12-1-2002

Arkansas Animal Science Department Report 2002

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Arkansas Animal Science

Department Report • 2002

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Editors

ARKANSAS AGRICULTURAL EXPERIMENT STATION
Division of Agriculture
University of Arkansas
December 2002
Research Series 499

Department of Animal Science annual reports are available on the web at: http://www.uark.edu/depts/agripub/Publications/researchseries/

Cover photo by Scott Bauer, USDA ARS

Technical editing and cover design by Cam Romund; graphics conversion by Shelia Kidd

Arkansas Agricultural Experiment Station, University of Arkansas Division of Agriculture, Fayetteville. Milo J. Shult, Vice President for Agriculture and Director; Gregory J. Weidemann, Dean, Dale Bumpers College of Agricultural, Food and Life Sciences and Associate Vice President for Agriculture–Research, University of Arkansas Division of Agriculture. PS720QX50. The University of Arkansas Division of Agriculture follows a nondiscriminatory policy in programs and employment.
ISSN:1051-3140 CODEN:AKAMA6

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ARKANSAS ANIMAL SCIENCE DEPARTMENT REPORT • 2002

JOHNSON AND KELLOGG

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ARKANSAS ANIMAL SCIENCE DEPARTMENT REPORT 2002

Edited by

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and

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INTRODUCTION

The faculty and staff of the animal science programs are pleased to present the fifth edition of the Arkansas Animal Science Report.

The highlight of the year was the ranking of the animal and poultry science programs among the top five in the country by Meat and Poultry Magazine. This is a tribute to the dedicated and talented faculty in both departments.

Our capacity to conduct research and teaching programs on swine was significantly enhanced with the completion of our new growing and finishing unit. Dr. Maxwell and his group put pigs in the facility literally the day the facility was completed. The program of depopulating the existing swine herd and replacing those pigs with disease-free lines of modern genetics ensures that our swine research is being conducted with the type of genetics used in the industry today. The crew at the swine unit is to be congratulated and thanked for their tireless efforts to complete the considerable task of construction, renovation, and repopulation.

Private support for animal science programs has been impressive and appreciated. New endowments and contributions to support the equine program and the livestock judging team have added needed base support for both these activities. With the addition of three new courses in the equine area, the expansion of the curriculum to reflect the interests of our changing student body has largely been completed.

The animal science programs (teaching, research, and extension) used a multi-disciplinary approach to collaboratively address many of the most challenging issues facing the Arkansas livestock industry. The extension programs provided a critical bridge between the evolving research and issues faced by Arkansans. Research-based solutions in the areas of beef, dairy, and horse production, forage and grazing management, waste management, plus many other livestock related areas were delivered to our industry stakeholders. On any given day, you could find animal science extension faculty taking forage samples, weighing cattle, presenting educational programs, serving on state, regional and national committees, teaching the youth of Arkansas, or visiting a ranch to help solve a problem.

The animal science extension program experienced a number of retirements this past year. Dr. George Davis, Mr. Bill Wallace, and Mr. Larry Sandage devotedly served the Arkansas livestock industry. Their years of expertise will be missed. Likewise, we will miss the contributions of Dr. Bernie Daniels, who retired from research and teaching in May. During his tenure, Dr. Daniels served in every capacity from assistant professor to interim associate vice president for agriculture.

Financial problems have weighed heavily on our University as they have weighed on most other institutions across the nation. The faculty have reacted by looking at ways to make our programs relevant, competitive and sustainable in this new educational environment. We are confident that they will succeed. The animal science faculty and staff look forward to serving the livestock industry in the coming year.

Sincerely,

Keith Lusby
Department Head

Tom Troxel
Section Leader

INTERPRETING STATISTICS

Scientists use statistics as a tool to determine which differences among treatments are real (and therefore biologically meaningful) and which differences are probably due to random occurrence (chance) or some other factors not related to the treatment.

Most data will be presented as means or averages of a specific group (usually the treatment). Statements of probability that treatment means differ will be found in most papers in this publication, in tables as well as in the text. These will look like ($P < 0.05$); ($P < 0.01$); or ($P < 0.001$) and mean that the probability (P) that any two treatment means differ entirely due to chance is less than 5, 1, or .1%, respectively. Using the example of $P < 0.05$, there is less than a 5% chance that the differences between the two treatment averages are really the same. Statistical differences among means are often indicated in tables by use of superscript letters. Treatments with any letter in common are not different, while treatments with no common letters are. Another way to report means is as mean ± standard error (e.g. 9.1 ± 1.2). The standard error of the mean (designated SE or SEM) is a measure of how much variation is present in the data – the larger the SE, the more variation. If the difference between two means is less than two times the SE, then the treatments are usually not statistically different from one another. Other authors may report an LSD (least significant difference) value. When the difference between any two means is greater than or equal to the LSD value, then they are statistically different from one another. Another estimate of the amount of variation in a data set that may be used is the coefficient of variation (CV) which is the standard error expressed as a percentage of the mean. Orthogonal contrasts may be used when the interest is in reporting differences between specific combinations of treatments or to determine the type of response to the treatment (i.e. linear, quadratic, cubic, etc.).

Some experiments may report a correlation coefficient (r), which is a measure of the degree of association between two variables. Values can range from –1 to +1. A strong positive correlation (close to +1) between two variables indicates that if one variable has a high value then the other variable is likely to have a high value also. Similarly, low values of one variable tend to be associated with low values of the other variable. In contrast, a strong negative correlation coefficient (close to –1) indicates that high values of one variable tend to be associated with low values of the other variable. A correlation coefficient close to zero indicates that there is not much association between values of the two variables (i.e. the variables are independent). Correlation is merely a measure of association between two variables and does not imply cause and effect.

Other experiments may use similar procedures known as regression analysis to determine treatment differences. The regression coefficient (usually denoted as b) indicates the amount of change in a variable Y for each one-unit increase in a variable X. In its simplest form (i.e. linear regression), the regression coefficient is simply the slope of a straight line. A regression equation can be used to predict the value of the dependent variable Y (e.g. performance) given a value of the independent variable X (e.g. treatment). A more complicated procedure, known as multiple regression, can be used to derive an equation that uses several independent variables to predict a single dependent variable. Associated statistics are r^2, the simple coefficient of determination, and R^2, the multiple coefficient of determination. These statistics indicate the proportion of the variation in the dependent variable that can be accounted for by the independent variables. Some authors may report the square root of the Mean Square for Error (RMSE) as an estimate of the standard deviation of the dependent variable.

Genetic studies may report estimates of heritability (h^2) or genetic correlation (r_g). Heritability estimates refer to that portion of the phenotypic variance in a population that is due to heredity. A genetic correlation is a measure of whether or not the same genes are affecting two traits and may vary from –1 to +1.

COMMON ABBREVIATIONS

Abbreviation	Term
ADFI	Average daily feed intake
ADG	Average daily gain
avg	Average
BW	Body weight
cc	Cubic centimeter
cm	Centimeter
CP	Crude protein
CV	Coefficient of variation
cwt	100 pounds
d	Day(s)
DM	Dry matter
DNA	Deoxyribonucleic acid
°C	Degrees Celsius
°F	Degrees Fahrenheit
EPD	Expected progeny difference
F/G	Feed:gain ratio
FSH	Follicle stimulating hormone
ft	Foot or feet
g	Grams(s)
gal	Gallon(s)
h	Hour(s)
in	Inch(es)
IU	International units
kcal	Kilocalories(s)
kg	Kilograms(s)
lb	Pound(s)
L	Liter(s)
LH	Lutenizing hormone
m	Meter(s)
mg	Milligram(s)
Meq	Milliequivalent(s)
Mcg	Microgram(s)
min	Minute(s)
mm	Millimeter(s)
mo	Month(s)
N	Nitrogen
NS	Not Significant
ng	Nanogram(s)
ppb	Parts per billion
ppm	Parts per million
r	Correlation coefficient
r^2	Simple coefficient of determination
R^2	Multiple coefficient of determination
s	Second(s)
SD	Standard deviation
SE	Standard error
SEM	Standard error of the mean
TDN	Total digestible nutrients
wk	Week(s)
wt	Weight
yr	Year(s)

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Effects of Nitrogen Fertilization on Phosphorus Removal in Bermudagrass Hay

W. K. Coblentz[1], J. L. Gunsaulis[2], M. B. Daniels[3], J. E. Turner[1], D. A. Scarbrough[1], J. B. Humphry[1], K. P. Coffey[1], K. A. Teague[2], J. D. Speight[2], and M. R. Gross[2]

Story in Brief

During 2000, three harvests of common bermudagrass [*Cynodon dactylon* (L.) Pers.] were made at two high soil-test phosphorus (P) sites (Latta and Stephens) in northwest Arkansas to assess the effects of N fertilization on P removal in bermudagrass hay. Ammonium nitrate was applied in split applications totaling 0, 50, 100, 150, 200, 250, or 300 lb N/acre for the year. On the third (final) harvest date, concentrations of P in the forage declined linearly with N fertilization rate at both sites ($P < 0.0001$), and ranged from 0.26 to 0.39% at the Latta site and 0.29 to 0.53% at the Stephens site. A quadratic effect ($P = 0.015$) was also observed at the Latta site. Generally, changes in concentrations of P on the first two harvest dates varied only marginally with N fertilization. Total yields of forage DM ranged from 9,692 to 12,532 lb/acre at the Latta site and from 4,533 to 8,688 lb/acre at the Stephens site. Cumulative P removal over three harvests increased linearly ($P = 0.013$) from 37.1 to 45.8 lb/acre at the highly fertile Latta site and linearly ($P = 0.0004$) from 17.9 to 26.7 lb/acre at the Stephens site. Droughty conditions late in the summer prevented a fourth harvest and reduced total P removal.

Introduction

Many soils in northwest Arkansas have excessively high levels of phosphorus (P) because of repeated applications of poultry and other animal wastes. One long-term technique that can be used to lower these high levels of soil-test P is removing all forage as hay or silage (mining). Unlike grazing situations, hay or silage produced on these sites can be removed to other locations for feeding, thereby preventing the livestock from recycling the P back onto the same site. Bermudagrass has been described for more than a century as one of the most important grasses grown in the Southeastern US. This highly productive, warm-season grass is used widely by beef and dairy producers for both grazing and hay production. Bermudagrass also is highly responsive to fertilization with N and is an important and valuable cash crop in northwest Arkansas. These traits make it an attractive forage choice for mining P from sites that are already excessively high in P. Our goal was to evaluate the relationships between concentrations of P or P removal and N fertilization rate for common bermudagrass grown on two sites in northwest Arkansas.

Experimental Procedures

Generation of Sample Sets. Twenty-eight 10-ft x 20-ft plots were established on two producer farms (Latta and Stephens) located near Lincoln, AR in the early spring of 2000. Both sites had past histories of poultry waste application. Manure from a caged layer operation was applied during the previous year (1999) at the Latta site only. Concentrations of soil-test P were 305 and 571 lb/acre at the Stephens and Latta sites, respectively. These sites are representative of many in northwestern Arkansas that have histories of intermittent or annual applications of poultry waste. Nitrogen was applied as ammonium nitrate (34-0-0) in split applications of 0, 50, 100, and 150 lb N/acre on April 28 and July 19. For the year, N fertilizer was applied at cumulative rates of 0, 50, 100, 150, 200, 250, and 300 lb N/acre as shown in Table 1. Plots at each site were arranged in a randomized complete block design with four replications. Plots were clipped to a 2-in stubble height on May 30, July 7, and August 18 with a sickle-bar mower. Fresh weights were obtained from each plot in the field and representative subsamples were retained for determination of percentage of DM and subsequent laboratory analysis. The extremely dry conditions in Arkansas during the late summer of 2000 prevented a final (fourth) harvest in early fall. On April 28 and November 4, 2000 and April 25, 2001, soil samples (eight 6-in cores per plot) were obtained and subsequently submitted to the University of Arkansas Agricultural Diagnostic Laboratory for determination of soil-test P by Mehlich III extraction.

Forage Preparation and Analysis. All forage samples were dried to a constant weight under forced air at 122°F. Dry forage samples were ground through a Wiley mill (Arthur H. Thomas, Philadelphia, PA) equipped with a 1-mm screen before analysis. Total plant P was determined by inductively coupled plasma spectroscopy following a digestion on a heating block in nitric acid and hydrogen peroxide.

Statistical Analysis. For each individual harvest at each site, orthogonal contrasts (PROC GLM; SAS Inst., Inc., Cary, NC) were used to test each response variable for linear, quadratic, and cubic responses to N fertilization. For each individual plot, fertilization rate (0, 50, 100, or 150 lb N/acre) was not necessarily the same on both application dates; therefore, for the first and second harvest, contrast statements were constructed based on the initial (April 28) application of ammonium nitrate. For the third harvest, contrast statements were based on the second application of fertilizer N on July 19. A combined analysis of all data from all three harvests at each site was conducted by similar methods. This analysis included seven N fertilization rates (0, 50, 100, 150, 200, 250, and 300 lb N/acre), and a test for quartic effects was included in the model.

Results and Discussion

Concentrations of Phosphorus in Forages. At the Stephens site, fertilization with N had no effect ($P > 0.05$) on concentrations of P in bermudagrass forage on the May 30 harvest date (Table 2). On the

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July 7 harvest date, a linear response (P = 0.056) was observed; however, the range of concentrations was small (0.31 to 0.35%) and is probably of little biological significance. Similarly, linear (P = 0.042) and cubic (P = 0.046) responses to N fertilization were observed at the Latta site on the May 30 and July 7 harvest dates, but these responses also were quite limited (overall ranges = 0.41 to 0.44% and 0.35 to 0.39%, respectively). In contrast, substantial reductions in concentrations of P with increasing levels of N fertilization were observed at both sites on the final (August 18) harvest date. These effects were linear (P < 0.0001) at the Stephens site, and quadratic (P = 0.015) at the Latta site. Concentrations of P in forages fertilized with 150 lb N/acre in July fell to 55 and 67% of those in unfertilized plots at the Stephens and Latta sites, respectively.

DM Yield. Yields for individual harvests ranged from 1,433 to 3,404 lb/acre at the Stephens site and 2,269 to 4,922 lb/acre at the Latta site. The effects of N fertilization on yields of DM were predictable (Table 3); DM yields increased linearly (P < 0.01) on May 30 and July 7 at the Stephens site and on May 30 at the Latta site. Quadratic effects (P < 0.052) were observed on the August 18 harvest date at both sites, and a cubic (P = 0.022) response was observed on the July 7 harvest date at the Latta site.

P Removal. Removal of P (Table 4) increased linearly (P < 0.005) on the May 30 harvest date at both sites, but the maximum removal at the Latta site was much greater (17.8 lb P/acre) than at the Stephens site (7.6 lb P/acre). This was largely the result of differences in DM yield, but concentrations of P also averaged about 0.10% higher at the Latta site on this date. A linear increase (P = 0.001) was observed at the Stephens site on the July 7 harvest date for carryover effects of the initial application of N; this was not observed at the Latta site (P > 0.05). Removal of P on the final harvest date was complicated by competing factors; DM yield increased with N fertilization at both sites, but concentrations of P in the forage declined substantially. Therefore, differences in P removal between the forages fertilized with 150 lb N/acre and unfertilized controls were very small (< 1.1 lb P/acre).

Cumulative Responses to N Fertilization. During 2000, the cumulative effects of N fertilization (Tables 5 and 6) were to increase DM yield linearly (P < 0.0001), but to reduce concentrations of P in the forage at both sites. These reductions were primarily linear (P < 0.0001), and were driven by the large changes in concentrations of P observed for the final harvest date. Removal of P increased linearly (P = 0.013) at the Latta site; a quadratic trend (P = 0.061) was observed at the Stephens site. The maximum removal of P was about 46 lb/acre on the highly fertile Latta site. Removal of P could have been higher at both sites, but a severe late-summer drought prevented a meaningful final (fourth) harvest.

Effects on Soil-Test Phosphorus. Between April 2000 and April 2001, soil-test P fell by 78 lb/acre (Table 7) at the Latta site; however, there was no response to N fertilization on any individual evaluation date.

Implications

Based on these limited results, a maximum of about 50 lb P/acre can be mined from a site with the bermudagrass harvested as hay. Increasing DM yield with heavy applications of fertilizer N may not necessarily result in proportional increases in P removal.

Table 1. Application scheme for fertilization of bermudagrass with ammonium nitrate (34-0-0) at the Stephens and Latta sites during 2000

Total N Applied[a]	1st Application[b]	2nd Application[c]
---------- lb N/acre ----------		
0	0	0
50	50	0
100	50	50
150	100	50
200	100	100
250	150	100
300	150	150

[a] Total application for the entire growing season.
[b] April 28, 2000.
[c] July 19, 2000.

Table 2. Effects of N fertilization on concentrations of P in bermudagrass harvested at two sites near Lincoln, AR

Fertilization	Stephens site			Latta site		
rate	May 30	July 7	August 18	May 30	July 7	August 18
lb N/acre	% of DM					
0	0.30	0.35	0.53	0.41	0.36	0.39
50	0.33	0.34	0.45	0.42	0.39	0.32
100	0.33	0.33	0.36	0.42	0.36	0.28
150	0.32	0.31	0.29	0.44	0.35	0.26
SEM[a]	0.011	0.015	0.013	0.007	0.010	0.009
Effect[b]	NS	L = 0.056	L < 0.0001	L = 0.042	C = 0.046	L < 0.0001
						Q = 0.015

[a] Standard error of the mean.
[b] NS, not significant (P > 0.05); L, linear effect; Q, quadratic effect; C, cubic effect.

Table 3. Effects of N fertilization on DM yield of bermudagrass harvested at two sites near Lincoln, AR

	Stephens site			Latta site		
Fertilization rate	May 30	July 7	August 18	May 30	July 7	August 18
lb N/acre	lb DM/acre					
0	1,514	1,433	1,712	3,070	4,487	2,269
50	1,718	1,735	2,866	3,714	4,256	3,114
100	1,811	1,943	3,225	3,722	4,922	3,676
150	2,350	2,480	3,404	4,113	4,782	3,756
SEM[a]	128	114	103	193	150	166
Effect[b]	L = 0.001	L < 0.0001	L < 0.0001	L = 0.007	L = 0.069	L < 0.0001
			Q = 0.0004		C = 0.022	Q = 0.052

[a] Standard error of the mean.
[b] L, linear effect; Q, quadratic effect; C, cubic effect.

Table 4. Effects of N fertilization on P removal from bermudagrass harvested at two sites near Lincoln, AR

	Stephens site			Latta site		
Fertilization rate	May 30	July 7	August 18	May 30	July 7	August 18
lb N/acre	lb/acre					
0	4.5	5.1	9.0	12.7	16.0	8.7
50	5.6	5.9	12.9	15.7	16.6	9.9
100	5.9	6.4	11.7	15.7	17.6	10.2
150	7.6	7.6	9.7	17.8	17.0	9.8
SEM[a]	0.45	0.36	0.62	0.98	0.62	0.54
Effect[b]	L = 0.001	L = 0.001	Q = 0.0002	L = 0.005	NS	NS

[a] Standard error of the mean.
[b] NS, not significant (P > 0.05); L, linear effect; Q, quadratic effect.

Table 5. Cumulative effects of N fertilization on DM yield, concentrations of P, and total removal of P in bermudagrass harvested at the Stephens site near Lincoln, AR during 2000

Fertilization rate	Yield	P	P Removal
lb N/acre	lb/acre	% of DM	lb/acre
0	4,533	0.39	17.9
50	5,197	0.41	21.0
100	6,495	0.36	24.3
150	6,399	0.38	24.9
200	7,064	0.33	23.6
250	7,648	0.34	26.7
300	8,688	0.29	25.4
SEM[a]	344	0.01	1.4
Effect[b]	L < 0.0001	L < 0.0001	L = 0.0004
			Q = 0.061

[a] Standard error of the mean.
[b] L, linear effect; Q, quadratic.

Table 6. Cumulative effects of N fertilization on DM yield, concentrations of P, and total removal of P in bermudagrass harvested at the Latta site near Lincoln, AR during 2000

Fertilization rate	Yield	P	P Removal
lb N/acre	lb/acre	% of DM	lb/acre
0	9,692	0.39	37.1
50	10,310	0.40	41.3
100	11,198	0.37	42.3
150	11,684	0.37	43.6
200	12,467	0.35	43.5
250	12,564	0.36	45.8
300	12,532	0.34	43.5
SEM[a]	492	0.01	2.1
Effect[b]	L < 0.0001	L < 0.0001	L = 0.013
		Qu = 0.072	

[a] Standard error of the mean.
[b] L, linear effect; Qu, quartic.

Table 7. Soil-test P for bermudagrass plots at the Stephens and Latta sites in April 2000, November 2000, and April 2001 as determined by Mehlich III extraction. Nitrogen fertilization rate demonstrated no effect (P > 0.05) on soil-test P at either site on any date; therefore, only overall means are presented

Sampling date	Stephens	Stephens SEM	Latta	Latta SEM
	---------- lb/acre ----------			
April 2000	306	6	572	10
November 2000	276	8	568	10
April 2001	NA[a]	- -	494	8

[a] Not available. Site lost after November 2000.

Quality Characteristics and In Situ Dry-Matter Disappearance Kinetics of Wheat Forages Harvested by Clipping or as Masticate

W.K. Coblentz[1], K.P. Coffey[1], J.E. Turner[1], D.A. Scarbrough[1], J.V. Skinner[2], D.W. Kellogg[1], and J.B. Humphry[1]

Story in Brief

Much of the previous work evaluating forage quality characteristics and in situ DM disappearance kinetics of cereal-grain forages has not considered the effects of diet selection. Our objective was to evaluate the effects of harvest technique and sampling date on the in situ DM disappearance kinetics and nutritive value of wheat (*Triticum aestivum* L.). Forage was harvested on three dates (March 6, March 27, and April 11, 2000) using five techniques. Techniques included freeze- (FDM) or oven-dried (122°F; ODM) masticate and whole-plant, random-pluck, or top-half samples harvested with garden shears. There was an interaction ($P < 0.05$) of harvest date and sampling technique for CP, NDF, ADF, hemicellulose, cellulose, lignin, and whole-plant ash. There were greater ($P < 0.05$) concentrations of most fiber components in ODM than in FDM on all harvest dates. Experimental forages also were evaluated for ruminal disappearance of DM in situ. There was no interaction ($P = 0.092$) of harvest date and sampling technique for rate (k_d) of DM disappearance. The FDM exhibited the fastest k_d (0.088/h); ODM (0.070/h) and the top-half (0.076/h) clipping treatments were similar ($P > 0.05$), but slower ($P < 0.05$) than FDM. Disappearance from other clipped treatments was at the slowest rate (0.055/h). None of the clipping treatments did a good job of mimicking the diet selected by grazing cattle.

Introduction

Cereal grains, such as wheat, have been used routinely across the southern Great Plains to provide fall, winter, and spring grazing for a variety of livestock. Numerous studies have evaluated the nutritive value of wheat or mixtures containing wheat as affected by harvest date or growth stage. Recently, in situ disappearance kinetics of DM and NDF for wheat, oats (*Avena sativa* L.), and rye (*Secale cereale* L.) were related to growth stage by linear and polynomial regression techniques (Coblentz et al., 2000). While these efforts have provided a solid understanding of the relationships between the nutritive value or in situ disappearance kinetics of cereal grains and the associated harvest date or growth stage, they have not addressed the impact that diet selection may play in these relationships. Our objective in this study was to evaluate the effects of various sampling techniques and sampling date on the in situ DM disappearance kinetics and nutritive value of wheat forage.

Experimental Procedures

Establishment and Management of Experimental Forages. A 4-acre site located at the University of Arkansas Forage Research Area in Fayetteville was clean-tilled and fertilized to meet the soil test recommendations of the Arkansas Cooperative Extension Service; this included an application of 60 lb/acre of actual N as NH_4NO_3. The site was seeded with 'Delta King 9027' soft-red winter wheat on September 10, 1999 at a rate of 120 lb/acre with a 7-ft Marliss drill (Marliss Industries, Jonesboro, AR). An additional 50 lb/acre of N was applied as NH4NO3 on February 15, 2000. Throughout the late fall of 1999 the site was grazed lightly to control fall growth.

Collection of Experimental Forages. In the spring of 2000, three sampling dates were chosen to approximately coincide with the vegetative, mid-elongation, and boot stages of growth for the wheat forage (March 6, March 27, and April 11, respectively). On each date, five sampling techniques were used to gather samples of wheat forage. These included three clipping techniques: 1) whole plant (clipped to a 1-in stubble height); 2) random pluck (clipped to a 1-in stubble height); and 3) top half of standing forage. Masticate samples were also collected from ruminally cannulated steers following manual ruminal evacuation. These samples were either freeze-dried (FDM) or oven-dried (ODM) under forced air (122°F).

Laboratory Analyses. Dried forages were ground through a 1- or 2-mm screen in a Wiley Mill (Arthur H. Thomas, Philadelphia, PA). Subsamples ground through a 1-mm screen were retained for standard assays of forage nutritive value that included NDF, ADF, cellulose, and acid detergent lignin; these were quantified by the batch procedures outlined by ANKOM Technology Corp. (Fairport, NY). Concentrations of hemicellulose were calculated as NDF - ADF. Concentrations of N in each forage were determined by rapid combustion (1562°F; LECO Model FP-428; LECO Corp., St. Joseph, MI); CP was calculated as the percentage of N in the sample x 6.25. Concentrations of whole-plant ash were determined by combusting 2-g samples of each forage at 932°F for 8 h in a muffle furnace. Subsamples ground through a 2-mm screen were retained for in situ analysis.

In Situ Procedures in Confinement. Five 739 ± 129-lb ruminally cannulated crossbred (Angus x Brangus x Angus) steers fitted with ruminal cannulae were housed in individual 11-ft by 16-ft pens with concrete floors that were cleaned regularly and offered a diet of alfalfa (*Medicago sativa* L.) hay (44.4% NDF, 32.9% ADF, and 17.7% CP) and a corn-based supplement (93.8% ground corn, 2.0% molasses, 4.0% trace mineral salt, and 0.2% vitamin A, D, and E premix). On a DM basis, the basal diet contained 87.3% alfalfa hay and 12.7% supplement, and was offered at 2.00% of BW daily in two equal portions (0700 and 1600 h). Water and a trace mineral block were provided for each steer for ad libitum intake. Steers were adapted to the basal diet for 9 d prior to initiating the trial. Other in situ procedures were consistent with the standardized in situ techniques described by Vanzant et al. (1998). Dacron bags containing 5-g samples of each experimental forage were incubated in the rumen for 0,

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3, 6, 9, 12, 24, 36, 48, 72, or 96 h, and subsequently washed in a top-loading washing machine (Coblentz et al., 1997).

Data were fitted to the nonlinear regression model of Mertens and Loften (1980) using PROC NLIN (SAS Inst., Inc., Cary, NC). Dry matter was partitioned into three fractions based on relative susceptibility to ruminal disappearance. The A fraction was defined as the immediately soluble portion; the B fraction was comprised of DM degraded at a measurable rate; and the C fraction was considered undegradable in the rumen. Fractions B and C, disappearance rate (k_d), and the lag time were determined directly from the nonlinear regression model. Fraction A was calculated for each forage as 100 - (B + C); similarly, the potential extent of disappearance was calculated as 100 - C. The effective degradability of DM for the wheat forages was calculated (Ørskov and McDonald, 1979) as A + B _ [k_d/(k_d + k_p)], where k_p = passage rate (0.035 + 0.009/h) that was determined experimentally in each steer using acid detergent insoluble ash as an internal marker.

Statistics. Growth characteristics (DM yield, plant height, and proportion of leaf) were analyzed as a randomized complete block design with harvest dates as treatments and four field replications as blocks. Nutritive value of the wheat forages was evaluated as a split-plot design with sampling techniques as whole plots, harvest dates as subplots, and field replications as the blocking term. Disappearance kinetics of DM were evaluated as a randomized complete block design with a factorial arrangement of five sampling techniques and three harvest dates; the five steers served as blocks. All analyses were conducted by PROC ANOVA (SAS Inst., Inc., Cary, NC).

Results and Discussion

Agronomic Characteristics of Wheat Forage. On March 6, tillers had not yet begun to elongate and plants remained vegetative. However, by the final sampling date, flag leaf sheaths were swollen, indicating that the reproductive head was ready to emerge. By this time, there was more than 7,395 lb DM/acre of available forage in the pasture, and about 3475 lbs DM/acre in the top half of the canopy (Table 1). All growth characteristics changed ($P < 0.05$) during each sampling interval. The proportion of leaf tissue in the forage canopy decreased ($P < 0.05$) from 47.0% on March 27 to 28.7% by April 11.

Nutritive Value of Wheat Forages. For CP, NDF, ADF, hemicellulose, cellulose, lignin, and whole-plant ash, there was an interaction ($P< 0.009$) of the main effects. Comparisons of subplot (sampling date) means within whole-plots (sampling technique) largely reflect changes in nutritive value associated with stem elongation; of greater interest are comparisons of sampling techniques within sampling date (Table 2).

The concentration of whole-plant ash in clipped samples did not differ ($P > 0.05$) within any sampling date; however, concentrations of ash in masticate ranged from 10.1 to 17.3 percentage units greater ($P < 0.05$) than those of associated clipped samples. Within sampling date, drying method did not affect ($P > 0.05$) concentrations of CP in masticate samples on March 6 and April 11, but CP was 2.3 percentage units greater ($P < 0.05$) in ODM on March 27. Although non-significant, this pattern was also observed on the other sampling dates. Concentrations of CP in samples clipped from the top half of the canopy were greatest ($P < 0.05$) on all sampling dates; these concentrations were 9.5 and 7.8 percentage units greater ($P < 0.05$) than FDM masticate collected on March 6 and 27, but both masticate treatments and forage clipped from the top half of the canopy did not differ ($P > 0.05$) on April 11. Clipped whole-plant forage had the lowest concentration of CP on all dates, but this differed ($P < 0.05$) from FDM and ODM on the final sampling date only.

The drying techniques that were used to dehydrate masticate samples had clear effects on the associated concentrations of fibrous components. On the March 6 sampling date, the concentration of NDF in masticate samples increased ($P < 0.05$) by 7.7 percentage units in response to oven drying compared to freeze drying; similar responses were observed on subsequent harvest dates. With relatively few exceptions, samples clipped from the top half of the canopy had lower ($P < 0.05$) concentrations of fibrous components than did random-pluck and whole-plant samples. Random-pluck and whole-plant samples had higher ($P < 0.05$) concentrations of NDF, cellulose, and hemicellulose than FDM on all sampling dates. However, this was not true for ODM; concentrations of NDF and hemicellulose for ODM did not differ ($P > 0.05$) from those of random-pluck or whole-plant treatments on at least one sampling date. Concentrations of ADF were lower ($P < 0.05$) for random-pluck and whole-plant samples than for FDM on March 6; however, concentrations did not differ ($P > 0.05$) on March 27, and ADF was greater in random-plucked and whole-plant samples than in FDM on April 11. Generally, lignin varied over treatments, but the concentration of lignin in FDM was lowest ($P < 0.05$) on all sampling dates. The ODM had greater ($P < 0.05$) concentrations of lignin than FDM on the initial two sampling dates and was numerically ($P > 0.05$) greater on the final sampling date.

Disappearance Kinetics. For the evaluation of in situ DM disappearance kinetics, the interaction of harvest date and sampling technique effects was significant ($P < 0.0001$) for fractions A, B, C, and the potential extent of disappearance; therefore, only interaction means are presented (Table 3). Overall, the large proportions of DM partitioned into fraction A (37.6 to 55.5% of DM) were indicative of high-quality forage. The FDM had greater ($P < 0.05$) proportions of soluble DM than did clipped samples on all sampling dates; this was also true ($P < 0.05$) for ODM on the March 6 and 27 sampling dates, but not ($P > 0.05$) on April 11. The smallest ($P < 0.05$) proportion of DM partitioned into fraction B was observed in FDM on all sampling dates. There were large differences between FDM and clipped treatments (10.3 to 15.5 percentage units) on the first two sampling dates, but these were relatively small (2.0 to 6.0 percentage units) on the final date. Oven-drying greatly increased ($P < 0.05$; 8.4 to 12.5 percentage units) fraction B relative to FDM on all harvest dates, but did not affect ($P > 0.05$) the portion of DM that was unavailable in the rumen. Fraction C for ODM and FDM varied by a maximum of only 0.6 percentage units within any given sampling date. Over all treatments, the potential extent of disappearance ranged from 83.3 to 96.3% of DM (Table 3), which is generally indicative of excellent forage nutritive value.

Sampling technique affected ($P = 0.027$) our estimates of lag time, but sampling date ($P = 0.139$) and the interaction of main effects ($P = 0.534$) did not (Table 4). Averaged over three sampling dates, FDM exhibited a shorter ($P < 0.05$) lag time (0.88 h) than did all other treatments (range = 1.58 to 1.68 h; Table 4). Sampling date and technique both affected our estimates of k_d ($P < 0.0001$), but their associated interaction did not ($P = 0.092$; Table 4). Averaged over three sampling dates, FDM exhibited the most rapid ($P < 0.05$) estimate of k_d (0.088/h). The ODM (0.070/h) and forage clipped from the top half of the canopy (0.076/h) did not differ from each other ($P > 0.05$), but both were slower ($P < 0.05$) than observed for FDM. Whole-plant (0.055/h) and random-pluck (0.055/h) forages had identical ($P > 0.05$) estimates of k_d that were slower ($P < 0.05$) than all other treatments.

Effective Degradability. For the effective ruminal degradability of DM, the interaction of main effects was significant ($P < 0.0001$). Within each sampling date, the effects of oven-drying reduced ($P < 0.05$) the effective degradability of DM relative to FDM. The effective ruminal degradability of DM for forage clipped from the top half of the canopy did not differ ($P > 0.05$) from that of FDM, and was

greater ($P < 0.05$) than ODM on the March 6 sampling date; however, both masticate treatments had greater ($P < 0.05$) estimates of effective degradability on subsequent sampling dates than other forage sampling techniques. On all sampling dates, forage clipped from the top half of the canopy exhibited a greater ($P < 0.05$) effective degradability than all other clipped treatments.

Implications

No clipping technique was successful at mimicking the diet selected by cattle grazing wheat pasture. Although oven-drying is a simpler method of processing masticate samples, quality characteristics and digestion kinetics are altered relative to freeze-drying.

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Table 1. Agronomic characteristics of experimental wheat forages harvested in Fayetteville during 2000

Harvest date	Whole-plant yield	Top-half yield	Plant height	Leaf proportion[1]
	---------- lb/acre ----------		inches	%
6 March	2,940[c]	1,158[c]	12.8[c]	ND[2]
27 March	5,079[b]	2,317[b]	20.7[b]	47.0[a]
11 April	7,395[a]	3,475[a]	26.0[a]	28.7[b]
SEM	178	116	0.4	0.9

[a,b,c] Means within a column with no superscript in common differ ($P < 0.05$).
[1] Leaf blade only.
[2] Not determined. Stem elongation had not begun.

Table 2. Nutritive value of wheat forage harvested by five sampling techniques on three dates

Harvest date/technique	Whole-plant ash	CP	NDF	ADF	Cellulose	Hemicellulose	Lignin
	---------- (% of DM) ----------						
6 March							
Freeze-dried masticate	25.4[a]	23.0[c]	39.3[c]	29.0[a]	7.4[b]	10.3[d]	2.4[c]
Oven-dried masticate	24.8[a]	24.1[c]	47.0[a]	30.0[a]	7.6[b]	17.0[c]	3.6[a]
Random pluck	9.7[b]	28.9[b]	44.1[b]	21.5[bc]	16.2[a]	22.7[a]	3.0[abc]
Top half	9.2[b]	32.5[a]	40.1[c]	20.4[c]	15.1[a]	19.7[b]	2.7[bc]
Whole plant	10.7[b]	23.5[c]	45.9[ab]	23.1[b]	15.8[a]	22.8[a]	3.1[ab]
27 March							
Freeze-dried masticate	22.5[a]	16.9[c]	43.8[d]	29.5[b]	10.7[c]	14.3[d]	2.7[c]
Oven-dried masticate	24.8	19.2[b]	52.7[b]	35.4[a]	9.8[c]	17.3[c]	5.6[a]
Random pluck	8.4[b]	16.8[c]	57.0[a]	30.3[b]	21.6[a]	26.7[a]	4.2[b]
Top half	7.5[b]	24.7[a]	49.0[c]	24.8[c]	18.1[b]	24.2[b]	3.9[b]
Whole plant	8.6[b]	18.1b[c]	56.5[a]	29.9[b]	20.8[a]	26.7[a]	4.2[b]
11 April							
Freeze-dried masticate	17.9[a]	18.0[a]	40.5[c]	24.8[b]	13.5[c]	15.7[c]	2.6[c]
Oven-dried masticate	16.7[a]	18.7[a]	54.3[ab]	30.1[a]	17.3[b]	24.2[b]	3.0[c]
Random pluck	6.6[b]	13.4[b]	55.4[a]	29.7[a]	20.9[a]	25.7[ab]	4.0[b]
Top half	7.0[b]	18.7[a]	52.4[b]	25.2[b]	18.4[b]	27.2[a]	3.2[c]
Whole plant	6.5[b]	13.0[b]	55.1[ab]	29.9[a]	20.8[a]	25.2[ab]	5.7[a]
SEM[1,2]	0.1	0.6	0.1	0.6	0.8	0.7	0.2

[a,b,c,d] Means in a column for a given harvest date without common superscripts differ ($P < 0.05$).

[1] Standard error of whole plot (sampling techniques) within subplot (sampling date) interaction means.

[2] Appropriate LSDs (0.05) for comparing interaction means of subplot (sampling date) within whole plot (sampling techniques) were 2.7, 1.8, 2.2, 1.7, 2.2, 1.9, and 0.5 percentage units for concentrations of ash, CP, NDF, ADF, cellulose, hemicellulose, and lignin, respectively. These differences can largely be explained on the basis of plant maturity. Mean separation is not shown.

Table 3. In situ DM disappearance characteristics for wheat forage harvested on three dates by various techniques. In situ evaluation of disappearance kinetics was performed in confinement. For clarity, only mean separation within an individual harvest date is shown

Harvest date/technique	A[1]	B	C	Extent[2]	Effective Degradability[3]
	---------- (% of DM) ----------				% of DM
6 March					
Freeze-dried masticate	55.5[a]	37.3[c]	7.2[a]	92.8[c]	82.3[a]
Oven-dried masticate	47.0[b]	45.7[b]	7.3[a]	92.7[c]	76.3[bc]
Random pluck	44.1[c]	52.2[a]	3.7[c]	96.3[a]	77.6[b]
Top half	43.6[c]	52.4[a]	4.0[bc]	96.0[ab]	80.6[a]
Whole plant	42.2[d]	52.8[a]	5.0[b]	95.0[b]	75.3[c]
27 March					
Freeze-dried masticate	53.7[a]	39.2[c]	7.1[b]	92.9[a]	80.2[a]
Oven-dried masticate	43.6[b]	48.7[b]	7.7[b]	92.3[a]	75.8[b]
Random pluck	37.6[d]	50.3[b]	12.1[a]	87.9[b]	65.3[d]
Top half	38.8[c]	53.6[a]	7.6[b]	92.4[a]	73.5[c]
Whole plant	38.7[c]	49.5[b]	11.8[a]	88.2[b]	66.5[d]
11 April					
Freeze-dried masticate	52.7[a]	42.3[d]	5.0[d]	95.0[a]	80.3[a]
Oven-dried masticate	39.7[c]	54.8[a]	5.5[d]	94.5[a]	72.5[b]
Random pluck	39.0[c]	44.3[c]	16.7[a]	83.3[d]	61.6[e]
Top half	41.1[b]	48.3[b]	10.6[c]	89.4[b]	68.2[c]
Whole plant	40.8[b]	44.4[c]	14.8[b]	85.2[c]	63.8[d]
SEM[4]	0.4	0.6	0.5	0.5	0.7

[a,b,c,d] Means in a column and within a given harvest date that are without common superscripts differ ($P < 0.05$).

[1] Abbreviations: A = Immediately soluble fraction, B = fraction disappearing at a measurable rate, and C = undegraded fraction.

[2] Potential extent of disappearance in the rumen.

[3] Calculated as $A + B(k_d/k_d + \text{passage rate})$, where k_d = disappearance rate and the mean passage rate for five steers was 0.035 ± 0.009/h.

[4] Standard error of sampling date by sampling technique interaction means (n = 5 steers).

Table 4. Summary of main effects for lag time and disappearance rate (k_d) determined in confined steers for experimental wheat forages. Sampling technique (P = 0.027) affected lag times, but sampling date did not (P = 0.139). For k_d, both sampling technique and sampling date were significant (P < 0.0001), but the interaction of these effects was not (P = 0.092).

Main effect/treatment	Lag time	k_d
	h	/h
Sampling Technique		
Freeze-dried masticate	0.88[b]	0.088[a]
Oven-dried masticate	1.68[a]	0.070[b]
Random pluck	1.67[a]	0.055[c]
Top half	1.58[a]	0.076[b]
Whole plant	1.67[a]	0.055[c]
SEM[1]	0.20	0.003
Sampling Date		
6 March	- - -	0.083[a]
27 March	- - -	0.069[b]
11 April	- - -	0.055[c]
SEM[1]	- - -	0.003

[a,b,c] Means in a column and within a given main effect that are without common superscripts differ (P < 0.05).

[1] Standard error of main effect mean.

Comparisons of In Situ Dry-Matter Disappearance Kinetics of Wheat Forages in Confined and Grazing Steers

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Story in Brief

Ruminal disappearance kinetics of various forages are necessary components of many of the current nutritional models available for balancing the diets of livestock. Most of these evaluations are conducted in situ with ruminally cannulated animals that are offered controlled diets in confinement; the appropriateness of using this approach for grazing animals has been questioned. Previously we evaluated a set of 15 wheat (*Triticum aestivum* L.) forage samples for in situ disappearance kinetics of DM in confined steers using standard techniques. In this study, we evaluated these same 15 forages in steers consuming a basal diet of primarily wheat pasture. For the immediately soluble fraction (A), the fraction degraded at a measurable rate (B), the undegradable fraction (C), potential extent, rate of disappearance (k_d), and effective ruminal degradability, linear regressions of values obtained for steers grazing wheat pasture on those obtained from confined cattle had significant ($P < 0.0001$) slopes and exhibited high r^2 statistics (> 0.821). For fractions A and B, and k_d, the slope of these regression lines did not differ from unity ($P > 0.378$), and the intercept did not differ ($P > 0.07$) from zero. For fraction C, potential extent of disappearance, and effective ruminal degradability, slopes differed ($P < 0.011$) from unity. For effective degradability, deviation of the slope from unity can be explained, in part, on the basis of passage rate. From a practical standpoint, the in situ disappearance kinetics of DM for these wheat forages did not appear to be altered substantially by evaluating them in grazing steers.

Introduction

Evaluating the digestion kinetics of various forages provides information that is necessary for many of the most recent nutritional models used to balance diets for various livestock classes. Usually, these in situ evaluations are conducted with ruminally cannulated steers that are housed in confinement; this is done largely to control the intake and make-up of the basal diet offered to the experimental steers. This approach has been criticized by some researchers who work primarily with grazing animals. Numerous questions have been raised about the value of data generated from confined animals for use in balancing the diets of grazing livestock. Previously, we evaluated a set of 15 wheat forages that were harvested by various techniques for in situ disappearance kinetics of DM in confined steers consuming an alfalfa (*Medicago sativa* L.)-based diet (Coblentz et al., 2002). Our objectives in this study were to: 1) evaluate the ruminal disappearance kinetics of DM for these same 15 wheat forages in steers grazing a basal diet of wheat pasture; and 2) relate, by linear regression techniques, various parameter estimates associated with the disappearance kinetics of DM determined in grazing steers with estimates obtained previously when steers were housed and fed in confinement.

Experimental Procedures

Experimental Forages. The 15 experimental wheat forages were collected on three dates (March 6, March 27, and April 11, 2001) with five sampling techniques (freeze- or oven-dried masticate and top-half, whole-plant, and random-plucked samples clipped with garden shears). This sample set has been described in detail previously (Coblentz et al., 2002).

Establishment and Management of Experimental Wheat Pasture. A 4-acre site located at the University of Arkansas Forage Research Area in Fayetteville was clean-tilled and fertilized to meet the soil test recommendations of the Arkansas Cooperative Extension Service; this included an application of 60 lb/acre of actual N as NH_4NO_3. The site was seeded with 'Delta King 9027' soft-red winter wheat on September 18, 2000 at a rate of 120 lb/acre with a 7-ft Marliss drill (Marliss Industries, Jonesboro, AR). An additional 50 lb/acre of N was applied as NH_4NO_3 on March 9, 2001. Throughout the late fall of 1999 the site was grazed lightly to control fall growth. On March 16, 2001, five 986 ± 108-lb crossbred (Angus x Brangus x Angus) steers fitted with ruminal cannulae were given access to the entire 4-acre wheat pasture. Steers remained on the pasture continuously, except for approximately 30 min each day when a corn-based supplement was fed individually in corrals located adjacent to the wheat pasture. At 0730 h each day, steers were offered the supplement at 0.25% of BW; any supplement not consumed was manually placed in the rumen via the ruminal cannula. The supplement contained (as is basis) 90.4% ground corn, 4.0% trace mineral salt, 2.4% liquid molasses, and 3.2% Bloat Guard® (Pfizer Animal Health, Exton, PA).

In Situ Procedures. Steers were adapted to these grazing conditions for 11 d prior to evaluating the DM disappearance kinetics of the 15 experimental wheat forages. All procedures associated with the determination of in situ disappearance kinetics were identical to those used when these wheat forages were evaluated in confined steers (Coblentz et al. 2002). Previously, Lippke et al. (2000) reported a rate constant of 0.062/h for the turnover rate of the age-independent compartment for 416-lb steers grazing winter wheat pasture and receiving a cottonseed hull/steam-rolled corn supplement. This passage rate was used subsequently in our calculations of effective degradability of DM.

On March 16 (d 1), March 27 (d 12), and March 31 (d 16), the wheat pasture was evaluated for canopy height, forage availability, and nutritive value (Table 1). These dates correspond to the date the steers began their adaptation period, and the beginning and end of the in situ evaluations, respectively. An additional steer of approximate-

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ly the same weight as those used for determining in situ disappearance kinetics was evacuated manually and allowed to collect a representative diet sample on d 12 and d 16 of the trial. Masticate samples were collected immediately after the other experimental steers were supplemented at 0730 h; all masticate samples were immediately frozen (-25°F) and freeze-dried prior to grinding. Samples (clipped and masticate) collected to characterize the nutritive value of the basal diet of wheat pasture were analyzed for NDF, ADF, CP, and ash by standard methodology.

Statistics. Disappearance kinetics were evaluated as a randomized complete block design with a factorial arrangement of five sampling techniques and three harvest dates; the five steers served as replications (blocks). All analyses were conducted by PROC ANOVA (SAS Inst., Inc., Cary, NC). Parameters associated with disappearance kinetics determined in steers grazing wheat pasture were related to those determined in confined steers by linear regression; additional test statements were included to evaluate whether slope = 1 and intercept = 0 (PROC REG; SAS Inst., Inc., Cary, NC).

Results and Discussion

Disappearance Kinetics in Grazing Steers. Generally, the statistical analysis of disappearance kinetics of DM evaluated in grazing steers was quite similar to that described previously for disappearance kinetics determined in confined steers (Coblentz et al., 2002). Sampling date and technique for the 15 experimental forages and their associated interaction affected ($P < 0.0001$) the immediately soluble fraction (A), the fraction disappearing at a measurable rate (B), the fraction undegradable in the rumen (C), the potential extent of disappearance, and the effective ruminal disappearance of DM. Within each sampling date, freeze-dried masticate had a larger ($P < 0.05$; Table 2) fraction A and effective rumen degradability than did oven-dried masticate or any of the clipping treatments. However, fraction C and the potential extent of disappearance for freeze-dried masticate did not differ ($P > 0.05$) from oven-dried masticate on any date; this suggests that oven-drying did not cause plant components to become unavailable in the rumen via nonenzymatic browning (Maillard) reactions. The potential extent of disappearance was high (> 81.6%) for all forages, indicating that forage quality was excellent on all dates.

Estimates of disappearance rate (k_d; Table 3) were affected ($P < 0.0001$) by sampling date and technique, but not by their associated interaction ($P = 0.349$). Freeze-dried masticate had the fastest k_d (0.092/h). The top-half clipping treatment had a slower k_d (0.079/h; $P < 0.05$) than freeze-dried masticate, but this rate was faster ($P < 0.05$) than all other treatments. Oven-dried masticate exhibited a disappearance rate (0.068/h) that did not differ ($P > 0.05$) from the whole-plant and random pluck clipping treatments. Therefore it appears that oven-drying slowed the rate of DM disappearance, relative to freeze-dried masticate, but did not affect the extent of potential disappearance in the rumen. Rates of disappearance slowed ($P < 0.05$) from 0.096/h on the March 6 sampling date to 0.054/h on the final (April 11) sampling date. These changes are likely associated with the growth stage of the wheat plants on these dates, which ranged from vegetative (pre-jointing) on March 6 to early boot stage on April 11. Lag time exhibited no significant treatment effects ($P > 0.073$) in grazing steers; this was in contrast with the significant ($P = 0.027$) effect for sampling technique described previously (Coblentz et al., 2002).

Regressions of Disappearance Kinetics in Grazing Steers on Those in Confinement. Excepting lag time, linear regressions (Table 4) of all in situ disappearance parameters determined in grazing steers on those determined in confined steers had significant slopes ($P < 0.0001$) and exhibited very high r^2 statistics ($r^2 > 0.821$). Lag time did not exhibit a significant slope ($P = 0.173$). Additional tests of slope = 1 and intercept = 0 indicated that the slope and intercept did not differ from unity ($P > 0.378$) and zero ($P > 0.070$), respectively, for fractions A and B, or for k_d. For fraction C, the potential extent of disappearance, and estimates of effective ruminal degradability, the relationship between the two methods was close ($r^2 > 0.964$), but the slopes ($P < 0.011$) and intercepts ($P < 0.032$) differed from unity and zero, respectively.

In agreement with the results observed when the 15 experimental forages were evaluated in confined animals, none of the clipping treatments was effective in mimicking the diet selected by grazing steers. Although oven-drying at 122°F is a much simpler technique for drying masticate samples, ruminal disappearance parameters clearly differed from those of freeze-dried masticate.

For fractions A and B, and k_d, it is encouraging that linear regressions of values obtained from grazing steers on similar estimates determined in confined steers had a slope and intercept that did not differ from unity ($P > 0.378$) and zero ($P > 0.070$), respectively (Table 4). This suggests that disappearance kinetics were not radically altered by the different experimental conditions, most notably the chemical composition and intake of the basal diets. However, it should be noted that the nutritive value of the forage component of the basal diets was relatively high in both cases. The high r^2 statistics ($r^2 > 0.821$) for all kinetic parameters, excepting lag time, further indicates that the relationship between methodologies was very close. It remains unclear whether these relationships would be altered appreciably if a forage with lower nutritive value had been used for the basal diet in our confinement study.

The negative intercepts associated with regressions of the potential extent of DM disappearance and effective ruminal degradability (Table 4) indicate that these estimates were numerically lower for steers grazing wheat pasture than they were in evaluations performed in confinement. Slopes in each of these cases (1.19) were greater than unity, thereby indicating that agreement between the two methods improved as the potential extent of disappearance and effective degradability increased. Overall (n = 15 forages), the mean potential extents of DM disappearance in confined and grazing steers were 91.6 and 88.6%, respectively; in practical terms, these estimates of the potential extent of DM disappearance determined in grazing steers do not represent a radical departure from estimates made in confinement. Overall means for effective degradability were 73.3 and 65.6% for confined and grazing steers, respectively. Numerically greater estimates of effective degradability in confined steers can be explained, in part, on the basis of the slower passage rate (0.035 vs. 0.062/h) used to calculate effective degradability. This is particularly relevant because the slope and intercept for fractions A and B, and k_d, which are the other factors required to calculate effective degradability, did not differ from unity and zero, respectively.

Implications

Although our estimates of the potential extent of disappearance and effective degradability of DM were lower in grazing steers, these results did not represent a radical departure from those observed in confined steers consuming a basal diet of primarily alfalfa hay. These results are encouraging because they suggest that parameter estimates for in situ disappearance kinetics obtained from confined steers may be relevant within a grazing context. This is helpful because the logistics of conducting these trials in confined animals are much simpler than conducting a similar trial with grazing animals.

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Table 1. Agronomic and nutritive value characteristics of wheat pasture used as the basal diet for determination of in situ DM degradation kinetics on pasture in Fayetteville during 2001

Date	Sample type	Forage availability	Plant height	CP	NDF	ADF	Ash
		lbs/acre	inches	---------- % of DM ----------			
16 March	clipped	802	7.5	22.0	45.4	26.7	14.5
27 March	clipped	1,069	5.9	19.4	50.0	30.5	14.6
	masticate			27.0	45.0	23.9	20.0
31 March	clipped	891	5.1	18.4	55.8	35.9	14.9
	masticate			26.7	46.3	23.8	25.8

Table 2. In situ DM disappearance characteristics for wheat forage harvested on three dates by various techniques. In situ evaluation of disappearance kinetics was performed on pasture; for clarity, only mean separation within an individual harvest date is shown.

Harvest date/technique	A[1]	B	C	Extent[2]	Effective degradability[3]
		---------- (% of DM) ----------			
6 March					
Freeze-dried masticate	53.8^{a}	38.3^{c}	7.9^{abc}	92.1^{abc}	77.9^{a}
Oven-dried masticate	44.3^{b}	46.1^{b}	9.6^{a}	90.4^{c}	69.9^{c}
Random pluck	42.3^{c}	50.9^{a}	6.9b^{c}	93.1^{ab}	71.3^{c}
Top half	42.1^{c}	51.4^{a}	6.5^{c}	93.5^{a}	74.4^{b}
Whole plant	40.2^{d}	51.2^{a}	8.6^{ab}	91.4^{bc}	69.1^{c}
27 March					
Freeze-dried masticate	50.3^{a}	40.4^{d}	9.3^{b}	90.7^{a}	73.9^{a}
Oven-dried masticate	38.8^{b}	51.9^{b}	9.3^{b}	90.7^{a}	64.8^{b}
Random pluck	33.7^{d}	49.4^{c}	16.9^{a}	83.1^{b}	55.5^{c}
Top half	35.1^{cd}	54.4^{a}	10.5^{b}	89.5^{a}	63.5^{b}
Whole plant	36.3^{c}	47.9^{c}	15.8^{a}	84.2^{b}	57.2^{c}
11 April					
Freeze-dried masticate	50.3^{a}	42.6^{c}	7.1^{d}	92.9^{a}	74.4^{a}
Oven-dried masticate	36.5^{c}	55.8^{a}	7.7^{d}	92.3^{a}	62.9^{b}
Random pluck	36.7^{c}	42.0^{c}	21.3^{a}	78.7	53.0^{c}
Top half	39.4^{b}	45.8^{b}	14.8^{c}	85.2^{b}	60.9^{b}
Whole plant	38.9^{b}	42.7^{c}	18.4^{b}	81.6^{c}	54.7^{c}
SEM[4]	0.5	0.8	0.6	0.6	0.9

^{a,b,c,d} Means in a column and within a given harvest date that are without common superscripts differ ($P < 0.05$).

[1] Abbreviations: A = Immediately soluble fraction, B = fraction disappearing at a measurable rate, and C = undegraded fraction.

[2] Potential extent of disappearance in the rumen.

[3] Calculated as $A + B(k_d/k_d + \text{passage rate})$, where k_d = disappearance rate and the passage rate (0.062/h) was based on the work of Lippke et al. (2000).

[4] Standard error of sampling date by sampling technique interaction means (n = 5 steers).

Table 3. Summary of main effects for disappearance rate (k_d) determined in grazing steers for experimental wheat forages. Both sampling technique and sampling date were significant (P < 0.0001), but the interaction of these effects was not (P = 0.349)

Main effect/treatment	k_d
	/h
Sampling Technique	
Freeze-dried masticate	0.092[a]
Oven-dried masticate	0.068[c]
Random pluck	0.061[c]
Top half	0.079[b]
Whole plant	0.059[c]
SEM[1]	0.004
Sampling Date	
6 March	0.096[a]
27 March	0.064[b]
11 April	0.054[c]
SEM[1]	0.003

[a,b,c] Means in a column and within a given main effect that are without common superscripts differ (P < 0.05).

[1] Standard error of main effect mean.

Table 4. Regressions (n = 15 forages) of parameter estimates for disappearance kinetics of DM obtained from in situ evaluations conducted in steers grazing wheat pasture on those obtained from in situ evaluations conducted in confinement

Parameter	Slope[1]	SE_{slope}[2]	P > F[3]	Intercept[4]	$SE_{intercept}$[5]	P > F[6]	r^2
Fraction A[7]	1.03	0.05	0.507	- 4.0	2.0	0.070	0.975
Fraction B	0.95	0.08	0.563	2.0	3.9	0.624	0.913
Fraction C	1.19	0.06	0.011	1.4	0.6	0.032	0.964
Extent	1.19	0.06	0.011	- 20.0	5.8	0.004	0.964
Lag time	NS[8]	- - -	- - -	- - -	- - -	- - -	- - -
k_d	1.13	0.15	0.378	- 0.007	0.010	0.541	0.821
Degradability[9]	1.19	0.06	0.010	- 21.7	4.6	< 0.001	0.965

[1] Slope of regression line.
[2] Standard error of the slope.
[3] Probability that slope = 1.
[4] Intercept of regression line.
[5] Standard error of the intercept.
[6] Probability that intercept = 0.
[7] Abbreviations: A = Immediately soluble fraction, B = fraction degradable at a measureable rate, C = undegraded fraction, and k_d = ruminal disappearance rate.
[8] Slope was not significant (P = 0.173).
[9] Calculated as $A + B(k_d/k_d + \text{passage rate})$, where k_d = disappearance rate. Passage rate (0.062/h) for steers was based on the work of Lippke et al., 2000). The passage rate for five steers housed in confinement was determined experimentally as 0.035 + 0.009/h.

Changes in Nutritive Value of Tall Fescue Hay as Affected by Natural Rainfall and Moisture Concentration at Baling

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Story in Brief

Relatively little is known about the combined effects of rain damage and spontaneous heating on the storage characteristics and nutritive value of tall fescue (*Festuca arundinacea Schreb*) hay. Our objectives were to assess the effects of these variables in five management situations. Endophyte-infested 'Kentucky 31' tall fescue was packaged in conventional rectangular bales at 9.9 (low, L), 16.4 (ideal, I), and 22.5% (high, H) moisture prior to rainfall, and at 24.6% moisture after a 0.9-in rainfall event (H-R), and at 9.3% moisture after an accumulation of 2.8 in of rain (L-R). Concentrations of fiber components immediately after baling were increased by rain damage, but crude protein (CP) was not affected. In situ dry matter disappearance was lower for the L-R hay immediately after baling than for those hays baled without rainfall. After a 40-d storage period, L and I hays exhibited a 3.1 to 3.5 percentage unit advantage for in situ dry matter disappearance over hays damaged by spontaneous heating (H), rainfall (L-R), or both (H-R). Generally, the effects of a single (0.9-in) rainfall event on the nutritive value of hay appeared to be relatively small compared to the changes that occur naturally as tall fescue matures. This suggests that producers could be more aggressive toward harvesting at an earlier date instead of waiting for better haying conditions when the crop is too mature.

Introduction

Tall fescue is the primary cool season grass forage species in the eastern half of the United States. The recommended growth stage for hay harvest (boot stage to early heading) often coincides with a high probability of rainfall. This can delay harvest, thereby decreasing nutritive value and subsequent animal performance. The alternative to delaying harvest is to subject tall fescue hay crops to a higher probability of rain damage. Most investigations of rainfall effects on wilting forages have been conducted with legumes, and relatively little work has focused on the examination of these effects in grasses. High probabilities of rainfall also may persuade producers to package and store hay at concentrations of moisture that are greater than the 20% moisture threshold level that is generally recommended to limit spontaneous heating and provide for acceptable storage characteristics in small rectangular bale packages. The objective of this research was to assess the influence of natural rainfall, baling moisture, and spontaneous heating on the nutritive value of tall fescue hay.

Experimental Procedures

Sample Generation. A well-established stand of endophyte-infected 'Kentucky-31' tall fescue was harvested when fully headed with a disc mower on May 23, 2000 at the University of Arkansas Forage Research Area in Fayetteville. This mower did not include a conditioning device. The forage used in this study was the initial spring growth. Fertilization consisted of 50 lb N/acre applied as ammonium nitrate on February 25. Forage was mowed in three blocks of 10 swaths each and allowed to dry until May 24, when the highest desired concentration of moisture was reached. The timeline for all raking and baling procedures, as well as daily and cumulative rainfall totals are summarized in Table 1.

Baling, Stacking, and Sampling. For each combination of moisture and field block, 12 conventional rectangular bales were made with a New Holland Model 320 baler (Ford New Holland, Inc., New Holland, PA). The method of stacking the baling treatments was similar to that previously reported (Coblentz et al. 2000; Turner et al., 2002). Core samples were taken from two bales within each replicate of 12 bales prior to stacking and at 4, 8, 12, 24, and 40 d post baling. The d 0 sampling date served as a pre-storage estimate of forage nutritive value. All forage samples were dried under forced air at 131°F for 72 h; for bales sampled on d 0, this technique was used to estimate the initial concentration of moisture for each baling treatment. Recoveries of DM were determined from calculated DM weight of each bale before and after storage. Bales sampled on d 40 of storage were visually appraised for mold growth by the method of Roberts et al. (1987).

Temperature Analysis. Prior to stacking, bales assigned to the 24 and 40-d sampling dates were fitted with single thermocouple wires inserted into the center of each bale. Bale temperatures were recorded twice daily (at 0630 and 1500 h) until all treatments had been in storage for 14 d and once daily (1500 h) during the remainder of the storage period. The temperature data were collected with an Omega 450 AKT Type K thermocouple thermometer (Omega Engineering, Stamford, CT). For each day of storage, heating degree days >86°F (HDD) were calculated by subtracting 86°F from the mean internal bale temperature. These differences were then summed over the 40-d storage period; therefore, HDD is a single number that represents both the magnitude and duration of heating in each bale.

Chemical Analysis of Forage. Dry forage samples were ground through a Wiley mill fitted with a 1-mm screen (Arthur H. Thomas, Philadelphia, PA) and subsequently analyzed for CP, neutral-detergent fiber (NDF), acid-detergent fiber (ADF), and lignin. The NDF, ADF, and lignin analyses were conducted using batch procedures outlined by ANKOM Technology Corp. (Fairport, NY). Sulfite and heat-stable α-amylase were omitted from the NDF procedure.

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Nitrogen was quantified by a modified Kjeldahl procedure (Kjeltech Auto 1030 Analyzer, Tecator, Inc. Herndon, VA); CP was calculated as %N x 6.25. A ruminally cannulated crossbred steer weighing 1060 lb was used to determine the disappearance of DM after a 48-h ruminal in situ incubation (by standard techniques) for bale samples obtained prior to and after the 40-d storage period. Duplicate dacron bags were used to evaluate each forage. The University of Arkansas Institutional Animal Care and Use Committee approved surgical procedures and anesthesia for the cannulation and care of the steer.

Statistical Analysis. Initial bale characteristics were analyzed by SAS PROC MIXED (SAS Inst., Inc., Cary, NC) as a randomized incomplete block design. Four treatments (H, I, L, and L-R) contained three field replications while treatment H-R had two. A similar model was used to test DM recovery, visual mold score, and indices of spontaneous heating for significant treatment effects.

Since the effects of rainfall should be evident prior to storage, the nutritive value of our treatment forages was evaluated by two separate analyses of variance. Rainfall effects were assessed on a pre-storage basis (d 0) using the model described previously. This model was also used to evaluate ruminal in situ DM disappearance for bales sampled prior to storage (d 0) and after the 40-d storage period was completed. Storage effects were evaluated as a split-plot design with baling treatments as whole plots and sampling dates (4, 8, 12, 24, or 40 d) as the subplot effect.

Results and Discussion

Bale Characteristics. Bale weights and densities (DM basis) generally decreased ($P < 0.05$) as the bales became drier at baling (Table 2). The H bales were heavier and more dense ($P < 0.05$) than the other treatments baled without rain (I and L), and H-R bales were 15.4 lb heavier and 2.9 lb/ft^3 more dense ($P < 0.05$) than L-R bales.

Temperature Responses. During the storage period, there was a sharp decline in bale temperatures between 12 and 15 d of storage. This was the result of cool overnight ambient temperatures that approached 50°F. The HDD accumulated during the storage period for hays baled without rain were greater ($P < 0.05$) for H bales than for I or L bales, which did not differ ($P > 0.05$; Table 3). Despite its higher ($P < 0.05$) moisture concentration at baling, the H-R bales accumulated fewer ($P < 0.05$) HDD than H bales. This could have occurred because nonstructural carbohydrates were leached from the H-R hay, thereby reducing the pool of available sugars that could potentially support spontaneous heating. However, a simpler explanation may be that the H-R treatment had a shorter interval of time in storage (by 2 d) prior to the onset of unseasonably cool weather. In a pattern similar to that observed for HDD, the average, minimum, and maximum internal bale temperatures generally decreased as the bales became drier at packaging. However, there was little practical difference in the heating characteristics of L and I bales. This suggests that any extra wilting time used by producers to attain excessively low moisture levels serves little practical purpose in small rectangular bales, but the effects in large round packages remain unclear.

Visible mold score was numerically greatest for H (Table 3), but this estimate differed ($P < 0.05$) only from that of L bales. The low visible mold scores can be explained on the basis of the low overnight temperatures that occurred between 12 and 15 d of storage and the comparatively low initial concentrations of moisture in these baling treatments. Recoveries of DM (Table 3) did not differ ($P > 0.05$) among treatments. However, the poorest recovery was observed in H bales that exhibited measurable heating characteristics. It should be noted that these estimates did not include field losses associated with rainfall events because DM recovery was determined from the DM weight of each bale immediately prior to storage and at 40 d after baling.

Changes in Nutritive Value Prior to Storage. The effects of rainfall on the concentrations of CP and fiber components for the five baling treatments sampled at baling (d 0) are shown in Table 4. Concentrations of total CP were not affected by treatment ($P > 0.05$). On a practical basis, there was little difference in concentrations of fiber components among treatments that did not incur rainfall during the wilting period. Concentrations of NDF, ADF, and lignin were confined to very narrow ranges across H, I, and L treatments on d 0, thereby suggesting there was little evidence of leaf shatter in the driest (L) forage. Concentrations of NDF, ADF, and lignin increased ($P < 0.05$) as the forage was exposed to increased rainfall. The L-R bales exhibited the greatest increases in NDF and ADF concentrations. Respective increases of these fiber components were 10.1 and 5.0 percentage units, relative to those measured for H bales. For H-R bales, increases in NDF and ADF were approximately half (5.6 and 2.8 percentage units, respectively) of those observed for L-R bales. Clearly, these responses reflect the differences in cumulative rainfall prior to baling for the H-R and L-R treatments. The greater concentrations of fiber in the H-R and L-R hays are likely an indirect result of leaching and prolonged respiration of nonstructural carbohydrates, but not an actual accumulation of additional fiber. Pre-storage in situ DM disappearance after a 48-h ruminal incubation (Table 4) was greater ($P < 0.05$) for baling treatments that had not been exposed to rainfall than for the L-R baling treatment. The H-R baling treatment exhibited a numerical decrease in response to rainfall, but did not differ ($P > 0.05$) from any other treatment.

Changes in Nutritive Value During Storage. Since baling treatment x sampling date interactions were found ($P < 0.05$) for concentrations of most fibrous components, only interaction means are presented and discussed (Table 5). Generally, concentrations of fiber components (NDF, ADF, and lignin) increased ($P < 0.05$) throughout the 40-d storage period. The H and H-R treatments exhibited the greatest ($P < 0.05$) change in concentrations of NDF and ADF during storage, as expected based on the larger heating increment in these bales. The maximum change in NDF during storage was 5.4 percentage units for the H-R treatment. Concentrations of CP were relatively stable across sampling dates in all treatments; differences ($P < 0.05$) over sampling dates were only observed for H and L-R treatments, and the magnitude of these differences was generally small with no apparent pattern.

Comparisons of Hays after Storage. Comparisons of nutritive value for treatment hays sampled on d 40 (Table 5; mean comparisons for baling treatments within the 40-d sampling date are not shown for CP, NDF, ADF, and lignin) are probably the most meaningful data for livestock and hay producers. Concentrations of NDF after 40 d in storage were greatest ($P < 0.05$) for the H-R bales. The H and L-R bales had lower ($P < 0.05$) concentrations of NDF, but the magnitude of these differences was small (4.3 and 2.8 percentage units, respectively), relative to H-R bales. The L bales had the lowest ($P < 0.05$) concentration of NDF after storage, and the difference in NDF between H-R and L bales was 10.7 percentage units. Concentrations of ADF were greatest ($P < 0.05$) in bales that were either baled at a higher than ideal concentration of moisture, received rainfall, or both (H, L-R, and H-R, respectively). The L and I baling treatments had greater ($P < 0.05$) post-storage in situ DM disappearance after a 48-h ruminal incubation than the other baling treatments. This may be due to enhanced conservation of nonstructural carbohydrates in the absence of rain damage and spontaneous heating. After 40 d of storage, the in situ DM disappearance of H, H-R, and L-R bales were virtually identical, and ranged from 3.1 to 3.5 percentage units less than the I and L treatments.

Implications

Drastic increases in NDF and concurrent decreases in digestibility occur when tall fescue matures past late-boot stage; by comparison, the effects of a single rainfall event appear to be relatively small. Generally, producers may benefit from pursuing harvest more aggressively, even when there is a chance of rain before the crop is dry.

Literature Cited

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Roberts, C. A., et al. 1987. Crop Sci. 27:783-785.
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Table 1. Timeline for mowing, raking, and baling events as well as cumulative rainfall for each of the five tall fescue baling treatments

Date	Treatments[1] mowed	Treatments baled	Raking time h	Precipitation in	Cumulative precipitation prior to baling[2] in
23 May	H, I, L, H-R, L-R				
24 May		H, I, L	0830[3]	0.9[4]	0
25 May			1500[5]		
26 May		H-R	0800[5]	1.8 [6]	0.9
27 May				0.1	
28 May					
29 May		L-R	1100[7]		2.8

[1] Abbreviations; H, high-moisture bales (22.5% moisture); I, ideal-moisture bales (16.4% moisture); L, low-moisture bales (9.9% moisture); H-R, high-moisture, rained-on bales (24.6% moisture, 0.9 in. total rainfall); and L-R, low-moisture, rained-on bales (9.3% moisture, 2.9 in.total rainfall).
[2] Total precipitation that fell prior to baling the treatments identified on that date.
[3] Treatments H, I, and L were raked at 0830 h.
[4] Precipitation fell after baling of H, I, and L treatments was complete.
[5] Treatments H-R and L-R were raked at these times.
[6] Precipitation fell after baling of H-R treatment was complete.
[7] Only treatment L-R was raked at this time.

Table 2. Bale characteristics of tall fescue hay made at five concentrations of moisture and with or without natural rainfall

Treatment[1]	Moisture content %	Bale length in.	Bale volume m^3	Bale weight (as-is) lbs	Bale density (as-is) lbs/ft^3	Bale weight (dry matter basis) lbs	Bale density (dry matter basis) lbs/ft^3
H	22.5^{b}	35.5^{b}	6.0^{b}	76.6^{a}	13.1^{a}	59.4^{a}	10.2^{a}
I	16.4^{c}	35.9^{b}	6.0^{b}	58.5^{b}	9.9^{b}	49.1^{bc}	8.3^{bc}
L	9.9^{d}	37.0^{a}	6.2^{ab}	49.7^{bc}	8.1^{c}	44.9^{cd}	7.3^{cd}
H-R	24.6^{a}	35.9^{b}	6.1^{ab}	68.6^{a}	11.5^{ab}	55.9^{ab}	9.4^{ab}
L-R	9.3^{d}	37.8^{a}	6.3^{a}	44.2^{c}	7.1^{c}	40.5^{d}	6.5^{d}
SE[2]	0.5	0.4	0.1	3.3	0.6	2.6	0.4

[a, b, c, d] Means in the same column with different superscripts differ ($P < 0.05$).
[1] Abbreviations; H, high-moisture bales (22.5% moisture); I, ideal-moisture bales (16.4% moisture); L, low-moisture bales (9.9% moisture); H-R, high-moisture, rained-on bales (24.6% moisture, 0.9 in. total rainfall); and L-R, low-moisture, rained-on bales (9.3% moisture, 2.8 in. total rainfall).
[2] SE = Standard error of the mean for the H-R treatment with n=2 replications. Other treatments had n=3 replications.

Table 3. Heating and storage characteristics of tall fescue hay bales made at five concentrations of moisture and with or without natural rainfall

Bale moisture[3]	HDD[1]	MIN °F	MAX °F	AVG °F	Visible mold[2]	DM recovery %
H	293[a]	72.1[a]	121.6[a]	88.2[a]	1.75[a]	93.4
I	58[c]	68.5[ab]	104.0[b]	81.9[c]	1.08[ab]	96.5
L	25[cd]	64.8b[c]	109.0[b]	76.6[d]	1.00[b]	98.1
H-R	232[b]	67.8[ab]	123.4[a]	85.6[b]	1.71[ab]	95.9
L-R	9[d]	62.6[c]	88.5[c]	76.6[d]	1.04[ab]	94.7
SE[4]	20	1.4	2.3	0.5	0.30	2.1

[a, b, c, d] Means in the same column with different superscripts differ (P < 0.05).

[1] Abbreviations: HDD, heating degree days > 86°F; MIN, minimum internal bale temperature; MAX, maximum internal bale temperature; and 40-d AVG, average internal bale temperature over the entire 40-d storage period.

[2] Visible mold assessment score 1 = no visible mold; 2 = presence of spores between flakes; 3 = presence of spores throughout the bale; 4 = mycelial mat between flakes; and 5 = mycelial mat throughout the bale (Roberts et al., 1987).

[3] Abbreviations; H, high-moisture bales (22.5% moisture); I, ideal-moisture bales (16.4% moisture); L, low-moisture bales (9.9% moisture); H-R, high-moisture, rained-on bales (24.6% moisture, 0.9 in. total rainfall); and L-R, low-moisture, rained-on bales (9.3% moisture, 2.8 in. total rainfall).

[4] SE = Standard error of the mean for the H-R treatment with n=2 replications. Other treatments had n=3 replications.

Table 4. Concentrations of fiber components in five baling treatments of tall fescue hay sampled immediately after baling (d 0) that illustrate the effects of natural rainfall during the wilting period

Baling treatment[2]	CP[1]	NDF	ADF	Lignin	In situ disappearance
	% of DM				
H	7.8	66.3[d]	37.6[d]	4.81[c]	64.2[a]
I	8.2	67.7[c]	38.3[c]	5.12[bc]	62.9[a]
L	7.9	67.3[c]	38.1[cd]	4.98[c]	63.9[a]
H-R	8.4	71.9[b]	40.4[b]	5.44[ab]	61.7[ab]
L-R	8.6	76.4[a]	42.6[a]	5.52[a]	59.7[b]
SE[3]	0.3	0.3	0.2	0.1	1.4

[a, b, c, d] Means in the same column with different superscripts differ (P < 0.05).

[1] Abbreviations: CP, crude protein; NDF, neutral-detergent fiber; ADF, acid detergent fiber.

[2] Abbreviations; H, high-moisture bales (22.5% moisture); I, ideal-moisture bales (16.4% moisture); L, low-moisture bales (9.9% moisture); H-R, high-moisture, rained-on bales (24.6%, 0.9 in. total rainfall); and L-R, low-moisture, rained-on bales (9.3% moisture, 2.8 in. total rainfall).

[3] SE = Standard error of the mean for the H-R treatment with n=2 replications. Other treatments had n=3 replications.

Table 5. Concentrations of fiber components in five baling treatments of tall fescue hay on five sampling dates and the 48-h in situ DM disappearance of bales sampled at the end of a 40-d storage period

Treatment[3]	Sampling date	CP[1]	NDF	ADF	Lignin	In situ disappearance[2]
	d	% of DM				
H	4	8.6^{ab}	69.5^{c}	38.7^{c}	5.11^{b}	-
	8	8.4^{ab}	71.6^{b}	40.2^{b}	6.01^{a}	-
	12	8.1^{b}	72.0^{b}	40.8^{b}	5.43^{ab}	-
	24	8.6^{ab}	73.4^{a}	39.7^{bc}	5.79^{a}	-
	40	8.9^{a}	74.5^{a}	43.4^{a}	5.89^{a}	59.8^{e}
I	4	8.3	66.7^{c}	39.1^{b}	5.10^{c}	-
	8	8.1	67.7^{bc}	38.7^{b}	5.39^{bc}	-
	12	8.2	68.8^{b}	38.4^{b}	5.13^{bc}	-
	24	8.3	69.3^{a}	38.8^{b}	5.78^{ab}	-
	40	8.2	70.5^{a}	41.1^{a}	6.20^{a}	62.9^{d}
L	4	7.9	66.9	38.7^{ab}	5.18^{bc}	-
	8	8.2	67.3	38.3^{b}	5.45^{abc}	-
	12	8.3	67.0	38.4^{b}	5.10^{c}	-
	24	8.6	67.3	38.3^{b}	5.96^{a}	-
	40	7.9	68.1	39.7^{a}	5.82^{ab}	63.1^{d}
H-R	4	8.4	73.4^{c}	40.5^{c}	5.80^{ab}	-
	8	8.1	76.2^{b}	43.1^{b}	6.35^{ab}	-
	12	8.6	75.8^{b}	42.8^{b}	6.15^{ab}	-
	24	8.4	77.0^{ab}	43.8^{ab}	5.61^{b}	-
	40	8.5	78.8^{a}	44.6^{a}	6.46^{a}	59.6^{e}
L-R	4	8.4^{a}	74.6^{b}	42.4^{b}	5.96^{b}	-
	8	8.4^{a}	74.6^{b}	44.0^{a}	5.74^{b}	-
	12	8.4^{a}	75.6^{ab}	43.5^{a}	6.01^{b}	-
	24	8.7^{a}	76.6^{a}	43.9^{a}	6.03^{b}	-
	40	7.7^{b}	76.0^{ab}	44.0^{a}	6.83^{a}	59.7^{e}
S.E		0.4[4]	0.7[4]	0.5[4]	0.28[4]	1.6[5]

$^{a, b, c}$ Means in the same column and baling treatment with different superscripts differ ($P < 0.05$).

$^{d, e}$ Means in the same column with different superscripts differ ($P < 0.05$).

[1]Abbreviations: CP, crude protein; NDF, neutral-detergent fiber; ADF, acid-detergent fiber.

[2]Ruminal DM disappearance during a 48-h incubation in situ. Analysis of variance and mean separation were conducted for the 40-d sampling date only.

[3]Abbreviations; H, high-moisture bales (22.5% moisture); I, ideal-moisture bales (16.4% moisture); L, low-moisture bales (9.9% moisture); H-R, high-moisture, rained-on bales (24.6% moisture, 0.9 in. total rainfall); and L-R, low-moisture, rained-on bales (9.3% moisture, 2.8 in. total rainfall).

