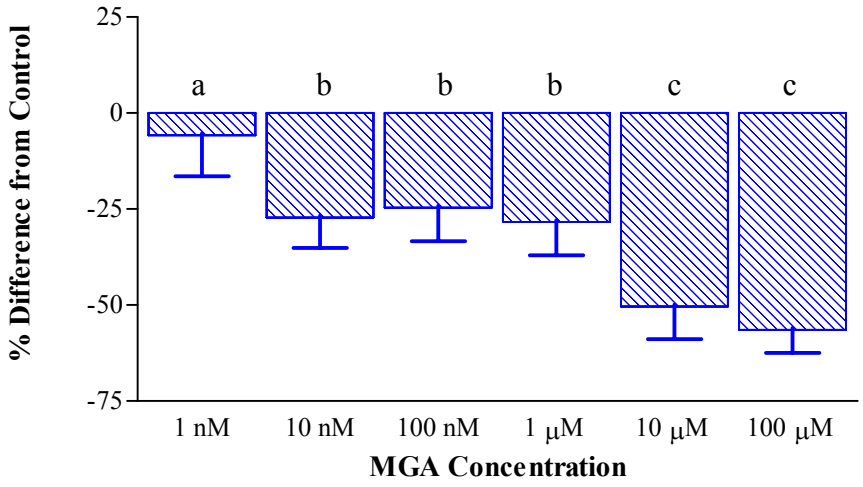


Figure 1. [^{3}H]-Thymidine Incorporation of Bovine Satellite Cells Treated with Various Doses of MGA. Bars with different superscripts differ P<0.05. Control and 1 n*M* MGA were similar.

Table 1. Fusion Percentage and Myotube Nuclei in Satellite Cell Cultures Treated with MGA

		MGA	
Item	Control	10 n*M*	100 μ*M*
Fusion, % [a]	24.5^c ± 2.0	22.5^c ± 1.6	3.8^d ± 0.56
Myotube nuclei [b] (nuclei/cm^2)	1600^c ± 173	1249^c ± 112	159^d ± 27
Total nuclei [b] (nuclei/cm^2)	6488^c ± 328	5510^d ± 260	4244^e ± 289

[a](myotube nuclei/total nuclei) x 100.
[b]168 hours after plating.
[c,d,e]Means in a row with different superscripts differ (P<0.05).

BIOLOGICAL VARIABILITY AND STATISTICAL EVALUATION OF DATA

The variability among individual animals in an experiment leads to problems in interpreting the results. Animals on treatment X may have a higher average daily gain than those on treatment Y, but variability within the groups may indicate that the difference between X and Y is not the result of the treatment alone. You can never be totally sure that the difference you observe is due to the treatment, but statistical analysis lets researchers calculate the probability that such differences are from chance rather than from the treatment.

In some articles, you will see the notation "P<0.05." That means the probability that the observed difference was due to chance is less than 5%. If two averages are said to be "significantly different," the probability is less than 5% that the difference is due to change C the probability exceeds 95% that the difference is true and was caused by the treatment.

Some papers report correlations C measures of the relationship between traits. The relationship may be positive (both traits tend to get larger or smaller together) or negative (as one gets larger, the other gets smaller). A perfect correlation is either +1 or B1. If there is no relationship at all, the correlation is zero.

You may see an average given as 2.5 " .1. The 2.5 is the average; .1 is the "standard error." That means there is a 68% probability that the "true" mean (based on an unlimited number of animals) will be between 2.4 and 2.6. "Standard deviation" is a measure of variability in a set of data. One standard deviation on each side of the mean is expected to contain 68% of the observations.

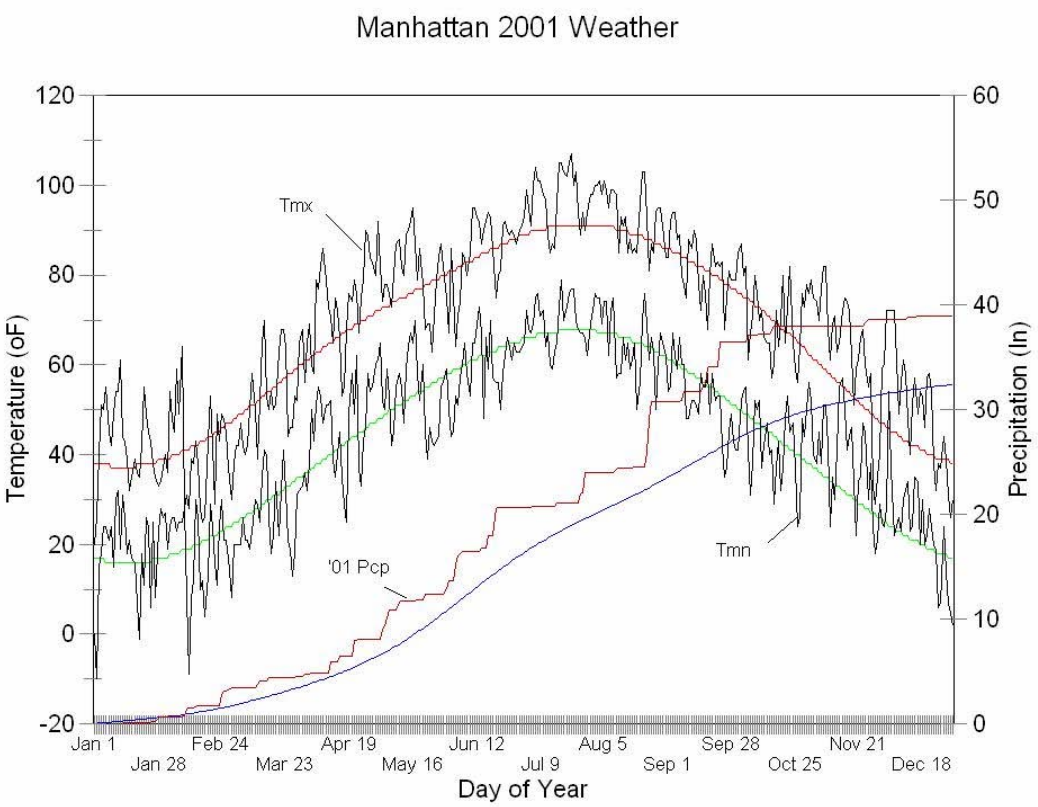
Many animals per treatment, replicating treatments several times, and using uniform animals all increase the probability of finding real differences when they actually exist. Statistical analysis allows more valid interpretation of the results, regardless of the number of animals in an experiment. In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

