12-1-2004

Arkansas Animal Science Department Report 2004

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Animal Science
Department Report • 2004

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Editors

ARKANSAS AGRICULTURAL EXPERIMENT STATION
Division of Agriculture
University of Arkansas System
December 2004
Research Series 522

ARKANSAS ANIMAL SCIENCE DEPARTMENT REPORT 2004

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(a unit of the University of Arkansas System's statewide Division of Agriculture)

INTRODUCTION

The faculty and staff of the Animal Science Program are pleased to present the seventh edition of the Arkansas Animal Science Department Report. The Program is proud of the 26 faculty members working in teaching, research and extension at the Fayetteville campus, the Extension headquarters in Little Rock, the Southwest Research and Extension Center in Hope, the Southeast Research and Extension Center in Monticello, and the Livestock and Forestry Branch Station in Batesville. Readers interested in learning more about the Animal Science Program should go to the web site at ANSCHOME.COM or www.uaex.edu.

Although budgets are certainly not where we would like them to be, we were fortunate in being able to refill some key positions in the Program. Dr. Paul Beck joins the Department at the Southwest Research and Extension Center in Hope. Paul earned B.S. and M.S. degrees from Oklahoma State and his Ph.D. from the University of Arkansas. He will conduct research with beef cattle nutrition and forage systems at Hope and Batesville and has a 40% appointment in Extension.

Mr. John Richeson joined the Animal Science Extension faculty to provide leadership with the Arkansas Beef Improvement Program. John earned his B.S from Oklahoma State and M.S. from Texas Tech University. His experience included supervising the cattle operations at the ContiBeef LLC research center in Lamar, Colo. At the research center, John was responsible for cattle health, performance records, shipping and receiving, carcass data, and various other duties required to insure accurate research of feedlot cattle health and nutrition.

Dr. Brett Barham joined the Animal Science Extension Faculty on September 1, 2004 as a breeding and genetics specialist. Dr. Barham grew up on a ranch in New Mexico and earned his B.S., M.S., and Ph.D. degrees from Texas Tech University. Brett will be developing state-wide Extension programs in the area of beef cattle breeding and genetics.

Although enrollment in Animal Science at 127 students is modest for many departments, this is the largest enrollment since Animal and Poultry Science were split into two departments in 1992. Pre-vet is the most popular option. Interest in equine programs continues to grow and in 2005, we expect to have a new minor approved in Equine Science. Private support for the equine program continues to be outstanding with over $300,000 in cash, gifts in kind, and proceeds from special events over the past three years. Almost half the students taking the five equine courses are from outside the department.

Finally, we want to thank the many supporters of our teaching, research, and extension programs. Whether providing grants to fund research or funds for scholarships, educational programs, extension programs, facilities, or donating horses and livestock, these friends are essential to maintaining a quality educational program. We thank each and every one of you on behalf of our faculty, staff, students and clientele. We hope you will find the research reported herein to be timely, useful, and making a contribution to the field of Animal Science.

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 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 letters in common 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 the amount of variation 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
ADF	Acid detergent fiber
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
NDF	Neutral detergent fiber
ng	Nanogram(s)
NS	Not significant
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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Technical editing and cover design by Camilla Romund

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ISSN:1051-3140 CODEN:AKAMA6

Factors Associated with Student Grades in Animal Physiology I

M.D. Hale, Z.B. Johnson, and C.F. Rosenkrans, Jr.[1]

Story in Brief

Students and faculty alike would like to know what factors are related to success in college courses. The purpose of this study was to evaluate factors that relate to a student's success in Animal Physiology I (ANSC/POSC 3032), an upper level animal science course at the University of Arkansas. Student data were confidentially collected and coded. Data collected were student high school grade point average (HSGPA), composite American College Testing (ACT) score; English, reading, math, and science subscores on the ACT, and student grades in English composition I and II, college algebra, chemistry, biology, microbiology, animal physiology II, and reproductive physiology. Prematriculation performance confirmed that students with higher HSGPA and(or) ACT scores had better grades in animal physiology I. However, ACT subscores were not more informative than the ACT composite score. Performance in prerequisite courses (chemistry and biology) was significantly related to student grades in Animal Physiology I. Student grades in related courses indicated the same results, that is, students that do well in high school tend to have better grades in college including Animal Physiology I.

Introduction

Predicting success of incoming students is typically based on performance on standardized tests, grades in introductory courses, and high school performance. Prematriculation factors such as high school grade point average (HSGPA) and American College Testing (ACT) scores are strong indicators of a student's potential in college, and are used for admission into the University of Arkansas. Most upper level undergraduate courses have prerequisite courses; therefore, one would expect performance in previous courses should have an impact on performance in upper level courses.

Our hypothesis was that specific prematriculation items and prerequisite course grades would be good predictors of performance in Animal Physiology I (Phys I). Specific objectives of this study were to determine: 1) the relationship between prematriculation performance and letter grade earned in Animal Physiology I; 2) if performance in prerequisite and core courses predicted success in Phys I; and 3) if performance in Phys I reflected performance in subsequent courses.

Experimental Procedures

Records for students (n = 169) enrolled in ANSC/POSC 3032 during the fall semesters of 2000, 2001, and 2002 were extracted from the University of Arkansas' database. The following information was collected from each students record: HSGPA, ACT composite and subsection scores, semester course load while enrolled in Animal Physiology I, term GPA, cumulative GPA, academic major, and course grade for 11 courses. The course grades evaluated were: Animal Physiology I (ANSC/POSC 3032), Principles of Biology (BIOL 1543), Fundamentals of Chemistry (CHEM 1074), University Chemistry II (CHEM 1123), Introductory Animal Science (ANSC 1003), Composition I (ENGL 1013), Composition II (ENGL 1023), College Algebra (MATH 1203), General Microbiology (MBIO 2013), Animal Physiology II (ANSC/POSC 3042), and Fundamentals of Reproductive Physiology (ANSC 3433). Principles of Biology and Fundamentals of Chemistry or University Chemistry II are the prerequisites for Animal Physiology I.

Letter grades were converted into numerical functions for ease of calculation. An "A" was assigned the number 4, "B" 3, "C" 2, "D" 1, and "F" 0. Eighteen of the 169 student transcripts examined were either withdrawals or incompletes in Animal Physiology I and were removed from data analysis. It also should be noted that the grading scale for ANSC/POSC 3032 was 92% and greater-A, 82-91%-B, 72-81%-C, 62-71%-D, and 61% and lower-F. Most other courses were graded on the scale of 90% and greater-A, 80-89%-B, 70-79%-C, 60-69%-D, and 59% and lower-F. Data were analyzed using the CORR, FREQ, and GLM procedures of SAS (SAS Inst., Inc., Cary, NC). Mean separation was accomplished by using the Tukey adjustment within the LSMEANS option. Data are presented as least-squares means.

Results and Discussion

In order to get a better understanding of our evaluated population, factors such as course load, term GPA, and cumulative GPA were evaluated to determine relationships with grades in Animal Physiology I. These values along with prematriculation scores are presented in Table 1. Mean course load (number of hours in which the student was enrolled during the semester he/she took Phys I) was 12.8 hours. Course load was correlated with Phys I grade ($r = 0.26$; $P < 0.001$). Separation of means for course load revealed no difference between the load of A through D students; however, students earning an F in Phys I were enrolled in fewer hours. Mean term GPA was 2.83, and mean cumulative GPA was 3.04. Both were correlated with Phys I grade ($r > 0.77$; $P < 0.0001$). The high correlations between Phys I grade and GPA were expected considering Phys I grade was a component of GPA calculations.

The two prematriculation indicators used in our analyses were HSGPA and ACT scores. Mean high school GPA was 3.40 and was correlated ($r = 0.35$; $P < 0.0001$) with Phys I grade. As shown in Table 1, students earning an A in Phys I had a greater ($P < 0.05$) high school GPA than students earning a C or D. Composite ACT score average was 23.7 (on a scale of 36) and was correlated ($r = 0.36$; P

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< 0.0001) with the Phys I grade. As shown in Table 1, students earning an A in Phys I had higher (P < 0.001) composite ACT scores than students earning a C or D. Similar results were found with the ACT subsection scores.

The second objective was to determine if performance in prerequisite and related core courses was related to Animal Physiology I grades. The University of Arkansas Catalog of Studies lists two prerequisites for Animal Physiology I. Those prerequisites were Principles of Biology (BIOL 1543) and University Chemistry II (CHEM 1123) or Fundamentals of Chemistry (CHEM 1074). To assess this objective, the letter grade students earned in the collateral classes were used as the main effect and Phys I grade as the response variable. Each of the selected classes was analyzed independently.

The BIOL 1543 grade was correlated with Phys I grade (r = 0.59; P < 0.0001). Sixty-four percent of the students who earned an A in BIOL 1543 made an A in Phys I. All of the students who earned an A in Phys I made either an A or B in BIOL 1543. Mean separation by BIOL 1543 letter grade is presented in Table 2.

Letter grade earned in CHEM 1123 or 1074 was correlated with Phys I grade (r > 0.61; P < 0.01). All of the students who made an A in Phys I made an A, B, or C in CHEM 1123, with 73% of them making either an A or B. Of the students who failed CHEM 1123 (received an F) 60% of them made a D or F in Phys I, with the highest grade received in Phys I being a C. Fifty-six percent of those that made an A in CHEM 1074 made an A in Phys I, and 89% made an A or B. Mean separation based on chemistry grades is presented in Table 2.

Mean separation for grades in additional selected classes is presented in Table 2. Grade in Phys I was correlated with MBIOL 2013 grade (r = 0.36; P < 0.0001). Seventy-three percent of the students who made an A in Phys I made an A or B in MBIO 2013. Seventy percent of the students who made a D in MBIO 2013 made a D in Phys I. College algebra grade was correlated with grade for Phys I (r = 0.41; P < 0.0001). Eighty-seven percent of those making an A in Phys I made either an A or B in MATH 1203. There was a correlation between ANSC 1003 grade and Phys I grade (r = 0.53; P < 0.0001). Sixty-one percent of the students who made an A in ANSC 1003 made an A in Phys I; 42% of the students who made a B in ANSC 1003 made a B in Phys I; 56% of those who made a C in ANSC 1003 made a C in Phys I; and all of those who made a D in ANSC 1003 made a D in Phys I. The strong relationship between ANSC 1003 and Phys I grade may be due to the fact that the same instructor taught both classes.

The third objective of this study was to determine the relationship between performance in Phys I and the performance in subsequent courses. The two subsequent courses evaluated were Animal Physiology II (ANSC/POSC 3042) and Fundamentals of Reproductive Physiology (ANSC 3433).

Grade in Phys I was correlated to grade in ANSC/POSC 3042 (r = 0.76; P < 0.0001) and to grade earned in ANSC 3433 (r = 0.83; P < 0.0001). Eighty-seven percent of those students who earned an A in Phys I made an A in ANSC/POSC 3042. Ninety-four percent of those students who made an A in Phys I made an A in ANSC 3433, and all of them made an A or B.

We consistently found that higher ability students, based on prematriculation data, tended to excel in most college courses. Those with high HSGPA and(or) ACT usually had high scores in college courses. This is consistent with other studies, where it was found that previous academic performance was the most significant predictor of collegiate academic performance. The number of hours enrolled in the semester the student took Phys I was lower for students ultimately earning an F in Phys I. That observation could be due to the UofA policy that restricts the number of hours a student may enroll in when they are at risk of academic suspension. Those low enrollment hours also could be associated with students working extensively outside of school.

It was interesting to note that students making an A in biological and physical sciences tended to have higher average grades in Phys I than students who made an A in composition or math courses. In addition, it is noteworthy to point out that students who failed biology, microbiology, introductory animal science, or composition courses did not choose to enroll or complete Phys I. Furthermore, very few of the students who earned a D in composition or introductory animal science enrolled in Phys I. Those courses are not usually considered “weedout” classes; however, they appear to eliminate some of the students.

Implications

The results of this study supported the hypothesis that prematriculation performance, prerequisite course performance, and performance in related courses would be correlated with performance in Animal Physiology I. Our results suggest that students with ability and(or) willingness to do well in some courses tend to do well in all courses.

Table 1. Least-squares means of prematriculation and term items as distributed by letter grade earned in Animal Physiology I.

	Grade in Animal Physiology I				
Item	A	B	C	D	F
Number of students	40	46	43	16	6
Course Load	14.3[a]	13.8[a]	13.5[a]	13.1[a]	8.8[b]
Term GPA	3.73[a]	3.29[b]	2.71[c]	1.87[d]	0.97[e]
Cumulative GPA	3.68[a]	3.23[b]	2.84[c]	2.47[d]	1.89[e]
High School GPA	3.65[a]	3.51[ab]	3.30[bc]	3.10[c]	3.18[ac]
ACT Scores					
Number of students	34	37	32	15	6
Composite	25.7[a]	24.1[ab]	22.3[b]	21.9[b]	22.5[ab]
English	26.3[a]	24.7[ab]	23.0[b]	21.9[b]	22.0[ab]
Reading	26.9[a]	24.6[ab]	22.8[b]	22.8[ab]	24.5[ab]
Math	23.7[a]	22.7[ab]	21.0[ab]	20.0[b]	19.5[ab]
Science	25.0[a]	23.6[ab]	21.5[b]	22.7[ab]	23.3[ab]

[a,b,c,d,e] Means, within a row, with no superscript in common differ (P < 0.05) when adjusted using the Tukey method.

Table 2. Least-squares means of Animal Physiology I grade as distributed by letter grade earned in selected courses.

	Selected Course Grade (n)				
Course	A	B	C	D	F
Biology	3.58[a] (39)	2.78[b] (50)	2.10[cd] (52)	1.56[d] (13)	–(0)
Fund. Chemistry	3.83[a] (9)	3.33[a] (7)	2.50[ab] (8)	1.60[b] (5)	2.00[ab] (2)
Univ. Chemistry II	3.64[a] (12)	3.42[a] (30)	2.64[b] (37)	2.14[bc](14)	1.00[c] (5)
Intro. Animal Sci.	3.48[a] (31)	2.23[b] (33)	2.06[b] (16)	1.00[ab] (1)	–(0)
Composition I	3.06[a] (58)	2.42[b] (61)	1.89[b] (30)	2.00[ab] (2)	–(0)
Composition II	3.18[a] (54)	2.38[b] (68)	2.04[b] (29)	2.00[ab] (3)	–(0)
College Algebra	2.92[a] (54)	2.73[ab](37)	2.09[bc] (37)	1.88[bc] (10)	0.67[c] (5)
Microbiology	3.26[a] (30)	2.89[a] (38)	2.68[ab] (34)	2.05[b] (21)	–(0)

[a,b,c,d,e] Means, within a row, with no superscript in common differ (P < 0.05) when adjusted using the Tukey method.

Degradation Kinetics of NDF for Crabgrass Harvested on Seven Dates in Northern Arkansas

R.K. Ogden[1], W.K. Coblentz[1], K.P. Coffey[1], J.E. Turner[1], D.A. Scarbrough[1], J.A. Jennings[2], and M.D. Richardson[3]

Story in Brief

Southern crabgrass [*Digitaria ciliaris* (Retz.) Koel.] is well-adapted to climatic conditions in North America, but its prolific nature and subsequent encroachment into field crops, gardens, and yards frequently makes it a unwanted species. Visual observations indicate that grazing livestock prefer crabgrass to other warm-season grasses. Our objectives were to evaluate the fiber composition and ruminal in-situ disappearance kinetics of neutral detergent fiber (NDF) for crabgrass harvested weekly between July 11 and August 22, 2001 and compare these estimates with those of alfalfa (*Medicago sativa* L.), bermudagrass [*Cynodon dactylon* (L.) Pers.], and orchardgrass (*Dactylis glomerata* L.) hays determined simultaneously. Concentrations of NDF, acid detergent fiber (ADF), and lignin in whole-plant tissue increased linearly ($P \leq 0.001$) over sampling dates; a quartic effect ($P = 0.034$) also was observed for lignin. Subsequently, crabgrass was evaluated for ruminal in-situ disappearance of NDF in five (843 ± 50.1 lb) ruminally cannulated crossbred steers. Crabgrass had a more rapid NDF disappearance rate than NDF from bermudagrass ($P < 0.0001$) and orchardgrass hays ($P < 0.0001$); in contrast, alfalfa NDF disappeared at a faster ($P < 0.0001$) rate than crabgrass. The effective ruminal degradability of NDF decreased over sampling dates with linear, quadratic, and cubic ($P < 0.0001$) effects; however, the effective degradability for crabgrass was greater than observed for alfalfa ($P < 0.0001$), orchardgrass ($P < 0.0001$), and bermudagrass ($P = 0.004$) hays.

Introduction

Visual observations indicate that livestock may prefer crabgrass to other summer forages, and cattle often exhibit good summer performance when consuming this forage (Dalrymple, 1999). Crabgrass is often undesirable as a hay crop because its color and texture are distinctive, and it is often presumed to be a weedy species.

Bermudagrass is the most common warm-season grass used in the southern US. It is very hardy and can tolerate close continuous grazing and drought. Although improvements in the quality characteristics of bermudagrass have been noted recently, it still is poorer in quality than most cool-season grasses. Warm-season grasses are more efficient at utilizing simple sugars and N for growth than cool-season grasses, which may result in higher yields. However, this is often accompanied by higher concentrations of lignin and lower concentrations of cell-soluble carbohydrates than are observed typically in cool-season grasses. Lignification renders some of the protein, hemicellulose, and cellulose unavailable to the ruminant and limits digestion, intake, and animal production. There is a need throughout the South for a summer forage that will meet the nutrient demands of high-producing ruminants such as stockers or dairy cattle. Objectives for this study were to determine the in-situ disappearance kinetics of NDF for crabgrass harvested at weekly intervals throughout the summer, and to compare these kinetic measurements with those of bermudagrass, alfalfa, and orchardgrass hays determined concurrently.

Experimental Procedures

Collection of Experimental Forages. An existing stand of crabgrass was divided into four 12 x 24-ft field blocks and fertilized with ammonium nitrate at a rate of 75 lb actual N/acre on June 16, 2001. In the summer of 2001, crabgrass was harvested by clipping two 2.69-ft^2 frames per block to a 1-in stubble height with garden shears. Crabgrass plots were clipped weekly beginning on July 11, 2001, and ending on August 22. All forage samples were dried under forced air at 122°F. Prior to grinding, a subsample of each dried forage was retained for separation into leaf and stem components. Leaves were separated from the stem by separating each leaf at the collar, and each part was ground separately in order to provide material for analysis of leaf and stem tissue.

Laboratory Analysis. Dried crabgrass samples were ground through a 1 or 2-mm screen in a Wiley Mill (Arthur H. Thomas, Philadelphia, Pa.). Subsamples ground through the 1-mm screen were analyzed sequentially for NDF, ADF, cellulose, hemicellulose, and acid detergent lignin by the batch procedures outlined by ANKOM Technology Corp. (Fairport, N.Y.). Sodium sulfate and α-amylase were omitted from the neutral detergent solution. Subsamples of crabgrass ground through a 2-mm screen were retained for subsequent analysis in-situ.

The alfalfa, bermudagrass, and orchardgrass hay controls were harvested as small square bales at the Forage Research Area in Fayetteville. All bales were made during the spring and summer of 2002, and bales exhibited no evidence of spontaneous heating or molding. Flakes were taken from the center of each bale and ground through a 2-mm screen prior to in-situ analysis. In general, the bermudagrass hay (62.1% NDF, 27.0% ADF, and 17.1% CP) had excellent nutritional value, but the alfalfa (51.9% NDF, 38.7% ADF, and 16.1% CP) and orchardgrass (67.2% NDF, 34.9% ADF, and 12.3% CP) had only moderate nutritive value.

In-Situ Procedures in Confinement. Five (843 ± 50.1 lb) ruminally cannulated crossbred (Gelbvieh x Angus x Brangus) steers were used to determine the in-situ disappearance kinetics of NDF for crabgrass and the control hays. The cannulations and care of the steers were approved by the University of Arkansas Animal Care and Use Committee. Steers were housed in individual 11- x 16-ft pens

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with a concrete floor that was cleaned regularly. They were offered a diet of alfalfa hay (16.1% CP, 51.9% NDF, and 38.7% ADF) and a corn-based supplement (94.7% cracked corn, 3% molasses, and 2.3% trace mineral salt) at 2.0% of BW daily. On an 'as is' basis, the basal diet contained 85.0% alfalfa hay and 15.0% supplement, and it was offered in equal portions at 0630 and 1430 h. Fresh water was offered on an ad libitum basis. Steers were adapted to the basal diet for 10 d prior to initiating the trial. In-situ procedures were consistent with the standardized techniques described by Vanzant et al. (1998) and followed the procedures outlined by Ogden et al. (2003).

Data were fitted to the nonlinear regression model of Mertens and Loften (1980) using PROC NLIN of SAS (SAS Inst., Inc., Cary, N.C.). The NDF 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 represented that portion of NDF that disappeared at a measurable rate; and fraction C was defined as the portion of NDF that was undegraded in the rumen. Fractions B and C, disappearance rate (k_d), and the discrete lag time were determined directly by the nonlinear regression model. For each forage, fraction A was calculated as 100 – (B + C); similarly, the potential extent of disappearance was calculated as 100 – C. For all forages, the degradability of DM and NDF was calculated as A + B x $[k_d/(k_d + k_p)]$, where k_p = passage rate. Ruminal passage rate was determined for each steer by using acid detergent insoluble ash (ADIA) as an internal marker.

Statistics. Characteristics of nutritive value for the experimental crabgrass forages were analyzed as a randomized complete block design with field blocks (n = 4) as replications and seven harvest dates as the treatment term. Harvest dates were evaluated by single degree-of-freedom orthogonal contrasts for linear, quadratic, cubic, and quartic effects of time. Disappearance kinetics of NDF for crabgrass harvested on seven dates and for the alfalfa, orchardgrass, and bermudagrass hay controls were evaluated as a randomized complete block design with the five steers as blocks. Single degree-of-freedom contrasts were utilized to evaluate the effects of harvest date on the disappearance kinetics of crabgrass, and to compare crabgrass with the control hays.

Results and Discussion

Nutritive Value of Crabgrass. Concentrations of NDF, ADF, and lignin in whole-plant forage increased linearly ($P \leq 0.001$) over sampling dates; a quartic effect ($P = 0.034$) also was observed for lignin (Table 1); this fluctuation can probably be explained on the basis of new tiller development following a total of 1.3 in of rainfall that fell between July 25 and 30. Leaf fiber contents (NDF, ADF, and lignin) increased in a linear pattern ($P \leq 0.002$) over sampling dates; in addition, a quadratic effect was observed for NDF and ADF ($P \leq 0.002$), and a cubic effect was observed for NDF ($P = 0.034$). Concentrations of NDF, ADF, and lignin in the stem tissue increased linearly ($P \leq 0.014$) over harvest dates; in addition, NDF and ADF exhibited cubic effects ($P \leq 0.027$). The increase in NDF (from 55.5 to 61.9%) and ADF (from 27.5 to 31.8%) over harvest dates represents a very narrow range. The NDF and ADF concentrations exhibited by crabgrass were lower by 17.7 to 23.6 percentage units and 5.8 to 13.1 percentage units, respectively, than the average concentrations of NDF (72.3%) and ADF (35.3%) exhibited by bermudagrass in other studies (Hill et al., 1993; Kloppenburg et al., 1995; Coblentz et al., 2000).

Disappearance Kinetics of NDF. Fraction A for crabgrass forages changed in quadratic ($P = 0.003$) and cubic ($P = 0.005$) patterns over harvest dates (Table 2). Fraction B decreased over harvest dates from a maximum of 76.3% on July 18 to 70.1% of NDF on the August 15 harvest date. Linear, quadratic, cubic, and quartic ($P \leq 0.009$) effects of time were observed in association with this decrease. In contrast, fraction C increased from 18.0 to 23.7% over harvest dates in linear, quadratic, and quartic ($P < 0.0001$) patterns. Crabgrass had a smaller fraction A ($P < 0.0001$) and C ($P < 0.0001$), and a greater fraction B ($P < 0.0001$) than alfalfa. A mean of 21.6% for the C fraction indicates that 78.4% of the NDF in crabgrass is potentially available to the animal within the rumen.

For crabgrass forages, degradation rates declined in a cubic and linear ($P = 0.002$) manner as plants matured. Crabgrass had a more rapid NDF disappearance rate than bermudagrass ($P < 0.0001$) and orchardgrass hays ($P < 0.0001$), but the disappearance rate was slower ($P < 0.0001$) than observed for alfalfa.

The potential extent of NDF disappearance was higher ($P < 0.0001$) for crabgrass than for alfalfa, but it was lower for crabgrass than the bermudagrass ($P < 0.0001$) and orchardgrass ($P = 0.003$) hays. On a practical basis, these differences were relatively small in scope, particularly considering the wide time interval over which crabgrass forages were harvested. Ruminal degradability of NDF for crabgrass declined linearly, quadratically, and cubically ($P < 0.0001$) over sampling dates, and the effective ruminal degradability of NDF was greater ($P \leq 0.004$) for crabgrass than for any of the other hays.