[4]SE = Standard error of the baling treatment x sampling date interaction mean for H-R bales with n=2 replications. Other treatments had n=3 replications.

[5]SE = Standard error of the baling treatment mean for H-R bales with n=2 replications. Other treatments had n=3 replications.

Using Orchardgrass and Endophyte-Free Tall Fescue Versus Endophyte-Infested Tall Fescue Overseeded on Bermudagrass for Cow Herds - 2000 and 2001

Wayne K. Coblentz[1], Kenneth P. Coffey[1], D. A. Scarbrough[1], Timothy Smith[2], Kenneth Harrison[2], Brad McGinley[2], Donald Hubbell[2], and Jason Martin[2]

Story in Brief

A trial was initiated in January 2000 to evaluate endophyte-free tall fescue (*Festuca arundinacea* Schreb.) or orchardgrass (*Dactylis glomerata* L.) overseeded into dormant common bermudagrass [*Cynodon dactylon* (L.) Pers.] sods for spring-calving cows. Two management systems were evaluated in an effort to help these cool-season grasses persist; these included rotations to new paddocks twice weekly (HM) or twice monthly (LM). Generally, orchardgrass and endophyte-free tall fescue persisted well, but cow and calf performance was only marginally better in these pastures than with a more typical mixture of endophyte-infested tall fescue and bermudagrass. Cow and calf performance on endophyte-infested tall fescue pastures in 2000 and 2001 did not usually differ ($P > 0.1$) from all orchardgrass and endophyte-free tall fescue grazing systems. Continued monitoring of these pastures will be necessary to assess the long-term benefits of these grazing systems with traditionally less-persistent forages.

Introduction

Many cow-calf enterprises in the Ozarks are maintained on pasture systems that are mixtures of endophyte-infested tall fescue and common bermudagrass. The association of the fungus *Neotyphodium coenophialum* with tall fescue has a positive effect on plant persistence, but the negative effects of the toxins produced by this fungus can have a detrimental effect on livestock performance. Other perennial cool-season grasses, such as endophyte-free tall fescue and orchardgrass, have generally persisted poorly when subjected to the same types of management as endophyte-infested tall fescue. A trial was initiated to evaluate the effectiveness of overseeding endophyte-free tall fescue or orchardgrass into dormant common bermudagrass sods for spring-calving cows. Two management systems (HM, rotation to new paddocks twice weekly and LM, twice monthly) were used in an effort to help these cool season grasses persist. Our objective was to compare these forage management systems with a typical mixture of endophyte-infested tall fescue and common bermudagrass managed on a LM rotation schedule. This report includes data from the initial two years of the study. Our intention is to evaluate these systems for at least three years prior to making a final summary.

Experimental Procedures

Pasture Establishment and Maintenance. Nine 10-acre mixed-species pastures with a base sod of common bermudagrass were sprayed (Roundup Ultra®, Monsanto Company, St. Louis, MO 63167) in the spring of 1998 to eliminate annual and perennial cool-season grasses. In the late summer of 1998, cattle were used to remove summer growth of forage that was primarily bermudagrass. Cattle were used to remove available forage because many of the pastures were not suitable for haying.

In September and early October 1998, thirteen 10-acre pastures (including the nine pastures sprayed in the spring) were fertilized to soil test recommendations of the Arkansas Cooperative Extension Service, and >Benchmark= orchardgrass and endophyte-free >Kentucky 31' tall fescue were overseeded into five and four of these pastures, respectively. The remaining four pastures had mixtures of endophyte-infested tall fescue and bermudagrass that had been established previously, and these were retained as controls. In April 1999, three independent observers evaluated each overseeded pasture for continuous row coverage by cool-season seedlings. During the 1999 growing season, pastures were grazed lightly to control forage growth. All pastures were fertilized with urea (46-0-0) at a rate of 60 lb N/acre on September 9-10, 1999. Similar applications were made in both 2000 and 2001 in mid February, early June, and early September. Soil tests were obtained each year in August and any needed P and K was applied based on soil test recommendations each September.

All 13 pastures were evaluated initially (November 1999; prior to initiating the trial) for basal cover and species composition by the modified step-point method (Owensby, 1973). These procedures were repeated in June and November of each subsequent year to assess the effects of grazing on the species composition and basal cover of experimental pastures. The trial was initiated on January 11, 2000.

Grazing Management. Each 10-acre pasture was subdivided into either eight (1.25-acre) or two (5-acre) paddocks using electric fencing to supplement existing permanent fences. Orchardgrass and endophyte-free tall fescue mixtures with bermudagrass were managed with either a twice weekly rotation to a fresh 1.25-acre paddock (HM) or a twice-monthly rotation to new 5-acre paddock (LM). Endophyte-infested tall fescue pastures were managed on a LM rotation schedule. There were two replications of the orchardgrass pastures managed with the LM system, and three replications of the HM system. There were two replicates of both the LM and HM systems for the endophyte-free tall fescue pastures. Pastures were evaluated monthly for forage availability using a rising-plate disk meter. In order to protect the non-toxic forages from trampling and overgrazing when forage was limiting, cattle were fed bermudagrass hay on single 1.25-acre paddocks in the HM system and on an area of comparable size constructed with electric wire in the LM system.

Livestock. Sixty-five spring-calving cows were stratified by weight, age, and breeding and assigned to one of the thirteen pastures

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(five per pasture) on January 11, 2000. Initially, at least one cow per pasture had a Hereford sire and Brahman x Angus dam; the balance of the cows were purebred Angus. Cows and calves were not supplemented other than with hay when forage was limiting, but a commercial mineral mix was offered free choice throughout the trial. From mid-May through mid-July of each year, one Gelbvieh bull was assigned to each pasture. Cows were weighed and evaluated for body condition on a monthly basis. Calves were weighed monthly and weaned in early October. Actual and 205-d adjusted weaning weights were obtained and analyzed as response variables. Milk production was evaluated by the weigh-suckle-weigh method in May and July of each year.

Cows initially assigned to each pasture remained on their assigned pasture continuously throughout the trial in order to assess the cumulative effects of each grazing system on animal performance. Cows were checked for pregnancy by rectal palpation in January of each year, and any open cows were replaced with pregnant first-calf heifers. Similarly, any cows without calves at the end of the calving season (May 1) were replaced with a primiparous cow and her calf.

In an effort to control the flush of forage growth that occurs in the spring, extra thin cows were placed on these pastures in order to improve their body condition. This technique was used because all pastures were not suitable for harvesting extra forage as hay. Extra cows were assigned to a specific 10-acre pasture and remained there as long as forage availability permitted. Within each pasture, cows were co-mingled and managed with the same rotation schedule as the five permanently assigned cows. Additional grazing days for these extra cows were tabulated for each pasture and analyzed as a response variable.

Statistics. Forage species composition and basal cover data were analyzed as a repeated measures design with grazing systems as the whole-plot term and evaluation date (November 1999, June 2000, November 2000, June 2001, and November 2001) as the repeated measures term. Forage availability was analyzed with a similar design; within year, grazing systems served as whole plots and month was the repeated measures term. Since this report is preliminary, all animal performance data are analyzed by year as a completely randomized design with unequal replication. Since open cows were replaced with primiparous cows each spring, cow weight was used as a covariate for the 2001 animal performance data. Significance is declared at the $P = 0.1$ level of confidence unless otherwise indicated.

Results and Discussion

Establishment. Visual evaluation of continuous row coverage by cool-season seedlings in April 1999 indicated that there were no differences ($P = 0.81$) between orchardgrass and endophyte-free pastures. The overall mean for both forages was 68.4%, indicating that establishment was relatively good. In sites where establishment was poor, the bermudagrass sod was often particularly vigorous and competitive, and the cattle did not effectively remove the entire existing bermudagrass canopy prior to seeding.

Species Composition and Basal Cover. The percentage of the desired cool-season grass within experimental pastures was affected by evaluation date ($P < 0.001$) and the interaction of grazing system and evaluation date ($P = 0.057$). The percentage of endophyte-infested tall fescue did not change ($P \geq 0.19$) over the five evaluation dates (Table 1), and the overall mean for the five dates was 51.8%. Percentages of both orchardgrass and endophyte-free tall fescue varied ($P < 0.1$) among evaluation dates, regardless of rotation frequency. Through June 2001, percentages of both forages were generally higher in June than on November evaluation dates; however, there were no differences ($P \geq 0.17$) in percent composition for these forages between the June and November 2001 evaluation dates. On November 2001, HM and LM endophyte-free tall fescue and HM orchardgrass comprised more than 50% of the sward, indicating that our overseeded forages had persisted throughout two grazing seasons. Orchardgrass managed as LM made up less of the sward (31.9%), but this did not differ ($P > 0.1$) from the percentage observed at the start of the trial (36.9%).

The percentage of bermudagrass in our experimental pastures (Table 2) was not affected by grazing system ($P = 0.715$) or the interaction of grazing system and evaluation date ($P = 0.187$), but was affected by evaluation date ($P = 0.002$). More ($P \leq 0.048$) bermudagrass was observed on November evaluation dates than on June dates, but the overall range was relatively small (29.3 to 37.7%). There was no difference ($P = 0.775$) in the percentage of bermudagrass in November 2001 and at the beginning of the trial. The percentage of total basal cover (Table 2) was affected by evaluation date only ($P < 0.001$), and was lower ($P \leq 0.001$) in November 2000 and June 2001 than on the other three evaluation dates.

Forage Availability. In both 2000 and 2001, sampling date affected ($P < 0.001$) forage availability, but grazing system only exhibited an effect ($P = 0.092$) in 2000. The associated interaction of these main effects was not significant ($P \geq 0.726$) either year. The addition of extra cows in the spring was an effective technique for controlling the flush of spring growth. Available forage DM ranged from 1974 to 5068 lb/acre in 2000, but remained less than 2600 lb/acre until the July sampling date, which was after extra cows were removed. In 2001, available forage DM ranged from 2589 to 3462 lb/acre between April and October, but increased to more than 4000 lb/acre in early November, which was after calves were weaned. In 2000, grazing system had no effect ($P = 0.163$) on the animal grazing days accumulated by extra cows in the spring; the overall mean was 354 animal days per 10-acre pasture. In 2001, extra cows grazing orchardgrass pastures (HM or LM) accumulated more ($P < 0.1$) additional animal grazing days than did extra cows grazing LM endophyte-free tall fescue pastures or endophyte-infested tall fescue pastures (Table 3).

Cow Performance 2000. There were no differences among grazing treatments for cow weight (overall mean = 1,212 lb) or body condition score (overall mean = 6.2) at the initiation of the trial ($P \geq 0.32$). By weaning, grazing system had affected both body condition score and cow weight ($P \leq 0.011$). Cows grazing pastures overseeded with both orchardgrass and endophyte-free tall fescue gained between 65 and 175 lb and 1.1 to 1.2 body condition scores between January and October. There were no differences between these grazing systems ($P \geq 0.14$) for either of these response variables. In contrast, cows grazing pastures with endophyte-infested tall fescue lost 87 lb during this same time period, and this response differed ($P < 0.029$) from the cow performance on all other grazing systems. There were no differences ($P \geq 0.24$) among grazing systems for May or July milk production (overall means = 13.1 and 8.6 lb/day, respectively). Pregnancy rate, as determined by rectal palpation in January 2001, was not affected ($P = 0.35$) by grazing system (overall mean = 77%).

Cow Performance 2001. Cow weights (Table 4) were affected by grazing system at calving ($P = 0.079$) and weaning ($P = 0.035$), but not at breeding ($P = 0.84$). Grazing system did not affect ($P \geq 0.11$) body condition score at any of these time periods (overall means = 6.7, 7.2, and 7.1, respectively). Milk production (Table 4) in May was not affected by grazing system ($P = 0.56$), but was in July ($P = 0.001$). Milk production in July was highest ($P < 0.1$) for cows grazing overseeded HM orchardgrass pastures. The next highest production was observed in cows grazing endophyte-infested tall fescue, which

exceeded (P < 0.1) the milk production level on all remaining grazing systems. Pregnancy rate was good on all grazing systems (overall mean = 94%), and did not differ across treatments (P = 0.70).

Calf Performance 2000 and 2001. Generally, calves performed well during both years on all grazing systems. Grazing system affected (P ≤ 0.098) calf performance measured as actual and 205-d adjusted weaning weights in both years (Table 5). In 2000, the numerically greatest weaning weights were observed in LM endophyte-free tall fescue pastures, but this performance did not differ (P > 0.1) from that of calves grazing LM orchardgrass pastures. In 2001, the numerically greatest weaning weights were observed for calves grazing HM orchardgrass pastures, but performance was similar (P > 0.1) on LM orchardgrass pastures. In both years, calf performance on endophyte-infested pastures was either numerically poorest, or did not differ (P > 0.1) from the grazing system where performance was numerically poorest. Overall, this suggests that dilution of endophyte-infested tall fescue with bermudagrass may have reduced the effects of toxins produced by the endophyte and limited the differences in performance observed between calves grazing endophyte-infested pastures and those with non-toxic perennial cool-season grasses.

Implications

The management systems used in this study were effective at maintaining orchardgrass and endophyte-free tall fescue in these pastures. Generally, cow and calf performance were only marginally better with these forages in the pasture than with a more typical mixture of endophyte-infested tall fescue and bermudagrass. Continued monitoring of these systems is necessary to assess long-term benefits of these grazing systems with traditionally less-persistent forages.

Literature Cited

Owensby, C. E. 1973. J. Range Manage. 26:302-303.

Table 1. Percentage of desired cool-season grasses within the sward at Batesville, AR, from November 1999 through 2001[1]

	Evaluation date					
Treatment[2]	Nov 1999	June 2000	Nov 2000	June 2001	Nov 2001	SE
OG - HM	36.9[b]	52.1[a]	32.9[b]	50.4[a]	52.9[a]	3.6
OG - LM	36.3[b]	48.6[a]	34.4[b]	40.7[ab]	31.9[b]	4.4
FF - HM	45.1[b]	63.5[a]	55.4[ab]	60.3[a]	64.1[a]	4.4
FF - LM	52.3[c]	68.8[b]	59.1b[c]	72.5[a]	67.2[ab]	4.4
IF - LM	49.0	52.6	54.6	54.2	48.6	3.1

[a,b,c] Means in a row without common superscripts differ (P < 0.1).
[1] Data were determined by the modified step-point method (Owensby, 1973). The grazing system x evaluation date interaction affected species composition at P = 0.057.
[2] Abbreviations: OG, orchardgrass; FF, endophyte-free tall fescue; IF, endophyte-infested tall fescue; HM, cattle rotated to fresh paddocks twice-weekly; and LM, cattle rotated to fresh paddocks twice-monthly.

Table 2. Percentages of bermudagrass and basal cover in pastures at Batesville, AR[1]

Evaluation date	Bermudagrass, %	Basal Cover, %
November 1999	36.9[a]	44.5[a]
June 2000	31.6[b]	45.4[a]
November 2000	37.7[a]	36.3[b]
June 2001	29.2[b]	36.8[b]
November 2001	36.3[a]	47.7[a]
SE	1.6	1.5

[a,b] Means in a column without common superscripts differ (P < 0.1).
[1] The main effect of evaluation date affected (P = 0.002) both percentage of bermudagrass and basal cover, but other effects and interactions did not (P > 0.1). Data were determined by the modified step-point method (Owensby, 1973).

Table 3. Extra grazing days accumulated by additional cows to control spring forage growth during 2000 and 2001 at Batesville, AR

Treatment[1]	2000	2001
OG - HM	371	159[a]
OG - LM	454	153[a]
FF - HM	311	108[ab]
FF - LM	231	70[b]
IF - LM	375	84[b]
SE	50	18

[a,b] Means in a column without common superscripts differ (P < 0.1).
[1] Abbreviations: OG, orchardgrass; FF, endophyte-free tall fescue; IF, endophyte-infested tall fescue; HM, cattle rotated to fresh paddocks twice-weekly; and LM, cattle rotated to fresh paddocks twice-monthly.

Table 4. Cow performance in 2001 in overseeded pastures at Batesville, AR

	---------- Cow weight, lb ----------			-- Milk production, lb/d --	
Treatment[1]	Calving	Breeding	Weaning	May	July
OG - HM	1,404[ab]	1,217	1,357[a]	11.2	11.7[a]
OG - LM	1,409[ab]	1,289	1,437[a]	11.7	2.6[b]
FF - HM	1,431[a]	1,132	1,445[a]	7.9	4.0[b]
FF - LM	1,408[ab]	1,324	1,206[b]	10.6	0.6[b]
IF - LM	1,366[b]	1,114	1,232[b]	5.5	8.8[a]
SE	14	51	50	2.8	1.3

[a, b] Means in a column without common superscripts differ (P < 0.1).
[1] Abbreviations: OG, orchardgrass; FF, endophyte-free tall fescue; IF, endophyte-infested tall fescue; HM, cattle rotated to fresh paddocks twice-weekly; and LM, cattle rotated to fresh paddocks twice-monthly.

Table 5. Calf performance (weaning weights) at Batesville, AR, in 2000 and 2001

	-------2000------		------2001------	
Treatment[1]	Actual, lb	205-d Adjusted, lb	Actual, lb	205-d Adjusted, lb
OG - HM	540[b]	536[b]	622[a]	600[a]
OG - LM	554[ab]	565[ab]	567[ab]	546[b]
FF - HM	538[b]	520[bc]	495[c]	485[c]
FF - LM	589[a]	591[a]	514[bc]	514[bc]
IF - LM	527[b]	498[c]	517[bc]	505[bc]
SE	16	15	19	15

[a,b,c] Means in a column without common superscripts differ (P < 0.1).
[1] Abbreviations: OG, orchardgrass; FF, endophyte-free tall fescue; IF, endophyte-infested tall fescue; HM, cattle rotated to fresh paddocks twice-weekly; and LM, cattle rotated to fresh paddocks twice-monthly.

Effect of Tillage Intensity and Seeding Date on Growth-Performance of Heifers Grazing Sod-seeded Wheat and Ryegrass Pastures

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Story in Brief

The first year of a proposed 3-year study was conducted using a total of 40 Gelbvieh x Angus crossbred heifers (543 ± 10.7 lb initial BW). The heifers grazed one of eight 5-acre pastures of common bermudagrass overseeded with wheat and ryegrass during the winter of 2002. One half of the pastures were seeded during the first week of September (EARLY) and half were seeded in mid-October (LATE). Within each seeding date, half of the pastures was disked once (1x) and the other half was disked twice (2x) before seeding. Grazing began December 20 on all pastures and continued through May 11. Forage mass was greater ($P < 0.10$) during early sampling periods from EARLY vs. LATE seeded pasture. Body weights tended ($P < 0.10$) to be greater on January 15 and were greater ($P < 0.05$) on February 15 from heifers grazing EARLY pastures than from those grazing LATE pastures. By the end of the grazing season, total gains did not differ ($P > 0.10$) because of tillage intensity or seeding date. Therefore, as far as animal gains are concerned, producers may have considerable flexibility in their decisions as to when to seed annual forages and to what level they till their sod.

Introduction

Sod-seeded winter annual forages provide a high-quality feed source for wintering weaned calves. In a previous 3-year study at the University of Arkansas Southeast Research and Extension Center, weaned calves gained approximately 2 lb/day between mid-December and mid-April while grazing sod-seeded winter annuals (Coffey et al., 2002). The major disadvantages of the sod-seeded winter annual program were the year to year variability and the inability to begin grazing prior to mid-December. This means producers must find other forage alternatives to winter annuals between the time of weaning and initiation of grazing in mid- to late December. Our objective in this study was to evaluate earlier seeding dates and more intensive tillage of the bermudagrass sod to determine if those practices would allow for earlier grazing or greater animal gains.

Experimental Procedures

A total of 40 Gelbvieh x Angus crossbred heifers (543 ± 10.7 lb initial BW) grazed one of eight 5-acre pastures of common bermudagrass during the winter of 2002 that were previously overseeded with winter annual forages. All pastures were seeded with 30 lb/acre of 'Marshall' annual ryegrass plus 120 lb/acre of 'Madison' soft wheat. One half of the pastures were seeded during the first week of September (EARLY) and half were seeded in mid-October (LATE). Within each seeding date, half of the pastures was disked once (1x) and the other half was disked twice (2x) prior to seeding. The eight pastures were divided into two blocks of four pastures and the pastures were allocated randomly within block to one of the four treatment combinations. Pastures were fertilized with a complete fertilizer mixture of N, P_2O_5, and K_2O (as KCl) during the fall and with an additional 50 lb/acre of N in the spring.

Grazing began December 20 on all pastures and continued until May 11. Heifers were weighed on December 17 and 18 at the Livestock and Forestry Branch Experiment Station at Batesville without prior removal from pasture and water to determine initial BW. Heifers were stratified by weight and allocated randomly to one of eight groups. They were then transported to the University of Arkansas Southeast Research and Extension Center at Monticello, weighed and turned directly onto their assigned pasture. Weights were measured monthly without prior removal from pasture and water. Heifers were offered 2 lb/day of a grain sorghum-based supplement that contained trace mineralized salt and 150 mg Rumensin,.

Available forage mass was determined monthly during the study using a calibrated disk meter. Data were analyzed within date using SAS (SAS Inst., Inc., Cary, NC) GLM procedures for a 2 x 2 factorial arrangement of treatments.

Results and Discussion

No seeding date by tillage intensity interactions were detected ($P < 0.05$) for any of the measurements in this study. Therefore, only main effects are presented and discussed. Available forage mass tended ($P < 0.10$) to be higher from EARLY than from LATE on December 20 and February 15, and was higher ($P < 0.05$) from EARLY than from LATE on January 14 (Table 1). However, assuming a DM intake of 2.5 % of BW and 50% utilization of the forage, the average differential in available forage between December 20 and February 15 between EARLY and LATE should sustain only an additional 12 extra grazing days per acre. Available forage mass did not differ ($P > 0.10$) between seeding dates on the other sampling dates, and did not differ ($P > 0.10$) between tillage intensity on any of the sampling dates.

Heifers grazing EARLY pastures tended ($P < 0.10$) to be heavier than those grazing LATE on January 15, but BW did not differ ($P > 0.10$) between treatments on the other dates (Table 2). During the first period, BW gain by heifers grazing EARLY was greater ($P < 0.10$) than those by heifers grazing LATE. Other gains did not differ ($P > 0.10$) among treatments. Likewise total gain and daily gain did not differ statistically ($P > 0.10$) among the different treatments. Heifers grazing pastures that were disked twice prior to seeding were 31 lb heavier numerically ($P > 0.10$) than those grazing pastures that were disked only once.

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A mid-October seeding date would generally impose less environmental stress on new seedlings and less competition from the bermudagrass sod than an earlier seeding date. Although pastures seeded earlier had greater forage mass earlier in the grazing season, this increase in forage mass did not translate into greater animal production. Greater tillage and soil disturbance should reduce bermudagrass competition. However, in this study, there was no apparent advantage to multiple diskings on forage mass or animal gains. Therefore, based on the first year of a proposed 3-year study, tillage intensity and/or seeding date are not critical factors in determining total season forage and animal production. However, varied environmental conditions during the fall could differentiate between treatments in subsequent years of the study.

Implications

Sod-seeded winter annuals appear to be a viable feed source for developing heifers for the subsequent breeding season. During the course of this study, heifer gains averaged 2 lb/day and no additional hay was fed between December 20 and May 11. There were no overall statistically significant differences between seeding in early September vs. mid-October, or between disking once or twice prior to seeding the annual forages.

Literature Cited

Coffey, K. P., et al. 2002. J. Anim. Sci. 80:926.

Table 1. Winter annual forage mass (lb/acre) of sod-seeded winter annuals planted in early September (EARLY) or mid-October (LATE) after one or two diskings

	Tillage intensity		Seeding date		
Date	Once	Twice	EARLY	LATE	SE
December 20[a]	1,633	1,609	1,859	1,383	126.4
January 14[b]	2,008	2,042	2,289	1,761	129.1
February 15[a]	514	596	621	490	40.6
March 22	940	952	966	927	54.9
April 12	1,605	1,716	1,792	1,529	156.6

[a]Differences were detected between seeding dates (P<0.10).
[b]Differences were detected between seeding dates (P<0.05).

Table 2. Growth performance by heifers grazing sod-seeded winter annuals planted in early September (EARLY) or mid-October (LATE) after one or two diskings

	Tillage intensity		Seeding date		
Item	Once	Twice	EARLY	LATE	SE
BW, lb					
December 18[a]	543	544	543	543	0.2
January 15[b]	570	574	579	565	3.7
February 15[a]	636	653	658	631	12.8
March 15	696	718	720	694	12.5
April 12	768	794	793	769	14.1
May 11	815	846	836	825	15.9
Daily gain, lb					
Dec. 20 – Jan. 15[b]	0.96	1.09	1.28	0.77	0.130
Jan. 15 – Feb. 15	2.13	2.55	2.54	2.14	0.415
Feb. 15 – March 15	2.15	2.31	2.20	2.25	0.277
March 15 – April 12	2.57	2.70	2.61	2.66	0.233
April 12 – May 11	1.62	1.81	1.49	1.95	0.197
Total gain, lb	272	302	293	282	15.8
Daily gain, lb	1.89	2.10	2.03	1.96	0.110

[a]The December 18 weight represents an average of full weights measured Dec. 17 and 18 prior to shipping the heifers from Batesville to Monticello, AR.
[b]Differences were detected between seeding dates (P < 0.10).

Influence of Harvesting Management on Regrowth Performance and Nutritive Value of Eastern Gamagrass (*Tripsacum dactyloides* L.)

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Story in Brief

Yield and nutritive value of regrowth from a 2-yr old stand of 'Pete' eastern gamagrass (EGG) (*Tripsacum dactyloides* L.) were evaluated at the University of Arkansas Forage Research Farm in Fayetteville. Forage samples were harvested at 2-wk intervals beginning on July 11, 2001. Measurements were taken on the regrowth at cutting intervals of 4-, 6-, 8-, and 10-wk after initial harvest. From wk 4 to 10, plant height, number of tillers, and yield of dry matter (DM) increased. Dry matter yields were 1,098, 2,172, 3,848, and 5,470 lb/acre on wk 4, 6, 8, and 10, respectively. There was an increase in concentration of neutral detergent fiber (NDF) and acid detergent fiber (ADF) from 61.1 to 71.4% and from 29.6 to 37.0%, from wk 4 and 10, respectively. Acid detergent lignin (ADL), hemicellulose (HEM), and cellulose (CELL) increased from 7.4 to 10.2, 31.5 to 34.4 and 22.2 to 26.8%, respectively. Crude protein (CP) concentration decreased over time from 16.1, 12.4, 8.2, to 7.8% after 4, 6, 8, and 10 wk of regrowth, respectively. More studies are required to evaluate the optimum time for harvesting EGG.

Introduction

Eastern gamagrass (EGG) is a native, perennial, warm season bunch grass that is native to the eastern half of the United States. The EGG cultivar 'Pete' was developed from 70 accessions originating from native EGG populations in Kansas and Oklahoma (Fine et al., 1990). Productivity and quality of EGG has been studied (Burns et al., 1992). Brejda et al. (1996) reported that EGG produced abundant regrowth following defoliation, and this allows multiple harvests during the growing season.

There are few studies reported on intensity of EGG defoliation. A recommended minimum stubble height is 6 to 8 in. This is simple to maintain during hay production; however, under grazing conditions a higher stubble height is recommended (Gillen, 2001). Chemical composition of EGG regrowth clipped at 56 d following clipping at boot stage has been studied (Coblentz et al., 1998). Concentrations of NDF, ADF, ADL and CP were 77.2, 44.4, 5.1 and 8.2% respectively. In northern Missouri, Brejda et al. (1996) reported on the response of EGG to different harvesting intervals and nitrogen rates. Total forage yield was greater with the 42-d harvest interval than for the 28-d interval. However, the concentration of CP in regrowth was greater with the 28-d than 42-d harvest interval. They suggested that the decision to harvest at 28 or 42 d intervals depends on the objectives of the forage producer. They also suggested that harvesting at 28 d intervals during a year with drought stress reduced plant vigor during the following harvest and season. Rest periods of 28 to 45 d for EGG have been recommended under rotational stocking (Gillen, 2001). However there is evidence indicating that a 28-d rest period is not enough to maintain vigor. Plants clipped at 6 to 8 in at the early heading stage of growth followed by 28- to 42-d clipping intervals lost vigor and after 3 yr were almost dead (Fick and Coblentz, 1994). Brakie (1998) reported increases in EGG yields with longer harvesting intervals. Yields were 8,640, 10,700, and 13,240 lb/acre of EGG harvested at 30, 45, or 60 d intervals after the first harvest. The objective of this study was to evaluate the regrowth performance and nutritive value of a 2-yr old stand of 'Pete' EGG.

Experimental Procedures

A hay plot of EGG was established in rows spaced 40-in apart during spring 1999. The experimental site was fertilized on April 27, 2001 with poultry litter at 2 T/acre. The plot was divided into four blocks with eight rows. After hay cutting by a mower on June 13, 2001 stubble height was 8 in; EGG hay was harvested at heading stage. Regrowth sampling was initiated on July 11, 2001 (4 wk later). Forages were harvested by hand-clipping 39 in of each row at an 8-in stubble height with a hedge cutter. On each harvest date, the height of EGG was established by measuring the tallest plants within each 39-in section of rows that were sampled on that date. Harvest dates were July 11, July 25, August 8, and August 22. Harvest intervals were 28, 42, 56, and 70 d. Harvested samples were dried to a constant dry weight under forced air at 122°F.

Dried whole-plant samples were ground through a 1-mm screen in a Wiley mill (Arthur H. Thomas, Philadelphia). Whole plant concentration of NDF, ADF, and ADL were sequentially determined using batch procedures outlined by ANKOM Technology Corp. (Fairport, NY). Crude protein was calculated from the percentage of N in each sample, as determined by a modified Kjeldahl procedure (Kjeltech Auto 1030 Analyzer, Tecator, Inc., Herndon, VA).

Analysis of variance (PROC ANOVA; SAS Inst., Inc., Cary. NC) was used to analyze yield, height, and tillers response over ten harvest dates. For each individual harvesting date, regression analysis (PROC REG) was used to analyze chemical concentrations (NDF, ADF, ADL, HEM, CELL, and CP) for linear, quadratic, and cubic responses.

Results and Discussion

Plant height and tiller density of EGG regrowth increased ($P < 0.05$) with cutting interval. Plant height increased ($P < 0.05$) from 39.5 to 74.9 in between 28 and 70 d, respectively. Tiller counts at 28 and 70 d were 1.0 and 40.2 tillers/ft^2, respectively (Table 1). The number of tillers and the overall trend toward greatly increased tiller density was highest between 42 and 56 d of regrowth.

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Yields of DM increased ($P < 0.05$) with the length of harvesting interval. Yields ranged from 1,098 to 5,470 lb/acre on 28 and 70 d, respectively (Table 1). These yields of EGG regrowth were within ranges commonly reported in other studies.

Chemical composition of whole-plant EGG regrowth is shown in Table 2.

Concentrations of NDF and ADF increased over time from 61.1 to 71.4%, and 29.6 to 37.0%, respectively. In this study, the concentration of NDF and ADF of EGG regrowth harvested after 56-d interval was lower than that reported by Coblentz et al. (1998). In that study, EGG regrowth was harvested following clipping at boot stage, but in the present study EGG regrowth was harvested following hay cutting at the heading stage. Both HEM and CELL concentrations at 56 d were lower in this study compared to values reported by Coblentz et al. (1998).

Fiber composition of whole plant EGG regrowth is described by the following equations:

Whole plant NDF = 55.6375 + 7.287 (d) – 2.1462 (d) 2 + 0.3279 (d) 3; $R^2 = 0.99$; RMSE = 0.28.

Whole plant ADF = 27.48 + 2.35929 (d); $R^2 = 0.95$; RMSE = 0.62.

Whole plant ADL = 5.0031 + 2.9606 (d) – 0.4168 (d) 2; $R^2 = 0.95$; RMSE = 0.25.

Crude protein decreased from 16.1, to 7.8% for regrowth harvested after 4 to 10 wk, respectively, and can be explained by the following equation:

Whole plant CP = 14.96 + 5.07 (d) – 4.62 (d) 2 + 0.73 (d) 3; $R^2 = 0.99$; RMSE = 0.17.

The CP concentration of EGG regrowth harvested at 56 d interval was consistent with findings reported by Coblentz et al. (1998). In that study the concentration of CP was 8.2%, which was the same as we found in this study.

Implications

The nutritive value and yield of DM observed in this study is comparable to other reported research work. The yield of DM increased with an increase in cutting interval; however, the CP concentration decreased as the cutting interval was increased. The concentration of CP was higher at wk 4 and 6 cutting intervals than on the other harvest dates. More work is required to determine the optimum harvesting time and to evaluate the regrowth performance and nutritive value of EGG harvested at different cutting intervals.

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Table 1. Growth performance and yield of eastern gama-grass regrowth harvested from July 11, to August 22, 2001

Date	Weeks	Height, in	Tillers/ft^2	Yield, lb/acre
7/11/01	4	39.5^d	1.0^d	1,098^d
7/25/01	6	45.3^c	1.3^c	2,172^c
8/08/01	8	70.8^b	31.3^b	3,848^b
8/22/01	10	74.9^a	40.2^a	5,470^a

^{a,b,c,d,} Means in a column without a common superscript differ ($P < 0.05$).

Table 2. Chemical concentration1 (%) of whole plant eastern gamagrass regrowth harvested from July 11 to August 22, 2001

Date	Weeks	NDF	ADF	ADL	HEM	CELL	CP
7/11/01	4	61.1^c	29.6^a	7.5^a	31.4^a	22.2^a	16.1^c
7/25/01	6	64.2	32.7	9.5	31.6	23.2	12.4
8/08/01	8	67.0	34.2	9.9	32.8	24.3	8.2
8/22/01	10	71.4	37.0	10.2	34.4	26.8	7.8

[1]NDF = neutral detergent fiber, ADF = acid detergent fiber, ADL = acid detergent lignin, HEM = hemicelluloses, CELL = cellu lose, CP = crude protein.

[a]Linear effect ($P < 0.01$) with increase harvesting interval.

[b]Quadratic effect ($P < 0.01$) with increase harvesting interval.

[c]Cubic effect ($P < 0.01$) with increase harvesting interval.

In-Situ Dry Matter Degradability of Eastern Gamagrass (T*ripsacum dactyloides* L.) Harvested at Ten Stages of Maturity

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Story in Brief

An in-situ trial with whole-plant 'Pete' eastern gamagrass (EGG), harvested on ten dates (from May 15 to July 17, 2000), was conducted to determine degradation of dry matter (DM) in five (856 + 80 lb) ruminally cannulated crossbred steers. The steers were offered a maintenance ration of bermudagrass hay (80%) and grain concentrate (20%). Chemical composition of whole plant EGG indicated that acid detergent fiber (ADF) increased with advancing harvest date up to the fourth harvest (June 5, 2000), but thereafter ADF increased only gradually. The eighth harvest had the highest ADF content (44.5%). Crude protein (CP) content of EGG declined from 14.6% (first harvest) to 5.7% (last harvest). Ruminal disappearance of DM was determined at 0, 3, 6, 9, 12, 24, 48, 72, 96, and 120 h for each harvest date. The lag time of DM degradation did not change ($P > 0.05$) as harvest date increased. Effective degradation of DM decreased ($P < 0.05$) from the first harvest to the last. With advancing harvest dates, the potential extent of DM degradation declined ($P < 0.05$). The potential extent of DM disappearance was highest ($P < 0.05$) at 85.9% on the first harvest date compared with 85.4, 83.8, 79.2, 79.4, 78.8, 78.8, 75.4, 76.3 and 75.7% for harvest dates 2, 3, 4, 5, 6,7, 8, 9 and 10, respectively. Degradability of DM was faster (4.6%/h) for the first harvest ($P < 0.05$) compared to subsequent harvest dates. The DM disappearance declined in relation to advancing harvesting date of EGG.

Introduction

Limited research work has been done on eastern gamagrass (EGG) compared to other warm season grasses. Interest in working with EGG gained momentum during the late 1980s and 1990s when the cultivar 'Pete' was developed and registered as a composite from 70 accessions originating from US native EGG populations in Kansas and Oklahoma (Fine et al., 1990). Chemical composition of EGG has been studied by Coblentz et al. (1998) who reported that CP concentration exceeds 12.5% at the boot and anthesis stages. At moderate N fertilization, CP concentration approached 20% of the whole plant at boot stage. Studies done on digestibility of EGG in Kansas by Coblentz et al. (1998) revealed that the potential extent of ruminal degradation of dry matter and neutral detergent fiber (NDF) at boot stage was comparable to that of high quality legumes; however, degradation occurred at slower rate. The fibrous components of EGG resemble the composition of C_4 grass species; therefore, the proportion of cell wall in the whole plant is high. The objective of this study was to measure in situ dry matter disappearance of the whole plant 'Pete' eastern gamagrass harvested at ten different dates.

Experimental Procedures

Five ruminally cannulated crossbred steers (mean BW = 855.6 ± 80 lb) were used as replicates to determine in situ degradation of EGG. These animals were cannulated by approved procedures of the University of Arkansas Institute of Animal Care and Use Committee. Steers were housed in individual pens, and fed a basal diet of 80% bermudagrass hay and 20% concentrate composition. Steers were fed 2.2% BW twice daily at 7:30 am and 4:00 pm. Water supply was ad libitum to all steers. Steers were adapted to the basal diet for 10 days before the trial period.

A pasture plot of eastern gamagrass established in the spring of 1999 was divided into four equal size blocks (82 x 82 ft) before the first forage samples were harvested on May 15, 2000. Whole plant forage sample harvesting was done by hand clipping a 39.4 in row at a height of 8 in above the ground. Two replicate whole plant samples were harvested from each block and were dried to a constant weight under forced air at 122°F. Whole plant harvesting dates were as follows: May 15, 22, and 29, June 5, 12, 19, and 26, July 3, 10, and 17, and were labeled as harvest date 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10, respectively.

Dried EGG whole plant samples were ground through a 2-mm screen for in-situ analysis. A small grab of representative sample from each whole plant replication was ground through I-mm screen for chemical analysis. The NDF and acid detergent fiber (ADF) analyses were conducted by batch procedures as outlined by ANKOM Technology Corp. (Fairport, NY). The CP was calculated from N determined by a modified Kjeldahl procedure (Kjeltec Auto 1030 Analyzer, Tecator, Inc. Herndon, VA).

A total of 500 dacron bags (3.9 x 7.9 in. 53-mm pore size; ANKOM Technology Corp; Fairport, NY) were filled with 5 g samples and carefully sealed by using an impulse heat sealer (Model CD-200; National Instrument Co; Inc; Baltimore, MD). Ten dacron bags for each period were placed into each 14.2 x 13.8 in mesh bag. All mesh bags were soaked at the same time in tepid (109°F) water for 20 min to wash out water-soluble components and minimize time lag associated with wetting. All mesh bags containing sample bags, excluding those labeled 0 h, were immediately inserted into the ventral rumen simultaneously and incubated for 3, 6, 9, 12, 24, 48, 72, 96, and 120 h. After insertion animals were fed the basal diet.

Zero hour soaked bags and incubated bags from the rumen were rinsed by a washing machine (Whirlpool Corp; model# Lx R 7144 EQ1, Benton Harber, MI) ten times in 12 gal 1 min agitation, 2 min spin per rinse according to procedure described by Coblentz et al. (1997). Rinsing was done to minimize microbial N contamination.

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In situ DM residues were divided into three fractions (Wilkerson et al., 1995) based on susceptibility to ruminal degradation and were defined as follows: A = the immediately soluble fraction; B = the fraction that was degraded at a measurable rate; and C = the fraction unavailable in the rumen. Fractions A, B, and C were derived directly or indirectly from non- linear regression (PROC NLIN of SAS Inst., Inc, Cary, NC) as the percentage of DM that remained after incubation times. Lag times, degradation rate constants, and fractions B and C were determined directly from the model. The maximum theoretical extent of degradation was determined similarly (total DM – C). The immediately soluble portion, fraction A, was calculated by difference (total DM – (B+C)).

For each individual harvesting date regression analysis (SAS, PROC REG) was used to analyze chemical concentrations (NDF, ADF, and CP) for linear, quadratic, and cubic responses over the ten harvesting dates.

Results and Discussion

Quality of Eastern Gamagrass. Chemical composition of whole plant eastern gamagrass for each harvest date is shown in Table 1. The NDF and ADF content increased as gamagrass harvest date advanced. Acid detergent fiber increased from 32.3 % in the first harvest to 44.5 % at the eighth harvest. The protein content of the whole plant EGG decreased with advancing harvest date from 14.6 to 5.7 % for the first and the last.

In this study NDF content of EGG was 66.2% during the first harvest (May 15) and the level rose ($P < 0.01$) to 79.4 during the eighth harvest date July 3) and then dropped again. The fiber concentration of whole plant and CP is described by the following equations:

$$\text{Whole plant NDF \%} = 66.0 + 0.4258(d) - 0.0038\ (d)^2$$

$$\text{Whole plant ADF \%} = 33.2 + 0.2859\ (d) - 0.0020\ (d)^2$$

$$\text{Whole plant CP \%} = 14.2 - 0.1290\ (d).$$

The concentration of NDF and ADF were comparable with findings reported by Coblentz et al. (1997) who reported that EGG at boot stage had 69.4% and 35.3% NDF and ADF respectively. The anthesis stage EGG had 73.1% NDF and 39.6 % ADF, while at physiological maturity NDF and ADF content were 78% and 44.8% respectively. In the present study NDF content of EGG was 66.2% at the first harvest, and rose to 79.4 at eighth harvest. In this trial CP% content decreased linearly ($P < 0.01$) form 14.6% during the first harvest to 5.7% during the last harvest (Table 2).

Degradation Kinetics of DM. In situ degradation kinetics of whole plant EGG are presented in Table 2. In this study, immediately soluble DM between first and third harvest was 24.2 to 22.7% ($P < 0.05$) and could be compared to that found at boot and anthesis stages by Coblentz et al. (1998).

The lag time of DM degradation did not change ($P > 0.05$) with advancing harvest date of EGG. Effective degradation of DM decreased ($P < 0.05$) from the first harvesting date to the last. Measurable degradable DM was 61.8 to 58.0% ($P < .05$). The potential extent of DM degradation declined ($P < 0.05$) but the undegradable fraction increased with advancing harvest dates. The potential extent of DM disappearance was highest on the first harvest with 85.9% and declined with increasing harvesting dates.

Implications

Degradation characteristics of dry matter indicated a decline with advancing harvest dates. The results of this study suggest that more trials should be carried out to determine and compare degradation characteristics of other nutrients concentrations of eastern gamagrass.

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Table 1. Composition of whole plant forages of eastern gamagrass harvested at ten dates from May 15 to July 17 (as % DM)

Harvest date	NDF[1]	ADF[2]	CP[3]
1	66.2[b]	32.3[b]	14.4[a]
2	67.8	35.1	13.1
3	70.2	36.7	12.6
4	74.4	38.9	9.8
5	73.9	38.6	11.1
6	76.6	40.3	10.1
7	74.2	39.4	9.4
8	79.4	44.5	7.1
9	79.0	42.2	6.5
10	76.2	43.0	6.3
SEM	0.6	0.9	0.4

[1] NDF = neutral detergent fiber.
[2] ADF = acid detergent fiber.
[3] CP = crude protein.
[a] Linear effect ($P < 0.01$) with harvesting dates.
[b] Quadratic effect ($P < 0.01$) with harvesting dates.

Table 2. In situ DM degradation[1] of the whole plant eastern gamagrass at ten harvest dates (as % DM)

Harvest date	A	B	C	EXT	EFF	LAG, h	Rate, K_d
1	24.2^{a}	61.8^{ab}	14.0^{e}	85.9^{a}	58.8^{a}	1.5	4.6^{a}
2	22.7^{ab}	62.7^{a}	14.6^{ed}	85.4^{a}	55.6^{b}	0.7	3.9^{b}
3	22.7^{ab}	61.2^{ab}	16.3^{d}	83.8^{a}	55.4^{b}	1.7	4.1^{ab}
4	19.2^{bc}	60.0^{ab}	20.8^{c}	79.2^{b}	50.4^{c}	1.8	3.9^{b}
5	19.1^{c}	60.3^{ab}	20.6^{c}	79.4^{b}	46.9^{d}	1.2	3.0^{c}
6	15.7^{cd}	62.3^{a}	21.9^{bc}	78.8^{bc}	44.0^{e}	1.2	2.9^{cd}
7	17.7^{cd}	62.3^{a}	21.2^{c}	78.8^{b}	42.5^{ef}	1.1	2.5^{cde}
8	14.5^{d}	60.9^{ab}	24.6^{a}	75.4^{d}	41.0^{f}	2.3	2.7^{cde}
9	16.1^{cd}	60.3^{ab}	23.7^{ab}	76.3^{cd}	40.5^{f}	1.6	2.5^{de}
10	17.7^{c}	58.0^{b}	24.3^{a}	75.7^{d}	40.7^{f}	1.6	2.3^{e}
SEM	7.7	11.1	3.1	3	3.2	2	0.001

$^{a\ b\ c\ d\ e\ f}$ Means in a column without a common superscript differ ($P < 0.05$).

[1]A= immediately soluble fraction; B=fraction degradable at a measurable rate;
C= un-degradable fraction; EXT=Potential extent of degradation; EFF=Effective degradation.

Effects of Nitrogen Fertilization Rate, Stockpiling Initiation Date, and Harvest Date on the Dry Matter Yield of Fall Stockpiled Bermudagrass

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Story in Brief

Well-established stands of 'Common' and 'Tifton 44' bermudagrass [*Cynodon dactylon* (L.) Pers.] located at Fayetteville and Batesville, AR, respectively, were chosen to evaluate the effects of stockpiling initiation date (August or September), and N fertilization rate (0, 33, 66, or 99 lb N/acre) on the dry matter (DM) yield potential of fall-stockpiled bermudagrass forage in 2000 and 2001. Harvest dates began in mid-October and continued at 3-wk intervals through late December. Soil types were a Captina silt loam at Fayetteville, and a Secesh silt loam at Batesville. Within year, DM yield increased linearly ($P \leq 0.008$) with N fertilization rate at Fayetteville in 2001, and in Batesville during both years. Stockpiling initiation date, harvest date, and their interaction affected ($P \leq 0.004$) DM yield. For August initiation dates, DM yield declined linearly ($P \leq 0.007$) with harvest date at both sites during both years; however, cubic responses ($P \leq 0.076$) also were observed in three of the four site-years. For September initiation dates, DM yield exhibited less consistent patterns over harvest dates. Yields of DM were greatest when stockpiling was initiated in early August, but overall yields, which ranged approximately from 90 to 4,200 lb/acre, were highly dependent on precipitation during August and early September.

Introduction

Beef cattle producers in Arkansas face many economic obstacles, including maintaining cows throughout winter months. Producers often rely on bermudagrass as the primary warm-season forage during the growing season because it has the potential to produce high forage yields in response to fertilization with N (Doss et al., 1966; Hill et al., 1993). This growth has traditionally been used to support grazing livestock, but large quantities are also harvested as hay that is fed during the late fall and early winter after bermudagrass is dormant. However, costs associated with hay production, and adverse weather conditions during spring and summer make extended grazing systems attractive to producers.

Recently, winter-feeding systems that involve stockpiling standing bermudagrass at the end of the growing season have received increased interest (Lalman et al., 2000; Scarbrough et al., 2001). Bermudagrass and other stockpiled forages can provide winter pasture for grazing livestock, thereby reducing the need for supplemental hay and its associated costs (Adams et al., 1994; Hitz and Russell, 1998). The objectives of this study were to evaluate the effects of N fertilization rate, stockpiling initiation date, and harvest date on the DM yield potential of stockpiled common and 'Tifton 44' bermudagrass forages throughout late fall and early winter.

Experimental Procedures

Forage Management. In August of 2000 and 2001, well-established stands of common and Tifton 44 bermudagrass were divided into four field blocks consisting of eight plots (12 x 20 ft) each at Fayetteville and Batesville, AR, respectively. Prior to initiating the study each year, the plot area at both locations was managed for hay production, and a final harvest was taken as close to the trial initiation date as possible. To initiate the trial, any additional forage in the plot area was clipped to a 2-in stubble height with a rotary mower equipped with a bagging attachment. Any mowed forage was removed from the site and discarded. Immediately thereafter, N fertilizer treatments (0, 33, 66, or 99 lb N/acre) were applied as ammonium nitrate (34-0-0) to half of the plots. Early initiation dates were on August 8, 2000 and August 7, 2001 at Fayetteville, and August 10, 2000 and August 9, 2001 at Batesville. A second (late) initiation date was also evaluated. These treatments were established on September 6, 2000 and September 4, 2001 at Fayetteville, and September 6, 2000 and September 6, 2001 at Batesville. Establishment techniques for the second initiation date were identical to those used in August. For treatments initiated in September, any bermudagrass growth that accumulated between the August and September initiation dates was clipped (2-in) as described previously and removed prior to fertilization.

Harvest Management. Forage growth was allowed to accumulate until mid-October, which coincides approximately with the expected first frost date for northern Arkansas. Plots were harvested by cutting a single swath across each plot with a self-propelled sickle-bar mower. Plots were harvested a total of four times at 3-wk intervals over a 9-wk period ending in December. During 2000, the fourth and final sampling date was delayed until early January due to poor weather conditions that included substantial snowfall and prolonged ground cover. Harvest dates in Fayetteville for 2000 were October 18, November 9, November 29, and January 8, while in Batesville the corresponding dates were October 19, November 10, November 30, and January 9. The January harvest dates at Fayetteville and Batesville were the first possible opportunity to harvest the plots after the snow cover melted. For 2001, harvest dates were on October 17, November 6, November 27, and December 18 at Fayetteville, and October 18, November 7, November 29, and December 19 at Batesville. A grab sample of each forage was dried to a constant weight in a forced-air oven (122°F) to determine the concentration of DM in the harvested forages. This value was used to calculate the total DM yield from each plot.

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Statistical Analysis. Because the growth characteristics of the bermudagrass varieties used in this study varied greatly (Burton and Monson, 1978), data for each location were analyzed independently. Data within each site-year were analyzed as a split-plot design (PROC GLM; SAS Inst., Inc., Cary, NC). Whole plots were arranged in a 2 x 4 factorial design that included two initiation dates (August or September) and four fertilization rates (0, 33, 66, or 99 lb N/acre). The subplot treatment factor was fall harvest date. Initially, the effects of year were included in the model, but there were numerous interactions ($P < 0.05$) of other treatment factors with year at both locations; therefore, each year was analyzed independently. Single degree of freedom orthogonal contrasts (PROC GLM; SAS Inst., Inc., Cary, NC) were used to describe the effects of N fertilization rate and harvest date on DM yield.

Results

Precipitation. Weather conditions were extremely dry in August 2000 at both locations; there was no measurable rainfall in Fayetteville, and only 0.13 in of precipitation fell at Batesville during this time period (Figures 1 and 2). Between July and December 2000, cumulative precipitation was only 89 and 63% of the 30-yr norm (National Oceanic and Atmospheric Administration, 2002) for the Fayetteville and Batesville sites, respectively. At Fayetteville in 2001, monthly precipitation exceeded the 30-yr norm during four of the six months between July and December. In August and November, months in which precipitation was less than the 30-yr norm, cumulative precipitation was at least 90% of expected levels. Similarly, precipitation at Batesville met or exceeded the 30-yr norm during five of the six months comprising this same time period. The lone exception to this trend was in August, when only 0.43 in of precipitation fell; this was only 14% of the 30-yr norm.

Batesville 2000. Fertilization rate tended to affect DM yield ($P = 0.057$; Table 1), but no interactions with fertilization rate were found ($P \geq 0.382$). Yield of DM increased linearly ($P = 0.008$; Table 2) with fertilization rate, but yields were low and the range was narrow (227 to 448 lb/acre). Main effects of initiation date and harvest date affected DM yield ($P < 0.001$; Table 1), as did their associated interaction ($P < 0.001$). For both initiation dates, DM yield declined in linear ($P \leq 0.013$) and cubic ($P \leq 0.024$) patterns over harvest dates, but plots initiated in September produced only 30 to 54% of the DM produced in companion plots initiated in August (Table 3). There was a 121 lb/acre increase in yield between the first and second harvest dates for plots initiated in September, but this was not observed for the other initiation date.

Fayetteville 2000. Yield of DM was not affected by N fertilization rate ($P = 0.559$; Table 1) or interactions of initiation date or harvest date with N fertilization rate ($P \geq 0.569$). Main effects of stockpiling initiation date and harvest date affected DM yield ($P < 0.001$), as did their associated interaction ($P < 0.001$). For the August initiation date, DM yield declined linearly ($P < 0.001$; Table 3) over harvest dates; a cubic effect ($P = 0.011$) was also detected, largely because DM yield increased by 123 lb/acre between the first and second harvest dates before declining sharply thereafter. Plots initiated in September yielded only 35 to 66% of the forage ($P < 0.001$) harvested from comparable plots that were initiated in August. Yield of DM from plots initiated in September increased by 102% between the first and second harvest dates. Overall, DM yield from September-initiated plots exhibited quadratic ($P < 0.001$) and cubic ($P < 0.001$) changes over harvest dates, and DM yield on the final harvest date exceeded that of the first harvest date by 127 lb/acre.

Batesville 2001. Fertilization rate strongly affected ($P < 0.001$) DM yield (Table 1); however, there also was a weak trend ($P = 0.084$) for an interaction between fertilization rate and initiation date. Yields of DM increased linearly ($P < 0.001$; Table 2) with fertilization rate; DM yield in plots fertilized at the highest rate accumulated more than three times as much DM as unfertilized checks, but all yields were poor, and the only treatment mean to exceed 1000 lb/acre was associated with the highest fertilization rate. Consistent with responses in other site-years, main effects of initiation and harvest dates ($P < 0.001$) and their interaction ($P = 0.003$) affected DM yield (Table 1). For treatments established in August, yield of DM declined linearly ($P = 0.007$; Table 3) from 1,190 to 734 lb/acre over the 9-wk sampling period. For plots initiated in September, a cubic response ($P = 0.053$) was observed where yield on the final harvest date was 139 lb/acre less than on the initial harvest date. However, yields for all treatments initiated in September were poor (312 to 464 lb/acre), and were, at best, only 50% of comparable treatments initiated in August.

Fayetteville 2001. Yield of DM was affected ($P = 0.007$; Table 1) by N fertilization rate, and there was a weak trend ($P = 0.092$) for a N fertilization rate by initiation date interaction. Yields increased linearly ($P = 0.002$), and were 25% greater in plots fertilized at the highest rate, compared to unfertilized controls (Table 2). A quadratic trend ($P = 0.060$) also was observed; this was likely because there was no yield response in plots fertilized with 33 lb N/acre relative to unfertilized checks. Main effects of initiation date and harvest date also affected yield ($P \leq 0.004$; Table 1), as did their associated interaction ($P < 0.001$). Regardless of initiation date, DM yield changed in linear ($P < 0.001$) and cubic patterns ($P \leq 0.076$) over harvest dates (Table 3). However, yields decreased over harvest dates in plots initiated in August, but increased in plots initiated in September because of contamination by winter-annual grasses and broadleaf weeds. These weed species were not observed in companion plots initiated in August, and suggest that the shading created with an August initiation date may have suppressed growth of winter-annual contaminants. As was observed at both sites in 2000, yields from plots initiated in September were only 16 to 55% of those from comparable treatments started in August.

Implications

These results suggest that acceptable accumulation of bermudagrass for use in grazing systems during the late fall and early winter is highly dependent on normal precipitation in August. Dry matter yields in excess of 4200 lb/acre were attained without drought stress in August-initiated plots grown at Fayetteville. In all cases, an August initiation date resulted in more DM yield than companion plots initiated in September. This system may be best adapted to less droughty sites, or where irrigation is available to insure adequate growth in dry years.

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Table 1. F-values and P > F for main effects and interactions of N fertilization rate (Nrate), stockpiling initiation date (I), and harvest date (H) for the DM yield of stockpiled bermudagrass harvested in Batesville and Fayetteville, AR in 2000 and 2001

	Fayetteville				Batesville			
	2000		2001		2000		2001	
Effect	F-value	P > F	F-value	P > F	F-value	P > F	F-value	P > F
Nrate[a]	0.7	0.559	5.4	0.007	2.9	0.057	23.0	< 0.001
I[b]	69.7	< 0.001	440.8	< 0.001	23.8	< 0.001	79.6	< 0.001
Nrate x I	0.5	0.717	2.5	0.092	0.8	0.546	2.5	0.084
H[c]	24.1	< 0.001	4.8	0.004	28.6	< 0.001	16.6	< 0.001
H x I	7.5	< 0.001	38.9	< 0.001	8.6	< 0.001	5.1	0.003
Nrate x H	0.9	0.569	0.8	0.614	1.1	0.382	1.4	0.222
Nrate x H x I	0.7	0.670	0.6	0.832	0.9	0.521	0.8	0.584

[a] Nitrogen fertilization rates were 0, 33, 66, and 99 lb/acre.
[b] Initiation dates were in early-August or early-September.
[c] Initial harvests were in mid-October, which approximately coincides with the expected first frost. Harvests were taken subsequently at three-week intervals through late December. The final harvest for 2000 was delayed at both sites until early January 2001 because of prolonged ice and snow cover.

Table 2. Orthogonal contrasts for the main effect of N fertilization rate on the DM yield of stockpiled bermudagrass

	Fayetteville		Batesville	
	2000	2001	2000	2001
N fertilization rate	DM yield	DM yield	DM yield	DM yield
Lb N/acre	lb/acre	lb/acre	lb/acre	lb/acre
0	924	2278	227	334
33	914	2253	298	580
66	996	2398	340	655
99	1032	2836	448	1018
SE	67.8	116.8	54.4	58.9
Effect[a]	NS	L = 0.002 Q = 0.060	L = 0.008	L < 0.001

[a] NS = nonsignificant (P ≥ 0.10); L = linear; Q = quadratic.

Table 3. Orthogonal contrasts for DM yield as affected by the interaction of stockpiling initiation date and harvest date for stockpiled bermudagrass forage grown in Batesville and Fayetteville, AR in 2000 and 2001

	2000				2001			
	Aug		Sept		Aug		Sept	
Harvest date[a]	Bat[b]	Fay	Bat	Fay	Bat	Fay	Bat	Fay
	lb/acre	lb/acre	Lb/acre	lb/acre	lb/acre	lb/acre	lb/acre	lb/acre
1	662	1438	196	506	1190	4227	464	657
2	595	1561	317	1024	853	3571	312	911
3	276	1038	107	572	867	3682	431	1575
4	305	963	165	633	734	3170	325	1734
SE	58.0	92.7	26.8	38.3	107.9	172.1	56.2	79.4
Effect[c]	L < 0.001 C = 0.024	L < 0.001 C = 0.011	L = 0.013 C < 0.001	Q < 0.001 C < 0.001	L = 0.007	L < 0.001 C = 0.076	C = 0.053	L < 0.001 C = 0.013

[a] Initial harvests were October 19, 2000 and October 18, 2001 at Batesville and October 18, 2000 and October 17, 2001 at Fayetteville, which approximately coincides with the expected first frosts at each site. Harvests were taken subsequently at three-week intervals through late December. The final harvest for 2000 was delayed until January 9, 2001 because of prolonged ice and snow cover.
[b] Bat = Batesville; Fay = Fayetteville.
[c] L = linear; Q = quadratic; and C = cubic.

Effect of Nitrogen Fertilization on Effective Ruminal Disappearance of Dry Matter, Fiber and Selected Macro–Minerals from Common Bermudagrass Harvested on Two Different Dates

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Story in Brief

Nutrient composition and digestibility of bermudagrass [*Cynodon dactylon* (L) Pers.] may vary with different management practices such as fertilization and time of harvest. This study evaluated nutritional value and ruminal disappearance of DM, neutral-detergent fiber (NDF) and selected macro-minerals from bermudagrass. Bermudagrass growing on a poultry layer–litter–amended site was fertilized with ammonium nitrate at four rates (0, 50, 100, and 150 lb N/acre) on April 28 and July 19, 2000, then harvested on May 30 and August 18, 2000. Five crossbred ruminally-cannulated steers (928 ± 45.0 lb BW) were used to determine DM, NDF, Ca, P, Mg, and K disappearance from dacron bags suspended in the rumen. Concentrations of NDF decreased ($P < 0.05$) and those of N, Ca, and Mg increased ($P < 0.10$) with increasing N fertilization rate on both harvest dates. Effective ruminal degradation of DM and NDF and effective ruminal disappearance of Mg increased ($P < 0.05$) with increasing N fertilization rate. Effective ruminal disappearance of Ca, P, and K were not affected ($P > 0.10$) by N fertilization rate on May 30, but effective ruminal disappearance of Ca increased and P decreased quadratically ($P < 0.05$) with increasing N fertilization rate on August 18. Effective ruminal disappearance of macro-minerals exceeded 70% in all cases and was highest for K followed by Mg, P, and Ca. Therefore, fertilization with higher rates of N has positive effects on nutritional quality and effective ruminal disappearance of common bermudagrass.

Introduction

Common bermudagrass is one of the most popular forage species adopted for beef production throughout the Southeastern U.S. due to its adaptability, persistence, aggressiveness (Aiken et al., 1995), high yield, and moderate nutritional quality. Bermudagrass responds well to N fertilization by increasing yield and N concentration in the plant. Crude protein and energy deficiencies are the principal factors associated with suboptimum ruminant livestock production. However, ruminants also require optimal levels of many mineral elements. Since a major goal of most livestock producers is to improve animal performance, it is essential to know the nutritional quality of bermudagrass and the proportion of those nutrients that may be utilized by the animal. The objective of this study was to determine the concentrations and effective ruminal disappearance of DM, neutral-detergent fiber (NDF), Ca, P, Mg, and K in bermudagrass fertilized with four N fertilization rates and harvested on two dates.

Experimental Procedures

Forage Samples. The forage used in this study was an established stand of common bermudagrass grown on a producer farm located near Lincoln, AR that had a poultry layer-waste application during 1999. Soil-test P and K concentrations were 571 and 496 lb/acre, respectively, and soil pH ranged from 6.8 to 7. In April 2000, 16 10-ft x 20-ft plots were arranged in a randomized complete block design with four replications. Nitrogen was applied as ammonium nitrate (34-0-0) in split applications of 0, 50, 100, and 150 lb/acre of actual N on April 28 and July 19. Bermudagrass from each plot was clipped to a 2-in stubble height with a sickle-bar mower on May 30 and August 18, 2000. Samples were composited across the four replications within each N fertilization rate for evaluation in an in-situ trial. The plots were also clipped on July 7, 2000, but no additional N was applied prior to this clipping and the forage samples were not used in the present experiment.

Forage Quality Analysis. Bermudagrass samples were dried to a constant weight under forced air at 122∞F and analyzed for N, NDF, and selected macro-minerals.

In Situ Procedures. Five ruminally-cannulated crossbred (Angus x Brangus x Angus) steers (mean BW = 928 ± 45.0 lb) were used in a randomized complete block design to determine the effective disappearance of DM, NDF and selected macro-minerals from bermudagrass. Steers were housed in individual 10 x 15 ft pens that were cleaned regularly. Steers were offered a basal diet of 86.4% bermudagrass hay and 13.6% concentrate mix. The basal diet was offered at 2% of body weight split into equal feedings at 0800 and 1700 h with ad libitum access to water.

The experimental forages were weighed into dacron bags and inserted into the rumen of all five steers simultaneously before feeding (0800 h) and incubated for 3, 6, 9, 12, 18, 24, 48, 72, or 96 h. After the appropriate time interval, dacron bags were removed from the rumen and subsequently, bags were placed into a top-loading washing machine and rinsed. Bags containing the 0-h samples were machine-rinsed also.

In-Situ Residue Analysis. After rinsing, dacron bags containing the incubated forage residues were dried and the residual DM was analyzed for NDF and macro-minerals. The non-linear model of Mertens and Loften (1980) was used to separate the different nutrients into a water-soluble fraction, a slowly degraded fraction, and an undegradable fraction and to calculate the rate of nutrient disappearance from the dacron bags. Effective disappearance was also calculated and represents the proportion of the particular nutrient that would be degraded in the rumen. It was calculated by correcting the slowly degradable fraction for both disappearance rate of the nutrient and passage rate of the diet, then adding this value to the water-soluble fraction.

Statistical Methods. Data pertaining to disappearance from dacron bags in the rumen were analyzed using PROC GLM of SAS (SAS Inst., Inc., Cary, NC) as a randomized complete block design

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with a 2 x 4 (harvest date x N fertilization rate) factorial arrangement of treatments. Effects of steer, date, the linear and (or) quadratic effects of N fertilization rate, and their interaction were included in the statistical model. A linear model was used when the fit was not improved ($P > 0.05$) by the quadratic model. Significant interactions implied that the quadratic or linear functions differed ($P < 0.05$) across harvest dates. When interactions were not detected ($P > 0.05$), a single quadratic or linear parameter estimate was calculated across harvest dates and used to describe the overall relationships between fertilization rate and the response variable.

Results and Discussion

A quadratic N fertilization rate by harvest date interaction was observed ($P < 0.01$) for whole plant N concentration (Table 1). It is common to observe an increase in N concentrations following N fertilization. Concentrations of NDF decreased linearly ($P = 0.01$) on both harvest dates as N fertilization increased. The NDF fraction was higher for bermudagrass harvested on August 18 than on May 30. This difference is best explained by the positive relationship between temperature and NDF concentration in forages. Macro-mineral concentrations in bermudagrass were, in general, above the requirements recommended for beef cattle. Calcium (Ca) concentrations tended ($P = 0.08$) to increase linearly as N fertilization rates increased on May 30 and August 18. However, Ca content did not differ between harvest dates ($P > 0.05$). Phosphorus (P) concentration in the whole plant showed a linear N fertilization rate by harvest date interaction ($P < 0.05$). This effect could be explained by a lack of response ($P = 0.99$) of P content across N fertilization levels on May 30 harvest, but a decrease ($P < 0.01$) of 29.4% with increasing N fertilization rates on the August 18 harvest. The calculated Ca:P ratio averaged 1.9 and 2.6 for bermudagrass harvested on May 30 and August 18, respectively. This ratio is within the recommended range for beef cattle. Magnesium (Mg) concentrations increased linearly by increasing N fertilization rates ($P < 0.01$). However, no difference was observed in Mg content at both harvest dates. Potassium (K) content did not differ ($P = 0.37$) with increasing N fertilization levels, but K concentration was higher in the May 18 than in the August 30 harvest. Hypomagnesemia (grass tetany) is not typically a problem with warm season grasses, and this study supported that since the K/(Ca + Mg) ratio was below the ratio of 2.2. A ratio of 2.2 or higher is considered to have the potential to educe grass tetany (Grunes et al., 1989). Therefore, there is probably little risk of grass tetany in lactating cows grazing this bermudagrass.

Dry matter effective degradability exhibited a linear N fertilization rate by harvest date interaction ($P > 0.01$, Table 2). The effective degradability of NDF increased linearly ($P < 0.01$) by 1.1 percentage unit for each 100 lb/acre with increasing N fertilization rates at both harvest dates. Effective degradability was 3.1% higher ($P < 0.05$) on May 30 than on August 18. Forage intake is related to the NDF degradation. Therefore, increasing effective degradability of NDF, should result in higher forage intake. This resulted because of the relationship between elevated temperatures and reduced cell wall digestibility. A quadratic N fertilization rate by harvest date was observed for the effective disappearance of Ca and P ($P < 0.05$). The effective disappearance of Ca averaged 74% and was the lowest compared with K, P, and Mg, probably due to chemical binding of Ca to large indigestible fractions in the plant. Effective disappearance of Mg and K exhibited a linear N fertilization rate by harvest date interaction. The effective K disappearance was greater than 99%. Potassium had the most extensive effective disappearance among all the other elements evaluated because K is present in the forage almost entirely as free or readily exchangeable ions.

Implications

Increasing N fertilization rates substantially improved nutritional quality of bermudagrass by increasing N content, slightly reducing the NDF fraction, and increasing calcium and magnesium concentrations. In addition, effective DM, NDF and macrominerals disappearance improved at both harvest dates. Therefore, forage intake may be enhanced and the need for supplemental minerals could be reduced.

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Table 1. Concentrations of nitrogen, NDF, and selected macro-minerals from bermudagrass fertilized with four N rates and harvested on May 30 and August 18

		N fertilization rates (lb/acre)[a]						Regression coefficients				
Item	Date	0	50	100	150	RMSE[b]	Fit[c]	Quadratic	Linear[d]	Intercept	R^2	P[e]
		---------- % of DM ----------										
N, %	May 30	2.7	2.8	3.0	3.2	0.002	Quadratic	0.00001	0.0010	2.7[f]	0.99	<0.01
	Aug 18	1.8	2.1	2.3	2.4	0.002	Quadratic	-0.00002	0.0060	1.8[g]	0.99	<0.01
NDF, %	May 30	65.9	65.8	65.4	64.1	0.39	Linear		-0.009	66.0[g]	0.97	0.01
	Aug 18	68.9	69.2	68.5	67.9	0.39	Linear			69.3[f]		
Ca, %	May 30	0.69	0.71	0.69	0.72	0.04	Linear		0.0006	0.66	0.79	0.08
	Aug 18	0.63	0.70	0.79	0.77	0.04	Linear			0.68		
P, %	May 30	0.37	0.37	0.37	0.37	0.009	NS		-0.000001	0.37[f]	0.98	0.99
	Aug 18	0.34	0.30	0.26	0.24	0.009	Linear		-0.0006	0.33[g]	0.98	<0.01
Mg, %	May 30	0.19	0.22	0.22	0.23	0.007	Linear		0.0003	0.20	0.88	<0.01
	Aug 18	0.20	0.21	0.24	0.24	0.007	Linear			0.20		
K, %	May 30	2.85	3.05	3.31	2.89	0.16	NS		0.0010	2.95[f]	0.87	0.37
	Aug 18	2.24	2.38	2.45	2.42	0.16	NS			2.31[g]		

[a] Nitrogen fertilization was applied on April 28 and July 19, 2000.
[b] RMSE = root mean square error for the polynomial model. If not significant for both linear and quadratic regression models, linear RMSE was used.
[c] Best fit of linear and quadratic effects of N fertilization rate.
[d] When only one slope is represented for an item, the date x fertilization level interaction was not significant (P<0.05). Therefore the slopes did not differ and the average slope of the linear effect of N fertilization rates across harvest dates is presented.
[e] P = Probability that the linear or quadratic parameter estimate was different from zero.
[f,g] Intercepts for an item differed (P<0.05) between May 30 and August 18 harvest dates.

Table 2. Effective disappearance of DM, NDF and selected macro-minerals from common bermudagrass fertilized with four N rates and harvested on May 30 and August 18

		N fertilization rates (lb/acre)[a]						Regression coefficients				
Item	Date	0	50	100	150	RMSE[b]	Fit[c]	Quadratic	Linear[d]	Intercept	R^2	P[e]
		---------- % of DM ----------										
DM, %	May 30	51.3	53.1	54.2	55.3	0.89	Linear		0.026	52.23[f]	0.90	<0.01
	Aug 18	49.0	50.0	49.8	51.7	0.89	Linear		0.015	49.63[g]	0.90	<0.01
NDF, %	May 30	38.1	39.4	39.8	40.7	1.36	Linear		0.011	39.57[f]	0.71	<0.01
	Aug 18	37.4	39.6	37.2	39.2	1.36	Linear			38.42[g]		
Ca, %	May 30	71.6	74.5	70.6	75.7	1.53	NS	0.00021	-0.015	71.8	0.76	0.13
	Aug 18	70.8	75.0	77.1	77.4	1.53	Quadratic	-0.00039	0.102	70.3	0.76	<0.0
P, %	May 30	86.8	87.4	87.6	87.8	0.54	NS	-0.00004	0.012	86.7[f]	0.95	0.40
	Aug 18	85.9	84.7	82.2	82.7	0.54	Quadratic	0.00018	-0.051	86.0[g]	0.95	<0.01
Mg, %	May 30	92.3	92.9	92.8	93.3	0.016	Linear		0.006	92.4f	0.92	<0.01
	Aug 18	92.1	92.5	93.1	93.7	0.016	Linear		0.009	92.0[g]	0.92	<0.01
K, %	May 30	99.8	99.8	99.8	99.8	0.04	NS		-0.0002	99.8f	0.43	0.25
	Aug 18	99.7	99.8	99.8	99.8	0.04	Linear		0.0005	99.7[g]	0.43	<0.01

[a] Nitrogen fertilization was applied on April 28 and July 19, 2000.
[b] RMSE = root mean square error for the polynomial model. If not significant for both linear and quadratic regression models, linear RMSE was used.
[c] Best fit of linear and quadratic effects of N fertilization rate.
[d] When only one slope is represented for a item, the date x fertilization level interaction was not significant (P<0.05). Therefore the slopes did not differ and the average slope of the linear effect of N fertilization rate across harvest dates is presented.
[e] P = Probability that the linear or quadratic parameter estimate was different from zero.
[f g] Intercepts for an item differed (P<0.05) between May 30 and August 18 harvest dates.

Mineral Content of Forages Grown on Poultry Litter-Amended Soils

B. McGinley[1], K. Coffey[1], B. Humphry[1], T. Sauer[2], and H. L. Goodwin[3]

Story in Brief

Four farms in northwest Arkansas and northeastern Oklahoma were used to monitor mineral concentrations in forages grown on poultry litter amended soils from April 2000 to March 2002. Mineral concentrations were compared to the requirements of beef cows in gestation and early lactation, and grass tetany ratios were calculated to determine the risk of grass tetany occurrence. For most of the grazing period, calcium, phosphorus (P), potassium (K), sulfur, and iron concentrations were adequate to meet the requirements of beef cows in gestation and early lactation. Forage magnesium (Mg) concentrations from all four farms were generally below the requirement for beef cows in early lactation during the winter months of 2001 and 2002. Forages from two farms surpassed the tetany ratio during the spring of 2000, indicating that grass tetany could be a potential problem in lactating cows during that period. In general, zinc concentrations were above requirements at three of the four farms, but barely met or were below beef cattle requirements during most of the fall and winter of 2000-2001 at Farm 1. With few exceptions, copper (Cu) concentrations at all farms were at or below cow requirements, indicating that Cu supplementation would be necessary throughout much of the year. Pastures fertilized with broiler litter may meet some but not all mineral requirements of beef cattle; therefore, supplementation with specific minerals, such as Mg and Cu, may be warranted.

Introduction

Large amounts of broiler litter are produced each year in Arkansas and used to fertilize pastures and hay meadows. The use of broiler litter as fertilizer significantly reduces reliance on commercial fertilizers and reduces production costs. Broiler litter has an N : P : K ratio of 4 : 3.7 : 3, but forages generally need only a ratio of 4 : 1 : 3. Broiler litter also contains a myriad of other macro and trace elements that are potentially available for uptake by forages. However, concentrations of these minerals in the plant may vary with species, stage of maturity, season, soil mineral concentrations, and the amount and type of fertilizer nutrients applied. The objective of this study was to monitor the mineral content of forages grown on broiler-litter amended sites throughout the year and compare each mineral with its respective requirement for beef cows during gestation and early lactation.

Experimental Procedures

Four farms in northwest Arkansas (Farms 1, 3) and northeast Oklahoma (Farms 2, 4) that have a history of utilization of broiler litter as a fertilizer source were sampled from April 2000 to March 2002. One pasture from each farm was chosen to monitor the addition and removal of nutrients. Soil samples were taken from each farm in February 2000 and March 2001 and analyzed for soil test phosphorus levels. Four cages were placed randomly throughout each experimental pasture to prevent removal of forage by grazing animals. On a monthly basis, cages were relocated within the pasture, available forage readings were measured from old and new cage sites as well as throughout the pasture, and representative forage samples were gathered; samples were not gathered if the producer was stockpiling forage for hay production. Each pasture and cage sample was analyzed for mineral concentrations.

Farm 1 was located in northeastern Oklahoma on a Nixa silt loam soil, with soil test phosphorus levels of 205 and 154 lb/acre in February 2000 and March 2001, respectively. The forage base consisted primarily of bermudagrass and crabgrass during the summer and fescue, orchardgrass, and winter annual weeds during the winter. The chosen pasture site was harvested for hay during the summer, then allowed to stockpile for grazing by cow-calf pairs during the winter. Broiler litter was applied (1.5 tons/acre) on May 6, 2000, May 5, 2001, and June 10, 2001. Farm 2 was located in northwest Arkansas on a Nixa silt loam soil. The forage base consisted of a mixture of fescue and bermudagrass. The site was grazed heavily, but intermittently during the spring, summer, and fall, and was used to house cows during the winter. Soil test phosphorus levels at this site were 568 lb/acre in February 2000 and 415 lb/acre in March 2001. No litter was applied in 2000, but it had been in previous years. Broiler litter (2.5 tons/acre) was applied on April 18, 2001 and 200 lb/acre of ammonium nitrate was applied in July 2001. Farm 3 was located in northeast Oklahoma on a Newtonia silt loam soil and had a forage base of bermudagrass, white clover, annual ryegrass, and winter annual weeds. The pasture was grazed intermittently except during April through October 2001, when forage was allowed to accumulate and subsequently harvested for hay. Soil test phosphorus levels were 253 and 226 lb/acre in February 2000 and March 2001, respectively. Broiler litter was applied (2.3 tons/acre) on June 5, 2001. Urea was also applied in June 2001 and September 2001 at rates of 250 and 150 lb/acre, respectively. Farm 4 was located in northwest Arkansas on a Nixa silt loam soil with soil test levels of 470 and 450 lb/acre in February 2000 and March 2001, respectively. The forage base consisted of bermudagrass and annual ryegrass and was grazed intermittently except for the period from June 2000 to August 2000 and April 2001 to October 2001 when forage was allowed to accumulate for hay production.

Mineral concentrations of the forage samples gathered throughout the 2-yr period were compared with the NRC (1996) requirements for gestating and lactating cows.

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Results and Discussion

Throughout most of the grazing season, concentrations of calcium (Ca), phosphorus (P), potassium (K), sulfur (S), and iron (Fe) in forages sampled on all farms exceeded the requirements of beef cattle. Forage Ca concentrations were adequate to meet the requirements for dry, pregnant cows on each sampling date at each farm (Figure 1). However, forage Ca concentrations on one sampling date at Farm 2 and on three dates at Farm 3 were not adequate to meet the requirements for a lactating cow. Forage P concentrations were below the requirements for a lactating cow in January and February 2001 for Farm 4 and in February 2001 for Farm 3 (Figure 2). Forage P concentrations were high during the spring of 2000 and 2001, ranging between 65 and 300% of the requirements for a lactating cow.