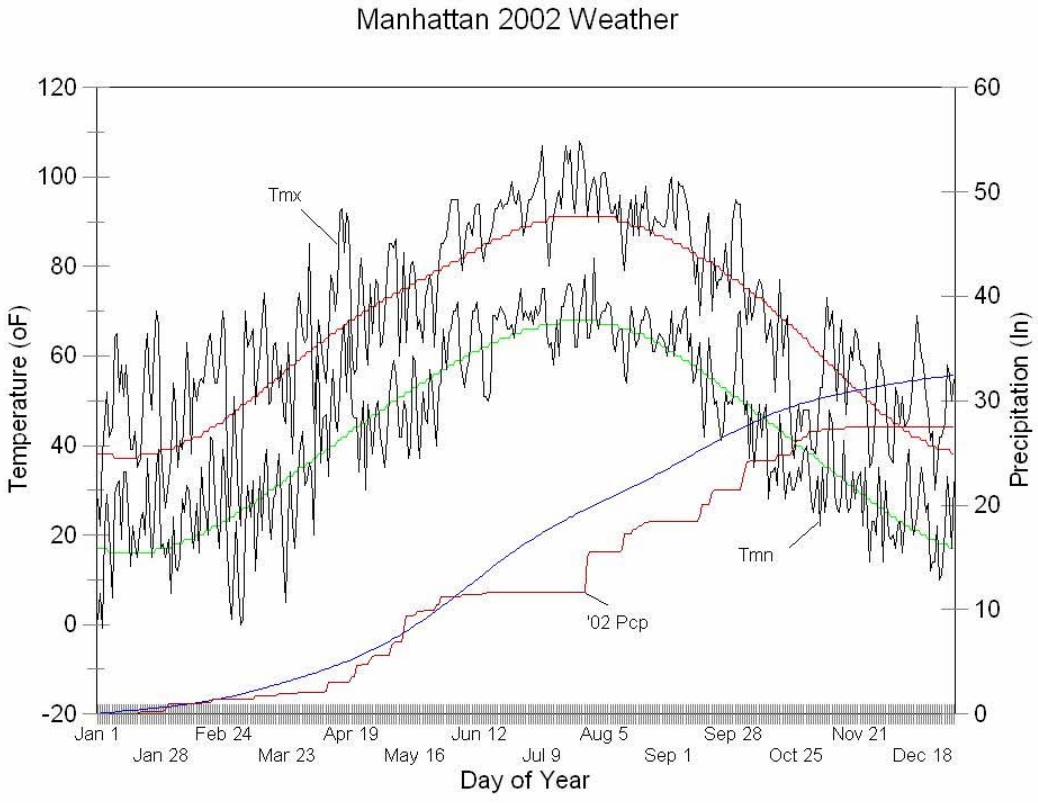
In most experiments, the statistical analysis is too complex to present in the space available. Contact the authors if you need further statistical information.

WEATHER DATA, 2001-2002

On the following page are graphs of the 2001 and 2002 Manhattan weather. They were produced by the Kansas State University Weather Data Library. The smooth line that starts in the lower left corner of each graph is the normal accumulated precipitation since January 1. The rough line starting in the lower left corner represents actual accumulated precipitation. A long horizontal section of that line represents time during which no precipitation fell. A vertical section represents precipitation. The other two smooth lines represent average daily high and low temperatures, and the rough lines represent actual highs and lows.

These graphs are included because much of the data in this publication, especially data on animal maintenance requirements and forage yields, can be influenced by weather. Weather graphs have been included in Cattlemen's Day publications since 1985.





ACKNOWLEDGEMENTS

Listed below are individuals, organizations and firms that have contributed to this year's beef research program through financial support, product donations, or services. We appreciate your help!

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Novartis Animal Vaccines, Bucyrus, Kansas
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