Implications

The mean effective ruminal degradability of NDF for crabgrass was greater than the bermudagrass hay evaluated in this study. These results indicate that crabgrass offers improved ruminal digestibility of fiber compared to bermudagrass hay, and should support greater animal performance during the summer months.

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Table 1. Fiber characteristics of leaf, stem, and whole-plant fractions for crabgrass forages harvested during 2001 near Prairie Grove, Ark.

Harvest date	NDF[a]	ADF	Hemicellulose	Cellulose	Lignin
	% of DM				
Leaf					
July 11	48.7	24.2	24.5	22.0	1.61
July 18	48.7	22.9	25.8	21.1	1.54
July 25	48.9	22.9	26.0	20.9	1.45
August 1	51.0	24.6	26.4	21.7	2.30
August 8	51.0	22.2	28.8	20.3	1.63
August 15	54.6	25.0	29.6	22.5	2.51
August 22	54.6	25.1	29.5	22.3	2.21
SEM[b]	0.37	0.3	0.28	0.29	0.197
Effect[c]	L < 0.0001 Q = 0.002 C = 0.034	L = 0.002 Q = 0.0002	L < 0.0001 C = 0.031 Qu = 0.002	L = 0.048 Q = 0.001	L = 0.002
Stem					
July 11	59.5	31.7	27.8	29.2	2.15
July 18	57.0	28.4	28.6	26.4	1.75
July 25	60.1	30.4	29.7	27.4	2.62
August 1	62.2	32.3	29.9	28.8	2.98
August 8	61.3	30.0	31.3	27.1	2.60
August 15	64.2	33.1	31.1	29.2	3.39
August 22	63.7	32.0	31.7	28.7	3.02
SEM[b]	0.67	0.68	0.42	0.55	0.168
Effect[c]	L < 0.0001 C = 0.026	L = 0.014 C = 0.027	L < 0.0001	Q = 0.049 C = 0.049	L < 0.0001
Whole plant					
July 11	55.5	29.4	26.1	26.4	2.35
July 18	55.6	27.5	28.1	25.2	1.89
July 25	57.4	28.8	28.6	25.9	2.44
August 1	60.8	31.2	29.6	27.4	2.89
August 8	58.8	28.9	29.9	26.0	2.60
August 15	61.9	31.3	30.6	27.2	2.90
August 22	61.2	30.9	30.3	27.7	2.81
SEM[b]	0.76	0.6	0.42	0.54	0.151
Effect[c]	L < 0.0001	L = 0.001	L < 0.0001 Q = 0.006	L = 0.013	L = 0.0003 Qu = 0.034

[a] Abbreviations: NDF, neutral detergent fiber; ADF, acid detergent fiber; lignin, acid detergent lignin.

[b] Standard error of the mean.

[c] L, linear effect; Q, quadratic effect; C, cubic effect; Qu, quartic effect.

Table 2. In situ degradation kinetics of NDF for common crabgrass harvested on weekly intervals near Prairie Grove, Ark., and compared with alfalfa, bermudagrass, and orchardgrass hay controls.

	Fraction						
Forage/harvest date	A[a]	B	C	Potential extent	Lag time	k_d	Degradability[b]
	% of NDF				h	/h	% of NDF
Crabgrass (CRAB)							
July 11	5.7	76.3	18.0	82.0	1.49	0.079	63.5
July 18	5.3	76.6	18.1	81.9	1.45	0.086	64.8
July 25	5.2	72.3	22.5	77.5	1.47	0.081	60.2
August 1	7.5	69.9	22.7	77.3	1.99	0.078	59.9
August 8	6.2	71.0	22.8	77.2	1.36	0.073	59.0
August 15	6.2	70.1	23.7	76.3	1.46	0.069	57.5
August 22	5.2	71.6	23.2	76.8	1.68	0.077	59.1
Alfalfa hay (ALF)	7.6	37.8	54.6	45.4	1.93	0.107	37.6
Bermudagrass hay (BER)	9.1	72.2	18.6	81.4	2.75	0.057	59.3
Orchardgrass hay (OG)	7.2	72.1	20.8	79.2	3.83	0.059	57.6
SEM[c]	0.35	0.47	0.24	0.24	0.214	0.003	0.41
Contrasts	P > F						
CRAB Linear[d]	0.455	<0.0001	<0.0001	<0.0001	0.673	0.002	<0.0001
CRAB Quadratic	0.003	<0.0001	<0.0001	<0.0001	0.753	0.78	<0.0001
CRAB Cubic	0.005	0.009	0.285	0.285	0.582	0.002	<0.0001
CRAB Quartic	0.054	0.001	<0.0001	<0.0001	0.148	0.828	0.075
CRAB vs. ALF	<0.0001	<0.0001	<0.0001	<0.0001	0.106	<0.0001	<0.0001
CRAB vs. BER	<0.0001	0.509	<0.0001	<0.0001	<0.0001	<0.0001	0.004
CRAB vs. OG	0.001	0.343	0.003	0.003	<0.0001	<0.0001	<0.0001
ALF vs. BER	0.002	<0.0001	<0.0001	<0.0001	0.008	<0.0001	<0.0001
OG vs. BER	<0.0001	0.826	<0.0001	<0.0001	0.001	0.66	0.004

[a] Abbreviations: A = immediately soluble fraction, B = fraction disappearing at a measurable rate, C = undegraded fraction, and k_d = disappearance rate.

[b] Calculated as $A + B[(k_d/(k_d + \text{passage rate})]$, where k_d = disappearance rate and the passage rate = 0.025 ± 0.005/h.

[c] Standard error of the mean.

[d] Linear, quadratic, cubic, and quartic effects of harvest date on each response variable.

Nitrogen Value and Protein Degradation Kinetics for Crabgrass Harvested on Seven Dates in Northern Arkansas

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Story in Brief

Common crabgrass [*Digitaria ciliaris* (Retz.) Koel.] is undesirable in fields of bermudagrass [*Cynodon dactylon* (L.) Pers.] hay fields because it dries more slowly than bermudagrass, which raises concerns about potential spontaneous heating and molding in hay. However, visual observations indicate that grazing livestock prefer crabgrass to many other summer forages. Our objectives were to assess the concentrations of various N fractions within leaf, stem, and whole-plant tissue in crabgrass forage, harvested on seven dates during 2001. In addition we evaluated ruminal in-situ disappearance kinetics of N and neutral detergent insoluble N (NDIN) and compared them with alfalfa (*Medicago sativa* L.), bermudagrass, and orchardgrass (*Dactylis glomerata* L.) hays. Crabgrass was harvested weekly beginning on July 11 and ending on August 22, 2001. Whole-plant concentrations of N declined linearly ($P = 0.001$) from 3.36 to 2.55% over this time period. Forage samples were evaluated for in-situ disappearance of N and NDIN in five (843 ± 50 lb) ruminally cannulated steers. Crabgrass had a more rapid N disappearance rate than bermudagrass ($P < 0.0001$), while alfalfa ($P < 0.0001$) had a faster rate than crabgrass. There was no difference between the disappearance rate for crabgrass and orchardgrass ($P = 0.15$). The effective ruminal degradability of N was greater ($P < 0.0001$) for crabgrass than for alfalfa, bermudagrass, or orchardgrass hays. The disappearance rate for NDIN was faster for crabgrass than bermudagrass ($P < 0.0001$) and orchardgrass ($P = 0.01$), but the disappearance rate for alfalfa hay was faster ($P < 0.0001$) than crabgrass. The effective ruminal degradability of NDIN was greater for crabgrass than for bermudagrass or alfalfa hays ($P < 0.0001$); but no difference ($P = 0.87$) was observed between crabgrass and orchardgrass.

Introduction

Crabgrass is a warm-season annual grass. Although crabgrass is not a perennial, it is a very prolific reseeder that is difficult to control. It is undesirable in bermudagrass hay fields because it dries more slowly than bermudagrass, creating concerns about the potential for spontaneous heating and molding in hay (Dalrymple, 1999). However, both visual observation and circumstantial evidence indicate that grazing livestock prefer crabgrass to many other summer forages, and cattle often exhibit good summer performance when consuming this forage.

The recent creation of new feeding models (Sniffen et al., 1992; NRC, 1996) has resulted in a need for in-depth knowledge of forage proteins. Nitrogen from forage is utilized more efficiently when these systems are used properly. Knowing the distribution of N within the fiber and cell-soluble fractions of the plant, and understanding the ruminal disappearance kinetics of forage N is important in order to acquire the greatest benefit from these feeding models.

Because crabgrass can be an alternative to other important forage species, we need to know more about its nutritive value and degradation properties in the rumen. Our objectives in this study were to: 1) determine the concentration of N fractions in leaf, stem, and whole-plant tissue; and 2) evaluate the ruminal in-situ disappearance kinetics of N and NDIN for common crabgrass harvested at weekly intervals during the summer.

Experimental Procedures

Collection of Experimental Forages and Laboratory Analysis. Crabgrass forages and control hays were collected, processed, and analyzed as described in a companion report (Ogden et al., 2004). Concentrations of N, neutral detergent soluble nitrogen (NDSN) and NDIN were determined by rapid combustion (1574°F; LECO Model FP-428; LECO Corp., St. Joseph, Mich.). Concentration of acid detergent insoluble N (ADIN) was determined by identical procedures following digestion of forage samples in acid detergent. Identical methodology for quantification of N was used to determine residual N and NDIN following ruminal incubation in-situ. Procedures for digestion of in-situ residues in neutral detergent prior to quantifying NDIN have been described previously (Ogden et al., 2004).

In-situ Procedures in Confinement. Procedures for determination of N and NDIN disappearance kinetics, determination of rate of passage, and statistical analysis are identical to those reported in a companion report evaluating disappearance kinetics of NDF (Ogden et al., 2004). Briefly, dacron bags were filled with 5-g of each experimental forage (4 x 8 in; 50 ± 10-µm pore size; ANKOM Technology, Corp., Fairport, N.Y.) and heat sealed with an impulse sealer (Type TISH-200; TEWI International Co., Ltd., Taipei, Taiwan). Samples were pre-incubated in tepid (102°F) water, incubated in the rumen for 3, 6, 9, 12, 24, 36, 48, 72, or 96 h, rinsed in a top load washing machine, and dried under forced air at 122°F. A separate set of bags was pre-incubated and then rinsed in the washing machine without ruminal incubation (0 h).

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Data for ruminal disappearance of N and NDIN were fitted to the nonlinear regression model of Mertens and Loften (1980) by PROC NLIN of SAS (SAS Inst., Inc., Cary, N.C.). Nitrogen and NDIN were partitioned into three fractions based on relative susceptibility to ruminal disappearance as described by Coblentz et al. (1998). The A fraction was defined as the immediately soluble portion; the B fraction represented that portion of N or NDIN that disappeared at a measurable rate; and fraction C was defined as the portion of N or NDIN that was undegradable in the rumen. Fractions B and C, disappearance rate (k_d), and the discrete lag time were determined directly by the nonlinear regression model. For each forage, fraction A was calculated as 100 – (B + C); similarly, the potential extent of disappearance was calculated as 100 – C. For all forages, the degradability of N or NDIN was calculated as A + B x [$k_d/(k_d + k_p)$], where k_p = passage rate (0.025 ± 0.005/h). Prior to making these calculations, a cross-section of in-situ residues (n = 50) representing all steers, forages, and incubation periods were analyzed for purines to assess microbial contamination by the method of Zinn and Owens (1986). Purine concentrations were found to be negligible and no corrections for microbial contaminant N were applied to the determination of kinetic parameters.

Statistics. Characteristics of nutritive value for the experimental crabgrass forages were analyzed as a randomized complete block design with field blocks (n = 4) as replications and seven harvest dates as the treatment term. Harvest dates were evaluated by single degree-of-freedom orthogonal contrasts for linear, quadratic, cubic, and quartic effects of time. Disappearance kinetics of N and NDIN for crabgrass harvested on seven dates and for the alfalfa, orchardgrass, and bermudagrass hay controls were evaluated as a randomized complete block design with the five steers as blocks. Single degree-of-freedom contrasts were utilized to evaluate the effects of harvest date on the disappearance kinetics of crabgrass, and to compare crabgrass with the control hays.

Results and Discussion

Nutritive Value of Crabgrass. In general, the concentration of N within leaf tissue (Table 1) declined linearly ($P < 0.0001$) throughout the harvest period. On August 1, concentrations of N exhibited a numerical increase from 3.40 to 3.68%; this increase can probably be explained on the basis of new tiller development following a total of 1.3 in of rainfall that fell between July 25 and 30. Concentrations of N in stem tissue declined linearly ($P = 0.002$) across harvest dates, ranging from 3.31 to 2.42%. Whole-plant concentrations of N declined linearly ($P = 0.001$) from 3.36 to 2.55% over sampling dates. Whole-plant concentrations of NDSN declined linearly ($P < 0.0001$) and cubically ($P = 0.006$), while concentrations of NDIN increased with the same polynomial effects (Table 1).

Disappearance Kinetics of N. Fraction A for crabgrass forages declined with linear ($P = 0.037$), quadratic ($P < 0.0001$), cubic ($P < 0.0001$), and quartic ($P < 0.0001$) effects over harvest dates (Table 2). Fraction B fluctuated over harvest dates in quadratic, cubic, and quartic ($P < 0.0001$) trends. In contrast, fraction C increased from 5.2 to 7.3% over harvest dates in a linear ($P < 0.0001$) pattern. Crabgrass had a larger fraction A ($P < 0.0001$), smaller fraction B ($P < 0.0001$), and smaller fraction C ($P < 0.0001$) than the alfalfa hay control.

To our knowledge, disappearance rates of N for crabgrass have not been determined previously. There was a linear ($P = 0.019$) decline for N disappearance rate (overall mean = 0.092/h) across sampling dates for crabgrass. In this study, crabgrass had more rapid disappearance rate than bermudagrass hay ($P < 0.0001$), but N from crabgrass disappeared at a slower ($P < 0.0001$) rate than observed for the alfalfa hay controls. There was no difference ($P = 0.153$) between the rate of N disappearance for orchardgrass hay and crabgrass. The potential extent of ruminal disappearance was greater for crabgrass ($P < 0.0001$) than for alfalfa and orchardgrass hays, but lower for crabgrass than bermudagrass hay ($P < 0.0001$). The effective ruminal degradability of N was greater for crabgrass ($P < 0.0001$) than for the alfalfa, bermudagrass, or orchardgrass hays.

Disappearance Kinetics of NDIN. Fraction B decreased from 89.9 to 87.9% in linear, quadratic and quartic ($P \leq 0.024$) pattern over harvest dates (Table 3). The C fraction increased over harvest dates in linear ($P < 0.0001$), quadratic ($P = 0.004$), and quartic ($P < 0.0001$) patterns. Crabgrass had a greater fraction B ($P < 0.0001$) and smaller C fraction ($P < 0.0001$) than alfalfa, but it exhibited a smaller fraction B ($P < 0.0001$) and greater fraction C ($P < 0.0001$) than bermudagrass. The disappearance rate for NDIN in crabgrass declined in a linear ($P = 0.001$) pattern over harvest dates. The rate of NDIN disappearance was faster for crabgrass than bermudagrass ($P < 0.0001$) and orchardgrass ($P = 0.010$) hays; in contrast, alfalfa hay exhibited a more rapid ($P < 0.0001$) NDIN disappearance rate than crabgrass. The effective ruminal degradability of NDIN for crabgrass declined in a linear ($P < 0.0001$) and quartic ($P = 0.002$) pattern over harvest dates from 73.4 to 70.8%. Crabgrass had a greater ($P < 0.0001$) effective ruminal degradability of NDIN than the alfalfa or bermudagrass hays.

Implications

The mean effective rumen degradability for crabgrass N (85.3%) and NDIN (72.0%) was 2.0 and 21.5 percentage units greater, respectively, than that of alfalfa hay utilized in this study. These results indicate that crabgrass N exhibits high ruminal availability, but disappearance rates are slower than observed for alfalfa hay, which may improve the efficiency of protein use in ruminants.

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Table 1. Nitrogen characteristics of leaf, stem, and whole-plant fractions for crabgrass forages harvested during 2001 near Prairie Grove, Ark.

Harvest date	N	NDSN[1]	NDIN	ADIN
	% of DM		% of N	
Leaf				
July 11	3.80	70.4	29.6	3.89
July 18	3.62	67.2	32.8	4.14
July 25	3.40	65.9	34.1	3.88
August 1	3.68	67.8	32.2	3.69
August 8	3.36	56.7	43.3	4.31
August 15	3.21	56.3	43.7	4.85
August 22	3.13	55.0	45.0	5.93
SEM[2]	0.110	1.56	1.56	0.349
Effect[3]	L < 0.0001	L < 0.0001 Qu = 0.049	L < 0.0001 Qu = 0.049	L = 0.0004 Q = 0.007
Stem				
July 11	3.31	79.8	20.2	4.05
July 18	2.98	78.1	21.9	3.87
July 25	2.61	76.5	23.5	6.09
August 1	3.10	79.1	20.9	4.14
August 8	2.81	73.4	26.6	5.46
August 15	2.53	72.1	27.9	5.81
August 22	2.42	69.2	30.8	6.73
SEM[2]	0.173	1.63	1.63	0.658
Effect[3]	L = 0.002	L < 0.0001	L < 0.0001	L = 0.005
Whole plant				
July 11	3.36	76.3	23.7	4.84
July 18	3.07	72.2	27.8	6.13
July 25	2.74	69.5	30.5	6.12
August 1	3.05	71.1	28.9	5.21
August 8	2.85	69.2	30.8	5.59
August 15	2.68	68.8	31.2	7.58
August 22	2.55	61.1	38.9	6.64
SEM[2]	0.148	1.51	1.51	0.696
Effect[3]	L = 0.001	L < 0.0001 C = 0.006	L < 0.0001 C = 0.006	L = 0.049 Qu = 0.046

[1]Abbreviations: NDSN, neutral detergent soluble N; NDIN, neutral detergent insoluble N; ADIN, acid detergent insoluble N.

[2]Standard error of the mean.

[3] L, linear effect; Q, quadratic effect; C, cubic effect; Qu, quartic effect.

Table 2. In situ degradation kinetics of N for common crabgrass harvested on weekly intervals near Prairie Grove, Ark., and compared with alfalfa, bermudagrass, and orchardgrass hay controls.

	Fraction						
Forage/harvest date	A[1]	B	C	Potential extent	Lag time	k_d	Degradability[2]
	% of N				h	/h	% of N
Crabgrass (CRAB)							
July 11	57.4	37.4	5.2	94.8	0.98	0.096	87.1
July 18	51.0	43.5	5.5	94.5	1.04	0.105	86.1
July 25	51.8	41.4	6.8	93.2	1.05	0.102	85.1
August 1	59.8	34.1	6.1	93.9	1.33	0.084	86.2
August 8	57.0	36.2	6.8	93.2	1.26	0.088	85.3
August 15	55.5	37.5	7.1	92.9	1.68	0.083	84.3
August 22	49.9	42.8	7.3	92.7	0.97	0.086	83.1
Alfalfa Hay (ALF)	43.4	44.8	11.8	88.2	0.94	0.223	83.3
Bermudagrass Hay (BER)	31.6	62.8	5.6	94.4	2.33	0.046	72.3
Orchardgrass Hay (OG)	27.1	64.1	8.7	91.3	4.86	0.081	76.0
SEM[3]	0.75	0.76	0.18	0.18	0.29	0.007	0.44
Contrasts	P > F						
CRAB Linear[4]	0.037	0.795	<0.0001	<0.0001	0.342	0.019	<0.0001
CRAB Quadratic	<0.0001	<0.0001	0.136	0.136	0.357	0.947	0.232
CRAB Cubic	<0.0001	<0.0001	0.131	0.131	0.227	0.141	0.031
CRAB Quartic	<0.0001	<0.0001	0.786	0.786	0.415	0.382	0.362
CRAB vs. ALF	<0.0001	<0.0001	<0.0001	<0.0001	0.428	<0.0001	<0.0001
CRAB vs. BER	<0.0001	<0.0001	<0.0001	<0.0001	0.0004	<0.0001	<0.0001
CRAB vs. OG	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.153	<0.0001
ALF vs. BER	<0.0001	<0.0001	<0.0001	<0.0001	0.001	<0.0001	<0.0001
OG vs. BER	<0.0001	0.211	<0.0001	<0.0001	<0.0001	0.001	<0.0001

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

[2]Calculated as $A + B[(k_d/(k_d + \text{passage rate})]$, where k_d = disappearance rate and the passage rate = 0.025 ± 0.005/h.

[3] Standard error of the mean.

[4] Linear, quadratic, cubic, and quartic effects of harvest date on each response variable.

Table 3. In situ degradation kinetics of NDIN for common crabgrass harvested on weekly intervals near Prairie Grove, Ark., and compared with alfalfa, bermudagrass, and orchardgrass hay controls.

	Fraction						
Forage/harvest date	A[1]	B	C	Potential extent	Lag time	k_d	Degradability[2]
	% of NDIN				h	/h	% of N
Crabgrass (CRAB)							
July 11	0.62	88.4	10.9	89.1	0.71	0.118	73.4
July 18	0.66	89.9	9.5	90.5	0.35	0.113	74.2
July 25	0.66	87.3	12.0	88.0	0.73	0.115	72.4
August 1	0.26	86.6	13.1	86.9	1.30	0.107	70.3
August 8	0.88	86.7	12.4	87.6	0.73	0.111	71.8
August 15	0.48	87.6	11.9	88.1	0.85	0.102	71.0
August 22	0.10	87.9	12.0	88.0	0.79	0.102	70.8
Alfalfa Hay (ALF)	0.00	59.0	41.0	59.0	3.00	0.15	50.5
Bermudagrass Hay (BER)	0.22	93.4	6.4	93.6	1.42	0.072	69.0
Orchardgrass Hay (OG)	2.73	88.0	9.3	90.7	4.07	0.098	72.1
SEM[3]	0.27	0.55	0.40	0.40	0.165	0.004	0.45
Contrasts	P > F						
CRAB Linear[4]	0.226	0.024	<0.0001	<0.0001	0.157	0.001	<0.0001
CRAB Quadratic	0.406	0.011	0.004	0.004	0.170	0.947	0.073
CRAB Cubic	0.389	0.094	0.083	0.083	0.307	0.936	0.286
CRAB Quartic	0.421	0.006	<0.0001	<0.0001	0.010	0.653	0.002
CRAB vs. ALF	0.071	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
CRAB vs. BER	0.287	<0.0001	<0.0001	<0.0001	0.0005	<0.0001	<0.0001
CRAB vs. OG	<0.0001	0.707	<0.0001	<0.0001	<0.0001	0.010	0.865
ALF vs. BER	0.569	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
OG vs. BER	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

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

[2]Calculated as $A + B[(k_d/(k_d + \text{passage rate})]$, where k_d = disappearance rate and the passage rate = 0.025 ± 0.005/h.

[3] Standard error of the mean.

[4] Linear, quadratic, cubic, and quartic effects of harvest date on each response variable.

Potential Use of Fescue in Grazing Systems Using Graze-Out Small-Grain Forages and Bermudagrass

S.A. Gunter[2], K.S. Lusby[1], D.S. Hubbell III[3] and Z.B. Johnson[1]

Story in Brief

The objective of this study was to determine if stocker calves backgrounded on endophyte-infected tall fescue compared to small-grain forages could achieve sufficient compensatory growth during subsequent grazing of either graze-out small-grain forages in spring or bermudagrass in summer to offset the expected reduced performance for fescue. A total of 40 steer calves in year 1 and 32 in year 2 grazed either fescue or wheat/rye pastures from November to the end of January, after which all calves grazed wheat/rye pastures to the end of graze-out in April. Similarly, 48 steer calves grazed either fescue or wheat/rye pastures during the graze-out period and were then moved to bermudagrass pasture for summer grazing. Calves grazing small-grain forages during graze-out gained more weight (91 lb in year 1 and 55 lb in year 2, $P < 0.01$) than calves on fescue. Subsequent weight gain during bermudagrass grazing was similar for both groups in both years. Calves grazing small-grain forages from November through January gained 51 lb more than calves grazing fescue ($P < 0.01$). However, no compensatory gain was observed during subsequent grazing on small-grain forages during graze-out. No compensatory gain was observed in spite of the significantly greater BW gain for calves that grazed small-grain forages compared to fescue.