Forage K concentrations were excessive throughout much of the year at each farm (Figure 3). Concentrations of K were particularly high during the spring of 2000 and 2001 when they reached a maximum of nine times (Farm 4) the requirement for beef cows during gestation. Forage K concentrations were below requirements for beef cows in gestation and early lactation during January 2001 and February 2001 at Farm 4 and during February 2001 at Farm 3. Forage magnesium (Mg) concentrations at Farm 4 were below the requirements for beef cows in early lactation for the entire two-year period except for April and May of 2000 and April of 2001 (Figure 4). Concentrations of Mg at the other three farms were below requirements for beef cows in early lactation during the winter months of 2000-2001 and 2001-2002. Grass tetany, also called hypomagnesemia, is a disorder caused by a Mg deficiency, and is usually associated with grazing lush pastures during the spring. High levels of K may block Mg absorption by the animal and cause the onset of grass tetany. Physical symptoms range from reduced appetite, dull appearance, and staggering gait to signs of increased nervousness, frequent urination and defecation, muscular tremors, and excitability followed by collapse, paddling of feet, coma, and death (Mayland and Cheeke, 1995). The probability of grass tetany increases when the equivalent ratio of reaches 2.2 or greater. Concentrations of forage minerals at Farms 2 and 4 resulted in tetany ratios that surpassed this tetany threshold during the spring of 2000, and again during April 2001 for Farm 4, thereby increasing the chance for animals to contract grass tetany (Figure 5).

Concentrations of sulfur (S) at the four farms were adequate to meet cow requirements during every month except February 2002 at Farm 1 (Figure 6). Forage Fe concentrations were adequate to meet the Fe requirements of beef cattle for the entire two-year grazing period, except for September 2000 on Farm 4 when the forage concentration was 3 ppm below the 50 ppm requirement (Figure 7). Concentrations of zinc (Zn) in forages sampled during the winter months of 2000-2001 and January 2002 at Farm 1 were generally below requirements for beef cows. Zinc concentrations were below cow requirements on two isolated dates at Farms 2 and 3. Generally, concentrations of Zn in forages at Farms 2, 3, and 4 were well above cow requirements. With few exceptions, forage copper (Cu) concentrations tended to remain at or below the requirements for beef cows at all farms during the period of May 2000 to March 2001. Concentrations of forage Cu at Farm 1 exceeded beef cow requirements in April 2001 and March 2002 only, but remained well below requirements for the majority of the two-year period. Forage Cu concentrations at Farm 2 were at or below cow Cu requirements for much of the first year, but were generally above cow requirements for the remainder of the trial. Concentrations of Cu in forage at Farms 3 and 4 were generally close to cow requirements of 10 ppm but exhibited occasional spikes in concentration.

Implications

Long-term applications of broiler litter to pasture may lead to accumulation of high levels of calcium, phosphorus, potassium, sulfur, and iron in the forage, but other minerals such as copper may be marginal to deficient. This may reduce supplemental mineral needs, but forage analyses should be used to ensure mineral concentrations are adequate to meet livestock requirements.

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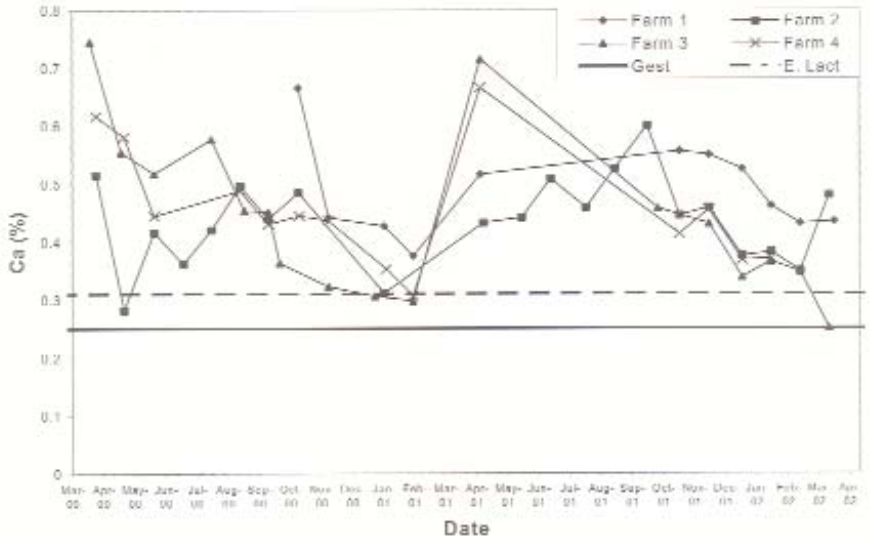

Figure 1. Concentrations of calcium in forage harvested at four farms compared with the requirements of beef cows in gestation (Gest) and early lactation (E. Lact).

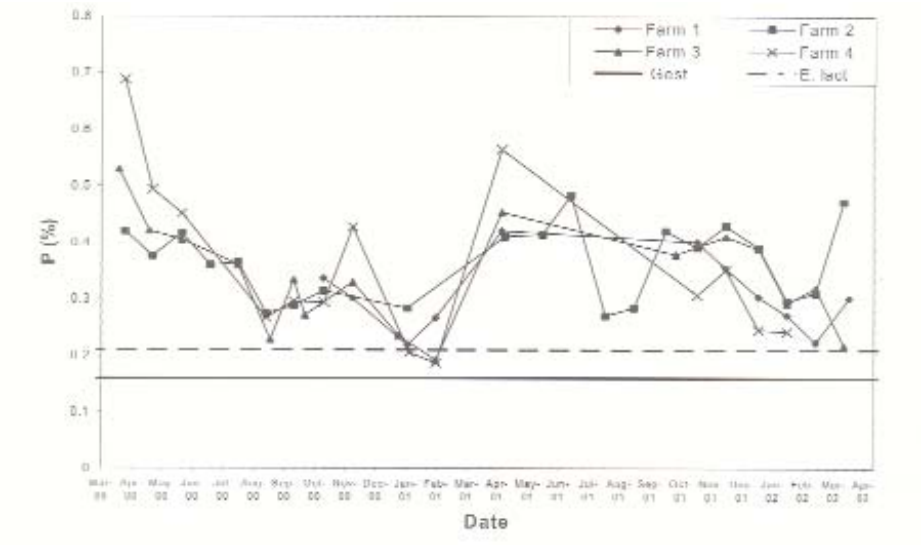

Figure 2. Concentrations of phosphorus at four farms compared with the requirements of beef cows in gestation (Gest) and early lactation (E. Lact).

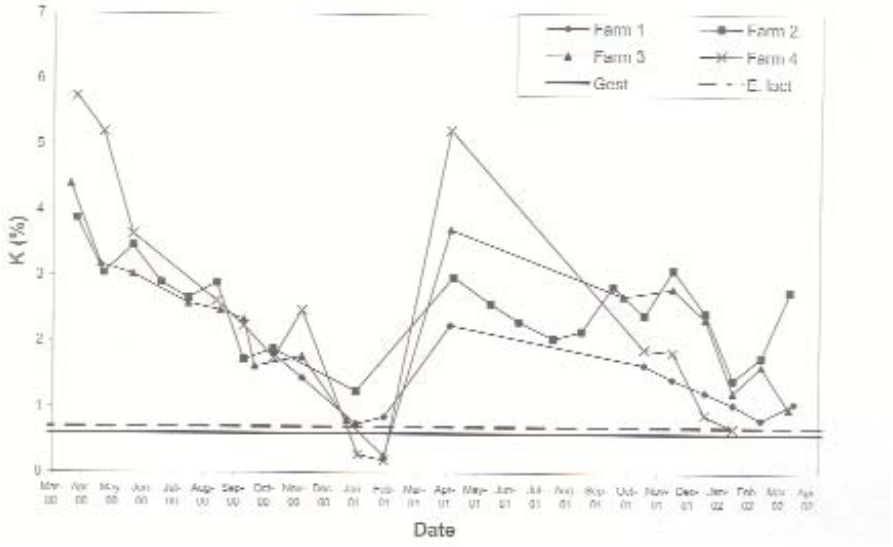

Figure 3. Concentrations of potassium at four farms compared with the requirements of beef cows in gestation (Gest) and early lactation (E. Lact).

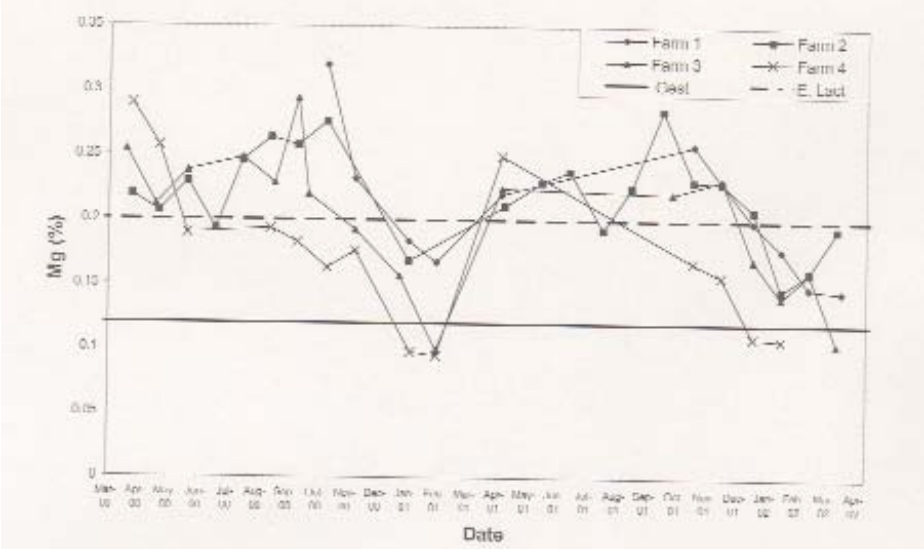

Figure 4. Concentrations of magnesium at four farms compared with the requirements of beef cows in gestation (Gest) and early lactation (E. Lact).

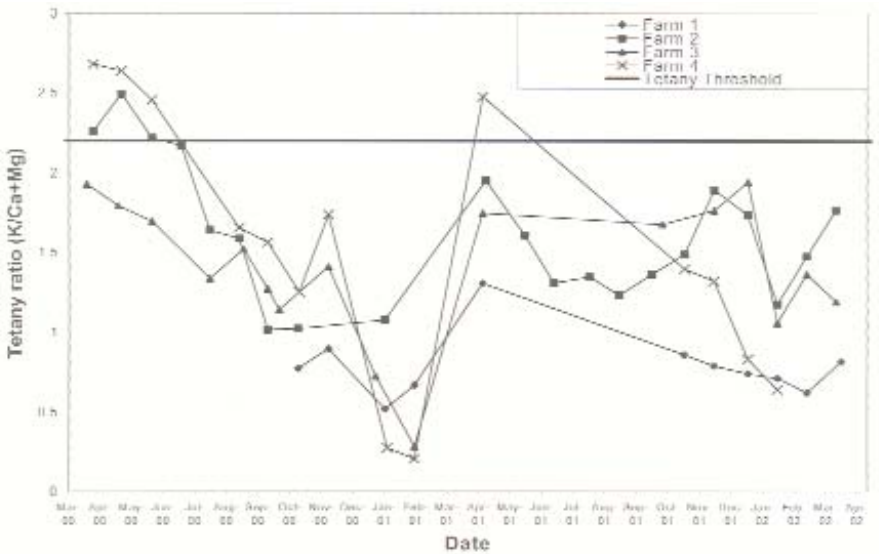

Figure 5. Grass tetany ratio at four farms compared with the tetany threshold.

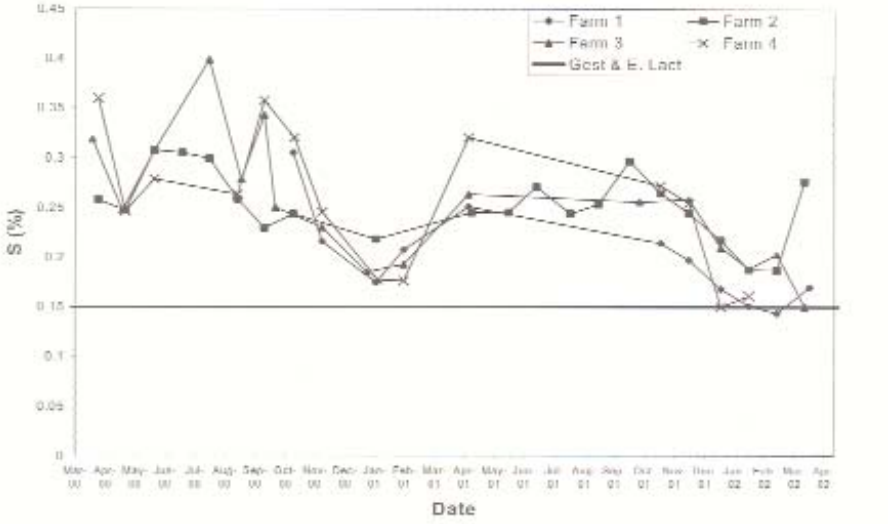

Figure 6. Concentrations of sulfur at four farms compared with the requirements of beef cows in gestation (Gest) and early lactation (E. Lact).

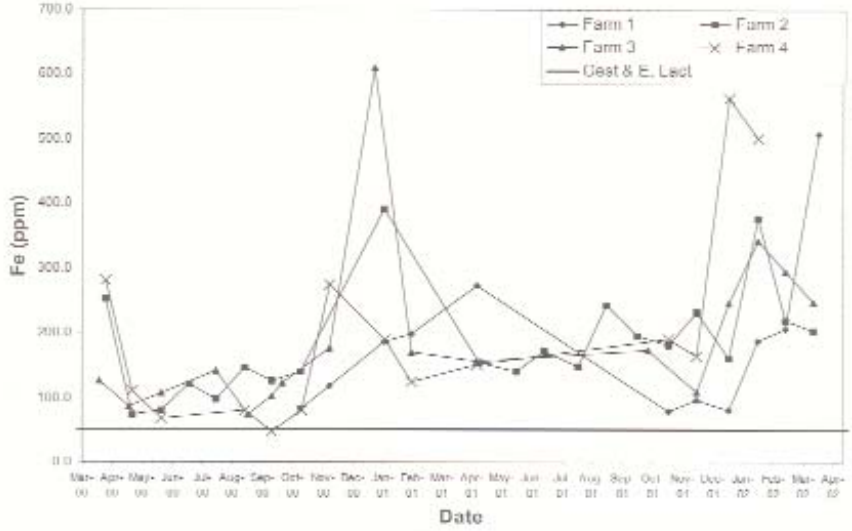

Figure 7. Concentrations of iron at four farms compared with the requirements of beef cows in gestation (Gest) and early lactation (E. Lact).

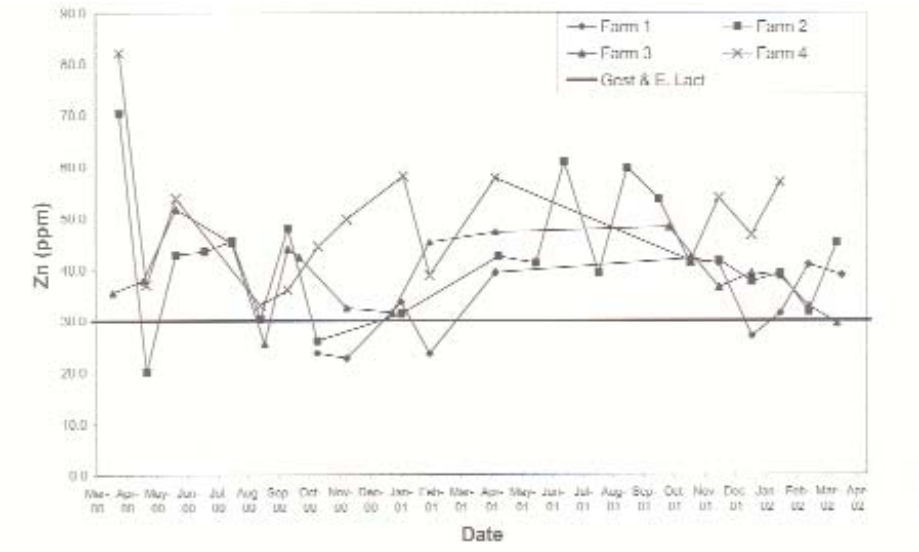

Figure 8. Concentrations of zinc at four farms compared with the requirements of beef cows in gestation (Gest) and early lactation (E. Lact).

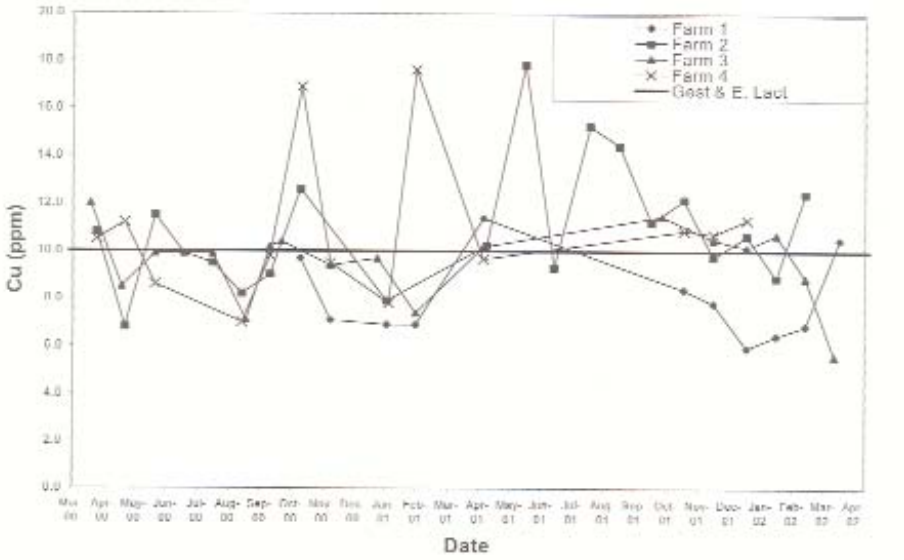

Figure 9. Concentrations of copper at four farms compared with the requirements of beef cows in gestation (Gest) and early lactation (E. Lact).

Relationship of Milk Yield and Quality to Preweaning Gain of Calves from Angus, Brahman and Reciprocal-cross Cows on Different Forage Systems

M.A. Brown[1], A.H. Brown, Jr.[2], and B.A. Sandelin[2]

Story in Brief

Interactions of the regression of preweaning ADG on dam milk yield and quality with breed group and forage environment were evaluated in a two-phase study. Phase I consisted of milk yield, quality and calf gain records from 1989 to 1991 for purebred Angus and Brahman cows mated to sires of both breeds. Phase II consisted of milk yield, quality and calf gain records from 1991 to 1997 for Angus, Brahman, Angus x Brahman and Brahman x Angus mated to Polled Hereford sires. In phase I forage environments included common bermudagrass and endophyte-infected tall fescue. In phase II forage environments included common bermudagrass and endophyte-infected tall fescue (1991-1995) and a rotational system of both forages (1995-1997) in which each forage was grazed during its appropriate growing season. Milk yield was estimated monthly during lactation from spring through fall and converted to a 24-h basis. Milk fat, milk protein, and somatic cell counts were analyzed by a commercial laboratory. In Phase I, the relationships of preweaning ADG to milk yield, milk fat yield, and protein yield were higher ($P < 0.05$) in Brahman cows on bermudagrass than Angus on bermudagrass. The regression of preweaning ADG on milk yield in Phase I was higher ($P < 0.05$) for cows on tall fescue than for cows that grazed bermudagrass. In Phase II, the relationships of preweaning ADG to milk yield, milk fat yield, and milk protein yield were higher ($P < 0.01$, $P < 0.11$, $P < 0.01$, respectively) in purebred cows compared to reciprocal-cross cows. The regression of preweaning ADG on milk yield and milk protein yield was higher ($P < 0.05$) on tall fescue than bermudagrass in Phase II. These results suggest that the influence of milk yield and quality on calf growth may differ among breed types and production system, and the efficacy of improvements in milk traits may depend on the breed type and forage environment.

Introduction

The maternal ability of beef cows has been shown to be a critical component of preweaning growth in their calves (Mallinckrodt et al., 1993) and profit potential in the herd (Miller et al., 1999). Consequently, considerable emphasis has been given to improvements in maternal ability of beef cows. While nutritional environment is an obvious factor influencing milk yield, little work has been done to evaluate the influence of both breed group and forage environment on the relationship of milk yield and preweaning growth. Moreover, more work is needed to evaluate the influence of milk fat and milk protein on preweaning growth in beef calves. Thus, our objectives in this research were to evaluate the interaction of the regression of calf preweaning ADG on milk yield, milk fat, milk protein, and somatic cell counts with breed group and forage environment in Angus, Brahman, and reciprocal-cross cows and their calves managed on three different forage systems.

Experimental Procedures

Nine years of milk production and calf growth data (1989 to 1997) on approximately 310 Angus, Brahman, and reciprocal-cross cow-calf pairs managed on common bermudagrass, endophyte-infected tall fescue, or a combination of the two forages were evaluated in this study. Data from 1989 to 1991 consisted of purebred Angus and Brahman cows and their purebred and reciprocal-cross calves managed on either common bermudgrass or endophyte-infected tall fescue. Data from 1991 to 1994 were from Angus (AA), Brahman (BB), and reciprocal-cross cows (AB and BA) and their Polled Hereford-sired calves managed on either common bermudagrass or endophyte-infected tall fescue. Data from 1995 to 1997 were from AA, BB, AB, BA and their Polled Hereford-sired calves managed on either common bermudagrass, endophyte-infected tall fescue, or a combination of the two forages in which each forage was grazed during its appropriate season, usually June through October for bermudagrass and November through May for tall fescue. Milk yield was estimated monthly six times during lactation from spring through fall by method of single cow milking machine and converted to a 24-h basis ([milk weight/14] x 24; Brown et al. 1996). Average days postpartum for estimates of milk yield were 65, 94, 122, 151, 173, and 199 d from 1989 to 1991 and 60, 89, 116, 145, 172, and 199 d from 1991 to 1997. Milk fat, milk protein, and somatic cell counts were analyzed by a commercial laboratory using a Milkoscan System 4000“ (Foss North America, Eden Prairie, MN; AOAC, 1990). Details on herd and pasture management and milking procedures can be found in Brown et al. (1993,1996, 2001). Because the data in 1989 to 1991 consisted of the production of purebred and reciprocal-cross calves from Angus and Brahman sires and the data from 1991 to 1997 were the production of two- and three-breed cross calves from Polled Hereford sires, data were reported separately from 1989 to 1991 (Phase I) and from 1991 to 1997 (Phase II). In phase I there were 32 AA and 32 BB cow years for milk yield and quality on bermudagrass while cow years for milk yield and quality on fescue included 32 AA and 30 BB. Sample size for phase II is given in Table 1.

Data were analyzed by methods of mixed model least squares. Linear models for 1989 to 1991 included the fixed effects of year, sire breed, dam breed, sex of calf, forage, and interactions among fixed effects; random effects included sire of calf nested in sire breed and the pooled interactions of sire in sire breed with fixed effects. Linear

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models for 1991 to 1997 included the fixed effects of year, grandsire breed, granddam breed, sex of calf, age of dam, forage, and interactions among fixed effects; random effects included sire of calf and the pooled interactions of sire with fixed effects. Covariates included in separate models were 24-hr milk yield, 24-hr milk fat yield, 24-hr milk protein yield, and somatic cell count, as well as interactions of these covariates with sire breed, dam breed, forage, sire breed x dam breed, sire breed x forage, dam breed x forage, and sire breed x dam breed x forage. Contrasts among regression coefficients for different classes were done using "t" statistics.

Results and Discussion

Breed and Forage Effects for Traits Analyzed. Least-squares means and standard errors for traits analyzed are given in Tables 2 and 3 for Phase I and Phase II, respectively. In Phase I, preweaning ADG of calves was lower ($P < 0.01$) on tall fescue than bermudagrass. There was an interaction ($P < 0.05$) of breed of dam with forage for milk yield where AA cows on tall fescue were lower ($P < 0.01$) than AA on bermudagrass while forage differences were not evident in BB cows. In Phase I, BB cows had higher ($P < 0.01$) milk fat yield than AA and milk fat yield was higher ($P < 0.01$) on bermudagrass than tall fescue. Similar to milk yield, milk protein yield was higher ($P < 0.01$) in AA on bermudagrass than AA on tall fescue but similar in BB on tall fescue and bermudagrass. In Phase I, forage effects for somatic cell counts were similar in AA, but BB on tall fescue had higher counts than BB on bermudagrass ($P = 0.05$). In Phase II, there was an interaction ($P < 0.05$) of grandsire breed x granddam breed x forage for preweaning ADG. Maternal heterosis for preweaning ADG was larger on tall fescue than bermudagrass ($P < 0.05$) while maternal heterosis was similar in tall fescue and the rotational system. Milk yield was higher ($P < 0.01$) on bermudagrass than either tall fescue or the rotational system and milk yield on the rotational system was higher ($P < 0.01$) than tall fescue. Heterosis for milk yield was similar in all forage systems and averaged 4.84 lb ($P > 0.26$). Milk fat yield differed ($P < 0.05$) among all of the forage systems and was largest on bermudagrass, intermediate on the rotational system, and lowest on tall fescue. There was marginal evidence that heterosis for milk fat yield differed among forages ($P < 0.15$) with heterosis on bermudagrass larger ($P < 0.10$) than heterosis on tall fescue. Milk protein yield differed ($P < 0.01$) among the forages and was highest on bermudagrass, intermediate on the rotational system, and lowest on tall fescue. Heterosis for milk protein yield was similar among forages and averaged 16.72 lb ($P > 0.37$). There was little evidence of forage differences in somatic cell count but heterosis was evident with somatic cell count in crossbred cows lower ($P < 0.05$) than counts in purebreds.

Regression of Preweaning ADG on 24-hr Milk Yield. Estimates of the regression of preweaning ADG on 24-hr milk yield and their standard errors are given in Tables 4 (Phase I) and 5 (Phase II). In Phase I there was little evidence of an interaction of 24-hr milk yield with sire breed. There was however evidence of an interaction ($P < 0.10$) of the relation of preweaning ADG to milk yield with dam breed and forage. On bermudagrass, preweaning ADG increased 0.102 lb per lb milk in calves from BB cows ($P < 0.01$) whereas the same relationship in calves from AA cows was 0.0257 lb per lb milk ($P = 0.30$). On tall fescue, the relationship was similar for calves from both breeds ($P = 0.63$). In the Phase II data there was evidence that the regression of preweaning ADG on 24-hr milk yield was different among grandsire breed x granddam breed subclasses ($P < 0.01$) and among forage classes ($P < 0.10$). The regression averaged across pasture types was higher ($P < 0.01$) in calves from AA than calves from Angus x Brahman and BA cows. The regression was also higher ($P < 0.05$) in calves from BB than BA cows. Consequently, the relationship was generally higher for calves from purebred cows than from crossbred cows with the average slope for calves from purebreds exceeding that of calves from crossbreds by .047 lb ADG per lb milk ($P < 0.01$). The regression of preweaning ADG on milk yield was higher ($P < 0.05$) on tall fescue compared to bermudagrass in Phase II where the regression on rotation was intermediate to the other two forage systems and not significantly different from either. The data from the current study support the hypothesis of stronger relationships of milk yield to preweaning ADG in lower producing cows where purebred cows had lower milk yield than crossbreds and where cows on endophyte-infected tall fescue had lower milk yields than cows on bermudagrass. However, the relationship of milk yield to preweaning ADG in Phase I was higher for calves from BB cows than calves from AA cows on bermudagrass, even though differences in milk yield were not significant.

Regression of Preweaning ADG on 24-hr Milk Fat Yield. Estimates of the regression of preweaning ADG on 24-hr milk fat yield and their standard errors are given in Tables 6 (Phase I) and 7 (Phase II). There was an interaction of the regression of preweaning ADG on milk fat yield with dam breed and forage type ($P < 0.05$). The relationship was higher ($P < 0.05$) in calves from BB cows than calves from Angus cows on bermudagrass (2.03 vs 0.278 lb/lb respectively), while the relationship in calves from the two breeds was similar on tall fescue ($P = 0.59$). In Phase II, the regression of preweaning ADG on milk fat yield, averaged over pasture types, was higher ($P < 0.05$) in calves from Angus than from AB, BA, and BB cows. The relationship in calves from AB was larger ($P < 0.10$) than the relationship in calves from BA. Additionally, the average regression of preweaning ADG on milk fat yield tended to be higher ($P = 0.11$) for calves from purebreds than from crossbreds. While the relationship between preweaning ADG and milk fat yield, averaged across breed types, was not significantly different among forages, the relationship for calves on tall fescue was numerically greater than bermudagrass or the rotational system.

Regression of Preweaning ADG on 24-hr Milk Protein Yield. Estimates of the regression of preweaning ADG on 24-hr milk protein yield and their standard errors are given in Tables 8 (Phase I) and 9 (Phase II). The regression of preweaning ADG on milk protein yield differed ($P < 0.10$) among dam breed x forage subclasses in Phase I. On bermudagrass, preweaning ADG increased 3.02 lb per lb increase in milk protein in calves from BB cows ($P < 0.01$), but only 0.82 lb per lb increase in milk protein in calves from Angus cows ($P > 0.23$). In Phase II, there was an interaction ($P < 0.01$) of milk protein yield with grandsire breed x granddam breed and an interaction with forage ($P < 0.10$). The regression of preweaning ADG on milk protein yield, averaged across forage types, was higher ($P < 0.01$) in calves from Angus than from AB and BA ($P < 0.01$), while the relationship was higher ($P < 0.10$) in calves from BB than from BA. Similar to the other two traits, the relationship was higher ($P < 0.01$) in the average of calves from purebreds compared to the average of calves from crossbreds. The regression of preweaning ADG on milk protein yield was higher ($P < 0.05$) in tall fescue than bermudagrass.

Regression of Preweaning ADG on Somatic Cell Counts. There was little evidence of a relationship of somatic cell counts to preweaning ADG in these data (data not shown). Estimates calculated were -2.2 x 10-5 ($P = 0.88$) and –8.8 x 10-5 ($P = 0.28$) lb per 1000 somatic cells increase in Phase I and Phase II, respectively. Simpson et al. (1995) reported no difference in weaning weights in calves from high somatic cell count cows and low somatic cell count cows. Brown et al. (1998) reported negative relationships between somatic cell count and weaning weight, but the results were not statistically significant.

Implications

Phenotypic improvements in yield of milk fat, and yield of milk protein are associated with improvements in preweaning ADG in beef cattle. However, the magnitude of the association appears to be less in breed groups or environments that support higher milk production. Consequently, further improvements in breeds and(or) environments where milk production is at relatively high levels may be less efficacious than improvements in breeds and(or) environments at lower levels of milk production. However, it is possible that improvements in productivity may be possible, even at higher levels of milk production, in certain genotypes and environments. Consequently, matching animal genotype to environment remains a consideration.

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Table 1. Cow-years for milk yield and quality estimates for forage, sire breed,and dam breed subclasses 1991-1997, Phase II

	Breed type[a]			
Forage	AA	AB	BA	BB
Bermuda	41	37	42	38
Fescue	41	37	39	35
Rotational	12	12	12	12

[a] A = Angus, B = Brahman; sire breed listed first.

Table 2. Least-squares means and standard errors for breed of dam x forage subclasses for calf growth and milk traits, Phase I

Breed[a]	Forage	Preweaning ADG[b]	24-hr Milk Yield[c]	24-hr milk fat[c]	24-hr milk protein[c]	Somatic Cells[d]
AA	Bermuda	2.02 ± 0.04	14.63 ± 0.75	0.48 ± 0.02	0.46 ± 0.02	165 ± 52
	Tall Fescue	1.85 ± 0.04	10.61 ± 0.75	0.33 ± 0.02	0.35 ± 0.02	108 ± 52
BB	Bermuda	1.98 ± 0.04	13.49 ± 0.75	0.55 ± 0.02	0.46 ± 0.02	158 ± 51
	Tall Fescue	1.85 ± 0.04	12.58 ± 0.75	0.46 ± 0.04	0.42 ± 0.02	304 ± 51
Approximate $LSD_{0.10}$		0.05	0.79	0.03	0.03	120

[a] A=Angus, B=Brahman; sire breed listed first.
[b] lb per day.
[c] lb per 24-hr.
[d] x 10^3 cells.
Approximate LSD is for comparison within or between breed group x forage subclass means for the given forage subclass.

Table 3. Least-squares means and standard errors for breed of grandsire x breed of granddam x forage subclasses for calf growth and milk traits, Phase II

Breed[a]	Forage	Preweaning ADG[b]	24-hr Milk Yield[c]	24-hr milk fat[c]	24-hr milk protein[c]	Somatic Cells[d]
AA	Bermuda	1.94 ± 0.04	15.33 ± 0.64	0.55 ± 0.02	0.48 ± 0.02	210 ± 52
	Tall Fescue	1.39 ± 0.04	9.00 ± 0.64	0.29 ± 0.02	0.29 ± 0.02	311 ± 52
	Rotation	1.63 ± 0.09	12.10 ± 1.23	0.44 ± 0.07	0.40 ± 0.04	278 ± 101
AB	Bermuda	2.33 ± 0.04	20.61 ± 0.66	0.81 ± 0.02	0.68 ± 0.02	205 ± 54
	Tall Fescue	2.00 ± 0.04	14.56 ± 0.665	0.48 ± 0.02	0.48 ± 0.02	159 ± 54
	Rotation	2.22 ± 0.09	18.63 ± 1.23	0.68 ± 0.07	0.62 ± 0.04	178 ± 101
BA	Bermuda	2.39 ± 0.04	21.98 ± 0.62	0.81 ± 0.02	0.75 ± 0.02	130 ± 51
	Tall Fescue	2.07 ± 0.04	15.00 ± 0.64	0.53 ± 0.02	0.53 ± 0.02	109 ± 52
	Rotation	2.24 ± 0.09	20.17 ±1.25	0.79 ± 0.07	1.17 ± 0.04	121 ± 102
BB	Bermuda	2.31 ± 0.04	17.03 ± 0.64	0.70 ± 0.02	0.59 ± 0.02	199 ± 52
	Tall Fescue	1.91 ± 0.04	12.82 ± 0.66	0.51 ± 0.02	0.44 ± 0.02	185 ± 54
	Rotation	2.11 ± 0.09	15.46 ± 1.23	0.66 ± 0.07	0.53 ± 0.04	259 ± 101
Approx. $LSD_{0.10}$	Bermuda vs Tall Fescue	0.05	0.68	0.03	0.02	122
Approx. $LSD_{0.10}$	Bermuda vs Rotation Fescue vs Rotation	0.07	1.04	0.05	0.03	188

[a] A=Angus, B=Brahman, sire breed listed first.
[b] lb per day.
[c] lb per 24-hr.
[d] x 103 cells.
Approximate LSD is for comparison within or between breed group x forage subclass means for the given forage subclass.

Table 4. Regression coefficients and standard errors for preweaningADG (lb) on average milk yield (lb) for Angus and Brahman cows on commonbermud agrass or endophyte-infected tall fescue, Phase I

	Breed[a]	
Forage	AA	BB
Bermuda	0.0257 ± 0.0249[b]	0.0932 ± 0.0253[c]
Tall fescue	0.0884 ± 0.0299[b]	0.0693 ± 0.0246[b]

[a] A = Angus, B = Brahman; sire breed listed first.
[bc] Mean coefficients in the same row without a common superscript differ (P < 0.05).

Table 5. Regression coefficients and standard errors for preweaning ADG (lb) on average daily milk yield (lb) for Angus, Brahman, and reciprocal-cross cows on common bermudagrass, endophyte-infected tall fescue or a combination of the two forages, Phase II

	Breed type[a]				
Forage	AA	AB	BA	BB	Average
Bermuda	0.0871 ± 0.016	0.0743 ± 0.017	0.0440 ± 0.017	0.0675 ± 0.016	0.0682 ± 0.008[b]
Tall fescue	0.1401 ± 0.200	0.0600 ± 0.015	0.0642 ± 0.017	0.1175 ± 0.022	0.0979 ± 0.010[c]
Rotation	0.1142 ± 0.026	0.0530 ± 0.024	0.0425 ± 0.023	0.1082 ± 0.039	0.0794 ± 0.016[bc]
Average	0.1137 ± 0.012[b]	0.0658 ± 0.012[cd]	0.0502 ± 0.012[c]	0.0977 ± 0.017[bd]	

[a] A=Angus, B=Brahman; sire breed listed first.
[bcd] Mean coefficients in the same row or column without a common superscript differ (P < 0.05).

Table 6. Regression coefficients and standard errors for preweaning ADG (lb)on average daily milk fat (lb) for Angus and Brahman cows on commonbermudagrass or endophyte-infected tall fescue, Phase I

	Breed[a]	
Forage	AA	BB
Bermuda	0.2785 ± 0.4937[b]	2.0396 ± 0.5106[c]
Tall fescue	1.7087 ± 0.5683[c]	1.2811 ± 0.5518[c]

[a] A=Angus, B=Brahman, sire breed listed first.
[bc] Mean coefficients in the same row without a common superscript differ (P < 0.05). Mean coefficients in the same column without a common superscript differ (P <0.10).

Table 7. Regression coefficients and standard errors for preweaning ADG (lb) on average daily milk fat (lb) for Angus, Brahman, and reciprocal-cross cows on common bermudagrass, endophyte-infected tall fescue or a combination of the two forages, Phase II

	Breed type[a]				
Forage	AA	AB	BA	BB	Average
Bermuda	2.009 ± 0.4580	1.3891 ± 0.3443	0.8815 ± 0.4259	1.3138 ± 0.3813	1.3985 ± 0.2072
Tall fescue	2.7014 ± 0.4930	1.4639 ± 0.3843	0.6888 ± 0.3601	1.5479 ± 0.4574	1.6005 ± 0.2317
Rotation	1.8900 ± 0.6043	1.2786 ± 0.6699	0.7623 ± 0.4675	0.3748 ± 1.3521	1.0764 ± 0.4530
Average	2.2000 ± 0.3018[b]	1.3772 ± 0.2829[c]	0.7775 ± 0.2429[d]	0.7775 ± 0.2429[cd]	

[a] A=Angus, B=Brahman; sire breed listed first.
[bcd] Mean coefficients in the same row without a common superscript differ (P < 0.10).

Table 8. Regression coefficients and standard errors for preweaning ADG (lb)on average daily milk protein (lb) for Angus and Brahman cows on commonbermudagrass or endophyte-infected tall fescue, Phase I

	Breed[a]	
Forage	AA	BB
Bermuda	0.8274 ± 0.6813[b]	3.0226 ± 0.7636[c]
Tall fescue	2.6770 ± 1.0283[c]	1.946 ± 0.7698[c]

[a] A=Angus, B=Brahman, sire breed listed first.
[bc] Mean coefficients in the same row without a common superscript differ (P < 0.05).

Table 9. Regression coefficients and standard errors for preweaning ADG (lb) on average milk protein (lb) for Angus, Brahman, and reciprocal-cross cows on common bermudagrass, endophyte-infected tall fescue or a combination of the two forages, Phase II

	Breed type[a]				
Forage	AA	AB	BA	BB	Average
Bermuda	3.0371 ± 0.5821	1.9776 ± 0.4628	0.9409 ± 0.5146	1.9723 ± 0.4666	1.9820 ± 0.2627 [b]
Tall fescue	4.2919 ± 0.6587	2.2244 ± 0.4888	1.9591 ± 0.5099	3.2560 ± 0.6184	2.9328 ± 0.3117 [c]
Rotation	3.7831± 0.8375	2.0374 ± 0.8008	1.3935 ± 0.7583	2.9346 ± 1.2956	2.5370 ± 0.5463 [bc]
Average	3.7039 ± 0.4110[b]	2.0799 ± 0.3731[cd]	1.4311± 0.3821[c]	2.7209 ± 0.5346[bd]	

[a] A=Angus, B=Brahman, sire breed listed first.
[bcd] Mean coefficients in the same row or column without a common superscript differ (P < 0.05).

Maternal Performance of Four Divergent Biological Types Resulting from Angus, Brahman, and Reciprocal Cross Cows Grazing Endophyte-Infected Tall Fescue or Common Bermudagrass

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Story in Brief

Maternal performance of four divergent biological cow types of Angus, Brahman, and reciprocal cross cows were evaluated over a 4-yr period. Growth curve parameters of mature weight (A) and rate of maturing (k) were estimated for 177 cows using the growth curve model as described by Brody. Cows were assigned to one of four biological types: large late maturing (LL, A > 1,283 lb, k < 0.045%), large early maturing (LE, A > 1,283 lb, k ≥ 0.045%), small late maturing (SL, A ≤ 1,283 lb, k < 0.045%), and small early maturing (SE, A ≤ 1,283 lb, k ≥ 0.045%). Measurements on 374 calves over the 4-yr period included: birth weight, weaning weight, and weaning height. Distribution of calf measurements by biological type included: LL (n = 98), LE (n = 52), SL (n = 78), and SE (n = 146). Included in the models for analysis of birth weight, weaning weight, weaning height and weaning weight:weaning height ratio were the independent variables of forage, biological type, calf birth year, age of dam, significant interactions and residual error. Calf birth year was significant (P < 0.05) for all reported traits. Age of dam was significant (P < 0.05) for weight:height ratio only. The interaction of biological type x forage was significant (P < 0.05) for all traits with the exception of weight:height ratio. These data suggest that biological type may have an effect on maternal performance.

Introduction

It is widely known that maternal effects have a substantial impact on early stages of growth (i.e. birth to weaning). The Germ Plasm Evaluation Program was established at the Roman L. Hruska U.S. Meat Animal Research Center (MARC) in 1969 (Cundiff et al., 1985) to characterize a broad range of biological types of cattle as represented by breeds that differed widely in genetic potential for milk production, growth rate, carcass composition, and mature size. Larger or smaller body size may have important biological advantages for adaptation to climate, feed resources, seasonal grazing, and marketing. By dividing animals into biological types, some of the variation in determining which biological type would perform best in a certain environment could be eliminated. Therefore, the objective of this study was to evaluate maternal performance of four biological types of cows resulting from Angus, Brahman, and reciprocal crosses grazing common bermudagrass or endophyte-infected tall fescue.

Experimental Procedures

Approximately 177 Angus (AA), Brahman (BB), Angus x Brahman (AB), and Brahman x Angus (BA) heifers born from 1988 to 1991 and 374 of their calves from 15 Polled Hereford sires born from 1991 to 1994 were evaluated in this study. The heifers were assigned to 40-acre endophyte-infected tall fescue pastures (100% infected) or 40-acre common bermudagrass pastures and were managed on these forages through their first four calf crops (1991 to 1994). Each pasture was stocked with approximately equal numbers of AA, BB, AB, and BA cows.

Heifers were bred as 2-yr-olds to calve at 3 yr of age to preclude introducing parity differences into the study due to the low percentage of purebred Brahman reaching sexual maturity at 15 mo of age. The breeding seasons were early May through mid-July of each year. Calves were born from late February through May in 1991 through 1994. Calves were weighed at birth and tagged. and bull calves were castrated by banding. Calves were weaned at an average age of 205 d, and were weighed and hip height measurements were taken.

The growth parameters of A and k were estimated on these cows using the three-parameter growth curve model as described by Brody (1945). Upon estimation of these parameters, cows were stratified into four biological types: large late maturing (LL, A > 1,283 lb, k < 0.045%, n = 98 calves), large early maturing (LE, A > 1,283 lb, k ≥ 0.045%, n = 52 calves), small late maturing (SL, A ≤ 1,283 lb, k < 0.045%, n = 78 calves), and small early maturing (SE, A ≤ 1,283 lb , k ≥ 0.045%, n = 146 calves). All breed types were represented in all biological types with the exception of straightbred Brahman in the large framed-early maturing type group (Table 1).

Data were analyzed by the GLM procedure of SAS (SAS Inst., Inc., Cary, NC). Included in models for birth weight, weaning weight, weaning height and weaning weight:weaning height ratio were the independent variables of forage, biological type, calf birth year, age of dam, biological type x forage interaction and a residual error term.

Results and Discussion

Presented in Table 2 are the least-squares means and standard errors for birth weight for the interaction of biological type and forage. This interaction was significant (P < 0.05) for all traits measured in this study with the exception of weight:height ratio.

Calves from LE cows grazing endophyte-infected fescue were larger (P < 0.05) at birth than calves from the LE cows on bermudagrass, LL on endophyte-infected fescue, SE on either forage, and SL on bermudagrass (84 lb vs. 73, 77, 73, 77 and 73 lb), respectively. Large-late maturing cows grazing bermudagrass had calves with heavier (P < 0.05) birth weights than did SE or SL cows on bermudagrass (79 lb vs. 73 and 73 lb, respectively). Small-late maturing cows

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grazing bermudagrass had calves with lighter ($P < 0.05$) birth weight than any cows grazing endophyte-infected fescue (73 lb v. 84, 77, 77, and 79 lb, respectively). Small-late maturing cows managed on endophyte-infected fescue had heavier ($P < 0.05$) birth weights than did LE, SE, or SL cows grazing bermudagrass (79 lb vs. 73, 73 and 73 lb, respectively).

Table 3 shows least-squares means and standard errors for the biological type x forage interaction for weaning weight. The LL cows grazing endophyte-infected fescue had smaller ($P < 0.05$) mean weaning weights than did the LE on bermudagrass and endophyte-infected fescue, the LL on bermudagrass, and the SE on endophyte-infected fescue (440 lb vs. 585 lb, 556 lb, 550 lb and 486 lb, respectively). The SE cows grazing bermudagrass weaned heavier ($P < 0.05$) calves than did the LL on endophyte-infected fescue (565 lb vs. 440 lb). Small-framed, early maturing cows on endophyte-infcected fescue had calves with lighter ($P < 0.05$) weaning weights than did the LE cows on either forage, or LL and SE on bermudagrass (486 lb vs. 585 lb or 556 lb, 550 lb and 565 lb, respectively). The SL cows grazing bermudagrass had calves with lighter ($P < 0.05$) weaning weights than did the LE and SE bermudagrass (528 lb vs. 585 lb and 565 lb). However these SL cows on bermudagrass weaned heavier ($P < 0.05$) calves than did the LL, SE, and SL on endophyte infected-fescue (528 lb vs. 440 lb, 486 lb and 449 lb, respectively). The SL on endophyte-infected fescue had smaller ($P < 0.05$) mean weaning weights than all other combinations with the exception of the LL grazing endophyte-infected fescue.

In general weaning weights of calves from early maturing cows were higher and weaning weights on bermudagrass were also generally higher than on endophyte-infected fescue. One likely reason for LE having higher weaning weights was the distribution of breed type x biological type in this group. There was only one purebred animal in this group of LE and the remainder were crossbreds. These crossbred animals may have exhibited heterosis thus increasing average weaning weight. Reynolds et al. (1990) found that calves from large sire breeds and from high-milk-level sire breeds were heavier at weaning than calves from their medium-sized, medium- milk production counterparts. Reported regression coefficients of weaning weights of progeny on weight of dams suggest that weaning weights increased by 8 to 24 lb for each additional 220 lb of dam weight (Benyshek and Marlowe, 1973).

Presented in Table 4 are least-squares means and standard errors for weaning hip height for the interaction of biological type x forage. Weaning hip height was greater ($P < 0.05$) in LE cows on endophyte-infected fescue than all other biological types on endophyte-infected fescue. The LL cows grazing endophyte-infected fescue had shorter ($P < 0.05$) mean hip heights at weaning than all other combinations with the exception of SL on endophyte-infected fescue. The LE on bermudagrass also had a higher ($P < 0.05$) mean weaning height than did the LL, SE or SL on endophyte-infected fescue. The SL cows grazing endophyte-infected fescue weaned calves with shorter ($P < 0.05$) mean weaning heights than did the LE or LL on bermudagrass and SE on either forage (44 in vs. 46 in, 45 in, 45 in and 45 in, respectively).

The interaction of biological type and forage was non-significant ($P > 0.05$) for the ratio of weaning weight:height. Table 5 shows least-squares means and standard error for the ratio of weaning weight: height for biological type. This ratio is often used to estimate condition at weaning. Klosterman et al. (1968) stated that this ratio can be used as a predictor of body composition in mature cows and is useful in describing the condition of cows that vary widely in type and size. Early maturing cows had greater ($P < 0.05$) mean ratios than the late maturing cows. This makes sense because late-maturing cows would have less condition at a constant age than the earlier maturing biological types. As expected the cows on bermudagrass weaned a more ($P < 0.05$) conditioned calf, and therefore yielded a higher value for this ratio than did the cows on endophyte-infected fescue (2.18 vs. 1.97; Table 6). This may indicate that endophyte-infected fescue had an effect on overall body condition score at weaning.

In our study, calf birth year was a significant ($P < 0.05$) source of variation for all traits with the exception of weaning height. This is expected due to temporary environmental effects because it is impossible to exactly duplicate pastures from year to year. Age of dam was a significant ($P < 0.05$) source of variation for the ratio of weaning weight: height, but not for other traits reported in this study. As expected the 6-yr-old cows had calves with a higher ($P < 0.05$) mean ratio than the 3 and 5-yr old cows, but there was no difference ($P > 0.05$) between the 6 and 4-yr old cows. This implies that the older cows are producing a more conditioned calf than are the younger dams.

Implications

These data suggest that biological type may need to be considered when choosing the correct match of genetics to production resources. Our data suggest that different combinations of rate of maturing and mature weight in Angus and Brahman cattle yield different results in maternal performance on two different types of forage.

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Table 1. Frequency of biological type by breed type

	Biological type[a]			
Breed type[b]	LE	LL	SE	SL
AA	1	43	31	34
AB	25	11	65	11
BA	26	27	30	4
BB	0	17	20	29

[a]LL=large framed, late maturing; LE = large framed, early maturing; SE=small framed, early maturing; SL=small framed, late maturing.
[b]AA=Angus x Angus; AB=Angus x Brahman; BA=Brahman x Angus; BB = Brahman x Brahman.

Table 2. Least-squares means and standard errors of birth weight (lb)for the interaction of biological type and forage

	Forage Environment[a]	
Biological type[b]	BG	E+
LE	73 + 2^{fgh}	84 + 2^{c}
LL	79 + 2^{cde}	77 + 2^{defg}
SE	73 + 2^{fgh}	77 + 2^{def}
SL	73 + 2^{h}	79 + 2^{cd}

[a] E+ = endophyte-infected tall fescue; BG = common bermudagrass.
[b] LL = large framed, early maturing; LE = large framed, early maturing; SE = small framed, early maturing; SL = small framed late maturing.
[cdefgh] Means in the table with no superscript in common differ (P < 0.05).

Table 3. Least-squares means and standard errors of weaning weight (lb) for the interaction of biological type and forage

	Forage Environment[a]	
Biological type[b]	BG	E+
LE	585 + 18^{c}	556 +13^{cde}
LL	550 + 11^{cdef}	440 + 15^{i}
SE	565 + 11^{cd}	486 + 11^{h}
SL	528 + 11^{efg}	449 + 7^{i}

[a] E+ = endophyte-infected tall fescue; BG = common bermudagrass.
[b] LL = large framed, early maturing; LE = large framed, early maturing; SE = small framed, early maturing; SL = small framed late maturing.
[cdefghi] Means in the table with no superscript in common differ (P < 0.01).

Table 4. Least-squares means and standard errors of weaning height (in) for the interaction of biological type and forage

	Forage Environment[a]	
Biological type[b]	BG	E+
LE	46 + 1^{cd}	47 + 1^{c}
LL	45 + 1de	44 + 1^{i}
SE	45 + 1^{def}	45 + 1^{efg}
SL	45 + 1^{efgh}	44 + 1^{h}i

[a] E+ = endophyte-infected tall fescue; BG = common bermudagrass.
[b] LL = large framed, early maturing; LE = large framed, early maturing; SE = small framed, early maturing; SL = small framed late maturing.
[cdefghi] Means in the table with no superscript in common differ (P < 0.05).

Table 5. Least-squares means and standard errors of weaning weight:height ratio for biological type

Biological type[a]	Weaning weight:height ratio
LE	2.19 + 0.03^{b}
LL	1.97 + 0.03^{c}
SE	2.06 + 0.02^{b}
SL	1.96 + 0.03^{c}

[a] LL = large framed, early maturing; LE = large framed, early maturing; SE = small framed, early maturing; SL = small framed late maturing.
[bc] Means with no superscript in common differ (P < 0.05).

Table 6. Least-squares means and standard errors of weaning weight:height ratio for forage

Forage[a]	Weaning weight:height ratio
E+	1.92 + 0.03^{b}
BG	2.19 + 0.03^{c}

[a] E+ = endophyte-infected tall fescue; BG = common bermudagrass.
[bc] Means with no superscript in common differ (P < 0.05).

The Involvement of Cytochrome P450 in Ergot Alkaloid Metabolism

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Story in Brief

This study was conducted to investigate the involvement of cytochrome P450 3A4 (CYP3A4) in the metabolism of ergotamine in beef liver microsomes. In addition, the effects of ergonovine and dihydroergotamine on CYP3A4 induction were examined in rats. When incubated with beef liver microsomes, ergotamine and its isomer were hydroxylated to their respective metabolites M1, M2, M1-Iso, and M2-Iso (8-hydroxy-derivatives). Maximum formation of metabolites was reached after 20 min, and ergotamine and its isomer were almost totally metabolized after 60 min of incubation. Ergonovine and dihydroergotamine treatments did not produce any increase ($P > 0.05$) in the induction of CYP3A4 activity over the control treatment in rats.

Introduction

Fescue toxicosis has been a problem for farmers and subject to extensive scientific investigation for some time. The presence of low levels of highly toxic ergot alkaloids in endophyte-infected (Acremonium coenophialum) tall fescue has been implicated in causing fescue toxicosis. There is good pharmacological evidence that some of the ergot alkaloids are linked to modulation of physiologi-cal mechanisms. An approach to solving the problem of fescue toxicosis would be to manipulate the process used by animals to eliminate the ergot alkaloids from circulation. The cytochrome P450 (CYP3A4) enzyme system plays a significant role in the elimination ergot alkaloids by extensive hepatic biotransformation (Pollock, 1994). Cytochrome P450 exists mainly in the liver, but is found in other tissues such as intestines, lungs, and kidneys (Krishna and Klotz, 1994).To our knowledge, no research has been done to evaluate the presence of CYP3A4 in beef liver microsomes. Furthermore, it is not known whether fescue toxins will induce such enzyme systems or inhibit them. Therefore, the objective of this study was to obtain preliminary information on the link between CYP3A4 and the metabolism of ergotamine, a representative ergot alkaloid, in beef liver. In addition, the effects of ergonovine (EN) and dihydroergotamine (DH) on the induction and the inhibition of cytochrome P450 activity were examined.

Experimental Procedures

The following chemicals were obtained from Sigma Chemical Co. (St. Louis, MO): bovine serum albumin (BSA), dexamethasone, ergotamine (ET), NADP+, D-glucose-6- phosphate, magnesium chloride, glucose-6-phosphate dehydrogenase, and EDTA. All chemicals and reagents used were of the highest quality commercially available.

Experiment 1: Five steers (992 to 1323 lb BW) were processed at the University of Arkansas abattoir. These steers had not been on any sort of fescue feed prior to necropsy. Liver tissues (0.11 to 0.22 lb) were collected and microsomes were prepared according to Kremers et al. (1981). Livers were diced with scissors and then washed with 150 mM sodium chloride buffer. Diced tissue was then ground at 1 g/10 ml of buffer (250 mM sucrose, 100 mM Tris-HCL, 1 mM EDTA, pH7.4) with ice-cold medium using a precooled blender for 10 to 20 sec, followed by homogenization with Potter-Elvehjem (5X). The homogenate was successively centrifuged at 800 x g for 10 min, at 13,500 x g for 20 min before collecting the supernate. The supernate was then centrifuged at 105,000 x g for 60 min, collecting the pellet containing the microsomal fraction. The pellet (microsomal fraction) was washed with 100 mM sodium pyrophosphate pH 7.5 and resuspended in buffer containing 100 mM sodium phosphate and 20% V/V glycerol to give 50 mg protein/ml concentration. Protein concentration was determined using BSA as a standard. Microsome suspensions were aliquoted and stored at -90oC and were used within 20 to 30 days.

Experiment 2: Male Sprague-Dawley rats (0.44 to 0.55 lb) were provided with laboratory chow and water ad libtium. After 4 days of adaptation, a total of 20 rats (five for each treatment) were treated intraperitoneally for 4 days with 100 mM levels of each of the following: a) dexamethasone (DXM), b) dihydroergotamine (DHET), c) ergonovine (EN), or d) control. Control rats received 0.5 ml of corn oil as the delivery vehicle. The dexamethasone was included as a reference treatment. Peyronneau (1994) reported that dexamethasone produced maximum induction of P450 activity at 4 days. Rats were sacrificed, livers were collected, and microsomes were prepared using the same procedure used for the bovine liver microsomes preparations.

The CYP3A4 activity in animals from both experiments was measured using ergotamine as a substrate. The metabolism of ergotamine was assayed in medium containing 100 mM Tris-HCl, 10 mM potassium phosphate, 0.1 mM EDTA, pH 7.5, cofactor generating system (NADPH), 20% glycerol, 1.0 mg/ ml ergotamine that had been fully isomerized, and 0.1 mg/ml microsomal protein in a total volume of 500 ml. The cofactor generating system was: 26 mM NADP+, 66 mM D-glucose-6- phosphate, 66 mM magnesium chloride, and 1 U Glucose-6-Phosphate dehydrogenase in sodium citrate. Bovine liver microsomes were diluted in assay buffer to a working concentration of 2.5 mg protein/ml and kept on ice. The reactions were started by adding the NADPH generating system and were terminated after 30 min by adding 100 ml of 94% acetonitrile and 6% glacial acetic acid and centrifuged at 12,000 x g for 5 min pH 7.5.

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Twenty ml of each of the supernatants from the enzyme assays were examined for the disappearance of ergotamine and its isomer and also for the appearance of the metabolites by using a modification of the high pressure liquid chromatography (HPLC) method described by Moubarak et al. (1993, 2000). A 20 ml sample loop was fitted to a Millennium32 Workstation HPLC system with auto-sample injector and a gradient programmer. The detection was accomplished by a Gilson 121 fluorescence detector (excitation at 250 nm and emission at 370 nm long pass filter). Separation was conducted on a 3x3 CR C18 cartridge column using acetonitrile and 2.6 mM ammonium carbonate in 10% methanol gradient elution at 1 ml/min flow rate. The gradient program was used to separate and quantitate the peak area of ergotamine, its isomer, and the metabolites with no carry over effects from run to run.

Results of experiment 1 are described and presented graphically. Data from experiment 2 were examined by one-way analysis of variance.

Results and Discussion

In experiment one where enzyme preparations from beef liver microsomes were used, results indicated the presence of CYP3A4 which is capable of metabolizing ergotamine. Figure 1 shows a representative HPLC chromatogram where ergotamine was metabolized by beef liver enzyme preparation (CYP3A4) to more water soluble metabolites M1 and M2. Similar chromatograms were obtained from all five steers. Similarly, the ergotamine isomer was also hydroxylated to M1-Iso and M2-Iso (8 or 9-hydroxy-derivatives). Further incubation resulted in a second hydroxlation of M1 and M2 to more water soluble metabolites M3 and M4 with 8,9-dihydroxy derivatives. The formation of these metabolites (M1, M2, M1-Iso and M2-Iso) was dependent on the presence of NADPH or the NADPH generating system and was also dependent on microsome concentration. Figure 2 shows the results of a time dependent incubation of ergotamine with beef liver microsomes. Values shown are means of evaluations for the five steers done in triplicate. Ergotamine was hydroxylated first to metabolites M1 and M2; then metabolites M1 and M2 were converted to M3 and M4 by the addition of a second hydroxyl group. Ergotamine and its isomer were almost totally metabolized after 60 min of incubation and the metabolites M1, M2, M3, and M4 appeared to be formed in a time dependent fashion with M1 and M2 formed first reaching a maximum level after 30 min. Similar data were reported in dexamethasone treated rats (Peyronneau et al., 1994) and human liver microsomes (Christians et al., 1996). Under normal conditions, animals possess a base-line level of CYP3A4 activity; however when they consume or are injected with drugs or toxins, one of the body's responses will likely be to elevate the level of CYP3A4 to speed up the clearance of such compounds from circulation.

The CYP3A4 activity in liver microsomes from rats treated with 100 mM DXM, DHET, or EN and controls is shown in Figure 3. Enzyme preparations from control animals produced a base line activity of 0.139 and 0.221nM/ mg protein/min (SE = 0.040) for ET and ET isomer. Dexamethasone treatment (100 mM) of rats for 4 days produced a significant ($P < 0.05$) 3.8-fold increase (0.535 nM/ mg protein/min) over control rats in CYP3A4 activity as determined by the conversion of ET to its metabolites. Treatment of rats with DHET or EN at a concentration of 100 mM did not produce any significant ($P > 0.05$) increase in CYP3A4 activity over the control rats. The enzyme system which is involved in metabolism of ergot alkaloid found in endophyte-infected tall fescue has not been fully characterized in beef animals, yet structurally related ergot alkaloids such as bromocriptine and dihydroergotamine have been found to be metabolized by animals and man, in vivo and in cell cultures by the CYP3A4 enzyme system (Maurer et. al., 1983). Our data documented the presence of CPY3A4 activity in liver of beef steers and clearly show its involvement in ergotamine metabolism. The first experiment demonstrated that beef steer liver microsomes have the enzymatic capability to metabolize the ergot alkaloid ergotamine. The second experiment demonstrated that ergot alkaloids of other families (DHET, as a representative of the ergopeptide, or EN, as representative of the lysergic acid amid derivative) did not induce additional, or above base line, CYP3A4 activity after 4 days of treatment. The lack of additional activity of CYP3A4 in liver microsomes collected from rats treated with EN or DHET raises the question as to whether they are not exerting any effects, are they interacting with CYP3A4 at the protein level hindering its activity, or could they be affecting the induction process upstream.

Implications

If we have a better understanding of the mechanisms by which ergot alkaloids are metabolized, then we can use this information to define markers that can be used to select animals that are resistant to fescue toxins. Part of those mechanisms are through the cytochrome P450 system.

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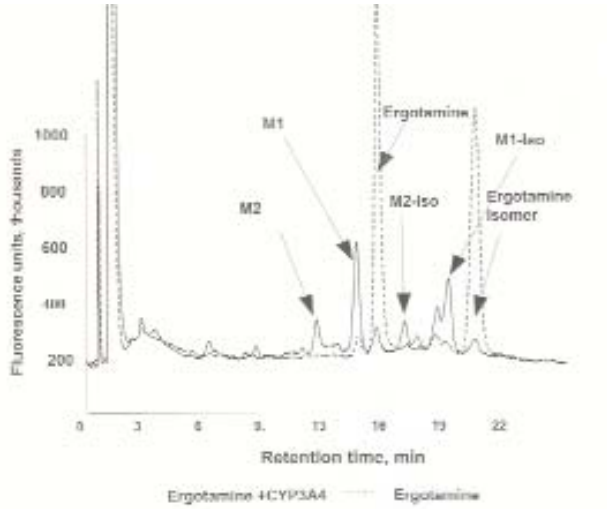

Fig. 1. A representative HPLC chromatogram of products from ergotamine incubation with beef liver microsomes. For incubation conditions see Materials and Methods.

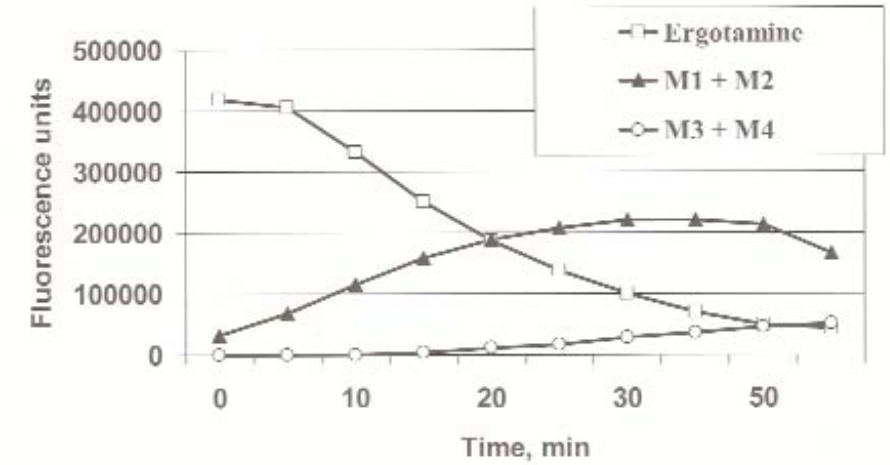

Fig. 2. Time dependent disappearance of ergotamine and appearance of metabolites when incubated with beef liver microsomes. Mean of determinations from five animals done in triplicate.
□=Disappearance of ergotamine; △=Formation of metabolites M1 and M2; o=Formation of metabolites M3 and M4.

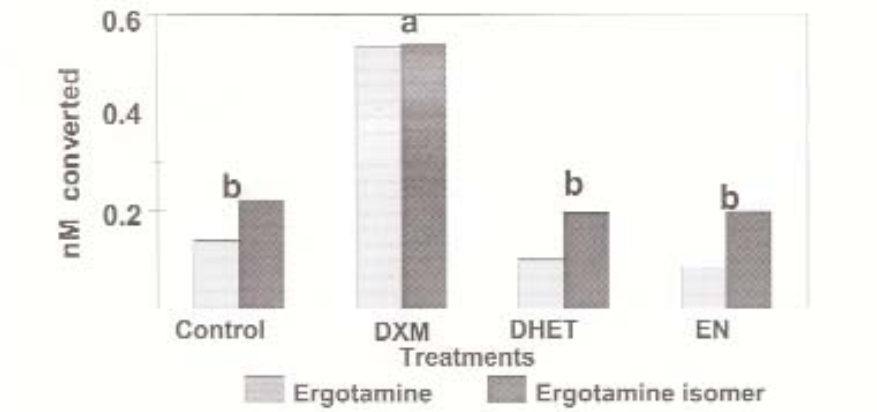

Fig. 3. Incubation of ergotamine and its isomer with liver microsomes from rats treated with the following: a) control, b) dexamethasone (DXM, 100 mM), c) dihydroergotamine (DHET, 100 mM), or d) ergonovine (EN, 100 mM).
a,b Means with no letters in common are different (P < 0.05) for both ergotamine and the ergotamine isomer.

Growth Performance of Stocker Calves Backgrounded on Sod-seeded Winter Annuals or Hay and Grain

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Story in Brief

Sod-seeded winter annual forages may produce less forage than those same forages planted by conventional tillage practices but have potential to provide an economically-viable option for retaining ownership of fall-weaned calves. A study was conducted during the winters of 1998, 1999, and 2000 using 180 crossbred calves (576 ± 6.2 lb initial BW; n = 60 each year) to compare sod-seeded winter annual forages with conventional hay and supplement backgrounding programs in southeast Arkansas. Calves were provided bermudagrass hay (ad libitum) and a grain sorghum-based supplement (6 lb/d) on 2.5-acre dormant bermudagrass pastures (HS) or were grazed on 5-acre pastures of bermudagrass/dallisgrass overseeded with 1) annual ryegrass (RG), 2) wheat plus RG, or 3) rye plus RG at a stocking rate of 1 calf/acre. Calves grazed from mid-December until mid-April, but were fed bermudagrass hay during times of low forage mass. Mean forage CP and in vitro dry matter digestibility (IVDMD) concentrations were 19.0 and 71.1%, respectively across sampling dates and winter annual forages. During the first two years, calves fed HS gained less ($P < 0.05$) BW than calves grazing winter annual forages, and gains did not differ ($P \geq 0.23$) among winter annual treatments. During the third year, undesirable environmental conditions limited growth of the winter annual forages, and total gain did not differ ($P = 0.66$) among the four treatments. Winter annual forages offer potential to provide high quality forage for calves retained until spring, but consistent forage production and quality are a concern when sod-seeding techniques are used.

Introduction

Considerable research has been conducted evaluating winter annuals as a forage source for stocker calves, but much of the research has been conducted using conventional tillage practices. Winter annual forages are generally high in quality (McCormick et al., 1998; Lippke et al., 2000) and capable of producing high rates of calf gain. Winter annuals seeded into warm-season forage sods may have lower and more variable forage production (Moyer and Coffey, 2000) and lower animal gains/acre (Moyer et al., 1995) than those seeded into prepared seedbeds. However, sod-seeded winter annuals offer the potential to improve land use efficiency (Moyer et al., 1995) and animal gains relative to those expected from calves wintered on other dormant forages (Wilkinson and Stuedemann, 1983). It is therefore necessary to evaluate different winter annual forage programs for their production potential and use in retained-ownership programs for stocker calves. The objectives of this study were to 1) compare BW gain of calves grazing sod-seeded ryegrass, wheat and ryegrass, or rye and ryegrass with gain of calves fed bermudagrass hay and supplemental grain during winter, and 2) compare forage quality and availability from the different combinations of winter annual forages throughout the grazing season.

Experimental Procedures

Nine 5-acre pastures containing 'common' bermudagrass (*Cynodon dactylon* (L.) *Pers.*) and dallisgrass (*Paspalum dilatatum Poir*.) were allocated randomly to one of three winter annual forage treatments in a 3-yr grazing study during the winter months of 1998, 1999, and 2000. In a fourth backgrounding treatment, calves were placed on three dormant bermudagrass pastures (2.5 acres) and provided ad libitum access to bermudagrass hay and fed a grain sorghum – based supplement (15.3% CP) at 6 lb/d along with 0.65 lb of cottonseed meal (HS, Table 1). Forage treatments consisted of overseeding the pastures with either 30 lb/acre of 'Marshall' annual ryegrass (RG), 30 lb/acre of 'Marshall' annual ryegrass plus 100 lb/acre of 'Bonel' rye (RRG), or 30 lb/acre of 'Marshall' annual ryegrass plus 120 lb/acre of 'Madison' soft wheat (WRG). Pastures were disked lightly and overseeded by broadcasting the respective forages in late-September of each year. Pastures were then harrowed lightly to help incorporate seed. Pastures were fertilized by broadcasting with 50 lb/acre each of N, P_2O_5, and K_2O (as KCl) in late-November and with an additional 50 lb/acre of N in early February. Once original randomization was determined, pastures received the same forage treatment throughout the entire 3-yr study. During the summer months, pastures were used to evaluate the impact of different supplementation programs on performance by stocker cattle grazing bermudagrass pastures. Those studies were terminated in sufficient time to allow grazing of each pasture at excessive stocking rates to remove excess bermudagrass forage prior to seeding winter annual forages.

Forage mass was measured monthly by clipping three random areas per pasture to a height of approximately 1 in and drying these samples to a constant weight. Random hay samples were collected each week as the bales were being fed and composited across dates. Since the same cutting of hay was fed in years 1 and 2, those samples were composited across years as well. Samples were analyzed for in vitro dry matter digestibility (IVDMD) and for crude protein (CP).

One hundred eighty crossbred calves (576 ± 6.2 lb; n = 60 per year) from the University of Arkansas Southeast Research and Extension Center cowherd were used over the 3-yr period. The cowherd consisted of either Brahman x Hereford or Brahman x Charolais cows bred to either Angus (yr 1 and 2) or Beefmaster (yr 3) sires. Calves were weighed on two consecutive days in mid-

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December of each year, stratified by weight and sex, and allocated randomly to one of twelve groups of five head each. Grazing began December 19, 1997, December 18, 1998, and December 17, 1999 and continued for 112, 112, and 119 d in yr 1, 2, and 3, respectively. In yr 1, one replicate of heifers and two replicates of steers were allocated to each treatment. In yr 2, one replicate of steers, one replicate of heifers, and one replicate of mixed steers and heifers were allocated to each treatment. In yr 3, two heifers and three steers were distributed within each replicate of calves. All calves had been weaned and vaccinated in October before beginning the grazing period. Steer and heifer calves were implanted with zeranol (36 mg; Ralgro; Schering-Plough Animal Health, Inc., Omaha, NE) and dewormed with oxfendazole (Synanthic; Ft. Dodge Animal Health, Overland Park, KS) immediately before allocation to experimental pastures or dormant bermudagrass lots during yr 1 and 2, but only steers were implanted in yr 3.

Once original pasture allocations were made, calves remained on their assigned pasture throughout the duration of the study. The exception to this was during yr 3 when low available forage dictated removal of calves from all winter annual forage pastures for 41 d. Adverse weather conditions led to low forage production on most pastures. These conditions were characterized by an extremely dry fall and early winter and a rapid decline in temperature in mid-December that caused considerable damage to the winter annual forages. Since available moisture was limiting and forage production during the ensuing period was anticipated as minimal, the decision was made to remove calves from the experimental pastures on d 28. Calves were offered hay as a group rather than leaving them on their respective pastures. This was done to allow the forage time to grow when growing conditions improved. Calves were returned to their original pastures on d 69 when available forage was adequate. During yr 1 and 2, bermudagrass hay was offered when available forage was deemed inadequate by visual appraisal (< 1.25-in forage height), but calves were allowed to remain on their respective pastures.

Calves grazing the winter annual pastures were fed 2 lb/animal daily of a grain sorghum-based supplement (11.4% CP) containing trace mineral salt, necessary minerals, and 200 mg monensin per calf (Elanco Animal Health, Indianapolis, IN; Table 1). Calves fed bermudagrass hay (12.0% CP, 54.0% IVDMD) were also fed 5.9 lb/d of a ground grain sorghum-based supplement (1% of initial BW in yr 1) and 0.65 lb/d of cottonseed meal. The supplement contained trace mineral salt, limestone, and monensin (200 mg/hd) to provide similar quantities of each of these components as was offered to calves on pasture. Square bales of bermudagrass hay were offered daily in feed bunks to provide ad libitum consumption.

Calves were weighed without prior removal from feed and water on two consecutive days in early April to determine ending weights and grazing was terminated on April 10, 1998, April 9, 1999, and April 19, 2000, in yr 1, 2, and 3, respectively.

Statistical analyses for IVDMD, CP, and forage mass were conducted using SAS (SAS Inst., Inc., Cary, NC) GLM procedures for a split-split plot design. Animal BW and gain data were analyzed using a repeated measures analysis of variance.

Results and Discussion

A 3-way interaction between year, treatment, and sampling date was detected ($P < 0.01$) for forage CP and IVDMD concentrations. Therefore, data were analyzed and reported within year. In yr 1, CP concentrations were lower ($P < 0.05$) from RG pastures than from WRG pastures on d 0 and 28 and from RRG pastures on d 28, but higher ($P < 0.05$) from RG than from RRG pastures on d 84. Forage CP concentrations did not differ ($P \geq 0.71$) among winter annual treatments on d 56 or 112. The change in trends for forage CP concentration among treatments is likely due to differential growth patterns between the cereal grains and ryegrass (Huneycutt, 1991; 1994; Aiken, 1998). Although not compared statistically, forage CP concentrations on d 112 were lower than those from day 28 through 84 and are a reflection of advancing forage maturity. Forage CP concentrations did not differ among treatments in yr 2 ($P = 0.59$) or yr 3 ($P = 0.71$), but did vary across sampling dates ($P < 0.01$).

The IVDMD did not differ among forages in yr 1 ($P = 0.57$) or yr 3 ($P = 0.23$), but did vary across sampling dates ($P < 0.01$) within both years. In vitro DM disappearance averaged 70% during yr 1 and 3 and ranged from 53.6 to 82.1%. In yr 2, mean IVDMD concentrations of RRG were higher ($P < 0.05$) than RG (76.5 vs. 70.6%). The IVDMD of WRG averaged 73.9% and did not differ from that of RRG ($P = 0.14$) and tended to be higher than that of RG ($P = 0.08$).

A 3-way interaction between year, treatment, and sampling date was detected ($P < 0.01$) for forage mass. Forage mass ranged from 403 to 4,276 kg/ha during the 3-yr study (Table 3). Sampling date effects were observed ($P < 0.01$) but neither forage effects nor sampling date x forage treatment effects were detected ($P \geq 0.17$).

A 2-way interaction between year and treatment was detected ($P < 0.01$) for total BW gain. Therefore, BW and gain data were analyzed within year. Total weight gains (d 0 to 112) during yr 1 and 2 were greater ($P < 0.05$) from calves grazing annual forages than those fed hay and grain (Table 4). During yr 1 and 2, weight gains averaged approximately 2.2 lb/d on the winter annual programs. Total weight gains did not differ ($P \geq 0.23$) among the annual forage treatments during yr 1 and 2. In yr 3, total weight gains did not differ ($P = 0.95$) among the four treatments. Overall gain by calves grazing winter annual forages during yr 3 (218 lb avg.) was numerically lower than that from yr 1 (257 lb) and yr 2 (246 lb), whereas gain by calves fed hay plus supplement was numerically higher during yr 3 than in yr 1 or 2. The probable reason for lower gain from winter annual forage treatments during yr 3 is that forage production was limited and the calves were removed from winter annual forages and fed bermudagrass hay along with the same level of supplement as fed daily on pasture. Hay quality during yr 3 was higher than in previous years (12.7 vs. 11.7% CP; 56.1 vs,53.0% IVDMD), possibly resulting in the higher gain by HS than from previous years.

Diets for calves fed HS were formulated based on feeding 1% of BW as ground grain sorghum using initial BW in yr 1, and were estimated to produce ADG of 1.5 lb/d. Average hay consumption for HS across the 3-yr study was 8.7 lb/d or approximately 1.3% of average BW. The low levels of forage intake are likely because of a negative associative effect on forage digestion that reduced forage intake and grain conversion efficiency (Goetsch et al., 1991; Elizalde et al., 1998). Actual gains by calves fed hay plus supplement in each year were greater than would be predicted from NRC (1996) equations based on the level of forage consumption. Therefore, it is probable that forage intake was actually greater than accounted for from measured hay consumption, and likely included consumption of dormant bermudagrass, annual grasses, and broadleaf weeds from the 2.5-acre lots.

Although interactions with year were detected for growth performance, the bottom line for producers wanting to use this type of information is animal performance averaged over multiple years. When averaged across years, animal BW gain averaged 61 lb greater ($P < 0.05$) and ADG averaged 0.54 lb/d faster ($P < 0.05$) from calves grazing the winter annual forages than from those fed HS. Daily hay consumption averaged 6.3 lb/d more ($P < 0.05$) from HS than from calves grazing the winter annual forage treatments. Animal gain and hay consumption did not differ ($P > 0.05$) among the winter annual treatments. Based on this information, producers can make econom-

ic decisions using their own costs to determine if retaining ownership of their calves will work for them.

Implications

Disking bermudagrass pastures and sod-seeding annual ryegrass alone or in combination with rye or wheat may provide winter grazing for fall-weaned calves. This could reduce hay and grain consumption, provide greater weight gains from calves, and allow cattlemen to market their calves on a more favorable spring market. Trends varied throughout the 3-yr study, but there was no apparent advantage of adding rye or wheat to ryegrass.

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Table 1. Daily feeding levels and formulations of supplements offered to calves grazing sod-seeded winter annual forages or provided ad libitum access to bermudagrass hay

Item	Winter annual	Hay + supplement
Total daily supplement, lb	2.0	6.6
	-- % of daily supplement[a] --	
Ground grain sorghum	90.04	87.28
Cottonseed meal		9.70
Ground corn	0.61	0.18
TM salt[b]	4.24	1.28
Ground limestone	5.00	1.51
Rumensin 80 premix[c]	0.12	0.04

[a]As-fed basis.
[b]Contained 96 – 98.5% salt, and not less than 0.35% Zn, 0.2% Mn, 0.2% Fe, 0.03% Cu, 0.007% I, and 0.005% Co.
[c]Contained 80,000 mg monensin/lb (Elanco Animal Health, Indianapolis, IN).