Introduction

Small-grains are high-quality cool season forages for cattle in the South (Daniels et. al., 2002). Typically, one group of calves grazes in fall and winter while a second group is used for the spring graze-out. While gain per animal and per acre during graze-out is excellent, total gain is limiting for stocker programs. Endophyte-infected tall fescue will remain the predominant cool season perennial forage in the South. Integrated grazing systems are needed that capitalize on the consistent forage production, but poor performance of tall fescue, and the excellent productivity, but short duration, of graze-out small-grain forages. If sufficient compensatory gain is realized when cattle are moved from fescue to either graze-out small-grain forages in spring or to bermudagrass in summer, fescue may serve as a low-cost forage for back grounding stocker calves. If the rapid gains on small-grain forages are carried over to graze-out small-grains or to summer bermudagrass, then small-grain forages may be a good alternative to tall fescue in areas compatible with their growth. The objective was to compare season-long grazing systems utilizing tall fescue or small-grain forages as precursors to spring graze-out on small-grain forages or summer grazing on bermudagrass.

Experimental Procedures

Trial 1. Forty bull and steer calves in 2002 and 32 in 2003 were purchased from a local auction barn in late January and received at the Livestock and Forestry Branch Station near Batesville in northeast Arkansas. Calves were vaccinated, bulls were castrated by banding, and sick calves were treated using protocols developed by a licensed veterinarian.

On March 14, each year, calves were allotted by weight, obvious breed characteristics, and sex status on arrival to two treatment groups; (1) Kentucky 31 fescue; or (2) wheat/rye pasture (60 lb/acre each of Elbon rye and Delta King 9027 wheat planted the previous September) until the end of "graze-out" that occurred on May 8. Fescue pastures had been established for seven years and had a 90% endophyte infection rate. Five replications of 4-acre pastures for each forage were used in 2002 and four replications were used in 2003. Stocking density was four calves per pasture and calves were not rotated between pastures. Pastures were separated by electric fencing and water was provided by automatic watering devices.

On May 8 of each year, all calves were moved to 40 acres of common Bermudagrass pasture and grazed as a single group until August 15, when the study was terminated. No supplemental feed was offered during the study. A mineral mix was offered free choice. All cattle weights were taken after overnight withdrawal from feed and water.

Trial 2. Forty-eight bull and steer calves purchased at a local auction barn were received in September 2002 using procedures described for Trial 1. On November 21, calves were allotted by sex (bull or steer at time of arrival), breed characteristics, and weight to either fescue or wheat/rye pastures. Pastures used were the same as used for Trial 1. Calves grazed 4-acre pastures of each forage until January 31, 2003. There were four replications of each forage type. Calves were then allotted by previous grazing treatment (fescue or wheat/rye) to fifteen 4-acre pastures of small-grain forage, with five each seeded by conventional drill, no-till drill or broadcast seeding. Calves grazed small grains pastures until the end of spring graze-out on April 22, 2003.

Statistical Analysis. Data for Trial 1 were analyzed as a completely randomized design, using PROC GLM of SAS (SAS Institute, Inc., Cary, N.C.). The model included treatment, year and the treatment x year interaction. Pasture within grazing treatment was used as the experimental unit. Data from Trial 2 were analyzed as a split plot using PROC MIXED of SAS. The whole plot was spring tillage treatment. Previous treatment (fescue or small grains) and previous treatment by tillage treatment were in the subplot. Random effects were tillage treatment within pasture and residual error.

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Results and Discussion

Trial 1. Because a significant year x forage type interaction was found for graze-out gain ($P < 0.05$), results of each year are shown separately (Table 1). Although graze-out gains were significantly greater for small-grain forages than for fescue both years, the difference in year 1 (91 lb) was less than in year 2 (55 lb). Regardless of significant differences in graze-out gain, no compensatory gain was observed during the summer grazing period when all calves grazed bermudagrass. The weight gain advantage observed for wheat/rye calves at the end of the spring graze-out period was maintained through the end of the study in mid-August.

Trial 2. In agreement with Trial 1, calves that grazed small-grain forages from November to the end of January gained significantly faster (51 lb) than calves grazing fescue (Table 2). However, as observed in Trial 1, there was no compensatory gain by calves that had grazed fescue when all calves were moved to small-grain forages for graze-out. Gains during the graze-out period when all calves grazed small-grain forages were virtually identical for calves that previously grazed fescue or small-grain forages.

These studies show a substantial advantage in weight gain for calves grazing small-grain forages; this occurs regardless of whether the grazing occurs during the fall, winter, or spring months. Furthermore, the advantage in gain from grazing small-grain forages can be expected to carry over through subsequent grazing of small-grain forages during spring graze-out or on bermudagrass during the summer. This suggests that any advantage from use of fescue compared to small-grain forages will have to come from lower production costs for the perennial fescue. The phenomenon of compensatory growth is difficult to predict. Jordan et al., (2001) reported that steers back grounded in Nebraska at restricted rates of gain from 0.5 to 1.0 lb/day compared to 1.5 lb/day for controls, only compensated for 25 to 32% of this difference when they subsequently grazed summer forages. They stated that previous work showing full compensation following summer grazing was not supported in four consecutive years of compensatory gain research.

The relative performance of calves grazing tall fescue, small-grain forages and bermudagrass forages in this study is consistent with other studies with these forages (Daniels et al., 2002, Parish et al., 2003). It is reasonable, therefore, to assume that the differences in performance between small-grain forages and tall fescue observed in the present study are consistent with previous findings and that the advantages for calves grazing small-grain forages will be carried over through grazing either on small-grain forages during the graze-out phase or on bermudagrass in the summer.

It is probable that the degree of restricted growth observed for endophyte-infected fescue in our study was not severe enough to trigger the classical definition of compensatory growth, which is a period of efficient growth following growth restriction. Drouillard and Kuhl (1999), in their review stated that extending the period of growth restriction decreases the likelihood of enhancing profitability in integrated systems because maintenance costs during the low-input phase become an increasing proportion of overall costs of production.

Implications

Poorer gains on fescue than for small-grain forages were not compensated when calves subsequently grazed small-grain forages during graze-out or bermudagrass in summer. Since reduced performance on fescue was carried through the entire grazing system, costs of reduced performance on fescue must be offset by reduced costs of forage production from the perennial tall fescue forage.

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Table 1. Effects of grazing fescue or small-grain forages during graze-out on subsequent performance on bermudagrass, 2002 and 2003, Trial 1.

	Winter-spring forage[a]		
Item	Tall fescue	Wheat/rye	SE[b]
2002			
Body wt, March 13, lb	444	443	
Graze-out gain, March 13 to May 8 (56d), lb	56[c]	147[d]	5.5
Summer gain, May 8 to Aug 15 (99 d), lb	198	188	6.1
Season gain, March 13 to Aug 15 (155 d), lb	254[c]	335[d]	8.3
2003			
Body wt, March 13, lb	503	508	
Graze-out gain, March 13 to May 8 (56 d), lb	65[c]	120[d]	5.5
Summer gain, May 8 to Aug 15 (99 d), lb	146	149	6.1
Season gain, March 13 to Aug 15 (155 d), lb	211[c]	268[d]	8.3

[a]Forage type during graze-out period, March 13 to May 8.

[b]n=5 for 2002 and 4 for 2003.

[c,d]Least squares means with no superscript in common differ ($P < 0.05$).

Table 2. Effects of fall-winter grazing on fescue or wheat/rye on small grains graze-out performance, Trial 2.

	Fall-winter forage[a]		
Item	Tall fescue	Wheat/rye	SE[b]
Body wt, November 21, 2002, lb	493	496	
Gain Nov 21 to Jan 31 (70 d), lb	80[c]	131[d]	6.7
Graze-out gain, Jan 31 to Apr 22 (81 d), lb	210	209	7.0
Season gain, Nov 21 to Apr 22 (151 d), lb	290[d]	340[c]	10.9

[a] Forage type grazed from Nov 21 to Jan 31

[b] n = 5

[c,d] Least squares means with no superscript in common differ (P < 0.05)

Comparison of Clean-Till to Minimum- and No-Till Systems for Production of Small-Grain Forages

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Story in Brief

The objective was to determine if no-till farming techniques for grain production could be successfully adapted for use in winter grazing programs. Clean-till planting was compared to planting with a no-till drill (no-till) or by lightly disking followed by broadcast seeding (minimum till). A mixture of 60 lb/acre each of wheat and rye was planted in September on five 4-acre replications of each planting method. One group of 90 stocker steers (470 lb) grazed the pastures when forage height in each pasture reached an average of 8 inches until January 31. A second group of 167 calves was used to compare productivity during the spring graze-out phase. The initial stocking was on January 31, 2003, the same day that calves used for the fall-winter phase were removed. Two additional stockings were made during March when forage production increased. Stocking rate decisions were made based on visual appraisal of standing forage mass. Over the entire grazing season from November to May, the number of steers per acre and grazing days per acre were less for minimum till ($P < 0.05$). However, ADG was greatest for minimum till, least for clean-till with no-till intermediate ($P < 0.05$). Total gain/acre was not different for tillage treatments. Based on this first year of study, it appears that small grains forages may be successfully established using no-till planting technology. However, visual appraisal may not be a reliable method for estimating available standing forage when comparing clean-till and no-till planted small grains.

Introduction

Research at the Batesville Station has shown that stockers can be productively grazed on winter small grains (Daniels et. al., 2002). To date, only clean till planting has been used. While this technology is proven, it requires significant costs for equipment, fuel, and labor. At least three issues are related to clean tillage production of small grain forages. Moisture is critical. While dry conditions limit forage growth, mud affects the feasibility of grazing many tilled fields in Arkansas. No-till practices, which leave stubble on the ground, may conserve summer moisture by limiting weed growth and reducing evaporative losses but also may permit grazing of acres unsuitable under clean-tillage.

Silting of waterways from cropped fields is a growing concern. The USDA (Release No. fs-0194.03), June 6, 2003, reported that most U.S. cropland soils have lost at least one-third and some up to 60 % of their carbon since they were first converted to crop production beginning about 200 years ago. No-till practices may improve fertility and erodibility of some soils (Rhoton, 2000). The objective of this research was to determine the impact of no-till, minimum tillage or clean-till farming practices on the production of small grains forages grazed by stocker cattle.

Experimental Procedures

This is the first year of a 5-year study conducted on 60 acres of the stocker research area at the Livestock and Forestry Branch Station near Batesville in northeast Arkansas. The area had been managed under clean tillage to produce winter small grains forage for the previous 6 years. The soil type is Pea Ridge silt loam.

Beginning with the end of the 2002 winter grazing season, 4-acre pastures were allotted to three treatment groups; (1) clean tillage, (2) no-till, planting with a no-till drill, and (3) minimum till planting by broadcasting of seed after minimum disking. Tillage methods were as follows. Clean tillage (five pastures) consisted of chisel plowing each treatment pasture one time followed by disking two times with a cutting disk to incorporate any plant material and nutrients (fertilizer and lime) into the soil. A finishing disk was used two times to break up clods and smooth out pastures prior to seeding. Seed was planted with a 12-ft John Deere (model 20X7B) drag-type grain drill. In the no-till treatment (five pastures) two quarts of Roundup were applied per acre for vegetation control one week prior to planting. Fertilizer and lime were surface applied separately followed by planting. Seed were planted using an 8-ft Tye no-till drill to a depth of approximately one inch. For the minimum tillage (five pastures), two quarts of Roundup per acre were applied for vegetative control one week prior to planting followed by a finishing disk to disturb the top 1 to 2 inches of soil. All plant nutrients were applied prior to disking. A conventional fertilizer buggy was used to broadcast seed after disking. Equal weights of wheat and rye seed were placed for mixing in a Gehl Mix-All (model 55) mixer. After mixing, seed was removed from the mixer and reweighed as it was loaded for seeding.

Tillage practices for the conventional clean-till, minimum tillage and no-till treatments were conducted between September 3 and 13. All pastures were seeded between September 23 and October 1. Fertilizer was applied at the rate of 50 lb/acre of actual N and lime; phosphorus and potash were applied according to soil tests for each pasture. Seeding rates were 60 lb of Wintergrazer 70 Rye and 60 lb of DK9027 soft red wheat per acre on all pastures.

Fall-winter grazing. Ninety English and continental crossbred calves (BW = 470 lb) were purchased from a local auction barn in mid-September, 2002. As per protocol developed by the Department of Animal Science veterinarian, calves were processed and received over a 60-day period in grass traps where they were provided free-choice bermudagrass hay and 2.25 lb/day of a supplement.

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Calves were allocated by weight, sex (steer or bull at time of receiving), and obvious breed characteristics to each of the three winter pasture treatments on November 13 and moved to small grains pastures between November 13 and December 3 when forage height in each pasture reached a visually estimated average height of 8 inches. Initial stocking density was six steers per 4-acre pasture. Cattle received no supplemental grain while on small-grain pastures and hay was only offered one day due to icy conditions. All weights were taken after overnight withdrawal from feed and water. A free-choice mineral was provided. Calves were removed from winter pastures on January 31, 2003.

Winter-spring grazing. A total of 167 calves were used to compare productivity of the three tillage treatments during the graze-out phase. An initial stocking of 45 calves (three per pasture) weighing about 600 lb was conducted on January 31, 2003, the same day that calves used for the fall-winter phase were removed. Two additional stockings were made during March when forage production increased. The initial group grazed until April 22.

A second group of 68 calves, weighing about 555 lb, was added on March 17 and grazed for 57 days until May 13. A third group, weighing about 650 lb, was added in mid-April in an attempt to balance the amount of standing forage in each pasture and grazed until removal on May 13. All weights were taken after overnight withdrawal from feed and water.

Data for cattle weight gains were analyzed as a completely randomized design using PROC MIXED of SAS (SAS Inst., Inc., Cary, N.C.). Pasture was the experimental unit. For analysis of total gain per acre, grazing days per acre, and average daily gain for the entire grazing season, pasture means (five per treatment) were analyzed using PROC GLM of SAS. Gain/acre was calculated as the product of average daily gain and the total grazing days/acre.

Results and Discussion

Fall-winter grazing. Cattle grazed clean-till pastures for more days ($P < 0.05$) than for either no-till or minimum tillage treatments (Table 1). Calves grazing clean-till pastures tended ($P < 0.16$) to have the greatest total gain but the least daily gain. This suggests that the clean-till pastures may have been stocked more heavily than the no-till or minimum tillage treatments. Daniels et. al. (2002) reported that small grain pastures at this site stocked at 750 lb/acre produced more total gain/acre but less gain/calf than pastures stocked at 650 lb/acre. Although stock densities were equal in this trial, clean-till pastures were grazed for more days, which would affect forage availability.

Graze-out phase. Because times and duration of grazing periods differed for the three grazing groups used during the graze-out phase, results are shown for each grazing group. Calves from the initial stocking group grazed for 81 days from January 31 to April 22. Calves grazing minimum tillage pastures tended ($P < 0.13$) to have greater gains than for no-till while the clean-till treatment was intermediate (Table 2).

Results were similar for calves that were added to pastures beginning March 14 and grazed for 57 days (Table 3). Calves grazing clean-till pastures gained less total weight ($P < 0.05$) and tended ($P < 0.09$) to have less ADG than calves on the no-till treatments. Less ADG for calves on clean-till pastures suggests that stock densities were greater for that treatment, consistent with results from the fall-winter grazing phase.

The short duration of grazing and disparity between the number of calves added to each tillage treatment that grazed less than 40 days makes meaningful interpretation of results difficult. However, ADG was less ($P < 0.04$) for calves grazing clean-till pastures suggesting that stock density was greater on the clean-till pastures.

Total beef production. During the fall grazing period, clean-till pastures had more ($P < 0.01$) grazing days per acre and greater gain per acre ($P < 0.10$) than either minimum or no-till treatments (Table 5). During graze-out, the number of steers grazing per pasture was less ($P < 0.05$) and average grazing days per acre tended ($P < 0.10$) to be less for minimum till compared to either clean-till or no-till treatments. Gain per acre was not different for tillage treatments during graze-out.

When compared for the total grazing season from November to May, significantly less calves grazed per pasture on minimum tillage compared to clean-till with no-till intermediate. The minimum till treatment also had the least grazing days per acre. However, ADG was greatest ($P < 0.05$) for minimum till. As a result, no significant differences were seen for total gain per acre.

Because adjustments in stocking density were made using visual interpretation of forage availability, it is possible that the method of planting affects visual interpretation and that a more objective method of determining forage availability needs to be utilized in future years. Visual appraisal of forage availability was selected in this initial year of the study because this method had been successfully used in previous years when all small-grain forages were planted with conventional tillage and because this is the common method used by producers.

Economic comparisons. As expected, no-till and minimum tillage treatments required less inputs of equipment in terms of both size and time needed for planting (Table 6). Costs for seed and fertilizer were the same for all treatments and herbicide costs were higher for no-till and minimum tillage treatments. Using costs shown in Table 6, no-till and minimum tillage treatments were planted for about $20 per acre less than clean-till planting.

Implications

Based on this first year of study, it appears that small grains forages may be successfully established using no-till or minimum-till planting technology. Visual appraisal alone may not be a reliable method for estimating available standing forage when comparing clean-till and no-till planted small grains.

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Table 1. Performance of steers grazing wheat/rye pastures from November to January (least-squares means).

Item	Clean-till	Minimum till	No-till	SE[a]
No. steers	30	30	30	
Starting weight, lb	465	474	469	
Avg grazing days, start to finish	79[b]	59[c]	66[c]	4.2
Total gain/steer, lb	146	124	131	7.6
Avg. daily gain, lb	1.84	2.11	2.03	0.11

[a] n = 15.
[b,c] Means in a row with no letter in common differ (P < 0.05).

Table 2. Performance of initial stocking group of steers grazing wheat/rye pastures during graze out (Jan 31 to Apr 22, 2003, least-squares means).

Item	Clean-till	Minimum till	No-till	SE[a]
No. steers	15	15	15	
Starting weight, lb	622	583	623	
Avg grazing days, start to finish	81	81	81	
Total gain/steer, lb	206	233	195	17.3
Avg. daily gain, lb	2.54	2.88	2.40	0.15

[a] n = 15

Table 3. Performance of steers added to wheat/rye pastures on March 17 and grazing to May 13, 2003, least-squares means).

Item	Clean-till	Minimum till	No-till	SE[a]
No. steers	22	23	25	
Starting weight, lb	552	551	561	
Avg grazing days, start to finish	57	57	57	
Total gain/steer, lb	94[b]	125[c]	120[c]	12.8
Avg. daily gain, lb	1.64[b]	2.22[c]	2.14[c]	0.25

[a] n = 15.
[b,c] Means in a row with no letter in common differ (P < 0.05).

Table 4. Performance of steers added to wheat/rye pastures for less than 40 days during graze out (Apr 15 to May 13, 2003, least squares means).

Item	Clean-till	Minimum till	No-till	SE[a]
No. steers	45	18	34	
Starting weight, lb	656	646	661	
Avg grazing days, start to finish	26	20	25	2.5
Total gain/steer, lb	57	69	66	8.5
Avg. daily gain, lb	2.23[b]	3.73[c]	3.11[c]	0.37

[a] n = 15.
[b,c] Means in a row with no letter in common differ (P < 0.05).

Table 5. Performance on per acre basis for all steers grazing wheat/rye pastures (November to May, least squares means).

Item	Clean-till	Minimum till	No-till	SE[a]
Steers grazing Nov to Jan 31				
Steers/pasture (4 acres)	6	6	6	
Grazing days/acre	119[c]	89[b]	93[b]	6.0
Gain/acre	219e	186[d]	188[d]	11.0
All steers grazing during graze out				
Steers/pasture (4 acres)	16.4[c]	11.2[b]	16.0[c]	1.4
Grazing days/acre	176[e]	132[d]	183[e]	15.1
Gain/acre	390	370	453	35.0
All steers Nov to end of graze out				
Steers/pasture (4 acres)	22.4[c]	17.2[b]	20.8[bc]	1.3
Avg daily gain	2.07[bc]	2.53[c]	2.35[bc]	0.11
Grazing days/acre	294[c]	221[b]	258[c]	8.4
Gain/acre	609	557	603	22.8

[a] n = 15.
[b,c] Means in a row with no letter in common differ (P < 0.05).
[d,e] Means in a row with no letter in common differ (P < 0.10).

Table 6. Comparison of tillage costs for three planting methods, 2002/2003.

Item	Clean-till	Minimum till	No-till
Hours/acre			
Chisel plow (8-ft)	0.5	-	-
Heavy disking (12-ft)	0.25	-	-
Spreading fertilizer	0.06	0.06	0.06
Culti-packer (12-ft)	0.25	-	-
Light disking	-	0.25	-
Drilling	0.25	-	0.25
Planting with spreader	-	0.06	-
Spraying weeds (Round-up)	-	0.19	0.19
Cost/acre ($)*			
Chisel plow (8 ft)	10.00	-	-
Heavy disking (12-ft)	10.00	-	-
Spreading fertilizer	4.50	4.50	4.50
Culti-packer (12-ft)	7.00	-	-
Light disking, tandem	8.00	8.00	-
Drilling	10.00	-	10.00
Planting with spreader	-	4.50	-
Spraying	-	5.00	5.00
Seed	19.50	19.50	19.50
Fertilizer	30.30	30.30	30.30
Chemical cost (Round-up)	-	9.00	9.00
Total cost per acre	99.30	80.80	78.30

* Source, Doane Marketing Research, Inc. 2003. Machinery Custom Rates Guide.

Aerobic Stability of Wheat and Orchardgrass Round-Bale Silage

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Story in Brief

In Arkansas, silage often is stored in long rows of round bales wrapped in plastic film that is described commonly as balage. It is important to evaluate the aerobic stability of this fermented forage when it is exposed to air, especially during the winter months when the majority of this product is fed to livestock, or sold as a cash crop. Two types of forage, orchardgrass (*Dactylis glomerata* L.) and wheat (*Triticum aestivum* L.), were harvested in May 2002 and stored as balage. Twenty-one bales of each forage type were unwrapped and exposed to air on December 10, 2002 for 0, 2, 4, 8, 16, 24, or 32 d to evaluate the aerobic stability of these silages. For both orchardgrass and wheat balage, final bale wt, dry matter (DM) content, and pH were not affected ($P > 0.05$) by exposure time. Across both balage types, DM recoveries were ≥ 97% for all bales, indicating that both types of balage were very stable when exposed to air. Concentrations of neutral detergent fiber (NDF) and 48-h ruminal in situ digestibility were not affected ($P > 0.05$) by exposure time for either balage type. Concentrations of N were greater ($P = 0.045$) for orchardgrass balage exposed to air for 16 d or longer compared to balage sampled at exposure (d 0), but this response was not observed ($P > 0.05$) for wheat balage. These results suggest that the balage evaluated in this trial was very stable after exposure to air for up to 32 d. This should allow considerable flexibility with respect to feeding, transport, and marketing of balage during winter months without significant aerobic deterioration.

Introduction

Recently, an alternative methodology has been developed that allows small-sized producers to make silage by baling long-stem forages in large round packages and then wrapping them in plastic. This form of storage, often called balage, has become very common in northwest Arkansas. Balage is often stored in long rows of bales that are wrapped with an in-line bale wrapper. This is very convenient and efficient at harvest, but leads to possible problems at feeding, especially when the balage is marketed as a cash crop. Once a long row of balage is opened, oxygen has access to the exposed silage and aerobic deterioration can occur if the balage is not fed or sold quickly. Common indicators of aerobic deterioration in silages include mold development, spontaneous heating, dry matter (DM) loss, elevated pH, and reduced forage quality. Forage producers interested in marketing balage as a cash crop often inquire whether balage will remain stable during loading, transport, and subsequent feeding operations at the buyers' facility. Currently, the aerobic stability of exposed balage, particularly during winter months when most of this product is fed or sold, remains unclear. Our objectives were to evaluate the aerobic stability of orchardgrass and wheat balage exposed to air during December and January.

Experimental Procedures

Forages, Ensiling, and Storage. On May 6 and 7, 2002, "Benchmark" orchardgrass and an unstated variety of soft-red winter wheat were harvested with a mower conditioner (Model 1411; Ford New Holland, Inc., New Holland, Pa.) and allowed to wilt to an appropriate DM concentration for ensiling as balage. The orchardgrass was harvested at the heading stage of growth, while the wheat was harvested when the grain head reached the milk stage of development. When the forages had been wilted to the desired DM concentrations, they were raked into windrows with a New Holland Model 258 side-delivery rake. Immediately after raking, forages were packaged into 4 x 4-ft round bales (Model XL604; Vermeer Manufacturing Co., Pella, Iowa). Bales were hauled out of the field and wrapped with six layers of plastic film (Sunfilm; AEP Industries, Inc., Mt. Top, Pa.) on an in-line bale wrapper (Reeves Manufacturing Ltd., Miscouche, PE, Canada). The bales were stored on a concrete pad in rows that were at least 23 bales long. Each row contained only one forage type. Bales remained there, undisturbed, until December 10, 2002.