Table 2. Crude protein and IVDMD of forages clipped on different dates during the grazing season from bermudagrass pastures overseeded with winter annual forages

Study year	Sampling date	Forage treatment			SE
		Ryegrass	Rye + ryegrass	Wheat + ryegrass	
Crude protein, % of DM					
1997-98[de]	12/19	16.8[h]	22.2[gh]	24.1[g]	1.87[b]
	1/16	17.1[h]	23.3[g]	23.5[g]	
	2/13	21.0[g]	21.8[g]	21.2[g]	
	3/13	26.8[g]	20.5[h]	23.9[gh]	
	4/10	14.5[g]	13.6[g]	14.1[g]	
1998-99[d]	12/19	23.6	26.8	21.8	0.70[c]
	1/15	15.6	20.7	17.1	
	3/11	23.2	20.2	19.9	
	4/8	27.9	25.2	29.9	
1999-00[d]	12/17	15.5	16.1	16.3	0.78[c]
	1/14	13.4	13.5	15.0	
	2/24	17.7	20.1	19.6	
	3/22	16.4	12.7	14.1	
	4/14	11.4	8.5	10.3	
IVDMD, % of DM					
1997-98[d]	12/19	48.8	68.8	73.1	2.14[c]
	1/16	72.6	75.8	79.2	
	2/13	63.4	68.9	64.3	
	3/13	82.1	76.4	78.9	
	4/10	77.7	78.1	74.9	
1998-99[df]	12/19	78.9	80.3	81.3	1.10[c]
	1/15	50.7	66.5	58.8	
	3/11	77.3	80.6	74.5	
	4/8	75.5	78.8	80.9	
1999-00[d]	12/17	61.1	62.8	63.1	1.86[c]
	1/14	53.6	55.4	59.9	
	2/24	62.6	63.9	69.6	
	3/22	75.6	81.7	77.8	
	4/14	69.8	74.3	77.8	

[b] Standard error of the mean for comparison of forage means within a sampling date.
[c] Standard error of the mean for comparison of main effect forage means across all sampling dates.
[d] Sampling date main effects were detected ($P < 0.01$).
[e] Date x forage interaction was detected ($P < 0.05$).
[f] Forage treatment main effects were detected ($P < 0.05$).
[g,h] Forage means within a sampling date without a common superscript letter differ ($P < 0.05$).

Table 3. Forage mass (lb/acre) on different dates during the grazing season from bermudagrass pastures overseeded with winter annual forages

		Forage treatment			
Study year	Sampling date	Ryegrass	Rye + ryegrass	Wheat + ryegrass	SE[b]
1997-98[c]	12/19	1,399	1,409	1,594	84.5
	1/16	583	635	648	
	2/13	721	590	1,203	
	3/13	759	442	638	
	4/10	1,616	1,213	1,498	
1998-99[c]	12/19	1,118	1,352	1,254	98.6
	1/15	693	858	572	
	3/11	428	541	360	
	4/8	1,616	1,213	1,498	
1999-00[c]	12/17	1,217	1,138	1,155	280.7
	1/14	1,406	604	735	
	2/24	2,211	1,975	1,546	
	3/22	1,987	2,089	1,750	
	4/14	3,818	3,798	2,591	

[b] Standard error of the mean for comparison of main effect forage means across all sampling dates.
[c] Sampling date main effects were detected (P < 0.01).

Table 4. Growth performance and apparent hay consumption by calves grazing different winter annual forages or provided ad libitum access to hay along with a grain sorghum-based supplement

		Forage treatment			
Item	Hay + supplement	Ryegrass	Rye + ryegrass	Wheat + ryegrass	SE
		---------- 1997-98 ----------			
Weight, lb					
12/19	590	588	590	589	6.1
4/10	756	860	834	843	27.2
Total gain, lb d 0 to 112	166[e]	272[d]	243d	254[d]	22.7
Hay consumption, lb/d[a]	9[d]	0[e]	1[e]	0[e]	0.6
		---------- 1998-99 ----------			
Weight, lb					
12/19	568	566	568	573	18.6
4/8	724	829	816	800	33.3
Total gain, lb	157[e]	263[d]	247[d]	227[d]	19.7
Hay consumption, lb/d	10[d]	1[e]	0[e]	1[e]	0.4
		---------- 1999-00 ----------			
Weight, lb					
12/17	569	571	569	569	1.0
4/14	782	789	783	792	11.9
Total gain, lb[b]	213	218	214	223	12.1
Apparent hay consumption, lb/d[c]	7[f]	6[g]	6[g]	6[g]	0.4
		---------- 3-year average ----------			
Total gain, lb	179[e]	251[d]	234[d]	234[d]	13.8
Daily gain, lb	1.56[e]	2.20[d]	2.06[d]	2.05[d]	0.121
Hay consumption, lb/d	8.7[d]	2.1[e]	2.9[e]	2.1[e]	0.28

[a] Apparent hay consumption is expressed on an as-is basis.
[b] Represents total weight gain from d 0 through d 112 including the period when calves assigned to winter annual forages were removed from pasture.
[c] Hay consumption was allocated equally across winter annual treatments because all replication were combined from d 29 to 69 of the study.
[de] Means within a row without a common superscript letter differ (P < 0.05).
[fg] Means within a row without a common superscript letter differ (P < 0.10).

Prepubertal Growth Characteristics Associated with Calving Rates of Replacement Angus Heifers

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Story in Brief

Angus heifers (n = 88) were used during three years to determine the relationship between two sets of traits considered to be indicators of growth. Data were collected at weaning (7-8 mo), yearling (10-11 mo), and prebreeding (13-14 mo), and included body weight (BW), hip height (HH), hip width (HW), pelvic height (PH), pelvic width (PW), lactate dehydrogenase activity (LDH), longissimus muscle area (LMA) and backfat thickness (BKFAT). Measurements were grouped into two sets of traits; Set I included BW, HH, HW and LDH while Set II included PH, PW, LMA and BKFAT. Weight was correlated ($P < 0.01$) with all variables studied except LDH activity. At weaning, heifers with lower LDH activity had a larger pelvic height just prior to the breeding season. The first canonical correlations between Set I measurements at weaning or yearling and Set II measurements at prebreeding were greater than 0.8 ($P < 0.01$). Additional linear combinations of Set I traits at weaning and yearling were correlated ($r > 0.48$; $P < 0.01$) with linear combinations of Set II traits at prebreeding. These results suggest that the Set I measurements, as early as at weaning, could be used as indicators of Set II variables at prebreeding. The canonical coefficients of Set I traits were used to rank heifers as either above or below the mean. Ranking heifers based on Set I measurements at weaning resulted in a greater ($P < 0.01$) percentage of heifers calving as a 2-year old. Correlations between Set I and Set II traits suggest that external measurements coupled with LDH activity could be used in identifying replacement beef heifers that have larger pelvic dimensions at breeding and a greater frequency of calving as 2-year olds.

Introduction

Selection criteria of replacement heifers should include traits that will reflect how well heifers will consistently reproduce in the cow herd. Heifers conceiving and calving at a young age produce more pounds of total beef compared to contemporaries conceiving at a later age. Typically, beef heifers do not breed until they reach about 65% of their potential mature body weight. Attainment of puberty in the heifer is not modulated solely on body weight. Age, hip height, and other elements may be limiting factors, suggesting that selection of replacement heifers based solely on BW may be insufficient.

Body composition, specifically body fat, of postweaning heifers has been related to the attainment of puberty. Previously, we have shown that lactate dehydrogenase (LDH) was highly heritable, and useful as a predictor of subsequent body composition of finished cattle. Age-related differences of several serum constituents, including LDH at the time of puberty, have been reported. Those results suggest that LDH activity may be useful in selecting heifers that have early maturing reproductive systems.

Knowledge of the association among indicators of long bone maturation (skeletal measurements) and metabolic maturation (LDH) could allow for the ranking of heifers at an early age (i.e., weaning). Thus, our objective was to determine relationships between two sets of traits that are indicators of growth and body composition in the replacement beef heifer and subsequent calving rates for those heifers.

Experimental Procedures

Traits were determined on three groups (one group in each of three consecutive years) of purebred Angus replacement heifers (n = 88). Trait information was obtained at weaning (7 to 8 mo), yearling (10 to 11 mo) and prior to the breeding season (13 to 14 mo).

Data were collected for the following traits: body weight (BW), height and width at hips (HH and HW, respectively), pelvic height and width (PH and PW, respectively), longissimus muscle area (LMA) and backfat thickness (BKFAT). A sliding caliper, developed specifically to measure external body dimensions in beef cattle, was used to measure HH and HW. Measurements for PH and PW were taken per rectum using a Rice Pelvimeter (Lane Manufacturing, Denver, CO). Longissimus muscle area and BKFAT were determined by ultrasonic measurements. An individual technician conducted all ultrasound scans using real-time ultrasonography (Aloka 500 Vâ, Corometrics, Wallingford, CT, equipped with a 3.5-MHz, 17 cm transducer with superflab attachment). Measurements were taken between and parallel to the 12th and 13th ribs 4 inches from the dorsal midline. Ultrasonic images were captured on tape, and analyzed using the AniMorp software, version 1.4 (Woods Hole Educational Assoc., Woods Hole, MA)

Blood samples also were collected at each of the three measurement ages. Samples were allowed to clot and then centrifuged at 2,300 x g for 30 min. Serum was decanted and stored at –20° C until assayed. Total protein concentration was determined on serum samples using the Biuret method. Serum LDH activity was evaluated using a quantitative, colormetric assay (Sigma Diagnostics, St. Louis, MO) and was reported as I.U. of LDH activity per milligram of serum protein.

Heifers were maintained on common bermudagrass and tall fescue, overseeded with winter annuals of wheat, rye, and ryegrass. In addition, heifers were fed a supplement (1% BW/d) consisting of cracked corn and soybean meal.

Traits were assigned to one of two sets. The first group of traits (Set I) included BW, HH, HW and LDH. The second group of traits (Set II) included PH, PW, LMA and BKFAT. Assignment of traits to

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set was based on the desire to include indicators of skeletal size and body composition in each set. Relationships among these two sets of traits were examined by Pearson correlation and canonical correlation analyses.

The objective of the canonical correlation analysis was to find a linear combination of one group of variables (Set I) that had a maximal correlation with a linear combination of a second group of variables (Set II). That process continues until the number of pairs of canonical variables equals the number of variables in the smaller group. Two separate canonical analyses were examined on this data set.

Analysis I compared Set I traits at weaning with prebreeding Set II traits. Analysis II compared yearling Set I traits with Set II traits at prebreeding. Results are presented as correlations of the canonical variates (v1-3, and w1-3) with the original measured variables, along with estimated canonical correlations. Standardized canonical coefficients [(X – mean X)/(SD of X)] for first and second variates of analyses I and II were generated, X represents each trait of either Set I or Set II. Those coefficients were used to generate a score for each heifer. Heifers were then ranked as below or above the mean value for each score. Distribution of heifers calving as a 2-year old and categorized as above or below the mean value for each canonical variate was analyzed by Chi-square analysis.

Results and Discussion

Table 1 presents the means and standard deviations for heifer age and the traits determined. Those data indicate that the heifers had a modest postweaning growth rate (approximately 1.3 lb/day) and were representative of moderately-sized replacement Angus heifers. Table 2 presents the Pearson correlation coefficients between traits determined at either weaning or yearling with those same traits at prebreeding. The simple correlation coefficients were quite variable; however, there were negative ($P < 0.01$) coefficients between weaning or yearling LDH activity with PH and PW at prebreeding. Conversely, BW and HH at weaning or yearling were positively ($P < 0.01$) correlated with PH and PW at prebreeding, indicating taller heifers at weaning had larger pelvic areas prior to the breeding season. Hip width was correlated at all ages with body weight. These results suggest Set I traits at weaning could be useful in describing pelvic dimensions and to a lesser extent body composition at prebreeding.

Canonical correlation analyses of weaning (analysis I), and yearling (analysis II) Set I variables with Set II variables at prebreeding showed these two sets of variables to be highly correlated (Table 3). Both analyses I and II resulted in three significant and independent linear combinations of the two sets of variables. For analysis I, the largest canonical correlation was 0.81. That particular canonical variate had a high positive correlation with hip height and a high negative correlation with LDH of the set I variables, and had high positive correlations with set II variables PH and LMA. For analysis II, the canonical correlations ranged from 0.51 to 0.80. The first canonical variate had relatively high correlations with all of the traits determined except BKFAT. These data suggest that linear combinations could maintain external body dimensions, weight, and rib fat thickness while increasing pelvic area.

Table 4 presents the standardized canonical coefficients for the first and second variates for analyses I and II. Each heifer's score was classified as above or below the mean canonical score for all heifers. Table 5 presents the percentage of heifers calving for each ranking within analyses I and II. For analysis I, heifers with canonical scores below the mean v1 had a greater ($P < 0.06$) percentage of heifers calving as a 2-year old than those with scores above the mean. Conversely, for analysis I, heifers with canonical scores above the mean v2 had an increased ($P < 0.02$) calving rate when compared with those heifers with canonical scores below the mean. When Set II traits were used to develop canonical coefficients (w1 and w2) there were no differences ($P > 0.3$) in calving rates. Collectively, these results suggest that at weaning Set I traits (BW, HH, HW, LDH) could be used to segregate heifers into groups that would be more likely to calve as 2-year olds. Set II traits (PH, PW, LMA, BKFAT) at neither weaning nor yearling were useful in segregating heifers into calving groups.

Implications

Our results confirm the high correlation between internal and external measurements of heifer long-bone growth. Selection of replacement heifers using data from Set I traits (body weight, hip height, hip width, and lactate dehydrogenase activity) at weaning could be used to increase the percentage of heifers that calve as a 2-year old. Those traits were associated with increased pelvic area at breeding, which may decrease dystocia. While pelvic dimensions alone will not prevent dystocia, heifers with larger pelvic openings should have fewer problems in calf delivery.

Table 1. Means and standard deviations (SD) for weaning, yearling and prebreeding traits of Angus heifers

Trait[a]	Weaning (SD)	Yearling (SD)	Prebreeding (SD)
Age (d)	245 (19.6)	341 (23.6)	416 (19.1)
BW (lb)	397 (57.5)	526 (75.6)	626 (80.1)
HH (in)	39.7 (2.37)	42.9 (2.74)	44.4 (2.97)
HW (in)	12.8 (1.32)	13.4 (1.00)	14.7 (1.05)
PH (in)	3.80 (0.788)	4.30 (0.718)	5.01 (0.514)
PW (in)	3.44 (0.432)	4.07 (0.389)	4.25 (0.454)
LMA (in^2)	4.22 (0.725)	4.97 (0.727)	5.92 (0.929)
BKFAT (in)	0.12 (0.042)	0.13 (0.039)	0.17 (0.041)
LDH (IU/mg protein)	603 (266)	768 (321)	719 (264)

[a]Traits are age of heifer at time of measurement, body weight (BW), hip height (HH), hip width (HW), pelvic height (PH), pelvic width (PW), ultrasonic longissimus muscle area (LMA) and backfat thickness (BKFAT) between the 12th and 13th ribs, and serum lactate dehydrogenase (LDH) activity.

Table 2. Pearson correlation coefficients of body measurements at weaning or yearling with those at prebreeding of Angus heifers

Measurement[a]	Date of measurement	Prebreeding							
		WT	HH	HW	PH	PW	LMA	BKFAT	LDH
BW	Weaning	0.77**	0.67**	0.74**	0.47**	0.53**	0.46**	0.22*	-0.25*
	Yearling	0.88**	0.74**	0.81**	0.53**	0.59**	0.49**	0.25*	-0.32**
HH	Weaning	0.68**	0.75**	0.55**	0.53**	0.40**	0.46**	-0.07	0.06
	Yearling	0.78**	0.87**	0.68**	0.66**	0.56**	0.46**	0.04	-0.13
HW	Weaning	0.49**	0.28*	0.77**	-0.22	0.14	-0.01	0.19	-0.71**
	Yearling	0.76**	0.67**	0.65**	0.57**	0.50**	0.55**	0.13	-0.02
PH	Weaning	0.12	0.48**	0.11	0.48**	0.57**	0.08	0.14	-0.25*
	Yearling	0.13	0.40**	0.06	0.68**	0.66**	0.23*	0.05	-0.06
PW	Weaning	0.39**	0.27**	0.33**	0.08	-0.01	0.28**	0.05	0.17
	Yearling	0.47**	0.24*	0.41**	0.21*	0.14	0.42**	0.11	0.17
LMA	Weaning	0.63**	0.42**	0.56**	0.21	0.23*	0.59**	0.18	-0.05
	Yearling	0.74**	0.48**	0.61**	0.31**	0.29**	0.70**	0.26*	-0.04
BKFAT	Weaning	0.18	-0.10	0.39**	-0.14	0.12	-0.06	0.54**	-0.46**
	Yearling	0.25*	-0.14	0.39**	-0.12	0.10	0.06	0.60**	-0.30**
LDH	Weaning	0.17	-0.20*	0.34**	-0.58**	-0.39**	-0.17	-0.01	-0.25*
	Yearling	-0.02	-0.29**	-0.16	-0.28**	-0.59**	0.13	-0.03	0.68**

[a]BW = Body weight, HH = hip height, HW = hip width, PH = pelvic height, PW = pelvic width, LMA = longissimus muscle, BKFAT = backfat thickness,and LDH = lactate dehydrogenase.
*P < 0.05; **P < 0.01.

Table 3. Results of canonical correlation analyses of measurements at weaning and yearling with measurements at prebreeding of Angus heifers (Analyses I and II)

Measurement	Correlations with canonical variates (Analysis I)			Correlations with canonical variates (Analysis II)		
Set I[a]	v_1	V_2	v_3	v_1	v_2	V3
Body weight	0.41	-0.08	0.90	0.80	0.25	0.51
Hip height	0.70	0.51	0.34	0.90	0.28	-0.08
Hip width	-0.21	-0.13	0.87	0.79	0.46	0.19
Lactate dehydrogenase	-0.80	0.20	0.55	-0.55	0.79	-0.27
Set II[b]	w_1	W_2	w_3	w_1	w_2	w3
Pelvic height	0.94	0.12	-0.06	0.89	0.13	-0.27
Pelvic width	0.37	0.49	0.77	0.88	-0.37	0.27
Longissimus muscle	0.76	-0.33	0.21	0.49	0.82	0.24
Backfat thickness	0.07	-0.76	0.53	0.06	0.17	0.72
Canonical correlation	0.81**	0.48**	0.38+	0.80**	0.57**	0.51**

[a]Set I measurements were taken at weaning for Analysis I and at yearling for Analysis II.
[b]Set II measurements were taken prior to breeding for both analyses.
+P < 0.1; **P < 0.01

Table 4. Standardized canonical coefficients[a] for first and second variates for analyses I and II

Measurement	Analysis I		Analysis II	
Set I	v_1	v_2	v_1	v_2
Body weight	0.4791	-0.0563	-0.3123	0.4877
Hip height	0.3015	1.1334	0.6853	0.0383
Hip width	-0.1788	-1.1904	0.4931	0.1641
Lactate dehydrogenase	-0.6898	1.2813	-0.4345	1.0074
Set II	w_1	w_2	w_1	w_2
Pelvic height	0.7432	0.0512	0.4504	0.2096
Pelvic width	-0.0057	0.6199	0.5686	-0.6876
Longissimus muscle	0.4102	-0.2981	0.2114	0.8617
Backfat thickness	-0.0650	-0.7776	-0.1115	0.0521

[a]Individual canonical variable scores may be calculated for Set I and Set II by multiplying appropriate standardized canonical coefficient by standardized observation [i.e. (X - mean X)/(SD of X)] and summing over all traits for Set I or Set II, respectively.

Table 5. Results of Chi-square analyses for calving status versus high or low ranking of standardized canonical variates

			Calved[a]		
Analysis	**Ranking[b]**	**N[c]**	**N**	**Percent**	**Chi-square statistic[d]**
I	High v_1	35	16	46	
	Low v_1	24	17	71	3.64
I	High v_2	26	19	73	
	Low v_2	33	14	42	5.54
II	High v_1	52	35	67	
	Low v_1	36	19	53	1.89
II	High v_2	34	20	59	
	Low v_2	54	28	52	0.41
I	High w_1	33	17	52	
	Low w_1	26	16	62	0.59
I	High w_2	29	17	59	
	Low w_2	30	16	53	0.17
II	High w_1	51	33	65	
	Low w_1	37	21	57	0.57
II	High w_2	45	30	67	
	Low w_2	43	24	56	1.09

[a]Represents the number of heifers, and the percentage of heifers within that ranking that calved as a two-year old.
[b]Variates were ranked as high if they were above zero and as low if they were below zero; i.e. above or below the mean for the standardized canonical variable score.
[c]Number of heifers within that ranking and analysis.
[d]Chi-square analysis of calving (yes vs. no) and ranking (high vs. low) within canonical variate analysis. Significant Chi-square statistics were 3.64 (P = 0.06) and 5.54 (P = 0.02).

Variation in Ultrasonically Determined Intramuscular Fat in Brangus Cattle

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Story in Brief

The objectives of this research were to determine: 1) the effects of sire on the expression of intramuscular fat, and 2) the relationship of intramuscular fat to selected performance traits. Purebred Brangus cattle were subjected to Real-time ultrasound evaluation of body composition, and traits recorded were the 12th and 13th rib subcutaneous fat thickness (FT), longissimus muscle area (LMA), and percentage intramuscular fat (IMF). Performance data provided by the International Brangus Breeder's Association (IBBA) included: birth weight (BRW), weaning weight (WWT), yearling weight (YWT), and scrotal circumference (SC). Data were analyzed to determine genetic relationships with the animal model using multiple trait restricted maximum likelihood (MTDFREML) procedures. Contemporary group was included in the model as a fixed effect, and age of days was included as a covariate. Analyses of covariant models were examined to determine the relative importance of sire and carcass traits to percentage IMF. Genetic correlations of IMF with LMA, FT, and YWT were –0.25, 0.36, and 0.31, respectively, indicating that as LMA increased IMF decreased. Sire, FT, and LMA were important ($P < 0.05$) sources of variation in percentage of IMF; BRW, WWT, YWT, SC, and age did not ($P > 0.05$) influence percentage IMF. These data suggest that percentage of IMF is under genetic control of a quantitative nature, and therefore should be considered when selecting for increased quality grade.

Introduction

Percentage intramuscular fat (IMF) is an important trait in the cattle industry for several reasons. It is economically important because it influences discounts and premiums in grid marketing and is the primary factor used to determine quality grade for carcasses of cattle. Because of its influence on quality grade, it is implicated in palatability and product consistency. Consumers associate U.S.D.A. quality grade with eating quality of meat. In the production segment, as pressure increases to produce a higher quality, consistent product, intramuscular fat will become of increasing importance to seedstock and commercial beef producers.

There is currently some debate whether percentage IMF is under more of an environmental or genetic control, and which factors have an impact on the phenotypic expression of IMF. It is well known that if a trait is heritable, the quickest way to affect the trait is through selection of the parental generation, and especially selection of the sire (Falconer and MacKay, 1996). Recently, there has been much interest in effectively evaluating IMF using ultrasound technology (Brethour, 2000; and Hassen et al., 2001). Hassen et al. (2001) reported that Critical Vision Software is the more accurate predictor of IMF, and a correlation of about 0.61 has been reported for actual carcass to live animal ultrasonically predicted IMF (Herring et al., 1998).

Considering the relative importance of IMF to the industry, Wilson et al., (1994) concluded that evaluation of IMF should be included in seedstock performance programs. The recent advances in ultrasonic image processing technology make this more practical; therefore, the objectives of this study were to determine the effects of sire on the expression of IMF and to determine the relationship of intramuscular fat to selected performance traits.

Experimental Procedures

Purebred Brangus cattle were subjected to Real-time ultrasound evaluation for estimation of body composition. Ultrasound measurements were taken in accordance to Beef Improvement Federation guidelines (BIF, 1996) for percent intramuscular fat (IMF), longissimus muscle area (LMA), and 12-13th-rib fat thickness (FT). In addition to ultrasound data, birth weight (BRW), weaning weight (WWT), yearling weight (YWT), scrotal circumference (SC), ranch location, sex of animal, age of animal, and animal registration number in accordance with the International Brangus Breeders Association (IBBA, San Antonio, TX) were also collected. All animals included in the study had pedigrees traceable to paternal and maternal grandparents.

The Real-time ultrasound equipment utilized for data collection was an Aloka 500V system (distributed by Aloka USA, Inc., Wallingford, CT) along with a superflab to ensure proper fit of the transducer to the curvature of the animal's natural body shape. Image visualization and data capture were accomplished using Critical Vision Software (Critical Vision, Inc., Atlanta, GA), which predicts the percentage of IMF (ether extractable equivalent) from the LMA image.

Images were collected on the left side of the chute and transducer placement was first determined by palpating the animal between the 12th and 13th ribs. Once the scanning area was determined, the location was oiled, curried free of dirt and debris, and oiled again before transducer placement. The ultrasound probe was placed toward the midline, between and parallel to the 12th and 13th rib bones and moved laterally until the longissimus muscle came into full view on the screen (Perkins et al., 1992). All 12th-rib FT and LMA images were captured and down loaded on a computer to be viewed later. The technician traced the outline of the muscle image then counted pixels to determine LMA. Fat thickness was estimated at the 3/4 position from the chine bone end of the longissimus mus-

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cle (U.S.D.A. beef carcass grade standards) using the cross sectional longissimus muscle image. A single longitudinal image of the longissimus muscle was taken (included the 11-12-13th ribs) for calculation of IMF.

In this study, data were edited to ensure uniformity of the equipment, software, and guidelines of the IBBA. Only purebred Brangus bulls and heifers intended to be used in the future as seedstock or replacement animals were in the data set. According to IBBA guidelines, yearling animals are considered 365 ± 45 days of age. Therefore, yearling weights were only considered from those animals weighed within 45 days of a year of age. Animals must have also had a measurement recorded for IMF to be included in the data set. Animals remaining in the data set were divided into contemporary groups based on sex, breeding season, and environment for restricted maximum likelihood analysis. Contemporary groups containing only one sire were eliminated from the data set. Represented in 21 contemporary groups were the progenies of 297 sires. Descriptive statistics for the edited data set used for analysis are shown in Table 1.

Single-trait animal models were used to estimate starting variances for subsequent multiple-trait analysis. All possible combinations of multiple-trait analysis were performed two traits at a time. This procedure fits an additive genetic effect for animals with records as well as all parents analyzed in the pedigree database. Genetic parameters were estimated for LMA, FT, IMF, and YWT. There were not enough data points for the traits of BRW, WWT, and SC for MTDFREML to converge on permissible heritabilities and correlations. Prior to variance component estimation, the MIXED procedure of SAS (SAS Inst., Inc., Cary, NC) was used to determine the significance of fixed effects for contemporary group, days of age, and the interaction of contemporary group x days of age for inclusion into the final animal model. In addition, starting variance components for the Multiple Trait Restricted Maximum Likelihood program of Boldman et al. (1993) and Boldman and Van Vleck (1991) were also estimated using MIXED procedures. Contemporary group was significant ($P < 0.001$), the linear effect of days of age was significant ($P < 0.001$), but the interaction of contemporary group x days of age was not significant ($P > 0.05$). Therefore, contemporary group was included in single and multiple-trait animal models as a fixed effect, and days of age was included in the models as a covariate. Analyses of covariance models were examined using GLM procedures of SAS (SAS Inst., Inc., Cary, NC) to determine significant effects of LMA, FT, BRW, WWT, SC, days of age, and sire on IMF. Sire was considered as a random variable, and the test option was used to ensure that proper F-tests were computed. Days of age was included in the model as a covariate. Interactions and main effects were tested, however interactions were not significant and therefore not included in the final model.

Results and Discussion

Sire effects. Sire had a significant effect on the expression of IMF ($P = 0.0004$). Approximately 32% of the variation for IMF was accounted for by the sire term of the model used in the analysis. The Brangus sires represented in these data produced progeny that averaged about 3.5% IMF. Mean and coefficients of variation for IMF of 10 bulls with 10 or more progeny are presented in Table 2. Some of the sires represented produced progeny that averaged up to 6.9% IMF. There is sufficient variation in IMF to support artificial selection for genetic change in the trait.

Carcass Traits. Longissimus muscle area had a significant effect on the expression of IMF ($P = 0.03$). The genetic correlation between these two traits was –0.25. This correlation is in agreement with the –0.21 between LMA and marbling score reported by Koots et al. (1994), in a review of published literature. However, Wilson et al. (1993) found a much lower correlation of –0.04 between LMA and marbling score. The moderately low, negative correlation found in this study indicates that as LMA increases IMF will tend to decrease. This relationship is not fully understood, but could be due in part to the position on the growth curve of the animals involved. Breeding cattle are usually managed for growth. At one year of age, Brangus cattle in this study were likely still growing with little impetus for fattening. Twelfth-rib fat thickness was also found to have a significant effect on the expression of IMF ($P < 0.0001$), and a moderately positive genetic correlation of 0.36 (Table 3). The correlation found in this study is in agreement with both Wilson et al. (1993) and Koots et al. (1994) who found correlations of 0.38 and 0.35, respectively, for FT and marbling score. This relationship is however antagonistic on a value based pricing system. Brethour (2000) reported that when feeding cattle to achieve a desired quality grade, yield grade would most likely suffer. It was found that external fat increases at a much quicker rate than IMF during the fattening period. Selection of the proper sires, ones that have high breeding value for IMF and percentage retail product, could possibly allow the progeny to achieve a high quality grade without having to sacrifice yield grade.

Growth Traits. Birth weight, WWT and YWT did not ($P > 0.05$) have a significant effect on the variation found in IMF. As SC increased, IMF slightly decreased, indicating that selection for increased SC might have an antagonistic effect on IMF. This relationship could be explained by the fact that bulls that are not castrated will produce testosterone and have a longer growth curve, therefore causing them to deposit muscle longer, and deposit fat at a later stage in the life. Days of age also approached significance on the expression of IMF ($P = 0.11$). Brethour (2000) demonstrated that as days on feed increased so did the amount of IMF that was deposited. This is likely a response to the fact that as an animal matures, muscle accretion decreased and fat deposition increases.

Implications

Percent intramuscular fat is under quantitative influence, and there are many traits that may affect it. In this study approximately one-third of the variation of IMF was accounted for by variation due to sire. Therefore, selection for sires could be the best way to cause an increase in the amount of IMF. However, in the real world of animal breeding, selection for a single trait is rare, because breeders typically are interested in improving a number of traits.

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Table 1. Descriptive statistics for edited data

Trait	Number of Records	Mean	Standard Deviation
PFAT[a], %EE	1,215	3.27	0.92
LMA[a], in^2	1,214	11.10	2.28
FT[a], in	1,214	0.22	0.11
BW[b], lb	323	84.04	10.23
WW[b], lb	328	641.32	59.27
YW[a], lb	1,087	1,028.52	191.27
SC[b], in	329	15.01	1.04

[a]LMA = 12th-rib longissimus muscle area, ultrasonically measured on live yearling bulls and heifers; FT = 12th to 13th-rib fat thickness, ultrasonically measured on live yearling bulls and heifers; PFAT = percent intramuscular fat from 12th-rib longissimus muscle area, ultrasonically measured on live yearling bulls and heifers; YW = live weight of yearling bulls and heifers taken at time of ultrasound.
[b]Measurement was recorded by producer and obtained from sale catalogs for: BW = birth weight; WW = weaning weight; SC = scrotal circumference.

Table 2. Variation in intramuscular fat by sire progeny group

Sire No.	1	2	3	4	5	6	7	8	9	10
N	21	38	11	26	13	10	15	25	12	29
Mean, %	3.72	3.00	2.80	3.42	3.36	3.35	2.58	3.21	2.90	3.58
CV	15.1	34.0	26.7	16.3	18.7	13.7	62.0	17.9	39.6	19.3

Table 3. Heritabilities estimated from two-trait models and correlationsfor estimates of ultrasonic carcass characteristics

Trait[b]	LMA	FT	IMF	YW
LM[A]	0.31	-0.09	-0.25	0.44
FT	0.16	0.27	0.36	0.42
IMF	-0.08	0.17	0.15	0.31
YW	0.44	0.33	0.03	0.53

[a]Heritability estimates on diagonal, genetic correlations above diagonal, phenotypic correlations below diagonal.
[b]LMA = 12th-rib longissimus muscle area, ultrasonically measured on live yearling bulls and heifers, in cm2; FT = 12th to 13th-rib back fat thickness, ultrasonically measured on live yearling bulls and heifers, in cm; IMF = Percent intramuscular fat from 12th-rib longissimus muscle area, ultrasonically measured on live yearling bulls and heifers; YW = Live weight of yearling bulls and heifers taken at time of ultrasound, in kg.

Effects of Restraint and Isolation Stress on Stress Physiology and the Incidence of Dark-cutting Longissimus Muscle in Holstein steers

J. K. Apple, E. B. Kegley, C. B. Boger, J. W. Roberts, D. Galloway, and L. K. Rakes[1]

Story in Brief

Thirty-two Holstein steers, weighing approximately 300 lb, were used to test the effects of varying durations of restraint and isolation stress (RIS) on endocrine and blood metabolite status, and the incidence of dark-cutting longissimus muscle (LM). Calves were blocked by weight, and assigned randomly within blocks to one of four treatments: unstressed controls, or 2, 4, or 6 h of RIS. Serum cortisol, as well as plasma glucose and lactate, concentrations were elevated ($P < 0.01$) in RIS-calves, regardless of stressor duration, compared with their unstressed counterparts. Insulin concentrations were similar among treatment groups during the first 80 min after stressor application, but, from 100 to 340 min, calves subjected to RIS had greater ($P < 0.01$) plasma insulin levels than unstressed calves. In the LM, 24- and 48-h pH values were in excess of 6.0, and higher ($P < 0.01$) in calves subjected to 6 h RIS than unstressed controls and calves subjected to 2 or 4 h RIS. Dark-cutting meat is characterized by muscle pH in excess of 6.0, a high water-holding capacity, and a dark-red to almost-black lean color. Based on these criteria, 75% of carcasses from calves exposed to 6 h of RIS were deemed to be dark-cutters; whereas, only 25% of carcasses of calves subjected to 2 or 4 h RIS, and no controls, were classified as dark-cutters. Therefore, subjecting young, lightweight Holstein steers to 6 h of RIS may be an effective, reliable animal-model to study the dark-cutting condition.

Introduction

Dark-cutting meat is a persistent quality defect characterized by an elevated muscle pH (≥ 6.0), high water-holding capacity, dry, firm, and "sticky" lean, and a dark-red to almost-black lean color. More importantly, the dark-cutting condition (DCC) costs the U.S. beef industry between $132 and $170 million annually (Smith et al., 1995).

It is widely accepted that reduced muscle glycogen reserves prior to harvest is the mechanism responsible for the formation of the DCC. Reductions in muscle glycogen reserves may arise from any change in the physical or psychological well-being of an animal, including handling, transportation, feed deprivation, and co-mingling cattle. However, the inability to consistently produce dark-cutting carcasses impedes replication of experimental results, and hinders the ability to test possible management practices and/or treatments to reduce/eliminate the DCC.

Attempting to develop an animal-model to study the DCC, Apple and co-workers used sheep and tested a physical stressor (Apple et al., 1994) and a psychological stressor (Apple et al., 1993). After some modifications, Apple et al. (1995) demonstrated that exposing sheep to a single 6-h bout of restraint and isolation stress effectively reduced antemortem glycogen reserves, and produced 100% dark-cutting carcasses. However, questions were raised concerning the applicability of this animal-model to cattle; therefore, the primary objective of this study was to develop a repeatable, reliable animal-model using lightweight Holstein steers.

Experimental Procedures

Thirty-two Holstein steers, weighing approximately 300 lb, were purchased from a local supplier and blocked by weight into four blocks. Within blocks, calves were assigned randomly to one of four treatments: 1) unstressed controls (Ctrl); 2) subjected to a single 2-h bout of restraint and isolation stress (RIS); 3) subjected to a single 4-h bout of RIS; or 4) subjected to a single 6-h bout of RIS. Calves had ad libitum access to a high-concentrate diet and water for a minimum of four weeks before each replicate. Seven days before stressor treatment, each block of calves was moved from the University of Arkansas Beef Cattle Research Unit to the University of Arkansas Calf Research Facility, individually stanchioned in metabolic crates, and individually fed the high-concentrate diet at a rate of 2.5% of their individual body weight. Calves had ad libitum access to water via automated bowl-waterers attached to each crate.

Calves were fitted with indwelling jugular catheters 24 h before stressor treatment to facilitate repeated blood sampling. On the morning of stressor treatment, samples of blood were collected at 40, 20, and 0 min before stressor application. After the 0-min blood sample, RIS-calves were moved from their home stanchions to another area where they were isolated from visual and tactile contact with other calves. Restraint was achieved by placing calves on their right sides, then binding both forelimbs and both hindlimbs together with nonadhesive tape. Finally, both sets of limbs were bound together with elastic tape. To minimize physical discomfort during stressor treatment, restrained calves were placed on 4 to 5 in of carpet padding. Control calves remained in their home stanchions, and, with the exception of blood sampling, were subjected to minimal handling and stress. Samples of blood were collected at 20-min intervals for the duration of each treatment, and assayed for serum cortisol and plasma glucose, lactate, and insulin.

Upon completion of the specified duration of RIS, calves were transported approximately 300 yd to the University of Arkansas Red Meat Abattoir, and harvested according to industry-accepted procedures. Immediately following non-penetrating, captive bolt stunning and exsanguination, samples of the longissimus muscle (LM) were excised from the right side of each carcass. Subsequently, LM samples were removed at 0.75, 1.5, 3, 6, 12, and 24 h after stunning. Approximately 2 g of LM were used for pH determinations, while the

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remainder of the sample was frozen immediately in liquid nitrogen for determination of muscle glycogen and lactate concentrations at a later date.

After a 48-h chilling period at 34°F, left sides were ribbed between the 12th and 13th ribs, and the wholesale rib was fabricated from the forequarter. Three 1.0-in thick LM steaks were removed from each rib, and subjective and objective color measurements were collected on two steaks; whereas, the third LM steak was used to measure moisture content and water-holding capacity. Longissimus muscle color was subjectively evaluated using the six-point, Japanese color standards for pork (Nakai et al., 1975) by a three-person panel after a 30-min bloom period at 38°F. Objective color of LM chops steaks was measured with a Hunter Lab MiniScan XE. Simultaneously, L*, a*, and b* values were determined from a mean of four random readings on each steak using illuminant C and a 10° standard observer. After color measurements were collected, both 1.0-in thick steaks were paper-wrapped and stored at -20°F for further analyses.

Approximately 1 g of excised muscle at each sampling time was homogenized with 10 mL of 5 mM sodium iodoacetate in 150 mM of potassium chloride (Bendall, 1973). The pH of the homogenate was measured with a temperature-compensating, combination electrode attached to a pH/Ion/FET-meter (Denver Instrument Co., Arvada, CO). In addition, moisture content of the LM was determined according to the freeze-drying procedure of Apple et al. (2001), and LM water-holding capacity was measured using the Carver press/compensating planar planimeter method of Urbin et al. (1962).

All data were analyzed as a randomized complete block design with calf as the experimental unit. Blood data, as well as postmortem pH decline data, were analyzed as a repeated measure using PROC MIXED (SAS Inst., Inc., Cary, NC) with sampling time as the repeated variable, calf as the subject, and stressor treatment and treatment x sampling time included in the model as fixed effects (random effects included block and block x treatment x calf). PROC MIXED was also used to generate the analysis of variance for all beef-quality data. The lone fixed effect was stressor treatment, whereas block and block x treatment were the random effects included in the model. Least squares means were computed for all main and interactive effects, and separated statistically using pair-wise t-tests (PDIFF option of SAS).

Results and Discussion

Serum cortisol concentrations were elevated ($P < 0.01$) in RIS-calves, regardless of stressor duration, compared with their unstressed counterparts (Figure 1). Typically, an animal responds to a stressor by releasing ACTH from the anterior pituitary gland, which propagates the release of glucocorticoids (cortisol and corticosterone) from the adrenal cortex. The glucocorticoids serve to adapt the body to stressors by affecting cardiovascular, energy-producing, and immune systems. Therefore, the treatment imposed on the calves effectively elicited a stress response.

Plasma glucose (Figure 2) and lactate (Figure 3) levels were higher ($P < 0.01$) in calves subjected to RIS than in unstressed controls. Plasma glucose levels began to rise after 40 to 60 min after stressor application, but it wasn't until after 80 min of RIS that circulating concentrations were different between stressed-calves and controls (Figure 2). On the other hand, plasma lactate levels began to rise immediately after stressor application, and after 40 min of RIS, calves subjected to 2 h of RIS had higher plasma lactate levels than calves subjected to either 4 or 6 h of RIS (Figure 3). Insulin concentrations were similar among treatment groups during the first 80 min after stressor application, but, from 100 to 340 min, calves subjected to RIS had greater ($P < 0.01$) plasma insulin levels than unstressed calves (Figure 4).

The hyperglycemia observed in this study is a typical response observed during stress, and is induced by increased adrenal secretion of epinephrine and cortisol. These hormones accelerate glucose production by stimulating glycogenolysis and gluconeogenesis, as well as reducing glucose clearance from circulation; therefore, the net result is elevated plasma glucose concentrations. In the present study, concomitant increases in both glucose and insulin by RIS was expected; however, plasma glucose levels did not decrease in response to the elevated levels of plasma insulin – a classical example of insulin-resistance.

Postmortem pH decline in the LM is presented in Figure 5. In the LM, pH values were similar among treatment groups during the first 12 h after death; however, pH values were greater ($P < 0.01$) in the LM from calves subjected to 6 h RIS at 24 and 48 h postmortem than unstressed controls and calves subjected to 2 or 4 h RIS (Figure 5). More importantly, ultimate (24- and 48-h) pH values for the LM of calves stressed for 6 h were in excess of 6.0, the threshold level associated with the DCC. Normal postmortem muscle pH declines in a curvilinear fashion from its initial value of approximate 7.2, until it reaches a normal ultimate pH value between 5.5 and 5.7. The decline in pH is a response to the increased accumulation of lactic acid in the muscle as a result of anaerobic metabolism of muscle glycogen. Therefore, the high ultimate pH value for the LM of calves subjected to 6 h of RIS would indicate that muscle glycogen reserves were almost completely depleted at the conclusion of the stressor treatment.

The LM from RIS-calves received darker ($P < 0.01$) color scores and lower L* ($P < 0.01$) values than the LM from unstressed calves (Table 1). Finally, even though LM moisture content was similar ($P > 0.10$) among the treatment groups, the LM from calves subjected to 6 h of RIS had a greater ($P < 0.01$) percentage of bound, and a lower ($P < 0.01$) percentage of free, water than the other treatment groups. Dark-cutting meat is characterized by an elevated muscle pH in excess of 6.0, a high water-holding capacity, a dry, firm, and "sticky" lean, and a dark-red to almost-black lean color. Based on these criteria, 75% (6 of 8) of the carcasses from calves exposed to 6 h of RIS were deemed to be dark-cutters; only 25% of the carcasses of calves subjected to 2 or 4 h RIS were classified as dark-cutters; and no (0 of 8) controls were remotely close to being dark-cutters. Therefore, subjecting young, lightweight Holstein calves to 6 h of RIS may be an effective animal-model to study the DCC condition.

Implications

Subjecting calves to restraint and isolation stress effectively elicited dramatic elevations in cortisol and circulating energy reserves, and curtailed normal postmortem pH decline. Results from this study suggest that exposing calves to a single six-hour bout of restraint and isolation stress is an effective, reliable animal-model to study the dark-cutting condition in a controlled laboratory setting.

Acknowledgments

The authors are indebted to the Arkansas Beef Council for financial support of this study. Moreover, the authors wish to express their sincerest appreciation to: Pete Hornsby, Gordon Carte, and John Sligar for animal care and management; Troy Wistuba, Ellen Davis, Jim Turner, Broc Sandelin, Rapeepong Panivivah, Brad McGinley, and Dari Brown for assistance with blood collection; Jerry

Stephenson, Jennifer Leach, Juan Jimenez-Villarreal, Rebecca Miller, and Nicholas Simon for assistance with animal harvest, fabrication, and sample collection; and Dr. Zelpha Johnson for statistical consultation.

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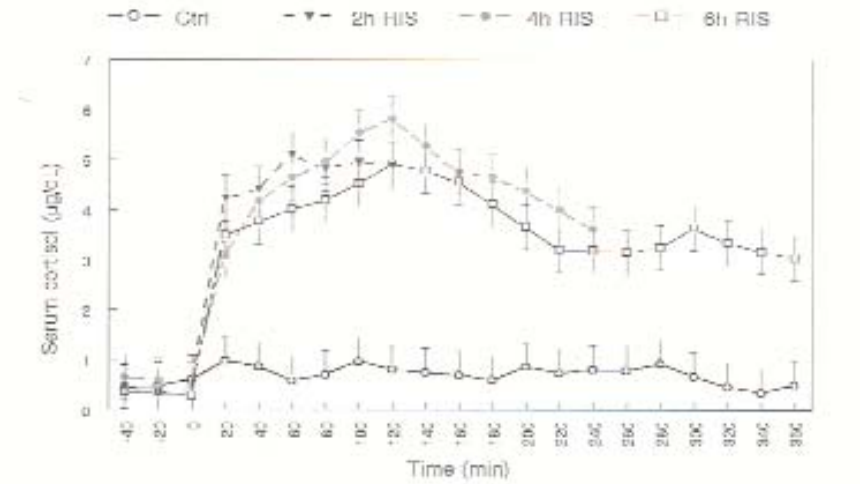

Fig. 1. Effect of duration of restraint and isolation stress (RIS) on serum cortisol concentrations (treatment x time interaction; P < 0.0001).

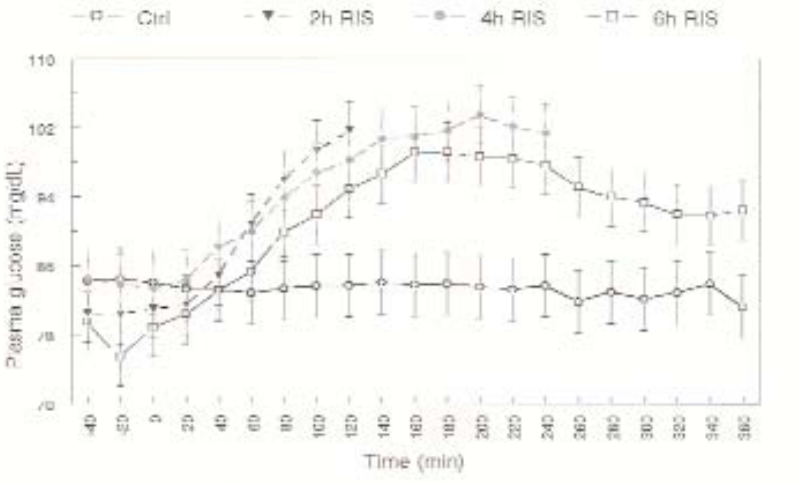

Fig. 2. Effect of duration of restraint and isolation stress (RIS) on plasma glucose concentrations (treatment x time interaction; P < 0.0001).

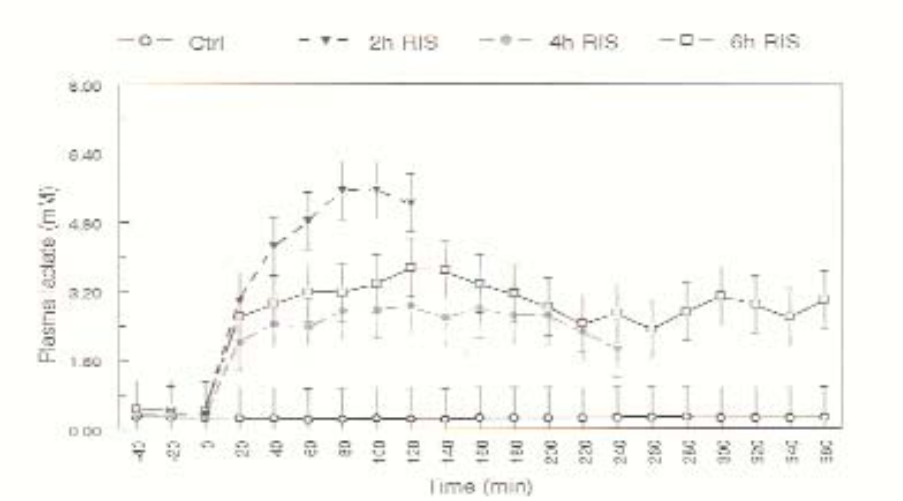

Fig. 3. Effect of duration of restraint and isolation stress (RIS) on plasma lactate concentrations (treatment x time interaction; P < 0.0001).

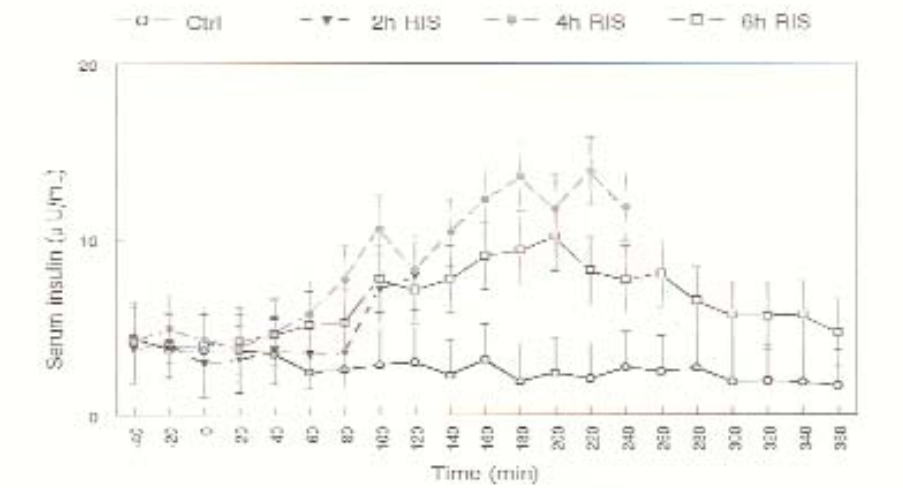

Fig. 4. Effect of duration of restraint and isolation stress (RIS) on plasma insulin concentrations (treatment x time interaction; P < 0.0001).

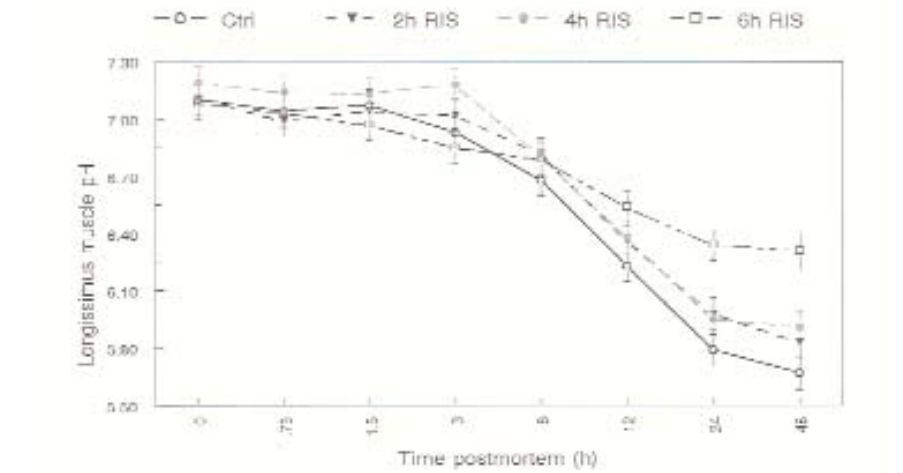

Fig. 5. Postmortem pH decline in the longissimus muscle as affected by duration of restraint and isolation stress (RIS; treatment x time interaction; P < 0.0005).

Table 1. Effect of restraint and isolation stress on beef quality attributes of Holstein calves

	Restraint & isolation stress, h				
Quality trait	Control	2	4	6	S.E.
Color score[a]	3.9[e]	4.8[d]	4.9[d]	5.6[c]	0.29
CIE L*[b]	45.28[c]	40.59[d]	40.85[d]	38.28[d]	1.201
CIE a*[b]	9.40	10.19	9.69	10.09	0.392
CIE b*[b]	13.09[x]	12.46[xy]	12.08[y]	11.92[y]	0.692
Moisture content, %	77.5	77.2	78.2	77.3	0.46
Bound water, %	61.1[d]	63.9[d]	64.4[d]	72.5[c]	2.52
Free water, %	38.9[c]	36.1[c]	35.6[c]	27.5[d]	2.52

[a] Color score: 1 = pale gray to 6 = dark purple (Nakai et al., 1975).
[b] L* values are a measure of lightness to darkness (lower number indicates a darker color); a* values are a measure of redness (larger number indicates redder color); and b* values are a measure of yellowness (larger number indicates more yellow color).
[c,d,e] Within a row, least squares means lacking a common superscript letter differ ($P < 0.01$).
[x,y] Within a row, least squares means lacking a common superscript letter differ ($P < 0.06$).

Influence of Time and Duration of Fish Oil Supplementation on Performance and Carcass Characteristics of Cattle

T. J. Wistuba, E. B. Kegley, and J. K. Apple[1]

Story in Brief

In the mid-1990's the role of dietary fat type in the maintenance of healthy life in humans focused on the importance of long-chain omega-3 (n-3) fatty acids (FA) in the diet. Inclusion of fish oil (a source of n-3 fatty acids) in beef diets may fortify the fatty acid composition of meats. Therefore, two experiments were conducted to determine the effects of time and duration of fish oil supplementation on growth performance and carcass characteristics of steers. Experiment 1 utilized 48 crossbred steers (773.8 ± 69.5 lb initial BW) that had been fed supplements with or without fish oil (0 or 0.06 lb/d for 78 d) while on pasture. The steer calves were moved to drylots and stratified across previous dietary treatments (three calves per pen; eight pens per dietary treatment) for a 56-d growing study. Dietary treatments consisted of: 1) control and 2) the control diet with 3% fish oil. Calves supplemented with fish oil had decreased ADG (3.62 vs. 2.45 lb), feed intake and feed efficiency (6.9 vs. 8.1) ($P < 0.01$). Experiment 2 utilized 32 steers (944.5 ± 84.5 lb initial BW) from Exp. 1 that were shipped to a commercial feedlot to be fed out on a common diet. Steers had received fish oil during the grazing phase (0.06 lb/d for 78 d), the growing phase (3% fish oil in the diet as-fed basis; for 56 d), throughout the entire period (134 d), or not at all. Final weight (1,343.7 ± 121 lb), longissimus muscle area (13.1 ± 1.5 in^2), marbling score, dressing percentage, percentage internal fat, and quality grade did not differ due to time and duration of fish oil supplementation ($P > 0.10$). However, steers that received fish oil during the growing period had lower ($P < 0.05$) yield grades, carcass weights, and 12th rib fat depths than the other treatments.

Introduction

Ruminants have the ability to utilize by-products from numerous industries as nutrients. Fish industry by-products are potential sources of valuable nutrients, including energy and protein. Therefore, methods of converting fish industry by-products into reliable sources of animal feeds would benefit both the beef and fish industries by providing a market for the fish oil and an economical energy source for cattle diets. Fish industry by-products are good sources of n-3 fatty acids, which contain the long chain EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid) that are found almost uniquely in foods of marine origin. Several authors (Ashes et al., 1992; Mandell et al., 1997; and Ponnampalam et al., 2001) have found that diets supporting modified n-3 content of muscle membrane structural phospholipid also significantly altered plasma insulin concentrations, lipid metabolite concentrations in plasma, and intramuscular fat content in the carcass. These same authors have shown that the long chain n-3 fatty acids (FA), such as EPA and DHA can be increased two to three fold in muscle by feeding fish meal at high levels. The nutritional composition of feedstuffs can be very complex and supplements provided for one reason (protein) may also provide other nutrients (fat) and have physiological effects that, for example, influence energy partitioning, carcass composition, and muscle lipid composition. The objective of these studies was to determine the effects of time and duration of fish oil supplementation on performance and carcass characteristics.

Experimental Procedures

In Exp. 1, 48 crossbred steers (773.8 ± 69.5 lb initial BW) were obtained from the University of Arkansas Stocker and Receiving Unit in Savoy. Calves were stratified by previous dietary treatment, blocked by weight, and assigned to pens. Previous dietary treatments on a grazing study were supplementation with 0 or 0.06 lb/d of fish oil for 78 d from May to August. There were three steers in each of the sixteen pens, for a total of 24 steers per dietary treatment. Dietary treatments (Table 1) consisted of: 1) control and 2) the control diet with 3% fish oil replacing a portion of the corn. The diets were mixed at approximately weekly intervals. Fish oil for the rations was delivered on approximately monthly intervals. Steers were fed their respective diets for 56-d. Steers were weighed on consecutive days at d 0 and 56 to start and finish the trial and an interim weight was taken on d 28.

In Exp. 2, 32 steers (944.5 ± 84.5 lb initial BW) from the previous study were shipped to a commercial feedlot and fed a common diet for 189 d. The calves had received fish oil during the grazing phase (0.06 lb/d for 78 d), the growing phase (3% fish oil in the diet as-fed basis for 56 d), throughout the entire period (0.06 lb fish oil/d for 78 d then 3% fish oil in the diet as-fed basis for 56 d), or not at all. Calves were shipped to a commercial abattoir and harvested on d 191. Steers were harvested when a high percentage were estimated to have approximately 0.4 in of external fat. Steers were stunned via captive bolt pistol and exsanguinated. Hot carcass weights were obtained on the day of slaughter, whereas 12th-rib fat thickness; longissimus muscle area; percentage of kidney, pelvic and heart fat; marbling scores; and bone maturity scores were collected after carcasses had hung at 25°F for 24 h. Chromatography paper was used to make an image of the longissimus muscle and grid measurements were made of the image. Quality grades were determined based on the USDA grid of marbling and bone and lean maturity scores.

In Exp. 1 analysis of variance were conducted on performance data using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC). The model for the data included block and dietary treatment. In Exp. 2 the calves were assigned to one of four management categories as

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never receiving fish oil, receiving fish oil during the grazing or growing phase, or receiving fish oil during both the grazing and growing phases. Analysis of variance was conducted on carcass data, the model included block and category. If category was significant ($P < 0.10$), then a student's t-test was used to separate means.

Results and Discussion

In Exp. 1, daily feed intake was decreased at 28 d (20.9 vs. 19.6 lb; $P < 0.01$) and for the entire 56 d study (24.9 vs. 19.8 lb; $P < 0.01$) by dietary supplementation of fish oil (Table 2). Subsequently, ADG was also decreased for the entire 56 d study (3.62 vs. 2.45 lb; $P < 0.01$). Feed:gain showed a similar trend and was superior for the control diet during the entire 56-d study (6.9 vs. 8.1; $P < 0.01$).

In Exp. 2, fish oil supplementation throughout the entire trial period did not alter final weight, carcass weight, longissimus muscle area, marbling score, dressing percentage, percentage internal fat, or quality grade (Table 3). However, fish oil supplementation during the growing period decreased hot carcass weight, fat thickness, and yield grade when compared to calves that received no fish oil and calves that received fish oil during the grazing period ($P < 0.05$).

Table 1. Ingredient composition (as-fed basis) of experimental diets fed in Exp. 1

Ingredient	Control	Fish oil
	%	
Corn, cracked	65.4	62.4
Cottonseed hulls	20	20
Soybean meal	11.2	11.2
Cane molasses	2	2
Dicalcium phosphate	0.4	0.4
Limestone, 38%	0.85	0.85
Salt	0.15	0.15
Fish oil	0	3
Rumensin premix[a]	+	+
Vitamin E premix[b]	+	+
Vitamin premix[c]	+	+
Trace mineral premix[d]	+	+

[a] Premix supplied 200 mg of monensin per day.
[b] Premix supplied 0.075 IU vitamin E per pound of diet
[c] Premix supplied per pound of diet: 225 IU of vitamin A, 75 IU of vitamin D_3, and 0.075 IU vitamin E
[d] Premix supplied: 20 ppm of Zn as ZnO, 10 ppm of Mn as MnO, 0.10 ppm of Se as Na_2SeO_3, and 0.10 ppm of Co as $CoCO_3$.

Implications

Supplementing fish oil in the current studies decreased feed intake, ADG, and hot carcass weights. However, some of this decrease in hot carcass weight seems to be from the reduction in ADG when fish oil was supplemented during the growing period. These findings may be beneficial in establishing a method of supplementing fish oil to cattle without the deleterious affects on feed intake and ADG.

Acknowledgments

The authors would like to extend their deepest gratitude to J. A. Hornsby, G. Carte, and J. Sligar for the management and care of the experimental animals. The authors would also like to acknowledge Omega Protein for donating the fish oil.

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Table 2. Influence of fish oil supplementation on ADG, ADFI, and F:G in Exp. 1

Item	Control	Fish oil	SEM	P<
d 0-28				
ADG, lb	2.49	1.43	0.19	0.01
ADFI[a], lb	20.9	19.6	0.21	0.01
Feed/gain	8.39	13.7	0.20	0.02
d 0-56				
ADG, lb	3.62	2.45	0.11	0.01
ADFI[a], lb	24.9	19.8	0.36	0.01
Feed/gain	6.9	8.1	0.15	0.02

[a] As-fed basis, calculated as daily pen intake divided by three.

Table 3. Influence of time and duration of fish oil supplementation on carcass characteristics in Exp. 2

	Fish oil				
Item	None	Grazing	Growing	Throughout	SEM
Final weight	1357.5	1363.75	1303.13	1325.0	33.09
Carcass weight, lb	834.4[c]	832.3[c]	771.8[d]	789.3[cd]	19.9
Dressing percent	61.4	61.1	59.7	59.7	1.13
Longissimus muscle area, in^2	12.99	13.01	13.65	12.65	0.52
Fat thickness, in	0.59[c]	0.68[c]	0.39[d]	0.53[cd]	0.064
Marbling score[a]	292.0	308.8	270.6	272.5	22.34
Quality grade[b]	572.9	587.3	572.8	550.0	18.4
Kidney, pelvic and heart fat, %	2.43	2.31	2.28	2.63	.13
Yield grade	3.48[c]	3.66[c]	2.49[d]	3.30[c]	0.22

[a] Coded: minimum slight = 200, minimum small = 300, etc.
[b] Coded: minimum select = 500, minimum choice = 600, etc.
[cd] Within a row, means without a common superscript differ ($P < 0.05$).

Influence of Fish Oil Addition to Finishing Diets on Carcass Characteristics, Immune Function, and Growth Performance of Cattle

T.J. Wistuba, E.B. Kegley, and J.K. Apple[1]

Story in Brief

Inclusion of fish oil, a source of omega-3 fatty acids, in ruminant diets may fortify the fatty acid composition of meats and modulate the animal's immune system. Therefore, an experiment was conducted to determine the effects of fish oil supplementation on carcass characteristics, immune function, and growth performance. The 70-d study used 16 crossbred steers (972 ± 69.9 lb initial BW; 4 calves/pen; 2 pens/dietary treatment) consuming a high concentrate ration. Dietary treatments consisted of: 1) control (75% corn, 11% soybean meal, and 10% cottonseed hull based diet); and 2) the control diet with 3% fish oil replacing a portion of the corn. Calves were stratified by treatment and harvested on d 71 and 72. Fish oil supplementation decreased daily feed intake (30.8 vs. 25.3 lb, $P < 0.01$). Conversely, ADG or feed efficiency did not differ due to fish oil supplementation ($P > 0.10$). Fish oil did not alter color of the longissimus muscle (LM), LM area, yield grade, dressing percentage, marbling, quality grade, or fat thickness. However, calves fed fish oil had reduced hot carcass weight (723 vs. 667 lb, $P < 0.05$), and tended to have a lower percentage of internal fat (2.3 vs. 1.9, $P = 0.12$). Fish oil supplementation increased the number of receptors expressed on lymphocytes ($P < 0.01$) and tended to increase the ratio of the number of receptors on T lymphocytes compared to the number of receptors on B lymphocytes ($P = 0.06$). Fish oil supplementation in this trial had no negative effects on growth performance or feed efficiency. Results indicated that fish oil supplementation did modulate the immune system. However, more research may be required to document or elicit the exact immunological changes that occur at the cellular level.

Introduction

There are two types of essential fatty acids important to human health, the omega-6 type (n-6) and the omega-3 (n-3) type. While the amount of n-6 that we eat has risen, n-3 levels have fallen. Ideally, intake of n-6 fatty acids should be no more than four or five times that of n-3 fatty acids. Today in the USA, intake of the n-6 fatty acids is ten or twelve times more than the intake of n-3 fatty acids. This imbalance is gradually being recognized as a major contributor to health problems.

The n-3 family of polyunsaturated fatty acids can be further divided into two groups: short chain and long chain. Short chain ALA (alpha linolenic acid) can be obtained from plant foods, nuts and seeds, whereas long chain EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid) are found almost uniquely in foods of marine origin. Recently, the dietary recommendation for the highly unsaturated n-3 fatty acids has increased, specifically EPA and DHA, from 0.15 to 0.65 g/d. To meet these recommendations, Americans will either have to adjust their diet, or the nutrient composition of some foodstuffs (beef) may need to be fortified. However, feeding diets that alter the fatty acid content of meat may also affect other aspects of beef production. Nutritional status has a profound effect on immune function. Energy, protein, minerals, and vitamins all affect immune status. The objective of this study was to determine the effects of dietary fish oil addition on carcass characteristics, growth performance and immune function of cattle consuming a high concentrate diet.

Experimental Methods

Sixteen Angus crossbred steers (972 ± 69.9 lb initial BW) were obtained from the University of Arkansas Stocker and Receiving Unit in Savoy. Calves were blocked by weight and assigned randomly to pens. There were four steers in each of the four pens, for a total of eight steers per dietary treatment. Dietary treatments (Table 1 and 2) consisted of: 1) control and 2) the control diet with 3% fish oil replacing a portion of the corn. The diets were mixed at approximately weekly intervals.

Steers were fed their respective diets for 70-d. Steers were weighed on consecutive days at d 0 and 70 to start and finish the trial and interim weights were taken on d 28 and 56. On d 63, all calves were bled by jugular venipuncture for flow cytometric analysis to determine the populations of leukocytes and plasma fatty acid concentrations. Calves were stratified by treatment and harvested on d 71 and 72. Steers were stunned via captive bolt pistol and exsanguinated. Hot carcass weights were obtained on the day of slaughter, whereas 12th-rib fat thickness; longissimus muscle area; percentage of kidney, pelvic and heart fat; marbling scores; and bone maturity scores were collected after carcasses had hung at 25°F for 24 h. Chromatography paper was used to make an image of the longissimus muscle and grid measurements were made of the image. Quality grades were recorded based on the USDA grid of marbling and bone maturity scores.

Analyses of variance were conducted on proportions of lymphocyte population data using SYSTAT 9.0 software (SPSS Inc., Chicago, IL). Analyses of variance were conducted on growth per-

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formance, carcass, and plasma data using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC). The model included dietary treatment and block.

Results and Discussion

Daily feed intake for the entire 70-d study (Table 3) was decreased (30.8 vs. 25.3 lb, $P < 0.01$) by dietary supplementation of fish oil. Previous research has indicated that feed intake could be depressed when diets contain over 8% fat because of adverse effects of fat, particularly polyunsaturated fat, on rumen microbial populations. In the current trial, dietary fat level was increased to 6.6% with the addition of fish oil; therefore, the depression in intake was most likely due to several factors such as palatability, energy density of the ration, and total fat. Despite the deleterious effect of fish oil on intake in the present study, ADG (3.13 vs. 2.84 lb) and F/G did not differ due to fish oil supplementation ($P > 0.10$).

Concerns about consumer intake of fat, particularly saturated fatty acids, have resulted in closer scrutiny of the fatty acid composition of ruminant products. It has been shown in the past that the C20 and C22 fatty acids in fish oil, even when not protected, are not hydrogenated to any significant extent. Therefore it is not surprising that plasma fatty acid profiles taken on d 63 were significantly affected by fish oil supplementation (Table 4). Fish oil supplementation increased the concentrations of monounsaturated fatty acids, as well as, the concentrations of linolenic and eicosapentaenoic acid, which are part of the n-3 fatty acids that humans are deficient in. Incorporation of the n-3 fatty acids into beef would make it a more health conscious product for the consumer because high n-6 to n-3 fatty acid ratios (10-12:1) have been accepted as the cause of several health problems. However, fish oil supplementation did decrease the concentrations of polyunsaturated fatty acids (n-6) and linoleic acid, which is the fraction of the fatty acids that contains conjugated linoleic acid, the anticarcinogen.

Fish oil supplementation decreased hot carcass weight (723 vs. 667 lb, $P < 0.05$), and tended to decrease percentage internal fat (2.3 vs. 1.9, $P = 0.12$), but LM area, yield grade, dressing percentage, marbling, quality grade, or fat thickness did not differ ($P > 0.10$) between treatments (Table 5). Differences in feed intake and the subsequent decrease in ADG were probably responsible for the effect of fish oil on HCW. Fish oil supplementation did not alter color of LM, cooking loss, or Warner-Bratzler shear force (Table 6).

Ground sections of the 9th, 10th, and 11th rib were chemically analyzed for their nutrient composition (Table 7). Fish oil supplementation had no effect on the DM, CP, fat or ash composition of the ground rib sections. Values are typical for steers of this type and at this stage of growth.

Flow cytometric analysis of the blood indicated that fish oil supplementation had no effect on the proportions of leukocytes in the blood of steers on d 63 (Table 8). However, fish oil supplementation increased the fluorescence of lymphocytes ($P < 0.01$), and tended to increase the ratio of the fluorescence of T lymphocytes compared to the fluorescence of B lymphocytes ($P = 0.06$). The fluorescence expressed by a population of cells is related to the amount of monoclonal antibody marker that binds to its respective surface receptor on a given population of cells. The numbers of receptors expressed on a cell is correlated to the activity of that cell and therefore the more receptors available for expression the more likely antigens are to be eliminated.

Implications

Supplementing fish oil decreased hot carcass weights; however, some of this decrease seems to be from a reduction in the percentage of internal fat. As indicated by the increased concentration of eicosapentaenoic acid in the plasma, fish oil supplementation has shown promise to enhance the fatty acid composition of beef. In this study supplementation of fish oil has also indicated that it may increase the responsiveness of the immune system.

Acknowledgments

The authors would like to extend their deepest gratitude to J. A. Hornsby, G. Carte, and J. Sligar for the management and care of the experimental animals. The authors would also like to acknowledge Omega Protein for donating the fish oil.

Table 1. Ingredient composition (as-fed basis) of experimental diets

Ingredient	Control	Fish oil
	%	
Corn, cracked	75.4	72.4
Cottonseed hulls	10	10
Soybean meal	11.2	11.2
Cane molasses	2	2
Dicalcium phosphate	0.4	0.4
Limestone, 38%	0.85	0.85
Salt	0.15	0.15
Fish oil	0	3
Rumensin premix[a]	+	+
Vitamin E premix[b]	+	+
Vitamin premix[c]	+	+
Trace mineral premix[d]	+	+

[a] Premix supplied 200 mg of monensin per day.
[b] Premix supplied 0.075 IU vitamin E per pound of diet
[c] Premix supplied per pound of diet: 225 IU of vitamin A, 75 IU of vitamin D_3, and 0.075 IU vitamin E.
[d] Premix supplied: 20 ppm of Zn as ZnO, 10 ppm of Mn as MnO, 0.1 ppm of Se as Na_2SeO_3, and 0.1 ppm of Co as $CoCO_3$.

Table 2. Nutrient composition of diets

Item	Control	Fish oil
Dry matter, %	88.3	86.8
Crude protein, %	13.78	13.45
Acid detergent fiber, %	7.8	7.6
Neutral detergent fiber, %	11.5	11.4
Fat[a], %	3.44	6.66
NE_m, Mcal/cwt[a]	94.61	98.45
NE_g, Mcal/cwt[a]	59.84	62.99

[a] Calculated

Table 3. Influence of fish oil supplementation on ADG, ADFI and F/G

Item	Control	Fish oil	SEM	P<
ADG, lb	3.15	2.85	0.07	0.2
ADFI[a], lb	30.9	25.5	0.04	0.01
Feed/Gain	9.84	8.91	0.42	0.26

[a] As-fed basis, calculated as daily pen intake divided by four.

Table 4. Influence of fish oil supplementation on plasma fatty acid composition

Fatty acid[a]	Control	Fish oil	SEM	P<
Myristic (C14:0)	0	1.1	0.19	0.01
Palmitic (C16:0)	13.6	19.3	0.58	0.01
Palmitoleic (C16:1)	0	1.6	0.19	0.01
Stearic (C18:0)	20.1	11.8	0.39	0.01
Oleic (C18:1)	6.1	11.0	0.47	0.01
C18:1cis-9	0	5.1	0.46	0.01
C18:1cis-11	6.1	4.4	0.32	0.01
C18:1trans-11	0	1.6	0.27	0.01
Linoleic (C18:2)	53.6	39.1	0.75	0.01
Linolenic (C18:3)	0.3	4.0	0.18	0.01
Bishomopinolenic (C20:3)	2.6	0.2	0.33	0.01
Arachidonic (C20:4)	3.2	0.61	0.22	0.01
Eicosapentaenoic (C20:5)	0	5.95	0.15	0.01
Saturates	33.7	32.3	0.51	0.08
Monounsaturates	6.1	12.6	0.47	0.01
Polyunsaturated fatty acid	59.7	49.8	0.86	0.01

[a] Weight percentage values are relative proportions of all peaks observed by gas liquid chromatograph

Table 5. Influence of fish oil supplementation on carcass characteristics

Item	Control	Fish oil	SEM	P<
Carcass weight, lb	723	667	17.6	0.05
Dressing percentage	58.6	57.9	0.42	NS
Longissimus muscle area, in^2	12.7	12.1	0.17	NS
Fat thickness, in	0.43	0.44	0.34	NS
Marbling score[a]	255	258	39	NS
Quality grade[b]	608	608	18	NS
Kidney, pelvic, and heart fat, %	2.3	1.9	0.15	0.12
Yield grade	2.79	2.74	0.096	NS

[a] Coded: minimum slight = 100, minimum small = 200, etc.
[b] Coded: minimum select = 500, minimum choice = 600, etc.

Table 6. Influence of fish oil supplementation on cooking and color characteristics

Item	Control	Fish oil	SEM	P <
Cooking loss, %	24.12	24.00	0.54	NS
Warner-Bratzler shear force, lb	7.63	7.5	0.42	NS
Color				
L*[a]	39.24	37.82	0.91	NS
a*[b]	22.29	21.90	0.37	NS
b*[c]	21.15	20.52	0.39	NS

[a] Measure of lightness(larger number indicates a lighter color).
[b] Measure of redness(larger number indicates a more intense red color).
[c] Measure of yellowness(larger number indicates a more yellow color).

Table 7. Influence of fish oil supplementation on ground rib chemical composition

Item	Control	Fish oil	SEM	P <
Dry matter, %	54.0	52.83	1.5	NS
Crude protein, %	15.03	15.15	0.61	NS
Fat, %	38.5	37.1	1.9	NS
Ash, %	0.65	0.67	0.02	NS

Table 8. Influence of fish oil supplementation on proportions and fluorescence of bovine leukocyte populations

Cell Type	Control	Fish oil	P<
% Lymphocytes	90.51	75.9	NS
T lymphocyte:B lymphocyte	1.88	1.75	NS
Granulocyte:monocyte	0.34	0.39	0.20
Activated T lymphocyte: T lymphocyte	1.19	1.41	NS
Flourescence			
% Lymphocytes	219.58	275.76	0.01
T lymphocyte:B lymphocyte	4.19	4.75	0.06
Granulocyte:monocyte	0.32	0.33	NS
Activated T lymphocyte: T lymphocyte	2.54	3.22	0.20

Immunological and Growth Performance Responses of Finishing Steers Supplemented with Menhaden Fish Oil

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Story in Brief

Inclusion of fish oil in ruminant diets may fortify the fatty acid composition of meat and modulate the immune system. Therefore, an experiment was conducted to determine the effects of supplemental menhaden fish oil on growth performance and immune function of beef calves. The 72-d study used 20 crossbred steers (965.6 ± 61.7 lb initial BW). Dietary treatments consisted of either a control diet or the control diet with 2% fish oil. Calves were bled by jugular venipuncture on d 0, 21, 42, and 63 and in vitro blastogenic response of peripheral lymphocytes to phytohemagglutinin (PHA), concanavalin A (CONA) and pokeweed mitogen (PWM) was measured. Fish oil supplementation decreased ADFI (32.01 vs. 29.28 lb, $P < 0.05$, as-fed); conversely, ADG and feed efficiency did not differ due to fish oil supplementation (4.59 vs. 4.17 lb and 6.97 vs. 7.02; $P > 0.10$). There was no effect of fish oil on mitogen stimulation of isolated lymphocyte proliferation on d 0, 21, or 63. There was a treatment x time interaction ($P < 0.01$) because lymphocytes isolated on d 42 from calves fed the 2% fish oil diet had a smaller proliferation response to stimulation with CONA ($P < 0.01$) and PWM ($P < 0.01$) and tended to have a smaller response to stimulation with PHA ($P < 0.08$) than lymphocytes from calves fed the control diet. Since CONA predominantly stimulates T cells, PWM predominately stimulates B cells, and PHA stimulates both T and B cells, this change indicated that fish oil supplementation on d 42 limited the proliferation of both sets of lymphocytes. More research may be required to document or elicit the exact immunological changes that occur at the cellular level.

Introduction

Ruminants have the ability to utilize by-products from numerous industries as nutrients. Fish industry by-products are potential sources of valuable nutrients, including energy and protein. Fish oil is currently not widely utilized by the cattle industry; however, the effect of feeding other fats to ruminants has been studied. Typically fat is limited to less than 5% of the diet in order to minimize negative effects on ruminal fiber digestion. In the rumen, most triglycerides are broken down and the fatty acids are hydrogenated; however, recent research indicated that increasing the proportion of long-chain omega-3 (n-3) fatty acids in ruminant diets may modify the fatty acid composition in milk.

In the future, there will be considerable emphasis on modification of fatty acid composition of beef. Recently, the dietary recommendation of the highly unsaturated n-3 fatty acids for humans, specifically eicosapentaenoic acid and docosahexaenoic acid, has increased from 0.15 to 0.65 g/d. However, including fish oil (or other types of fat) may have other effects on beef production. Nutritional status has a profound effect on immune function; energy, protein, minerals, and vitamins all affect immune status. Previous research has indicated that isolated lymphocytes from grazing steers supplemented with fish oil had a greater immune response than from steers offered a basal supplement. The objective of this study was to determine the effects of menhaden fish oil addition on growth performance and immune function of cattle consuming a high concentrate ration.

Experimental Procedures

Twenty crossbred steers (965.6 ± 61.7 lb initial BW) were shipped to the University of Arkansas Stocker and Receiving Unit in Savoy prior to the start of the study. Calves were weighed upon arrival, blocked by weight (5 blocks) and assigned randomly to pens. There were two steers in each of the 10 pens, for a total of 10 animals per treatment. All steers were fed a totally mixed ration formulated to meet NRC (1996) recommendations. Dietary treatments (Table 1) consisted of either a control diet or the control diet with 2% menhaden fish oil (substituted for corn).

Steers were weighed on d 0, 1, 21, 42, 63, 72, and 73 and were observed daily for signs of clinical disease. On d 0, 21, 42, and 63 of the study, all calves were bled by jugular venipuncture, and blastogenic response of peripheral lymphocytes to phytohemagglutinin (PHA; Sigma Chemical Co., St. Louis, MO), concanavalin A (CONA; Sigma Chemical Co.) and pokeweed mitogen (PWM; Sigma Chemical Co.) was measured using [^{3}H]thymidine. Skin-fold response to intradermal injection of 150 mg PHA was conducted on d 70.

Feed intake, ADG, and feed efficiency data were analyzed using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC). The model included block and dietary treatment. Lymphocyte blastogenesis and skinfold thickness response to PHA injection data were analyzed using the MIXED procedure of SAS (SAS Inst., Inc., Cary, NC). The model included block, treatment, time, and the treatment x time interaction, with the random effect being treatment x block, the repeated measure being time and the subject being pen.

Results and Discussion

Fish oil supplementation decreased ADFI ($P < 0.05$). However, ADG and feed efficiency did not differ ($P > 0.10$; Table 2). Previous research supports this finding that oil or oil seed supplementation decreases ADFI but ADG and feed/gain do not differ (Bolte et al., 2002; Madrone et al., 2002; and Mandell et al., 1997).

Dietary treatment did not affect unstimulated lymphocytes isolated from steers, but the treatment x time interaction was detected

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($P < 0.01$) for mitogen stimulated lymphocyte proliferation. There was no effect of fish oil supplementation on mitogen stimulation of isolated lymphocytes on d 0, 21, or 63 (Table 3), but lymphocytes isolated from calves fed the 2% fish oil diet had a decreased proliferation response to stimulation with CONA ($P < 0.01$) and PWM ($P < 0.01$), and tended to have a decreased ($P < 0.08$) response to stimulation with PHA than lymphocytes from calves fed the control diet on d 42. Because CONA predominantly stimulates T cells, PWM predominately stimulates B cells, and PHA stimulates both T and B cells, this change indicates that fish oil supplementation limited the proliferation response of both sets of lymphocytes on d 42. Theis et al. (1999) suggested that dietary polyunsaturated fatty acids may act as antiinflammatory agents. Previous research has indicated that dietary lipids modify the cytokine response to intraperitoneally injected bacterial lipopolysaccharide in mice (Sadeghi et al., 1999). They found that peak plasma TNF-alpha, IL-1beta and IL-6 concentrations were lower in fish oil supplemented mice and concluded that these fatty acids might be useful tools in acute and chronic inflammatory diseases. In the current study, skin-fold response to intradermal injection of PHA on d 70 did not differ among treatments (data not shown).

Implications

Fish oil supplementation in this trial had no negative effects on growth performance or feed efficiency. Results indicated that fish oil supplementation modulated lymphocyte immune response in vitro on d 42, but had no effect on in vivo cell-mediated immune response to phytohaemagglutinin. More research may be needed to document the significant immunological changes that occur at the cellular level.

Acknowledgments

The authors would like to extend their deepest gratitude to J. A. Hornsby, G. Carte, and J. Sligar for the management and care of the experimental animals. The authors would also like to acknowledge Omega Protein for donating the fish oil.

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Table 1. Ingredient composition (as-fed basis) of experimental diets

Ingredient	Control	Fish oil
	%	
Corn, cracked	75.4	73.4
Cottonseed hulls	10	10
Soybean meal	11.2	11.2
Cane molasses	2	2
Dicalcium phosphate	0.4	0.4
Limestone, 38%	0.85	0.85
Salt	0.15	0.15
Fish oil	0	2
Rumensin premix[a]	+	+
Vitamin E premix[b]	+	+
Vitamin premix[c]	+	+
Trace mineral premix[d]	+	+

[a] Premix supplied 200 mg of monensin per day.
[b] Premix supplied 0.075 IU vitamin E per pound of diet
[c] Premix supplied per pound of diet: 225 IU of vitamin A, 75 IU of vitamin D_3, and 0.075 IU vitamin E.
[d] Premix supplied: 20 ppm of Zn as ZnO, 10 ppm of Mn as MnO, 0.1 ppm of Se as Na_2SeO_3, and 0.1 ppm of Co as $CoCO_3$.

Table 2. Effect of fish oil supplementation on growth performance responses

Item	Control	Fish oil	SEM
ADFI, lb as fed	32.01[a]	29.28[b]	0.56
ADG, lb	4.59	4.17	0.29
Feed efficiency	6.97	7.02	0.02

[a,b] Means within a row without a common superscript differ ($P < 0.05$).

Table 3. Effect of fish oil supplementation on lymphocyte blastogenic response

Mitogen	Time, d	Control	Fish oil	SEM
		Blastogenic response, 1,000 cpm		
Unstimulated[a]				
	0	3.8	7.1	1.95
	21	13.4	13	1.95
	42	4.9	3.6	1.95
	63	3.2	2.8	1.95
Concanavalin A[b], 25 mg/ml				
	0	205	263	29.4
	21	289	253	29.4
	42	305[c]	186[d]	29.4
	63	219	189	29.4
Phytohaemagglutinin[b] 40 mg/ml				
	0	190	208	23
	21	170	175	23
	42	217[e]	159[f]	23
	63	83	79	23
Pokeweed mitogen[b], 15 mg/ml				
	0	81	108	14.8
	21	123	114	14.8
	42	143[c]	88[d]	14.8
	63	62	58	14.8

[a] Effect of time ($P < 0.01$).
[b] Treatment x time interaction ($P < 0.01$).
[c,d] Means within a row without a common superscript differ ($P < 0.01$).
[e,f] Means within a row without a common superscript differ ($P < 0.08$).

Use of an Immunostimulant to Decrease the Incidence and Severity of Bovine Respiratory Disease Complex.

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Story in Brief

Consumer concerns with the development of antibiotic-resistant pathogens has created research opportunities for examining the use of different management practices, and using products other than antibiotics to treat and prevent disease. The objective of this study was to determine if a bovine immunostimulant, approved by the USDA for use in calves up to 5 days of age, decreases the incidence and severity of bovine respiratory disease in stocker calves acquired from sale barns. Seventy-four stocker calves (496 ± 32 lb) were purchased from several sale barns in Central Arkansas and delivered as a group to the University of Arkansas Beef Cattle Research Facility in Savoy. Calves were randomly assigned to one of two treatment groups (bulls were stratified through treatment groups). Group one (IMM) received 5.0 cc of the immunostimulant, subcutaneous, 24 hours after arrival, group two served as a control (C) and did not receive any immunostimulants. Calves were randomly placed into one of nine grass lots (1.1 acre), with both treatments represented in each lot. Although there were differences in the immune parameters measured, there were no significant differences between the IMM and C groups with regards to clinical illness score, ADG, and medical cost per head. Treatment success for bovine respiratory disease, failure and relapse percentages also showed no differences between treatments.

Introduction

Bovine respiratory disease (BRD) is a costly disease in the cattle industry, both in terms of medical and labor costs and losses in production performance. Bacterial respiratory pathogens, such as Pasteurella spp., can be isolated from the nasal cavity in normal animals. Stressful conditions, such as transportation, processing, crowding, temperature extremes or concurrent viral infection can result in mild to severe BRD (Griffin, 1997). Antibiotic resistance is a concern to the animal and human health industry. The Center for Veterinary Medicine is currently developing guidelines for using antibiotics in food animals. Producers and veterinarians will have to consider alternative management practices and new therapies that will minimize the incidence and severity of BRD.

Immunostimulants can be potentially used to stimulate the immune system and decrease the amount of antibiotics used for BRD. Vaccination stimulates the immune system to produce antibodies to specific pathogens. This method of immunomodulation has been in use for over 100 years, but doesn't always produce the desired results. Non-specific immunostimulants can be used to enhance the immune responses prior to, following, or at vaccinations. They may also help the animal's immune system overcome the immunosuppressive effects of stress and exposure to infectious agents involved with BRD (Quinn, 1990).

The objective of this study was to determine if Immunoboost, decreases the incidence and severity of bovine respiratory disease in stocker calves acquired through the sale barn.

Experimental Procedures

Seventy-four stocker calves (65 bulls and 9 steers, 496 ± 32 lb) were purchased from several sale barns in Central Arkansas and delivered as a group to the University of Arkansas Beef Cattle Research Facility in Savoy, and all calves were randomly assigned to one of two treatment groups (bulls were stratified through treatment groups to nullify any effects of castration). The animals assigned to group one (IMM) were administered 5.0 cc (5 times labeled dose) of Immunoboost® (Vetrepharm, Athens, GA), subcutaneous, 24 h after arrival. Group two served as a control (C) and did not receive any immunostimulant. Calves were randomly placed into one of nine grass lots (1.1 acre), with both treatments represented in each lot. The animals were initially offered a 16% CP supplement (Table 1) at a rate of 2 lb per head per day. This was gradually increased to a maximum of 4 lb per head per day. This amount was offered daily until the end of the study (35 d). Bermudagrass hay was available ad libitum.

All animals were processed within 24 h of arrival. This included a modified-live viral vaccine (Frontier 4-Plus®, Bayer Corp., Shawnee Mission, KS), a multivalent clostridial bacterin (Vision-7®), and a tetanus toxoid. (Vision-CDT,). A pour-on endectocide (Eprinex,, Merial, Athens, GA) was used for parasite control. All animals were re-vaccinated with the same products two weeks after initial processing, however the endectocide was not used. At this time the bulls were castrated using a banding method (Callicrate bander®, No-Bull Enterprises, St. Francis, KS) and any horns were tipped.

Calves with clinical signs of BRD were assigned a clinical illness score (CIS; Table 2) then removed from their home pens and evaluated for treatment. Calves were treated according to a preplanned protocol (Table 3) and moved to a hospital pen until recovery. Therapy success was characterized by a reduction in body temperature by 2°F or < 104°F. No reduction in body temperature was considered to be a therapy failure, and the successive therapy was initiated. A BRD relapse was defined as showing clinical signs of BRD within 21 d of recovery. There were designated hospital pens for first, second and third treatments.

Blood samples were taken from calves via jugular venipuncture at 0 (prior to processing), 24, 48, and 72 h after processing. Serum was collected for infectious bovine rhinotracheitis (IBR) and bovine viral diarrhea (BVD) antibody titers. Whole blood was collected for a total white blood cell count (TWBC) and differential counts on neutrophils, monocytes, lymphocytes, eosinophils and basophils. A neu-

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trophil:lymphocyte (N:L) ratio was calculated. Blood samples for serum were centrifuged at 2060 x g for 20 min, aliquoted into tubes and stored at -4°F until analysis. Serum samples for IBR and BVD titers were analyzed using a virus serum neutralization test at the Oklahoma Animal Disease and Diagnostic Laboratory (OADDL), Stillwater, OK. Results from OADDL were transformed using log base 2. Sodium heparinized whole blood was analyzed within 4 hours of being drawn, for TWBC and differential count, using a CELL-DYN 3500 SL (Abbott, Abbot Park, IL). For the interferon gamma (IFNγ) test, sodium heparinized whole blood was stimulated with 5 mg/ml of phytohemagglutanin (Sigma, St. Louis, MO) and incubated at 98.6°F for 18 to 24 h. The blood was centrifuged at 2060 x g for 20 min. Plasma was aliquoted into two 1.5 ml tubes and stored at -4°F until analysis. Interferon gamma concentrations were determined using Bovigam, Bovine Gamma Interferon Test (Biocor, Animal Health, Omaha, NE). A standard curve was developed for the positive control provided.

Treatment differences between ADG, medical cost/head, cost/lb of gain, CIS, TWBC and N:L ratios were analyzed using PROC GLM (SAS Inst., Inc., Cary, NC). After a base 2 log transformation, IBR titers, BVD titers, and IFNγ were analyzed using PROC GLM. Percentage therapy success, failure and relapse were analyzed using Chi-square.

Results and Discussion

There were no differences between groups for ADG, average medical cost or cost/lb of gain (Table 4). If the cost of Immunoboost“ is factored into the cost/lb of gain, the results for the C group were numerically lower than for the IMM group. The cost of the product for heavier animals may not be cost effective at the dose investigated and would have to be re-evaluated for use in stocker cattle. There were no differences in CIS between groups (Table 4). There also were no differences between groups with regards to therapy success, failure and relapses (Table 5).

There were no differences between groups when the TWBC was examined (Table 6). The N:L ratio peaked for both groups at 24 h (Table 6), and was not different between groups. By 48 h, the ratio for IMM group was lower than the C group, approaching significance ($P = 0.08$), and by 72 h, the ratio of the IMM group was significantly lower than the C group ($P = 0.04$). This is indicative of the stimulation of lymphocyte production by the Immunoboost®. The IBR and BVD titers both increased from sample d 0 to 14 to 35, which is indicative of a vaccination response. The IBR titers for the IMM group were numerically higher at day 35 ($P = 0.13$). These results may be due to IFNγ's role in the enhancement of antibody production.

The IFNγ levels increased from 0 h to 72 h (Table 7). The IFNγ concentrations in the IMM group were higher than in the C group at 48 h ($P = 0.07$) and at 72 h ($P < 0.05$). This is consistent with how the immunostimulant functions.

Interferons are proteins produced by several cells of the immune system. Some of them have the ability to kill viruses and prevent further spread. Interferon gamma is the primary cytokine produced by several cells of the immune system. It enhances macrophage phagocytosis and stimulates lymphocytes involved with the production of specific antibodies (Abbas et al., 2000). Human recombinant IFNγ has been administered to cattle at vaccination and has been shown to enhance antibody production (Babiuk, et al., 1984).

A mycobacterium cell wall fraction (Immunoboost®, Vetrepharm, Athens, GA) was administered (1 ml, given once) to Holstein and Holstein-cross calves less then 24 h old. There was a positive effect on ADG, health (decreased treatment days), and economics (antibiotic use decreased 17%) (Nosky et al., 1999). Additionally, 250 Holstein-cross calves were given 1 or 3 ml of Immunoboost® on entry to a feedyard. Those receiving Immunoboost® significantly out-performed control calves over a 102-d observation period (Biwer et al., Personal Communication). In another study, calves weighing 500 to 600 lb treated with Immunoboost, upon arrival, had a 14 % greater increase in ADG when compared to the control group (Vetrepharm Technical Report, 1999).

With regards to the immune parameters measured, the Immunoboost® was successful in boosting the immune response. The clinical picture, however, did not reflect greater protection against disease. The reported success of the product in young calves, and not this group of cattle may be due to several things: 1). Immune stimulants may have a more profound effect on the immature developing immune system of a younger calf. 2). Increases in growth rates may be more difficult to attain in heavier cattle. 3). The stress involved with castration compromises evaluation of immune responses. 4). These results are more likely a result of when the product was administered. The calves in this study had already received considerable pathogen challenge at the sale barn. It would be more reasonable to administer the product from 0 to 72 h before they are shipped to the sale barn from the ranch, or as they arrive at the sale barn. The way cattle are processed through the livestock marketing system, it is doubtful that the administration of a product upon arrival at the sale barn would be well received.

Implications

Immunoboost® did show numerically positive results for the immune parameters examined, indicating that there may be additional stimulation of the immune system using this product. However, there were no differences in level of morbidity, response to therapy, medication costs, and cost/lb of gain. The product should be evaluated further with different size and types of calves, and different dosages and times of administration before deciding its usefulness in stocker operations.

Acknowledgments

The authors would like to thank Pendergrass Cattle Company for providing the calves for this project. In addition, the provision of the Immunoboost“ from Vetrepharm is greatly appreciated.

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Table 1. Nutrient composition of supplement

Ingredient	%
Corn-cracked	77
Soybean meal, 48% CP	18
Molasses	2
Dicalcium phosphate	0.18
Limestone	1.8
Salt	1
Vitamin premix	+
Vitamin E Premix	+
Trace mineral/corn premix[1]	+
Rumensin/corn premix[2]	+

[1] Trace mineral premix added 26 mg zinc and 0.1 mg selenium/kg diet
[2] Added to provide 33.6 mg lasalocid/kg diet

Table 2. Clinical illness score (CIS) for calves treated for bovine respiratory disease (BRD)[a]

CIS	Description	Clinical appearance
1	Normal	No abnormal signs noted
2	Slightly ill	Mild depression, gaunt, +/- ocular/nasal discharge
3	Moderately ill	Ocular/nasal discharge, gaunt, lags behind other animals in the group, coughing, labored breathing, moderate depression, +/- rough hair coat, weight loss
4	Severely ill	Severe depression, labored breathing, purulent ocular/nasal discharge, not responsive to human approach
5	Moribund	Near death

[a] Modified from BRD clinical assessment score criteria provided by Dr. David McClary, Elanco Animal Health, Greenfield, IN.

Table 3. Therapy schedule for calves treated for bovine respiratory disease (BRD)

Therapy 1: Nuflor: 6 ml/100 lb (40 mg/kg) Subcutaneous
- Check in 48 h
- If rectal temperature is <104°F then treatment success. Return animal to home pen.
- If rectal temperature is ≥ 104°F and has dropped 2 degrees, therapy is successful, thus give a second dose of Nuflor and hold in hospital pen another 48 h
- If rectal temperature is ≥ 104°F and has not dropped 2 degrees, then go to therapy 2 (therapy failure).

Therapy 2: Excenel 1.5 ml/100 lb (2.2 mg/kg) subcutaneous
- Treat for 3 consecutive days.
- If rectal temperature after 3rd day is < 104°F then therapy is successful. Return animal to home pen.
- If rectal temperature after 3rd day is ≥104°F and has dropped 2 degrees, therapy is successful, thus give a fourth dose of Excenel and hold in hospital for another 24 h
- If rectal temperature after 3rd day is ≥ 104°F and has not dropped 2 degrees, go to therapy 3 (therapy failure).
- Also for animals that recovered from therapy 1 and relapse at a later date.

Therapy 3: Penicillin (BenzaPen) 2 ml/150 lb subcutaneous
- Check in 48 h
- If rectal temperature is < 104°F then therapy is successful. Return to home pen.
- If rectal temperature is ≥ 104°F and has dropped 2 degrees, therapy is successful, thus give a second dose of Penicillin and hold in hospital pen another 48 h.
- If rectal temperature is ≥ 104°F and has not dropped 2 degrees, then give 2nd dose of Penicillin (therapy failure).
- Also for animal that recovered from therapy 2 and relapsed at a later date.

Table 4. Means ± SE of clinical illness score, ADG, medication cost, and cost/lb of gain

	Group		
Item	IMM[a]	C[b]	P-value
Average clinical illness score[c]	2.48 ± 0.12	2.50 ± 0.11	0.89
ADG (lb/hd/d)	2.12 ± 0.14	2.04 ± 0.14	0.67
Average medical cost/head, $	8.92 ± 1.37	9.42 ± 1.35	0.80
Cost per pound of gain, $	1.75 ± 0.81	0.96 ± 0.80	0.49
Cost/lb/gain w/IMM, $	2.35 ± 1.06	0.96 ± 1.04	0.35

[a] IMM = Immunoboost® group
[b] C = Control group
[c] Average clinical illness score when animals were initially pulled.

Table 5. Percentage of treatment success, failure, and relapse in stocker calves treated for bovine respiratory disease[ab]

	Group	
Item	IMM[c]	C[d]
Therapy success, %	84 (21/25)	86 (24/28)
Therapy failure, %	4 (1/25)	0 (0/28)
Relapse, %	12 (3/25)	14 (4/28)

[a] Data include therapy 1, 2, and 3
[b] Chi-square P = 0.56
[c] IMM = Immunoboost® group
[d] C = Control group

Table 6. Total white blood cells (TWBC), neutrophil:lymphoctye ratio (N: L), and serum titers for infectious bovine rhinotracheitis (IBR) and bovine viral diarrhea (BVD) prior to processing (0 h) and 24, 48, 72 h after processing

	Group		
Item[a]	IMM[b]	C[c]	P-value
TWBC (cells/ml)			
0 h	10,744 ± 518	10,005 ± 518	0.32
24 h	10,141 ± 456	10,098 ± 456	0.95
48 h	9,254 ± 503	10,011 ± 503	0.29
72 h	9,550 ± 497	9,462 ± 947	0.90
N:L ratio			
0 h	0.37 ± 0.042	0.37 ± 0.042	0.97
24 h	0.65 ± 0.057	0.65 ± 0.057	0.97
48 h	0.36 ± 0.055	0.50 ± 0.055	0.08
72 h	0.28 ± 0.041	0.40 ± 0.041	0.04
IBR titer			
d 0	0.57 ± 0.192	0.46 ± 0.192	0.70
d 14	2.06 ± 0.223	1.68 ± 0.220	0.22
d 35	2.51 ± 0.169	2.15 ± 0.167	0.13
BVD titer			
d 0	0.88 ± 0.353	0.88 ± 0.353	1.00
d 14	1.32 ± 0.427	1.33 ± 0.421	0.99
d 35	4.30 ± 0.303	4.42 ± 0.299	0.78

[a] IBR and BVD Data transformed to log base 2
[b] IMM = Immunoboost® group
[c] C = Control group

Table 7. Mean interferon-g (IFNγ)[a] assay for stocker calves prior to processing (0 h) and 24, 48, 72 h after processing

	Group		
Hours after processing	IMM[b]	C[c]	P-value
0	0.202 ± 0.033	0.140 ± 0.033	0.20
24	0.285 ± 0.066	0.158 ± 0.066	0.18
48	0.670 ± 0.127	0.338 ± 0.127	0.07
72	1.177 ± 0.207	0.491 ± 0.207	0.02

[a] µg/ml
[b] IMM = Immunoboost® group
[c] C = Control group

Effects of Lysine and Energy Density of Diets of Finishing Pigs fed Ractopamine. I. Performance and Carcass Yield

D. C. Brown[1], J. K. Apple[1], Charles V. Maxwell[1], Kim G. Friesen[1], R. E. Musser[2], Z. B. Johnson[1], and T. A. Armstrong[3]

Story in Brief

A total of 216 crossbred barrows and gilts (Yorkshire x Landrace females mated to Dekalb EB sires) were used to test the effects of energy density (E) and lysine-to-energy ratio (Lys:ME) on performance and carcass composition of finishing pigs fed ractopamine. Pigs, with an initial BW of 185 lb, were blocked by weight and sex and assigned to one of 36 pens. Pens were randomly assigned to one of six dietary treatments arranged in a 2 x 3 factorial design, with two levels of E (1.50 or 1.58 Mcal/lb of ME) and three Lys:ME ratios (1.7, 2.4 or 3.1 g lysine/Mcal). All diets included 9 g/ton ractopamine and were fed for 28 d prior to harvest. Overall main effects are reported where no E x Lys:ME interaction ($P > 0.05$) was observed. Pigs had a higher fat depth measurement and a lower percentage standardized lean yield (SLY) and F/G when fed 1.58 Mcal/lb of ME compared to pigs fed 1.50 Mcal/lb of ME. Pigs had a greater ($P < 0.05$) ADG, hot carcass weight, LM depth and percentage SLY, and a reduced ($P < 0.05$) fat depth and F/G as the level of Lys increased in the diet. Results indicate that to optimize lean tissue deposition in pigs fed ractopamine, 1.50 Mcal/lb is sufficient energy and lysine requirements may be higher than reported in the literature and higher than levels currently utilized in the swine industry.

Introduction

Ractopamine hydrochloride (Paylean™, Elanco Animal Health, Greenfield, IN) effectively repartitions nutrients from fat deposition (Dunshea et al., 1993) toward increased protein synthesis (Bergen et al., 1989) and muscle protein accretion without impacting pork quality (McKeith et al., 1988). The observed increase in lean growth in pigs fed diets containing ractopamine would require increased dietary protein content and(or) amino acids to sustain protein synthesis and accretion in finishing swine (Dunshea et al., 1993).

During the finisher phase, diets are formulated to maintain the reduced amino acid requirements due to reduced lean tissue synthesis/deposition. These amino acid levels may not be sufficient to meet the requirements of pigs fed ractopamine. It also appears that ractopamine is capable of producing maximal lean composition in pork carcasses at low energy intakes by repartitioning energy for maximum protein deposition (Williams et al., 1994). These studies indicate that the lysine-to-metabolic energy (Lys:ME) ratio may impact performance and carcass characteristics in ractopamine-fed pigs more than absolute energy intake values. Therefore, the objective of this study was to determine the interactive effect, if any, of energy density and Lys:ME ratios on performance and carcass characteristics of finishing swine fed ractopamine.

Experimental Procedures

Allotment of Pigs and Experimental Treatments: A total of 216 crossbred barrows and gilts (Yorkshire x Landrace females mated to DeKalb EB sires) with an average body weight of 185 lb, were purchased from The Pork Group (a division of Tyson Foods, Inc., Rogers, AR), and moved to the University of Arkansas Swine Research Facility. Pigs were blocked by BW and sex, and allotted to 36 pens (six pigs/pen). After a one-week adjustment period when a common diet (devoid of ractopamine) was fed, pens were assigned randomly within blocks to one of six dietary treatments in a 2 x 3 factorial arrangement, with two levels of energy (1.50 or 1.58 Mcal/lb) and three lysine-to-energy (Lys:ME) ratios (1.7, 2.4, or 3.1 g lysine/Mcal). Ractopamine was included in all diets at a level of 9 g/ton, and diets (Table 1) met, or exceeded, NRC (1998) requirements for 175 to 240 lb pigs. Diets were formulated to provide total lysine levels from a low of those recommended by NRC (1998) to a high of those sufficient to meet estimated lysine requirements of pigs fed Paylean™ (Schinckel et al., 2000). The lowest Lys:ME ratio (1.7 g/Mcal) was selected based on the level typically fed in commercial swine finishing operations (personal communication); whereas, the highest Lys:ME ratio (3.1 g/Mcal) was based on the optimal ratio suggested by Chiba et al. (1991) and K. G. Friesen (personal communication).

Performance Data: Pigs were fed experimental diets for 28 d, and individual pig weights and feed disappearance were recorded at 7-d intervals during the experiment to calculate ADG, ADFI, and feed-to-gain ratio (F/G).

Carcass Data: At the completion of the trial, pigs were transported approximately 10 h to a commercial pork harvest/fabrication plant (Excel Corp.; Beardstown, IL). Carcass weight and fat depth opposite the first rib, last rib, and last lumbar vertebra were recorded at 24 h postmortem. Hams from the left sides were analyzed for lean and fat composition using a TOBEC unit. Prediction equations utilized to estimate carcass lean yield and fat content are the intellectual property of Excel Corp. (Wichita, KS) and cannot be presented.

Statistical Analysis: Performance, carcass yield, and pork quality data were analyzed as a randomized complete block design with pen as the experimental unit and blocks based on initial body weight. Analysis of variance was generated using the GLM procedure of SAS (SAS Inst. Inc. Cary, NC) with energy density, Lys:ME ratio, and energy x Lys:ME as the main effects in the model. Linear and quadratic contrasts were used to detect the response of Lys:ME ratio across and within energy levels, as well as the contrast between energy levels (1.50 vs. 1.58 Mcal ME/lb).

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Results and Discussion

Performance. For the overall trial, there were no differences (P > 0.10) in ADG and ADFI (Table 2) among the dietary energy levels. Pigs fed the high energy diets were more efficient (P < 0.02), as evidenced by lower F/G, than pigs fed the low energy diets. Increasing the Lys:ME ratio in the diets of pigs resulted in linear increases (P < 0.001) in ADG and BW. Feed disappearance was similar (P > 0.10) across Lys:ME ratios; however, F/G decreased linearly (P < 0.05) as Lys:ME ratio increased from 1.7 to 3.1 lb/Mcal. Thus, increasing the Lys:ME ratio in the diets of pigs resulted in improvements in performance and feed efficiency. As observed in the current study, previous research has shown that ADG increased proportionally as lysine-to-energy ratios increased from 3.0 to 4.0 g/Mcal ME (Brendemuhl and Harrison, 1990); whereas, ADG and efficiency were improved in pigs fed diets with lysine-to-energy ratios of 3.64 and 4.44 lb/Mcal (Libal et al., 1990).

Carcass. Energy density of finishing diets had no effect (P > 0.10) on the overall hot carcass weight (HCW) and longissimus muscle (LM) depth of pigs (Table 2). However, HCW (P < .02) increased quadratically with increasing Lys:ME ratio. Carcasses from pigs fed 1.58 Mcal/lb were fatter than carcasses from pigs fed the low energy diets, resulting in lower (P < 0.06) standardized lean yields compared to carcasses from pigs fed 1.50 Mcal/lb. It should be noted, however, that these differences were due primarily to large increases in 10th rib fat depth in pigs fed the lower Lys:ME diet at the higher energy level. This resulted in an energy level by Lys:ME ratio interaction (Table 3; Linear, P < 0.06). Longissimus muscle depth and carcass lean yield increased (P < 0.003) as Lys:ME ratio increased from 1.7 to 3.1 g/Mcal (Table 2). The magnitude of increase in lean yield with increasing Lys:ME ratio was greater in pigs fed the higher energy diets than in pigs fed the low energy diets (Table 3; Linear Interaction, P < 0.06). These results are similar to other studies that have found that ractopamine fed pigs are capable of achieving maximum lean gains at lower energy levels (Williams et al., 1994).

Implications

The results from this study indicate that 1.50 Mcal ME/lb of energy is sufficient energy in diets for pigs fed ractopamine to optimize ADG, F/G and lean tissue deposition. The level of lysine in diets for pigs fed ractopamine may be higher than reported to optimize performance and lean yield.

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Table 1. Finisher diet composition

	Lysine:ME ratio for low energy (1.50 Mcal/lb)			Lysine:ME ratio for high energy (1.58 Mcal/lb)		
Ingredient, %	1.7 (g/Mcal)	2.4 (g/Mcal)	3.1 (g/Mcal)	1.7 (g/Mcal)	2.4 (g/Mcal)	3.1 (g/Mcal)
Corn	71.295	67.075	58.685	65.325	60.695	51.825
Wheat middlings	15.00	15.00	15.00	15.00	15.00	15.00
Soybean meal, 48%	9.65	13.75	22.13	11.15	15.68	24.54
Fat	1.10	1.10	1.15	5.59	5.59	5.62
Urea	1.05	1.05	1.05	1.05	1.05	1.05
Calcium carbonate	0.85	0.83	0.76	0.83	0.81	0.75
Salt	0.50	0.50	0.50	0.50	0.50	0.50
Dicalcium phosphate	0.25	0.22	0.21	0.25	0.21	0.19
Vitamin premix[a]	0.125	0.125	0.125	0.125	0.125	0.125
Mineral premix[b]	0.10	0.10	0.10	0.10	0.10	0.10
Paylean™ 9	0.05	0.05	0.05	0.05	0.05	0.05
Ethoxyquin	0.03	0.03	0.03	0.03	0.03	0.03
Lysine	0.00	0.15	0.15	0.00	0.15	0.15
Methionine	0.00	0.00	0.02	0.00	0.00	0.03
Threonine	0.00	0.02	0.04	0.00	0.01	0.04
Total composition, %						
Crude protein	16.00	17.68	21.00	16.16	18.05	21.58
Lysine	0.562	0.793	1.024	0.592	0.835	1.079
Methionine	0.22	0.25	0.31	0.22	0.25	0.32
Methionine & cysteine	0.47	0.53	0.63	0.47	0.53	0.65
Valine	0.61	0.69	0.84	0.62	0.71	0.87
Threonine	0.46	0.55	0.70	0.47	0.55	0.72
Tryptophan	0.14	0.16	0.21	0.14	0.17	0.22
Calcium	0.45	0.45	0.45	0.45	0.45	0.45
Phosphorus	0.15	0.15	0.15	0.15	0.15	0.15
Energy (Mcal/lb)	1.50	1.50	1.50	1.58	1.58	1.58
Calculated available composition, %						
Lysine	0.482	0.702	0.914	0.510	0.742	0.965
Methionine	0.20	0.22	0.28	0.20	0.22	0.29
Methionine & cysteine	0.42	0.46	0.56	0.42	0.46	0.57
Threonine	0.39	0.47	0.60	0.40	0.48	0.63
Tryptophan	0.12	0.14	0.19	0.13	0.15	0.20

[a] Nutra-Blend Vitamin Premix (NB-6157B) which meets, or exceeds, NRC (1998) requirements.
[b] Nutra-Blend Mineral Premix (NB-8557B) which meets, or exceeds, NRC (1998) requirements.

Table 2. Main effects of energy density and lysine-to-energy ratio on live pig performances and carcass yield for the overall trial

	Energy (Mcal/lb)			Lysine:energy (g/Mcal)			
Item	1.50	1.58	SE	1.7	2.4	3.1	SE
ADG, lb[a]	1.41	1.49	0.050	1.28	1.45	1.63	0.028
ADFI, lb	4.74	4.58	0.092	4.68	4.69	4.61	0.112
F:G[a,b]	3.44	3.12	0.080	3.72	3.28	2.85	0.098
BW, lb[a]	232.9	235.1	0.682	228.6	235.1	238.3	0.835
Hot carcass weight, lb[c]	172.2	172.6	1.091	168.0	175.0	174.2	1.336
Fat depth, mmd,[e]	19.1	20.2	0.392	20.7	19.3	18.9	0.541
LM depth, mm[f]	59.1	58.7	0.685	56.7	59.3	60.7	0.854
Lean yield, %d,[f]	51.40	50.59	0.299	50.07	51.23	51.69	0.373

[a] Linear effect of lysine-to-energy ratio ($P < 0.001$).
[b] Effect of energy density ($P < 0.02$).
[c] Quadratic effect of lysine-to-energy ratio ($P < 0.02$).
[d] Effect of energy density ($P < 0.06$).
[e] Linear effect of lysine-to-energy ratio ($P < 0.02$).
[f] Linear effect of lysine-to-energy ratio ($P < 0.003$).

Table 3. Treatment means of energy density and lysine-to-energy ratio on carcass yield

	Energy:ME ratio for energy density of 1.50 Mcal/lb			Energy:ME ratio for energy density of 1.58 Mcal/lb			
Item	1.7 (g/Mcal)	2.4 (g/Mcal)	3.1 (g/Mcal)	1.7 (g/Mcal)	2.4 (g/Mcal)	3.1 (g/Mcal)	SE
Fat depth, mm[a]	19.5	18.8	19.1	21.9	19.8	18.9	0.728
Lean yield, %1	50.97	51.65	51.58	49.16	50.82	51.80	0.555

[a] Energy by Lysine:ME ratio effect (Linear, P < 0.06).

Effects of Lysine and Energy Density of Diets of Finishing Pigs fed Ractopamine. II. Pork Quality

D. C. Brown[1], J. K. Apple[1], Charles V. Maxwell[1], Kim G. Friesen[1], R. E. Musser[2], Z. B. Johnson[1], and T. A. Armstrong[3]

Story in Brief

Crossbred barrows and gilts (n =216; Yorkshire x Landrace females mated to Dekalb EB sires) were used to test the effects of energy density (E) and lysine-to-energy ratio (Lys:ME) on pork quality of finishing pigs fed ractopamine. Pigs were blocked by initial BW (185 ± 0.88 lb) and sex and assigned to one of 36 pens. Pens were randomly assigned to one of six dietary treatments in a 2 x 3 factorial arrangement, with two levels of E (1.50 or 1.58 Mcal/lb of ME) and three Lys:ME ratios (1.7, 2.4 or 3.1 g lysine/Mcal). All diets included 9 g/ton ractopamine and were fed for 28 d prior to harvest. There was a linear decrease ($P < 0.001$) in intramuscular lipids and marbling, while the protein content of the longissimus muscle (LM) and shear force increased linearly ($P < 0.01$) as the Lys:ME ratio increased in the diet of pigs. The LM from pigs fed 2.4 g/Mcal lysine had lower pH than pigs fed 1.7 and 3.1 g/Mcal lysine at the low energy level; however, for the high energy diets the reverse occurred (Quadratic interaction, $P < 0.04$). Lightness values decreased with increasing Lys:ME ratio in pigs fed both energy levels; however, the decrease was greater in pigs fed 2.4 g/Mcal lysine at the higher energy level (Linear interaction, $P < 0.05$). Results indicate that ractopamine-fed pigs can be fed lower energy levels without affecting pork quality traits and that feeding reduced levels of lysine can increase marbling and associated tissue lipid levels.

Introduction

Inclusion of ractopamine hydrochloride (Paylean™, Elanco Animal Health, Greenfield, IN) to finishing pig diets has consistently been shown to improve growth and carcass leanness without affecting the quality of the carcass (Williams et al., 1994; Dunshea et al., 1993). Ractopamine has the ability to repartition the dietary nutrient intake towards protein accretion leading to increased protein synthesis (Bergen et al., 1989), while also stimulating lipolysis and inhibiting lipogensis (Dunshea, 1993). This increased muscle accretion due to the inclusion of ractopamine increases the dietary protein and/or amino acid requirement of finishing pigs (Dunshea et al., 1993). Additionally, studies have shown that ractopamine-fed pigs are capable of achieving maximum lean gains at lower energy levels (Williams et al., 1994). These studies indicate that the lysine-to-energy (Lys:ME) ratio may impact pork quality in ractopamine-fed pigs more than absolute energy intake values. Therefore, the objective of this study was to determine the interactive effect, if any, of energy density and Lys:ME ratios on pork quality of finishing swine fed ractopamine.

Experimental Procedures

Allotment of Pigs and Experimental Treatments: A total of 216 crossbred barrows and gilts (Yorkshire x Landrace females mated to DeKalb EB sires), with an average body weight of 185 lb, were purchased from The Pork Group (a division of Tyson Foods, Inc., Rogers, AR), and moved to the University of Arkansas Swine Research Facility. Pigs were blocked by BW and sex, and allotted to 36 pens (six pigs/pen). After a one-week adjustment period when a common diet (devoid of ractopamine) was fed, pens were assigned randomly within blocks to one of six dietary treatments arranged in a 2 x 3 factorial design, with two levels of energy (1.50 or 1.58 Mcal/lb) and three lysine-to-energy (Lys:ME) ratios (1.7, 2.4, or 3.1 g lysine/Mcal). Ractopamine was included in all diets at a level of 10 ppm, and diets (refer to Table 1 in companion manuscript; Brown et al., 2002) met, or exceeded, NRC (1998) requirements for 175 to 240 lb pigs.

At the completion of the trial, pigs were transported approximately 10 h to a commercial pork harvest/fabrication plant (Excel Corp.; Beardstown, IL). After a 6-h rest at the plant, all pigs were harvested according to industry-accepted procedures. Following a 24-h rapid chilling period, bone-in pork loins from left sides were captured during fabrication and subsequently vacuum-packaged, boxed, and transported back to the University of Arkansas for pork quality data collection.

Upon arrival, pork loins were removed from the packaging material, cut between the 10th and 11th ribs, and the area of the longissimus muscle (LM) was traced onto acetate paper. The area of the LM was measured using a compensating polar planimeter at a later date. Then, LM chops were removed from the posterior portion of the loin, starting at the 11th rib in the following order: 1) two 1.0-in thick chops used for subjective and objective pork quality measurements; 2) two 1.50-in thick chops used for drip loss determination; and 3) one 1.0-in thick LM chop trimmed free of all bone, external fat, and connective tissue, vacuum-packaged, and frozen for LM moisture and proximate compositional analysis.

After a 30-min bloom period at 38°F, the 1.0 in thick LM chops were visually evaluated for marbling (1 = devoid to 10 = abundant), firmness (1 = very soft and watery to 5 = very firm and dry), and color based on both the American (1 = pale, pinkish gray to 6 = dark purplish red) and Japanese color standards (Nakai et al., 1975). For color analysis of LM the L*, a*, and b* values were determined from a mean of four random readings made with a HunterLab MiniScan using illuminant C and a 10° standard observer. The saturation index, or chroma (C*) was calculated as $C^* = (a^2 + b^2)^{0.5}$ and is a measure

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of the total color, or vividness of the color, of the LM. After quality data collection, both LM chops were wrapped in white, polycoated, heavy-weight freezer paper, and frozen at -4°F before cooking and Warner-Bratzler shear force (WBSF) determinations.

Drip loss percentage was determined following a modified suspension procedure of Honikel et al. (1986), and moisture content was determined according to the freeze-drying method of Apple et al. (2001). Additionally, 2 g of LM from each chop after core removal was homogenized in 20 mL of distilled, deionized water, and the pH of the homogenate was measured with a temperature compensating, combination electrode attached to a pH/Ion/FET-meter (Model AP25; Denver Instrument Co., Arvada, CO).

Longissimus muscle chops were thawed for 16 h at 36°F, then weighed, and cooked to an internal temperature of 160°F in a preheated commercial convection oven (Blodgett Oven Co., Burlington, VT) preheated to 325°F. Internal temperature was monitored with Teflon-coated thermocouple wires placed into the geometric center of each LM chop and attached to a multichannel data logger. Immediately after removal from the oven, chops were blotted dry on paper towels and weighed, and the difference between precooked and cooked weights was used to calculate cooking loss percentage. Chops were allowed to cool to room temperature, and five 0.5-in diameter cores were removed parallel to the muscle fiber orientation. Then, each core was sheared once through the center with a Warner-Bratzler shear force device attached to an Instron Universal Testing Machine with a 110-lb tension/compression load cell and a crosshead speed of 250 mm/min.

Statistical Analysis: Pork quality data were analyzed as a randomized complete block design with pen as the experimental unit and blocks based on initial body weight. Analysis of variance was generated using the GLM procedure of SAS (SAS Inst. Inc. Cary, NC) with energy density, Lys:ME ratio, and energy x Lys:ME as the effects in the model. Linear and quadratic contrasts were used to detect the response of Lys:ME ratio across and within energy levels, as well as the contrast between energy levels (1.50 vs. 1.58 Mcal ME/lb).

Results and Discussion

Dietary energy density had no effect ($P > 0.10$) on any pork quality trait measured (Table 1). Moreover, drip loss, Japanese color score, American color score, firmness score, redness (a*) value, LM moisture and ash content, and cooking loss were not ($P > 0.10$) affected by Lys:ME ratio. These data are similar to the study by Jeremiah and coworker (1994) where altering the level of protein in the diets of pigs fed ractopamine did not modify meat quality traits.

The yellowness (b* value) and vividness of color (C* value) of the LM decreased linearly ($P < 0.02$; Table 1) as Lys:ME increased from 1.7 to 3.1 g/Mcal; however, differences between Lys:ME levels are quite small and seemingly irrelevant. The LM from pigs fed 2.4 g/Mcal lysine had lower pH values than the LM from pigs fed 1.7 and 3.1 g/Mcal lysine when pigs were fed the low energy diets. However, the reverse occurred in pigs fed the high energy diets where muscle pH was higher in loins from pigs fed 2.4 g/Mcal lysine compared to those fed 1.7 or 3.1 g/Mcal lysine (Quadratic interaction, $P < 0.04$; Table 2). The L* values decreased with increasing Lys:ME ratio in pigs fed either energy level, but the decrease was greater when pigs were fed the 2.4 g/Mcal lysine level in the higher energy diet. These data indicate that feeding increased Lys:ME levels produce darker colored pork without impacting redness.

The protein content of the LM also increased linearly ($P < 0.0006$; Table 1) with increasing Lys:ME ratio, indicating that the pork from pigs became leaner as Lys:ME ratio was increased in the diet. Additionally, both subjective and objective measures of intramuscular lipid decreased linearly ($P < 0.0004$) with increasing Lys:ME ratio. In finishing pigs, increasing the Lys:ME ratio in the diet resulted in a linear reduction in marbling ($P < .0004$) and a linear ($P < 0.0065$) increase in shear force of cooked LM chops as Lys:ME-ratio increased from 1.7 to 3.1 g/Mcal. As expected, feeding reduced levels of lysine increased intramuscular marbling and associated tissue lipid levels and decreased shear force values.

Implications

The results of this study indicate that altering the lysine-to-energy ratio or energy level in diets for pigs fed ractopamine to improve production efficiency and carcass composition has no adverse effects on pork quality.

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Table 1. Main effects of energy density and lysine-to-energy ratio on pork quality traits

	Energy (Mcal/lb)			Lysine:energy (g/Mcal)			
Item	1.50	1.58	SE	1.7	2.4	3.1	SE
Drip loss, %	3.86	3.88	0.135	3.88	3.67	4.07	0.165
Japanese color[a]	2.9	2.9	0.051	2.8	3.0	2.9	0.062
American color[b]	3.2	3.2	0.048	3.2	3.3	3.2	0.059
Marbling[c] [1]	2.0	2.1	0.077	2.4	2.0	1.8	0.094
Firmnessd	3.1	3.0	0.034	3.1	3.1	3.0	0.042
Redness (a*)[e]	6.37	6.47	0.105	6.51	6.52	6.23	0.129
Yellowness (b*)[e] [3]	14.06	14.16	0.081	14.30	14.08	13.96	0.100
Chroma (C*)[f] [3]	15.47	15.62	0.096	15.75	15.50	15.33	0.118
LM moisture, %	73.18	73.07	0.122	73.03	73.02	73.32	0.150
LM protein, %[4]	84.38	84.60	0.375	83.04	84.85	85.59	0.460
LM lipid, %[1]	8.12	8.41	0.375	9.84	7.76	7.20	0.459
LM ash, %	4.24	4.19	0.039	4.17	4.21	4.26	0.048
Cooking loss, %	24.65	24.81	0.429	24.53	24.42	25.24	0.525
Shear force, lb[5]	1.89	1.94	0.106	1.78	1.94	2.02	0.130

[a] Japanese color score: 1 = pale gray and 6 = dark purple (Nakai et al., 1975)

[b] American color score: 1 = pale pinkish gray and 6 = dark purplish red (NPPC, 1999)

[c] Marbling score: 1 = 1% intramuscular lipid and 10 = 10% intramuscular lipid (NPPC, 1999)

[d] Firmness core: 1 = very soft/very watery and 5 = very firm/very dry (NPPC, 1991)

[e] L* = measure of lightness to darkness (larger number indicates a lighter color); a* = measure of redness (larger number indicates a more intense red color); and b* = measure of yellowness (larger number indicates more yellow color)

[f] Chroma, or saturation index, is a measure of vividness of color (larger number indicates more vivid color).

[1] Linear effect of lysine-to-energy ratio ($P < 0.0004$)

[2] Quadratic effect of lysine-to-energy ratio ($P < 0.04$)

[3] Linear effect of lysine-to-energy ratio ($P < 0.02$)

[4] Linear effect of lysine-to-energy ratio ($P < 0.0006$)

[5] Linear effect of lysine-to-energy ratio ($P < 0.0065$)

Table 2. Interactive effect of energy density and lysine-to-energy ratio on pork quality traits

		Trait	
Energy level	Energy:ME ratio	Muscle pH[1]	Lightness (L*)[a,2]
1.50 Mcal/lb	1.7 (g/Mcal)	5.66	52.46
	2.4 (g/Mcal)	5.60	52.10
	3.1 (g/Mcal)	5.63	51.85
1.58 Mcal/lb	1.7 (g/Mcal)	5.60	52.76
	2.4 (g/Mcal)	5.66	50.94
	3.1 (g/Mcal)	5.62	51.86
SE		0.021	0.370

[a] L* = measure of lightness to darkness (larger number indicates a lighter color); a* = measure of redness (larger number indicates a more intense red color); and b* = measure of yellowness (larger number indicates more yellow color)

[1] Energy by Lys:ME ratio effect (Quadratic, $P < 0.02$)

[2] Energy by Lys:ME ratio effect (Quadratic, $P < 0.05$)

Efficacy of Pasteurized and Non-pasteurized Egg Protein as a Replacement for Spray-dried Plasma in the Diets of Weaned Pigs

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Story in Brief

A total of 216 segregated early-weaned barrows were fed one of six dietary treatments to evaluate the effects of pasteurization on the efficacy of egg protein as a complete or partial replacement for spray-dried animal plasma in weanling pig diets. Pigs (20 ± 2 d of age; 12.3 lb BW) were blocked based on initial BW and assigned to one of six treatments in a randomized complete block designed experiment. There was a total of six pens representing each dietary treatment with six pigs/pen. Six diets fed during phase 1 (d 0 to 10 after weaning) were as follows: 1) a negative control diet devoid of egg protein and spray-dried animal plasma, 2) a positive control diet containing 5% spray-dried plasma added at the expense of soybean meal on an equal lysine basis, 3) as 2, with pasteurized egg protein replacing 50% of the spray-dried plasma, 4) as 2, with pasteurized egg protein replacing 100% of spray-dried plasma, 5) as 2, with non-pasteurized egg protein replacing 50% of spray-dried plasma, and 6) as 2, with non-pasteurized egg protein replacing 100% of spray-dried plasma. Common phase 2 and phase 3 diets were fed from d 10 to 24 after weaning and d 24 to 38 after weaning, respectively. During phase 1, egg protein at the 50% inclusion level resulted in greater ADG ($P = 0.06$) and ADFI ($P < 0.05$) than when fed to pigs at the 100% inclusion level. Pigs fed non-pasteurized egg protein had improved ($P < 0.05$) F/G compared to pigs fed pasteurized egg product. The results of this experiment indicate that non-pasteurized egg product can successfully replace 50% of spray-dried plasma in nursery diets when plasma is included at 5% of the diet.

Introduction

Spray-dried animal plasma is often included in the diets of weanling pigs because it provides both a good protein source and a source of immunoglobulins for the young pig. However, plasma is an expensive dietary ingredient, and its use often results in loss of profitability for producers. Egg has a very good amino acid profile, and like plasma protein, it also contains immunoglobulins to aid in the transition time at weaning before the young pig's immune system has adequately matured. Egg protein may have the potential to serve as an alternative to spray-dried plasma when formulating diets for young pigs. Owen and coworkers (1993) observed that heat-treated egg protein could replace 3% of plasma or 6% of soybean meal, and yield comparable pig performance.

Eggs marketed for human consumption must undergo pasteurization, and excess eggs, as well as eggs that do not meet specifications for human consumption, are available for use in animal feeds. In the pasteurization process, liquid egg is partially sterilized by heating at 145.5°F for at least 3.5 min to destroy pathogens. Pasteurization is necessary for its anti-microbial action, but the procedure can denature proteins, decreasing amino acid digestibility and immunoglobulin activity. This study was conducted to evaluate the potential for pasteurized and non-pasteurized egg protein to serve as a complete or partial replacement for spray-dried animal plasma in the diets of newly-weaned pigs.

Experimental Procedures

A total of 216 weanling barrows (1/2 Large White x 1/4 Duroc x 1/4 Landrace; 20 ± 2 d of age; 12.3 ± 0.01 lb BW) were obtained from a single source and transported to the University of Arkansas off-site nursery facility. Pigs were sorted by weight and divided into six weight groups (blocks). Pigs within each weight group were allotted into equal subgroups (six pigs per pen), and treatments were randomly assigned to pens within each of the weight groups. Pig BW and feed intake were determined at the initiation of the study, on d 10, and weekly thereafter to evaluate ADG, ADFI, and F/G.

The six dietary treatments fed during phase 1 (d 0 to 10; 1.50% lysine) included: 1) a negative control diet devoid of egg protein and spray-dried animal plasma, 2) a positive control diet containing 5% spray-dried plasma added at the expense of soybean meal, 3) as 2, with pasteurized egg protein replacing 50% of the spray-dried plasma, 4) as 2, with pasteurized egg protein replacing 100% of spray-dried plasma, 5) as 2, with non-pasteurized egg protein replacing 50% of spray-dried plasma, and 6) as 2, with non-pasteurized egg protein replacing 100% of spray-dried plasma (Table 1). It was necessary to combine the egg protein with whey when pasteurizing to prevent coagulation. So, the non-pasteurized egg product was processed to contain the same ratio of egg and whey as the pasteurized product. Diets were formulated to include the whey in the egg product in the overall dietary whey, and whey was added to maintain total whey content across treatments. Also, biotin was supplemented to diets containing egg protein to alleviate any potential effects of the avidin contained in egg. Common diets were fed to all pigs during phase 2 (d 10 to 24, 1.35% lysine) and phase 3 (d 24 to 38, 1.20% lysine) to monitor any carry over effects from the dietary treatments fed during phase 1 (Table 2).

Pigs were housed in an off-site nursery facility in pens (64 in x 47 in) with one nipple waterer, a four-hole feeder, and Maxima nursery flooring (Agra Flooring International Ltd, Calgary, Alberta, Canada). Pigs in each pen had ad libitum access to feed and water. For the first week of the experiment, the nursery temperature was maintained at 84°F and was decreased by 1°F per wk.

Data were analyzed as a randomized complete block design with pen as the experimental unit and blocks based on initial BW. Analysis of variance was performed using the GLM procedure of SAS (SAS

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Inst., Inc., Cary, NC). Contrast statements were used to estimate the differences between the negative and positive control diets, the effects of source and level of egg protein, and interaction effects.

Results and Discussion

Growth responses of pigs on test are reported in Table 3. During phase 1, pigs fed diets in which egg protein replaced 50% of the spray-dried plasma had greater ADG ($P = 0.06$) and ADFI ($P < 0.05$) than pigs fed diets with egg protein replacing 100% of the spray-dried plasma contained in the diet. Pigs fed diets containing non-pasteurized egg protein had improved ($P < 0.05$) F/G compared to pigs fed diets containing pasteurized egg protein. The effects of feeding pasteurized and non-pasteurized egg protein carried over into the second week of phase 3, in which pigs previously fed non-pasteurized egg protein had greater ($P < 0.05$) ADG than pigs previously fed pasteurized egg protein.

The reduction in ADG and ADFI observed when pigs were fed diets containing egg protein replacing 100% of the spray-dried plasma compared to the 50% replacement level may have been a result of the increased levels of protease inhibitors present in the egg (Kato and Matsuda, 1997). Norberg et al. (2001) suggested that heat-treated, spray-dried egg protein may replace a portion of the plasma protein in nursery pig diets without impacting performance. The reduced response observed in this study when feeding pasteurized egg protein compared to non-pasteurized egg protein was likely due to the denaturation and insolubilization of protein (Herald and Smith, 1989) and the decreased bioavailability of amino acids (Evenepoel et al., 1998) in egg as a result of heat treatment during the pasteurization process.

Implications

Non-pasteurized egg protein may replace 50% of the spray-dried plasma in nursery pig diets, providing that spray-dried plasma is included at 5% of the diet.

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Table 1. Composition of experimental diets fed during phase 1 of the nursery period

	Treatment					
Item, %	Neg. control	Pos. control	50% Past.	100% Past.	50% Non-Past.	100% Non-Past.
Yellow corn	36.46	43.30	42.10	40.78	42.10	40.78
Steam rolled oats	5.00	5.00	5.00	5.00	5.00	5.00
Lactose	11.00	11.00	11.00	11.00	11.00	11.00
Spray-dried blood cells	1.75	1.75	1.75	1.75	1.75	1.75
Spray-dried porcine plasma	-	5.00	2.50	-	2.50	-
Soybean meal, 48% CP	19.50	7.63	7.63	7.63	7.63	7.63
Select menhaden fish meal	4.50	4.50	4.50	4.50	4.50	4.50
Processed soy protein	7.45	7.45	7.45	7.45	7.45	7.45
Whey	6.00	6.00	4.75	3.5	4.75	3.50
Whey (from egg protein)	-	-	1.25	2.5	1.25	2.50
Egg protein -pasteurized	-	-	5.00	10.00	-	-
Egg protein -non-pasteurized	-	-	-	-	5.00	10.00
Biotin supplement	-	-	0.30	0.61	0.30	0.61
Soybean oil	4.00	4.00	2.62	1.26	2.62	1.26
Ethoxyquin	0.03	0.03	0.03	0.03	0.03	0.03
Neo-Terramycin 10/5 [a]	1.00	1.00	1.00	1.00	1.00	1.00
Mineral Premix [b]	0.15	0.15	0.15	0.15	0.15	0.15
Vitamin premix [b]	0.20	0.20	0.20	0.20	0.20	0.20
Dicalcium phosphate	1.63	1.50	1.55	1.60	1.55	1.60
Calcium carbonate	0.40	0.57	0.41	0.26	0.41	0.26
Lysine	0.15	0.13	0.12	0.13	0.12	0.13
Methionine	0.17	0.13	0.09	0.05	0.09	0.05
Threonine	0.11	0.08	0.09	0.10	0.09	0.10
Isoleucine	-	0.08	0.01	-	0.01	-
Salt	0.50	0.50	0.50	0.50	0.50	0.50
Calculated composition						
Lysine	1.50	1.50	1.50	1.50	1.50	1.50
Threonine	0.97	0.97	0.97	0.97	0.97	0.98
Tryptophan	0.28	0.27	0.27	0.27	0.27	0.27
Isoleucine	0.88	0.86	0.85	0.89	0.85	0.85
Methionine + Cystine	0.86	0.86	0.86	0.86	0.86	0.86
Ca	0.90	0.90	0.90	0.90	0.90	0.90
P	0.80	0.80	0.80	0.80	0.80	0.80
Metabolizable energy (kcal/lb)	1485.68	1483.2	1488.4	1492.7	1488.4	1492.7
Lactose	14.70	14.70	14.70	14.70	14.70	14.70

[a] Provided 0.15 g of neomycin as neomycin sulfate and 0.11 g of oxytetracline per kg of feed.
[b] Vitamins and minerals met or exceeded NRC requirements (1998).

Table 2. Composition of Phase 2 and Phase 3 experimental diets

Item, %	Phase 2	Phase 3
Yellow corn	47.64	62.30
Soybean meal, 48% CP	28.30	30.00
Spray-dried blood cells	2.00	-
Select menhaden fishmeal	4.00	-
Ethoxyquin	0.03	0.03
Lysine	-	0.16
Zinc oxide	0.30	-
Neoterramycin 10/5 [a]	1.00	-
Lactose	10.00	-
Methionine	0.08	0.02
CuSO4	0.07	0.07
Mineral premix [b]	0.15	0.15
Vitamin premix [b]	0.25	0.25
Dicalcium phosphate	1.40	1.88
Fat	-	4.00
Soy oil	4.00	-
Calcium carbonate	0.38	0.61
Tylan 40 [c]	-	0.13
Salt	0.40	0.40
Calculated composition		
Lysine	1.35	1.20
Threonine	0.88	0.77
Tryptophan	0.26	0.24
Methionine + Cystine	0.78	0.67
Ca	0.80	0.80
P	0.70	0.70
Metabolizable energy (kcal/lb)	1542.00	1557.00
Lactose	9.80	-

[a] Provided 0.15 g of neomycin as neomycin sulfate and 0.11 g of oxytetracline per kg of feed.
[b] Vitamins and minerals met or exceeded NRC requirements (1998).
[c] Provided 0.11 g tylosin per kg of feed.

Table 3. Growth responses of pigs fed pasteurized vs. non-pasteurized egg protein at different levels during phase 1 of the nursery period[a]

			Egg protein source					Probability value			
			Pasteurized		Non-pasteurized						
Item	Neg. control	Pos. control	50% Replace	100% Replace	50% Replace	100% Replace	SE	Neg vs pos	Past vs. non-past	Egg prot. level	Level x source
Phase 1, d 0 to 10											
ADG, lb	0.35	0.37	0.31	0.30	0.38	0.29	0.03	0.49	0.34	0.06	0.14
ADFI, lb	0.51	0.51	0.53	0.47	0.53	0.37	0.05	0.99	0.35	0.04	0.38
F/G	1.46	1.41	1.70	1.56	1.39	1.31	0.11	0.76	0.02	0.36	0.79
Phase 2, d 10 to 17											
ADG, lb	0.83	0.93	0.93	0.87	0.98	0.95	0.05	0.18	0.26	0.41	0.80
ADFI, lb	1.30	1.33	1.30	1.31	1.44	1.28	0.06	0.72	0.32	0.20	0.13
F/G	1.56	1.42	1.40	1.56	1.50	1.37	0.07	0.20	0.53	0.86	0.07
Phase 2, d 17 to 24											
ADG, lb	1.20	1.26	1.26	1.26	1.25	1.25	0.03	0.17	0.68	0.92	0.87
ADFI, lb	1.56	1.66	1.60	1.60	1.68	1.61	0.05	0.11	0.36	0.37	0.41
F/G	1.30	1.32	1.27	1.27	1.36	1.29	0.04	0.69	0.19	0.37	0.35
Phase 3, d 24 to 31											
ADG, lb	1.12	1.18	1.10	1.16	1.07	1.17	0.04	0.40	0.71	0.07	0.62
ADFI, lb	2.05	2.35	2.13	2.05	2.13	2.30	0.09	0.03	0.19	0.65	0.18
F/G	1.84	2.01	1.97	1.78	2.00	1.96	0.08	0.15	0.20	0.18	0.36
Phase 3, d 31 to 38											
ADG, lb	1.47	1.51	1.47	1.47	1.52	1.64	0.05	0.56	0.04	0.28	0.26
ADFI, lb	2.83	3.00	2.69	2.72	2.86	3.10	0.17	0.50	0.13	0.45	0.54
F/G	1.92	1.98	1.82	1.85	1.88	1.89	0.09	0.69	0.60	0.83	0.96
Overall, d 0 to 38											
ADG, lb	0.94	1.00	0.96	0.96	0.99	0.98	0.03	0.18	0.35	0.93	0.96
ADFI, lb	1.56	1.66	1.56	1.54	1.62	1.61	0.07	0.30	0.35	0.77	0.92
F/G	1.65	1.66	1.63	1.61	1.64	1.63	0.04	0.91	0.68	0.83	0.95

[a]Treatments were: 1) a negative control diet devoid of egg protein and spray-dried animal plasma (neg. control), 2) a positive control diet containing 5% spray-dried plasma added at the expense of soybean meal (pos. control), 3) as 2, with pasteurized egg protein replacing 50% of the spray-dried plasma (pasteurized, 50% replace), 4) as 2, with pasteurized egg protein replacing 100% of spray-dried plasma (pasteurized, 100% replace), 5) as 2, with non-pasteurized egg protein replacing 50% of spray-dried plasma (Non-pasteurized, 50% replace), and 6) as 2, with non-pasteurized egg protein replacing 100% of spray-dried plasma (Non-pasteurized, 100% replace).

Efficacy of Milk Replacer during Lactation and to Small Pigs after Weaning to Enhance Nursery Performance

C. V. Maxwell[1], M. E. Davis[1], D. C. Brown[1], Z. B. Johnson[1], J. A. Coalson[2], and K. J. Touchette[2]

Story in Brief

An experiment was conducted to assess the effects of milk replacer supplementation on pre- and post-weaning pig performance. Sows and gilts (n=14) were blocked by parity and sire and allotted to three milk replacer treatments starting at farrowing. The three treatments were: 1) no milk replacer, 2) milk replacer (12.5% solids), and 3) milk replacer (18.5% solids). At weaning, pigs within each treatment group were blocked into eight weight groups, and six pigs from each block were assigned to a nursery pen. Pigs were fed a Phase 1 diet from d 0 to 14 and a Phase 2 diet from d 14 to 28. Pigs from the two lightest weight blocks of each lactation treatment were offered milk replacer for an additional 5 days after weaning. Pigs fed milk replacer containing 18.5% solids consumed more milk replacer than those fed 12.5% milk replacer. Pigs fed milk replacer containing 18.5% solids had greater ($P < 0.05$) ADG from d 10 after birth to weaning than pigs fed no milk replacer or milk replacer with 12.5% solids. During the nursery period, gain:feed (G/F) was greater ($P < 0.01$) when light-weight pigs were supplemented with milk replacer after weaning compared to pigs fed only the dry diet. These results indicate that supplementing with milk replacer during lactation and the transition to weaning improves gain in light-weight pigs. Optimal pre-weaning performance with milk replacer can be obtained by feeding a solids level above 12.5% solids (1.0 lb/gallon).

Introduction

Average weaning age of piglets has progressively decreased over the last 20 years in an attempt to maximize productivity of the sow herd. Although daily milk production of sows has increased during this 20-yr period, younger weaning ages and increased litter size has resulted in weaning weights that are frequently less than 10 lb. Supplementing the pig with a milk replacer has been shown to enhance weaning weight (Odle and Harrell, 1998) although the optimum solids content of the milk replacer necessary to optimize pre-weaning gain has not been established. Smaller pigs at weaning have a harder time handling the transition from the sow to the nursery phase; this results in poor performance and an increase in variation of pig weights within weaning groups. Previous reports (Harrell et al., 1993; Zijlstra et al., 1996) have demonstrated that either artificially rearing pigs on milk replacer or supplying milk replacer to all pigs after weaning results in larger pigs during the nursery period. The first objective of this study was to determine the effect of solids content of milk replacer on pre-weaning pig performance. The cost of providing milk replacer to all pigs during the post-weaning period may be prohibitive and may not decrease variation in pig weaning groups; thus, the second objective of this study was to determine the effect of supplying a supplemental milk replacer in the immediate post-weaning period to the smallest 25% of the pigs.

Experimental Procedures

A total of 14 sows and gilts were blocked by parity and sire and randomly allotted to one of three treatments as they were placed in the farrowing room at 110 to 112 days of gestation. Litters, starting at birth, received no supplemental milk replacer, supplemental milk replacer with 12.5% solids (1 lb/gallon) or supplemental milk replacer with 18.5% solids (1.5 lb/gallon). At weaning, pigs within each treatment group were ranked by weight. Each group was divided into eight weight blocks and six pigs were randomly selected from each weight block and allotted to one nursery pen (six pens of heavy pigs and two pens of light-weight pigs with six pigs/pen from each treatment). Pigs from the two lightest weight blocks were offered supplemental milk replacer (18.5%) for an additional 5 d. A common 1.5% lysine Phase I diet containing 3.75% spray-dried plasma and 15% lactose was fed for the first 2 wk post-weaning. A common Phase II diet (1.4% lysine) containing 1.0% plasma, 1.5% blood cells and at least 8% lactose was fed until the completion of the study (28 d).

The milk replacer system used in this study was an in-line system. The milk replacer was supplied to pigs ad libitum in a small bowl supplied by a central 30-gallon tank. The tank was equipped with a hydro pump with a pressure regulator that pumped the milk replacer to the pens as needed. A baby pig nipple inside each bowl that allowed milk to flow into the bowl only when touched by a pig's nose was used to minimize spillage and waste of the milk replacer. On a daily basis, the entire system was flushed with hot water to remove spoiled milk or sediment, and fresh milk was prepared using a commercial milk replacer (Merrick's Litter-Gro, Middleton, WI). The entire system was cleaned weekly with a mixture of Clorox and a non-foaming detergent.

Pigs were weighed to obtain individual birth weight, five and 10-d weights and weaning weight. Pigs were weighed during the nursery period on d 0, 5, 10 and 28 (termination of the study). A log of milk intake was recorded daily (during the lactation phase of the study) to permit calculation of daily milk replacer intake. Pig transfer was minimized after initial litter weight was determined. Data were analyzed as a 3 x 2 factorial with three levels of milk replacer during the pre-weaning period and 2 levels during post-weaning (SAS Inst., Inc., Cary, NC).

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[2] Merrick's Inc., Middleton, WI

Results and Discussion

Pigs fed milk replacer containing 18.5% solids increased total liquid intake (Figure 1) and total dry matter intake (Figure 2) when compared to those fed milk replacer containing 12.5% solids. It should be noted that the increase in liquid intake in pigs fed the higher dry matter level dramatically increased nutrient intake in pigs fed the 18.5% solids diet.

Pigs fed milk replacer containing 18.5% solids had greater ($P < 0.05$) ADG from d 10 after birth to weaning than pigs fed no milk replacer or milk replacer with 12.5% solids (Table 1). Most manufacturers of pig milk replacers suggest using a 1 lb/gallon mixing rate (12% solids). However, sow's milk is 20% solids. This study suggests that increasing solids to 18.5% will improve liquid intake and total dry matter intake throughout lactation. With this improvement in dry matter intake, growth in the last 8 days of lactation was improved by 45% when compared to pigs fed no milk replacer. Pre-weaning treatment had no significant effect on nursery performance. During the nursery period, gain:feed (G/F) was greater ($P < 0.01$) when light-weight pigs were supplemented with milk replacer after weaning compared to pigs fed only the dry diet (Table 2). As expected, light-weight pigs weighed less than heavier pigs through the nursery phase ($P < 0.03$). It should be noted, however that supplementing milk replacer during the first 5 days (Phase 1a) of the nursery phase reduced the initial difference by 2.2 lb. Differences in weight then tended to become greater as supplemental milk replacer was removed. Although supplemental milk replacer did not result in equivalent weight between the heavy and light-weight pigs, other studies have shown that the difference in weight was reduced when compared to light-weight pigs not receiving supplemental milk replacer.

Implications

These results indicate that supplemental milk replacer during lactation and the transition to weaning improves gain in light-weight pigs. Optimal pre-weaning performance with milk replacer can be obtained by feeding a solids level above 12.5% solids (1.0 lb/gallon). The 18.5% solids level (1.5 lb/gallon) closely matches normal solids found in sow's milk (20% solids).

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Table 1. Effect of milk replacer on pre-weaning gain

	Treatment			
Trait	12.5% solids	18.5% solids	No Milk Replacer	P-value
ADG, birth to 5 d, lb	0.85 ± 0.09	0.83 ± 0.08	0.78 ± 0.10	0.86
ADG, birth to 10 d, lb	1.12 ± 0.09	1.05 ± 0.08	1.04 ± 0.10	0.80
ADG, birth to weaning, lb	1.17 ± 0.09	1.30 ± 0.08	1.05 ± 0.10	0.20
ADG, 5 to 10 d, lb	1.39 ± 0.13	1.28 ± 0.12	1.29 ± 0.14	0.77
ADG, 5 days to weaning, lb	1.29 ± 0.10	1.47 ± 0.09	1.17 ± 0.11	0.14
ADG, 10 days to weaning, lb	1.22 ± 0.12[b]	1.60 ± 0.10[a]	1.10 ± 0.13[b]	0.03

[a,b] Means in a row with no letter in common differ ($P < 0.05$).

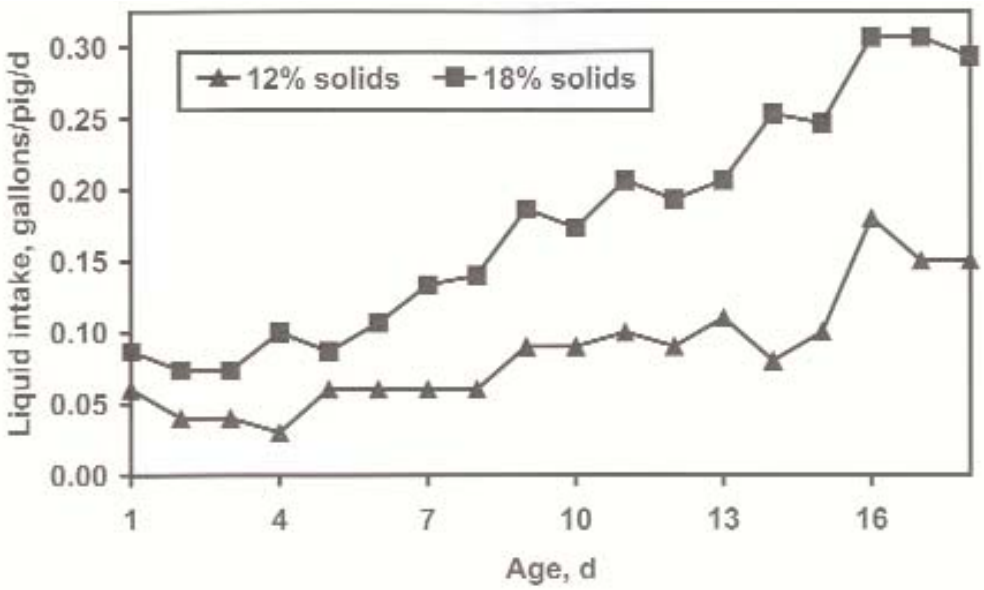

Fig. 1. Effect of percentage solids on liquid intake

Table 2. Main effect treatment means for milk replacer effects during the nursery phase

	Pre-weaning treatment				Post-weaning treatment	
Trait	12.5% solids	18.5% solids	No Milk Replacer	SE	Normal pigs	Small pigs
ADG, lb						
Phase 1 (d 0 to 14)	0.37	0.42	0.51	0.05	0.47 ± 0.03	0.40 ± 0.04
Phase 2 (d 14 to 28)	0.85	0.68	0.68	0.08	0.71 ± 0.05	0.76 ± 0.08
Phase 1-2 (d 0 to 28)	0.58	0.54	0.59	0.05	0.58 ± 0.03	0.56 ± 0.04
ADFI, lb						
Phase 1 (d 0 to 14)	0.46	0.46	0.54	0.03	0.64 ± 0.02	0.33 ± 0.03
Phase 2 (d 14 to 28)	0.76	0.66	0.62	0.09	0.66 ± 0.05	0.69 ± 0.08
Phase 1-2 (d 0 to 28)	0.60	0.55	0.58	0.05	0.65 ± 0.03	0.50 ± 0.05
Gain:feed						
Phase 1 (d 0 to 14)	0.881	1.063	.980	0.147	0.729 ± 0.087 [a]	1.221 ± 0.131 [b]
Phase 2 (d 14 to 28)	1.113	1.136	1.099	0.169	1.132 ± 0.101	1.099 ± 0.151
Phase 1-2 (d 0 to 28)	1.016	1.017	1.022	0.054	0.893 ± 0.032 [a]	1.143 ± 0.048 [b]
Weight, lb						
Initial	11.24	12.34	11.33	0.75	13.82 ± 0.44[c]	9.43 ± 0.66[d]
Phase 1a (d 5)	13.89	14.77	14.55	0.84	15.50 ± 0.51[c]	13.31 ± 0.75[d]
Phase 1b (d 10)	14.68	15.74	15.50	0.84	17.55 ± 0.51[c]	13.07 ± 0.75[d]
Phase 1c (d 14)	16.27	18.30	18.43	1.19	20.39 ± 0.70[c]	14.92 ± 1.08[d]
Phase 2a (d 21)	21.07	22.20	21.85	1.45	23.90 ± 0.88[c]	19.51 ± 1.30[d]
Phase 2b (d 28)	26.43	26.52	26.59	1.65	28.90 ± 1.01[c]	24.12 ± 1.48[d]

[a,b] Post-weaning means with different superscript differ, P < 0.01.
[c,d] Post-weaning means with different superscript differ, P < 0.03.

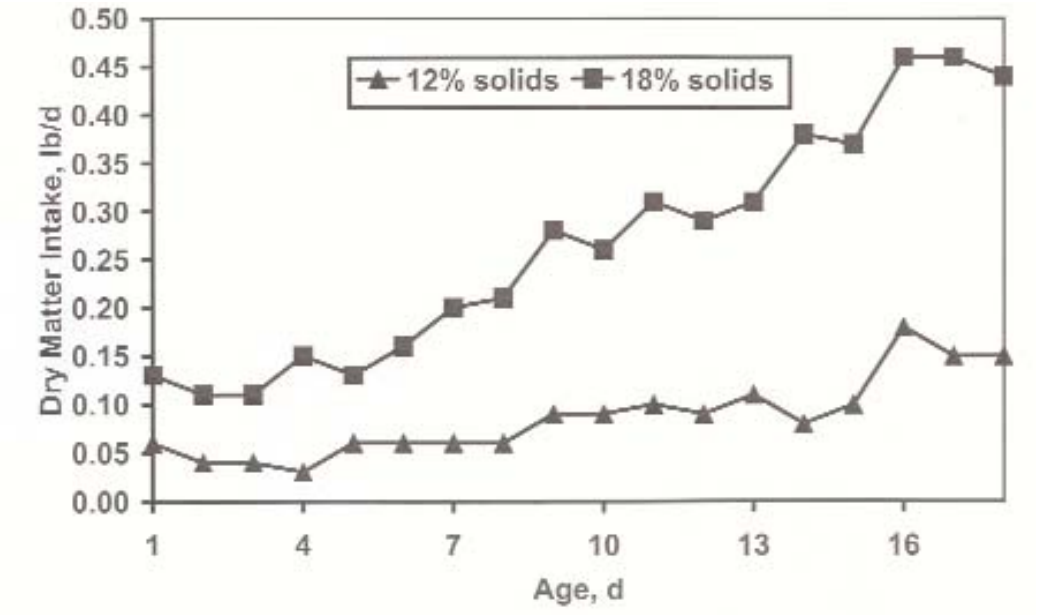

Fig. 2. Effect of solids on dry matter intake

Effects of Dietary Magnesium and Short-Duration Transportation. I. Stress Response of Finishing Swine

E.B. Kegley, J.K. Apple, C.V. Maxwell, Jr., and Doug Galloway[1]

Story in Brief

Crossbred pigs were used to determine the effect of feeding magnesium mica on performance and the stress response. Pigs were blocked by weight, penned in groups of six and pens (3 pens/diet) were randomly assigned to dietary treatments of either a control corn-soybean meal diet or the control diet supplemented with 2.5% magnesium (Mg) mica, added by substituting for corn. Diets were fed during the early-finisher (0.95% lysine; 96 to 151 lb) and late-finisher (0.85% lysine; 151 to 227 lb) periods. At the conclusion of the 71-d feeding trial, 12 pigs from each dietary treatment were randomly selected and subjected to either no stress or 3 h of transportation stress. Dietary Mg mica had no effect ($P > 0.10$) on ADG or ADFI; however, feed/gain was improved during the early-finisher period for pigs fed the Mg mica supplemented diets ($P < 0.05$). Plasma glucose concentrations were increased in the stressed pigs fed the control diet, but transportation did not affect the glucose concentrations in pigs fed 2.5% Mg mica (diet x stressor treatment interaction, $P < 0.05$). Mg mica had no effect on plasma lactate, cortisol, insulin, or nonesterified fatty acid concentrations in response to transportation stress (diet x stressor treatment interaction, $P > 0.10$). Plasma lactate, cortisol, and glucose increased in the transported pigs (stressor treatment x time interaction, $P < 0.01$). This transportation model elicited the expected changes in endocrine and blood metabolites; however, few effects of Mg mica on the pigs' response to stress were detected.

Introduction

Previous research has demonstrated benefits to pork quality from long-term supplementation of pigs with magnesium (Mg) mica (Apple et al., 1999). Pork quality is impacted by the response of the pigs to stressors involved in the harvesting process. Inclusion of a Mg supplement (either Mg fumarate or Mg aspartate) in the diets of pigs has been shown to reduce plasma cortisol and norepinephrine concentrations (Kietzman and Jablonski, 1985; Otten et al., 1993) and to improve pork quality.

The objectives of this study were to investigate the impact of long-term supplementation of Mg mica on growth performance of finishing pigs, and to measure the impact of a transportation stressor treatment on the endocrine and blood metabolite concentrations of pigs fed the control and Mg mica supplemented diets. This project was done in conjunction with a companion study (Apple et al., 2002) investigating the effect of Mg mica and transportation stress on pork quality characteristics.

Experimental Procedures

Prior to breeding, hair samples for a population of Yorkshire x Landrace females were collected and shipped to Pig Improvement Co. (PIC, Franklin, KY) for determination of halothane genotype. Seven females that were homozygous dominant, or negative, for the halothane gene were bred with semen from a synthetic-breed boar line (PIC) tested and guaranteed homozygous recessive, or reactor, for the halothane gene. The resulting offspring were heterozygous carriers of the halothane gene. This gene contributes to poor meat quality, pork that is lighter in color and has a greater drip loss percentage than desired.