Exposure to Air. On December 10, 2002, the plastic wrap covering each row of wheat and orchardgrass balage was cut and removed. The bales at the end of each row were discarded. The 21 internal bales in each row were sampled (Star Quality Samplers, Edmonton, AB, Canada) on one side with an 18-in bale probe to determine the DM content of the bales at the time of exposure. Bales were blocked, based on position in the row, and designated for a second sampling after either 0, 2, 4, 8, 16, 24, or 32 d of exposure. Since these bales were to be evaluated over a 32-d period, holes created by the initial 18-in core sample were filled with spray foam insulation to prevent air from accessing the core of the bale.

Initial Bale Evaluation. At exposure (d 0), bales were removed from the concrete pad, weighed, and placed on individual wooden pallets in an open-air pole barn. This method of stacking provided air space between the bales, and ensured equal air exposure for all bales. Bales were not moved with a hay spike; instead, a hydraulic grasping attachment was used that did not create holes or tunnels that reached into the core of the silage bale. Bale width and diameter were measured, and the volume and DM density of each bale were calculated. Bales that were designated for exposure to air for 32 d were fitted with thermocouple wires that were inserted into the core of each bale in order to monitor changes in internal bale temperature over time. Bale temperatures were taken once daily with an Omega 450 AKT Type K thermocouple thermometer (Omega Engineering, Stamford, Conn.).

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Final Bale Evaluation. Each bale of both forage types was evaluated a second time after 0, 2, 4, 8, 16, 24, or 32 d of exposure to air in order to evaluate aerobic stability over time. On each sampling date, three bales of each forage type were removed from the barn and weighed. The bales were core sampled on the opposite side of the bale from the initial 18-in core sample taken on d 0. A portion of each forage sample was dried under forced air at 122°F to determine the final DM content of each bale; the other portion was used to determine silage pH with a portable pH meter (Model AP5, Denver Instruments, Arvada, Colo., USA) . In addition, the three orchardgrass and wheat bales sampled on each of the seven sampling dates were appraised visually for mold and aerobic deterioration on a scale of 1.0 to 5.0, where 1.0 = ideal and 5.0 = white mold and/or other evidence of aerobic deterioration covering the entire outside surface of the bale. Increments of 0.25 were used during the evaluation process.

Forage Nutritive Value. Dry forage samples were ground through a Wiley mill (Arthur H. Thomas, Philadelphia, Pa.) fitted with a 1-mm screen and subsequently analyzed for N, NDF, and 48-hour ruminal in situ DM disappearance. Analysis of NDF was conducted using batch procedures outlined by ANKOM Technology Corp. (Fairport, N.Y.) for an ANKOM200 Fiber Analyzer. Total N for each silage sample was determined by combustion (Elementar Americas, Inc. Mt. Laurel, N.J., USA). Silage samples also were incubated in the rumen of two fistulated steers for 48 h to provide an estimate of digestibility for each forage (Turner et al., 2003). The University of Arkansas Institutional Animal Care and Use Committee approved surgical procedures for cannulations, and the subsequent care of the fistulated steers.

Statistics. Data were analyzed as a randomized complete block design with three replications. Each balage type was evaluated independently. Single-degree-of-freedom contrasts were used to evaluate the effects of exposure time on each response variable. Contrasts included linear, quadratic, and cubic effects of exposure time; in addition, all exposed bales (2, 4, 8, 16, 24, or 32 d) were compared with bales sampled at exposure (d 0), and bales exposed for 16 d or more (16, 24, or 32 d) also were compared with bales sampled at exposure (d 0).

Results and Discussion

Initial bale characteristics. Within balage type, no contrast was significant ($P > 0.05$) with respect to bale characteristics at the time of exposure to air (Tables 1 and 2). This was expected at the time of exposure because silage generally remains stable during storage unless the anaerobic environment is compromised. Generally, orchardgrass and wheat bales had virtually identical measurements of diameter, width, and volume. This also was expected since the bale size was pre-set electronically, and each bale was processed, wrapped in plastic, and stored in an identical manner. Although balage types were not compared statistically, the orchardgrass bales were substantially heavier (mean bale wt = 1,512 vs. 1,167 lb) when the silage plastic was removed. Part of the advantage in weight observed for the orchardgrass balage was associated with DM content; the mean DM content for orchardgrass at exposure was 8.0 percentage units lower than for wheat (62.4 vs. 54.4%; Tables 1 and 2). However, differences in bale weight between orchardgrass and wheat bales were not explained entirely on the basis of differences in concentrations of DM. The DM density of orchardgrass bales ranged from 12.6 to 14.7 lb/ft^3 compared to only 10.3 to 11.7 lb/ft^3 for wheat; however, the DM density of the wheat bales was still within the acceptable range (9.4 to 11.2 lb/ft^3) for round-bale silage reported by Savoie and Jofriet (2003). High bale or silage density is known to be effective at reducing the permeability of the silage mass to oxygen, thereby reducing subsequent microbial respiration, elevated internal bale temperatures, and DM loss (Pitt, 1990).

Internal bale temperatures. Generally, elevation of bale temperatures would be expected in bales undergoing aerobic deterioration (Pitt, 1990), but there was relatively little temperature response over the 32-d exposure period. One of the wheat bales monitored for 32 d exhibited some increase in internal bale temperature (Fig. 1), but this response was not observed until the bale had been exposed to air for at least 3 weeks. The elevated temperature in this specific wheat bale was an exception to the normal lack of response for other wheat and orchardgrass bales. An example of an individual wheat bale that exhibited little or no temperature response also is shown for comparison purposes in Figure 1. Internal bale temperatures fluctuated somewhat with changes in ambient air temperature; however, this would be expected, especially during a December and January exposure period when the ambient air temperatures can be very low. Monthly normals for maximum, mean, and minimum ambient temperatures at Fayetteville in December are 44.7, 37.9, and 28.1°F; similarly, these respective normal temperatures are 44.3, 34.3, and 24.2°F for January (NOAA, 2002).

It is not surprising that the bale exhibiting elevated internal temperatures was comprised of wheat forage. Orchardgrass bales were packaged at a substantially higher DM density that should theoretically reduce permeability of the air, and limit potential for heating via respiration. Many cereal grains, including wheat, have hollow stems, which results in a bulkier forage that is difficult to pack (Coblentz et al., 2001). This is reflected in the lower DM density of wheat balage (Tables 1 and 2) and the increased likelihood of elevated internal bale temperatures relative to orchardgrass balage.

Final bale characteristics. For both orchardgrass (Table 3) and wheat (Table 4), there were no changes ($P > 0.05$) in bale weight, concentration of DM, or pH over the 32-d exposure period. All recoveries of DM were ≥ 97% (Tables 3 and 4), which is near complete recovery and suggests that both balage types were very stable after exposure to air. The linear ($P = 0.011$) and quadratic ($P = 0.036$) decreases in DM recovery over the 32-d exposure period observed for orchardgrass represented a very small range (97.3 to 100%; Table 3), and were probably not biologically meaningful. Similarly, the cubic ($P = 0.034$; Table 4) response observed over time for wheat balage comprised a similar small range (97.0 to 100%), and also was probably of limited importance. Visual mold scores were very low (≤ 2.17) for all bales of both types, indicating the balage was well preserved at exposure and showed little sign of deterioration thereafter. No contrast was significant for wheat ($P > 0.05$; Table 4), but a cubic ($P = 0.009$; Table 3) response over exposure time was observed for orchardgrass. However, visual mold scores for the orchardgrass balage were extremely low, and the overall range was very narrow (1.08 to 1.42).

Final bale quality. Exposure time had no effect ($P > 0.05$) on concentrations of N, NDF, or digestible DM for wheat balage (Table 5), and no effect on ($P > 0.05$) on concentrations of NDF or digestible DM for orchardgrass. Bales of orchardgrass exposed to air for 16 d or more had greater ($P = 0.045$) concentrations of N than those sampled immediately after exposure. However, the total range of response (1.96 to 2.30%) was relatively narrow. Generally, the very limited responses over the exposure period further indicated that these bales were very stable after exposure to air during December and January.

Implications

Overall, this experiment showed that well-preserved wheat and orchardgrass balages were very stable for more than a month after exposure to air, and this could provide considerable flexibility for feeding, transport, and marketing during winter months without significant aerobic deterioration. It is important to emphasize that the exposure period occurred during the winter months when temperatures were low. It should not be inferred that aerobic stability would be the same during other months when temperatures are substantially warmer.

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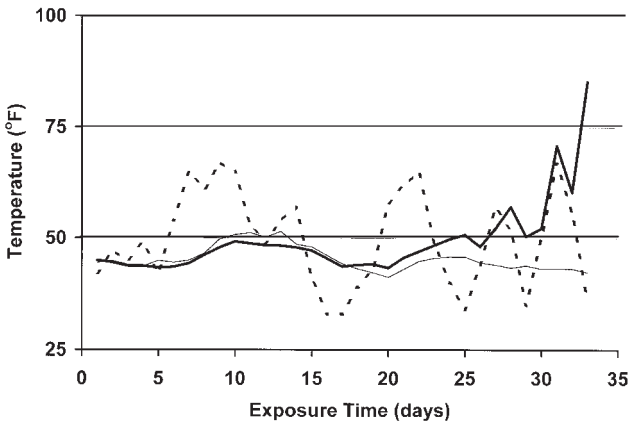

Fig. 1. Relationship between internal bale temperature and exposure time for unstable (bold, solid line) and stable (light, solid line) wheat balage. The maximum daily ambient air temperature (hashed line) also is shown for reference. Orchardgrass balage exhibited very little temperature response over exposure time and was omitted for clarity.

Table 1. Physical characteristics of bales of orchardgrass balage on the date of exposure (December 10, 2002) and allocated to various future sampling dates.

Exposure time	DM[1]	Diameter	Width	Volume	Wt (wet)	DM density
days	%	ft		ft^3	lb	lb DM/ft^3
0	51.00	4.31	4.08	59.7	1487	12.60
2	53.10	4.32	4.05	59.6	1573	14.00
4	58.20	4.29	4.10	59.2	1493	14.70
8	54.80	4.34	4.03	59.7	1473	13.50
16	51.20	4.34	4.06	60.2	1540	13.10
24	56.40	4.36	4.10	61.2	1540	14.10
32	56.40	4.38	4.14	62.4	1480	13.40
SEM[2]	4.81	0.064	0.049	1.78	38.6	0.90
Contrasts	P > F					
linear[3]	NS[4]	NS	NS	NS	NS	NS
quadratic[3]	NS	NS	NS	NS	NS	NS
cubic[3]	NS	NS	NS	NS	NS	NS
all exposed vs. 0-d[5]	NS	NS	NS	NS	NS	NS
exposed 16 d or more vs. 0-d[6]	NS	NS	NS	NS	NS	NS

[1] DM, dry matter.

[2] SEM, standard error of the mean.

[3] Linear, quadratic, or cubic effects of designated exposure time.

[4] NS, nonsignificant (P > 0.05).

[5] Contrast of bales to be exposed for 2, 4, 8, 16, 24, and 32 d vs. bales designated for immediate sampling (0-d).

[6] Contrast of bales to be exposed for 16, 24, or 32 d vs. bales designated for immediate sampling (0-d).

Table 2. Physical characteristics of bales of wheat balage on the date of exposure (December 10, 2002) and allocated to various future sampling dates.

Exposure time	DM[1]	Diameter	Width	Volume	Wt (wet)	DM density
days	%	ft		ft^3	lb	lb DM/ft^3
0	65.8	4.49	4.08	64.8	1013	10.3
2	60.0	4.57	4.04	66.4	1207	10.7
4	63.5	4.54	4.10	66.6	1187	11.3
8	60.9	4.56	4.06	66.1	1247	11.1
16	62.0	4.48	4.07	64.2	1133	10.9
24	62.8	4.49	4.03	63.8	1193	11.7
32	62.1	4.49	4.08	64.8	1187	11.4
SEM[2]	3.89	0.044	0.050	1.62	137.2	0.74
Contrasts	P > F					
linear[3]	NS[4]	NS	NS	NS	NS	NS
quadratic[3]	NS	NS	NS	NS	NS	NS
cubic[3]	NS	NS	NS	NS	NS	NS
all exposed vs. 0-d[5]	NS	NS	NS	NS	NS	NS
exposed 10 d or more vs. 0-d[6]	NS	NS	NS	NS	NS	NS

[1] DM, dry matter.

[2] SEM, standard error of the mean.

[3] Linear, quadratic, or cubic effects of designated exposure time.

[4] NS, nonsignificant (P > 0.05).

[5] Contrast of bales to be exposed for 2, 4, 8, 16, 24, and 32 d vs. bales designated for immediate sampling (0-d).

[6] Contrast of bales to be exposed for 16, 24, or 32 d vs. bales designated for immediate sampling (0-d).

Table 3. Characteristics of orchardgrass balage after exposure to air for 0, 2, 4, 8, 16, 24, or 32 days.

Exposure time	Bale wt (wet)	Visual score[1]	DM[2]	DM recovery	pH
days	lb		%	%	
0	1487	1.25	52.2	100.0	5.31
2	1567	1.17	54.1	99.7	5.12
4	1493	1.25	59.5	100.0	5.04
8	1460	1.08	56.4	100.0	5.26
16	1527	1.25	52.2	99.7	5.78
24	1513	1.42	58.8	100.0	5.04
32	1427	1.08	56.9	97.3	4.84
SEM[3]	39.5	0.075	4.82	0.57	0.305
Contrasts	P > F				
linear[4]	NS[5]	NS	NS	0.011	NS
quadratic[4]	NS	NS	NS	0.036	NS
cubic[4]	NS	0.009	NS	NS	NS
all exposed vs. 0-d[6]	NS	NS	NS	NS	NS
exposed 16 d or more vs. 0-d[7]	NS	NS	NS	NS	NS

[1] Visual score (scale 1 to 5); 1 = no evidence of aerobic deterioration, 5 = white mold and/or other evidence of aerobic deterioration over the entire bale surface.

[2] DM, dry matter.

[3] SEM, standard error of the mean.

[4] Linear, quadratic, or cubic effects of exposure time.

[5] NS, nonsignificant (P > 0.05).

[6] Contrast of bales exposed for 2, 4, 8, 16, 24, and 32 d vs. bales evaluated immediately (0-d).

[7] Contrast of bales exposed for 16, 24, or 32 d vs. bales evaluated immediately (0-d).

Table 4. Characteristics of wheat balage after exposure to air for 0, 2, 4, 8, 16, 24, or 32 days.

Exposure time	Bale wt (wet)	Visual score[1]	DM[2]	DM recovery	pH
days	lb		%	%	
0	1013	1.17	64.8	99.3	5.37
2	1213	1.33	58.2	98.7	5.39
4	1173	1.42	63.8	98.3	5.41
8	1227	1.08	59.2	97.0	5.15
16	1140	1.33	61.3	99.3	5.35
24	1180	1.33	65.8	100.0	5.52
32	1113	2.17	64.8	98.0	5.6
SEM[3]	129.5	0.375	3.53	0.95	0.239
Contrasts	P > F				
linear[4]	NS[5]	NS	NS	NS	NS
quadratic[4]	NS	NS	NS	NS	NS
cubic[4]	NS	NS	NS	0.034	NS
all exposed vs. 0-d[6]	NS	NS	NS	NS	NS
exposed 16 d or more vs. 0-d[7]	NS	NS	NS	NS	NS

[1] Visual score (scale 1 to 5); 1 = no evidence of aerobic deterioration, 5 = white mold and/or other evidence of aerobic deterioration over the entire bale surface.

[2] DM, dry matter.

[3] SEM, standard error of the mean.

[4] Linear, quadratic, or cubic effects of exposure time.

[5] NS, nonsignificant (P > 0.05).

[6] Contrast of bales exposed for 2, 4, 8, 16, 24, and 32 d vs. bales evaluated immediately (0-d).

[7] Contrast of bales exposed for 16, 24, or 32 d vs. bales evaluated immediately (0-d).

Table 5. Characteristics of nutritive value for orchardgrass and wheat balage exposed to air for 0, 2, 4, 8, 16, 24, or 32 days.

	Orchardgrass			Wheat		
Exposure time	N	NDF	Digestibility	N	NDF	Digestibility
days	% of DM[1]					
0	1.96	65.0	78.2	1.28	66.2	73.6
2	2.16	65.3	78.7	1.25	63.6	76.2
4	2.15	67.3	77.8	1.22	64.2	75.5
8	2.18	67.5	78.4	1.27	62.2	76.0
16	2.24	67.4	77.9	1.20	65.3	74.8
24	2.30	65.3	80.5	1.14	61.4	76.2
32	2.15	66.3	79.6	1.22	64.9	75.5
SEM[2]	0.103	1.24	0.83	0.044	2.49	1.7
Contrasts	P > F					
linear[3]	NS[4]	NS	NS	NS	NS	NS
quadratic[3]	NS	NS	NS	NS	NS	NS
cubic[3]	NS	NS	NS	NS	NS	NS
all exposed vs. 0-d[5]	NS	NS	NS	NS	NS	NS
exposed 16 d or more vs. 0-d[6]	0.045	NS	NS	NS	NS	NS

[1] DM, dry matter.

[2] SEM, standard error of the mean.

[3] Linear, quadratic, or cubic effects of exposure time.

[4] NS, nonsignificant (P > 0.05).

[5] Contrast of bales exposed for 2, 4, 8, 16, 24, and 32 d vs. bales evaluated immediately (0-d).

[6] Contrast of bales exposed for 16, 24, or 32 d vs. bales evaluated immediately (0-d).

Evaluation of Dry Matter Loss, Nutritive Value, and In Situ Dry Matter Disappearance for Wilting Orchardgrass Forages Damaged by Simulated Rainfall

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Story in Brief

'Benchmark' orchardgrass (*Dactylis glomerata* L.) was wilted to moisture concentrations of 67.4% (WET), 15.3% (IDEAL), and 4.1% (DRY) and subjected to 0, 0.5, 1.0, 1.5, 2.0, 2.5, or 3.0 in of simulated rainfall with a custom-built rainfall simulator. When simulated rainfall was applied to IDEAL orchardgrass, dry matter (DM) loss, total N, and all fiber components except hemicellulose increased with rainfall amount, exhibiting a significant ($P \leq 0.048$) polynomial effect or multiple effects in each case. Excluding the 0-in control, substantial DM loss (≥ 5.0%) was observed at all rainfall increments, and a maximum of 8.8% was reached when 3.0 in of simulated rainfall was applied. For DRY orchardgrass forage, DM losses increased to a maximum of 10.7% in linear ($P < 0.0001$), quadratic ($P = 0.001$), and cubic ($P = 0.033$) patterns with rainfall amount. For WET orchardgrass forage, DM loss increased linearly ($P = 0.006$) with rainfall amount, but the maximum DM lost was only 1.9% for this wetter forage. Simulated rainfall affected ($P \leq 0.044$) concentrations of N, NDF, ADF, hemicellulose, cellulose, lignin, and 48-h in situ digestibility for this wet forage, but polynomial effects were varied and the range of concentrations across rainfall amounts was generally quite narrow. Over the entire study, DM loss and deleterious changes in nutritive value were increased with simulated rainfall amount. Although not compared statistically, orchardgrass forages that were wilted substantially prior to applying simulated rainfall appeared to be more sensitive to DM loss and negative changes in nutritive value than were forages that were subjected to rainfall soon after mowing was completed.

Introduction

The harvest, storage, and cash sale of hay crops are important components of the cattle (*Bos taurus*; *B. indicus*) and equine (*Equus caballus*) industries, and hay packaged in small rectangular bales frequently receives a market price of $150/ton or more. Previously, most of the studies designed to assess the effects of rainfall on wilting forage crops have focused on alfalfa (*Medicago sativa* L.) and other legume hay crops, primarily because of their high potential feed and cash value. However, relatively few reports are available that describe the effects of graded levels of simulated or natural rainfall on wilting cool- and warm-season grasses. In addition, rainfall treatments generally have been limited to irregular and unpredictable natural events, or rather simplistic artificial application techniques. Recently, some scientists have adapted various types of rainfall simulation systems to address these research needs. These systems offer unique opportunities to apply graded levels of simulated rainfall to wilting forages, and therefore, more precisely identify variables that may affect the nutritive value of the damaged hay crop. The objectives of this study were to investigate the effects of simulated rainfall on losses of DM, concentrations of fibrous components and N, and ruminal DM degradability for orchardgrass forages wilted to 67.4, 15.3, or 4.1% moisture.

Experimental Procedures

Field and Rainfall Simulation Procedures. An established stand of 'Benchmark' orchardgrass, located at the University of Arkansas Forage Research Area in Fayetteville, Ark., served as the source of orchardgrass forage for the rainfall simulation studies. On June 18, 2001, orchardgrass forage was harvested to a 3.0-in stubble height with a New Holland Model 1411 disc mower-conditioner (Ford New Holland, New Holland, Pa.) equipped with rubber-covered metal conditioning rollers. This was the second harvest for 2001; therefore, the orchardgrass was primarily vegetative regrowth, but visual evaluation indicated that approximately 5% of all orchardgrass tillers were reproductive. A first harvest was taken on May 9, 2001 when forage was removed and ensiled as round-bale silage.

Immediately after mowing, three 2.7-ft^2 frames were placed directly on the hay swaths at random locations throughout the field. The mowed forage within each frame was clipped with handshears in order to estimate the density of the swath. The freshly swathed orchardgrass forage (67.4% moisture; WET) was then collected from throughout the experimental area, placed onto a tarp, and moved under a barn to minimize desiccation of plant tissues. Once under the barn, orchardgrass forage was weighed into 42 galvanized wire baskets (5.9 x 12.2 x 29.9 in; mesh size = 0.5 in), and baskets were filled with forage (0.1 ± 0.02 lb DM/ft^2) so that the forage density within the wire baskets was comparable to that calculated from frames clipped from swaths in the field. Thirty-six baskets were placed on a raised (3.5-in) wire platform under the rainfall simulator (4.9 x 20-ft coverage area). Baskets were placed on an elevated platform to eliminate contact with the soil surface, avoid puddling from runoff water, and to ensure the free movement of water through plant tissues. Baskets were separated into three experimental blocks designated on the basis of location underneath the simulator. The remaining six baskets served as controls, and did not receive simulated rainfall (0 in). Simulated rainfall was applied via a rainfall simulation system (Miller, 1987) to experimental forages at a constant rate of 3.0 in/h. Therefore, in order to apply treatments that represented graded amounts of rainfall, two baskets from each block were removed at random from under the simulator at 10-min increments. This resulted in six treatments that received either 0.5, 1.0, 1.5, 2.0, 2.5, or 3.0 in of simulated rainfall. After the baskets were removed from under the simulator, each basket was allowed to drip dry for

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approximately 0.5 h and the forage contents were then transferred to a paper bag and dried to a constant weight under forced air at 131°F. There was no evidence of significant leaf shatter or other loss of forage from the baskets during the application of simulated rainfall, or during handling. After completing this experimental process for WET orchardgrass forage, the entire experimental process was repeated when the forage was wilted to 15.3 and 4.1% moisture (IDEAL and DRY, respectively). Simulated rainfall was applied to all three forages (WET, IDEAL, and DRY) within one 24-h time interval.

Measurement of DM Losses. Loss of forage DM from wire-mesh baskets was calculated using concentrations of NDF as an internal marker. Calculations were made based on the equation of Fonnesbeck et al. (1986) that was modified to include NDF as the internal marker:

$$\text{DM loss (\%)} = [1 - (NDF_I/NDF_R)] \times 100\%,$$

where NDF_I = concentration of NDF (DM basis) before the rainfall event, and NDF_R = concentration of NDF (DM basis) after the rainfall event.

Chemical Analysis of Forage. Dry forage samples were ground through a Wiley mill (Arthur H. Thomas, Philadelphia, PA) to pass through either a 1-mm or 2-mm screen. Subsamples ground through a 1-mm screen were analyzed subsequently for NDF, ADF, hemicellulose, cellulose, lignin, and total N. Analyses for NDF, ADF, hemicellulose, cellulose, and lignin were conducted sequentially using the batch procedures outlined by ANKOM Technology Corporation (Fairport, N.Y.). Sodium sulfite and heat-stable alpha-amylase were not included in the NDF solution. Concentrations of N were quantified by a rapid combustion procedure (LECO Model FP-428; LECO, St. Joseph, Mich.). Two ruminally-cannulated crossbred steers (mean BW = 591 ± 46.8 lb) were used to determine in-situ ruminal DM degradability (DMD) of rain-damaged orchardgrass forages (previously ground through a 2-mm screen) during a 48-h ruminal incubation. The University of Arkansas Institutional Animal Care and Use Committee approved surgical procedures for cannulations, and the subsequent care of the fistulated steers.

Statistical Analysis. Each of the three test forages (WET, IDEAL, or DRY) had to be wilted different lengths of time prior to applying simulated rainfall; therefore, simulated rainfall could not be applied to each simultaneously. For this reason, an independent analysis of variance was conducted for each combination of forage and initial moisture concentration. Within each analysis of variance, data were analyzed as a randomized complete block design with seven levels of rainfall (0, 0.5, 1.0, 1.5, 2.0, 2.5, or 3.0 in) as treatments. Single-degree-of-freedom orthogonal contrasts were used to test for linear, quadratic, cubic, and quartic effects due to rainfall amount. Statistical significance was declared at $P < 0.05$, unless otherwise noted.