Thirty-six crossbred pigs (96.1 ± 8.8 lb; 24 barrows and 12 gilts) from the aforementioned matings, heterozygous for the halothane gene, were blocked by weight (3 blocks), and penned in groups of six (2 pens/block), stratifying across sex and litter of origin. Pens (3 pens/diet) were randomly assigned to either a control corn-soybean meal diet or the control diet supplemented with 2.5% Mg mica (Micro-Lite, Inc., Chanute, KS). Diets (Table 1) were fed during the early-finisher (0.95% lysine; 96 to 151 lb) and late-finisher (0.85% lysine; 151 to 227 lb) periods. The transition from the early- to late-finisher diet occurred when the average BW of the block was 150 lb. All diets were formulated to meet, or exceed, NRC (1998) requirements, and the control grower and finisher diets contained 0.18% and 0.38% Mg, respectively. The Mg mica was added by substituting for corn. Pigs were housed in 5 ft by 13 ft pens containing a single wet-dry feeder that allowed ad libitum access to feed and water. Pens were located in a curtain sided building. Pig weights were obtained at the start of the trial, at the transition from the early- to late-finisher diet, and on d 71.

On d 74 and 81, six pigs from each dietary treatment were randomly selected and assigned to either no stress or 3 h of transportation stress; resulting in a 2 x 2 factorial arrangement of treatments. These 24 pigs were surgically fitted with an indwelling jugular catheter. Pigs were then moved to individual pens in an environmentally controlled building. All pigs were fitted with tethers and restrained so that the pig could lay and stand, but had a limited range of movement. Pigs had ad libitum access to their appropriate diet (rubber pan feeders) and water (nipple waterers). Fifteen hours before stressor treatments, feed was removed.

On d 76 and 83, at approximately 0730, a -90 min blood sample was taken from all pigs, followed by -60, -30, and 0 min samples. After the time 0 sample, pigs that were to be stressed by transportation were removed from the individual pens, moved to a trailer, and tethered within the trailer to facilitate blood sampling. The six pigs that were transported had visual contact with each other, but not tactile contact. The trailer was moved on county roads for 3 h, stopping every 30 min to allow for blood sample collection. Pigs in the non-transported group remained tethered in their individual pens and were

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bled at 30 min intervals for 3 h. Upon completion of the stress treatment, all pigs were harvested at the University of Arkansas Red Meat Abattoir. Effects of treatments on muscle metabolism and meat quality are reported in a companion paper (Apple et al., 2002).

Growth performance data were analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC). Pen was used as the experimental unit, and the model included block and dietary treatment. Plasma data were analyzed as a 2 x 2 factorial design with pig as the experimental unit. Analysis of variance was performed with repeated measures using the MIXED procedure of SAS with dietary treatment, stressor treatment, the diet x stressor interaction, time, and their interactions in the model. Least squares means were computed for all main and interactive effects, and separated statistically using pairwise t-tests (PDIFF option of SAS) when a significant F-test was observed ($P < 0.10$).

Results and Discussion

There were no differences in ADG, ADFI, or feed/gain due to supplemental Mg mica for the 71-d feeding trial. However, feed/gain was improved ($P < 0.05$) during the early-finisher period by supplementation of Mg mica (Table 2).

There were no differences in plasma lactate, cortisol, nonesterified fatty acids (NEFA), insulin, Ca, or Mg due to supplemental Mg mica. Kuhn et al. (1981) reported that supplemental Mg as Mg aspartate produced a visibly calmer pig after long-distance transportation. We did not attempt to record such a subjective measure as calmness; however, cortisol is released from the adrenal cortex in response to stressful events. This lack of an effect of diet on cortisol concentrations contradicts other published research that suggested that Mg fumarate and aspartate, respectively, decreased plasma cortisol concentrations during stress in pigs (Otten et al., 1993) and in humans (Golf et al., 1984).

There was a diet x stressor treatment interaction ($P < 0.05$) for plasma glucose (Table 3). Plasma glucose concentrations were increased in the stressed pigs fed the control diet, but transportation did not affect the glucose concentrations in pigs fed 2.5% Mg mica. In other studies, an increase in plasma glucose is induced by stress. This is due to an increase in glucose production (glycogenolysis and gluconeogenesis) and/or a decrease in glucose clearance from the circulation. Magnesium supplementation altered one of these processes.

As previous researchers have shown, plasma lactate (Figure 1), cortisol (Figure 2), and glucose (Figure 3) increased dramatically when the pigs were stressed by transportation (stressor treatment x time interaction, $P < 0.01$). Increased plasma lactate is often associated with anaerobic metabolism. However, lactate production can also occur from aerobic metabolism and occurs because the rate of lactate production is greater than the rate of lactate uptake by skeletal muscle and the liver. This has previously been observed in light exercise in humans (Stanley et al., 1985) and a restraint and isolation stress event in lambs (Apple et al., 1995).

Although plasma glucose concentrations increased, plasma insulin concentrations were decreased by the stressor treatment, indicating insulin insensitivity in these stressed pigs.

Interestingly, upon the initiation of the stressor treatment, plasma nonesterified fatty acid concentrations (Figure 4) decreased in the transported pigs (stressor treatment x time interaction, $P < 0.01$). This has been associated with their rapid use of energy. However, nonesterified fatty acid concentrations were not different at the 60 and 90 min sampling times, and were increased in the transported pigs after 120 min of transportation. The increase in fatty acid concentrations after 120 min probably represent an increase in lipolysis in these stressed pigs. Stress-induced catecholamines stimulate lipolysis.

Plasma Ca concentrations (Table 3) were increased ($P < 0.05$) by transportation stress. While plasma Mg concentrations (Table 3) were not affected ($P > 0.10$) by supplemental Mg mica or transportation stress. Because the control diet was nutritionally adequate in Mg, it was not expected that supplemental Mg would increase plasma Mg concentrations; although in a study (D'Souza et al., 1998) investigating the impact of short-term (5-d) supplementation of 40 g of Mg aspartate, plasma Mg was increased in the supplemented pigs.

Implications

The transportation model used in this experiment elicited the expected endocrine and blood metabolite responses to stress in pigs. However, supplemental magnesium mica did not have dramatic effects on these parameters. The mechanism whereby supplemental magnesium mica improves pork quality remains to be elucidated.

Acknowledgments

The authors are grateful to Micro-Lite, Inc., Chanute, KS for donation of magnesium mica and financial support of this project. Additionally, the authors wish to express their appreciation to Ashley Hays, Lance Kirkpatrick, and Joe Leibrandt for animal care and performance data collection; Dr. Dianne Hellwig for assistance in jugular cannulation of pigs; Clay Bailey, Dari Brown, Gordon Carte, Ellen Davis, Pete Hornsby, Suzanne Krumpelman, Levi McBeth, Joanne Morris, Rapeepong Panivivat, Nathan Post, John Sligar, Jim Turner, Stephanie Williamson, and Troy Wistuba for assistance during blood sampling; and Zelpha Johnson for statistical analyses consultation.

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Table 1. Composition of experimental diets

	Early-finisher diets		Late-finisher diets	
	0% Mg mica	2.5% Mg mica	0% Mg mica	2.5% Mg mica
Ingredient, %				
Corn	66.975	64.295	71.115	68.615
Soybean meal, 48% CP	25.6	25.75	21.9	21.9
Animal and vegetable fat	4	4	4	4
Dicalcium phosphate	1.65	1.7	1.45	1.5
Magnesium mica	0	2.5	0	2.5
Calcium carbonate	0.77	0.75	0.68	0.63
Salt	0.5	0.5	0.5	0.5
Mineral premix[a]	0.15	0.15	0.1	0.1
Vitamin/trace mineral premix[b]	0.15	0.15	0.125	0.125
Tylosin-40	0.125	0.125	0.05	0.05
Copper sulfate	0.05	0.05	0.05	0.05
Ethoxyquin	0.03	0.03	0.03	0.03
Calculated composition, %				
Crude protein	18.11	17.95	16.67	16.45
Lysine	0.95	0.95	0.85	0.85
Methionine	0.29	0.29	0.27	0.27
Methionine and cystine	0.61	0.61	0.57	0.57
Threonine	0.7	0.7	0.64	0.64
Tryptophan	0.21	0.21	0.19	0.19
Magnesium	0.18	0.38	0.18	0.37
Calcium	0.8	0.8	0.6	0.6
Phosphorus	0.65	0.65	0.6	0.6
Metabolizable energy, kcal/lb	1583	1544	1591	1552

[a] Premix consisted of 11% iron, 11% zinc, 2.6% manganese, 1.1% copper, 0.02% iodine, and 0.02% selenium (Nutra Blend Corp., Neosho, MO).

[b] Premix consisted of 413,223 IU/lb vitamin A, 61,984 IU/lb vitamin D3, 1,653 IU/lb vitamin E, 3.6 ppm vitamin B12, 364 ppm vitamin K, 818 ppm riboflavin, 2,727 ppm d-pantothenic acid, and 4,546 ppm niacin (Nutra Blend Corp., Neosho, MO).

Table 2. Effect of magnesium mica[a] supplementation on performance of finishing pigs

	0% Mg mica	2.5% Mg mica	SE
Initial wt., lb	96.1	96.3	0.07
Final wt., lb	226.7	226.7	7.14
ADG, lb			
Early-finisher	1.72	1.76	0.084
Late-finisher	1.92	1.94	0.123
Overall, d 0 to 71	1.81	1.87	0.084
ADFI, lb			
Early-finisher	4.89	4.83	0.227
Late-finisher	6.88	7.05	0.119
Overall, d 0 to 71	5.89	5.97	0.161
Feed/gain			
Early-finisher[a]	2.85	2.74	0.015
Late-finisher	3.58	3.7	0.203
Overall, d 0 to 71	3.24	3.21	0.079

[a] Effect of Mg mica ($P < 0.05$).

Table 3. Effects of magnesium mica supplementation and a short duration transportation stressor on endocrine and blood metabolite concentrations of finishing pigs

	0% Mg mica		2.5% Mg mica		
	No stress	Stress	No stress	Stress	SE
Glucose, mg/dl[a]	90.7	100.3	95.2	95.6	1.86
Insulin, uIU/ml[b]	8.76	7.27	9.36	6.84	0.594
Ca, mg/dl[c]	13.05	13.21	12.98	13.20	0.072
Mg, mg/dl	2.13	2.12	2.1	2.13	0.051

[a] Mg mica x stressor treatment interaction (P < 0.05).
[b] Main effect of stressor treatment (P < 0.01).
[c] Main effect of stressor treatment (P < 0.05).

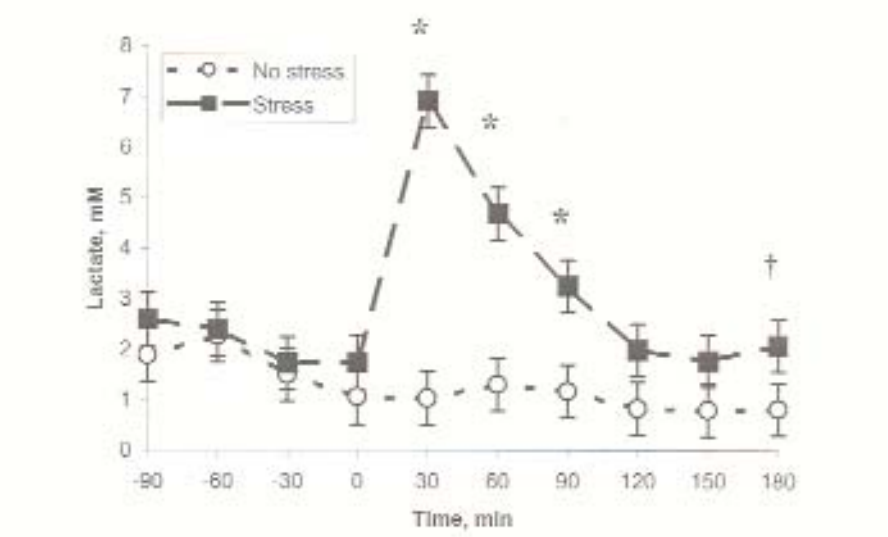

Fig. 1. Effect of stressor treatment on plasma lactate concentrations; Stressor treatment x time interaction (P < 0.01); †Stressor treatments differ (P < 0.10). *Stressor treatments differ (P < 0.05).

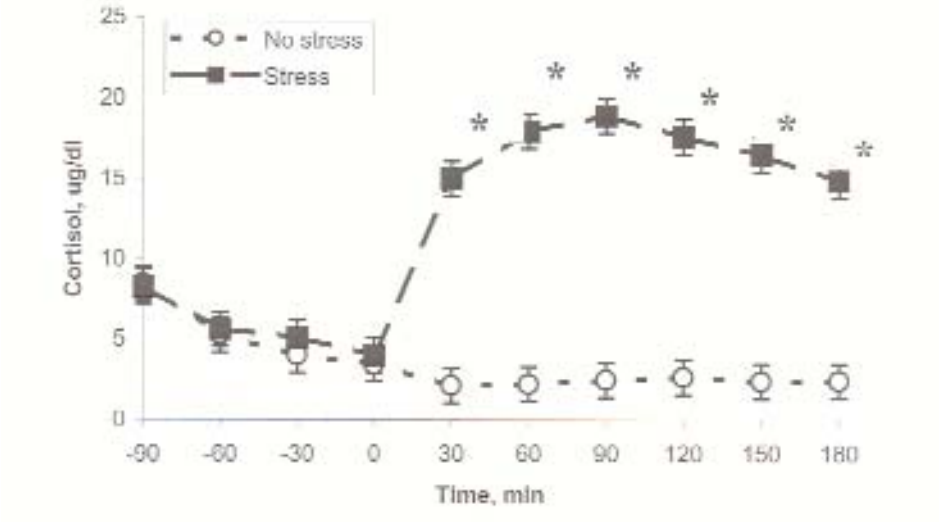

Fig. 2. Effect of stressor treatment on plasma cortisol concentrations. Stressor treatment x time interaction (P < 0.01). *Stressor treatments differ (P < 0.05).

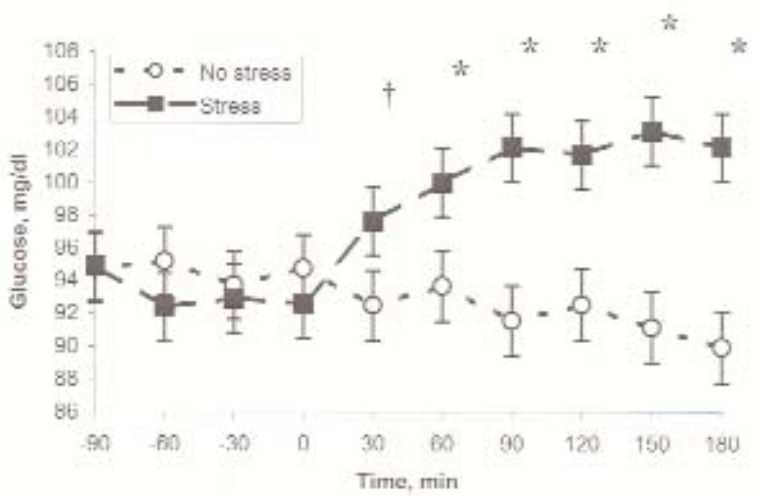

Fig. 3. Effect of stressor treatment on plasma glucose concentrations. Stressor treatment x time interaction (P < 0.01). †Stressor treatments differ (P < 0.10). *Stressor treatments differ (P < 0.05).

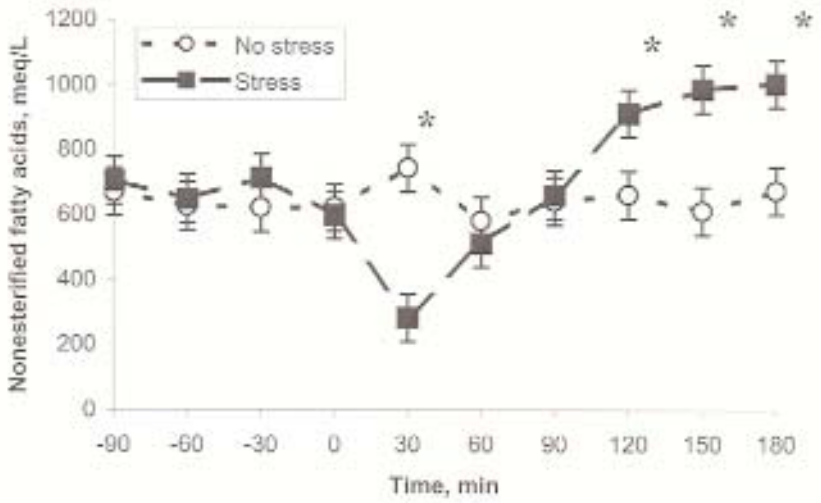

Fig. 4. Effect of stressor treatment on plasma nonesterified fatty acid concentrations. Stressor treatment x time interaction (P < 0.01). *Stressor treatments differ (P < 0.05).

Effects of Dietary Magnesium and Short-Duration Transportation. II. Postmortem Muscle Metabolism and Meat Quality of Finishing Swine

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Story in Brief

Crossbred pigs (n = 24), heterozygous for the halothane-gene, were used to determine the effects of long-term supplementation of magnesium mica (MM; 0.0 or 2.5%) and short-duration stress (3 h transportation stress [S] or unstressed controls [NS]) on postmortem muscle metabolism and pork quality. The longissimus muscle (LM) from pigs fed 2.5% MM and subjected to 3 h of transportation stress had higher ($P < 0.05$) initial (0-min) and 45-min pH values than the LM from S-pigs fed 0.0% MM, as well as NS-pigs fed either 0.0 or 2.5% MM. Moreover, S-pigs fed 2.5% MM had higher ($P < 0.05$) LM lactic acid concentrations and glycolytic potentials (GP) than NS-pigs fed 2.5% MM; whereas, pigs fed 0.0% MM had lactic acid and GP values intermediate to pigs fed 2.5% MM, regardless of transportation treatment. Neither MM nor the stress of transportation affected ($P > 0.10$) the color and water-holding capacity of the LM and semimembranosus muscle. Rapidly glycolyzing muscle, while muscle temperature is high, is the primary cause of pale, soft and exudative (PSE) pork; therefore, slowing postmortem glycolysis and elevating muscle pH by supplementing swine diets with 2.5% MM may reduce the incidence of PSE pork in halothane-carriers subjected to a routine stressor like short-duration transportation.

Introduction

Supplementing diets with magnesium (Mg) has been demonstrated to have beneficial effects on pork color, and reduce the incidence of pale, soft and exudative (PSE) pork (D'Souza et al., 1998). Although the mechanism by which dietary Mg improves pork quality is unclear, research has shown that increasing dietary Mg reduces the stress responses in pigs (D'Souza et al., 1998).

Magnesium mica (MM) is an inorganic, layered silicate product containing approximately 8% Mg that has been shown, in one experiment, to improve pork color and reduce the proportion of carcasses with quality traits characteristic of PSE pork (Maxwell et al., 1998). In a second experiment, however, long-term MM-supplementation had no appreciable effects on pork quality (Apple et al., 1999). It is apparent that the response in pork quality to Mg-supplementation is related to the stress-susceptibility, or resistance, of the pig (Schaefer et al., 1993) and level of stress experienced by the pig. Thus, the lack of a notable improvement in pork color with MM-supplementation between experiments could be attributed to a change in halothane-genotype of pigs (Apple et al., 1999).

Most studies have employed short-term supplementation, and little is known about the effectiveness of long-term Mg-supplementation on improving pork quality traits of pigs subjected to a routine stressor like transportation. Therefore, the objective of this experiment was to test the effect of MM-supplementation on the pork quality characteristics of finishing swine after three hours of transportation.

Experimental Procedures

Pigs from a companion growth and blood metabolite study (see Kegley et al., 2002 for details of genotype determination, diet formulation, and stressor treatment) were randomly assigned to treatments arranged in a 2 x 2 factorial design consisting of two supplemental magnesium mica (MM) levels (0.0 or 2.5%) and two stressor levels (either 3 h of transportation stress [S] or unstressed controls [NS]). The S-pigs were harvested first, and NS-pigs were transported approximately 16 miles to the abattoir approximately 2 h after S-pigs were harvested in an attempt to minimize the stress associated with co-mingling pigs, transportation, and preharvest handling. To avoid accelerated postmortem metabolism associated with electrical stunning, all pigs were rendered unconscious and insensitive to pain by a nonpenetrating, captive-bolt stunning method. Immediately after stunning, two 0.5-in diameter cores were removed from the *longissimus thoracis et lumborum* (LM) perpendicular to the length of the LM on the right side of each carcass. Subsequent LM samples were removed at 45, 90, 180, 360, 720, and 1440 min after stunning. Additionally, LM temperature was recorded at each sampling time with a digital thermometer. One core was homogenized in sodium iodoacetate for pH determinations, and the second core was frozen immediately after removal in liquid nitrogen for determination of glycolytic potential at a later date. Carcasses were weighed and chilled conventionally at 34°F for 48 h until fabrication.

After the 48-h chilling period, the left side of each carcass was fabricated into primal cuts, and the bone-in loin section posterior to the 11th rib was removed and subsequently fabricated into two 1.5-in thick LM chops and two 1.0-in thick LM chops. Additionally, the semimembranosus (SM) muscle was removed from the ham, and cut, perpendicular to the muscle fiber orientation, into two 1.5-in and two 1.0-in thick slices. The 1.5-cm thick chops from both the LM and SM were used to measure muscle drip loss (Apple et al., 1999), and moisture content according to the freeze-drying procedure outlined by Apple et al. (2001).

Marbling (NPPC, 1999), firmness (NPPC, 1991), and color based on the American (NPPC, 1999) and Japanese (Nakai et al., 1975) color standards were subjectively evaluated on both 1.0-in thick chops/slices by a three-person panel after a 30-min bloom period at 38°F. The Japanese color standards system consists of six plastic disks with meat-like texture and appearance developed from objective colorimetry, and scores range from 1 (pale gray) to 6 (dark purple). Objective color of LM chops and SM slices was measured with a Hunter MiniScan XE. Spectral reflectance was measured at

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10-nm intervals over the 400 to 700 nm range using illuminant C. Simultaneously, L*, a*, and b* values were determined from a mean of three random readings on each LM chop and SM slice using illuminant C and a 10° standard observer. Red color contributed by oxymyoglobin was estimated by the ratio of percent reflectance at 630 nm to the percent reflectance at 580 nm (%R630/%R580).

Details of the assay procedures used to estimate glycolytic potential (GP) were identical to those described by Miller et al. (2000). Values for GP were calculated using the formula of Monin and Sellier (1985), where: GP = 2 x ([glycogen] + [glucose] + [glucose-6-phosphate]) + (lactate).

All data were analyzed as a 2 x 2 factorial design with pig as the experimental unit. Analysis of variance was performed using PROC MIXED (SAS Inst., Inc., Cary, NC) with dietary treatment (0.0 or 2.5% MM), stressor treatment (NS or S), and the diet x stressor treatment interaction included in the model as fixed effects, and the pig x diet x stressor x replicate interaction as the random effect. Additionally, postmortem metabolism (GP and pH) data were analyzed as a repeated measure using PROC MIXED with time as the repeated variable and pig as the subject. Least squares means were computed for all main and interactive effects, and separated statistically using pair-wise t-tests (PDIFF option of SAS).

Results and Discussion

The interactive effect of MM level and transportation stress on postmortem pH decline of the LM is presented in Figure 1. The LM from pigs fed 2.5% MM and subjected to 3 h of transportation stress had higher ($P < 0.05$) initial (0-min) and 45-min pH values than the LM from S-pigs fed 0.0% MM, as well as NS-pigs fed either 0.0 or 2.5% MM. Moreover, neither stressor treatment nor supplemental MM level had an effect ($P > 0.10$) on LM temperature decline until 360 min postmortem, when temperature was lower ($P < 0.05$) in the LM of S-pigs than NS-pigs (data not shown). Interestingly, S-pigs fed 2.5% MM had higher ($P < 0.05$) LM lactic acid concentrations and glycolytic potentials than NS-pigs fed 2.5% MM (Figure 2); whereas, pigs fed 0.0% MM had lactic acid and GP values intermediate to pigs fed 2.5% MM, regardless of stressor treatment.

It is well documented that PSE pork is caused by very rapid postmortem glycolysis during the first hour of rigor mortis when muscle temperatures are the highest. This rapid drop in muscle pH, coupled with high temperatures, results in muscle protein denaturation and subsequent formation of PSE pork. Results indicate that feeding diets supplemented with 2.5% MM effectively retarded postmortem pH decline in stressed pigs is exciting, a finding consistent with other studies which found that Mg supplementation resulted in higher initial (45 to 60 min) muscle pH values (D'Souza et al., 1998; Schaefer et al., 1993).

Pigs fed 2.5% MM and subjected to 3 h of transportation stress had greater lactic acid concentrations in the LM than unstressed-pigs fed 2.5% MM, even though ultimate LM pH (measured at 1440 min) values were quite similar among all four treatment groups. This finding contradicts the general consensus that muscle pH declines in response to the accumulation of lactic acid within the muscle; however, other metabolites, in particular metabolites of the phosphagen energy system, may have a greater impact on hydrogen ion concentrations within muscle and muscle pH values than lactic acid accumulation. Moreover, D'Souza et al. (1998) reported that roughly handling pigs immediately prior to harvest increased lactic acid levels in the LM and biceps femoris at 5 and 40 min postmortem, and supplementing these pigs diets with Mg aspartate effectively lower early postmortem muscle lactic acid levels, resulting in higher initial pH values. In the present study, lower 0- and 45-min pH values in the LM of S-pigs would be indicative of higher LM lactic acid content, whereas, the higher 0- and 45-min pH values in the LM of S-pigs fed 2.5% would be consistent with lower LM lactic acid levels, which would be in general agreement with D'Souza and co-workers (1998).

There were no interactive effects ($P > 0.10$) of supplemental MM and transportation stress on any pork quality traits, and dietary MM had no effect ($P > 0.10$) on LM color, moisture loss, marbling, or firmness (Table 1). Additionally, subjective and objective measures of pork color, marbling and firmness scores, and drip loss percentages were not affected ($P > 0.10$) by stressor treatment. Yet, there was a tendency for the LM from pigs subjected to 3 h of transportation stress to have more ($P < 0.09$) moisture than the LM from unstressed pigs. Similar to the results reported for the LM, neither dietary MM level nor transportation stress had an impact on the color or water-holding capacity of the SM (Table 1).

Becker et al. (1989) failed to note differences in LM color and marbling scores in carcasses of pigs transported long distances. Furthermore, Leheska et al. (2002) reported that pork color scores actually increased, and L* values and drip loss percentages decreased, in the LM and SM as a result of transportation stress. On the other hand, results of the present study confirm previously published information from our laboratory that long-term supplementation of swine diets with MM did not affect drip loss or muscle color (Apple et al., 1999). Yet, other researchers have reported that altering dietary Mg in swine diets reduced LM drip losses (D'Souza et al., 1998; Schaefer et al., 1993) and L* values (D'Souza et al., 1998), and increased a* values (Schaefer et al., 1993).

Implications

Results from this study indicate that supplementing the finishing diets of swine with magnesium mica at a level of 2.5% effectively elevated early-postmortem (0 and 45 minutes) muscle pH values of pigs subjected to three hours of transportation stress. Rapidly glycolyzing muscle, while muscle temperature is high, is the primary cause of pale, soft and exudative pork; therefore, slowing postmortem glycolysis and elevating muscle pH by supplementing swine diets with 2.5% magnesium mica may reduce the incidence of PSE pork in halothane-carriers subjected to a routine stressor like short-duration transportation.

Acknowledgments

The authors are grateful to Micro-Lite, Inc., Chanute, KS for donation of magnesium mica and financial support of this project. Additionally, the authors wish to express their sincere appreciation to Ashley Hays, Lance Kirkpatrick, and Joe Leibrandt for animal care; Jerry Stephenson, Rebecca Miller, and Nicholas Simon for animal harvest, carcass fabrication, and sample collection; Dr. Floyd McKeith, at the University of Illinois, for the use of his laboratory and assistance with assay training; Karen Anschutz for laboratory assistance with the glycolytic potential assays; and Dr. Zelpha Johnson for statistical consultation.

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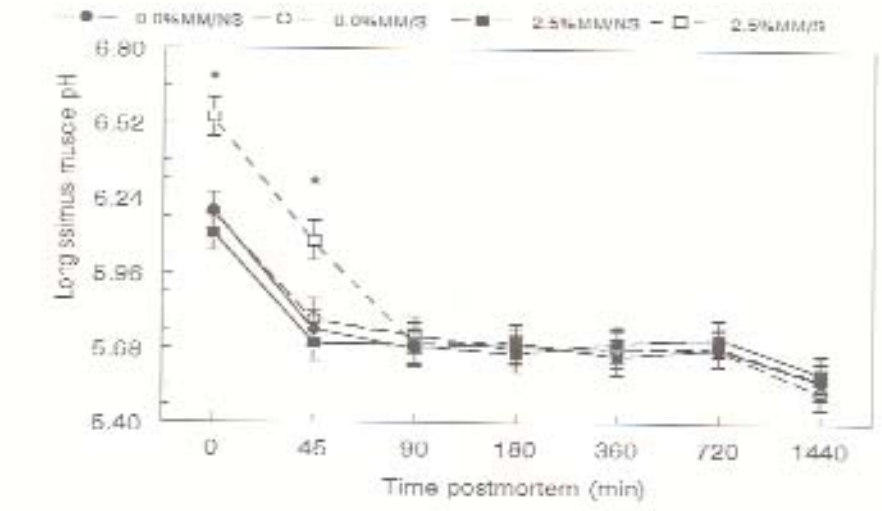

Fig. 1. Interactive effect of magnesium mica, transportation stress, and time postmortem (P < 0.01) on postmortem pH decline in the longissimus muscle (LM). Asterisks indicate that pigs fed 2.5% MM and subjected to 3 h of transportation stress were different (P < 0.05) from other treatment groups.

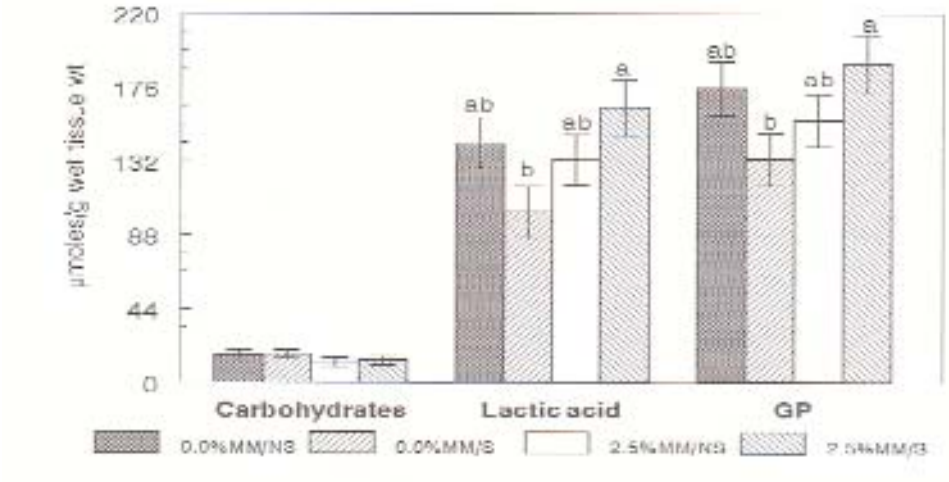

Fig. 2.The interactive effects of magnesium mica (0.0 or 2.5% MM) and transportation stress (no stress [NS] or 3 h of transportation stress [S]) on LM carbohydrates (glycogen + glucose + glucose-6-phosphate; P < 0.92); lactic acid (P < 0.03), and glycolytic potential (GP; P < 0.03). Bars within a group lacking a common superscript letter differ (P < 0.05).

Table 1. Main effects of dietary magnesium and transportation stress on pork quality characteristics of the longissimus and semimembranosus muscles[a]

	Magnesium mica, %			Transportation stress		
Quality trait	0.0	2.5	P <	No stress	Stress	P <
	---------- Longissimus muscle ----------					
American color score[b]	2.5 ± 0.26	2.4 ± 0.27	0.84	2.4 ± 0.26	2.6 ± 0.27	0.64
Japanese color score[c]	2.2 ± 0.28	2.1 ± 0.29	0.79	2.1 ± 0.28	2.2 ± 0.29	0.89
CIE L*[d]	58.88 ± 1.025	59.16 ± 1.075	0.85	60.02 ± 1.025	58.03 ± 1.075	0.20
CIE a*[d]	9.25 ± 0.345	8.92 ± 0.362	0.51	9.17 ± 0.345	9.00 ± 0.362	0.73
CIE b*[d]	19.20 ± 0.460	19.30 ± 0.483	0.89	19.63 ± 0.460	18.87 ± 0.483	0.27
%R630/%R580[e]	2.79 ± 0.059	2.74 ± 0.062	0.58	2.74 ± 0.059	2.79 ± 0.062	0.54
Marbling score[f]	1.3 ± 0.12	1.3 ± 0.12	0.92	1.2 ± 0.12	1.4 ± 0.12	0.39
Firmness score[g]	2.8 ± 0.23	2.7 ± 0.25	0.72	2.6 ± 0.23	2.9 ± 0.25	0.40
Drip loss, %	8.38 ± 0.854	8.23 ± 0.896	0.91	8.58 ± 0.854	8.03 ± 0.896	0.66
Moisture content, %	72.95 ± 0.231	73.45 ± 0.243	0.15	72.90 ± 0.231	73.51 ± 0.243	0.09
	---------- Semimembranosus ----------					
American color score[b]	3.4 ± 0.23	3.6 ± 0.24	0.53	3.3 ± 0.23	3.8 ± 0.24	0.18
Japanese color score[c]	3.0 ± 0.23	3.2 ± 0.24	0.56	3.0 ± 0.23	3.2 ± 0.24	0.41
CIE L*[d]	53.04 ± 1.403	51.87 ± 1.472	0.57	53.27 ± 1.403	51.64 ± 1.472	0.43
CIE a*[d]	9.96 ± 0.346	9.74 ± 0.363	0.67	9.90 ± 0.346	9.80 ± 0.363	0.85
CIE b*[d]	18.29 ± 0.391	17.19 ± 0.410	0.07	18.25 ± 0.391	17.22 ± 0.410	0.09
%R630/%R580[e]	3.03 ± 0.093	3.05 ± 0.098	0.88	2.98 ± 0.093	3.10 ± 0.098	0.37
Drip loss, %	5.89 ± 0.712	5.83 ± 0.747	0.96	5.83 ± 0.712	5.88 ± 0.747	0.96
Moisture content, %	73.93 ± 0.316	74.15 ± 0.331	0.64	73.83 ± 0.316	74.25 ± 0.331	0.37

[a] No significant ($P < 0.05$) dietary magnesium x transportation stress interactions; therefore, only least squares means (± SE) for main effects are reported.

[b] American color score: 1 = pale pinkish gray to 6 = dark purplish red (NPPC, 1999).

[c] Japanese color score: 1 = pale gray to 6 = dark purple (Nakai et al., 1975).

[d] L* values are a measure of lightness to darkness (larger number indicates a lighter color); a* values area measure of redness (larger number indicates a more intense red color); and b* values are a measure of yellowness (larger number indicates a more intense yellow color).

[e] Ratio of reflectance at 630 nm to reflectance at 580 nm is an indicator of oxymyoglobin content (higher ratio indicates more oxymyoglobin).

[f] Marbling score: 1 = 1% intramuscular lipid to 10 = 10% intramuscular lipid (NPPC, 1999).

[g] Firmness score: 1 = very soft/very watery to 5 = very firm/very dry (NPPC, 1991).

Estimates of Heritability for Body Length and Relationship to Other Performance Traits for Four Breeds of Swine.

Z. B. Johnson[1], J. J. Chewning[2], and R. A. Nugent III[2]

Story in Brief

The objective of this study was to estimate heritability for body length at the end of performance test and to estimate relationship of body length to other performance test traits for Landrace, Yorkshire, Duroc, and Hampshire breeds of swine. Data consisted of performance test records collected in a commercial swine operation from 1992 to 1999. At 100 d of age pigs were weighed (WT100) and selected for performance testing based on a combination of maternal and performance indexes which differed by breed. All pigs were weighed at the end of the 77 d performance test and backfat (BF), loin eye area (LEA), and body length (LEN) were measured. Average daily feed intake (ADFI) for boars and ADG for all animals were calculated. For each breed, genetic parameters were estimated using an animal model with litter effects and multiple-trait DFREML procedures. For each breed, a series of three-trait models including WT100, LEN, and one other trait were examined. Fixed effects included contemporary group and age as a covariate. Heritability estimates for LEN were 0.32 for Landrace, 0.23 for Yorkshire, 0.15 to 0.17 for Duroc, and 0.16 to 0.17 for Hampshire. Genetic correlations between body length and ADG were 0.64, 0.61, 0.38, and 0.57; between LEN and ADFI were 0.68, 0.55, 0.36, and 0.70; between LEN and BF were 0.28, 0.24, 0.10, and 0.41; and between LEN and LEA were 0.08, 0.06, –0.19, and 0.07 for Landrace, Yorkshire, Duroc, and Hampshire, respectively. Correlations indicated that pigs with higher ADG and ADFI on performance test were longer. Fatter pigs were also longer pigs; however correlations with LEA indicated very little or no relationship of this trait to body length.

Introduction

Genetic progress depends on accurate estimates of variances and heritabilities for traits of selection. Correlations with other traits may also be important.The objective of this study was to estimate heritability of body length at the end of postweaning performance tests and to estimate genetic correlations between body length and other performance test traits for Landrace, Yorkshire, Duroc, and Hampshire breeds of swine.

Experimental Procedures

Data for this study consisted of performance test records of Landrace, Yorkshire, Duroc, and Hampshire pigs collected in a commercial swine operation (The Pork Group, A Division of Tyson Foods, Inc., Rogers, AR) from 1992 to 1999. Two indexes (breeding values) for each animal were calculated at birth. One was a maternal index based on number born alive, farrowing interval, and litter weaning weight. The other was based on growth rate, leanness, and feed efficiency (Grow-Fin). The maternal index was computed using a three-trait model that included terms for the additive genetic effect, litter effects, and maternal genetic effects along with appropriate fixed effects. The Grow-Fin index was computed using a model that included only additive genetic effects and appropriate fixed effects. These two indexes were combined into an overall ranking depending on the breed. For Landrace equal emphasis was given to both indexes; for Yorkshire more emphasis was given to the maternal index; for Duroc more emphasis was given to the Grow-Fin index; and for Hampshire the emphasis was totally on the Grow-Fin index. Boars from approximately 60% of the litters were culled at weaning based on the breed specific index. Culled boars (barrows) were grown out and slaughtered. For economic reasons, these animals were not performance tested. Remaining boars and all females were grown to 100 d of age. At this time all pigs were weighed (WT100) and a second culling event occurred with recalculated indexes using any new information collected on animals in the breed. Fifty to sixty percent of the females and 20 to 25% of the remaining Yorkshire, Landrace and Duroc boars were put on performance test for approximately 77 d. A higher percentage (37%) of Landrace boars were performance tested.

Boars were individually penned in 2.79 m^2 pens with slotted gating on slatted concrete floors. Barns were curtain-sided buildings that were tunnel ventilated in the winter. Boars were fed for ad libitum consumption a pelleted corn-soybean meal diet that was 1.14% lysine, 19% protein, and 3,344 mcal/kg ME. Exact composition of the diet varied due to ingredient cost. Gilts were fed this same diet in groups of 8 to 10 pigs in a pen with each pig having an area of 1.2 m^2. Different size pens were available in different facilities, so pens in some barns held eight pigs and in other barns 10 pigs. All pigs had ad libitum access to water. All pigs were weighed at the end of the 77 d performance test, and body length (LEN) was measured from the top of the tail to the point of the shoulder when the head is down. At this time backfat (BF) and loin eye area (LEA) were measured at approximately the 12th rib using B-mode ultrasound equipment. Average daily feed intake (ADFI) was calculated for boars, and ADG was calculated for all animals.

Contemporary group was defined as all pigs of the same sex reared in the same house and started on test within a 3-mo period (quarter of a year). Data sets were edited to remove records of animals with missing sire or dam. Some description of the data sets is given in Table 1. There were 15,594, 55,497, 12,267, and 9,782 observations at 100 d of age for Landrace, Yorkshire, Duroc, and Hampshire, respectively. Of these, 7,951 Landrace, 26,656 Yorkshire, 5,240 Duroc, and 3,615 Hampshire had ADG records, with approximately the same number of observations for LEA and backfat. Because ADFI was only recorded for boars, a much lower number of observations were available for this trait.

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For each breed, genetic parameters were estimated using an animal model with litter effects and multiple-trait DFREML procedures (MTDFREML; Boldman et al., 1993; Boldman and Van Vleck, 1991). A series of three-trait models including WT100, LEN and one other trait (ADG, ADFI, BF or LEA) were examined. Fixed effects included contemporary group and age as a covariate. Initial test age (AGE100) was the covariate for WT100, ADG, and ADFI. Final test age (AGE177) was the covariate for BF, LEA, and LEN. WT100 was included in each analysis in an attempt to remove bias due to selection at 100 d of age; not all pigs weighed at 100 d of age were performance tested.

Results and Discussion

Means and standard deviations for performance test traits are given in Table 2. Mean weight at 100 days of age ranged from 86.2 lb for Hampshire to 101.2 lb for Landrace. Average weight at the end of the performance test was slightly above 250 lb for Landrace, Yorkshire and Duroc and lower for Hampshire (236.6 lb). Mean body length ranged from 35 inches for Yorkshire to 38.8 inches for Landrace.Results of analyses with ADG are given in Table 3. Estimates of heritability of WT100 ranged from 0.10 for Duroc to 0.24 for Landrace. Heritability estimates of ADG ranged from 0.17 for Hampshire to 0.25 for Yorkshire, and estimates of heritability of LEN ranged from 0.15 for Duroc to 0.32 for Landrace. The estimate of genetic correlation for WT100 with ADG was low (0.18) for Duroc, but higher for the other three breeds (0.39 to 0.46). Body length showed moderate to high correlations with WT100 (0.42 for Duroc to 0.66 for Hampsire) and ADG (0.38 for Duroc to 0.64 for Landrace). Common environmental litter effects explained from 22 to 27 % of the phenotypic variance for WT100, from 14 to 18 % of the phenotypic variance for ADG and from 15 to 22 % of the variance for body length.

Results of analyses with ADFI are given in Table 4. Estimates of heritability of WT100 are nearly the same as in analyses with ADG ranging from 0.11 for Duroc to 0.24 for Landrace. Heritability estimates of ADFI ranged from 0.20 for Hampshire to 0.32 for Yorkshire, and estimates of heritability of LEN (as in analyses with ADG) ranged from 0.15 for Duroc to 0.32 for Landrace. The Duroc breed had the lowest estimate of genetic correlation for WT100 with ADFI (0.19). This correlation was higher for the other breeds, ranging from 0.47 to 0.73. Moderate to high correlations were observed between LEN and ADFI (0.36 for Duroc to 0.70 for Hampshire). Again, common environmental litter effects explained from 22 to 27 % of the phenotypic variance for WT100. It explained from 20 to 24 % of the phenotypic variance for ADFI and from 15 to 22 % of the phenotypic variance for body length.

Results of analyses with backfat are given in Table 5. Estimates of heritability of WT100 and LEN are the same or similar to those obtained with the previous traits. Heritability estimates of BF were moderate ranging from 0.30 for Hampshire to 0.46 for Yorkshire. Estimates of genetic correlation for WT100 with BF were moderate to high ranging from 0.32 for Yorkshire to 0.54 for Hampshire. Correlations between WT100 and LEN were also moderate to high ranging from 0.44 for Duroc to 0.67 for Hampshire. Correlations between BF and LEN were lower ranging from 0.10 for Duroc to 0.41 for Hampshire. Common environmental litter effects for WT100 and LEN were the same or similar to those obtained in previous analyses with ADG and ADFI. They explained around 10 % of the phenotypic variance for BF (0.09 to 0.12 %).

Results of analyses with LEA are given in Table 6. Estimates of heritability of WT100 and LEN are the same or similar to those obtained with the previous traits. Heritability estimates of LEA were moderate ranging from 0.22 for Duroc to 0.34 for Landrace. Estimates of genetic correlation for WT100 with LEA ranged from 0.19 for Duroc to 0.35 for Hampshire. Correlations between WT100 and LEN were moderate to high ranging from 0.47 for Duroc to 0.68 for Hampshire. Correlations between BF and LEN were low ranging from 0.06 to 0.08 for Yorkshire, Hampshire, and Landrace, and negative for Duroc (-0.19). Common environmental litter effects for WT100 and LEN were similar to those obtained in previous analyses with ADG, ADFI, and BF. They explained 10 to 18 % of the phenotypic variance for LEA.

In summary, heritability estimates for LEN were 0.32 in all four analyses for Landrace, 0.23 in all analyses for Yorkshire, 0.15 in analyses with ADG, ADFI, and BF and 0.17 in analysis with LEA for Duroc, and 0.16 in analyses with ADG, ADFI and LEA and 0.17 in the analysis with BF for Hampshire. Estimates of genetic correlation between body length and ADG were 0.64, 0.61, 0.38, and 0.57; between LEN and ADFI were 0.68, 0.55, 0.36, and 0.70; between LEN and BF were 0.28, 0.24, 0.10, and 0.41; and between LEN and LEA were 0.08, 0.06, -0.19, and 0.07 for Landrace, Yorkshire, Duroc, and Hampshire, respectively. Correlations with ADG and ADFI indicated that longer pigs had higher ADG and ate more feed on performance test. Correlations with BF indicated that longer pigs were also fatter pigs; however, correlations with LEA indicated very little or no relationship between this trait and body length in these data sets.

Implications

Correlations with body length indicate that selection for post-weaning performance test data as practiced in these herds of swine can have an impact on this trait. In particular, selection for higher ADG and ADFI may result in longer pigs, while selection for decreased backfat may have the opposite result (i.e., shorter pigs). Loin eye area did not appear to be related to body length.

Literature Cited

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Table 1. Some descriptive statistics for data sets

	Breed			
Item	Landrace	Yorkshire	Duroc	Hampshire
N for WT100	15,594	55,497	12,267	9,782
N for ADG	7,951	27,656	5,240	3,615
N in A-1	16,028	56,943	12,581	9,950
No of contemporary groups	104	160	98	86
No of litters	2706	11,135	2119	1663
No of sires	204	550	168	87
No of dams	1016	3771	755	481

Table 2. Means and standard deviations for performance test traits for four breeds of swine

	Breed							
	Landrace		Yorkshire		Duroc		Hampshire	
Trait[a]	Mean	SD	Mean	SD	Mean	SD	Mean	SD
WT100, lb	101.2	16.8	97.7	16.9	92.7	17.1	86.2	16.2
Age100, d	98.7	2.9	99.3	2.9	99.0	2.8	100.1	2.9
ADG, lb	1.88	0.32	1.91	0.30	1.95	0.38	1.83	0.29
ADFI, lb	5.85	0.80	5.69	0.86	5.89	0.82	5.39	0.76
Backfat, in	0.67	0.18	0.65	0.19	0.72	0.17	0.59	0.14
LEA, in2	6.13	0.89	6.34	0.94	6.14	0.77	6.50	0.87
LEN, in	38.80	2.16	35.0	2.1	37.2	3.2	36.6	2.0
WT177, lb	252.5	31.5	251.6	28.8	250.8	27.1	236.6	29.3
Age177, d	175.7	4.1	176.4	3.8	176.0	3.9	177.2	4.0

[a] WT100 is weight at 100 days of age; ADG and ADFI are average daily gain and average daily feed intake on performance test, LEA, LEN and WT177 are loin eye area, body length and weight measured at the end of performance test.

Table 3. Genetic parameters for ADG and body length by breed

	Breed			
Item[a]	Landrace	Yorkshire	Duroc	Hampshire
h^2 WT100	0.24	0.19	0.10	0.16
h^2 ADG	0.22	0.25	0.18	0.17
h^2 LEN	0.32	0.23	0.15	0.16
r_g WT100 with ADG	0.46	0.39	0.18	0.43
r_g WT100 with LEN	0.65	0.48	0.42	0.66
r_g ADG with LEN	0.64	0.61	0.38	0.57
c^2 WT100	0.22	0.22	0.24	0.27
c^2 ADG	0.14	0.17	0.16	0.18
c^2 LEN	0.15	0.18	0.22	0.21

[a] WT100 is weight at 100 days of age; ADG is average daily gain on performance test; LEN is body length measured at the end of performance test. h^2 is estimate of heritability; r_g is estimate of genetic correlation; and c^2 is estimate of common environmental litter effect.

Table 4. Genetic parameters for average daily feed intake and body length by breed

	Breed			
Item[a]	Landrace	Yorkshire	Duroc	Hampshire
h^2 WT100	0.24	0.19	0.11	0.16
h^2 ADFI	0.24	0.32	0.23	0.20
h^2 LEN	0.32	0.23	0.15	0.16
r_g WT100 with ADFI	0.60	0.47	0.19	0.73
r_g WT100 with LEN	0.65	0.48	0.42	0.66
r_g ADFI with LEN	0.68	0.55	0.36	0.70
c^2 WT100	0.22	0.22	0.23	0.27
c^2 ADFI	0.23	0.20	0.24	0.22
c^2 LEN	0.15	0.18	0.22	0.21

[a] WT100 is weight at 100 days of age; ADFI is average daily feed intake on performance test; LEN is body length measured at the end of performance test. h^2 is estimate of heritability; r_g is estimate of genetic correlation; and c^2 is estimate of common environmental litter effect.

Table 5. Genetic parameters for backfat and body length by breed

	Breed			
Item[a]	Landrace	Yorkshire	Duroc	Hampshire
h^2 WT100	0.25	0.20	0.10	0.17
h^2 Backfat	0.44	0.46	0.36	0.30
h^2 LEN	0.32	0.23	0.15	0.17
r_g WT100 with backfat	0.36	0.32	0.40	0.54
r_g WT100 with LEN	0.65	0.48	0.44	0.67
r_g Backfat with LEN	0.28	0.24	0.10	0.41
c^2 WT100	0.22	0.22	0.24	0.27
c^2 Backfat	0.09	0.11	0.12	0.10
c^2 LEN	0.15	0.18	0.22	0.21

[a] WT100 is weight at 100 days of age; Backfat and LEN are backfat and body length measured at the end of performance test, respectively. h^2 is estimate of heritability; r_g is estimate of genetic correlation; and c^2 is estimate of common environmental litter effect.

Table 6. Genetic parameters for loin eye area and body length by breed

	Breed			
Item[a]	Landrace	Yorkshire	Duroc	Hampshire
h^2 WT100	0.25	0.20	0.11	0.17
h^2 LEA	0.34	0.28	0.22	0.24
h^2 LEN	0.32	0.23	0.17	0.16
r_g WT100 with LEA	0.28	0.20	0.19	0.35
r_g WT100 with LEN	0.65	0.49	0.47	0.68
r_g LEA with LEN	0.08	0.06	-0.19	0.07
c^2 WT100	0.22	0.22	0.23	0.27
c^2 LEA	0.10	0.14	0.12	0.18
c^2 LEN	0.15	0.18	0.21	0.21

a WT100 is weight at 100 days of age; LEA and LEN are loin eye area and body length measured at the end of performance test, respectively. h^2 is estimate of heritability; r_g is estimate of genetic correlation; and c^2 is estimate of common environmental litter effect.

Effects of Ascorbic Acid and Alpha-tocopherol on Cryopreserved Boar Sperm

C. Golden, C. Rosenkrans, Jr., and Z. Johnson[1]

Story in Brief

This study investigated the use of ascorbic acid and alpha-tocopherol to reduce the production of Reactive Oxygen Species (ROS) pre-freeze. Semen was centrifuged to remove extender and seminal plasma. Sperm was resuspended in Beltsville Thawing Solution (BTS) extender, concentrated, and assigned to treatments. Treatments were organized in a randomized complete block design with a 4 X 4 factorial treatment structure. Main effects were ascorbic acid and alpha-tocopherol at final concentrations of 0, 0.1, 1, and 10 mM. Sperm motility, viability, oxidation status, and the percentage of spermatozoa with intact acrosomes were used to evaluate sperm quality after cryopreservation. Three treatments (10 mM ascorbic acid and with either 0.1, 1 or 10 mM alpha-tocopherol) resulted in greater ($P < 0.01$) sperm motility after cryopreservation when compared with the control. Seven treatments increased ($P < 0.05$) boar sperm viability of which four treatments (0 mM ascorbic acid and 0.1 mM alpha-tocopherol; 10 mM ascorbic acid and 0, 0.1 or 1 mM alpha-tocopherol) greatly ($P < 0.01$) enhanced viability. Percentage of intact acrosomes was increased ($P < 0.05$) by adding 10 mM ascorbic acid and 1 mM alpha-tocopherol to the cryopreservation medium when compared with control. Interactive effects of ascorbic acid and alpha-tocopherol on sperm membrane oxidation were observed, the addition of 10 mM ascorbic acid at all concentrations of alpha-tocopherol to the cryopreservation medium decreased ($P < 0.05$) the oxidative damage to spermatozoa during cryopreservation compared to the control. The addition of 10 mM ascorbic acid and 1 mM alpha-tocopherol to BTS prior to cryopreservation resulted in improved post-thaw qualities of boar spermatozoa.

Introduction

Current cryopreservation methods for boar spermatozoa result in decreased sperm motility and viability. The reduction in viability and decline in fertility of cryopreserved boar spermatozoa is in part due to the production of reactive oxygen species (ROS). The generation of ROS is a normal consequence of oxidative metabolism. However, increased ROS production results in lipid peroxidation and ROS-induced membrane damage leading to loss of sperm motility, damage to the acrosomal membranes, and DNA oxidation.

Antioxidants such as ascorbic acid and alpha-tocopherol have a protective effect on both metabolic activity and cellular viability of cryopreserved bovine spermatozoa. Ascorbic acid acts as an antioxidant preventing oxidative damage of DNA in semen. Alpha-tocopherol is a well-recognized inhibitor of lipid peroxidation in biological membranes and demonstrates a protective effect on the plasma membrane of the bovine spermatozoa during cryopreservation. However, the effects of ascorbic acid and alpha-tocopherol on cryopreservation of boar sperm have not been tested.

The objective of the study was to determine the effects of adding ascorbic acid and alpha-tocopherol to the freezing medium on post-thaw boar sperm motility, viability, acrosome integrity, and oxidation of cryopreserved boar spermatozoa.

Experimental Procedures

Spermatozoa were distributed to treatment tubes containing the cryopreservation medium (Beltsville Thawing Solution; BTS) with combinations of ascorbic acid and alpha-tocopherol. The final concentration of spermatozoa was 6.2 X 10^7 million / ml. Conical tubes containing the sperm preparations were cooled to 5°C by placing the treatment tubes in 250 ml of water in a refrigerator for 2 h at 5°C. After 2 h, glycerol was added to a final concentration of 2 %. Preparations were gently mixed and flash frozen in 200 ml pellets on dry ice. Frozen pellets were plunged into liquid nitrogen.

Cryopreserved spermatozoa pellets (~20 pellets) were removed from liquid nitrogen and placed into 50 ml conical tubes for 3 min at room temperature (~ 20°C). Three milliliters of BTS (~ 20°C) were added to tubes containing pellets and placed in a water bath (50°C) and gently swirled until pellets were thawed. Conical tubes containing thawed pellets were placed in an incubator at 39°C until assays were conducted.

Sperm motility was determined by placing thawed spermatozoa on a prewarmed (39°C) microscope slide. The percentage of spermatozoa demonstrating forward motility was visually estimated. Microscope fields were chosen at random and magnification was set at 400X. A trained scientific panel consisting of five members independently evaluated sperm motility.

Sperm viability was determined using a Live/Dead kit (Molecular Probes, Eugene OR). A working solution of SYBR-14 was prepared by a 1:10 dilution in Dimethyl sulfoxide to achieve a final concentration of 0.1 mg/ml. Propidium iodide (PI; 2.4 mM) was used as provided in the kit. Five hundred microliters of spermatozoa were incubated with 0.5 ml of SYBR-14 for 5 min at 36°C followed by the addition of PI (5 ml) and incubation continued for an additional 10 min. The percentage of live, transitional, and dead spermatozoa were determined using a fluorescence-activated cell sorter (FACSCalibor). Fluorescence distributions of samples were acquired within 15 min post-incubation.

Acrosomal Integrity was determined by the use of the fluorescent stains; wheat germ agglutinin and PI. Five hundred microliters of spermatozoa were incubated with 30 ml of lectin-wheat germ agglutinin (FITC-WGA) and 2 ml PI for 15 min at 36°C. The percentage of spermatozoa with intact, transitional, or damaged acro-

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somes were determined using a FACSCalibor. Fluorescence distributions of samples were acquired within 15 min post-incubation. Intact acrosomal regions of spermatozoa were bound by FITC-WGA and fluoresced bright green; whereas, PI had a red fluorescence when bound to damaged acrosomal regions of spermatozoa.

Sperm oxidative levels were determined using the thiobarbituric acid (TBA) reaction. One milliliter of each spermatozoa treatment was incubated in the presence of 10 mM iron sulfate, 100 mM sodium ascorbate and 0.7 ml Tris buffer (100 mM, pH 7.4) at 37°C for 60 min. The reaction was stopped by adding 1 ml of 10 % trichloroacetic acid and kept on ice for 15 min. Samples were centrifuged at 7800 x g for 15 min and the supernatant retained. The progress of endogenous peroxidation was followed by adding 1 ml of 1 % TBA to 2 ml of supernatant. That mixture was boiled for 10 min, allowed to cool, and absorbance levels acquired by spectrometry at 530 nm.

Data were analyzed using a general linear model and SAS (SAS Inst., Inc., Cary, NC). If F-tests were significant, means were separated using the PDIFF option of PROC GLM. The model for the analysis included replicate, ascorbic acid, alpha-tocopherol, and main effect interactions.

Results and Discussion

The percentage of actively motile spermatozoa was 68 % at the initiation of the experiment; whereas, the mean sperm motility, averaged over all treatments, was 3.5 % after cryopreservation. Figure 1 presents the interactive effects of ascorbic acid and alpha-tocopherol on sperm motility after cryopreservation. Three treatments (10 mM ascorbic acid and either 0.1, 1 or 10 mM alpha-tocopherol) resulted in greater ($P < 0.01$) sperm motility after cryopreservation when compared with the control (15.0, 13.5, 11.8 vs. 3.5 %, respectively).

Mean sperm viability after cryopreservation, averaged over all treatments, was 8.7 %. The interactive effects of ascorbic acid and alpha-tocopherol on sperm viability after cryopreservation (Figure 2). Boar sperm viability was increased ($P < 0.01$) by adding 0 mM ascorbic acid and 0.1 mM alpha-tocopherol; 10 mM ascorbic acid and either 0, 0.1 or 1 mM alpha-tocopherol to the cryopreservation medium when compared to the control (12.1, 11.5, 11.0, 13.7 vs. 8.7%, respectively). Other combinations of ascorbic acid and alpha-tocopherol either had no effect or decreased sperm viability after cryopreservation.

Mean percentage of spermatozoa, averaged over all treatments, with intact acrosomes was 14 % after cryopreservation. Most combinations of ascorbic acid and alpha-tocopherol did not improve acrosomal integrity following cryopreservation (Figure 3). However, adding 10 mM ascorbic acid and 1 mM alpha-tocopherol to the cryopreservation medium increased ($P < 0.05$) the percentage of spermatozoa with intact acrosomes when compared with the control (19.5 vs. 14.2 %, respectively). In contrast, adding 0.1 mM ascorbic acid and 0.1 mM alpha-tocopherol to cryopreservation medium decreased the percentage of spermatozoa with intact acrosomes when compared with control spermatozoa (8.4 vs. 14.2 %, respectively).

Interactive effects of ascorbic acid and alpha-tocopherol on sperm membrane oxidation after cryopreservation (Figure 4). Seven treatments decreased ($P < 0.05$) the oxidative damage to spermatozoa during cryopreservation when compared to the control. The treatment of 10 mM ascorbic acid and 1 mM alpha-tocopherol greatly decreased ($P < 0.01$) oxidation levels as compared to the control (0.7535 vs. 1.0819, respectively). Sperm oxidative damage was lowest when 10 mM ascorbic acid and 1 mM alpha-tocopherol were added to the cryopreservation medium. Conversely, 0.1 mM ascorbic acid with either 0 or 10 mM alpha-tocopherol increased ($P < 0.05$) oxidative damage to spermatozoa during cryopreservation when compared with the control (1.2248 and 1.5186 vs. 1.0819, respectively).

Implications

This study suggests that the addition of 10 mM ascorbic acid and 1 mM alpha-tocopherol may result in favorable increases in boar sperm motility, viability and intact acrosomes, while lowering oxidative levels. However, additional refinement of methods is necessary to improve boar sperm post-thaw characteristics to an acceptable level.

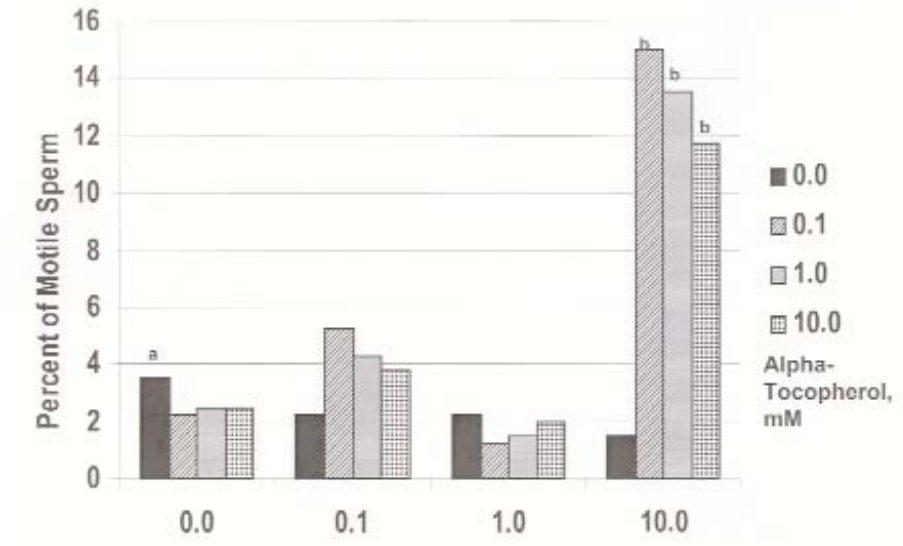

Fig. 1. Effects of adding ascorbic acid and alpha-tocopherol to cryopreservation medium on post-thaw motility of boar spermatozoa. [a,b] Percentages that were different ($P < 0.01$) from the control (indicated by [a]) are designated with [b].

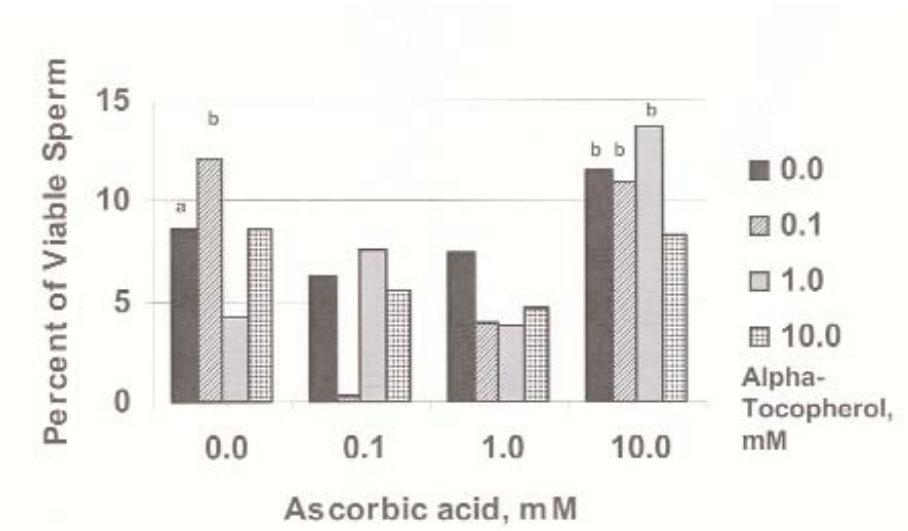

Fig. 2. Effects of adding ascorbic acid and alpha-tocopherol to cryopreservation medium on post-thaw viability of boar spermatozoa. [a,b] Percentages that were different (P < 0.01) from the control (indicated by [a]) are designated with [b].

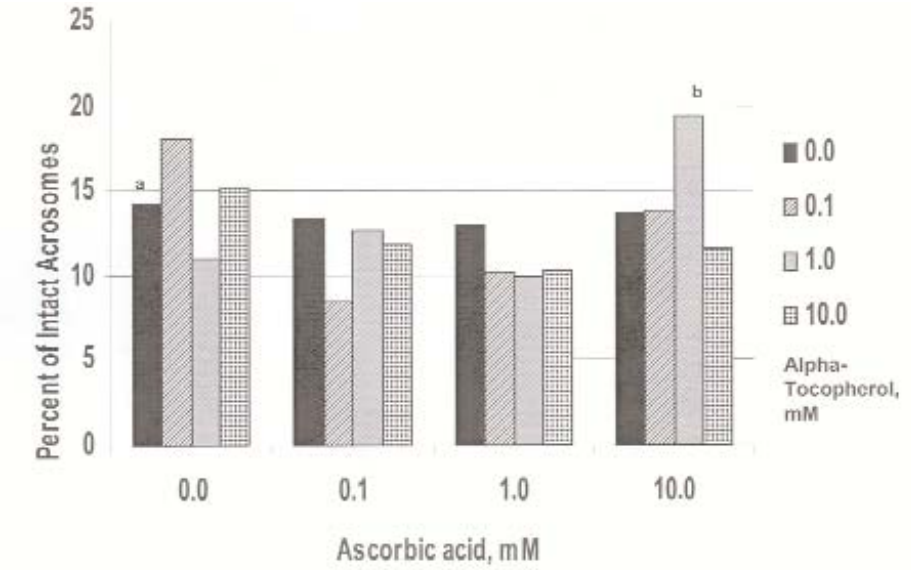

Fig. 3. Effects of adding ascorbic acid and alpha-tocopherol to cryopreservation medium on post-thaw acrosome integrity of boar spermatozoa. [a,b] Percentages that were different (P < 0.05) from the control (indicated by [a]) are designated with [b].

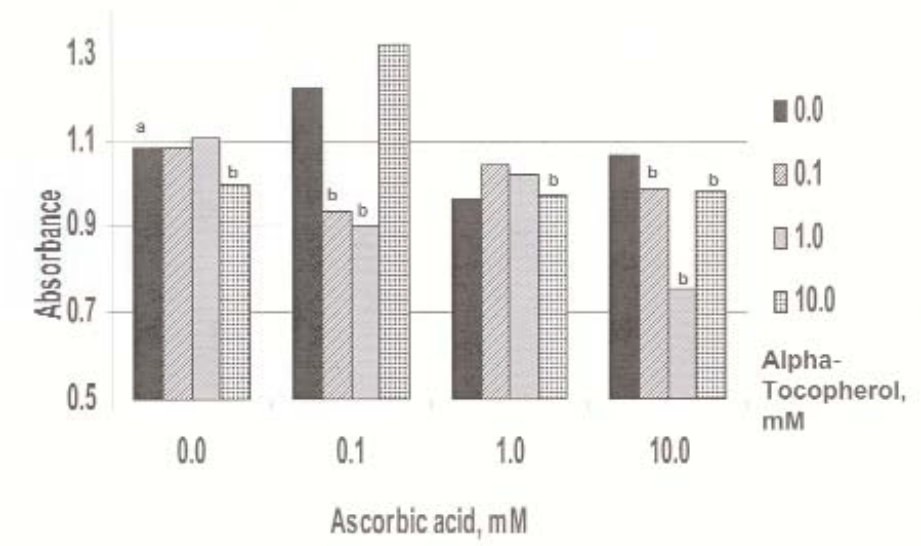

Fig. 4. Effects of adding ascorbic acid and alpha-tocopherol to cryopreservation medium on post-thaw membrane oxidation of boar spermatozoa based on TBAR. [a,b] Percentages that were different (P < 0.05) from the control (indicated by [a]) are designated with [b].

Comparison of Electronic Mount Monitors for Detection of Estrus in Cattle

R.W. Rorie, T.R. Bilby, and T.D. Lester[1]

Story in Brief

Electronic technologies have been developed in an attempt to improve estrus detection efficiency. This study compared three commercially available electronic devices (based on mounting activity) for estrus detection in crossbred dairy heifers. Starting at estrus synchronization treatment, the heifers were continuously monitored for estrus using either the HeatWatch system, or stand-alone ShowHeat and MountCount mount monitors. All heifers were artificially inseminated 4 to 14 h after the onset of estrus. The mount monitors were found to be equally effective in detecting estrus. Based on subsequent pregnancy rates (93 to 97%), all three mount-detection monitors were accurate in correctly detecting heifers in estrus. The HeatWatch system required the least labor and animal handling. While more labor intensive, the less expensive stand-alone mount ShowHeat and MountCount monitors also provided information for optimum timing of insemination. All three of the mount monitors evaluated in this study can improve the efficiency of estrus detection over that previously reported for visual observation.

Introduction

Artificial insemination programs require accurate and efficient detection of estrus. Detection efficiency is the percentage of animals in estrus that are actually detected, whereas accuracy is the portion of animals identified as in estrus that truly are in estrus. Visual observation for mounting activity is an accurate method for detecting estrus. There is only a 2% error in identifying cows in estrus, when they are observed standing immobile when mounted. The efficiency of estrus detection, however, is typically less than 50% for lactating dairy cows and 50 to 75% for beef cows. It is likely that many of the cows not detected by visual observation are those with short estrus periods and/or infrequent mounts. Approximately 25% of cows have estrus periods characterized by low intensity (few mounts) and short duration.

Electronic technologies have been developed in an attempt to improve estrus detection efficiency. The various electronic estrus detection technologies measure either increased physical activity that occurs before and during estrus, changes in secretions of the reproductive tract, or mounting activity. Mounting-activity detectors perhaps have the broadest application to beef and dairy cattle. Currently, there are three electronic mount-monitoring products commercially available that offer continuous, 24-h monitoring for mounting activity. The present study was conducted to compare the accuracy, efficiency, and dependability of these electronic estrus detection products.

Experimental Procedures

In this study, the HeatWatch electronic estrus detection system was compared with MountCount and ShowHeat mount detectors, using crossbred dairy heifers. The HeatWatch system (DDx, Inc., Denver, Co) consisted of individual rump-mounted mount detectors that transmit data (time and duration of each mount) via radio signal to a receiver. A buffer then stores the mount data until accessed with a computer, using HeatWatch software. The system default for standing estrus is at least three mounts of 2 sec or more each, occurring within a 4-h period. The time of the first mount in the 4-h period is identified as the onset of estrus.

MountCount is a stand-alone mount monitor available from DDx, Inc. The device has a series of three lights that flash to indicate either suspect heat, standing heat or optimum time for insemination. When a cow receives a single mount, the suspect light flashes. After the animal receives three or more mounts within a 4-h period, the standing heat light starts to flash. The breed light flashes during the preferred time after onset of estrus for breeding, depending on whether the monitor is programmed for beef or dairy cattle. For dairy cattle, the breeding light will flash for 10 h, from 4 until 14 h after the onset of estrus. For beef cattle, the breeding light is programmed to flash for a 12-h period, from 7 until 19 h after the onset of estrus.

ShowHeat is also a stand-alone mount monitor available from I.M.V. International (Minneapolis, MN). The device has a single light that is activated when the cow receives at least three mounts. The light flashes a sequence at 12-sec intervals, with each flash within the sequence representing 2 h since onset of estrus. The number of flashes in a sequence can be counted to calculate when the onset of estrus occurred and insemination can be timed accordingly. The light will continue to flash for up to 18 h after the onset of estrus.

The heifers (n = 89) were crossbred Holsteins, Jerseys and Brown Swiss between 14 to 16 mo of age and weighing 670 to 825 lb. Within breed groups, heifers were randomly assigned by weight and age to be monitored by HeatWatch, MountCount or ShowHeat mount monitors. Mount detector patches provided by the manufacturer were glued to the rumps of heifers, following the instructions provided by the manufacturer. HeatWatch and MountCount utilized nylon mesh patches that were glued on with contact cement whereas ShowHeat used burlap patches attached with spray adhesive.

The heifers received injections of prostaglandin F2alpha (PGF2a; 25 mg Lutalyse, im) at the start of the study and again 2 weeks later, if they were not detected in estrus. All heifers were penned twice daily and observed to determine if the lights on the MountCount and ShowHeat devices indicated estrus. Mount data from the HeatWatch system was also downloaded twice daily. All animals were artificially inseminated 4 to 14 h after the onset of estrus, using frozen semen from a single sire. Sixteen days after breeding, the ShowHeat and MountCount monitors were reset to detect return to estrus. Pregnancy was confirmed by ultrasonography

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at 30 to 45 d of gestation in heifers failing to return to estrus. Mount monitors remained on heifers until pregnancy was confirmed. Percentage data for number of animals detected in estrus and pregnancy rates were compared using chi-square analysis.

Results and Discussion

The mount monitors were found to be equally effective in detecting estrus (Table 1). Based on subsequent pregnancy rates, all three mount detection devices were accurate in correctly detecting heifers in estrus. However, there were two instances with ShowHeat and one with MountCount in which the devices indicated return to estrus but the heifers were later confirmed (by fetal size at ultrasonography) to be pregnant from the first insemination. No "false positives" occurred with the HeatWatch system.

There were differences in the labor required and ease of use for the three mount monitors. The HeatWatch system required the least labor to monitor the heifers after they were enrolled on the system. Mount detector/transmitter status and mount data could be assessed in 5 min or less daily and without animal handling, unless heifers needed to be sorted for insemination. Heifers monitored by MountCount and ShowHeat required close, twice-daily observation to determine if the lights on the monitors indicated estrus. On pasture, it was necessary to observe animals before sunup and after sundown. In sunlight, the animals needed to be penned and observed closely from behind to determine monitor status with any confidence. The light on ShowHeat monitors was brighter and easier to detect in sunlight than those on the MountCount, but the 12-sec delay between sequences of flashes increased observation time. Status of the MountCount devices could be determined quickly, but required very close inspection to observe the lights through the pouch on the mounting patches.

For any of the mount monitoring devices to work, they must remain properly attached to the animal. The patches tend to get torn loose by mounting activity and required re-gluing. The burlap patch provided with the ShowHeat monitor required the least maintenance. During the 40 d or more that ShowHeat patches were on animals, none were torn completely off by mounting activity. However, four patches and ShowHeat monitors required replacement because mounting activity tore open the pouches holding the monitors. About 25% of the HeatWatch and MountCount patches required periodic re-gluing during the evaluation period. One MountCount was lost when the patch was torn apart by mounting activity. None of the HeatWatch transmitters were lost from their pouches.

An advantage of the HeatWatch system is that transmitter function is monitored and can be confirmed at any time through the system software. The MountCount and ShowHeat devices do not have an easy way to determine if they are functioning and require resetting after each use. In our limited experience, the ShowHeat monitor was very reliable; none of the 40 devices malfunctioned. Four of 40 MountCount devices either did not work or failed during use. None of the devices were used more than five times during the study so long term reliability was not determined.

Overall, all three mount monitoring devices evaluated were effective for estrus detection. The HeatWatch system required the least labor and was more flexible in its application to either dairy or beef cattle. The MountCount and ShowHeat devices might be better suited to dairy cattle, where the devices can be monitored at each milking. They would also be applicable to other situations where animals are housed close to working facilities and can be monitored closely. The ShowHeat and MountCount devices also have the advantage of reducing the cost of continuous electronic estrus detection to about $5 per head.

Implications

Electronic mount monitoring devices can improve the efficiency of estrus detection, over that reported for visual observation. Of the devices evaluated, the HeatWatch system required the least labor and animal handling. However, the less expensive but more labor intensive, stand-alone ShowHeat and MountCount monitors also provided the necessary information for optimum timing of insemination.

Table 1. Efficiency of electronic mount monitors for estrus detection and subsequent pregnancy rates after artificial insemination

Mount Detector	No. (%) of heifers Detected in estrus[a]	First service pregnancy rate	Overall pregnancy rate
HeatWatch	29/29 (100)	21/29 (72.4)	27/29 (93.1)
MountCount	28/28 (100)	20/28 (71.4)	27/28 (96.4)
ShowHeat	30/30 (100)	21/30 (70.0)	29/30 (96.7)

[a] Indicates the percentage of heifers detected in estrus over a 28-d period. Two heifers (one heifer each in the HeatWatch and MountCount groups) were determined to be sterile (freemartins) and were excluded from the study.

Estrus Synchronization and Timed Artificial Insemination with Melengestrol Acetate Plus GnRH in Beef Females

N. M. Post, D.L. Kreider, R. Rorie, T. Lester, and K. Cole[1]

Story In Brief

Two trials were conducted to compare gonadotropin releasing hormone (GnRH) in combination with two melengestrol acetate (MGA) synchronization programs on pregnancy rates to timed artificial insemination (AI). In Trial 1, cows (n = 65) and heifers (n = 16) were assigned to one of four treatments. All treatments received supplement with 0.5 mg MGA/head/d on d 1 to 14, and supplement without MGA on d 15 to 31. Otherwise, treatments were: 1) Prostaglandin F2a (PGF2a) injection on d 32, and bred by AI at estrus for 8 d (MPG); 2) PGF2a on d 32, plus GnRH (100 µg) at 48 h after PGF2a and bred by timed AI (MPGG); 3) supplement plus 0.5 mg MGA/head/d on d 32 to 36, and bred by AI at estrus for 8 d (MM); 4) supplement plus 0.5 mg MGA/head/d on d 32 to 36, followed by GnRH at 72 h after MGA, and bred by timed AI (MMG). In Trial 2, cows (n=41) and first-calf heifers (n=15) were assigned to treatments identical to those in Trial 1 except that MM was not included. Days postpartum, weight, body condition score, and percent cycling prior to treatment did not differ among treatment groups in either trial. In Trial 1 45% (9/20) of MPG exhibited estrus after PGF2a injection compared to 40% (8/20) of MM following the second MGA withdrawal. Time to estrus was less ($P < 0.01$) in MPG than MM (62 ± 23 h vs. 110 ± 52 h, respectively). Pregnancy rates from AI at 30 to 40 d post AI were 11% (1/9), 43% (9/21), 18% (2/11), 50% (10/20) for MPG, MPGG, MM and MMG treatments, respectively ($P < 0.001$). Overall pregnancy rates determined by rectal palpation at 45 to 90 d were 70% (14/20), 81% (17/21), 45 % (9/20) 75 % (15/20) for MPG, MPGG, MM, and MMG treatments, respectively ($P < 0.07$). In Trial 2 pregnancy rates to AI at 30 to 40 d after insemination were 84% (11/13), 73% (14/19) 44% (8/18) for MPG, MPGG, and MMG treatments, respectively ($P < 0.04$). Overall pregnancy rates were 100% for MPG, 89% for MPGG, and 100% for MMG groups. Timed AI pregnancy rates of 43% and 73% for the MGA-Prostaglandin-GnRH group and 50% and 44% in the MGA-MGA-GnRH groups resulted in pregnancy rates similar to those achieved in other timed AI protocols.

Introduction

The effectiveness of an estrus synchronization system is measured by its ability to elicit a fertile, tightly synchronized estrus in a majority of treated females. Ideally, a system should be cost effective, require minimum labor, entail limited animal handling, and be user friendly to a producer. Orally administered melengestrol acetate (MGA) has been proven to effectively suppress estrus and achieve estrus synchronization. The inability to predict time of estrus for individual cows and heifers in a group makes AI impractical for some producers because of the time required for estrus detection. The development of an economical method for fixed single-time AI, at which the whole herd is inseminated, would decrease labor requirements and could lead to a dramatic increase in the use of AI (Wood et al. 2001). Feeding MGA at 0.5 mg/hd/d for 14 d followed by PGF2a injection 17 d after MGA withdrawal has been an effective method of estrous cycle control in heifers (Brown et al. 1988). Recent research has shown that a two-part MGA regime resulted in a higher percentage of cows in estrus and comparable pregnancy rates when compared to an MGA-PGF2a program (Wright et al., 1999). When used in combination with an MGA-PGF2a synchronization program, gonadotropin releasing hormone (GnRH) has decreased the time to estrus and given the potential for fixed-time insemination (Wood et al. 2001). Injecting cows at random stages of the estrous cycle with GnRH causes a luteinizing hormone (LH) release, which leads to ovulation. The objective of this study was to evaluate the use of a single injection of GnRH in combination with two different MGA synchronization programs on pregnancy rates to fixed-time AI.

Experimental Procedures

Animals. Animals used in this study were located at the University of Arkansas Cow/Calf Unit at Savoy and were primarily straightbred Angus cows and heifers. Animals were managed on predominantly fescue pastures before and after the treatment periods and were provided free access to fescue hay when pasture was limited. Animals in both trials were managed on a single pasture unit except during the second MGA feeding, during which time, all cows were penned and provided free access to fescue hay. Cows in both trials were at least 14 d postpartum at the start of the study. Animals that were not subjected to timed AI were monitored for estrus for an 8-d breeding period, using the Heat Watch® System. Following AI, cows were placed with fertile cleanup bulls through the remainder of a 60 d breeding season, beginning at approximately 14 d following AI. Pregnancy rates to AI were confirmed by ultrasound at approximately 30 d after AI. Overall pregnancy rates were determined by rectal palpation at 45 to 90 d after bull removal.

Trial 1. Cows (n=65) and heifers (n=16) were sorted by days postpartum, body condition score (BCS) and body weight and then randomly assigned to one of four treatments. Initially, cows and heifers in all treatment groups received 4 lb of supplement containing MGA (0.5 mg/hd/d) for 14 d. Thereafter, animals in Treatment 1 (MPG, n = 20) and Treatment 2 (MPGG, n = 21) received an intramuscular (i.m.) injection of PGF2a (25 mg Lutalyse; Pharmacia Animal Health, Kalamazoo, MI) 17 d after the last MGA feeding (d 31 of treatment). Animals in the MPG treatment were then subjected to estrus detection and AI for an 8-d period. Animals in the MPGG treatment received an i.m. Injection of GnRH (100 µg Cystorelin;

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Rhone Merieux, Inc., Athens, GA) 48 h after the PGF2a injection and were then subjected to timed AI at 16 to 18 h after GnRH. Cattle in Treatment 3 (MM, n=20) and Treatment 4 (MMG, n=20) were offered 4 lbs of supplement containing .5 mg MGA mg/hd/d for an additional 5 d, beginning at 17 d after first MGA withdrawal (d 32 of treatment). After the second 5 d MGA feeding, cows in the MM treatment were subjected to estrus detection and AI for 8 d. Animals in the MMG treatment were injected with GnRH at 72 hours after the last MGA feeding (d 38 of treatment) and were subjected to timed AI at 16 to 18 h after GnRH. Treatment protocols are illustrated in Figure 1.

Trial 2. In Trial 2, cows (n=41) and first-calf heifers (n=15) at random stages of their estrous cycles were sorted by days postpartum, BCS, and body weight and then randomly assigned to treatments. All treatments and procedures were the same as those described for Trial 1, except that Treatment 3 (MM) was not included. The MM treatment was not included due to a limited number of experimental animals and due to the fact that the primary purpose of the experiment was to compare alternative timed AI procedures to more commonly used conventional AI procedures. The number of animals per treatment groups was as follows: MPG (n=19), MPGG (n=19) and MMG (n=18).

Blood Collection and Radioimmunoassay (RIA). In both trials, blood samples were collected from all animals at -7 d and d 1 of MGA feeding to determine postpartum reproductive status. All animals were also bled prior to the PGF2a injection or the second MGA feeding (d 32 of treatment) to determine if a functional corpus luteum (CL) was present. Ten milliliters of blood was collected via jugular venipuncture and held on ice to clot. Blood was then centrifuged and serum was harvested and stored at –20° C until assayed for progesterone (P4) by RIA (Coat-A-Count, Diagnostic Products Corporation, Los Angeles, CA). Cattle were considered to be cycling if either of the two (d –7, or d 1) serum samples had P4 concentrations greater than or equal to 1.5 ng/ml. Animals were considered to have a functional CL on d 32 of treatment if the P4 concentration in the sample on d 32 was greater than or equal to 1.5 ng/ml.

Statistical Analyses. The general linear models and chi-square test (SAS Inst., Inc., Cary, NC) were used to compare pregnancy rates to AI, overall pregnancy, animals determined to be cycling and animals with a functional CL. Proc GLM and a test of the least significant difference between least-squares means were used to compare means for all other variables studied.

Results and Discussion

Trial 1. Average initial days postpartum, body weight, body condition score (BCS) and the percent of animals cycling at the start of the experimental treatments is in Table 1. There was no significant difference among treatment means for any of the initial variables measured.

Reproductive response variables by treatment group are presented in Table 2. The number of animals with a functional CL at d 31 of treatment did not differ statistically among treatment groups. Of the two treatment groups in which heat was detected, no significant difference was observed in the percent of animals that exhibited estrus, however, the time to estrus measured from the time of the PGF2a injection (MPG group) or from the last MGA feeding (MM group) was longer ($P < 0.0002$) for the MM group compared to the MPG group. The percent of animals pregnant to AI was higher ($P < 0.001$) in both of the timed AI groups (MPGG and MMG) than either of the groups bred by estrus detection (MPG and MM). Overall pregnancy rates were lower ($P < 0.07$) in the MM treatment group than in the MPG, MPGG or the MMG treatment groups.

Trial 2. Means for initial days postpartum, body weight, body condition score (BCS) and the percent of animals cycling at the start of the experiment are in Table 3. There were no significant differences among treatment means for any of the initial variables measured.

Means for the reproductive response variables measured in Trial 2 are in Table 4. As in Trial 1, there were no significant differences in the number of animals determined to have a functional CL at the time of the PGF2a (MPG and MPGG treatment groups) or at the start of the second MGA feeding (MMG treatment group). Pregnancy rate to AI was higher ($P < 0.04$) in the MPG and the MPGG groups than in the MMG groups, however overall pregnancy rates (AI + natural service) were not different among treatment groups.

Discussion

The timed AI pregnancy rates of 43% and 73% for the MGA-Prostaglandin-GnRH group and 50% and 44% in the MGA-MGA-GnRH groups suggests that either of these methods give timed AI pregnancy rates similar to those achieved in other timed AI protocols such as the Co-Synch or Ovsynch procedures. We are unable to explain the low pregnancy rates achieved in the MPG and MM treatments in Trial 1. The MM protocol has typically given much higher pregnancy rates in previous studies (Wright et al., 1999).

Implications

The results of this study indicate that the combination of MGA and Prostaglandin plus gonadotropin releasing hormone or a two part MGA treatment plus gonadotropin releasing hormone can be used effectively in a timed AI program. The cost and number of times animals are handled is less than most other timed AI protocols. Exact costs would be dependent on whether animals would normally be receiving supplement during the postpartum period.

Literature Cited

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Table 1. Initial days postpartum, body weight, body condition score (BCS) and percent cycling by treatment group (Trial 1)

	Treatment			
Item	MPG	MPGG	MM	MMG
Animals (n)	20	21	20	20
Days PP (days)	38.8 ± 2.1	34.7 ± 2.1	32.8 ± 2.1	37.7 ± 2.1
Body Weight (kg)	454 ± 17	459 ± 16	452 ± 17	452 ± 17
BCS (1-9)	5.2 ± 0.1	5.2 ± 0.1	5.2 ± 0.1	5.2 ± 0.1
Cycling (%)	45 (9/20)	38 (8/21)	40 (8/20)	55 (11/20)

Table 2. Reproductive status, estrus response and pregnancy rates by treatment group (Trial 1)

	Treatment			
Item	MPG	MPGG	MM	MMG
Functional CL (%)	55 (11/20)	57 (12/21)	55 (11/20)	76 (15/20)
Detected in estrus (%)	45 (9/20)	---	55 (11/20)	---
Time to Estrus (h)[a]	62 ± 23	---	110 ± 52	---
Pregnant to AI (%)[b]	11 (1/9)	43 (9/21)	18 (2/11)	50 (10/20)
Overall pregnancy (%)[c]	70 (14/20)	81 (17/21)	45 (9/20)	75 (15/20)

[a] $P < 0.0002$
[b] $P < 0.001$
[c] $P < 0.07$

Table 3. Initial days postpartum, body weight, body condition score (BCS) and percent cycling by treatment group (Trial 2)

	Treatment		
Item	MPG	MPGG	MMG
Animals (n)	19	19	18
Days PP (days)	37.3 ± 2.5	35.8 ± 2.5	35.7 ± 2.5
Body Weight (kg)	490 ± 14	498 ± 14	483 ± 14
BCS (1-9)	5.21 ± 0.14	5.31 ± 0.14	5.16 ± 0.14
Cycling (%)	52 (10/19)	52 (10/19)	55 (10/18)

Table 4. Reproductive status, estrus response and pregnancy rates by treatment group (Trial 2)

	Treatment		
Item	MPG	MPGG	MMG
Functional CL (%)	89 (17/19)	89 (17/19)	72 (13/18)
Detected in estrus (%)	68 (13/19)	---	---
Time to estrus (h)	74 ± .74	---	---
Pregnant to AI (%)[a]	84 (11/13)	73 (14/19)	44 (8/18)
Overall pregnancy (%)	100 (19/19)	89 (17/19)	100 (18/18)

[a] $P < 0.04$

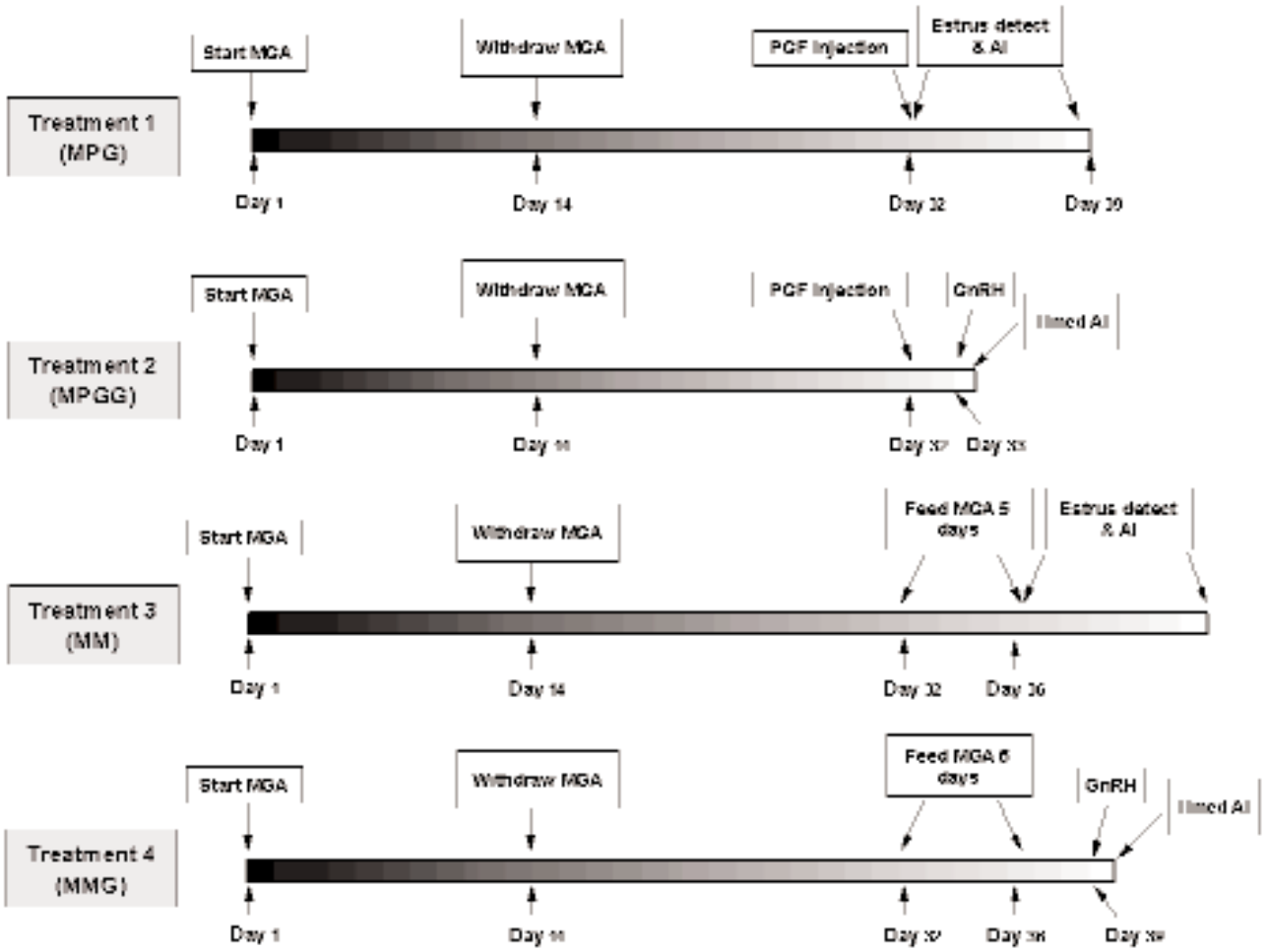

Fig. 1. Estrus synchronization protocols.

Comparison of Lutalyse and Estrumate for Inducing Estrus in Beef Cows and Heifers

R.W. Rorie and T.D. Lester[1]

Story in Brief

The objective of this study was to compare the effectiveness of two prostaglandin F2alpha ($PGF_{2\alpha}$) products, Lutalyse (dinoprost) and Estrumate (cloprostenol), for induction of estrus in beef cattle. A total of 385 Angus or crossbred beef cows and heifers from three herds was used in the study. Depending on the herd, cows received either no pre-synchronization treatment, a gonadotropin-releasing hormone (GnRH) injection followed 7 days later with $PGF_{2\alpha}$ or a $PGF_{2\alpha}$ injection 14 days prior to dinoprost or cloprostenol treatment. Heifers were initially synchronized by feeding them melengestrol acetate (MGA) for 14 days. Within herds, the cows or heifers were randomly selected to receive the recommended dosage of either dinoprost or cloprostenol to induce estrus. All animals were continuously monitored for estrus, using a HeatWatch electronic mount monitoring system. HeatWatch mount transmitters were placed on the cows and heifers at the time of dinoprost or cloprostenol treatment. The time of treatment was recorded so that the interval from treatment to onset of estrus could be determined. The results of this study indicate that dinoprost or cloprostenol are equal in their effectiveness in inducing estrus in beef cows and heifers. A similar percentage of animals were detected in estrus after treatment, regardless of the estrous synchronization scheme in which the products were used. The interval from treatment to estrus and intensity of estrus were similar for both products. With both dinoprost and cloprostenol, the number of animals in estrus peaked about 60 hours after treatment.

Introduction

Prostaglandin F2alpha ($PGF_{2\alpha}$ products have been used for a number of years for synchronization of estrus in cattle. Prostaglandin F2alpha induces estrus in cattle when given during the luteal phase of the estrous cycle, which occurs between 7 and 17 days after the onset of estrus. Lutalyse and Estrumate are $PGF_{2\alpha}$ products that are widely used for estrous synchronization before artificial insemination or embryo transfer. Lutalyse is the naturally occurring $PGF_{2\alpha}$ (dinoprost), whereas Estrumate is a more potent analog of $PGF_{2\alpha}$ (cloprostenol).

Some livestock producers and embryo transfer technicians have suggested that cloprostenol results in a higher percentage of treated animals in estrus than does dinoprost. Others have suggested that cloprostenol induces estrus sooner after treatment and that a higher than recommended dosage of dinoprost is necessary to induce estrus in larger framed cows. The present study was conducted to directly compare the effectiveness of dinoprost and cloprostenol for estrous synchronization in beef cattle. Also investigated was the interval from treatment to onset of estrus.

Experimental Procedures

The cattle used for this study were 385 beef cows or heifers, maintained at the Animal Science Department's physiology farm, or owned and maintained by two producer-cooperators. The herds consisted of 179 Angus cows and 51 heifers at one location and 155 crossbred cows at the other two locations. All cows and heifers were in good body condition (BCS of 5 to 8) at the start of the study. The cows were 50 or more days post-calving.

The Angus heifers were initially synchronized by feeding 0.5 mg of melengestrol acetate (MGA) per day for 14 days. The heifers were then assigned to receive either dinoprost or cloprostenol 17 days after withdrawal of MGA. The Angus cows were synchronized by treatment with gonadotropin-releasing hormone (GnRH, Cystorelin, 100 µg, im) followed 7 days later by either dinoprost or cloprostenol. The crossbred cows received either no pre-synchronization treatment (n = 89) or an injection of dinoprost (n = 83) 14 days prior to their dinoprost or cloprostenol treatment. Both $PGF_{2\alpha}$ products were given intramuscularly at the recommended dosage of 25 mg (5 cc) for dinoprost and 500 µg (2 cc) for cloprostenol.

All animals were continuously monitored for estrus, using a HeatWatch electronic mount monitoring system. HeatWatch mount transmitters were placed on the cows and heifers at the time of dinoprost or cloprostenol treatment. The time of treatment was recorded so that the interval from treatment to onset of estrus could be determined. Estrus was determined to have occurred when an animal received three or more mounts within a 4-hour period. The first mount within the 4-hour period was identified as the onset of estrus. Animals that failed to exhibit estrus within 5 days of dinoprost or cloprostenol treatment were considered to be non-responders.

The Angus cows and heifers used in the study were artificially inseminated 8 to 20 hours after the onset of estrus. Fourteen days after insemination, the cows and heifers were placed with cleanup bulls. Ultrasonography was used 60 to 90 days after insemination to determine pregnancy status. Fetal size was used to determine whether pregnancies resulted from the artificial insemination or natural service.

Data were analyzed, using JMP Statistical software (SAS Inst., Inc., Cary, NC). Chi-square analysis was used to compare the percentage of animals exhibiting estrus after dinoprost or cloprostenol treatment, as well as the overall percentage of animals exhibiting estrus for the various synchronization schemes. The effect of synchronization treatment on the pregnancy rate of Angus cows and heifers was also compared using Chi-square. Analysis of variance was used to compare data for interval from dinoprost or cloprostenol treatment to estrus and the number of mounts during estrus.

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Results and Discussion

The effect of estrous synchronization pre-treatment or scheme on percentage of cows expressing estrus after treatment with dinoprost or cloprostenol is presented in Table 1. Within estrus synchronization pre-treatments, there were no differences ($P \geq 0.262$) in the percentage of cows expressing estrus after treatment with either dinoprost or cloprostenol. Regardless of whether dinoprost or cloprostenol was used, more ($P = 0.032$) animals expressed estrus after pre-synchronization with $PGF_{2\alpha}$ (83%) or MGA (78%) that did after either no pre-synchronization (66%) or treatment with GnRH (60%). The various estrous synchronization schemes used in this study were designed to increase the percentage of animals that exhibit estrus, by increasing the number of animals in the luteal phase of their reproductive cycle and thus, responsive to treatment with $PGF_{2\alpha}$. Therefore, it was surprising that a similar percentage of animals expressed estrus after GnRH pre-treatment (60%) as did after no pre-treatment (66%). This may have been due to differences in herd fertility. In our past experience we have observed that typically, 70% or more of the cows exhibit estrus after treatment with GnRH followed by $PGF_{2\alpha}$.

Across synchronization treatment schemes, a similar ($P = 0.515$) percentage of animals were detected in estrus after dinoprost or cloprostenol treatment (Table 2). These results are in agreement with a recently published study (Salverson et al., 2002) that reported dinoprost or cloprostenol are equally effective in inducing estrus in beef heifers. Some embryo transfer practitioners have suggested that cloprostenol induces estrus sooner after injection than Lutalyse. If that were true, then it would be necessary to use different injection times in order to achieve good embryo donor-recipient synchrony. However, the results of this study indicate the interval from treatment to estrus was almost identical for dinoprost or cloprostenol. With both products, the number of animals in estrus peaked at about 60 hours after treatment.

In this study, the number of mounts occurring during estrus was recorded as a measure of the intensity of induced estrus. Some previous studies (Rorie et al., 2002) have suggested that the intensity of estrus may be related to fertility. Again, no differences were noted for intensity of estrus between the two products. The single-service pregnancy rate for the Angus cows and heifers used in the study were 74 and 65% for the animals treated with dinoprost or cloprostenol, respectively. Although numerically different, the percentages were statistically similar ($P = 0.202$). Others (Salverson et al., 2002) reported identical pregnancy rates for beef heifers treated with either dinoprost or cloprostenol. Overall, the results of this study indicate both dinoprost and cloprostenol are equal in effectiveness at inducing estrus at the recommended dosages.

Implications

The results of this study indicate that dinoprost or cloprostenol are equal in their effectiveness in inducing estrus in beef cows and heifers. A similar percentage of animals were detected in estrus after treatment, regardless of the estrous synchronization scheme in which the products were used.

Literature Cited

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Salverson R.R., et al. 2002. Theriogenology 57:853-858.

Table 1. Effect of estrous synchronization scheme on percentage of cows expressing estrus after treatment with Lutalyse or Estrumate

	Pre-synchronization treatment*			
Item	$PGF_{2\alpha}$	GnRH	MGA	None
No. (%) in estrus after cloprostenol (Estrumate)	29/34 (82)	56/91 (62)	19/26 (73)	31/43 (72)
No. (%) in estrus after dinoprost (Lutalyse)	26/32 (81)	52/88 (59)	21/25 (84)	28/46 (61)
Overall, No. (%) in estrus after treatment	55/66 (83)[b]	108/179 (60)[a]	40/51 (78)[b]	59/89 (66)a

*See materials and methods for descriptions of pre-synchronization treatments.
[a,b] Numbers within rows with different superscripts differ ($P = 0.032$).

Table 2. Effect of Dinoprost or Cloprostenol on expression of estrus, interval from treatment to estrus and mounting activity

	Synchronization treatment		
Item	Cloprostenol	Dinoprost	P-Value
No. % in estrus after treatment	135/194 (70%)	127/191 (67%)	0.515
Hours, treatment to estrus	63 ± 2.1	65 ± 2.2	0.624
No. of mounts during estrus	44 ± 4.2	39 ± 4.3	0.417

Factors Affecting the Selling Price of Feeder Cattle Sold at Arkansas Livestock Auctions

T. R. Troxel, M. S. Gadberry, S. Cline, J. Foley, G. Ford, D. Urell, and R. Wiedower[1]

Story in Brief

Data were collected from 17 Arkansas livestock auctions to determine factors affecting selling price. Data included gender, breed or breed type, color, muscle thickness, horn status, frame score, fill, body condition, age, health, and weight. Data were randomly collected on 81,703 calves. The selling prices for steers ($99.70 ± 0.07), bulls ($95.07 ± 0.08), and heifers ($88.75 ± 0.06) were different from each other (P < 0.001). Charolais x Limousin feeder cattle sold for the highest price ($97.96 ± 0.22), and Longhorns sold for the lowest price ($74.52 ± 0.46). Hereford x Charolais, Hereford x Brahman x Angus, Charolais, and Angus x Brahman feeder cattle selling prices were greater than the overall mean and were not different from each other. One-quarter Brahman x other crosses, Simmental, Hereford, Brahman and Longhorn selling prices were less than the overall mean and were different (P < 0.01) from each other and all other breeds or breed types. Yellow feeder cattle received the highest selling price ($96.47 ± 0.12), and spotted or striped feeder cattle received the lowest ($83.84 ± 0.23). Muscle score, horn status, frame score, fill and body condition impacted selling price (P < 0.001). A number of management and genetic factors affected the selling price of feeder cattle.

Introduction

Cow-calf producers are challenged to produce feeder calves that are acceptable to the industry. When buyers at a livestock auction view feeder calves, they must appraise individual characteristics (muscle thickness, frame score, breed composition, etc.) as predictors of quality and animal performance and adjust their bids accordingly. Many of these factors such as breed or breed type are very subjective. Therefore, many cow-calf producers believe that feeder cattle are priced inconsistently. Producers do not understand why some phenotypic characteristics are discounted and others are not. Most feeder calf market reports list the selling prices of steers and heifers by weight groups, and frame and muscle score. Other reports have indicated that breed or breed type, health, gender, frame and muscle scores, and other noticeable factors do affect feeder calf selling price (Brown and Morgan, 1998; Neel et al., 1998). Therefore, the objective was to determine the factors that affect the selling price of feeder cattle in Arkansas weekly livestock auctions.

Experimental Procedures

Five USDA certified livestock market reporters collected data from 17 weekly livestock auctions in Arkansas from January 1, 2000 to December 31, 2000. The livestock auctions were located in Ash Flat, Charlotte, Conway, Fort Smith, Glenwood, Green Forest, Harrison, Hope, Marshall, Morrilton, Nashville, Ola, Ozark, Pocahontas, Ratcliff, Springdale and Texarkana. The data collected included calf gender (bull, steer, or heifer), breed or breed type, color, muscle thickness, horn status (polled (dehorned) or horned), frame score (large, medium, or small), fill (gaunt, shrunk, average, full or tanked), condition (very thin, thin, average, fleshy, or fat), age (calf or yearling), health (dead hair, stale, sick, bad eye(s), lame, or healthy), and weight. In 2000, a total of 533,283 feeder cattle were sold through these livestock auctions, and data was randomly collected (every 6th to 7th calf) on 81,703 animals (15.3%).

Frame and muscle scores were determined based on the U.S. Standards for Grades of Feeder Cattle (USDA, 2000). On October 1, 2000, USDA changed the scoring system for estimating muscle thickness. When comparing the 1980 (USDA, 1980) muscle score system (1, 2, and 3) to the 2000 muscle score system (1, 2, 3, and 4), the top two thirds of the 1980 No. 1's became the 2000 No. 1's. The lower third of the 1980 No. 1's and the upper one-third of the No. 2's became the 2000 No. 2's. The bottom two thirds of the 1980 No. 2's became the 2000 No. 3's and the 1980 3's became the 2000 No. 4's. Starting on wk 31, muscle score data were reported in thirds of a score (1+, 1, 1-, 2+, 2, 2-, etc.) using the 1980 muscle score system. This was accomplished so that muscle score data could be sorted and analyzed based on either the 1980 or 2000 muscle score system.

Data analyses. The percentage of calves within age, gender, breed or breed type, color, horn status, frame score, muscle score (1980 and 2000 muscle score system), fill, condition, weight group and health were determined by the frequency procedure of SAS (SAS Inst., Inc., Cary, NC) for the entire dataset (n = 81,703). Due to the lack of observations, feeder cattle that were not designated as calves or yearlings and those weighing less than 300 lb or greater than 750 lb were not used for statistical analyses. All feeder calves in this study were sold as individuals. The final data set included 56,563 feeder calves. There were 26,449 observations in the analysis for the main effect of 2000 muscle score system on selling price. Due to the unbalanced nature of the data, calf characteristics were analyzed individually as independent variables in which the model included month, weight and nearby feeder cattle futures reported for the fourth workday of the week as covariates. Sale price was the dependent variable. All other variables contributed to the error sum of squares. The analysis of variance was performed with the GLM procedure of SAS. Least-squares means were generated, separated based on predicted differences, and are reported throughout. Since all colors are not represented within each breed or breed type, color and breed or breed type data are somewhat inherently confounded. All selling prices reported are in US dollars/100 lb.

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Results and Discussion

The mean selling price for all calves in 2000 was $93.69, and all main effects reported were significant sources of variation (P < 0.001). Over 63% of the feeder cattle were classified as calves and 36.6% were classified as yearlings. The selling price of calves ($90.93 ± 0.16) was greater (P < 0.001) than the selling price of yearlings ($85.58 ± 0.19). Selling price varied by month with greater prices recorded in the spring (February, March and April) and lesser prices in the late summer and early fall (August, September and October; P < 0.001; Figure 1.) This seasonal trend followed the 5-, 10- and 20- year average seasonal trend (Cheney and Troxel, 2001). Over 75% of the cattle sold weighed less than 550 lb (Figure 2). As selling weight increased, price per cwt. decreased.

Heifers made up 44% of the cattle sold whereas steers and bulls made up 33% and 23%, respectively (Table 1). The selling prices for steers ($99.70 ± 0.07), bulls ($95.07 ± 0.08) and heifers ($88.75 ± 0.06) were all different (P < 0.001). Castration is a common practice to reduce management problems associated with aggressive and sexual behavior associated with commingling bull calves. The prices received for bulls were lower due to the expected reduction in animal performance experienced with these animals subsequent to castration.

Table 1 summarizes the percentage of the population sampled and selling price based on muscle score (1980 and 2000) horn status, health status, frame score, body fill and body condition. All factors affected the selling price. Buyers discounted feeder calves that were light muscled, horned, unhealthy, small-framed, appeared to have the potential for excessive shrinkage and over-conditioned.

Two hundred and seventy-seven different breeds or breed types were identified in the survey. Eighteen breeds or breed types represented 94.2% of the total feeder cattle. The breed or breed type was based upon common industry perception rather than actually knowing the breed composition. This, however, is what a buyer must do before a bid price can be offered. Table 2 summarizes the number of observation, frame scores, muscle scores, and color percentages of the 18 breeds or breed types. The main effect of cattle breed or breed type on the selling price of feeder cattle was significant (P < 0.001; Table 3). There was a $23.40 difference between the Charolais x Limousin feeder cattle, which sold for the greatest price ($97.96 ± 0.22), and Longhorn feeder cattle, which sold for the least price ($74.52 ± 0.46). Many of the cattle breeds or breed types that had selling prices greater (P < 0.01) than the overall mean ($93.69) were not different from each other (P > 0.10); however, those breeds or breed types that had selling prices less than (P < 0.01) the overall mean were different from each other (P < 0.01).

It appeared that buyers were hesitant to bid on feeder cattle where the breed or breed type was not clearly identifiable. The Brahman x other crosses and 1/4 Brahman x other crosses groups consisted of Brahman breeding (1/2 or 1/4) with other breeds or breed types that were less common or indefinable. That may explain why Hereford x Brahman x Angus, Angus x Brahman, and Brangus had greater selling prices than Brahman x other crosses and 1/4 Brahman x other crosses.

One hundred and seventy different colors or color combinations were recorded in the survey. Ten colors represented 96.3% of the total population (Table 4). Yellow feeder cattle received the greatest selling price ($96.47 ± 0.12), and spotted or striped feeder cattle received the least selling price ($83.84 ± 0.23).

Implications

The majority of cow-calf producers in Arkansas sell feeder cattle at local livestock auctions. The major factors affecting selling prices of feeder cattle were calf health, perceived breed or breed type, muscle thickness, frame score, fill, color, body condition, calf gender, and horn status. The combination of all these factors determines the final selling price. Most of the major factors affecting selling price can be addressed through genetic selection and management. Once the impact of these factors are identified and understood, cow-calf producers can make cost effective management changes that can improve feeder calf value and total returns.

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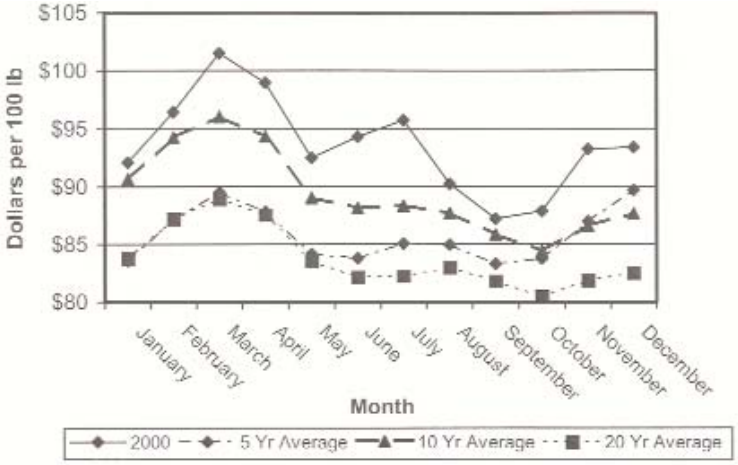

Fig. 1. The mean selling price for year 2000 and the 5-, 10- and 20-yr averages for 400 to 500 lb feeder cattle by month[a, b]

[a] Main effect of month on selling price (P < 0.0001).

[b] All least-squares means for 2000 are different (P < 0.01) except January and May, February and July, May and November, May and December, June and December, and November and December.

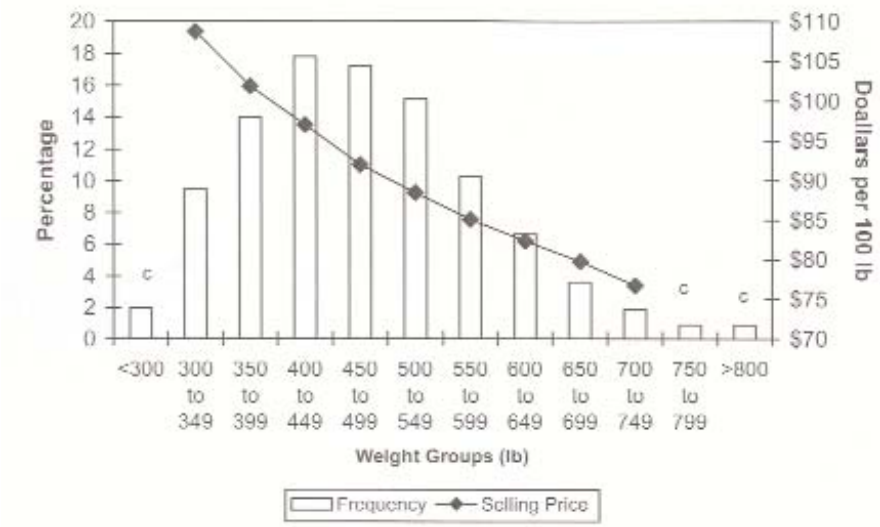

Fig. 2. The percentage of the sampled population and mean selling price of calves by weight groups[a,b,c]

[a] Main effect of weight group on selling price (P < 0.0001).
[b] Least squares mean (dollars/100 lb).
[c] Due to the lack of the number of observations, these weight groups were excluded from statistical analysis.

Table 1. The percentage of the sampled population and mean ± SE selling price due to calf gender, muscle score (1980 and 2000), health, frame score, body condition, horn status and body fill

Item	Percentage of the sampled population	Selling price ($/cwt.)	Item	Percentage of the sampled population	Selling price ($/cwt.)
Calf gender:[a]			**Frame score:[a]**		
Bulls	23.0	$95.07 ± 0.08	Large	56.8	$94.34 ± 0.06
Steers	33.0	$99.70 ± 0.07	Medium	42.1	$93.38 ± 0.07
Heifers	44.0	$88.75 ± 0.06	Small	1.1	$74.81 ± 0.40
1980 Muscle score:[a]			**Body condition:[a]**		
1	87.1	$95.02 ± 0.05	Thin	22.8	$96.03 ± 0.09
2	12.4	$85.35 ± 0.12	Average	58.9	$93.63 ± 0.06
3	0.3	$70.51 ± 0.91	Very thin	1.4	$85.94 ± 0.05
			Fleshy	15.7	$91.76 ± 0.11
			Fat	1.3	$88.94 ± 0.41
2000 Muscle score:[a]					
1	65.0	$92.32 ± 0.07			
2	28.5	$87.60 ± 0.11	**Horned status:[a]**		
3	6.2	$78.92 ± 0.23	Polled/ dehorned	71.1	$94.12 ± 0.05
4	0.3	$69.67 ± 1.08	Horned	28.9	$92.63 ± 0.08
Health status:			**Body fill:[a]**		
Healthy	97.8	$94.12 ± 0.05[b]	Gaunt	14.2	$97.12 ± 0.11
Dead hair	0.3	$83.37 ± 0.78[c]	Shrunk	21.4	$95.47 ± 0.10
Stale	1.2	$82.49 ± 0.38[c]	Average	52.4	$93.26 ± 0.06
Bad eyes	0.2	$81.57 ± 0.87[c]	Full	11.5	$88.53 ± 0.13
Sick	0.2	$68.27 ± 0.78[d]	Tanked	0.5	$82.16 ± 0.67
Lame	0.3	$66.67 ± 0.74[d]			

[a] All least-squares means within an item are different from each other (P < 0.001).
[b,c,d] Least-squares means without a common superscript differ (P < 0.01).

Table 2. The number of observations (n), frame and muscle score, and color percent of eighteen breed or breed type feeder cattle

Breed or breed type[a]	n	Frame score (%)			Muscle score (%)[b]				Color[c] (%)								
		Large	Medium	Small	1	2	3	B	G	R	S	W	BW	GW	RW	YW	Y
CLm	2,079	71.0	28.9	< 1.0	92.2	7.8	0			3.0						1.2	94.1
HC	1,601	62.8	36.7	< 1.0	96.4	3.4	< 1.0		4.6			3.8			2.3	76.0	12.8
HBA	1,806	55.1	44.7	< 1.0	78.0	21.7	< 1.0	2.2					96.3		1.2		
C	10,659	79.9	20.0	< 1.0	97.1	2.9	0		6.3			43.2				12.1	37.7
AB	5,665	58.2	41.7	< 1.0	79.9	19.9	< 1.0	98.5					< 1.0				
HLm	3,112	34.9	64.5	< 1.0	88.2	11.6	< 1.0	1.1		1.6			1.6		93.5	1.8	
Lm	6,722	42.0	57.7	< 1.0	94.5	5.4	< 1.0	8.7		86.7					2.4		1.9
AH	3,291	11.4	86.5	2.1	98.7	1.3	0						86.8		12.5		
CBq	1.567	89.3	10.7	0	84.9	15.1	< 1.0		17.3	2.2	1.9	24.3				1.9	51.5
A	4,799	6.3	89.2	4.5	98.2	1.8	< 1.0	94.3		5.2							
ABq	3.995	53.5	46.3	< 1.0	85.8	14.2	0	88.8		9.0							
AC	1,404	46.6	53.0	< 1.0	98.2	1.8	0		90.9			3.4		1.7			3.1
Bx	1,508	66.9	33.0	< 1.0	65.3	34.0	< 1.0	3.3	15.0	15.9	6.9	21.5	4.5	2.7	15.7	3.1	11.4
Bq	9,186	72.2	27.4	< 1.0	74.1	25.8	< 1.0	15.5	4.7	31.7	7.3	1.6	10.5	1.4	16.9	3.5	6.9
Sm	2,053	91.0	8.0	< 1.0	86.5	13.4	< 1.0		8.9	2.0	36.9		4.3	16.1	18.5	11.5	
H	1,746	7.2	75.6	17.2	84.9	14.6	< 1.0	2.4		2.1					95.0		
B	847	67.7	30.2	2.1	22.5	75.0	2.5	23.9	18.1	28.3	16.1	5.2	2.1	1.3	1.9		3.0
Lg	573	13.4	74.2	12.4	20.9	73.3	5.8	3.7	2.3	13.3	64.6	5.4			2.8		6.1

[a] Breed type = A - Angus, AB - Angus x Brahman, ABq - Brangus, AC - Angus x Charolais, AH - Angus x Hereford, B - Brahman, Bq - 1/4 Brahman x other crosses, Bx - Brahman x other crosses, C - Charolais, CBq - Charolais x 1/4 Brahman, CLm - Charolais x Limousin, H - Hereford, HBA - Hereford x Brahman x Angus, HC - Hereford x Charolais, HLm - Hereford x Limousin, Lm - Limousin, Lg - Longhorn, Sm – Simmental

[b] 1980 muscle score system (USDA, 1980)

[c] Color = B - black, G - gray, R - red, S - spots or stripes, W - white, BW - black white face, GW- gray white face, RW - red white face, YW - yellow white face, Y – Yellow

Table 3. The percentage of the sampled population and mean ± SE selling price of feeder calves sold based on breed or breed type[a]

Breed or breed type[b]	Percentage of the sampled population	Selling price[c]
CLm	3.9	$97.96 ± 0.22[d]
HC	2.5	$96.39 ± 0.27[e]
HBA	2.8	$95.90 ± 0.0.24[e, f]
C	15.7	$95.79 ± 0.10[e, f]
AB	8.8	$95.63 ± 0.14[e, f, g]
HLm	4.6	$95.54 ± 0.19[f, g, h]
Lm	10.4	$95.21 ± 0.13[g, h]
AH	5.1	$94.94 ± 0.19[h]
CBq	2.3	$93.99 ± 0.27[i]
A	7.2	$93.33 ± 0.16[i]
Abq	6.1	$93.06 ± 0.14[i, j]
AC	2.5	$92.87 ± 0.28[i, j]
Bx	1.6	$92.39 ± 0.28[j]
Bq	13.1	$91.75 ± 0.12[k]
Sm	2.8	$89.69 ± 0.24[l]
H	2.6	$83.37 ± 0.26[m]
B	1.3	$80.94 ± 0.37[n]
Lg	0.9	$74.52 ± 0.46[o]

[a] Main effect of breed or breed type on selling price ($P < 0.0001$).

[b] Breed type = A - Angus, AB - Angus x Brahman, ABq - Brangus, AC - Angus x Charolais, AH - Angus x Hereford, B - Brahman, Bq - 1/4 Brahman x other crosses, Bx - Brahman x other crosses, C - Charolais, CBq - Charolais x 1/4 Brahman, CLm - Charolais x Limousin, H - Hereford, HBA - Hereford x Brahman x Angus, HC - Hereford x Charolais, HLm - Hereford x Limousin, Lm - Limousin, Lg - Longhorn, Sm - Simmental.

[c] Least-squares mean ± SE (dollars/100 lb).

[d, e ,f, g,....o] Least-squares means without a common superscript differ ($P < 0.01$).

Table 4. The percentage of the sampled population and the mean ± SE selling price of feeder calves sold based on calf color[a]

Calf color	Percentage of the sampled population	Selling price[b]
Yellow	12.1	$96.47 ± 0.12[c]
Yellow-white Face	5.6	$95.65 ± 0.19[d]
Black-white Face	9.3	$95.23 ± 0.14[d,e]
White	7.9	$94.93 ± 0.15[e]
Black	24.8	$94.29 ± 0.09[f]
Red	15.7	$92.74 ± 0.11[g]
Gray	5.0	$91.85 ± 0.18[h]
Red-white Face	11.5	$91.81 ± 0.12[h,i]
Gray-white Face	1.3	$91.73 ± 0.37[i]
Spots or Stripes	3.1	$83.84 ± 0.23[j]

[a] Main effect of calf color on selling price ($P < 0.0001$).

[b] Least-squares mean + SE (dollars/100 lb).

[c, d, e, .., j] Least-squares means without a common superscript differ ($P < 0.01$).

The Impact of Livestock Auction Location, Number of Buyers, Sell Order and Grouping on the Selling Price of Arkansas Feeder Cattle Prices

T. R. Troxel, M. S. Gadberry, S. Cline, J. Foley, G. Ford, D. Urell and R. Wiedower[1]

Story In Brief

Data were collected from 17 Arkansas livestock auctions to determine if livestock auction location, number of buyers, sell order and selling in groups affected the selling price of feeder cattle. Data collected included how calves were sold (single or groups), gender, breed or breed type, color, muscle thickness, horn status, frame score, fill, body condition, age, health, BW, price, and when during the sale the calf was sold. Longitudinal and latitudinal coordinates and the number of buyers were determined for each livestock auction. Selling prices differed across livestock auctions ($P < 0.001$). Livestock auction location was not related ($P > 0.10$) to feeder calf prices. The livestock auctions with higher than average selling prices sold a higher percentage (59%) of feeder cattle breeds or breed types that sold for a higher than average selling price ($P < 0.01$) compared to livestock auction with below average selling prices (45%). A positive relationship existed between livestock auction volume and selling price ($P < 0.05$). As the number of buyers increased to approximately 15 to 17, the selling prices of feeder cattle increased. When the number of buyers exceeded 17, the selling prices of feeder cattle did not continue to increase. There was a difference in the selling price based on sell order and grouping ($P < 0.01$) but those differences were very small. Therefore, the difference between selling prices across livestock auctions was related to feeder cattle quality and the number of buyers present at the auction.

Introduction

The majority of Arkansas cow-calf producers market feeder cattle through local livestock auctions. Many cow-calf producers believe that the factors that affect the selling price of feeder cattle are subjective and are priced inconsistently from one livestock auction to another. Cattle producers are concerned with where the calves are sold, how the calves are handled at the livestock auction and if these factors affect selling price.

Therefore, the objective was to determine if livestock auction location, number of buyers, sell order and grouping of calves affected the selling price of feeder cattle across weekly Arkansas livestock auctions.

Experimental Procedures

Five USDA certified livestock market reporters collected data weekly from 17 livestock auctions in Arkansas from January 1, 2000 to December 31, 2000. The livestock auctions were located in Ash Flat, Charlotte, Conway, Fort Smith, Glenwood, Green Forest, Harrison, Hope, Marshall, Morrilton, Nashville, Ola, Ozark, Pocahontas, Ratcliff, Springdale and Texarkana. In 2000, a total of 533,283 feeder cattle were sold through these livestock auctions and data was randomly collected (approximately every 6th to 7th calf) on 81,703 animals (15.3%).

Longitudinal and latitudinal coordinates for each livestock auction were used to determine the relationship between location and selling price using a regression analysis. Regression analysis was also used to determine the impact of sale volume on selling price, sale volume and average number of buyers attending a sale, and number of buyers on selling price. Chi-square analysis (SAS Inst., Inc., Cary, NC) was used to determine if the livestock auctions that sold feeder calves above the mean price sold more feeder cattle that were of breeds or breed types priced higher. Due to the unbalanced nature of the data, sell order was analyzed as an independent variable in a model that included month, BW, and nearby feeder cattle futures reported for the fourth work day of the week as covariates. Sale price was the dependent variable. All other variables contributed to the error sum of squares.

A second data subset (n = 22,121) consisting of cattle that were marketed at three locations (Harrison, Fort Smith and Springdale) was used to determine the effect of number of head per lot marketed on price. Livestock auctions that sold less than 20% of their sales volume in groups of two or more were excluded from this analysis. Sale lots with two to five calves were grouped together as well as those with 6 or more calves. The analysis of variance was performed with the Generalized Linear Model procedure of SAS. All selling prices are reported in US dollars/100 lb.

Results and Discussion

There was a significant difference in the selling price of feeder calves across weekly livestock auctions ($P < 0.001$). The mean selling prices by livestock auctions ranged from \$88.98 ± 0.37 to \$96.77 ± 0.15. The livestock auctions with higher than average selling prices sold a higher percentage (59%) of feeder cattle breeds or breed types that sold for a higher than average selling price ($P < 0.01$) compared to livestock auction with below average selling prices (45%). The longitude and latitude locations were not significantly related ($P > 0.10$) to feeder calf selling prices. Therefore the quality of feeder cattle influenced livestock auction selling prices and the location of livestock auctions had no effect on selling price. There was a positive relationship between the yearly sales volume per livestock auction and selling price ($P < 0.05$; $y = 4E - 05x + 91.676$; $r = 0.5227$; $R^2 = 0.2732$). It was speculated that the larger livestock auctions (in term of sales volume) sold feeder cattle for higher prices because more buyers were present. There was no linear relationship ($P > 0.10$; $y =$

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5E-05x + 14.061; r = 0.1847; R^2 = 0.0341) between the number of buyers and the yearly sales volume per livestock auction but there was a quadratic relationship (P < 0.01; y = -8E - 09x^2 + 0.0006x + 6.6695; R^2 = 0.3069). The number of buyers increased as the annual sales volume increased to approximately 40,000 animals. As the annual sales volume increased over 40,000 animals, the number of buyers decreased. Therefore, it was concluded that it was not an increase in the number of buyers at the larger livestock auctions that caused the increase in selling price.

There was a quadratic relationship (P < 0.01; y = -0.0244x^2 + 0.9795x + 84.545; R^2 = 0.5405) between the number of buyers present at an auction and selling price (Figure 1). As the number of buyers increased to approximately 15 to 17, the selling prices of feeder cattle increased. As the number of buyers continued to increase, the selling prices of feeder cattle did not continue to increase but rather leveled off or even slightly decreased.

The selling prices of feeder cattle that were sold in the first third ($93.64 ± 0.07) and second third ($93.90 ± 0.08) of the sale were not different (P > 0.10; Table 1). There was a difference between the selling prices of feeder calves sold during the second and last third ($93.90 ± 0.08 vs. $93.55 ± 0.08; P < 0.01) of the sale. There were no differences detected (P > 0.10) between the selling prices of feeder cattle sold during the first third and the last third of the sale. Although the main effect of time of sale on the selling price of feeder cattle was significant (P < 0.001), the differences were very small ($0.35 per cwt.). It was hypothesized that there would be a greater difference in feeder cattle selling prices throughout the sale. As cattle buyers fulfill their orders, the bids would be lesser. This did not occur.

The only livestock auctions that sold enough feeder cattle in groups to analyze were located at Fort Smith, Harrison and Springdale (Table 1). The selling price for feeder cattle sold in groups of two to five calves was greater than the selling price of feeder cattle sold as singles ($95.14 ± 0.17 vs. $93.90 ± 0.12; P < 0.01). The selling price of singles was not different than the selling price for those sold in groups of six or more ($93.90 ± 0.12 vs. $94.61 ± 0.33; P > 0.10). The selling price between feeder cattle sold in groups of two to five calves and in groups of six or more were also not different ($95.14 ± 0.17 vs. $94.61 ± 0.34; P > 0.10). This lack of statistical difference may have been due to the small sample size of the feeder cattle that were sold in groups.

Implications

The majority of cow-calf producers in Arkansas sell feeder cattle at local livestock auctions. Selling prices for feeder cattle are different across livestock auctions in Arkansas. That difference is due to cattle quality and the number of buyers. Grouping cattle into uniform groups of two to five head will improve selling price compared to selling feeder cattle as singles.

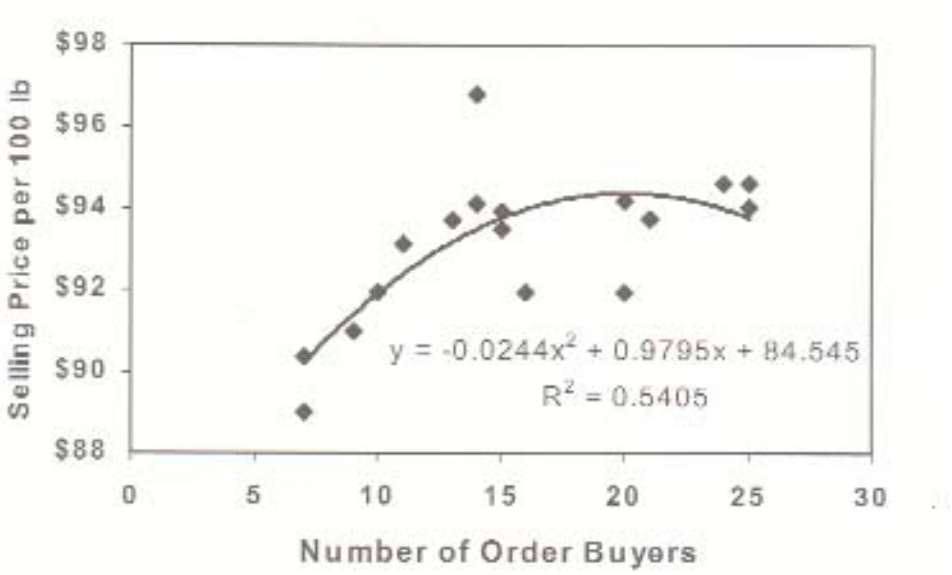

Fig. 1. The quadratic relationship between the number of buyers present per livestock auction and the selling price of feeder cattle (P < 0.0001).

Table 1. The mean ± SE selling price of feeder calves based on when the calf was sold during the sale and grouping

Item	Selling price[a]
Time of sale:	
First third	$93.64 ± 0.07[b,c]
Second third	$93.90 ± 0.08[b]
Third third	$93.55 ± 0.08[c]
Grouping:	
Singles	$93.90 ± 0.12[b]
2 to 5 hd	$95.14 ± 0.17[c]
6 or more	$94.61 ± 0.33[b,c]

[a] Least squares mean ± SE (US dollars/100 lb).

[b,c] Least squares means within column within item without a common superscript differ (P < 0.01).

Arkansas Feedout Program
2000-2001

Tom Troxel, George Davis, Shane Gadberry, and William Wallace[1]

Story in Brief

The objective of the Arkansas Feedout Program is to provide cow-calf producers information about the postweaning performance and carcass characteristics of their calves. For the past three feedouts (1998 to 2001), hot carcass weight, year, days on feed, quality grade, yield grade, medicine cost, feed cost of gain and dressing percentage were significant factors that affected the return over specified cost. With the information gained from this program, cow-calf producers can better evaluate their cattle breeding programs.

Introduction

The Feedout Program allows producers to learn more about the characteristics of their calf crop and the factors that influence value beyond the weaned-calf phase. The program is not a contest to compare breeds or breeders, or a retained ownership promotion program. It creates an opportunity for producers to determine how their calf crop fits the needs of the beef industry and provides information needed to determine if changes in genetics and/or management factors are warranted.

Experimental Procedures

On November 2, 2000, 415 calves (50 heifers and 365 steers) from 45 Arkansas producers representing 20 counties were placed on feed at Neill Cattle Company Feedyard at Welch, Oklahoma. Upon arrival, steers were eartagged, weighed, and processed (Synovex-S, Ivomec Plus, Vision 7 and Bovishield). An experienced order buyer placed an arrival value on all calves. Steers were sorted to four feeding pens based upon weight, frame and condition. Heifers were placed in a pen and fed separately from the steers. Management factors such as processing, medical treatments, and diets were the same as the other cattle in the feedyard. The feedyard manager selected animals for slaughter when they reached the weight and condition regarded as acceptable for the industry and market conditions. Calves were slaughtered in three groups (April 11, May 2 and May 14, 2001). The cattle were sold on a carcass weight basis with premiums and discounts for quality grade, yield grade, and carcass weight. Feed, processing, medicine costs and other feedyard expenses were financed by the feedyard. All expenses were deducted from the carcass income, and proceeds were sent to the owner. Carcass value for Choice-Yield Grade 2 carcasses was $129.50, $122.50, and $122.50 for April 11, May 2 and May 14 harvest dates, respectively.

Descriptive statistics were computed to describe general program results. Because there were only 50 heifers, the heifer data was not used in the statistical analysis. Of the 365 steers that started in the fall, three died and two carcasses were used by IBP (Iowa Beef Processors) for quality control checks and therefore, carcass data were not obtained. These steers (5 head) were not included in the statistical analyses. The final dataset analyzed consisted of feedlot and carcass data from 360 steers.

Carcasses of steers were also grouped according to whether or not they fit an industry standard for carcass merit (at least Choice, yield grade < 3.5, with a hot carcass weight between 550 and 950 lb). Steers either fit the industry standard or they did not, which resulted into two groups. The group main effect and interaction on the dependent variables of carcass value, ADG and net return were determined using the PROC GLM of SAS (SAS Inst., Inc., Cary, NC). Least-squares means were computed and reported.

Factors affecting feedlot return (gross income minus feedlot direct expenses) for the past three years of the top 25% steers and the bottom 25% steers were determined using the Stepwise method of PROC REG of SAS. Independent variables included arrival weight; percentage Brahman, percentage English, and percentage Continental breeding; ADG; yield grade; quality grade; feed cost per lb of gain; hot carcass weight; days on feed; medicine cost; ribeye area; ribeye area/hot carcass cwt.; and dressing percentage.

Results and Discussion

The steer and heifer financial reports are summarized in Tables 1 and 2, respectively. Average steer and heifer gross income per head was $930.10 (range = $428 to $1,192) and $841.68 (range = $453 to $1,089). The feedlot returns for steers and heifers averaged $655.18 and $574.58, respectively, whereas the calculated returns averaged $103.71 (range = $-312 to $279) and $69.46 ($-229 to $206), respectively.

Thirty-two calves (7.8%) were treated for sickness. The average medicine cost per sick calf was $35.21. The medicine cost for the entire group averaged $2.73 per head. The health status of cattle in the feedyard usually has a major impact on performance and profit. Healthy steers had higher feedlot returns ($666) than steers that became sick ($541; $P < 0.001$). In addition, healthy steers had a higher dressing percentage (63.6%) than steers that became sick (62.0%; $P < 0.001$). Significant differences ($P < 0.001$) were detected between healthy steers and steers that became sick for carcass value ($120.26 vs. $113.98 per cwt.), total cost of gain ($0.48 vs. $0.55), and percent grading Choice (sick calves = 34% and healthy calves = 47%). Only 0.6% of the healthy calves were classified as Dark Cutters whereas 10.3% of the sick calves were classified as Dark Cutters ($P < 0.001$). Unlike previous years, no differences were detected in average daily gain, final weight, feed cost of gain and days on feed between healthy steers and steers treated for an illness. One reason for the lack of dif-

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ferences detected may have been that so few steers were treated (7.8%).

The steer and heifer average off-the-truck arrival weights were 643 (range = 400 to 900) and 624 lb (range = 480 to 810), respectively. The steer average daily gain, average days on feed, feed cost per lb of gain, and total cost per lb of gain were 3.33 lb (1.47 to 4.99), 174 days (156 to 188), $0.42 ($0.31 to $0.71), and $0.49 ($0.36 to $0.90), respectively. The heifer average daily gain, average days on feed, feed cost per lb of gain, and total cost per lb of gain were 2.59 lb (1.73 to 3.43), 176 days, $0.52 ($0.40 to $0.79), and $0.59 ($0.45 to $0.90), respectively.

The average steer carcass weight, ribeye area, dressing percentage, yield grade, and fat thickness were 775 lb (504 to 977), 13.0 in^2 (8.8 to 19.7), 63.5% (55.7% to 68.8%), 2.25 (0.95 to 5.97), and 0.52 in. (0.16 to 1.20), respectively. Forty-six percent of the carcasses graded Choice whereas 47% and 6% graded Select and Standard, respectively. A few carcasses graded Prime (0.6%).

Listed below are eight significant factors that affected the return over specified costs for the past three Feedout Programs (1998 – 99, 1999 – 00 and 2000 – 01). Factors are listed from the most important to the least important.

Factors Affecting Returns Over Specified Cost

1. Hot Carcass Weight
2. Year
3. Days on Feed
4. Quality Grade
5. Yield Grade
6. Medicine Cost
7. Feed Cost of Gain
8. Dressing Percentage

1. Hot Carcass Weight – The relationship between hot carcass weight and feedlot returns over specified cost was positive. As hot carcass weight increased so did feedlot returns. The more carcass pounds sold, the greater the gross income and feedlot returns. Table 3 shows the relationship between hot carcass weight, total cost of gain, average daily gain and feedlot returns over specified costs. Hot carcass weight discounts were observed for carcasses weighing less than 550 lb and greater than 950 lb.

2. Year – The prices of Choice/ Yield grade 3 carcasses for the 1998 – 99, 1999 – 00 and 2000 – 01 Feedout programs were $103.00, $115.00 and $129.50 per cwt., respectively. The price difference across years is the reason why year was the second most important factor.

3. Days on Feed – There was a negative relationship between days on feed and returns over specified cost. This means that on the average, the longer that cattle were on feed the lower the returns (Table 4). A factor that affected the relationship between days on feed and feedlot return over specified costs was the price difference between Choice and Select quality grades on the three slaughter days. For example, early in the spring (April 11, 2001), there was a $4 per carcass cwt. discount between Choice and Select, but on May 14, 2001 the spread was $8 per carcass cwt.

4. Quality Grade – Cattle that graded Prime, Choice, Select, Standard and Dark Cutters had feedlot returns of $739, $704, $627, $551 and $426, respectively for the 2000 – 2001 program. Marbling is the main factor that affects a calf's ability to grade Choice. Three main factors that affect marbling are: (1) the genetic ability to marble; (2) the maturity, or the physiological age, not the chronological age; and (3) diet. Some cattle breed associations report marbling EPD's in their sire summary. Carcass traits such as marbling are highly heritable; therefore, selecting high marbling EPD bulls can impact the marbling ability of their progeny. Breed type can also influence a calf's ability to grade Choice.

5. Yield Grade – As yield grade increased from 3 to 4, feedlot return decreased ($632, $666, $664 and $505 for yield grades 1, 2, 3 and 4, respectively) in 2000-2001.

6. Medicine Cost – Healthy calves had a higher dressing percentage (63.6% vs. 62.0%) and a higher feedlot return over specified costs ($666 vs. $541) than calves that were treated for illness. Healthy calves had a calculated return of $134 more than sick calves.

7. Feed Cost of Grain – Feed cost of gain had a negative relationship to feedlot return over specified costs. As feed cost of gain decreased, return over specified costs increased. Based on returns over specified costs, the average feed cost of gain for steers in the bottom 25% was $0.43 per pound compared to $0.41 per pound for steers in the top 25% in 2000-2001. The average feed cost per gain for all the steers was $0.42 in 2000-2001.

8. Dressing Percentage – The relationship between dressing percentage and feedlot net return was positive. As dressing percentage increased so did feedlot net return. Many of the factors that affect hot carcass weight also affect dressing percentage.

Table 5 summarizes the performance and carcass data from the steers that were in the bottom 25% and top 25% (based on returns over specified costs) and the average of all the steers. In summary, the calves in the bottom 25% had high feed and medicine cost, low dressing percentage and failed to grade Choice. The cattle that performed the best were medium to large framed, heavy muscled, gained well, had a high dressing percentage, did not get sick, and graded Choice.

The beef cattle industry has set the standard that quality grade should be Choice, yield grade should be < 3.5, and hot carcass weight between 550 and 950 lb. In the 2000-2001 feedout, 44% of the steer calves fit all those requirements. The breed makeup of the steers that met the industry standards were 57% English, 7% Brahman and 34% Continental. Steers that met the industry standards had higher average daily gain (3.40 vs. 3.20 lb) and averaged $100 more per head than those that did not fit the industry standards ($P < 0.01$). They had higher carcass values ($1.25 vs. $1.18) because they graded Choice, were not discounted for yield grades greater than 4.0 and no carcasses were outside the weight range (550 to 950 lb). The three-year average difference between steer calves that fit the industry requirements and those that did not fit the industry requirements was $80.

Implications

Extremes in feedlot return over specified costs, health costs, performance factors and carcass parameters exist in the beef industry. A producer's goal should be to reduce these factors and parameters to produce a product that meets the needs of all segments of the beef industry. Value-based marketing at all levels of the industry is rapidly becoming a reality. Ranchers who produce a product that meets the demands will be more competitive in the market place.

Table 1. 2000-01 Arkansas feedout summary
Steer financial results

Item	Average	Range
Gross income	$930.10	$428 to $1,192
Expenses		
Feed	$236.85	$186 to $288
Medicine	$2.89	0 to $104
Freight, processing, yardage, interest, etc	$35.19	$24 to $40
Total feedlot expenses	$274.92	$220 to $364
Feedlot return	$655.18	$181 to $888
Steer calf in value	$551.47	$396 to $693
Return over specified cost	$103.71	$-312 to $279

Table 2. 2000-01 Arkansas feedout summary
Heifer financial results

Item	Average	Range
Gross income	$841.68	$453 to $1,089
Expenses		
Feed	$232.26	$178 to $278
Medicine	$1.61	0 to $52.50
Freight, processing, yardage, interest, etc	$33.23	$31 to $35
Total feedlot expenses	$267.10	$226 to $312
Feedlot return	$574.58	$192 to $777
Heifer calf in value	$505.126	$403 to $649
Return over specified cost	$69.46	$-229 to $206

Table 3. Summary of hot carcass weight, total cost of gain, average daily gain, feedlot returns, and calculated returns

Hot carcass weight (lb)	Total cost of gain/lb	ADG (lb)	Feedlot returns	Calculated return
<600	$0.63	2.2	$360	$-117
600-699	$0.52	2.8	$509	$19
700-799	$0.49	3.2	$641	$95
800-899	$0.40	3.7	$735	$155

Table 4. Effect of days on feed on average daily gain, total cost of gain, carcass value and feedlot returns

Slaughter dates	Days on feed	ADG (lb)	Total cost of gain/lb	Carcass value (per cwt)	Feedlot return
April 11	156	3.4	$0.50	$126	$754
May 2	176	3.5	$0.49	$118	$658
May 14	188	3.2	$0.48	$116	$563

Table 5. The performance of the bottom 25%, average, and top 25% steers based on feedlot returns

	Bottom 25%	Average	Top 25%
Number of steers	90	360[a]	90
In weight (lb)	566[b]	643	720[c]
Muscle score	1.5[b]	1.3	1.3[c]
Frame score			
Large	22%[d]	39%	58%[e]
Medium	77%[d]	60%	42%[e]
Final weight (lb)	1,123[b]	1,221	1,310[c]
Average daily gain (lb)	3.00[b]	3.33	3.66[c]
Gross income	$782[b]	$930	$1,063[c]
Carcass value per lb	$1.12[b]	$1.20	$1.26[c]
In value per head	$499	$551	$597
Hot carcass weight (lb)	699[b]	775	843[c]
Dressing percentage	62.2%[b]	63.5%	64.4%[c]
Medicine	$7.61[b]	$2.91	$0.25[c]
Total feed cost per head	$231	$237	$239
Total expense	$274	$275	$274
Feedlot returns	$508[b]	$655	$789[c]
Calculated returns	$9[b]	$104	$192[c]
Days on feed	185[b]	174	161[c]
Feed cost per lb of gain	$0.43[f]	$0.42	$0.41[g]
Total cost per lb of gain	$0.51[b]	$0.49	$0.47[c]
Ribeye area (in^2)	11.7[b]	13.0	14.1[c]
Fat thickness (in)	0.48[f]	0.52	0.54[g]
Quality grade			
Prime	0%	0.6%	1%
Choice	19%[f]	46%	73%[g]
Select	62%[f]	47%	23%[g]
Standard	13%[f]	6%	3%[g]
Dark cutter	6%	1%	0%
Yield grade	2.31	2.25	2.42

[a] Five calves were not used in this data set; three calves died and two were used as IBP quality control checks.
[b,c] Values within rows without a common superscript are significantly different ($P < 0.01$).
[d,e] Values within rows without a common superscript are significantly different ($P < 0.001$).
[f,g] Values within rows without a common superscript are significantly different ($P < 0.05$).

Preference for and Bacterial Counts in Sand and Granite Fines as Bedding for Lactating Cows

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Story in Brief

The objective of this study was to observe cow preference for and bacterial counts in sand and granite fines used as bedding. Eighteen stalls were bedded with either sand or granite fines. The use of stalls with sand was 2.8 times more likely than the use of stalls with granite fines ($P < 0.01$). Moreover, when cows were using the stalls, they were lying on sand 60.8% of the time and were standing on granite fines 57.5% of the time. On d 24, hardness, measured at 200 lb of pressure, for granite fines was greater than for sand ($P < 0.05$). This difference indicated cows preferred to lie on the softer bedding surface. In addition, there were no differences in cleanliness scores, temperature at the back of stalls, amount of additional bedding material needed to maintain stalls weekly, DM, pH, and absorbency between sand and granite fines. There were bedding material by day interactions for gram-negative bacteria ($P < 0.01$) and *Streptococci* ($P < 0.05$). Before addition to the stalls, gram-negative bacteria in granite fines were non-detectable; however, gram-negative bacteria were present on sand. One day after addition to stalls, numbers of gram-negative bacteria did not differ between materials. Coliforms were not affected ($P > 0.10$) by treatment, but *Klebsiella spp* was increased in the stalls bedded with granite fines. These data indicated that cows preferred the stalls bedded with sand, and these stalls tended to have lower bacterial counts.

Introduction

The bedding materials used for free stalls is one of many factors that can increase milk production, decrease mastitis, and increase cow comfort by allowing the cow to more easily enter, exit, lie, stand, rise and rest in the stalls. Bernard et al. (1999) concluded that cows preferred sand with a rubber free stall base compared to a waterbed, Dunlop Mat®, or Pasture Mat®. However, with sand in the free stalls, large quantities of sand are incorporated into manure when cows leave the stalls. Sand causes excessive wear on pumping equipment and settles out in the storage pond. Therefore, most dairy farmers using sand in free stalls have a system based on daily hauling of manure (Bickert and Ashley, 1991).

Using a new bedding material, such as granite fines, might not only reduce the amount of sand deposited in the manure drain but also reduce bacteria in bedding materials and subsequent mastitis. The objective of this study was to determine cow preference, bacterial counts, and economics of using granite fines or sand.

Experimental Procedures

This study was conducted at the Ark-Tenn Dairy Research and Development Facility near Center Ridge, AR between November 26 and December 22, 2001. Free-stall dairy barn dimensions were 80 ft wide x 800 ft long containing 1,000 free-stalls. Eighteen free stalls with rubber free stall bases (SAND TRAP™, Topper Inc., Monticello, IA) were equally assigned to receive sand (Lentz Company, Morrilton, AR) or granite fines, a by-product of crushing syenite granite rock (Donna Fill, Little Rock, AR). The 18 free stalls were divided into six groups (3 stalls/group) and randomly assigned to sand or granite fines treatment. During the experiment, approximately 130 lactating cows (31 to 90 days in milk) were housed in the pen containing the treatment stalls, which contained 160 total stalls.

On d 1, 5, 8, 13, 20, and 24 the temperature and relative humidity were measured with two wireless thermo-hygrometers set on a post at the end of both sides of the experimental pen and one central wireless thermo-hygrometer (RadioShack ®, Ft. Worth, TX) outside the barn. Wind speed was measured via a pocket weather™ meter (Kestrel, Chester, PA; Table 1). On the same days, stall use was observed beginning 3 h post-milking in the morning at approximately 9:00 a.m.

Five observations were made each day at 30 min intervals. At each observation time the presence or absence of cows in each stall was recorded. If a cow was present in the stall, whether the cow was lying or standing was recorded. At noon until 1:30 p.m. while the cows went to milk, temperature of the bedding material at the front and the back part of stalls, and cleanliness score were measured. A score of 5 indicated the stall was dry and clean, and a score of 1 indicated that more than 80% of the free stall surface was dirty or wet. Amount of bedding materials added was measured on d 5, 13, and 24 after cow observations. On d 24 the middle stall of each type of bedding material was measured for hardness with a DICKEY-john Soil Compaction Tester at 100 and 200 lb pressure with a 3/4-in tip.

Bacteria attributed to environmental mastitis (gram-negative bacteria, *Streptococci*, coliforms, and *Klebsiella spp*) were measured by sampling the bedding material prior to use (d 13 of the study and d 0 for bacteria counts) and the bedding materials at the back one-third of the stalls on d 14, 20 and 24 of the experiment by using 5 oz paper cups (Dixie, Fort James, Norwalk, CT) and plastic gloves. The middle stall of each group of stalls was sampled ($n = 6$). Upon arrival at the laboratory, 20 g of the bedding sample was removed and analyzed for DM by drying it in an oven at 212°F for 24 h. Ten grams were removed and mixed with 20 ml of deionized water and analyzed for pH (Denver Instrumental Company), and 10 g (ambient weight) was removed and mixed with 20 ml deionized water for 3 h to allow absorption of water, and then excess water was poured from the sample (wet weight; Zehner, 1985). Absorbency was calculated by the equation: Absorbency = {(wet weight – ambient weight) x 100}/ ambient weight.

Bacterial populations were evaluated by weighing 10 g of bedding sample into 90 ml of sterile phosphate buffer saline (PBS) at pH 7.2 with sterile stomacher bags before mixing, using a Stomacher®

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Model 400 (Seward, London, England) at low speed for 1 min. A serial dilution of 1:10 was aspirated with 1 ml of solution into 9 ml of sterile PBS per tube. Each dilution starting at 1 x 10^3 to 1 x 10^7 was plated on the surface of the appropriate medium. MacConkey agar (Remel, Lenexa, KS) was used to identify gram-negative bacteria and coliforms. Edward's modified agar (Oxiod LTD., Basingstoke, Hampshire) with 50 mg/L sterile bovine blood was the medium for *Streptococci*. MacConkey agar with 10 mg/L myo-inositol and 75 mg/L carbenicillin (Sigma Chemical Co., St. Louis) was the medium for *Klebsiella spp.* Bacteria were counted after being incubated for 24 h at 98.6°F and recorded as colony-forming units (cfu) per gram wet weight. Plates with 30 to 300 colonies were used to calculate cfu/g.

The free-stall usage was analyzed by the logistic procedure (SAS Inst., Inc., Cary, NC). Treatments were two bedding materials. The bacterial counts, DM, pH, absorbency, temperature and stall cleanliness score were analyzed by the GLM procedure of SAS with a split-plot in time design. Model effects for bacterial counts, DM, pH, absorbency, temperature, and stall cleanliness score were treatment, stall(treatment), day, and treatment x day. Treatment was tested with stall(treatment) as the error term. The amount of replacement bedding added to stalls and the hardness of the two bedding materials were analyzed by the GLM procedure of SAS with a completely randomized design. Least-squares means were compared between treatments.

Results and Discussion

Preference for and Physical Characteristics of Bedding Materials. An average of 130 lactating cows were housed in the pen containing a total of 160 stalls during this study, giving an animal per free stall ratio of 0.81. Friend et al. (1977) noted that increasing the animal per free stall ratio above 1.5 reduced average resting time and changed the cows' behavior. The areas occupied and cow behavior are summarized in Table 2. The stall usage was over 70% and similar to that in the research of Rodenburg et al. (1994). Preference for sand bedding was greater (Table 3) and odds ratio from the logistic procedure indicated that a cow was 2.77 times more likely to prefer sand to granite fines. On d 1, cows numerically occupied the stalls with granite fines more than those with sand since the softness of granite fines was possibly similar to or softer than sand, but in the long term granite fines were packed and became harder than the sand surface (3.4 versus 1.6 ± 0.44 in on sand and granite fines, respectively, $P < 0.05$; Table 5). Cow behavior of lying down on sand was greater than on granite fines (Table 4). Cows prefer to lie down to rest for long periods on softer surfaces, and to stand on harder surfaces (Sugita et al. 2000; Muller and Botha, 1997). Cleanliness score and amount of replacement material added to each stall for bedding materials were not significantly different (4.96 versus 4.94 ± 0.02, and 48.4 versus 49.3 ± 1.57 lb/wk for sand and granite fines, respectively; Table 5). Temperature of granite fines at the front of stalls was lower ($P = 0.01$) than that of sand (58.3 versus 61.0°F ± 0.59 for granite fines and sand, respectively), and tended to be lower ($P = 0.08$) in the back of stalls (60.1 versus 61.9°F ± 0.67 for granite fines and sand, respectively; Table 5).

Bacterial Counts on Bedding Materials. Bacterial counts between granite fines and sand for new material and d 0, 1, 7, and 11 after placing in stalls (d 13, 14, 20, and 24 of the study) are shown in Figure 1. An interaction between bedding material and day was found for gram-negative bacteria ($P < 0.01$) and *Streptococci* ($P < 0.05$). However, coliforms were not affected by treatment ($P > 0.10$). *Klebsiella spp* exhibited a tendency to be increased in the stalls containing granite fines ($P = 0.06$). Prior to being added to the stalls (i.e. new bedding material), granite fines were free of gram-negative bacteria and sand was not, while *Streptococci* cfu were similar between granite fines and sand. After being in the stalls for 1 d, gram-negative bacteria and *Streptococci* in sand and granite fines were greater than at d 0 and almost equal. Gram-negative bacteria and *Streptococci* in granite fines were greater on d 7 and 11 after addition of bedding material to the stalls. In addition, on d 1, 7 and 11 *Klebsiella spp* in granite fines were greater than that in sand. These data showed that sand tended to maintain lower bacterial counts, possibly because the sand was softer and it was easier to rake the feces out of the stalls. Dry matter, pH, and absorbency of bedding materials did not differ between bedding materials ($P > 0.05$; Figure 2).

Based on a cost of $4.00/ton for sand and $2.00/ton for granite fines (factory price) and that it took 1,320 lb of sand and 1,540 lb of granite fines to fill each stall; the cost/stall for the material was $1.40 for granite fines and $2.40 for sand. It should be noted that transportation costs on a per mile basis should be similar for both the sand and granite fines. However, the required transportation distance for each material could significantly impact the on-farm price.

Implications

Cows preferred the stalls with sand to those with granite fines. No differences were found in stall cleanliness scores, DM, pH, and absorbency of bedding materials. *Klebsiella spp* tended to be greater in the stalls bedded with granite fines.

Acknowledgments

The authors thank Ferrell Gray with Donna Fill, Little Rock, AR for providing material for this study. The assistance of Gerald Brock, Larry Anglea and Jeff Buck at Ark-Tenn Dairy Research and Development Facility near Central Ridge, AR is gratefully appreciated.

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Table 1. The range of temperature, relative humidity, and wind inside and outside of the free stall barn. Measurements were taken on d 1, 5, 8, 13, 20, and 24

Item	Inside barn	Outside barn
Temperature, °F	45.5 to 61.0	47.6 to 68.0
Relative humidity, %	39.0 to 97.0	27.0 to 93.0
Wind, mph[1]	1.1 to 5.3	3.1 to 5.4

[1] Measurement taken approximately 5.6 to 8.0 ft above the ground.

Table 2. The percentage of cows using or not using stalls 3 h post-milking and feeding in the morning

Area	Lying	Standing	Total
	---------- (%) ----------		
Stall	54.73	15.60	70.33
Alley	0.00	26.85	26.85
Water	0.13	2.69	2.82

Table 3. The percentage of free stall use over time for each bedding material

Day	Sand	Granite fines	P-value
	---------- (%) ----------		
1	43.33	56.67	0.34
5	77.78	22.22	< 0.001
8	55.77	44.23	0.11
13	55.36	44.64	0.09
20	50.72	49.28	0.56
24	54.69	45.31	0.03
Average	56.27	43.73	0.09

Table 4. Cow behavior observed over time in free stalls with different bedding materials

	Lying		Standing		
Day	Sand	Granite fines	Sand	Granite fines	P-value
1	38.64	61.54	75.00	25.00	0.17
5	78.13	21.88	75.00	25.00	0.89
8	68.42	31.58	21.43	78.57	0.01
13	58.33	41.67	44.44	55.56	0.44
20	53.97	46.03	16.67	83.33	0.08
24	67.39	32.61	22.22	77.78	0.01
Average	60.81	42.46	39.22	57.54	0.24

Table 5. Physical characteristics of bedding materials

Items	Sand	Granite fines	SEM	P-value
Cleanliness score[1]	4.96	4.94	0.02	0.62
Hardness, in[2]				
Tip pressure, 100 lb	2.44	0.68	0.30	0.01
Tip pressure, 200 lb	3.37	1.56	0.44	0.04
Temperature, °F				
At the front part of stall	61.0	58.3	0.59	0.01
At the back part of stall	61.9	60.1	0.67	0.08
Amount added per stall, lb/wk	48.4	49.3	1.57	0.91
Cost per stall, dollars[3]	2.4	1.4		

[1] Cleanliness score on scale of 1 to 5, where 1 = more than 80% of surface dirty or wet, and 5 = dry and clean.
[2] Higher numbers indicates softer surfaces.
[3] Calculated based on a cost of $4.00/ton for sand and $2.00/ton for granite fines at factory price; 1,320 lb of sand and 1,540 lb of granite fines needed to fill each stall the first day.