Results and Discussion

WET Forage. Dry matter losses increased linearly ($P = 0.006$; Table 1) with rainfall amount; however, the magnitude of these losses was minimal and the overall range was quite narrow (0 to 1.9%), indicating that WET forage was relatively resistant to DM loss via leaching and continued respiration. This relative resistance was reflected in concentrations of fiber components. Although significant ($P \leq 0.044$), and sometimes multiple, polynomial effects of rainfall amount were observed for each fiber component, concentrations changed only minimally, and remained within a very narrow range. For example, the concentration of NDF in forage receiving 3.0 in of simulated rainfall increased by only 0.9 percentage units when compared to forage receiving no simulated rainfall. Although significant effects ($P \leq 0.011$) were observed for both total N and DMD, the magnitude of each response to simulated rainfall also was limited. Total N increased linearly ($P = 0.003$) with rainfall amount, but much (0.20 percentage units) of the total increase was observed between the 2.5- and 3.0-in increments of simulated rainfall. For DMD, significant cubic ($P = 0.011$) and quartic ($P = 0.010$) effects were observed, but these may largely be explained by the depressed DMD at 0.5 in of applied rainfall that was not observed at other application levels.

IDEAL Forage. Dry matter loss, total N, and all fiber components except hemicellulose increased with rainfall amount, exhibiting significant ($P \leq 0.048$) polynomial effects in each case; however, there was no clear or consistent pattern of effects across these response variables (Table 2). Unlike observations made for the WET orchardgrass, there was substantial DM loss (≥ 5.0%) at all rainfall amounts, and a maximum of 8.8% was reached when 3.0 in of simulated rainfall was applied. These losses increased with linear ($P < 0.0001$), quadratic ($P < 0.0001$), cubic ($P = 0.048$), and quartic ($P = 0.013$) effects of simulated rainfall.

Concentrations of total N increased quadratically ($P = 0.042$); however, this effect was created largely by an increase of 0.21 percentage units in response to the first 0.5 in of simulated rainfall, but there was little evidence of additional response thereafter. Concentrations of ADF, cellulose, and lignin each increased with cubic ($P \leq 0.005$) and linear ($P < 0.0001$) effects, reaching levels that were 9.9, 6.2, and 3.74 percentage units higher, respectively, than those observed for forages receiving no simulated rainfall. Similarly, NDF increased by 6.3 percentage units over the 3.0-in range of applied rainfall; however, this response was explained by quartic ($P = 0.019$), quadratic ($P < 0.0001$) and linear ($P < 0.0001$) effects. Unlike the other fiber components, concentrations of hemicellulose declined over simulated rainfall levels with all polynomial terms contributing ($P \leq 0.016$) to the response. In-situ DMD declined with rainfall amount, exhibiting quartic ($P = 0.045$), quadratic ($P = 0.001$), and linear ($P = 0.010$) effects, but these effects were clearly influenced by the poor DMD (68.5%) at the 1.5-in rainfall application rate. Excepting this aberrant value, concentrations of DMD were essentially minimized by the 1.0-in application rate, and somewhat variable, but generally static, responses were observed thereafter.

DRY Forage. Orchardgrass forage that was wilted to excessively dry concentrations of moisture (4.1%) lost a maximum of 10.7% of DM (Table 3), which was numerically higher by 1.9 percentage units than the maximum loss observed for IDEAL forage. As observed for IDEAL forage, a large loss (5.8%) was associated with the first 0.5-in increment of applied rainfall, which was greater than losses observed over the subsequent 2.5 in of applied water. Losses of DM were explained by linear ($P < 0.0001$), quadratic ($P = 0.001$), and cubic ($P = 0.033$) terms.

Unlike WET and IDEAL forages, concentrations of N in DRY forage were not affected ($P \geq 0.174$) by simulated rainfall. Concentrations of all fiber components increased with simulated rainfall, but there was no consistent pattern with respect to polynomial effects; NDF and hemicellulose exhibited cubic ($P \leq 0.048$), quadratic ($P \leq 0.003$), and linear ($P < 0.0001$) effects, while ADF and cellulose increased in a linear ($P < 0.0001$) manner. Concentrations of lignin changed in a cubic ($P = 0.037$) pattern with rainfall amount, but these results were variable, and concentrations after 2.0, 2.5, and 3.0 in of rainfall were only marginally different than observed for forage receiving no rain. Concentrations of DMD declined in a linear ($P = 0.0003$) pattern with simulated rainfall at a rate of about 1.3

percentage units per in of applied rainfall.

Comparing Across Forages. When the results of these orchardgrass studies are considered together, several major trends become obvious. One trend is the positive relationship between DM loss and rainfall amount. Losses of DM for WET, IDEAL, and DRY orchardgrass forages all increased with rainfall, exhibiting significant ($P \leq 0.048$) polynomial or multiple polynomial effects, but these effects were not necessarily consistent over the three orchardgrass forages. Although not compared statistically, it also is clear that IDEAL and DRY orchardgrass were far more susceptible to DM loss than WET forage that was damaged soon after mowing. For WET orchardgrass forage, DM losses were minimal (≤ 1.9%) at all rainfall application amounts, while for IDEAL and DRY orchardgrass, losses ranged from 5.0 to 10.7% for any simulated rainfall application, except for the 0-in control. Generally, these trends also were evident with respect to characteristics of forage quality; concentrations of N and most fiber components increased with rainfall amount, while DM digestibility decreased concomitantly. Overall, changes in forage quality appeared to be more substantial in IDEAL and DRY forages than in forage that was still well hydrated at the time simulated rainfall was applied.

Implications

For the orchardgrass forages in this study, DM loss and negative changes in nutritive value were increased with rainfall amount. These responses were quite pronounced in forages that were dry enough to bale, but the magnitude of response was greatly reduced when rainfall simulation was applied immediately after the forage was mowed.

Literature Cited

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Table 1. Effects of rainfall amount on DM loss, and concentrations of N, fiber components, and ruminal DM degradability for orchardgrass forage that was wilted to 67.4% moisture (WET) before simulated rainfall was applied.

Treatment	DM Loss[1]	N	NDF[2,3]	ADF	Hemicellulose	Cellulose	Lignin	DMD
Rainfall, in					%			
0	0	2.11	63.6	35.5	28.1	32.0	3.36	76.2
0.5	0.6	2.15	64	36.5	27.5	32.8	3.04	71.4
1.0	1.2	2.27	64.4	37.0	27.4	33.2	3.24	74.6
1.5	1.2	2.29	64.4	37.5	26.9	33.0	3.87	74.2
2.0	1.9	2.22	64.9	36.6	28.3	31.9	4.03	73.8
2.5	1.6	2.23	64.7	35.0	29.7	31.8	2.70	74.7
3.0	1.4	2.43	64.5	34.2	30.3	28.5	2.71	74.3
SEM[4]	0.46	0.062	0.3	0.29	0.31	1.04	0.189	0.65
Contrasts					P > F			
Linear	0.006	0.003	0.006	<0.0001	<0.0001	0.016	NS	NS
Quadratic	NS[5]	NS	NS	<0.0001	<0.0001	0.016	0.001	NS
Cubic	NS	NS	NS	NS	NS	NS	0.025	0.011
Quartic	NS	NS	NS	0.044	0.044	NS	0.001	0.01

[1] Dry matter loss determined using NDF as an internal marker.

[2] Abbreviations: NDF, neutral-detergent fiber; ADF, acid-detergent fiber; and DMD, 48-h ruminal in-situ disappearance.

[3] Fiber components determined sequentially.

[4] Standard error of the main effect mean.

[5] Nonsignificant (P > 0.05).

Table 2. Effects of rainfall amount on DM loss, and concentrations of N, fiber components, and ruminal DM degradability for orchardgrass forage that was wilted to 15.3% moisture (IDEAL) before simulated rainfall was applied.

Treatment	DM Loss[1]	N	NDF[2,3]	ADF	Hemicellulose	Cellulose	Lignin	DMD
Rainfall, in	%							
0	0	2.18	65.0	34.7	30.2	31.2	2.85	76.9
0.5	5.7	2.39	68.9	37.4	31.5	32.5	4.31	74.7
1.0	5.0	2.32	68.4	39.3	29.1	34.0	4.62	72.2
1.5	7.3	2.32	70.1	39.9	30.2	34.5	4.55	68.5
2.0	8.3	2.40	70.9	40.3	30.6	34.1	5.39	72.0
2.5	8.6	2.22	71.2	42.1	29.1	35.9	5.43	73.0
3.0	8.8	2.31	71.3	44.6	26.6	37.4	6.59	72.4
SEM[4]	0.52	0.050	0.38	0.46	0.39	0.36	0.177	1.16
Contrasts	P > F							
Linear	< 0.0001	NS[5]	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.01
Quadratic	< 0.0001	0.042	< 0.0001	NS	0.0002	NS	NS	0.001
Cubic	0.048	NS	NS	0.001	0.01	0.005	0.0002	NS
Quartic	0.013	NS	0.019	NS	0.016	NS	NS	0.045

[1] Dry matter loss determined using NDF as an internal marker.

[2] Abbreviations: NDF, neutral-detergent fiber; ADF, acid-detergent fiber; and DMD, 48-h ruminal in-situ disappearance.

[3] Fiber components determined sequentially.

[4] Standard error of the main effect mean.

[5] Nonsignificant (P > 0.05).

Table 3. Effects of rainfall amount on DM loss, and concentrations of N, fiber components, and ruminal DM degradability for orchardgrass forage that was wilted to 4.1% moisture (DRY) before simulated rainfall was applied.

Treatment	DM Loss[1]	N	NDF[2,3]	ADF	Hemicellulose	Cellulose	Lignin	DMD
Rainfall, in	%							
0	0	2.21	65.2	34.0	31.2	29.7	3.91	76.8
0.5	5.8	2.18	69.3	35.3	34.0	29.1	6.20	75.7
1.0	7.6	2.15	70.6	36.5	34.1	31.1	4.87	73.6
1.5	8.4	2.30	71.2	36.5	34.7	30.9	5.91	74.1
2.0	9.1	2.26	71.7	37.5	34.2	33.3	4.09	73.8
2.5	10.1	2.22	72.6	37.8	34.7	33.6	3.87	73.6
3.0	10.7	2.29	73.0	38.3	34.8	33.5	4.28	73.0
SEM[4]	0.9	0.060	0.68	0.39	0.43	0.72	0.647	0.72
Contrasts	P > F							
Linear	<0.0001	NS	<0.0001	<0.0001	<0.0001	<0.0001	NS	0.0003
Quadratic	0.001	NS	0.003	NS	0.001	NS	NS	NS
Cubic	0.033	NS	0.048	NS	0.016	NS	0.037	NS
Quartic	NS[5]	NS	NS	NS	NS	NS	NS	NS

[1] Dry matter loss determined using NDF as an internal marker.

[2] Abbreviations: NDF, neutral-detergent fiber; ADF, acid-detergent fiber; and DMD, 48-h ruminal in-situ disappearance.

[3] Fiber components determined sequentially.

[4] Standard error of the main effect mean.

[5] Nonsignificant (P > 0.05).

Estimating Losses of Dry Matter in Response to Simulated Rainfall for Bermudagrass and Orchardgrass Forages Using Plant Cell Wall Components as Internal Markers

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Story in Brief

Previous methodologies used to measure losses of dry matter (DM) in wilting hays subjected to natural or simulated rainfall have generally relied upon gravimetric techniques, resulting in variable and questionable estimates of DM loss. The objective of this study was to evaluate the use of fiber components as internal plant markers for accurately predicting losses of DM in bermudagrass (*Cynodon dactylon* L. Pers.) and orchardgrass (*Dactylis glomerata* L.) forages that were damaged by simulated rainfall. For both forages, concentrations of neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose (HEMI), cellulose (CELL), and lignin generally increased with the amount of simulated rainfall in primarily linear patterns. Recoveries of fiber components were high (> 98.2%), and did not change in response to artificial rainfall for orchardgrass ($P \geq 0.115$). A quadratic tendency ($P = 0.063$) towards reduced recovery was observed for NDF in bermudagrass forage, but the overall range was very small (98.8 to 100.1%). There were no observed effects for any other fiber component ($P \geq 0.180$). Predicted losses of DM increased in primarily linear patterns with simulated rainfall for both forages when NDF, ADF, HEMI, and CELL were used as an internal marker. Linear regressions of predicted losses of DM on gravimetrically determined values were good ($r^2 = 0.735$; $P \leq 0.029$) when concentrations of any fiber constituent were used to calculate losses of DM; however, NDF was an especially effective ($Y = 1.12 X – 0.5$; $r^2 = 0.971$; $P < 0.0001$) predictor.

Introduction

Methodologies used to estimate losses of dry matter (DM) in experiments with rain-damaged forages generally have been based on gravimetric techniques, but these techniques often have been problematic. An alternative technique used by only a limited number of scientists is based upon the principle that fiber components are insoluble in water (Van Soest, 1982). Concentrations of cell wall constituents generally increase in response to rain-damage; however, these changes are associated indirectly with decreased concentrations of cell-soluble constituents (particularly sugars) that are leached from the forage. In theory, the actual amount or pool of cell wall components remains unchanged during rainfall events. Therefore, cell-wall components should be potentially useful as internal markers to accurately predict losses of DM. Based on this premise, Fonnesbeck et al. (1986) suggested that losses of DM in rain-damaged forages could be determined by the equation:

$$\text{DM loss (\%)} = [1 - (CW_I/CW_R)] \times 100\%,$$

where CW_I = cell wall concentration before the rainfall event, and CW_R = cell wall concentration after the rainfall event. The objective of this study was to evaluate the efficacy of using cell wall constituents as internal markers to predict losses of DM in bermudagrass and orchardgrass forages damaged by simulated rainfall.

Experimental Procedures

Rainfall Simulation. Two separate studies were conducted. One study utilized a second cutting of 'Benchmark' orchardgrass harvested on June 20, 2001 at the University of Arkansas Forage Research Area in Fayetteville. The second study utilized common bermudagrass harvested as hay from an adjacent field at the same research site during the summer of 2001. Hays were packaged in small rectangular bales and stored in an open-air pole barn until January 2002. On January 4, 2002, samples were taken from duplicate bales of each forage, and chopped to a 1.0-in length using a standard 24- x 24-in paper cutter. Chopped, 8-g samples of each forage were weighed into 24 dacron bags (4 x 8 inches; ANKOM Technology, Fairport, N.Y.), sealed with an impulse heat sealer (Model CD-200; National Instrument Co., Baltimore, Md.), and dried to a constant weight in a forced air oven at 131°F. Bags were removed from the drier and immediately weighed (hot) before the forage particles could absorb water from the atmosphere. This procedure was used in order to obtain the most accurate estimation possible of the total amount of forage DM in each bag prior to wetting by simulated rainfall.

Twenty bags containing bermudagrass forage were placed under a custom-built rainfall simulator, and separated into four blocks. Each block designation was associated with a single corresponding sprinkler head on the rainfall simulator, and artificial rainfall was applied to bags at a constant rate of 33 in/h. One bag from each block was removed from under the simulator in specific time intervals that resulted in applications of 2.0, 4.0, 8.0, 16.0, or 24.0 in of artificial rainfall. An undamaged control was included in the study that consisted of four bags of bermudagrass hay that did not receive any application of simulated rainfall (0 in). Although the rate of application was extremely high in comparison to typical rates of natural rainfall events, much of the applied water was shed by the dacron bags. Our goal was to generate different amounts of DM loss that covered the range expected under normal field conditions following rainfall events. Losses of DM generated by these techniques

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generally were within this range (Table 1). After bags were wetted by simulated rainfall, they were allowed to drip dry for 0.5 h and then dried to a constant weight under forced air (131°F). Bags were removed from the oven and immediately weighed (hot) to determine the final amount of forage DM contained within each individual bag. Actual losses of DM were calculated as differences in initial and final amounts of DM within each bag, and these losses are reported on a percentage basis. At the conclusion of the bermudagrass study, the exact same procedures were used to apply simulated rainfall to dacron bags filled with orchardgrass forage.

Chemical Analysis of Forage. All dry forage samples were ground through a Wiley mill (Arthur H. Thomas, Philadelphia, PA) to pass a 1-mm screen and analyzed for concentrations of neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose (HEMI), cellulose (CELL), and lignin. The NDF, ADF, HEMI, CELL, and lignin analyses were conducted sequentially, using the batch procedures outlined by ANKOM Technology Corporation (Fairport, N.Y.). Sodium sulfite and heat-stable α-amylase were not included in the NDF solution.

Recoveries of Potential Markers. The utility of any marker is dependent upon its ability to remain unaffected by the application of treatment, and complete recovery of the marker is expected following treatment. Each of the markers in this study was evaluated by calculating the amount of each marker on a weight basis (g), both before and after simulated rainfall treatments. Recoveries for each potential marker were calculated as:

Marker Recovery (%) = [marker recovered (g)/ marker before treatment (g)] x 100%.

In order to get the best possible estimate of the initial concentration of each potential marker in the experimental forages, subsamples of each chopped forage were taken regularly (12 per forage) as the dacron bags were filled. These subsamples were composited, thoroughly mixed, ground, and analyzed for fiber components as described previously. Therefore, marker recoveries from dacron bags receiving no simulated rainfall (0 in) sometimes differed slightly from complete recovery (100%), and these differences reflect sampling, handling, and laboratory errors during the experimental procedures.

Calculated DM Loss. Concentrations of fiber components before and after rainfall treatments were used to estimate losses of DM using the equation suggested by Fonnesbeck et al. (1986), which was described previously.

Statistical Analysis. Data for the bermudagrass and orchardgrass trials were analyzed independently as a randomized complete block design with four replications (blocks) based on positioning under the rainfall simulator. The sums of squares were partitioned into linear, quadratic, cubic, and quartic effects of simulated rainfall amount, and tested for significance with the residual error mean square. Agreement between the marker-based estimates of DM loss and actual DM losses determined by gravimetric procedures was tested by linear regression. A slope of unity and an intercept of zero would indicate ideal agreement between methods. Initially, tests of homogeneity were conducted to detect differences in parameter estimates (intercept and slope) between bermudagrass and orchardgrass forages. If both slope and intercept did not differ ($P > 0.05$) across forages, data were combined, and a common regression equation was reported. If the regression lines for all forages were not homogenous ($P < 0.05$), a separate regression equation was generated for each forage. As part of the regression procedures, an additional test statement was included to evaluate whether slope = 1. Throughout the study, statistical significance was declared at $P \leq 0.05$, and important trends necessary to explain the results were identified at $P < 0.1$.

Results and Discussion

Actual (Gravimetric) DM Losses. Actual losses of DM ranged from 0 to 9.8% (Table 1), which was consistent with expectations for actual field conditions. The cubic ($P = 0.023$) and linear ($P < 0.0001$) terms described the increased losses of DM that occurred from dacron bags containing bermudagrass forage following simulated rainfall. For orchardgrass, actual DM losses increased similarly with simulated rainfall, but all polynomial terms were significant ($P \leq 0.032$).

Concentrations of Markers. Previous work by Collins (1982) shows clearly that concentrations of fiber components increase indirectly as total sugars and other nonstructural carbohydrates are leached from the forage. Generally, this occurred in this study. For example, the concentration of NDF was 3.5 percentage units greater in bermudagrass forage receiving 24 in of simulated rainfall compared to the undamaged (0 in) control (Table 2). Generally, greater responses were observed for orchardgrass forage (Table 3). Perennial cool-season grasses often contain much larger concentrations of sugars than do perennial warm-season grasses, such as bermudagrass. Therefore, there is increased potential for leaching of these water-soluble components that should result indirectly in greater increases in concentrations of fiber components. In this study, concentrations of NDF for orchardgrass increased by 7.3 percentage units in forage that received the most simulated rainfall (24 in), relative to the undamaged (0 in) control. These responses were explained by a tendency for a quartic increase ($P = 0.050$) in response to simulated rainfall, while all other polynomial terms were significant ($P \leq 0.044$).

Estimated Recoveries of Internal Markers. In theory, internal markers rely upon the assumption that the marker is not affected by experimental treatments, and that it is completely recovered following treatment. Therefore, when expressed as a proportion of initial quantities, marker recoveries should be approximately 100%. In these studies, recoveries of all fiber components from both forages were high (≥ 98.2%; Tables 4 and 5) at all levels of simulated rainfall, suggesting that these components may be acceptable for use as internal indicators of DM loss. In some cases, recoveries exceeded 100%, and this was especially true for lignin, for which recoveries reached a maximum of 104.9% in orchardgrass forage. Analyzing for lignin is tedious and problematic work; it is likely that the excessive recovery of lignin is related to procedural limitations, rather than deposition of any additional lignin.

Predicted Losses of DM. For bermudagrass forage (Table 6), predicted losses of DM estimated with NDF as an internal marker increased from 0 to 4.6% in cubic ($P = 0.026$) relationship with simulated rainfall; the linear term also was significant ($P < 0.0001$). Losses of DM predicted using concentrations of ADF, HEMI, and CELL increased linearly ($P \leq 0.033$) in response to simulated rain damage, but losses of DM predicted with lignin increased only numerically ($P \geq 0.327$). For orchardgrass (Table 7), predicted losses of DM calculated with NDF as an internal marker increased from 0 to 10.2% over the entire range of simulated rainfall, and all polynomial terms were significant ($P \leq 0.038$). Losses of DM estimated with ADF and CELL increased in a quadratic ($P \leq 0.014$) pattern with a significant linear term ($P < 0.0001$), but losses of DM estimated with HEMI and lignin increased only in linear patterns ($P \leq 0.010$) with simulated rainfall.

Predicted vs. Actual Losses of DM. Statistics for predicted DM loss calculated on the basis of internal markers regressed on actual DM losses determined by gravimetric techniques are presented in Table 8. For both forage types, relationships between predicted and

actual losses of DM were good ($r^2 \geq 0.735$; $P \leq 0.029$), regardless of which internal marker was used. Relationships were particularly good when concentrations of NDF were used to predict losses of DM ($Y = 1.12 X - 0.5$; $r^2 = 0.971$; $P < 0.0001$). In this relationship, the slopes and intercepts for the two forages did not differ ($P \geq 0.230$; data not shown), and data for the two forages were combined into a common regression equation. The resulting slope (1.12) of the combined regression tended ($P = 0.075$) to be greater than unity, but the intercept did not differ ($P = 0.122$) from zero. Other fiber components that exhibited homogenous regression relationships across forages included cellulose and lignin; however, the slope for lignin (1.62) far exceeded ($P = 0.037$) unity.

In this study, lignin comprised a much smaller proportion of the total forage DM than did NDF, ADF, HEMI, and CELL, and procedures for quantifying lignin are far more tedious and problematic than those for other fiber components. Predicting DM loss on the basis of relatively subtle differences in concentrations of lignin may be problematic relative to NDF, which is easy to quantify and comprises a large proportion of the total forage DM. An additional consideration in choosing an internal marker is that NDF and ADF are likely to be included in nearly all evaluations of forage nutritive value; therefore, predicting DM loss via one of these internal markers would not require additional analytical costs.

Implications

Concentrations of most fiber components increased in response to rainfall and were completely recovered from bermudagrass and orchardgrass forages after simulated rainfall damage occurred. Reliable estimates of DM loss may best be predicted with NDF due to the good relationship between actual (gravimetric) and predicted losses of DM observed in this study, the relatively rapid and inexpensive nature of the NDF procedure, and because NDF is generally determined as part of routine forage testing procedures.

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Table 1. Actual losses of dry matter (DM) in bermudagrass and orchardgrass forages determined by gravimetric techniques after application of graded amounts of simulated rainfall.

Simulated rainfall	Bermudagrass	Orchardgrass
in	%	
0	0	0
2	1	3.3
4	1.3	5.4
8	2.7	5.9
16	3	8.5
24	4.7	9.8
SEM[a]	0.32	0.60
Response	P > F	
Linear	<0.0001	<0.0001
Quadratic	0.162	0.001
Cubic	0.023	0.021
Quartic	0.441	0.032

[a] Standard error of the mean.

Table 2. Concentrations of fiber components in bermudagrass forage as affected by graded levels of simulated rainfall. Fiber components were determined sequentially.

Simulated rainfall	NDF[a]	ADF	HEMI	CELL	Lignin
in	%				
0	73.7	30.8	42.3	27.0	4.16
2	74.2	31.7	42.4	27.8	4.19
4	74.8	32.1	42.6	27.9	4.39
8	75.0	32.3	42.7	28.1	4.46
16	75.1	32.3	42.8	28.1	4.40
24	77.2	32.5	44.4	28.3	4.40
SEM[b]	0.37	0.39	0.50	0.33	0.199
Response	P > F				
Linear	<0.0001	0.012	0.006	0.03	0.380
Quadratic	0.317	0.106	0.303	0.2	0.399
Cubic	0.026	0.125	0.381	0.175	0.602
Quartic	0.857	0.485	0.833	0.438	0.832

[a] Abbreviations: NDF, neutral-detergent fiber; ADF, acid-detergent fiber; HEMI, hemicellulose; and CELL, cellulose.

[b] Standard error of the mean.

Table 3. Concentrations of fiber components in orchardgrass forage as affected by graded levels of simulated rainfall. Fiber components were determined sequentially.

Simulated rainfall	NDF[a]	ADF	HEMI	CELL	Lignin
in			%		
0	64.0	32.6	31.5	28.8	3.88
2	67.0	33.5	33.2	30.1	4.01
4	67.8	34.6	33.2	30.5	4.04
8	68.6	34.6	34.0	31.1	4.26
16	70.4	35.7	34.7	31.7	4.44
24	71.3	35.8	35.5	31.8	4.76
SEM[b]	0.51	0.37	0.51	0.41	0.224
Response			P > F		
Linear	<0.0001	<0.0001	<0.0001	<0.0001	0.004
Quadratic	0.002	0.011	0.121	0.020	0.907
Cubic	0.044	0.312	0.214	0.234	0.799
Quartic	0.050	0.198	0.422	0.420	0.879

[a] Abbreviations: NDF, neutral-detergent fiber; ADF, acid-detergent fiber; HEMI, hemicellulose; and CELL, cellulose.

[b] Standard error of the mean.

Table 4. Recoveries of potential internal markers in bermudagrass forage after application of graded levels of simulated rainfall. Fiber analysis was by sequential methodology.

Simulated rainfall	NDF[a]	ADF	HEMI	CELL	Lignin
in			%		
0	100.0	100.0	100.0	100.0	100.0
2	99.6	102.0	99.1	101.9	99.7
4	100.1	103.0	99.4	102.1	104.0
8	99.0	102.0	98.3	101.2	104.2
16	98.8	101.8	98.2	101.0	102.6
24	99.8	100.8	99.9	99.9	100.8
SEM[b]	0.45	1.21	1.18	1.17	4.69
Response			P > F		
Linear	0.478	0.791	0.92	0.397	0.939
Quadratic	0.063	0.18	0.183	0.34	0.455
Cubic	0.455	0.34	0.861	0.466	0.735
Quartic	0.691	0.336	0.983	0.301	0.884

[a] Abbreviations: NDF, neutral-detergent fiber; ADF, acid-detergent fiber; HEMI, hemicellulose; and CELL, cellulose.

[b] Standard error of the mean.

Table 5. Recoveries of potential internal markers in orchardgrass forage after application of graded levels of simulated rainfall. Fiber analysis was by sequential methodology.

Simulated rainfall	NDF[a]	ADF	HEMI	CELL	Lignin
in			%		
0	100.0	101.5	100.2	100.3	100.1
2	101.1	101.0	102.1	101.4	99.8
4	100.3	102.1	100.0	100.4	98.6
8	100.9	101.6	101.8	101.8	103.5
16	100.7	102.0	101.1	100.9	104.9
24	100.5	100.8	101.8	99.9	110.1
SEM[b]	0.71	1.4	1.26	1.11	5.9
Response			P > F		
Linear	0.910	0.807	0.565	0.637	0.115
Quadratic	0.563	0.576	0.911	0.350	0.816
Cubic	0.805	0.837	0.699	0.858	0.998
Quartic	0.765	0.958	0.958	0.831	0.695

[a] Abbreviations: NDF, neutral-detergent fiber; ADF, acid-detergent fiber; HEMI, hemicellulose; and CELL, cellulose.

[b] Standard error of the mean.

Table 6. Losses of dry matter (DM) in bermudagrass forage predicted on the basis of concentrations of fiber components after application of graded levels of simulated rainfall.

Simulated rainfall	NDF[a]	ADF	HEMI	CELL	Lignin
In			%		
0	0	-0.1	-0.1	-0.1	-1.4
2	0.6	2.9	0.1	2.9	-1.2
4	1.4	4.2	0.8	3.4	5.1
8	1.7	4.6	1.0	3.8	6.4
16	1.8	4.7	1.2	3.9	4.8
24	4.6	5.4	4.6	4.6	5.4
SEM[b]	0.48	1.2	1.15	1.2	5.01
Response			P > F		
Linear	<0.0001	0.012	0.006	0.033	0.327
Quadratic	0.369	0.099	0.348	0.191	0.391
Cubic	0.026	0.113	0.366	0.169	0.546
Quartic	0.872	0.46	0.848	0.422	0.803

[a] Abbreviations: NDF, neutral-detergent fiber; ADF, acid-detergent fiber; HEMI, hemicellulose; and CELL, cellulose.

[b] Standard error of the mean.

Table 7. Losses of dry matter (DM) in orchardgrass forage predicted on the basis of concentrations of fiber components after application of graded levels of simulated rainfall.

Simulated rainfall	NDF[a]	ADF	HEMI	CELL	Lignin
in			%		
0	0	0	-0.1	0	-1
2	4.4	2.8	5.1	4.3	3
4	5.6	5.8	5.2	5.4	2.6
8	6.7	5.9	7.3	7.2	6.9
16	9.1	8.9	9.3	9	12.4
24	10.2	9.1	11.2	9.4	18.4
SEM[b]	0.71	1.01	1.4	1.24	5.63
Response			P > F		
Linear	<0.0001	<0.0001	<0.0001	<0.0001	0.01
Quadratic	0.001	0.008	0.091	0.014	0.908
Cubic	0.029	0.258	0.182	0.192	0.917
Quartic	0.038	0.169	0.33	0.362	0.942

[a] Abbreviations: NDF, neutral-detergent fiber; ADF, acid-detergent fiber; HEMI, hemicellulose; and CELL, cellulose.

[b] Standard error of the mean.

Table 8. Linear regressions of dry matter (DM) losses predicted with various internal markers on actual losses measured gravimetrically for bermudagrass and orchardgrass forages.

Marker[a]	Forage[b]	N[c]	Slope	SE_{slope}[d]	P_{slope}[e]	Intercept	SE_{int}[f]	P_{int}[g]	r^2	$P_{regression}$[h]
						---------- % ----------				
NDF	B	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
	O	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
	COMB[i]	12	1.12	0.062	0.075	- 0.5	0.30	0.122	0.971	< 0.0001
ADF	B	6	1.02	0.305	0.962	1.5	0.80	0.139	0.735	0.029
	O	6	0.99	0.065	0.879	0	0.41	0.996	0.983	0.001
	COMB	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
HEMI	B	6	0.93	0.218	0.754	- 0.7	0.57	0.578	0.819	0.013
	O	6	1.09	0.106	0.439	0.3	0.67	0.644	0.964	0.001
	COMB	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
CELL	B	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
	O	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
	COMB	12	0.92	0.077	0.304	1.0	0.37	0.024	0.935	< 0.0001
Lignin	B	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
	O	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
	COMB	12	1.62	0.259	0.037	- 1.1	1.26	0.421	0.796	< 0.0001

[a] Abbreviations: NDF, neutral-detergent fiber; ADF, acid-detergent fiber; HEMI, hemicellulose; CELL, and cellulose.
[b] Forage: B, bermudagrass; O, orchardgrass; and COMB, regression includes data from both forages.
[c] Number of treatment means in the linear regression.
[d] Standard error of the slope.
[e] Probability that the slope = 1.
[f] Standard error of the intercept.
[g] Probability that the intercept = 0.
[h] P > F for the overall regression model.
[i] Indicates regression lines for orchardgrass and bermudagrass forages were homogenous, and data for both forages were combined.

Using Orchardgrass and Endophyte-Free Fescue Versus Endophyte-Infected Fescue Overseeded on Bermudagrass for Cow Herds: Final Four-Year Summary of Forage Characteristics

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Story in Brief

A trial was initiated on January 11, 2000 to 1) evaluate endophyte-free tall fescue (FF; *Festuca arundinacea* Schreb.) or orchardgrass (OG; *Dactylis glomerata* L.) overseeded into dormant common bermudagrass [*Cynodon dactylon* (L.) Pers.] sods for spring-calving cows, and 2) compare these forage systems with mixtures of endophyte-infected tall fescue (IF) and bermudagrass that are observed commonly throughout the southern Ozark region. Two management systems were evaluated in an effort to help the OG and FF forages persist; these include rotations to new paddocks twice weekly (2xW) or twice monthly (2xM). Evaluation date and the forage system x evaluation date interaction affected ($P < 0.004$) the percentage of the desired cool-season species in each pasture, but the forage system did not ($P = 0.262$). Generally, FF and IF remained stable over the entire study. Pasture systems with either FF-2xW and FF-2xM had similar ($P > 0.1$) percentages of FF on the June 2000 and November 2003 evaluation dates. For both rotation frequencies, the percentage of FF was greater than 58% on all dates since grazing was initiated. Through June of 2002, the 2xW and 2xM rotation systems maintained at least as high a percentage of OG as observed on the initial evaluation date (November 1999); however, the percentage of OG in pastures managed with 2xM fell off sharply ($P < 0.1$) from 34.1 to 14.7% between June and November 2002, and did not improve ($P > 0.1$) by the final (November 2003) evaluation date. These data suggest that FF may be a better choice than OG as an alternative to IF for spring-calving cow herds in the southern Ozark region.

Introduction

Many cow-calf enterprises in the Ozarks are maintained on pasture systems that are mixtures of endophyte-free tall fescue and common bermudagrass. The association of the fungus *Neotyphodium coenophialum* with tall fescue (IF) has a positive effect on plant persistence, but the toxins produced by this fungus negatively affect livestock performance. Generally, other perennial cool-season grasses, such as endophyte-free tall fescue (FF) and orchardgrass (OG), have persisted poorly when subjected to the same harsh types of management as IF. A trial was initiated in January 2000 to evaluate the effectiveness of overseeding FF or OG into dormant common bermudagrass sods for spring-calving cows. Our objective was to compare these forage management systems with a typical mixture of approximately 50% IF and common bermudagrass that was managed with a twice monthly (2xM) rotation schedule. This is a final report and includes data collected from 2000 to 2003.

Experimental Procedures

Establishment and Maintenance of Pastures. Nine 10-acre mixed-species pastures with a base sod of common bermudagrass were sprayed (Roundup Ultra™, Monsanto Company, St. Louis, Mo.) 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 'Kentucky 31' FF and 'Benchmark' OG were overseeded into four and five of these pastures, respectively. The remaining four pastures had mixtures of IF and bermudagrass that had been established previously, and these were retained as controls that represent typical pastures in the southern Ozarks. In April 1999, three independent observers evaluated each pasture overseeded with OG and FF for continuous row coverage by cool-season seedlings. During the 1999 growing season, overseeded pastures were grazed lightly to control forage growth. All pastures were fertilized with urea (46-0-0) at a rate of 60 lbs N/acre on September 9 or 10, 1999. Similar applications were made each subsequent year in mid February, early June, and early September; therefore, a total of 180 lbs N/acre were applied annually. Soil tests were obtained each year in August and any needed phosphorus (P), potassium (K), or lime was applied based on soil test recommendations each September. All 13 pastures were evaluated prior to initiating the trial (November 1999) 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 the experimental pastures.

Pasture Rotation Schedules. Ten-acre pastures managed with the twice weekly (2xW) rotation frequency were subdivided into eight 1.25-acre paddocks prior to initiating the trial using electric fencing to supplement existing permanent fences. Cattle grazing these pastures were rotated to fresh paddocks twice each week at

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intervals of approximately 3.5 d. For pastures managed with the 2xM rotation frequency, each 10-acre pasture was subdivided into two 5.0-acre paddocks. For the 2xM rotation system, cattle were rotated to fresh paddocks twice each month at approximately 15-d intervals. The OG and FF pastures were managed with both 2xW and 2xM rotation schedules, but the IF control pastures were managed with the 2xM rotation frequency only. There were two replications of the FF-2xW, FF-2xM, OG-2xM forage systems, three replications of OG-2xW, and four replications of the IF-2xM control. 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 a single 1.25-acre paddock in the 2xW system and on an area of comparable size constructed with electric wire for the 2xM system. Hay offered to each replicate was tabulated for each year and evaluated as a response variable.

Cattle Management. Sixty-five spring-calving cows (1,208 ± 150 lb) were stratified by weight, age, and breeding and assigned to one of the 13 pastures (five per pasture) on January 11, 2000. 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 live 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, extra grazing cows were co-mingled and managed with the same rotation schedule as the five permanently assigned cows.

Statistics. Forage species composition, basal cover, and forage availability data were analyzed as a split-plot design with grazing systems as the whole-plot term and evaluation date as the repeated measures term. The quantity of hay offered was analyzed similarly, with year as the repeated measures term. However, to clarify and concisely summarize these results, data also were averaged over four years and single-degree-of-freedom contrasts were used to compare the five forage systems. Contrasts included: 1) IF vs. OG and FF; 2) FF vs. OG, 3) 2xW vs. 2xM (excluding IF), and 4) the interaction of contrasts #2 and #3. Significance for all response variables was declared at $P < 0.1$ unless otherwise indicated.

Results and Discussion

Establishment. Visual evaluation of continuous drill row coverage by cool-season seedlings in April 1999 indicated that there were no differences ($P = 0.81$) between OG and FF pastures. The overall mean 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 remove the entire existing bermudagrass canopy adequately prior to seeding.

Forage Availability. The sampling date main effect and the interaction of main effects affected forage availability ($P \leq 0.010$), but grazing system did not ($P > 0.601$). Overall, considerable care was taken to avoid overgrazing, and this is reflected in the overall mean forage availability (3,393 lb/acre) for the four-year study. It should be noted that the extra grazing cows used to control the flush of spring forage growth (Coblentz et al., 2004) partially controlled the accumulation of excessively mature forage in the late spring and reduced the mean forage availability across the whole study.

Cool-Season Grasses. The grazing system x evaluation date interaction affected ($P = 0.004$) the percentage of the desired cool-season species in each pasture. The percentage of FF and IF varied somewhat ($P < 0.1$) over the nine evaluation dates; however, on a practical basis, these forages remained relatively stable for the entire study (Table 1). Both of the rotation systems had greater ($P < 0.1$) percentages of FF on the last (November 2003) evaluation date than on the initial evaluation date (November 1999), and the percentage of fescue was greater than 58% on all dates after grazing was initiated (Table 1). Through June 2002, both rotation frequencies maintained a percentage of OG that was at least ($P > 0.1$) as high as observed on the initial evaluation date; however, the percentage of OG in pastures rotated 2xM declined sharply ($P < 0.10$) from 34.1 to 14.7% between June and November 2002, and was only 22.2% on the last (November 2003) evaluation date. With a greater rotation frequency (2xW), OG persistence was somewhat improved. The percentage of OG in 2xW pastures did not differ ($P > 0.1$) between the initial and final evaluation dates; however, there was a decline of 20.7 percentage units between the high of 56.9% observed during June 2002 and the final evaluation date.

Bermudagrass. Percentages of bermudagrass were not affected by forage system ($P = 0.550$), but were affected by evaluation date ($P = 0.002$) and the interaction of main effects ($P = 0.034$). Although the percentage of bermudagrass in IF and FF pastures varied ($P < 0.1$) somewhat over time, these differences were relatively minor, and the proportion of bermudagrass remained low for all evaluation dates (≤ 41.0%; Table 2). The shading caused by the high proportion of FF and IF likely limited the competitiveness of bermudagrass in these pastures. In OG pastures, the percentage of bermudagrass generally increased over evaluation dates with sharp increases ($P < 0.1$) observed after June 2002 for both the 2xW and 2xM rotation frequencies. For OG-2xM pastures, the percentage of bermudagrass reached a maximum of 59.7% in June 2003, indicating that bermudagrass was filling in areas in each pasture vacated by dying OG plants.

Other Species. Forage system did not affect ($P = 0.308$) the percentage of contaminating species in these pastures, but contamination was affected by evaluation date ($P = 0.0001$). Although tall fescue (FF and IF), OG, or bermudagrass accounted for the vast majority of the forage plants found in the experimental pastures, there were other contaminating grasses and broadleaf weeds. The predominate species included little barley, annual ryegrass, cheat, downy brome, crabgrass, goosegrass, and foxtail. Generally, contaminating species declined over time, from a high of 18.0% immediately before grazing was initiated to a low of 8.8% on the final evaluation date (Table 3).

Basal Cover. Basal cover was not affected by grazing system ($P = 0.679$) or the interaction of grazing system and evaluation date ($P = 0.354$), but was affected by evaluation date ($P < 0.0001$; Table 3). Generally, basal cover was relatively consistent over time, ranging from 36.3 to 51.5%, and falling below 42% on only two dates. The poorest ($P < 0.1$) levels of basal cover were observed in November 2000 (36.3%) and June 2001 (36.8%).

Hay Offered. There was an interaction of main effects ($P = 0.0256$) for total hay offered and hay offered per animal. Generally, more hay was offered on the nontoxic (OG and FF) pastures during 2000 and 2001 than in subsequent years, but these differences were not always significant ($P < 0.1$) statistically. Unlike the nontoxic forages, the minimum ($P < 0.1$) amount of hay offered on IF pastures occurred in 2001. During 2000, between 42.9 and 53.0% of the hay

was offered during the summer months to prevent overgrazing, but it was not necessary to supplement cattle with hay during the summer months in any subsequent year. When summarized over the entire four-year study, it was necessary to offer more (P = 0.0002) hay on nontoxic pastures than on IF. Roughly, this differential was about 5,000 lb/year or 1,000 lb/head/year for OG-2xW, OG-2xM, and FF-2xM pastures; however, intermediate responses were observed for FF-2xW.

Implications

The endophyte-free tall fescue overseeded into common bermudagrass sods persisted well over the four-year study. By avoiding overgrazing and using fertilization strategies that favor cool-season grass production, endophyte-free tall fescue can be a viable forage option, and may be a better choice than orchardgrass as a long-term alternative to endophyte-infected tall fescue for spring-calving cow herds.

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Table 1. Percentages (%) of orchardgrass (OG), endophyte-free tall fescue (FF), or endophyte-infected tall fescue (IF) forages in pastures managed with twice weekly (2xW) or twice monthly (2xM) rotation frequencies at Batesville, Ark. (1999-2003).

	Forage system				
Evaluation date	OG (2xW)	OG (2xM)	IF (2xM)	FF (2xW)	FF (2xM)
	%				
Nov-99	36.9^{c}	36.3^{abc}	49.0^{b}	49.2^{c}	54.0^{b}
Jun-00	52.1^{ab}	48.6^{a}	55.4^{b}	63.5^{ab}	68.8^{a}
Nov-00	32.9^{c}	34.4^{bcd}	54.9^{b}	58.2^{bc}	61.6^{ab}
Jun-01	50.4^{ab}	40.7^{ab}	54.2^{b}	62.2^{abc}	73.5^{a}
Nov-01	52.9^{ab}	31.9^{bcd}	48.6^{b}	67.5^{ab}	68.5^{a}
Jun-02	56.9^{a}	34.1^{bcd}	46.9^{b}	58.1^{bc}	64.7^{ab}
Nov-02	42.7^{bc}	14.7^{e}	53.4^{b}	61.3^{abc}	68.5^{a}
Jun-03	40.9^{c}	25.4^{cde}	56.2^{b}	69.1^{ab}	72.2^{a}
Nov-03	36.2^{c}	22.2^{de}	65.8^{a}	72.5^{a}	71.0^{a}
SE	4.51	5.52	3.91	5.52	5.52

^{a,b,c,d,e}Means in a column without common superscripts differ (P < 0.1).

Table 2. Percentages (%) of bermudagrass in pasture mixtures of orchardgrass (OG), endophyte-free tall fescue (FF), or endophyte-infected fescue (IF) overseeded into bermudagrass and managed with twice weekly (2xW) or twice monthly (2xM) rotation frequencies at Batesville, Ark. (1999-2003).

	Forage system				
Evaluation date	OG (2xW)	OG (2xM)	IF (2xM)	FF (2xW)	FF (2xM)
	%				
Nov-99	41.3^{abc}	46.0^{bcde}	30.2^{ab}	35.7^{ab}	31.5^{ab}
Jun-00	32.9^{cd}	38.6^{e}	28.8^{bc}	29.7^{b}	27.6^{ab}
Nov-00	48.3^{ab}	44.1^{cde}	28.0^{bc}	32.8^{ab}	35.4^{a}
Jun-01	34.2^{cd}	39.7^{de}	21.7^{c}	27.9^{b}	22.8^{b}
Nov-01	35.4^{cd}	52.2^{abc}	36.8^{a}	26.9^{b}	30.1^{ab}
Jun-02	31.5^{d}	49.4^{abcd}	37.7^{a}	41.0^{a}	34.1^{ab}
Nov-02	40.0^{bcd}	56.9^{a}	35.4^{ab}	33.1^{ab}	29.4^{ab}
Jun-03	44.4^{ab}	59.7^{a}	30.7^{ab}	29.4^{b}	26.6^{ab}
Nov-03	49.5^{a}	56.3^{ab}	28.5^{bc}	26.3^{b}	27.8^{ab}
SE	3.67	4.50	3.18	4.50	4.50

^{a,b,c,d,e}Means in a column without common superscripts differ (P < 0.1).

Table 3. Percentages of basal cover and other forage species in pastures evaluated at Batesville, Ark. (1999-2003).

Evaluation date	Basal cover	Other species
	%	
Nov-99	44.5[bc]	18.0[a]
Jun-00	45.2[bc]	10.8[cde]
Nov-00	36.3[d]	13.9[bc]
Jun-01	36.8[d]	14.6[b]
Nov-01	47.7[b]	9.9[de]
Jun-02	42.5[c]	9.2[e]
Nov-02	43.9[c]	12.9[bcd]
Jun-03	51.5[a]	9.1[e]
Nov-03	45.2[bc]	8.8[e]
SE	1.59	1.45

[a,b,c,d,e] Means in a column without common superscripts differ (P < 0.1).

Table 4. Bermudagrass hay offered to cattle grazing pastures containing orchardgrass (OG), endophyte-free fescue (FF), or endophyte-infected fescue (IF) and managed with twice weekly (2xW) or twice monthly (2xM) rotation frequencies at Batesville, Ark.

	Forage system				
Year	OG (2xW)	OG (2xM)	IF (2xM)	FF (2xW)	FF (2xM)
Total offered [1,2]	lb				
2000	23,898[a]	23,329[a]	15,932[a]	19,346	23,329[a]
2001	22,464[ab]	20,484[ab]	11,949[b]	19,471	21,203[ab]
2002	16,461[c]	18,209[b]	17,220[a]	16,500	18,359[b]
2003	19,347[bc]	19,346[ab]	17,354[a]	17,070	18,209[b]
Overall mean[3]	20,542	20,342	15,614	18,097	20,275
Hay offered/head	lb/hd				
2000	4,780[a]	4,666[a]	3,186[a]	3,869	4,666[a]
2001	4,493[ab]	4,097[ab]	2,390[b]	3,894	4,241[ab]
2002	3,292[c]	3,642[b]	3,444[a]	3,300	3,672[b]
2003	3,869[bc]	3,869[ab]	3,471[a]	3,414	3,642[b]
Overall mean[4]	4,108	4,068	3,123	3,619	4,055
Summer hay offered	% of total				
2000	42.9[a]	46.1[a]	49.1[a]	53.0[a]	51.3[a]
2001	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
2002	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
2003	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
Overall mean[5]	10.7	11.5	12.3	13.2	12.8

[a,b,c] Yearly means for a response variable without common superscripts differ (P < 0.1).

[1] Five cow-calf pairs per 4.0-ha pasture unit.

[2] Standard errors of forage system x year interaction means for n = 2 pastures per forage system are 1,711.9 lb 342.3 lb/head, and 1.85% for total hay offered, hay offered/head, and percentage of hay offered during the summer months, respectively.

[3] Hay offered on nontoxic pastures (OG and FF) was greater (P = 0.0002) than offered on IF pastures.

[4] Hay offered per head on nontoxic pastures (OG and FF) was greater (P = 0.0002) than offered on IF pastures.

[5] Percentage of total hay offered on FF pastures during summer months was greater (P = 0.062) than offered on OG pastures.