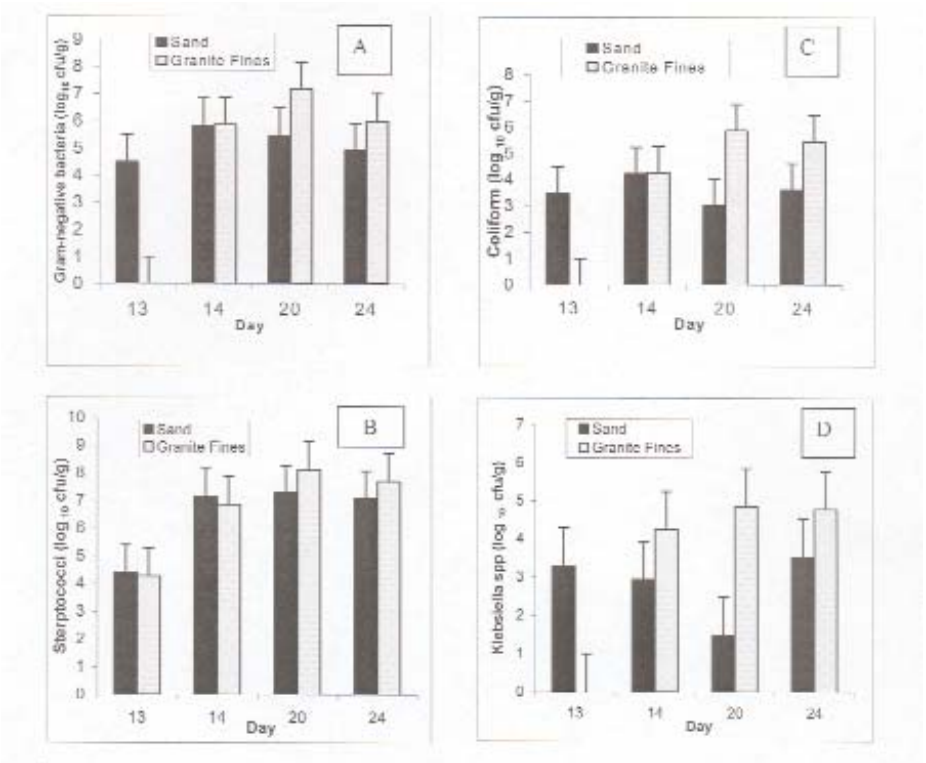

Fig. 1. Bacterial counts over time of (A) gram-negative bacteria (bedding material x day interaction; P<0.01), (B) Streptococci (bedding material x day interaction; P < 0.05), (C) coliforms, and (D) Klebsiella spp (main effect of bedding material; P = 0.06). Experimental d 13, 14, 20, and 24 correspond to d 0, 1, 7, and 11 after new bedding was added to stalls.

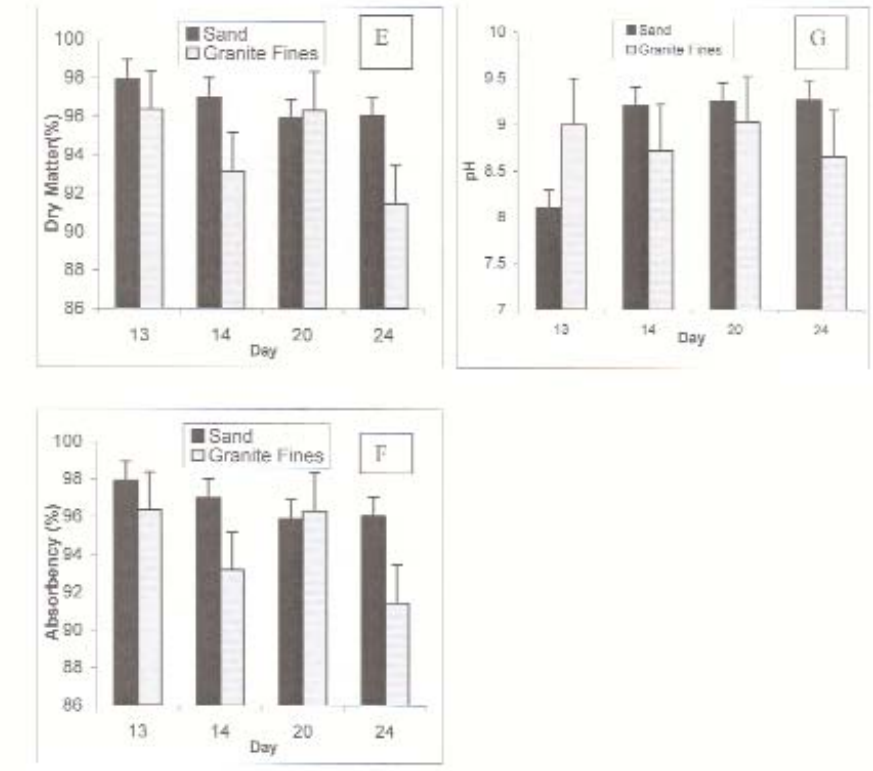

Fig. 2. Dry matter (E), absorbency (F), and pH (G) of sand and granite fines. Experimental d 13, 14, 20, and 24 correspond to d 0, 1, 7, and 11 after new bedding was added to stalls.

DairyMetrics

J. A. Pennington[1], J. S. Clay[2], and C. N. Vierhout[2]

Story in Brief

DairyMetrics, a new benchmarking tool from Dairy Records Management Systems, can be used to compare 73 variables for dairy herds on Dairy Herd Improvement program. The variables concern general herd traits, genetics, production, reproduction, and udder health for these herds and can be compared to other herds in the state or region. DairyMetrics was used to obtain the number of herds in the comparison, average of herds, standard deviation, and highest and lowest herds of the variables for herds of all breeds in Arkansas and the average for Holsteins. DairyMetrics was also used to compare groups of Arkansas herds to illustrate the importance of genetic merit of cows, days open, calving interval, percentage cows in milk, feed costs, and income over feed costs on efficiency of producing high levels of milk production as indicated by daily income-over–feed costs. It also showed that herd size and percent of fat in milk had little effect on income-over-feed costs per cow. DairyMetrics also indicated that conception rate at first service did not markedly affect income-over-feed costs. DairyMetrics was also used to illustrate the effect of herd size on selected variables for Holstein and Jersey herds in the southern region of the United States. These variables showed that Holstein herds had greater production per cow, greater income-over-feed costs per cow, lower fertility traits, and greater culling rates than Jersey herds in the southern United States.

Introduction

DairyMetrics is a new benchmarking tool that herds on the Dairy Herd Improvement (DHI) program can use to compare 76 variables on their DHI records to other herds in the state or region. Introduced in 2001 from Dairy Records Management Systems (DRMS) in Raleigh, North Carolina, DairyMetrics compares information concerning general herd traits, genetics, production, reproduction, and udder health. These comparisons can be used to show individual dairy producers their herd variable average and percentile compared to other herds, which can indicate how they might improve the herd. The database for DairyMetrics includes herd summary information from almost 14,000 herds that are routinely processed by DRMS.

DairyMetrics can also be used to compare these variables among groups of herds to illustrate how the various parameters affect efficiency of producing milk. For example, Arkansas herds of various sizes can be compared to determine the relationship of herd size with other parameters included in DairyMetrics. These comparisons of variables can be used in not only individual herd comparisons but also group comparisons in extension meetings to illustrate the importance of recommended practices on the efficiency of producing milk, especially daily income-over-feed costs. Income-over-feed costs are most correlated with the profitability of milk production of the variables included in DHI records. DairyMetrics can also be used to compare groups of animals across a section of the United States or in different states within the United States as well as herds that vary in these different variables (i.e., herds of greater than 1,000 cows versus herds with less than 100 cows per herd).

Experimental Procedures

DairyMetrics was used to obtain the average, standard deviation, and low and high herds for various general genetics, production, reproduction, and udder health variables in Table 1 for herds of all breeds in the state, plus the average of these variables for Holsteins.

DairyMetrics was also used to compare groups of Arkansas herds for selected variables in Table 2 to illustrate the importance of these variables on efficiency of milk production, using daily income-over-feed costs as the indicator of efficiency. Because Arkansas has less than the required minimum of six herds with greater than 500 cows per herd and has few Jersey herds on DHI test, herds from throughout the southern United States were used to illustrate the effect of selected variables in Table 3 on Holstein and Jersey herds of various sizes. The southern states ranged from North Carolina to Oklahoma and Texas and south to Florida.

Results and Discussion

The average, standard deviation, low herd, and high herd for 73 variables from DairyMetrics for all herds in Arkansas are shown in Table 1. Individual variables can be selected for comparison; however, each category must have at least six herds to assure anonymity of individual herds. If an individual herd comparison is conducted, the herd mean for each trait and percentile is displayed. The percentile of each variable is relative to the variables that are selected for comparison (e.g., the cohort herds or selected group of herds). Holstein herds are the predominant herd on DHIA test in Arkansas.

Table 2 shows the results of comparisons of groups of Arkansas Holstein herds using DairyMetrics. These summaries indicate the positive effect on daily income-over-feed costs of greater net genetic merit, fewer days open, greater percent cows in milk, lower feed costs per day, greater rolling herd average for milk, and shorter calving intervals. Additionally, rolling herd average, calving interval, percent cows leaving the herd, and somatic cell count are shown to illustrate the importance of these independent variables on efficiency of producing milk. In total, this data illustrates the importance of having cows of high genetic merit, getting them bred back at a reasonable time, and keeping them in milk.

Table 2 also illustrates that daily income-over-feed costs per cow were not greatly affected by herd size and percent fat in the milk.

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Milk fat may not have much effect, a result that is related to an income-over-feed cost because milk per cow is often greater in lower fat herds. Additionally, conception rate at first service did not markedly affect income-over-feed costs; this can likely be explained by greater milk production in herds with lower conception rates.

DairyMetrics also allows further divisions of the data if more than six herds are in each category. As expected, herds with greater than $5 daily income-over-feed costs ($5.94) tended to be more profitable than herds with less than $5 income-over-feed costs ($3.16) (Table 2). To illustrate the importance of shorter calving intervals in herds with high income-over-feed costs, herds with greater than $5 income-over-feed costs were divided into herds with greater than a 15-month calving interval versus those with less than a 15-month calving interval; herds with less than 15-month calving intervals had $6.31 daily income-over-feed costs compared to $5.78 daily income-over-feed costs for the herds with the greater calving intervals. Further divisions are possible, but they require at least six herds in each category.

DairyMetrics from DRMS was used to compare 73 traits of Jersey and Holstein herds in the southern states by herd size. The Holstein herds ranged to 3,673 cows/herd compared to a maximum of 805 cows/herd for the Jerseys. Selected variables are in Table 3. Holstein herds had greater days in milk, higher percentage of cows leaving the herd, higher percentage of the herd bred to non-AI bulls, greater milk production, longer calving interval, more days to first service, and higher somatic cell counts than Jersey herds; Jersey herds had a greater percentage of cows identified by sire and greater percentage of heats observed compared to Holstein herds. Larger Holstein herds had greater change in herd size and less percentage of cows identified by sire than smaller Holstein herds but had only a slight increase in percentage of cows leaving the herd compared to smaller herds. There were smaller differences in other parameters for these Holstein and Jersey herds with fewer than 1,000 cows.

In summary, most variables were correlated with daily income-over-feed costs, as expected. Within the general herd traits, genetics, production, reproduction, and udder health parameters indicated that cows of high genetic merit, shorter calving intervals, and lower feed costs were very important in maintaining an efficient level of milk production. Throughout the southern states, Holstein herds had greater income-over-feed costs and production levels than Jerseys but also culled a greater percentage of animals and had greater somatic cell counts than Jerseys. Jersey herds tended to have lower culling rates and greater fertility than Holstein herds throughout the southern region.

Implications

DairyMetrics can be used effectively either by individual producers to compare their herds to other herds throughout the region or in an educational activity to illustrate the importance of specific management practices on profitability and efficiency of milk production, as indicated by daily income-over-feed costs.

Literature Cited

DRMS. 2001. Proc. Spring Workshop, May 16-18, 2001. Dairy Records Management Systems, Raleigh, North Carolina.

Table 1. DairyMetrics summary for all herds on DHIA in Arkansas

DairyMetrics	No. of herds	Avg of herds	Std dev	Lowest herd	Highest herd	Avg of Holstein
			GENERAL			
Number of cows	68	123	152	27	1224	113
Year change in no. of cows	64	0	19	-68	73	0
No. of 1st lactation cows	68	35	58	1	465	31
No. of 2nd lactation cows	68	35	68	1	567	29
No. of 3+ lactation cows	68	52	38	2	212	53
Cows in milk on test day, %	68	84	8	40	100	85
Days in milk	68	172	33	116	256	168
Age of 1st lact cows	68	27	2	21	33	28
Cows left herd,%	63	30	15	0	96	31
Cows died, %	63	5	5	0	42	6
Daily value of production, milk cows, $	68	8.00	1.67	2.50	11.77	8.13
Daily feed cost, milk cows, $	56	2.97	0.53	2.01	4.21	3.04
Daily income/feed, milk cows, $	59	5.18	1.45	2.16	8.63	5.29
Daily feed cost/cwt milk, $	60	5.54	1.29	2.06	9.63	5.45
Milk blend price, $	68	14.91	1.46	12.00	19.18	14.62
			GENETICS			
Rank of proven AI bulls, %	68	34	28	0	87	32
Rank of young AI bulls, %	68	20	31	0	96	18
Herd bred to proven AI bulls, %	68	39	37	0	100	38
Herd bred to young bulls, %	68	7	16	0	77	7
Herd bred to non-AI bulls, %	68	39	40	0	100	40
Net merit for 1st lact cows, $	47	42	97	-215	301	56
Net merit for heifers, $	57	60	75	-127	212	68
Net merit for all cows, $	53	-4	95	-280	195	14
Heifers IDd by sire, %	57	40	32	0	100	38
Cows IDd by sire, %	68	53	41	0	100	46

Table 1. DairyMetrics summary for all herds on DHIA in Arkansas, continued.

DairyMetrics	No. of herds	Avg of herds	Std dev	Lowest herd	Highest herd	Avg of Holstein
		PRODUCTION				
Rolling average milk, lb	62	15,932	3,020	11,068	22,990	16,448
Year change in rolling average milk, lb	60	-348	1,307	-3,811	3,504	-518
Rolling average protein, lb	62	501	89	348	694	509
Rolling average fat, lb	62	565	107	336	903	571
Daily milk, milk cows, lb	67	54.5	11.3	35.5	79.4	56.7
Daily milk, all cows, lb	64	47.2	10.7	30.2	71.6	49.3
Daily fat, %	68	3.7	0.4	2.6	4.8	3.6
Daily protein, %	68	3.2	0.2	2.9	4.0	3.1
Summit milk lst lactation cows, lb	66	54	9	38	77	56
Summit milk 2nd lactation cows, lb	66	66	12	44	95	67
Summit milk 3+ lactation cows, lb	67	70	13	38	102	71
Projected 305-d ME milk, lb	66	17906	3198	12508	25314	18435
Standard 150-d milk, lb	67	56.3	11.8	34.4	81.4	58.3
		REPRODUCTION				
Projected minimum calving interval, month	68	15.0	1.0	12.0	20.0	15.0
Current actual calving interval, month	68	14.4	1.8	12.0	21.9	14.5
Projected min days open, total herd	68	189	55	99	344	190
Projected min days open, 1st lactation	68	207	76	64	485	211
Projected min days open, 2nd lactation	68	186	62	99	352	188
Projected min days open, 3+ lactations	67	182	56	91	336	181
Voluntary waiting period (VWP), d	63	51	7	45	60	51
Days to 1st service (%herd < VWP)	60	13	13	0	64	13
Days to 1st service (%herd with VWP to 100 d)	60	42	17	0	84	42
Days to 1st service (%herd > 100 d)	60	43	19	9	100	43
Days 1st service, total herd	60	113	33	46	208	113
Conception rate past 12 mos, 1st service, %	68	43	26	0	100	43
Conception rate past 12 mos, 2nd service, %	68	37	25	0	100	34
Conception rate past 12 mos, 3+ services, %	68	37	26	0	100	37
Heats observed for year, %	57	29	15	6	65	26
Number abortions in past year	68	0	1	0	12	0
Number calvings in past year	68	87	110	0	828	82
Cows dry less than 40 d, %	61	12	8	1	34	12
Cows dry more than 70 d, %	67	36	19	5	93	37
		UDDER HEALTH				
SCC actual (x 1,000)	65	468	239	104	1264	490
SCC linear score (SCCS)	66	3.4	0.6	2.0	4.8	3.5
Cows with SCCS of 0-3, %	66	53	12	25	91	52
Cows <41 d with SCCS >4, %	67	27	17	0	100	28
1st lactation cows with SCCS of 0-3, %	65	61	20	0	100	59
2nd lactation cows with SCCS of 0-3, %	66	58	18	0	100	57
3rd lactation cows with SCCS of 0-3, %	66	45	15	0	79	44
Cows culled for mastitis, %	63	2	4	0	14	2
SCCS for 1st lactation cows	34	3.0	0.5	2.1	4.1	3.0
SCCS for 2nd lactation cows	39	3.2	0.7	1.7	4.5	3.2
SCCS for 3rd lactation cows	52	3.9	0.6	2.3	5.1	4.0
SCCS for cows 41- 100 d	50	2.9	0.7	1.1	4.6	2.8
SCCS for cows 101-199 d	52	3.4	0.8	1.7	5.3	3.4
SCCS for cows 200-305 d	41	3.9	0.9	2.3	6.2	4.1
SCCS for cows 306+ d	50	4.1	0.7	2.5	5.4	4.1
Value product loss from SCC	68	3	2	0	15	3

Table 2. Comparison of Arkansas Holstein herds using DairyMetrics

Trait	Trait Avg	RHA-Milk (lbs)	Daily IOF ($)[a]	Calving Interval (months)	Cows Left Herd (%)	SCC (x1000)
Herds of 1-49 net merit $	26	15,922	$4.44	16.0	27	483
Herds of > 50 net merit $	101	17,955	$5.58	14.3	39	499
Herds < 149 days open	137	17,520	$5.36	13.6	35	474
Herds > 150 days open	212	16,104	$4.67	14.9	30	490
Herds of < 86% in milk	76	15,486	$4.11	14.8	33	565
Herds > 85% in milk	90	16,966	$5.15	14.3	30	449
Herds < $3.00 feed cost/day	$2.61	15,777	$5.18	14.7	30	426
Herds > $3.00 feed cost/day	$3.45	16,803	$4.22	14.6	27	475
Herds < 16,000 RHA milk	13,629 lb	13,628	$3.84	14.3	28	576
Herds > 16,000 RHA milk	18,863 lb	18,863	$5.75	14.2	33	576
Herds < 15 month calving interval	13.8	17,361	$5.36	13.8	32	478
Herds > 15 month calving interval	15.2	15,536	$4.24	15.2	31	494
Herds < 3.5% fat	3.2%	17,247	$5.03	14.2	36	376
Herds > 3.5% fat	3.7%	16,211	$4.73	14.7	38	508
Herds < 44% conception %	1st 28%	17,002	$4.82	14.8	33	528
Herds > 44% conception %	1st 60%	16,058	$4.87	14.1	30	443
Herds of 1-99 cows/herd	54	16,299	$4.87	14.6	34	467
Herds > 99 cows/herd	162	16,782	$4.85	14.3	28	477
Herds > $5 IOF	$5.94	18,481	$5.36	14.5	32	436
Herds < $5 IOF	$3.16	14,954	$4.24	14.5	27	495

[a] Income over feed cost.

Table 3. Comparison of selected DairyMetrics traits for Holstein and Jersey herds of different sizes in the southern United States

Item	Size of herd (number of cows) 0-49	50-99	100-199	200-299	300-599	600-999	1000-1999	2000-3673
Holstein herds								
Number of cows/herd	39	77	142	242	418	756	1,330	2,670
Change in number of cows	-6	-4	-2	0	5	3	92	111
Days in milk	188	185	183	181	184	185	184	190
Cows left herd, %	33	34	34	35	37	36	43	38
Herd bred to non-AI bulls, %	27	37	43	39	50	44	40	54
Cows identified by sire, %	62	53	50	49	31	31	21	31
Rolling average milk, lb	17,604	17,671	18,188	18,140	18,367	19,371	19,627	21,509
Actual calving interval, mo	14.7	14.3	14.2	14.3	14.4	14.2	14.0	14.3
Days to 1st service, herd	114	107	106	101	105	98	89	96
Heats observed for year, %	33	30	31	34	30	40	41	41
SCC actual (x1000)	458	430	408	406	403	323	412	344
Jersey herds[a]								
Number of cows/herd	35	74	140	250	442	683		
Change in number of cows	-14	1	0	9	19	27		
Days in milk	172	177	161	185	171	169		
Cows left herd, %	30	31	32	26	29	31		
Herd bred to non-AI bulls, %	18	24	24	25	9	13		
Cows identified by sire, %	87	87	84	91	85	87		
Rolling average milk,lb	13,664	14,305	14,907	14,482	13,760	13,979		
Actual calving interval, mo	13.6	13.6	13.5	14.2	13.7	13.6		
Days to 1st service-herd	82	89	84	94	83	79		
Heats observed for year, %	43	42	47	48	51	54		
SCC actual (x1000)	351	406	342	384	388	366		

[a] The highest range for Jersey herds was 805 cows

2001 Dairy Herd Improvement Herds in Arkansas

Jodie A. Pennington[1]

Story in Brief

In December, 2001, 83 of the 345 dairy cattle herds in Arkansas were enrolled in the Dairy Herd Improvement (DHI) program. Seventy-five herds completed at least four DHI tests and averaged 9.8 tests per year with a rolling herd average of 16,075 lb milk, 579 lb and 3.6% fat, and 499 lb and 3.1% protein; mature equivalent averages were 18,192 lb milk, 3.5% fat, and 3.1 protein. The Arkansas average for milk/cow was 13,085 lb/year on all cows. Herds not on DHI records averaged less than 12,000 lb/year compared to the 16,075 lb for herds on DHI. This difference of over 4,000 lb/cow/year affected income per cow by almost $600/cow or approximately $60,000/herd/year. The quartile data of milk production for the Holsteins with DHI records also reinforced that income over feed costs increased as milk production increased. Other records for health, reproduction, genetics, and inventory as well as production contributed to this difference in income/cow. Higher producing Holstein herds culled a greater percentage of cows than lower producing herds. Overall, 32.5% of the Holsteins left the herd, and 20% of those left because of death. That statistic is up slightly from last year and perhaps related to the ice storms. Since less than 25% of the state's herds are enrolled in the DHI record-keeping program, opportunities exist for raising the level of milk production and profitability in the state by encouraging more producers to use DHI records.

Introduction

Successful dairy producers must have accurate and reliable records to make sound management decisions. The Dairy Herd Improvement (DHI) program provides a comprehensive herd analysis and management report that includes information concerning production, reproduction, genetics, herd health, animal and feed inventory, and finances. The data can be used to improve efficiency of milk production by (1) identifying least profitable cows for culling, (2) feeding for more efficient production, (3) selecting animals with the greatest genetic potential for production as replacements, and (4) utilizing summaries of the data to make precise management decisions that improve net income.

Typically, herds on DHI produce 3,500 to 4,500 lb nationally more milk per year than herds not on DHI. This difference in production has a significant effect on net income for the dairies. Income over feed costs is associated with greater milk production per cow. The dairy herd summaries also allow a dairy producer to compare production, health, reproduction, and financial aspects of his dairy to other dairies, so that areas of management that need improvement can be detected.

Experimental Procedures

Dairy cattle herds on test (n = 83) were used to report production and management data for DHI herds. The test milking (or day) for each cow included weighing milk, taking a sample of milk to be analyzed for percentage of fat and protein and somatic cell counts (SCC); plus recording of other management parameters as indicated in Table 1. Milk samples were analyzed at the Heart of America DHI Lab in Manhattan, KS. Records were processed at Dairy Records Management Services (DRMS), Raleigh, NC.

Results And Discussion

In December 2001, 83 of the 345 dairy cattle herds in Arkansas were enrolled in the Dairy Herd Improvement (DHI) program. Seventy-five herds completed at least four DHI tests and averaged 9.8 tests per year with a rolling herd average of 16,075 lb milk, 579 lb and 3.6% fat, and 499 lb and 3.1% protein, mature equivalent averages were 18,192 lb milk, 3.5% fat, and 3.1 % protein.

Rolling herd averages for breeds of DHI herds with the 10 tests needed to be considered official herds are in Table 1. Few non-Holstein herds were on DHI, but the Jersey herds showed a similar trend in yield to other reports. In the United States, over 95% of the cows on test were Holsteins and almost 4% of cows on test were Jerseys. The average milk/cow for the 68 herds in Arkansas with at least six test periods during the year was 15,932 lb/year with 3.7% fat and 3.2% protein; the mature equivalent averages were 17,906 lb milk, 3.5% fat, and 3.1% protein.

Table 2 shows the Holstein DHI averages for herds with 10 tests by quartile of milk production. The quartile data for the 33 Holstein herds illustrate the relationship of higher milk production to higher income over feed costs. Income over feed costs averaged $1,466 this year for the Holstein herds compared to $1,198 last year. The increase in income over feed costs is primarily related to record high milk prices in 2001, which were much higher than in 2000. Herds in the top quartile also had lower somatic cell scores and less days in milk than other herds.

Table 3 shows that higher producing herds also had superior genetics as indicated by the higher predicted transmitting abilities for dollars (PTA$) of the cows, less days open, lower calving intervals, greater percentage of heats reported detected than lower producing herds. They bred more cows to proven sires. In larger data sets, lower producing herds have superior fertility compared to higher producing herds.

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Table 4 shows that 32.5% of Holstein cows left the herd last year. Only 6.3% of the Holstein cows leaving the herd left because of low production. This compares to 20% of the cows leaving because they died, and another 17.8% left because of reproduction. Either injury, disease, or death accounted for 31.4% of the Holstein cows leaving the herd compared to 24.1% in 2000. This increase may have resulted because of the ice storms in late 2000 and early 2001. However, the overall cull rate dropped from 34.7% to 32.5% in the last year. This data is similar to results from all states included in the Heart of America DHIA Summary for 2000.

The 68 dairy cattle herds reported here are less than the 83 or more dairy herds that have been reported on DHI through other summaries. The primary reason for the difference in numbers is that herds reported here have at least six test periods. For quartile data, the 33 Holstein herds have been official herds with 10 tests during the year. There also were five goat herds on DHI, plus the list included any herd on DHI in 2000, including herds no longer on the DHI program. Additionally, one dairy cattle herd used the PC DART on-farm computer program for production testing and would not have been included in the 83 dairy cattle herds listed here that were processed through DRMS. Still, less than 25% of the 345 herds in 2001 were involved in the DHI program. Herds on DHI averaged 16,075 lb milk/cow/year compared to the Arkansas average of 13,085 lb milk/cow/year, according to the Arkansas Agricultural Statistics Service. Omitting DHI herds from the state average indicates that the non-DHI herds averaged less than 12,000 lb milk/year. The difference of over 4,000 lb milk/cow/year affects income by almost $600/cow/year. This difference in milk income is $60,000 per year in a 100-cow herd.

Implications

DHI program participation affords dairy producers an opportunity to maintain milk production records on individual cows and other management practices. Herds utilizing DHI records averaged 16,075 lb milk/cow/year versus less than 12,000 lb/cow for herds not on DHI test. We should continue to encourage producers to enroll in the DHI Testing program.

Table 1. 2001 Arkansas DHIA breed averages on selected items

	Breed[a]	
Item	Holstein	Jersey
Number of herds	25	2
Rolling herd average, milk, lb	17,270	14,351
Peak milk, lb	70.7	55.0
Average SCC[b] (x 1000)	505	306
Days to 1st service, total	82.7	77.5
Days open	187.8	99.5
Projected calving interval (month)	15.4	13.0
Income minus feed costs ($)	$1,505	$1,697

[a] Only one Ayrshire herd and no Brown Swiss or Guernsey herds had 10 tests during 2001.
[b] SCC = Somatic cell count.

Table 2. 2001 Arkansas DHIA averages for official Holstein herds

Production items	Quartile1[a]	Quartile 2	Quartile 3	Quartile 4
Number of herds	8	8	8	9
Number of cows	119	154	103	72.9
Rolling herd average milk, lb	21,262	18,129	15,586	12,564
Rolling herd average fat, lb	724	640	553	432
Rolling herd average protein, lb	652	561	489	387
Average days in milk	183	198	191	196
Average test day milk (milking cows)	68	58	53	42
Average cows in milk, %	86	86	82	82
Average standardized 150-d milk, lb	73	63	57	45
Peak milk, 1st lactation, lb	74	64	63	49
Peak milk, 2nd lactation, lb	92	78	75	57
Peak milk, 3+ lactations, lb	94	88	80	61
Peak milk average, all lactations, lb	82	74	68	54
Average SCC[b] (x 1000)	377	488	498	619
SCC linear scores of 0 – 3, 1st lact[c] cows, %	63	60	70	57
SCC linear scores of 0 – 3, 2nd lact cows, %	68	60	57	63
SCC linear scores of 0 – 3, 3+ lact cows, %	47	51	54	38
SCC linear scores of 0 – 3, all lact cows, %	58	56	58	47
Income minus feed cost ($)	1,996	1,672	1,434	760

[a] Quartile 1 = top 1 - 25 percentile herds; Quartile 2 = top 26 - 50 percentile herds; Quartile 3 = bottom 26 - 50 percentile herds; and Quartile 4 = bottom 1 - 25 percentile herds.
[b] SCC = Somatic cell count.
[c] Lact = Lactation.

Table 3. 2001 Arkansas DHIA for official Holstein herds

Breeding and reproduction items	Quartile 1[a]	Quartile 2	Quartile 3	Quartile 4
1st lactation AIPL[b] PTA$[c] , cows	126	87	-65	126
2nd lactation AIPL PTA$, cows	95	108	19	-54
3+ lactation AIPL PTA$, cows	35	63	-63	-64
All lactations AIPL PTA$, cows	81	66	-79	22
1st lactation AIPL PTA$, sires	266	236	153	237
2nd lactation AIPL PTA$, sires	206	225	122	256
3+ lactation AIPL PTA$, sires	119	175	83	50
All lactations AIPL PTA$, sires	198	213	94	188
Days to 1st service, current	80	95	72	74
Days to 1st service, total	76	95	73	95
Services per pregnancy, pregnant cows	1.7	1.6	1.2	2.0
Services per pregnancy, all cows	2.7	2.2	1.7	2.8
Average days dry	75	66	91	78
Average days open	152	176	217	198
Projected calving interval (month)	14.2	15.0	16.4	15.7
Successful first breedings, %	42	52	30	44
Successful total breedings,%	41	50	30	46
Average heats reported, %	37	31	30	25
Herd bred to proven sires, %	69	44	20	28
Herd bred to AI young sires, %	5	5	7	5
Herd bred to other sires, %	13	39	36	55

[a] Quartile 1 = top 1 - 25 percentile herds; Quartile 2 = top 26 - 50 percentile herds; Quartile 3 = bottom 26 - 50 percentile herds; and Quartile 4 = bottom 1 - 25 percentile herds.
[b] AIPL = From USDA Animal Improvement Programs Laboratory.
[c] PTA$ = Predicted Transmitting Ability Dollars.

Table 4. 2001 Arkansas DHIA for cows entering and leaving herds from official Holstein herds[a]

Production items	Quartile 1[b]	Quartile 2	Quartile 3	Quartile 4	Avg
Number left herd, all lactations	40.7	49.0	37.4	17.0	36.0
Total % left herd	41.7	30.5	32.9	25.0	32.5
% left for dairy	14.5	21.6	14.0	9.4	14.9
% left for low production	4.9	6.1	2.4	11.8	6.3
% left for reproduction	16.5	15.1	22.5	17.1	17.8
% left for mastitis	9.3	12.4	2.7	18.8	10.8
% left for udder	3.9	0.0	0.0	5.9	2.5
% left feet & legs	7.1	5.1	0.9	4.7	4.4
% left for injury or other	17.0	9.7	3.0	3.5	8.3
% left for disease	4.7	2.0	0.0	5.9	3.1
% died	17.5	20.6	12.5	27.6	20.0
% not reported	4.9	7.1	55.9	6.4	18.6
Number entered herd, all lactations	53.4	47.0	45.0	15.4	40.2
Percent entered herd, all lactations	50.5	30.5	42.4	23.2	36.7

[a] Some cows may have more than one reason for leaving herd.
[b] Quartile 1 = top 1 - 25 percentile herds; Quartile 2 = top 26 - 50 percentile herds; Quartile 3 = bottom 26 - 50 percentile herds; and Quartile 4 = bottom 1 - 25 percentile herds.

Effects of Cetylpyridinium Chloride and Trisodium Phosphate as Single or Multiple Interventions on Microbial, Instrumental Color, and Shelf Life Characteristics of Comminuted Pork

K.S. McElyea, F.W. Pohlman, and Z.B. Johnson[1]

Story in Brief

The efficacy of antimicrobial interventions was studied for their effects on ground pork in relation to microbial proliferation and instrumental color through simulated retail display. Lean pork trimmings were treated during aerobic tumbling with either: 1) 1.0% cetylpyridinium chloride (CPC); 2) 10% trisodium phosphate (TSP); 3) a 50:50 CPC/TSP mixture (CT); or 4) water control (C). Trimmings were drained and inoculated with 8 log CFU/ml mixture of *Listeria innocua* (LI), *E. coli* (EC), and *Salmonella typhimurium* (ST). Trimmings were ground, packaged, and sampled at days 0, 1, 3, and 7 of simulated retail display for LI, EC, ST, coliforms (CO), aerobic plate counts (APC), and instrumental color. The CT treatment lowered ($P < 0.05$) microbial counts of all bacterial types except APC, whereas, LI and APC were greatly reduced ($P < 0.05$) by CPC treatment. In addition, CPC treatment caused ground pork to be lighter (L*; $P < 0.05$) in color, whereas TSP enhanced ($P < 0.05$) pork redness (a*) compared to the control. Therefore, the use of antimicrobials was effective for the reduction of microbial pathogens in pre-treatment to inhibit contamination of pork trimmings post processing.

Introduction

Bacterial contamination continues to be a key food safety issue for the meat industry. Decontamination of meat carcasses by processing steps is somewhat effective; however, further fabrication of carcasses allows microorganisms remaining on the carcass or be reinnoculated onto the meat cuts. Antimicrobials can be used as a carcass spray or additive to beef or chicken prior to grinding (Pohlman et. al, 2002, Yang et. al, 1998). Bacterial decontaminants either disrupt the normal biological processes of cellular metabolism and reproduction or inhibit their ability to attach and bind to meat surfaces. Addition of antimicrobials to beef trim meat significantly reduced the levels of *E. coli, Salmonella typhimurium, Listeria monocytogenes*, coliforms, and aerobic bacteria (Pohlman et. al., 2002; Siragusaet al., 1993).
The effects of antimicrobials on meat color and sensory properties are important for the ability to maintain red color through retail display. Premature discoloration of meat by some antimicrobial treatments adversely affects meat color early in retail display (Unda et. al., 1989). Therefore, the objective of this research was to determine the effects of antimicrobial treatments of pork trimmings on the reduction, or elimination, of bacterial contamination in ground pork, as well as determine the effects on instrumental color through retail display.

Experimental Procedures

Bacterial Enumeration, Preparation, and Inoculation. Bacterial inoculums were enumerated from pure frozen (-112°F) stock cultures of *Escherichia coli* (ATCC # 11775), *Listeria innocua* (ATCC# 33090) and a nalidixic acid resistant strain of *Salmonella typhimurium* (ATCC # 1769 NR). *E. coli* and *Listeria innocua* cultures were maintained by Brain Heart Infusion Broth (BHI) (Difco Laboratories, Detroit, Michigan, USA) with glycerol (20%). *Salmonella typhimurium* was maintained in BHI/glycerol mixtures containing additional nalidixic acid (86 mmol; Fisher Scientific, Fairlawn, New Jersey, USA) at 0.2g/l. Frozen cultures of *E. coli*, *Salmonella typhimurium*, and *Listeria innocua* were thawed and 0.1 ml of each pure culture were inoculated into separate 40 ml aliquots of BHI. *Salmonella typhimurium* aliquots were added to BHI containing nalidixic acid (86mmol). After 18 h of incubation at 98.6°F, the bacterial aliquots were refrigerated (True Manufacturing Co., St. Louis, Missouri, USA) for 24 h at 34°F. Bacterial aliquots were pelletized by centrifugation (3700 x g, 20 min at 75°F) (Beckman GS-6, Fullerton, California, USA), resuspended in 40 ml buffered peptone water (Difco Laboratories, Detroit, Michigan, USA), vortexed (Vortex Genie II, Pro Scientific, Bohemia, New York, USA), and pooled together to make a bacterial inoculum cocktail (1000 ml each of *E. coli, S. typhimurium, L. innocua* to make a total of 3,000 ml of 8 log colony forming units (CFU)/ml of *E. coli, S. typhimurium, and L. innocua*).

Antimicrobial Treatment Applications and Sampling Procedure. For this study, antimicrobial treatment combinations included: 1) an untreated control (C); 2) 1% solution (vol: vol) cetylpyridinium chloride (Safe Foods, Fayetteville, Arkansas, USA)(CPC); 3) 10% (wt: vol) trisodium phosphate (FMC Corporation, Philadelphia, Pa., USA)(TSP); and 4) 1% CPC and 10% TSP in a 50:50 (vol: vol) mixture (CPC/TSP). All treatments were prepared using Millipore water (U.S. Filter, Tulsa, Oklahoma, USA). Pork trimmings were from one lot batch, purchased at wholesale level, and received no prior postharvest interventions. Each 10 lb batch was placed in a clean meat tumbler with 500 ml of the respective antimicrobial treatment and aerobically tumbled (22 rpm) for 3 min, aerobically rested for 5 min, and aerobically tumbled again for 2 min. Meat trimmings were removed from the tumbler and placed on perforated screens to dripdry for 3 h at 40°F. All treated batches of meat trimmings were placed in plastic bags (9.7 in x 15 in; Koch, Kansas City, KS, USA) inside tubs and subsequently set in walk-in cooler (Jamison Walk-in, Hagerstown, Maryland, USA) for microbial inoculation. The microbial cocktail was cooled to 39.5°F and added to thawed, boneless, treated pork trimmings (10 lb per batch, 4 batches) and allowed to attach for 3 h. The pork trim batches were drained and maintained at 39.5°F for 18 h to allow for further microbial attachment. Meat trimmings were ground twice using a 3.2 mm plate (Model 310, Hobart

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Inc., Troy, Ohio, USA), subsequently allocated into 1 lb samples, packaged on styrofoam trays with absorbent diapers, and over wrapped with a polyvinyl chloride film (PVC) with an oxygen transmission rate of 1400/cc/m2/24 h/1 atm (Borden Inc., Dallas, Texas, USA). Ground pork samples were individually tray packed from each treatment to allow for independent sampling procedures and were stored under simulated retail conditions (39.2°F) (deluxe warm white Alto fluorescent lighting, 1630 lux, Phillips Inc., Somerset, New Jersey, USA).

Trays of ground pork were sampled for fat content, pH, CPC residuals, microbial and instrumental color analyses on each sampling day (0, 1, 3, and 7) of display. Fat content was determined using a Hobart Fat Analyzer (Model F101, Hobart Inc., Troy, Ohio, USA). The pH of treated ground pork was measured by using 0.06 oz. ground pork homogenized in 18 ml of Millipore water (1:10 vol: vol) and evaluated using an Orion Model 420A pH meter with a Ross Electrode attached to an Orion pH meter (Orion Research Inc, Beverly, MA, USA).

Instrumental Color. Instrumental color was measured using a Hunterlab MiniScan XE Spectrocolorimeter (Model 4500L; Hunter Associates Laboratory Inc., Reston, WV, USA) on days 0, 1, 3, and 7. Samples were evaluated for CIE (L*, a*, and b*) color values using illuminant A/10° observer. Reflectance measurements were taken in the 580 nm to 630 nm ranges in the visible spectrum. The oxymyoglobin portion of myoglobin pigment was estimated using the 630/580 reflectance ratios (Strange et al., 1974). Hue angle or true red (tan –1(b*/a*)) and saturation index or vividness ((a*+b*) 0.5) were also calculated. Prior to color measurement, the spectrocolorimeter was standardized using a white tile, black tile, and working standard (red). Six measurements were taken of each sample.

Statistical Analysis. This experiment was replicated three times. The randomized complete block factorial (four antimicrobial treatments and four sampling days) experiment was analyzed using the GLM procedure of SAS (SAS Inst., Inc., Cary, N.C.). Treatments were blocked by replicate then analyzed with main effects of antimicrobial treatment and day of simulated retail display and their interaction in the model. For random variables, least-squares means were generated and separated using the PDIFF option of PROC GLM.

Results and Discussion

Effects of Treatments and Display on Microbial Growth. The results of using different antimicrobial treatments on pork trimmings before grinding on microbial counts, CPC residuals, and pH are represented in Table 1. *Listeria innocua* was reduced ($P < 0.05$) 2.41 log CFU/g by CPC, but only slightly impaired ($P < 0.05$) by the CPC/TSP (C/T) hurdle treatment (0.79 log) when compared to the control (C). Breen et al. (1995) found that CPC inhibited the growth of *Salmonella* species, which is in agreement with our findings. The CPC/TSP treatments reduced ($P < 0.05$) *E. coli*, coliforms, and *Salmonella typhimurium* versus the control. The pH effect of the TSP treatment may have been neutralized by the more neutral pH of the CPC treatment yielding a reduced efficacy against *Listeria* in the multiple interventions treatment compared with the single CPC treatment; however, further studies are needed. The CPC residuals were tested and reported in ug/g pork, which indicated that CPC containing treatments also maintained residuals that might be beneficial for extended microbial control.

Effects of Antimicrobial Treatments and Display on Instrumental Color. Antimicrobial treatments had an impact on instrumental color (Table 2). Ground pork from the CPC treatment was lighter (L*)($P < 0.05$), more yellow ($P < 0.05$) (hue angle),and less vivid ($P < 0.05$)(saturation index) than C. However, TSP made the meat redder ($P < 0.05$) in color (a*, and hue angle) than C. Ground pork from the CT treatment was similar ($P > 0.05$) to C in lightness (L*), redness (a*), yellowness (b*), hue (hue angle), vividness (saturation index), and oxymyoglobin content.

Ground pork pooled across treatments remained similar ($P > 0.05$) in lightness (L*) throughout display (Table 3); however, ground pork became less ($P < 0.05$) red (a*) and vivid (saturation index) in color as expected through 3 days of display (Table 3). By Day 1 of display, comminuted pork color became more ($P > 0.05$) yellow (hue angle) and less ($P > 0.05$) vivid (saturation index) in color; but, oxymyoglobin content (630/580) remained unchanged ($P > 0.05$) through display.

The use of CPC on pork trimmings before grinding was effective for reducing *Listeria innocua* and APC while the combined CPC/TSP treatment was effective for reducing *E. coli*, coliforms, *Salmonella typhimurium*, and *Listeria innocua* in ground pork with minimal impact on pork color. Therefore, the use of these antimicrobials may be useful for pretreatment to inhibit post processing trimmings contamination while maintaining retail shelf life.

Implications

The antimicrobials utilized within this study are effective in retarding the growth of *Listeria* as well as the other bacterial species represented in this study. This is important for reaching mandated zero tolerance levels of pathogenic microorganisms in processed meat products by reducing or eliminating microorganisms and extending shelf life of meat products.

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Table 1. Effect of antimicrobial treatments[a] applied to pork trimmings on least-squares mean log CFU[b]/g *E. coli*, coliforms, *Salmonella typhimurium, Listeria innocua*, aerobic plate counts (APC), and CPC residuals[c], pH, and percentage fat

	Treatment				
Item	C	CPC	TSP	C/T	SE
Microorganism					
E. coli	7.82[z]	7.64[z]	7.60[z]	7.46[y]	0.09
Coliforms	7.79[z]	7.64[z]	7.59[zy]	7.46[y]	0.09
Salmonella typhimurium	8.65[z]	8.46[z]	8.34[zy]	7.99[y]	0.16
Listeria innocua	9.03[z]	6.62[x]	9.33z	8.24[y]	0.17
APC	8.67[z]	8.15[x]	8.84z	8.47[zy]	0.10
Physiochemical Analysis					
CPC residual	0.00[x]	511.03[z]	0.00[x]	99.43[y]	27.11
pH	5.88[yx]	6.34[y]	6.95[z]	6.57[zy]	0.16
Fat, %	17.33	19.83	20.33	16.83	2.32

[a] C = control; CPC = 1.0% cetylpyridinium chloride; TSP = 10% trisodium phosphate; and C/T = 50:50 solution cetylpyridinium chloride and trisodium phosphate.
[b] Log colony forming units.
[c] CPC residual in ug/g.
[xyz] Least-squares means within a row without a common superscript differ (P < 0.05).

Table 2. Effect of antimicrobial treatmentsa applied to pork trimmings on least-squares means instrumental color characteristics of ground pork

	Treatments				
	C	CPC	TSP	C/T	SE
Brightness, L*[b]	62.09[y]	65.28[x]	61.63[z]	61.57[y]	0.61
Redness, a*[c]	15.91[yz]	13.46[z]	17.66[x]	16.94[xy]	0.45
Hue angle[d]	47.46[x]	53.38[y]	43.97[z]	46.87[x]	1.04
Saturation index[e]	23.88[x]	22.26[y]	24.26[x]	24.76[x]	0.52
630/580f	1.74	1.45	1.96	2.50	0.43

[a] C = control; CPC = 1.0% cetylpyridinium chloride; TSP = 10% trisodium phosphate; and C/T = 50:50 solution cetylpyridinium chloride and trisodium phosphate.
[b] L*: 0 = black and 100 = white.
[c] a*: -60 = green and +60 = red.
[d] Calculated as tan-1(b*/a*).
[e] Calculated as $(a^{*2} + b^{*2})^{0.5}$.
[f] Calculated as 630 nm reflectance/580 nm reflectance.
[xyz] Least-squares means within a row without a common superscript differ (P < 0.05).

Table 3. Effect of duration of display on least-squares mean (+SE) instrumental color values

	Days of display			
	0	1	3	7
Brightness L*[a]	62.59 + 0.61	62.81 + 0.61	63.09 + 0.61	62.07 + 0.61
Redness a*[b]	18.02 + 0.45[x]	16.11 + 0.45[y]	14.57 + 0.45[yz]	15.27 + 0.45[z]
Hue angle[c]	45.56 + 1.21[y]	48.36 + 1.21[x]	49.94 + 0.91[x]	47.83 + 0.91[x]
Saturation index[d]	25.76 + 0.60[x]	24.03 + 0.60[y]	22.57 + 0.45[y]	22.80 + 0.45[y]
630/580[e]	1.88 + 0.49	1.61 + 0.49	1.69 + 0.37	2.74 + 0.37

[a] L*: 0 = black and 100 = white.
[b] a*: -60 = green and +60 = red.
[c] Calculated as tan-1(b*/a*).
[d] Calculated as $(a^{*2} + b^{*2})^{0.5}$.
[e] Calculated as 630 nm reflectance/580 nm reflectance.
[xyz] Least-squares means within a row without a common superscript differ (P < 0.05).

The Impact of Single Antimicrobial Intervention Treatments with Cetylpyridinium Chloride, Trisodium Phosphate, Chlorine Dioxide or Lactic Acid on Ground Beef Patty Sensory and Lipid Stability

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Story in Brief

The effects of antimicrobial agents on ground beef patties were evaluated to determine their impact on pH, sensory and odor characteristics, and lipid oxidation under simulated retail display conditions. Beef trimmings were treated with either 0.5% cetylpyridinium chloride (CPC), 200 ppm chlorine dioxide (CLO), 2% lactic acid (LA), 10% trisodium phosphate (TSP), or an untreated control prior to grinding. Trimmings were ground, pattied and sampled at 0, 1, 2, 3 and 7 days of display. Panelists found TSP and CPC patties were similar ($P > 0.05$) or superior ($P < 0.05$) to control patties on beef and off-odor on days 3 and 7 of display. The TSP patties had a lower ($P < 0.05$) TBARS number, as a measurement of lipid oxidation, than control on day 7 only. There was no difference ($P > 0.05$) in thiobarbituric acid reactive substances (TBARS) values, sensory visual or sensory color characteristics between the control and any other treatment through 3 days of display. Therefore, treatment of beef trimmings before grinding with TSP, CPC, CLO and LA will improve ground beef safety as found in previous studies (Pohlman et al, 2002; Stivarius et al., 2002) while maintaining product

Introduction

Several technologies have been investigated for reducing microorganisms on beef carcasses, including organic acid rinses, hot water washing, and steam pasteurization. Recent research in this area has focused on decontaminating beef trimmings before grinding utilizing chlorine dioxide, cetylpyridinium chloride, organic acids and trisodium phosphate (Stivarius, et al., 2002; Pohlman, et al., 2002). While each of these technologies reduced microorganisms in ground beef, these inoculated studies found ground beef produced using lactic acid to be similar in redness and overall color to an untreated control during display. Conversely, beef trimmings inoculated with *E. coli* and *Salmonella*, then treated with cetylpyridinium chloride or trisodium phosphate before grinding, remained redder in instrumental and sensory evaluated color through display compared with an inoculated control phosphate (Stivarius, et al., 2002; Pohlman, et al., 2002).

Additionally, little is known regarding the effect of these on processing, textural, lipid, and sensory characteristics when used at antimicrobial inhibition levels in traditional ground beef. Therefore, the objective of this study was to evaluate the effect of chlorine dioxide, cetylpyridinium chloride, lactic acid, and trisodium phosphate on sensory color, sensory odor, and thiobarbituric acid reactive substances (TBARS) values when used in a ground beef patty production system.

Experimental Procedures

Antimicrobial Treatment Application and Sample Processing. Antimicrobial treatments for this study included: 0.5% cetylpyridinium chloride (CPC), 200 ppm chlorine dioxide (CLO), 2% lactic (LA), or 10% trisodium (TSP) solutions, and an untreated control. For antimicrobial treatments 4.54 lb of beef trimmings (80% lean and 20% fat) were placed into a meat tumbler with 1,250 ml of the selected antimicrobial treatment and aerobically tumbled for 3 min (16 rpm), then removed, and allowed to drip dry for 3 min.

Once the antimicrobial application phase was completed, beef trimmings were ground twice using a Hobart grinder with a 1/8 in plate. Patties (0.485 lb) were then made using a Hollymatic patty machine and placed on styrofoam trays with absorbent diapers. The trays were overwrapped with polyvinyl chloride film with an oxygen transmission rate of 1400 cc/m2/24 h/ 1 atm and stored under simulated retail conditions (35.6°F, deluxe warm white fluorescent lighting, 1,630 lx). Multiple trays of ground beef patties for each treatment were packaged to allow for independent use for sensory color and odor evaluation on days 0, 1, 2, 3 and 7 of display. Ground beef was sampled on days 0, 3, and 7 of display for TBARS evaluation.

Sensory Color and Odor. An 11 member trained sensory panel was used to evaluate sensory color and odor characteristics of ground beef patties through display. The panelists were selected and trained by an experienced panel leader according to the American Meat Science Association Guidelines (AMSA, 1978; Hunt et al., 1991). Sensory panelists evaluated worst point color (5 = bright purplish, 4 = dull purple red, 3 = slightly brownish red, 2 = moderately brownish red, 1= brown), overall color (7 = bright purplish, 6= dull purple red, 5= slightly dull purple red, 4= brownish red, 3= slightly brownish red, 2= moderately brownish color, 1= brown), and percentage surface discoloration (7 = no discoloration (0%), 6 = slight discoloration (1-20%), 5 = small discoloration (20-39%), 4 = modest discoloration (40-59%), 3 = moderate discoloration (60-79%), 2 = extensive discoloration (80-95%), 1 = total discoloration (96-100%)) on days 0, 1, 2, 3, and 7 of display. Panelists also evaluated beef odor (8 = extremely beef like, 7 = very beef like, 6 = moderately beef like, 5 = slightly beef like, 4 = slightly non-beef like, 3 = moderately non-beef like, 2 = very non-beef like, and 1= extremely non-beef like) and off odor characteristics (5 = no off odor, 4 = slight off odor, 3 = small off odor, 2 = moderate off odor, and 1 = extreme off odor) (Hunt et. al., 1991) at the same display intervals. Packages were visually evaluated under simulated retail lighting conditions, then taken to a static pressure opened room, and evaluated by panelists for beef odor and off odor characteristics.

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TBARS Characteristics. For TBARS analysis, 2 grams of ground beef were collected from each sample on the appropriate day of display and homogenized in 8 ml of cold (35.6°F) 50 mM phosphate buffer mix standardized to a pH of 7 and also containing 0.1% EDTA and 0.1% n-Propyl Gallate for 20 sec. Then, 2 ml of trichloroacetic acid was added to the slurry. The mixture was centrifuged for 5 min and filtered using Whatman No. 4 filter paper. A 2-ml aliquot of clear supernatant was transferred into a clear 10-ml screw cap tube, mixed with 2 ml of 0.02 M of 2-thiobarbituric acid reagent, and boiled for 20 min. Immediately after boiling, tubes were placed into an ice bath for 5 min. Samples were read using a Shimadzu at 533 nm and the absorbency was multiplied using a factor of 12.21 to obtain the TBARS value (mg malonaldehyde per kg of meat).

Statistical Analysis. The experiment was arranged in a randomized complete block 5 x 5 factorial design where the main effects were antimicrobial treatment and days of display. The experiment was replicated three times and was analyzed using the GLM procedures of SAS (SAS Inst., Inc., Cary, NC). Treatments were blocked by replicate and then analyzed for the main effects of antimicrobial treatment, day of display, and treatment by day interactions. For sensory panel data, a panelist term was added to the model to account for sensory panelist variation. For variables involved in interactions, interaction means were generated and then separated using the PDIFF option of PROC GLM. Least-squares means for all other variables not confounded by interaction were generated and separated using the PDIFF option.

Results and Discussion

Panelists failed to find any differences ($P > 0.05$) among treatments in overall color on days 0, 1 and 7 of display; however, on day 2, TSP, CLO, and CPC treatments were similarly ($P > 0.05$) bright red color as the control, but TSP and CPC had a brighter ($P < 0.05$) red color than CLO and LA (Table 1). Likewise, on day 3 of display TSP patties had a brighter ($P < 0.05$) red color than the rest of the treatments and the control. Also, CPC and LA were redder ($P < 0.05$) than the control and CLO by day 3 of display (Table 1).

Sensory panelists were unable to detect differences ($P > 0.05$) in worst point color among treatments on day 0 of display, and only LA treated patties were different ($P < 0.05$) from control patties by day 1 of display (Table 1). On day 2, panelists found TSP patties redder ($P < 0.05$) than the control, with no difference ($P > 0.05$) between CPC and the control. But CPC was redder ($P > 0.05$) than CLO and LA. Likewise, on day 3 TSP was redder ($P > 0.05$) than the rest of the treatments with no significant difference ($P > 0.05$) between CLO and CPC. But, CPC was also found redder ($P < 0.05$) than the control and LA. On day 7 panelists were unable to find any difference ($P > 0.05$) between TSP, CPC, CLO and the control but all were redder ($P < 0.0.5$) than LA.

Sensory panelists found no difference ($P > 0.05$) among treatments on day 0 or day 7 of display for percentage of discoloration (Table 1). In addition, CLO, CPC and TSP patties were not different ($P > 0.05$) from the control for percentage discoloration on day 1 of display. By day 3 of display, however TSP ground beef patties were less ($P < 0.05$) discolored than the control or any other treatment, and CLO, CPC and LA were similar ($P > 0.05$) in discoloration to the control. These results agree with Pohlman et al. (2002) and Stivarius et al. (2002) who reported that the CLO, TSP, CPC and LA treated patties were similar in overall color, worst point color, and percent of discoloration on days 0 and 1 of display; however CLO treatment was less red than the control on days 1, 2, 3 and 7 of display for overall color. Also it was reported that TSP treated patties were redder than control patties on days 2, 3 and 7 of display for overall color and worst point color and were less discolored than control patties on the same days. However and in agreement with the current study, Pohlman et al. (2002) reported that CPC treated patties were redder and less discolored than the control patties on day 2 and 3 of display but were not different from control patties on day 7 of display.

Pohlman et al. (2002) found that the use of cetylpyridinium chloride and trisodium phosphate did not affect ground beef odor and off odor. Stivarius et al. (2002) also reported that LA treatment did not affect these same attributes on days 0 and 1 of display, but on day 3 of display LA treated patties had less off odor and beef odor than control patties. Our results are in agreement with these results where it was found that sensory panelists found no differences ($P > 0.05$) in beef odor or off odor characteristics among treatments on days 0, 1, and 2 of display (Table 2). Likewise, panelists could not distinguish any difference ($P > 0.05$) in beef odor between the control and any other treatment by day 3 of display; however, on day 3, panelists found TSP treated patties had less ($P < 0.05$) off odor than the control patties. Also, panelists were unable to detect any difference ($P > 0.05$) in off odor between the control and any other treatment by day 3 of display. On day 7, TSP and CPC had more ($P < 0.05$) beef odor than the control. Sensory panelists also did not find any difference ($P > 0.05$) in beef odor or off odor between ground beef patties from the LA, CLO and the control treatments. In addition, on day 7 of display, TSP was found by the sensory panelists to have less ($P < 0.05$) off odor than the rest of the treatments.

There was no difference ($P > 0.05$) in lipid oxidation among treatments on days 0 and 3 of simulated retail display, but on day 7, TSP and CPC had similar ($P > 0.05$) TBARS values as the control but less ($P < 0.05$) lipid oxidation than LA and CLO (Fig. 1). Likewise, CLO had lower ($P < 0.05$) TBARS values than LA after 7 days of display.

Implications

Results from this study show that trisodium phosphate, cetylpyridinum chloride, chlorine dioxide and lactic acid treatments of beef trimmings before grinding could improve, or maintain, the same sensory and instrumental color, sensory odor and lipid oxidation characteristics as traditionally processed ground beef patties. Therefore these antimicrobial treatments could be used in industry as a measure of safety improvement without a negative impact on the fresh product.

Acknowledgments

Appreciation is expressed to the Arkansas Beef Council for funding this research. The authors would like to thank J. Stephenson, K. McElyea, L. Rakes, J. Leach, J. Roberts and B. Boger for their assistance in conducting this trial.

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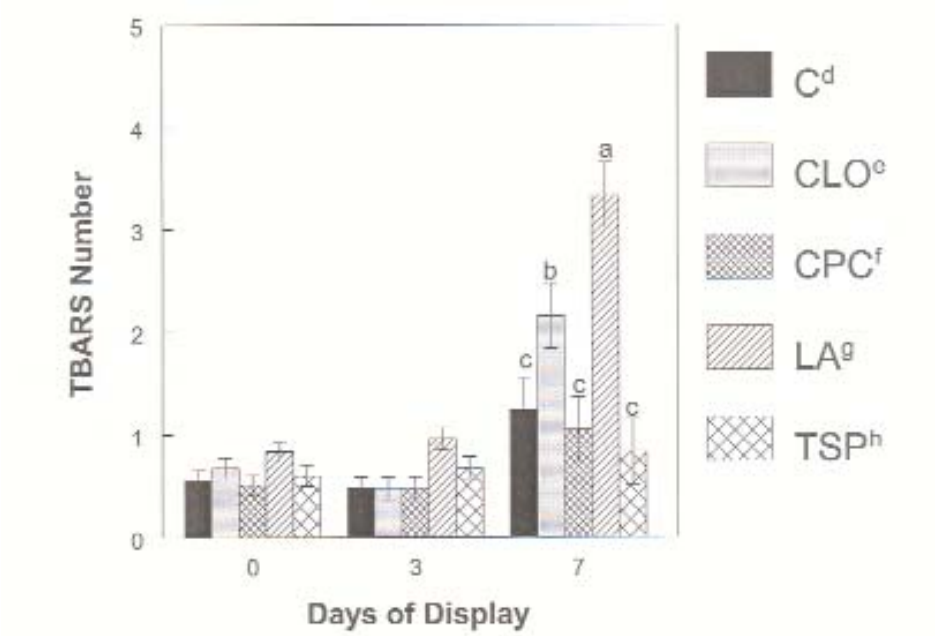

Fig. 1. Days of display by antimicrobial treatment interaction effect on the least-squares means for TBARS values (±SE) of ground beef through simulated retail display.

Table 1. Effect of days of display by antimicrobial treatment[a] interaction effect on least-squares means for overall color, worst point color and % discoloration of ground beef through simulated retail display

		Days of Display				
Attribute	Treatment	0	1	2	3	7
Overall color[b]						
	Control	6.3	6.4	5.7^{xy}	3.8^{z}	3.8
	CLO	6.3	6.2	5.1^{yz}	3.9^{z}	3.9
	CPC	6.2	6.5	6.1^{x}	4.8^{y}	3.8
	LA	6.0	5.8	4.5^{z}	4.3^{y}	3.1
	TSP	6.3	6.5	6.2^{x}	6.2^{x}	4.3
	SE	0.12	0.20	0.25	0.29	0.41
Worst point color[c]						
	Control	4.8	4.6^{y}	3.6^{xy}	2.5^{z}	2.6^{y}
	CLO	4.8	4.4^{y}	3.2^{yz}	2.6^{yz}	2.5^{y}
	CPC	4.9	4.6^{y}	3.9^{wx}	3.1^{y}	2.5^{y}
	LA	4.6	4.0^{z}	2.9^{z}	2.3^{z}	1.9^{z}
	TSP	4.7	4.5^{y}	4.2^{w}	4.3x	2.8^{y}
	SE	0.07	0.12	0.18	0.22	0.21
% Discoloration[d]						
	Control	5.4	4.8^{y}	3.9^{y}	3.0^{z}	2.7
	CLO	5.4	4.6^{y}	3.3^{z}	2.9^{z}	2.7
	CPC	5.3	4.6^{y}	4.0^{xy}	3.3^{z}	2.7
	LA	5.3	4.1^{z}	2.9^{z}	2.9^{z}	2.2
	TSP	5.4	4.7^{y}	4.4^{x}	4.4^{y}	2.9
	SE	0.11	0.11	0.15	0.21	0.27

[a] CLO = chlorine dioxide, CPC = cetylpyridinium chloride, LA = lactic acid and TSP = trisodium phosphate.
[b] Overall color: 7 = bright purplish, 1= brown.
[c] Worst point color: 5 = bright purplish, 1= brown.
[d] Percentage of discoloration: 7 = no discoloration (0%), 1 = total discoloration (96-100%).
[xyz] Least-squares means within a column bearing different superscripts are different ($P < 0.05$).

Table 2. Days of display by antimicrobial treatment[a] interaction effect on the least-squares means for sensory evaluated beef odor and off odor of ground beef through simulated retail display

Attribute		Days of Display				
	Treatment	0	1	2	3	7
Beef Odor[b]						
	Control	7.3	6.5	6.7	5.6^{yz}	1.9^{z}
	CLO	7.3	6.8	6.4	5.2^{z}	1.8^{z}
	CPC	7.3	6.6	6.3	6.0^{yz}	3.4^{xy}
	LA	7.1	6.6	6.1	5.0^{z}	2.5^{yz}
	TSP	7.3	6.6	6.5	6.5^{y}	4.2^{x}
	S.E.	0.22	0.27	0.28	0.37	0.39
Off odor[c]						
	Control	4.8	4.7	4.7	4.0^{yz}	1.4^{yz}
	CLO	4.9	4.9	4.5	3.8^{z}	1.3^{z}
	CPC	4.9	4.9	4.7	4.4^{xy}	2.6^{x}
	LA	4.9	4.7	4.4	3.7^{z}	1.9^{y}
	TSP	4.9	4.8	4.7	4.7^{x}	3.2^{w}
	S.E.	0.06	0.09	0.28	0.37	0.39

[a] CLO = chlorine dioxide, CPC = cetylpyridinium chloride, LA = lactic acid and TSP= trisodium phosphate.
[b] Beef odor score: 8 = extremely beef like 1= extremely non-beef like.
[c] Off odor score: 5 = no off odor, 1 = extreme off odor.
[wxyz] Least-squares means within a column bearing different superscripts are different ($P < 0.05$).

The Effects of Chlorine Dioxide, Cetylpyridinium Chloride, Lactic Acid and Trisodium Phosphate on Processing, Textural, Instrumental Color and Sensory Characteristics when used in a Ground Beef Patty Production System

J. R. Jimenez-Villarreal, F. W. Pohlman, Z. B. Johnson, and A. H. Brown, Jr.[1]

Story in Brief

The impact of beef trimmings treated with either 0.5% cetylpyridinium chloride (CPC), 200-ppm chlorine dioxide (CLO), 2% lactic acid (LA), or 10% trisodium phosphate (TSP) prior to grinding on instrumental color, sensory characteristics, pH and Lee-Kramer shear under simulated retail display were evaluated. Trimmings were ground, pattied, packaged and sampled at 0, 1, 2, 3 and 7 days of display. Patties from LA, CPC, and CLO treatments were lighter (L*; $P < 0.05$;) and TSP patties were redder (a*; $P < 0.05$) and more vivid in color than the control. Therefore treatment of beef trimmings before grinding with TSP, CPC, CLO, and LA may not only improve ground beef safety but also may maintain or enhance patty shelf life.

Introduction

Chemical interventions such as chlorine dioxide, cetylpyridinium chloride and trisodium phosphate have been investigated for decontaminating carcass tissues. However, only recently has research focused on decontaminating beef trimmings before grinding utilizing chlorine dioxide, cetylpyridinium chloride, organic acids and trisodium phosphate to reduce microbial numbers (Stivarius, et al. 2002; Pohlman et al. 2002). In these studies, beef trimmings inoculated with *E. coli* and *Salmonella* then treated with cetylpyridinium chloride or trisodium phosphate before grinding remained redder in instrumental and sensory evaluated color through display compared with an inoculated control. Likewise, utilization of chlorine dioxide, cetylpyridinium chloride, lactic acid or trisodium phosphate either had little impact on ground beef color or improved color stability during display in these inoculated studies. However, it is unknown how these compounds might affect ground beef color when used on non-inoculated beef trimmings and in a patty system. Therefore the objective of this study was to evaluate the effect of chlorine dioxide, cetylpyridinium chloride, lactic acid and trisodium phosphate on processing characteristics, instrumental and sensory taste characteristics when used in a ground beef patty production system.

Experimental Procedures

Antimicrobial Treatment Application and Sample Processing. Antimicrobial treatments for this study included; 0.5% cetylpyridinium chloride (CPC), 200-ppm chlorine dioxide (CLO), 2% lactic (LA) or 10% trisodium (TSP) solutions, and an untreated control. For antimicrobial treatments 4.54 lb of beef trimmings (80% lean and 20% fat) were placed into a meat tumbler with 1250 ml of the selected antimicrobial treatment and aerobically tumbled for 3 min (16 rpm), then removed, and allowed to drip dry for 3 min.

Once the antimicrobial application phase was completed, beef trimmings were ground twice using a Hobart grinder with a 1/8 in plate. Patties (0.485 lb) were then made using a Hollymatic patty machine and placed on styrofoam trays with absorbent diapers. The trays were overwrapped with polyvinyl chloride film with an oxygen transmission rate of 1400 cc/m2/24 h/ 1 atm and stored under simulated retail conditions (35.6°F, deluxe warm white fluorescent lighting, 1630 lx). Multiple trays of ground beef patties for each treatment were packaged to allow for independent use for instrumental color on pre-assigned days 0, 1, 2, 3 and 7 days of display. Also, ground beef pH of each treatment was also determined on day 1 of display by homogenizing 0.004 lb of ground beef in 18 ml of distilled water and evaluated a pH meter with a ROSS electrode. Taste panel, cook loss percentage and Lee-Kramer shear force characteristics were analyzed using patties sampled at day 2 of display.

Processing Abilities. To evaluate processing abilities of ground beef, sensory analysis was conducted using a four member, trained sensory panel. Sensory panelists evaluated grinding ability (6 = extreme smearing, 5 = moderate smearing, 4 = slight smearing, 3 = slight cut-grind, 2 = moderate cut-grind, 1 = extreme cut-grind) and patty forming ability (6 = extremely fragile, 5 = moderately fragile, 4 = slightly fragile, 3 = slightly cohesion, 2 = moderate cohesion, 1 = extreme cohesion) for each treatment.

Instrumental Color. Instrumental color was measured on days 0, 1, 2, 3 and 7 days of simulated retail display using a HunterLab MiniScan XE Spectrocolorimeter, Model 4500L (Hunter Associates Laboratory Inc., Reston, West Virginia, USA). Samples were read using illuminant A/10° observer and evaluated for CIE (L*, a* and b*) color values. Also, reflectance measurements were taken in the visible spectrum from 580 nm to 630 nm where the reflectance ratio of 630 nm/580 nm was calculated to estimate the proportion of oxymyoglobin (Strange, et al., 1974). Hue Angle was calculated ($\tan^{-1}(b^*/a^*)$), as well as the saturation index ($(a^{*2} + b^{*2})^{0.5}$), which describes the vividness of color. Before use, the spectrocolorimeter was standardized using a white tile, black tile, and a working standard. Five measurements were taken of each sample and averaged for statistical analysis.

Sensory Taste. Sensory panelists were selected and trained by an experienced panel leader according to the American Meat Science Association Guidelines (AMSA, 1978). Ground beef patties were cooked on a gas griddle to an internal temperature of 170.6°F (AMSA, 1978). During cooking, internal patty temperature was continuously monitored using copper thermocouples attached (1.5 mm in diameter) to a Doric. Patties were sectioned and randomly presented to the panelists using a complete block design, where all panelists received all treatments during the evaluation sessions. Panelists rated each sample for juiciness, bind, and beef flavor on an 8-point scale (8

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= extremely juicy, extremely bind, extremely intense beef flavor, to 1 = extremely dry, extremely fragile and no beef flavor). Furthermore, panelists evaluated off flavor as a 5-point scale (5 = no off flavor to 1 = extreme off flavor). The test was conducted with no contact between panelists in individual booths and under low pressure sodium (18 Watts, 120 Volts) color neutralizing light to avoid bias.

Shear Force and Cooking Yield. Ground beef patties were cooked using a gas griddle to an internal temperature of 170.6°F (AMSA, 1978). Internal patty temperature was continuously monitored using a Doric recorder. Patties were cooled to room temperature (77°F) and then sectioned (2.36 in X 2.36 in) for Lee-Kramer analysis. Shear force was analyzed using an Instron universal testing machine with a Lee-Kramer shear device, a 50 kg load cell and a 250 millimeters/min cross head speed. Also, cooking loss was determined using a Mettler Toledo balance, and calculated by weight differences between fresh weight vs. cooked weigh using the following equation: Cooking loss (%) = (Cooked wt ÷ Fresh wt) X 100.

Statistical Analysis. The experiment was arranged in a randomized complete block 5 x 5 factorial design where the main effects were antimicrobial treatment and days of display. The experiment was replicated three times and was analyzed using the GLM procedures of SAS (SAS Inst. Inc., Cary, NC). Treatments were blocked by replicate and then analyzed for the main effects of antimicrobial treatment, day of display and treatment by day interactions. For sensory panel data, a panelist term was added to the model to account for sensory panelist variation. For variables involved in interactions, interaction means were generated and then separated using the PDIFF option of PROC GLM. Least-squares means for all other variables not confounded by interaction were generated and separated using the PDIFF option.

Results and Discussion

Panelists indicated that CPC, LA and TSP patties had slightly less ($P < 0.05$) particle definition than control patties, which were similar to CLO for grinding ability; however panelists were unable to find any differences between C, TSP, LA and CLO for patty forming ability (Table 1). Ground beef patties from the LA, CPC and CLO treatments were lighter (L*, $P < 0.05$) in color compared to control, but TSP and the control had similar ($P > 0.05$) L* values. Also, the TSP treatment resulted in a more ($P < 0.05$) red color than the control; whereas, LA patties were less ($P < 0.05$) red, and CPC and CLO patties were similar ($P > 0.05$) in redness, compared with control patties (Table 1). All treatments were similar ($P > 0.05$) to the control for estimated oxymyoglobin content, but TSP had a higher ($P < 0.05$) proportion of oxymyoglobin than LA and CLO. There was no difference ($P > 0.05$) between any treatment and the control for CIE b* values and hue angles. However, TSP was more ($P < 0.05$) vivid in color than the control, LA and CLO treatments (Table 1). Pohlman et al. (2002) reported that ground beef treated with TSP and CPC was redder (a* value) and had more oxymyoglobin content than the control. The control and CPC were similar in vividness, and TSP treated ground beef was more vivid than the control. Stivarius et al. (2002) indicated that LA treated ground beef had less oxymyoglobin content and was lighter (L*) than the control in an inoculate study. Therefore Pohlman et al. (2002) and Stivarius et al. (2002) agree with the results of this study.

Ground beef from the TSP and CPC treatments had higher ($P < 0.05$) pH values compared to the rest of the treatments. As expected, ground beef from the LA treatment had the lowest ($P < 0.05$) pH of any treatment, whereas CLO and the control were similar in pH ($P > 0.05$) (Table 1).

Sensory panelists were unable to detect any difference in beef flavor among treatments (Table 2). Likewise, TSP, CPC and LA patties were similar ($P > 0.05$) in off flavor to the control but higher ($P < 0.05$) in off flavor than ground beef from the CLO treatment. The TSP, CLO and LA treatments were scored juicier ($P < 0.05$) than the control, and CPC was rated similar ($P > 0.05$) to the control. The TSP, CPC, CLO and LA treatments had slightly less ($P < 0.05$) bind compared to the control. Ground beef patties from the TSP treatment produced the lowest ($P < 0.05$) peak force to shear compared with the rest of the treatments. The CPC, CLO and the control treatments had similar ($P > 0.05$) shear force peaks; however, the LA patties needed more force ($P < 0.05$) to be shorn when compared to the control patties. Cook loss (%) was also affected by the treatments where TSP and the control patties were similar ($P > 0.05$) in cook loss (%), but had less ($P < 0.05$) loss during cooking than patties on the CLO, CPC and LA treatments.

Implications

Ideally the use of any antimicrobial treatment on beef trimming prior to grinding should reduce microbial loads without affecting sensory, quality characteristics and lipid oxidation. This experiment showed that the use of trisodium phosphate, cetylpyridinium chloride, chlorine dioxide and lactic acid as multiple antimicrobial interventions could improve sensory taste characteristics, instrumental texture and instrumental color without affecting processing characteristics of ground beef. Use of these antimicrobial treatments could extend retail shelf life of ground beef without having any negative impact on the product.

Acknowledgments

Appreciation is expressed to the Arkansas Beef Council for funding this research. The authors would like to thank J. Stephenson, K. McElyea, L. Rakes, J. Leach, J. Roberts and B. Boger for their assistance in conducting the trials.

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Table 1. Effect of antimicrobial treatments[a] applied to beef trimmings on least-squares means for processing abilities, CIE L*, a* and b* values, oxymyoglobin, hue angle, saturation index, and pH

	Treatment					
	Control	CLO	CPC	LA	TSP	S.E.
Processing abilities						
Grinding ability[b]	2.0^{z}	2.0^{z}	3.3x	3.0^{y}	3.0^{y}	0.0
Patty forming[c]	2.0^{z}	2.0^{z}	3.3^{y}	2.0^{z}	2.0^{z}	0.0
Instrumental color and pH						
CIE L*[d]	39.79^{z}	42.05^{y}	42.49^{xy}	44.22^{x}	41.65^{yz}	0.66
CIE a*[d]	22.30y^{z}	21.31^{z}	23.78^{xy}	21.02^{z}	24.84^{x}	0.83
CIE b*[d]	18.69	18.48	20.17	19.28	20.22	0.60
Oxymyoglobin[e]	3.45^{xyz}	3.15^{yz}	3.62^{xy}	2.82^{z}	4.05^{x}	0.22
Hue Angle[f]	40.12	41.23	40.49	43.01	38.99	0.87
Vividness[g]	29.22^{yz}	28.37^{z}	31.27^{xy}	28.65^{z}	32.05^{x}	0.87
pH	6.10y	6.06^{y}	6.25^{x}	5.52^{z}	6.76^{w}	0.03

[a] CLO = chlorine dioxide, CPC = cetylpyridinium chloride, LA = lactic acid and TSP = trisodium phosphate
[b] Grinding ability score: 6 = extreme smearing, 1 = extreme cut-grind
[c] Patty forming ability score: 6 = extremely fragile, 1 = extreme cohesion
[d] L*: 0= black and 100= white; a*: -60= green and 60= red, b*: -60=blue and 60= yellow
[e] Calculated as the ratio 630nm/580nm reflectance
[f] Calculated as $\tan^{-1}(b^*/a^*)$
[g] Calculated as $(a^{*2} + b^{*2})^{0.5}$
[wxyz] Least-squares means within a row bearing different superscripts are different ($P < 0.05$)

Table 2. Effect of antimicrobial treatments[a] applied to beef trimming on least-squares means of beef flavor, off flavor, juiciness, bind characteristics, shear force and cook loss % of ground beef patties

	Treatment					
	Control	CLO	CPC	LA	TSP	S.E.
Sensory Taste						
Beef flavor[b]	5.5	5.4	5.8	5.7	6.1	0.32
Off flavor[c]	4.7^{y}	4.0^{z}	4.6^{y}	4.4^{yz}	4.5^{y}	0.25
Juiciness[d]	3.9^{z}	5.2^{x}	4.4^{yz}	4.7^{xy}	5.6^{x}	0.27
Bind[e]	5.9^{y}	4.6^{z}	5.0^{z}	4.8^{z}	4.9^{z}	0.24
Shear force, cook loss %[f]						
Shear force (lb)	55.00^{xy}	46.90^{y}	52.30^{xy}	59.12^{x}	34.96^{z}	2.98
Cook loss %	31.38^{yz}	34.99^{xy}	34.28^{xy}	37.37^{x}	28.23^{z}	1.15

[a] CLO = chlorine dioxide, CPC = cetylpyridinium chloride, LA = lactic acid and TSP= trisodium phosphate.
[b] Beef flavor score: 8 = extremely intense beef flavor, 1 = no beef flavor.
[c] Off flavor score: 5 = no off flavor, 1 = extreme off flavor.
[d] Juiciness score: 8 = extremely juicy, 1 = extremely dry.
[e] Bind score: 8 = extreme bind, 1 = extremely fragile.
[f] Calculated as (cooked patty weight÷fresh patty weight) X 100.
[xyz] Least-squares means within a row bearing different superscripts are different ($P < 0.05$).