Using Orchardgrass and Endophyte-Free Fescue Versus Endophyte-Infected Fescue Overseeded on Bermudagrass for Cow Herds: Final Four-Year Summary of Cattle Performance

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Story in Brief

A trial was initiated on January 11, 2000 to 1) evaluate endophyte-free tall fescue (FF; *Festuca arundinacea* Schreb.) or orchardgrass (OG; *Dactylis glomerata* L.) overseeded into dormant common bermudagrass [*Cynodon dactylon* (L.) Pers.] sods for spring-calving cows, and 2) compare these forage systems with mixtures of endophyte-infected tall fescue (IF) and bermudagrass that are observed commonly throughout the southern Ozark region. Two management systems were evaluated in an effort to help the OG and FF forages persist; these include rotations to new paddocks twice weekly (2xW) or twice monthly (2xM). Actual weaning weight, adjusted 205-d weaning weight, total gain from birth to weaning, and average daily gain from birth to weaning were greater ($P \leq 0.083$) for calves on non-toxic forages (FF or OG) than for those on IF pastures. Calves raised on OG-2xW, OG-2xM, and FF-2xM exhibited a 47 to 59-lb advantage in actual weaning weight over those on IF pastures. It is not clear why calves raised on FF-2xW pastures exhibited only a 21-lb numerical advantage. Cows grazing OG and FF pastures exhibited higher ($P \leq 0.035$) body weights and body condition scores (BCS) at calving, breeding, and weaning than cows grazing IF pastures; however, BCS for cows grazing IF pastures remained within an acceptable range (6.1 to 6.7). Cow-calf performance was improved marginally by including non-toxic, perennial cool-season grasses in bermudagrass pastures, but establishment costs and additional management requirements, relative to those necessary for mixtures of IF and bermudagrass, may limit the acceptability of this approach.

Introduction

Many cow-calf enterprises in the Ozarks are maintained on pasture systems that are mixtures of endophyte-infected tall fescue (IF) and common bermudagrass. The association of the fungus *Neotyphodium coenophialum* with tall fescue has a positive effect on plant persistence, but the toxins produced by this fungus affect livestock performance negatively. Dilution with other forages is a commonly accepted management practice designed to limit the effects of the toxins produced by this fungus, and to improve animal performance. Unlike IF pastures in the northern part of the fescue region, many southern Ozark pastures that appear to be dominated by IF contain both IF and bermudagrass; in reality, these pastures often contain 60% IF or less. A trial was initiated in January 2000 to evaluate the effectiveness of overseeding endophyte-free tall fescue (FF) or orchardgrass (OG) into dormant common bermudagrass sods for spring-calving cows. Our objectives were to 1) evaluate FF or OG overseeded into dormant common bermudagrass sods for spring-calving cows, and 2) compare these forage systems with mixtures of approximately 50% IF and bermudagrass that are typical throughout the southern Ozark region.

Experimental Procedures

Cattle Management. Detailed descriptions of the establishment of FF and OG forages and all forage management practices are found in a companion report (Coblentz et al., 2004). Sixty-five spring-calving cows (1,208 ± 150 lb) were stratified by weight, age, and breeding and assigned to one of the 13 ten-acre pastures (five cows per pasture) on January 11, 2000. For pastures managed with a twice weekly (2xW) rotation frequency, cattle were rotated to fresh paddocks twice each week at intervals of approximately 3.5 d. For pastures managed with the twice monthly (2xM) rotation frequency, each 10-acre pasture was subdivided into two 5.0-acre paddocks, and cattle were rotated to fresh paddocks at approximately 15-d intervals. The OG and FF pastures were managed with both 2xW and 2xM rotation schedules, but the IF control pastures were managed with the 2xM rotation frequency only. 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 bermudagrass 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 monthly for body condition score (BCS) on a scale of 1 to 9 (1 = emaciated, 9 = obese). 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 and blood was drawn from the cows in June of each year to quantify levels of serum prolactin.

Cows initially assigned to a specific 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 live calves at the

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end of the calving season (May 1) were replaced with a primiparous cow and her calf, and these data were included in the statistical analysis for each year. All data presented are 4-year averages.

Extra Grazing Cows. 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 with the five permanently assigned cows and rotated to fresh paddocks as a single group. Additional grazing days, weight gains, and BCS for these extra cows were tabulated for each pasture and analyzed as response variables.

Statistics. Data were analyzed as a split-plot design with forage system (OG-2xW, OG-2xM, FF-2xW, FF-2xM, and IF) as the whole-plot term and year as the repeated measures term. While there was some year-to-year variability in the responses of cows, calves, and extra grazing cows, generally there were few interactions of main effects. Therefore, to concisely summarize results, only 4-year means for each forage system are presented and discussed. Four-year least-squares means were compared with four contrast statements that evaluated: 1) IF vs. non-toxic forages (FF and OG); 2) FF vs. OG; 3) 2xW vs. 2xM (excluding IF); and 4) the interaction of #2 and #3. Significance was reported at $P < 0.10$), unless otherwise indicated.

Results and Discussion

Calf Performance. Birth weight of calves (Table 1) was not affected by grazing system ($P > 0.10$). Actual weaning weight, adjusted 205-d weaning weight, total gain from birth to weaning, and average daily gain from birth to weaning were greater ($P \leq 0.083$) for calves raised on non-toxic forages (OG and FF) than for those on IF pastures. No other contrast was significant ($P > 0.10$) for any of these response variables. Calves raised on OG-2xW, OG-2xM, and FF-2xM pastures exhibited a 47 to 59-lb advantage in actual weaning weight over those on IF pastures. It is not clear why calves raised on FF-2xW pastures exhibited only a 21-lb numerical advantage. Overall, actual weaning weights for calves raised on all non-toxic pastures exhibited a statistical advantage ($P = 0.083$) of about 45 lb over weaning weights for calves raised on IF. Generally, calves raised on IF pastures with approximately 50% dilution exhibited a level of performance (actual weaning weight = 508 lb) that may be quite acceptable to the many part-time producers operating in northern Arkansas, but this performance was clearly poorer than observed for calves raised on the non-toxic forage systems.

Cow Performance. Cow weights and BCS (Table 2) at calving, breeding, and weaning were lower ($P < 0.035$) for cows grazing IF pastures than for those grazing OG or FF pastures; however, BCS for cows grazing IF pastures remained within an acceptable range (6.1 to 6.7) throughout the trial. At breeding, BCS were higher ($P = 0.028$) for cows grazing non-toxic pastures managed as 2xM compared to those managed with the higher rotation frequency, but all cows grazing OG and FF maintained a high BCS (7.0 to 7.4).

The mean age of cows did not differ ($P > 0.100$; Table 3) across forage systems. Milk production in May was higher ($P = 0.011$) by 2.2 lb/d for cows grazing non-toxic forages than for cows grazing IF, but milk production on non-toxic forages did not differ ($P > 0.10$) from that of IF in July. For both May and July evaluation periods, there was an interaction ($P \leq 0.032$) between non-toxic forages and rotation frequencies. For OG, milk production was numerically higher with the 2xW rotation frequency, while the inverse relationship occurred for FF. Concentrations of serum prolactin, which are normally low in cows consuming IF forages, were higher ($P = 0.005$) for cows grazing non-toxic pastures compared to those grazing IF (179 vs. 90 ng/mL). Pregnancy rate did not differ ($P > 0.10$) between nontoxic and IF forage systems, nor did any other contrast differ ($P > 0.10$) for this response variable. Overall, the mean pregnancy rate for the entire 4-year study was 85.9%.

Performance of Extra Grazing Cows. The extra grazing cows were effective at controlling spring forage growth, but this technique also was beneficial because the condition of these cows was improved. Final weights for extra cows leaving the experimental pastures and total grazing days did not differ ($P > 0.10$; Table 4) between non-toxic and IF forage systems, nor were any other contrasts significant ($P > 0.10$) for these response variables. However, there were consistent numerical advantages ($P > 0.10$) in final weight for cows grazing non-toxic pastures compared to those grazing IF; over the entire study, this advantage was about 57 lb (1,210 vs. 1,153 lb). Total gain, BCS change, and average daily gain were greater ($P \leq 0.049$) for extra cows grazing non-toxic pastures than for those grazing IF pastures. These advantages for non-toxic pastures were 59 lb, 0.3 BCS unit, and 1.17 lb/d, respectively, compared to extra cows grazing IF pastures. In addition, total gain, BCS change, and average daily gain were all greater ($P \leq 0.044$) for extra cows on OG pastures compared to those grazing FF pastures.

Implications

Over 4 years, cattle performance on non-toxic forage systems was better than observed for cattle grazing IF pastures with approximately 50% dilution; however, these differences were somewhat marginal. Based on the returns demonstrated by this study it remains unclear whether cow-calf producers will make the commitments necessary to establish and maintain these non-toxic forages. The excellent performance of extra grazing cows that were added to control the flush of spring growth may partially offset some of the cost of these management commitments.

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Table 1. Growth performance of calves weaned from orchardgrass (OG), endophyte-free tall fescue (FF), or endophyte-infected tall fescue (IF) pastures managed with twice weekly (2xW) or twice monthly (2xM) rotation frequencies at Batesville, Ark. (January 2000-October 2003).

Grazing system	Birth weight	Actual weaning weight	205-d adjusted weight	Total gain	Average daily gain
	lb				lb/d
OG (2xW)	82.9	567	554	485	2.29
OG (2xM)	82.2	562	557	479	2.32
FF (2xW)	80.7	529	519	448	2.14
FF (2xM)	81.8	555	553	474	2.29
IF (2xM)	80.0	508	496	428	2.03
SE[1]	1.92	26.7	22.5	25.4	0.101
Contrasts					
IF vs. OG + FF	NS[2]	0.083	0.032	0.081	0.028
FF vs. OG	NS	NS	NS	NS	NS
2xW vs. 2xM[3]	NS	NS	NS	NS	NS
Interaction[4]	NS	NS	NS	NS	NS

[1] Standard error of the 4-year grazing-system mean when n = 2 pasture replications.

[2] NS = nonsignificant, P > 0.100.

[3] Contrast excludes IF pastures.

[4] Interaction of FF vs. OG and 2xW vs. 2xM contrasts.

Table 2. Summary of weights and body condition scores (BCS; 1 = emaciated, 9 = obese) for cows grazing orchardgrass (OG), endophyte-free tall fescue (FF), or endophyte-infected tall fescue (IF) pastures managed with twice weekly (2xW) or twice monthly (2xM) rotation frequencies at Batesville, Ark. (2000-2003).

System	Calving weight	Breeding weight	Weaning weight	BCS calving	BCS breeding	BCS weaning
	lb					
OG-2xW	1394	1292	1314	6.8	7.0	7.1
OG -2xM	1477	1391	1409	7.0	7.2	7.2
FF-2xW	1455	1327	1321	7.1	7.0	7.0
FF-2xM	1464	1383	1369	7.2	7.4	7.2
IF-2xM	1343	1147	1125	6.7	6.5	6.1
SE[1]	28.2	45.9	43.2	0.08	0.15	0.16
Contrasts						
IF vs. FF and OG	0.011	0.035	0.027	0.021	0.011	0.005
FF vs. OG	NS[2]	NS	NS	NS	0.028	NS
2xW vs. 2xM[3]	NS	NS	NS	NS	NS	NS
Interaction[4]	NS	NS	NS	NS	NS	NS

[1] Standard error of the 4-year grazing-system mean when n = 2 pasture replications.

[2] NS = nonsignificant, P > 0.10.

[3] Contrast excludes IF pastures.

[4] Interaction of FF vs. OG and 2xW vs. 2xM contrasts.

Table 3. Summary of age, milk production, pregnancy rates, and serum prolactin levels for cows grazing orchardgrass (OG), endophyte-free tall fescue (FF), or endophyte-infected tall fescue (IF) pastures managed with twice weekly (2xW) or twice monthly (2xM) rotation frequencies at Batesville, Ark. (2000-2003).

System	Mean age	Milk production (May)	Milk production (July)	Serum prolactin[1]	Pregnancy rate
	years	lb/d		ng/mL	%
OG-2xW	4.7	15.5	10.0	197	81.7
OG -2xM	4.7	14.0	8.7	166	92.5
FF-2xW	5.0	12.3	7.6	127	87.5
FF-2xM	5.1	15.1	10.7	227	90.0
IF-2xM	4.9	12.0	8.8	90	82.5
SE[2]	0.4	0.82	0.89	27.4	8.9
Contrasts					
IF vs. FF and OG	NS[3]	0.011	NS	0.005	NS
FF vs. OG	NS	NS	NS	NS	NS
2xW vs. 2xM[4]	NS	NS	NS	NS	NS
Interaction[5]	NS	0.026	0.032	NS	NS

[1] Data from 2000 through 2002 only.

[2] Standard error of the 4-year grazing-system mean when n = 2 pasture replications.

[3] NS = nonsignificant, P > 0.10.

[4] Contrast excludes IF pastures.

[5] Interaction of FF vs. OG and 2xW vs. 2xM contrasts.

Table 4. Summary of cattle performance for extra grazing cows on orchardgrass (OG), endophyte-free tall fescue (FF), or endophyte-infected tall fescue (IF) pastures managed with twice weekly (2xW) or twice monthly (2xM) rotation frequencies at Batesville, Ark. (2000-2003).

System	Initial weight	Final weight	Total gain	BCS Change	Average daily gain	Total grazing days
	lb				lb/day	day
OG-2xW	1041	1226	186	1.3	3.07	270
OG -2xM	1032	1204	173	1.3	2.87	251
FF-2xW	1078	1215	138	1.1	2.14	245
FF-2xM	1054	1193	140	0.8	2.25	224
IF-2xM	1054	1153	100	0.8	1.41	244
SE[1]	35.5	37.9	10.8	0.16	0.309	18.5
Contrasts						
IF vs. FF and OG	NS[2]	NS	0.001	0.049	0.003	NS
FF vs. OG	NS	NS	0.016	0.044	0.043	NS
2xW vs. 2xM[3]	NS	NS	NS	NS	NS	NS
Interaction[4]	NS	NS	NS	NS	NS	NS

[1] Standard error of the 4-year grazing-system mean when n = 2 pasture replications.

[2] NS = nonsignificant, P > 0.10.

[3] Contrast excludes IF pastures.

[4] Interaction of FF vs. OG and 2xW vs. 2xM contrasts.

Effect of Harvest Date on in situ Disappearance, Forage Quality, and Yield of Brown Midrib and Non-Brown Midrib Sorghum x Sudangrass Hybrids

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Story in Brief

When present in warm-season annual plants, the brown midrib (BMR) gene can result in reduced lignification, which increases digestibility and intake of forages by ruminants. Sorghum x sudangrass hybrids Sweet Sunny Sue (SSS) , a non-BMR sorghum-sudangrass; Nutri + Plus BMR (Nutri +), a BMR sorghum-sudangrass; and MS505 DS (MS505) an experimental BMR hybrid were planted in twelve 0.5-acre plots to test the effect of date of harvest and the presence of the BMR gene on forage yield, quality, and in situ DM disappearance. Standing height was measured and maturity was assessed using a coding system developed by Biologische Bundesanstalt, Bundessortenamt and Chemical Industry (BBCH) on plants in ten 5.4 ft^2 quadrants per plot prior to hand clipping to 1-in stubble height at weekly intervals from 34-d post-planting. Clippings were then dried at 122°F in a forced air oven to determine DM yield. Samples from d 34, 48, and 63 were composited within plot for determination of NDF, ADF, N, and in situ DM disappearance. Dry matter yield increased ($P < 0.01$) with harvest date in all varieties; however, the increase for the BMR gene forages was at a slower rate than for the other forage. Concentrations of NDF and ADF were lower ($P < 0.01$) for the BMR than the non-BMR varieties, while N concentrations were not affected ($P > 0.41$) by variety across harvest dates. Effective degradability (using 3.5% passage rate) was higher ($P < 0.02$) for BMR varieties than non-BMR at all harvest dates. These results indicate that forage fiber fractions are reduced and in situ DM disappearance is improved with the inclusion of the BMR gene.

Introduction

Warm-season perennial grasses such as bermudagrass and switchgrass develop lignin rapidly as they mature, which reduces their digestibility (Ball et al., 2002). While these types of grasses may be high in CP, it may be unavailable to the animal because of being trapped in the highly lignified cell walls. Warm-season annuals such as sorghum-sudangrass hybrids can contribute to the development of year-round forage systems where high forage quality is important, such as for lactating dairy cows or rapidly growing animals (Fribourg, 1995). Warm-season annual grasses tend to be more drought tolerant, more responsive to N fertilization, and of higher quality than warm-season perennials. Stage of maturity of forage crops has a large impact on forage quality. For instance, extending the harvest interval from 4 to 7 weeks can reduce the CP content of bermudagrass hay by more than 50%. This loss in hay quality will affect the productivity of animals; in that, lactating beef cows and growing cattle require CP levels of 10 to 13%. Brown-midrib (BMR) mutations, when present in the homozygous recessive state, result in reduced lignification and cell wall concentration, and increased digestibility and voluntary intake by ruminants (Cherney et al., 1991). Highly lignified forages remain in the rumen longer because of their slow rate of digestion, decreasing DM intake which reduces animal performance (Ball et al., 2002). This research was designed to determine the effect of harvest date and the presence of the BMR gene on forage DM yield, quality constituents, and in situ DM disappearance.

Experimental Procedures

Sweet Sunny Sue (SSS), a non-BMR sorghum-sudangrass; Nutri + Plus BMR (Nutri +), a BMR sorghum-sudangrass; and MS505 DS (MS505), an experimental BMR sorghum x sudangrass were planted in twelve 0.5-acre plots on June 26, 2003 to test effect of harvest date and the presence of the BMR on forage yield, quality, and ruminal in situ DM disappearance. These plots were located at the Southwest Research and Extension Center in Hope, Ark. Standing height and Biologische Bundesanstalt, Bundessortenamt and Chemical Industry (BBCH) based maturity scores (Stauss, 1994) were assessed on plants in ten 5.4 ft^2 quadrants per plot prior to clipping to 1 in height with garden shears at weekly intervals beginning 34 d after planting. Samples were dried in a forced air oven at 122°F to a constant weight, and weighed DM yield was determined. Dried sorghum-sudangrass samples were ground to pass a 2mm screen in a Wiley Mill (Arthur H. Thomas, Philadelphia, Pa.). Composite sub-samples for d 34, 48, and 63 were retained to determine ruminal in situ DM disappearance and analysis of N, NDF, and ADF. For in situ DM disappearance, 1-g samples were weighed into ANKOM F57 filter bags (25 µm pore size; ANKOM Technology, Macedon, NY). Duplicate samples were placed simultaneously in the ventral rumen of three ruminally cannulated steers (BW = 1,288 ± 22.9 lb) and incubated for 6, 12, 24, 36, 48, 72, 96, or 120 hours. All animal procedures in this experiment were approved by the University of Arkansas Institutional Animal care and use committee. Steers were maintained on free-choice bermudagrass and dallisgrass mixed hay (10% CP, 55% TDN). Samples from each harvest date were incubated in one steer during each period in a 3 x 3 Latin square. Upon removal the samples were rinsed in a hand-operated washer (Wonder Clean; Wonder Wash Corp., Bala Cynwyd, Pa.) 10 times for 2 min each until rinse water was clear. Effective degradability was calculated by $A + B (K_d/K_d + K_p)$, where the A fraction is immediately soluble in the rumen, the B fraction is potentially degradable and disappears at a measurable rate, K_d is defined as the rate of disappearance, and K_p or ruminal particulate passage rate was assumed to be 3.5%/h.

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The effect of harvest date and variety on forage maturity and DM yield were analyzed by regression using PROC REG in SAS (SAS Institute, Inc., Cary, N.C.). Forage NDF, ADF, and N was analyzed as a completely random design using PROC GLM of SAS. In situ DM disappearance was analyzed as a Latin square design using PROC MIXED in SAS.

Results and Discussion

In the regression analysis of DM yield (Figure 1) the effect of harvest date and the harvest date by BMR gene interaction were significant ($P < 0.04$). This analysis reveals that DM yield increased ($P < 0.01$) with advancing harvest date for all varieties, but that DM yield was higher ($P = 0.04$) for the non-BMR gene variety than the BMR varieties at later harvest dates. In the regression analysis of BBCH maturity scores, the effects of harvest date, BMR gene, variety of BMR hybrid, and the interactions were significant ($P < 0.01$). Lower DM yield with the BMR varieties may be a result of lower ($P < 0.01$) maturity scores of the BMR varieties compared to non-BMR on later harvest dates. Within BMR forages, MS505 had higher maturity scores ($P < 0.01$) on later harvest dates than Nutri +. On d 34, the predicted maturity scores for the hybrids were of 29, 32, and 32 for SSS, Nutri +, and MS505, respectively. A maturity score of 30 corresponds to the beginning of stem elongation. On d 48, predicted maturity scores were 46, 40 and 43 corresponding to late, early, and mid-boot stage of development, respectively. On d-63, predicted maturity scores were 63, 50, and 55 corresponding to anthesis, early-heading, and mid-heading, respectively.

The effects of harvest date and BMR gene on forage quality are shown in Table 1. Concentrations of fiber constituents (NDF, ADF, and ADL) increased with advancing harvest date, and CP concentrations decreased with advancing harvest date. Concentrations of NDF and ADF, were lower ($P < 0.01$) for the BMR varieties than the SSS across harvest dates. Acid detergent lignin was lower ($P < 0.01$) for the BMR varieties than non-BMR on d 63, but CP concentrations were not affected ($P > 0.41$) by variety at any harvest date. Reductions in fiber fractions observed in BMR hybrids compared to the non-BMR indicate higher digestibility, which agrees with increased ($P < 0.02$) effective in situ DM disappearance for BMR varieties over non-BMR at all harvest dates. The effective disappearance decreased for all hybrids over harvest dates ($P < 0.01$). The harvest date by variety interaction for effective DM disappearance was also significant ($P < 0.01$). Based on equations from the NRC (1996), at 34 d post-planting, there was adequate energy to promote ADG in a 500 lb medium-frame steer of 0.55 lb from non-BMR or 0.77 lb from BMR hybrids. Forages cut from non-BMR on d 48 or 63 would not meet maintenance requirements of these steers, while the BMR hybrids would promote 0.12 to 0.33 lb gain/d. Similarly for mid-gestation beef cows, the non-BMR hybrid would meet the maintenance energy requirements only up to d 34, while the BMR hybrids would meet maintenance energy requirements through the entire 63-d harvest period. But the BMR hybrids would only meet the maintenance energy requirements of late gestation beef cows up to the 34-d harvest.

Implications

The present study provides evidence that the BMR gene addition to warm season forages such as sorghum x sudangrass hybrids may improve the quality. These results indicate superior forage quality of sorghum x sudangrass hybrids with the BMR gene, but forages must be harvested at the proper stage of maturity for increased forage quality.

Acknowledgments

The authors would like to thank Patrick Capps for his assistance with data collection and analysis. The authors would also like to thank Kaufman Seed for providing the seed for this project.

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Table 1. Effect of day of harvest on quality constituents of brown midrib (BMR) and non-BMR sorghum x sudan hybrids.

	Variety[a]				Contrast	
Constituent/ Harvest Day	SSS	Nutri +	MS505	SE	BMR vs Non-BMR	MS505 vs Nutri +
	% of DM					
NDF[b]						
34	65.2	62.3	63.6	1.09	<0.01	0.13
48	71.4	68.5	68.8	0.84	<0.01	0.63
63	70.5	66.1	68.7	1.15	<0.01	<0.01
ADF						
34	33.3	29.7	30.4	0.72	<0.01	0.16
48	39.5	33.5	34.8	1.14	<0.01	0.15
63	38.5	32.5	33.5	0.61	<0.01	0.04
ADL						
34	4.9	3.1	4.4	1.22	0.2	0.17
48	4.9	5.1	3.9	1.32	0.64	0.28
63	5.2	3.0	3.0	0.35	<0.01	0.98
CP						
34	12.1	10.5	12.1	1.44	0.41	0.15
48	7.0	6.7	8.4	1.31	0.54	0.1
63	4.6	4.7	5.0	0.61	0.51	0.61
Effective degradability						
34	56.0	58.5	58.5	1.94	0.02	0.47
48	46.9	52.3	52.1	1.94	<0.01	0.79
63	45.4	54.1	51.8	1.94	<0.01	0.17

[a] Sweet Sunny Sue (SSS), non-BMR; Nutri + Plus (Nutri +), BMR; MS505 DS (MS505), BMR

[b] Abbreviations: NDF, neutral detergent fiber; ADF, acid detergent fiber; ADL, acid detergent lignin; CP, crude protein

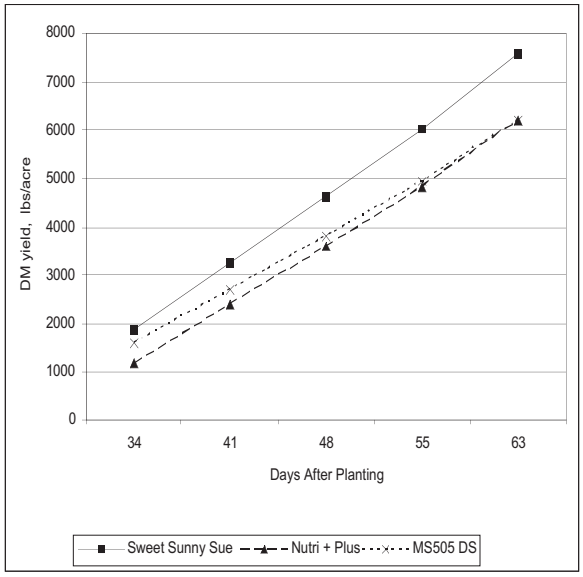

Fig. 1. Effect of Harvest Date (D) on predicted dry matter yield of brown midrib (Nutri + Plus BMR lb DM/acre = 172.7D-4,694.6, and M505 DS BMR, lb DM/acre = 159.1D-3,830.2) and non-brown midrib (Sweet Sunny Sue, lb DM/acre = 196.2D-4,795.5) sorghum x sudan hybrids.

Impact of Rotation Frequency and Weaning Date on Performance by Fall-Calving Cow-Calf Pairs Grazing Endophyte-Infected Tall Fescue Pastures

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Story in Brief

A 3-year study was initiated in April 2000 to investigate the impact of rotational management (2x monthly vs. 2x weekly) program and weaning date (mid April vs. early June) on production of fall-calving cow-calf pairs grazing Neotyphodium coenophialum–infected tall fescue overseeded with legumes and crabgrass. After three calving cycles, rotation frequency did not substantially impact ($P > 0.10$) cow weight, hay offered, milk production, calving interval, calf birth weight, or actual or adjusted weaning weights. However, cows rotated twice monthly had 0.3 units higher ($P < 0.05$) body condition score (BCS) at the time of breeding than cows rotated twice weekly. Calves weaned later (early June) had higher ($P < 0.05$) actual weaning weight and weighed more ($P < 0.05$) on the June weaning date, but 205-d adjusted weaning weights did not differ ($P > 0.10$) across weaning dates. Total weight loss during a simulated transport and sale, as well as the days required to regain the lost weight, were lower ($P < 0.05$) by early-weaned calves than by later weaned calves. Therefore, after three calving cycles, there appears to be little advantage for animal performance to more rapid rotation programs, and weaning fall-born calves grazing endophyte-infected tall fescue pastures at approximately 188 d of age appears to be detrimental to calf performance compared with delaying weaning until 243 d of age.

Introduction

Toxic compounds produced by the endophytic fungus *N. coenophialum* are blamed for tall fescue toxicosis, a syndrome in which cattle have elevated temperatures, eat less, and grow at a slower rate. Numerous studies have demonstrated that dilution of *N. coenophialum*-infected tall fescue with other forages, particularly legumes, is beneficial to animal performance. Also, based on previous work (Coffey et al., 2001), it appears that much of the negative impact of consuming tall fescue toxins occurs during the last month of spring. The goal of this project is to reduce the long-term impacts of tall fescue toxicosis on cattle through rotational grazing management and by reducing exposure of calves during times of highest toxin concentrations.

Experimental Procedures

Sixty pregnant (confirmed by rectal palpation) cows and heifers of predominantly Angus breeding were stratified by age and weight and allocated randomly to one of 11 pasture groups in early April, 2000. Pastures were composed of established stands of endophyte-infected tall fescue and ranged between 10 and 16 acres in size. The number of cows per group was determined to set an initial stocking rate of 2.5 acres/cow. Additional acreage was added in 2002 to provide 12, 16-acre pastures and additional cows were added to maintain a stocking rate of 2.5 acres/cow. The pasture area was located on a block of Clarksville very cherty silt loam; characterized as being deep, somewhat excessively drained, and having moderate to steep slopes. It is one of the predominant soil types in the Ozark Highlands and is not adapted to tillage.

Pastures were allocated randomly to one of four pasture and calf management treatments in a 2 x 2 factorial treatment arrangement (Table 1). Treatments consisted of dividing each pasture area into either two or eight paddocks and rotating cows to a new paddock either twice weekly or twice monthly. Within each of the rotation schedules, calves were weaned either in mid-April (188 days of age) or early June (243 days of age).

Broadcasting techniques were used to overseed the entire pasture area with a mixture of 2 lb/acre ladino clover, 6 lb/acre red clover, and 12 lb/acre lespedeza in late February and early March 2000. Crabgrass seed was broadcast at a rate of 4 lb/acre in May. Legumes and crabgrass were overseeded again in the spring of 2002.

Cows were fed corn-based supplements to meet NRC (1996) requirements during the breeding season. Endophyte–infected tall fescue hay harvested from another field on the research station was fed as needed during the winter when forage availability was low.

The forage fertility program consisted of applications of 40 lb N/acre in early June and late August. Phosphorus and potassium were applied per soil test recommendation in late August, and 1 to 2 lb boron/acre were applied each year in the spring to enhance legume growth. Available forage was estimated on a monthly basis using a calibrated disk meter when cows were grazing.

Cows were weighed and body condition score (BCS; 1 to 9 scale) estimated prior to the initiation of calving, prior to breeding, and at weaning. Milk production was determined prior to breeding using the weigh-suckle-weigh technique.

The weaning program consisted of vaccination against respiratory infection at 4 weeks followed by a booster vaccination 2 weeks prior to weaning. At weaning, calves from each treatment were removed from their dams, weighed, then transported approximately 30 miles to an auction facility and were handled according to routine auction procedures. Calves were weighed at the auction facility between 8 and 9:30 pm to determine sale value. Calves were then held overnight at the sale barn and transported back to the University of Arkansas facility. Upon return to the University of Arkansas cat-

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tle processing facility, calves were weighed, blood samples were gathered via jugular venipuncture and calves were kept in a drylot facility for 21 days and fed alfalfa hay ad libitum along with 2 lb of ground corn daily. Calves were observed three times daily for sickness over the 3-week period following weaning. Calves diagnosed as having respiratory illness were treated with Micotil® initially and with Nuflor® if a second treatment was necessary.

Statistical analyses were conducted using SAS (SAS Inst., Inc., Cary, N.C.) procedures for a repeated measures experiment with a 2 x 2 factorial treatment arrangement. The pasture group was considered the experimental unit for all measurements and year was the repeated measurement.

Results and Discussion

Cow weight at calving and breeding did not differ ($P > 0.10$) across treatments over the 3-year experiment (Table 2). Various interactions between year and treatments were observed ($P < 0.05$) for cow weight change between different production phases. Weight change between breeding and weaning and the overall weight change between calving and weaning were lower ($P < 0.05$) or less negative from cows whose calves were weaned in June compared with April. Body condition scores at breeding were 0.3 units higher ($P < 0.05$) for cows rotated twice monthly than for those rotated twice weekly. Milk production, calving interval, and the amount of hay offered during the winter did not differ ($P > 0.10$) among treatments. A three-way interaction was detected ($P < 0.05$) among year, rotation frequency, and weaning date for calving rate. During year 1, calving rates were higher ($P < 0.05$) from cows rotated twice monthly with calves weaned in April than from those rotated twice monthly and weaned in June or those rotated twice weekly and weaned in April. Calving rate from cows rotated twice weekly with calves weaned in June was intermediate and did not differ ($P > 0.10$) from the other groups. However, calving rates averaged greater than 92% over the 3-year period for all treatment combinations, and differences represent a difference of only one open cow per treatment in most instances.

Calf birth date and weight did not differ ($P > 0.10$) among rotation and weaning treatments (Table 3). Calves weaned in mid-April were 130 lb lighter ($P < 0.05$) at the time they were weaned than those weaned late, but pasture rotation frequency did not affect ($P > 0.10$) actual weaning weights. A tendency for a rotation frequency by weaning date interaction was detected ($P < 0.10$) for actual calf weight measured at the April weaning date. Weights of calves weaned in April from the twice-monthly rotation schedule were greater ($P < 0.10$) than those weaned in April from a twice-weekly rotation schedule. On the April weaning date, weights of calves to be weaned in June were intermediate and did not differ ($P > 0.10$) from either group weaned in April. Actual calf weights on the June weaning date were 74 lb heavier ($P < 0.05$) from calves weaned in June compared with those weaned in April. Adjusted 205-d weaning weights (adjusted only for calf age) did not differ ($P > 0.10$) across rotation schedules or weaning dates. A tendency ($P < 0.10$) for a year by weaning date by rotation frequency interaction was observed for gain during the period between April and June weaning dates. Overall, however, weight gain during this period was greater ($P < 0.05$) by calves weaned in June compared with those weaned in April.

Actual weight loss during transport to the local auction facility, and total weight loss during the day calves were removed from their dams, transported to the auction facility, and returned to the experiment station was greater ($P < 0.05$) from calves weaned late (Table 4). Percentage shrink during transport to the auction facility tended ($P < 0.10$) to be lower and that during the evening at the auction facility tended to be greater ($P < 0.10$) from calves weaned in June compared with those weaned in April. Overall percentage shrink during transport to the auction facility and return to the experiment station did not differ ($P > 0.10$) among treatments. Daily gain during the 21-day receiving period was greater ($P < 0.05$) from calves previously managed in a twice weekly rotation compared with a twice monthly rotation, and from calves weaned in April compared with those weaned in June. Calves weaned in early June required approximately 11 more days ($P < 0.05$) to recover the weight that was lost during transport to the local auction facility and consumed more hay during the 21-day receiving period than calves weaned in April.

Implications

Fall-born calves grazing endophyte-infected tall fescue prior to weaning should not be weaned in mid-April. Early weaning appears to provide no benefit to the cow, and may have negative effects on calf performance that may not be overcome after weaning when calves are placed on non-infected forages. Calving rates on all treatments were greater than 92% indicating that fall calving may be a viable alternative for enhancing reproductive performance on toxic tall fescue.

Literature Cited

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Table 1. Treatment structure for an experiment to evaluate the impact of rotation frequency and weaning date on cow and calf production and forage species composition changes.

Forage management	No. pastures	Weaning date	Grazing duration	Rest duration
2X/mo rotation	3	Mid-April	14 days	14 days
2X/mo rotation	3	Early-June	14 days	14 days
2X/wk rotation	2[a]	Mid-April	3-4 days	24-25 days
2X/wk rotation	3	Early-June	3-4 days	24-25 days

[a]Two pasture replicates were used for the 2000 and 2001 grazing seasons and three replicates were used in the 2002 and 2003 grazing seasons.

Table 2. Performance of cows grazing endophyte – infected tall fescue pastures managed as a twice weekly or twice monthly rotation with calves weaned in mid-April or early June -- 3-year summary.

	2 rotations/month		2 rotations/week			
Item	April	June	April	June	SE	Effect[a]
Cow weights, lb						
Initial	1,090	1,091			0.5	
At calving[b]	1,394	1,330	1,332	1,301	30.0	Y
At breeding[c]	1,312	1,283	1,250	1,235	32.0	Y
At weaning	1,270	1,301	1,177	1,257	37.0	Y,r
Cow weight change, lb						
Calving to breeding	-79	-46	-73	-68	17.4	Y, Y*R*W
Breeding to weaning	-44	18	-68	22	16.3	W,Y,R*Y, Y*R*W
Calving to weaning	-123	-29	-141	-44	25.1	W, Y
Body condition score						
At calving	7.0	6.7	6.8	6.8	0.12	Y
At breeding	6.3	6.3	5.9	6.1	0.13	R,Y,r*y
At weaning	6.3	6.5	5.9	6.3	0.23	Y, R*Y
Body condition score change						
Calving to breeding	-0.7	-0.4	-0.8	-0.7	0.1	R,Y
Breeding to weaning	0	0.2	0	0.2	0.2	Y
Calving to weaning	-0.7	-0.2	-0.8	-0.5	0.2	w,Y,r*y
Hay offered, lb	3,087	3,065	3,107	3,182	225.6	ns
Milk production, lb/d[d]	12.6	12.3	12.8	13.9	1.01	Y
Calving interval, d	365	362	364	363	3.5	Y
Calving rate, %	94.4	92.1	92.9	94.4	2.90	Y,Y*R*W
Calving rate, %						
Year 1	100.0[x]	82.0[y]	83.0[y]	94.3[xy]	5.15	
Year 2	94.3	100	100	100	4.95	
Year 3	88.9	94.4	94.4	88.9	4.95	

[a] Y = year effects (P < 0.05); R and r = rotation frequency effect (P < 0.05 and P < 0.10, respectively); Y*R*W = 3-way interaction among years, rotation frequency, and weaning date; W and w = weaning date effect (P < 0.05 and P < 0.10, respectively); R*Y and r*y = rotation frequency by year interaction (P < 0.05 and P < 0.10, respectively); ns = not different statistically (P > 0.10).

[b] Last weight prior to the start of the calving season.

[c] Beginning of breeding season.

[d] Milk production measured by the weigh-suckle-weigh technique when the calves averaged 2 months in age.

[xy] Means within the same row without a common superscript letter differ (P < 0.05).

Table 3. Performance of calves grazing endophyte – infected tall fescue pastures managed as a twice weekly or twice monthly rotation with calves weaned in mid-April or early-June -- 3-year summary.

	2 rotations/month		2 rotations/week			
Item	April	June	April	June	SE	Effect[a]
Birth date	Sept. 30	Oct. 2	Oct. 2	Sept. 30	2.5	ns
Birth wt, lb	78	76	79	79	3.7	Y
Actual weaning wt, lb	492	589	452	615	21.4	W,Y
April wt, lb	490[x]	463[xy]	450[y]	481[xy]	13.5	r*w,Y
June, wt, lb	542	589	514	615	21.4	W,Y
Wt gain to June, lb	450	514	419	536	19.2	W,Y*W
Wt gain to June, lb/day	2.18	2.12	2.03	2.18	0.084	Y,Y*W
Adjusted 205-day wt, lb[b]	542	509	512	529	19.8	y*w
Age at weaning, days	190	242	185	244	3.5	W
Wt gain April to June, lb	51	121	60	132	9.7	W,y*w,y*r*w

[a] ns = not different statistically (P > 0.10); Y = year effects (P < 0.05); W = weaning date effect (P < 0.05); r*w = rotation frequency by weaning date interaction (P < 0.10); Y*W and y*w= year by weaning date interaction (P < 0.05 and P < 0.10, respectively); y*r*w = 3-way interaction among year, rotation frequency, and weaning date (P < 0.10).

[b] Weaning weights were adjusted for age of the calf but additive factors for age of dam were not used.

[xyz] Means within a row without a common superscript letter differ (P < 0.05).

Table 4. Weaning performance of calves grazing endophyte-infected tall fescue pastures managed as a twice weekly or twice monthly rotation with calves weaned in mid-April or early June -- 3-year summary.[a]

	2 rotations/month		2 rotations/week			
Item	April	June	April	June	SE	Effect[b]
Wt loss, lb						
To salebarn	26	29	24	29	1.5	W,Y,W*Y
Sale to farm	11	15	9.0	18	2.3	W,Y,W*Y
Total	36	44	33	48	3.1	W,Y,W*Y
% Shrink						
To salebarn	5.3	4.9	5.0	4.7	0.17	W,Y,W*Y
Sale to farm	2.2	2.7	2.0	3.2	0.38	W,Y,W*Y
Total	7.4	7.4	6.8	7.7	0.40	Y,W*Y
ADG, receiving period, lb	2.09	1.54	2.47	1.94	0.157	R,W,W*Y
Recovery time, d	10.8	22.4	7.7	18.3	3.26	W, W*Y
Hay offered, lb	183	211	187	216	8.5	W

[a] At weaning, calves were removed from their dams, transported directly to a local auction facility and held without feed or water, weighed at approximately 9 pm, held overnight in pens with water, and transported back to the research station.

[b] W and w = weaning date effect (P < 0.05 and P < 0.10, respectively); Y = year effects (P < 0.05); W*Y = weaning data by year interaction (P < 0.05); R = rotation frequency effect (P < 0.05).

Impact of Rotation Frequency and Weaning Date on Forage Availability, Species Composition, and Digestibility of Endophyte-Infected Tall Fescue Pastures Overseeded with Crabgrass, Lespedeza, and Red and White Clover

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Story in Brief

A 3-year study was initiated in April 2000 to investigate the impact of rotational management (2x monthly vs. 2x weekly) program and weaning date (mid April vs. early June) on production of fall-calving cow-calf pairs grazing *Neotyphodium coenophialum*–infected fescue overseeded with legumes and crabgrass. Secondary objectives of the experiment were to monitor differences in quantity and quality of available forage and to evaluate changes in forage species composition. Pastures were predominated by tall fescue throughout the first three grazing seasons and the proportion of bare ground was greater ($P < 0.05$) in pastures rotated twice weekly vs. those rotated twice monthly. The proportion of legumes was very low in all treatment combinations, but the proportion of crabgrass continued to increase linearly ($P < 0.05$) and quadratically ($P < 0.05$) during the summer and fall samplings throughout the study regardless of rotation program. Digestibility and mineral concentrations varied minimally due to rotation frequency or weaning date. Therefore, after the third grazing season of the experiment, rotation frequency and/or weaning date has had little impact of forage species composition or forage quality.

Introduction

Toxic compounds produced by the endophytic fungus *N. coenophialum* are blamed for tall fescue toxicosis, a syndrome in which cattle have elevated temperatures, eat less, and grow at a slower rate. Numerous studies have demonstrated that dilution of *N. coenophialum*-infected fescue with other forages, particularly legumes, will have a positive benefit on animal performance and partially offset the negative toxic effects. These diluting forages are fairly persistent on better soils, but more intensive management may be needed to ensure the persistence of high quality diluting forages on shallow, more drought-prone soils. Also, based on previous work, it appears that much of the negative impact of consuming tall fescue toxins occurs during the last month of spring (June). The goal of this project is to reduce the long-term impacts of tall fescue toxicosis on cattle by improving longevity of overseeded, less persistent, non-infected forages, and by reducing exposure of calves to toxic fescue during times of highest toxin concentrations.

Experimental Procedures

Sixty pregnant fall-calving cows and heifers (Avg. calving date = Oct. 1) were stratified by age and weight and allocated randomly to one of 11 pasture groups in early April 2000. The groups of cows were then allocated to one of 11 pastures with established stands of infected tall fescue that ranged between 10 and 16 acres in size. The number of cows per group was determined to set an initial stocking rate of 2.5 acres/cow. Additional acreage was added in 2002 to provide 12, 16-acre pastures and additional cows were added to maintain a stocking rate of 2.5 acres/cow. The pasture area was located on Clarksville very cherty silt loam; characterized as being deep, somewhat excessively drained, and having moderate to steep slopes. It is one of the predominant soil types in the Ozark Highlands and is not adapted to tillage.

Pastures were allocated randomly to one of four pasture or calf management treatments in a 2 x 2 factorial treatment arrangement (Table 1). Pasture treatments were applied by dividing each pasture area into either two or eight sections or paddocks and rotating cows to a new paddock either twice weekly (2x/wk) or twice monthly (2x/mo). Within each of the rotation schedules, calves were weaned either in mid-April (Early; 189 d of age) or early June (Late; 243 d of age).

Broadcasting techniques (PTO driven broadcast seeder) were used to overseed the entire pasture area with a mixture of 2 lb/acre ladino clover, 6 lb/acre red clover, and 12 lb/acre lespedeza in late February and early March 2000. Crabgrass seed was broadcast at a rate of 4 lb/acre in May. Legumes and crabgrass were overseeded again in the spring, 2002. Prior to each seeding, the pastures were grazed closely with larger groups of cows. The pastures were then grazed again with large groups of cows to help trample in the seed.

Soil samples were taken at a 6-inch depth in 50 random locations within each pasture in July of each year. The samples were mixed and a representative sample sent to the Arkansas Soil Testing Laboratory. The forage fertility program consisted of applications of 40 lb N/acre in early June and late August. Phosphorus and potassium were applied per soil test recommendation in late August, and 1 to 2 lb boron/acre was applied each year in the spring to enhance legume growth. Lime was applied as needed based on soil test recommendations.

Available forage was estimated using a disk meter and samples for forage quality analyses were gathered by clipping forage to a 1-inch stubble height on a monthly basis while cattle were grazing. Samples were not taken when cows were being fed hay.

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Forage species frequency and basal cover were determined in February, July, and October of 2000; April, July, and October of 2001 and 2002; and April and July of 2003 by a modified step-point procedure. Each pasture was walked in a random zigzag manner carrying a step-pointer, which is a tripod constructed of PVC pipe. Extending beyond the tripod is a screw rod of approximately 15 inches. When the desired number of steps was walked, the step-pointer was placed on the ground. The observer recorded the forage species contacted by the screw rod. Direct contact was reported if the screw rod contacted the crown of a plant, otherwise bare ground was recorded if the screw rod did not contact the plant crown. If bare ground was recorded, the forage species closest to the screw rod within a 180° radius in front of the step-pointer was also recorded. Fifteen observations were measured per acre.

Statistical analyses were conducted using SAS (SAS Inst., Inc., Cary, N.C.) procedures for a repeated measures analysis of variance with year considered the repeated measurement. The error term for treatment effects was the variation in pastures within the rotational management by weaning date interaction.

Results and Discussion

Soil pH tended ($P < 0.10$) to be greater from the 2x/mo rotation schedule than from the 2x/wk rotation schedule (Table 2). Soil organic matter did not differ ($P > 0.10$) among treatments. Soil calcium was greater ($P < 0.05$) and soil potassium and magnesium tended ($P < 0.10$) to be greater in pastures rotated twice monthly compared with those rotated twice weekly. Available forage did not differ ($P > 0.10$) among treatments on most sampling dates (Figure 1).

The proportion of basal cover was greater ($P < 0.05$) on pastures rotated 2x/mo than on those rotated 2x/wk when averaged across sampling dates and years (Table 3). The pastures were dominated by tall fescue throughout the study, averaging 60% fescue across all sampling dates and years. Pastures contained very low proportions of red and ladino clovers, and lespedeza percentages were less than desirable across treatments. The summers of 2000 and 2001 were extremely dry, possibly contributing to the low percentage of clover in the pastures. Furthermore, the study site is a harsh environment with drought-prone soil. In all cases, weaning date or rotation frequency had little impact ($P > 0.10$) on forage species composition.

The year x season interaction was detected ($P < 0.05$) for each forage species. Therefore, data are presented by year and season in Table 4. Contrasts were used to determine linear and quadratic trends across years within a season. Basal forage cover decreased ($P < 0.05$) across years in the spring but increased ($P < 0.05$) across years in the summer and fall. Part of this could be directly attributed to seasonal differences, but part of these differences was also attributed to an infestation of armyworms that consumed the spring fescue growth in June 2001 causing a reduction in tall fescue plants with larger crowns that would tend to increase basal cover by the methods used in this study.

Tall fescue proportion responded both linearly ($P < 0.05$) and quadratically ($P < 0.05$) across years during the spring and fall, and responded linearly ($P < 0.05$) during the summer. Statistical trends (linear and quadratic decreases, $P < 0.05$) were also detected for the proportion of red and white clover, but those changes were minimal and of little significance to the grazing animal. Pastures contained their greatest proportion of lespedeza in July 2002 and 2003, averaging approximately 11 and 15% of the forage species. These increases in lespedeza are promising, but still do not reflect a substantial diluting effect on the tall fescue.

The proportion of crabgrass showed the most promise in a mixture with tall fescue at the research site. The proportion of crabgrass increased linearly ($P < 0.05$) and quadratically ($P < 0.05$) across years in both the summer and fall, reaching a peak at 29 and 24% of the total species present in October 2001 and July 2002, respectively. At this proportion, crabgrass should significantly dilute out some of the toxic effects of tall fescue. The major observed disadvantage of the crabgrass is that its production occurs primarily after mid-July. At this time, moisture restrictions can severely hamper its production.

Most of the experimental pastures contained plant species other than those mentioned above (Table 4). The other contaminating species were divided into other grasses and broadleaf weeds. Other grasses included orchardgrass, annual cool-season grasses such as cheat and little barley, and bermudagrass. Year effects were detected ($P < 0.05$) within seasons, but the proportion of other grasses or broadleaf species was not affected ($P > 0.10$) by rotational management or weaning date.

Effects of rotation, weaning, or their interaction were detected ($P < 0.05$) for in vitro digestibility on only five of 30 sampling dates, and a tendency for rotation or weaning effects were detected ($P < 0.10$) on another seven sampling dates (Table 5). The dates on which differences were detected appear to be distributed randomly across sampling dates. Therefore, weaning date and rotational management had little impact on forage in vitro digestibility.

The majority of forage mineral concentrations varied by year, but not because of rotation or weaning date (Table 6). Concentrations of most minerals were at or above the requirements for lactating cows. However, both copper and zinc were present at approximately half of the normal requirement for cows.

Implications

After over three years of grazing tall fescue pastures overseeded with legumes and crabgrass, differences observed in forage species composition, availability, and quality were due to season and year but not increased frequency of pasture rotation or weaning management. Therefore, it is likely that improvements in beneficial plant species, carrying capacity, and forage quality resulting from weaning date or more frequent pasture rotation will require greater than three years to become apparent on sites with steep slopes and poor soil.

Table 1. Forage availability (lb DM/acre), crude protein, acid detergent fiber (ADF), in vitro dry matter digestibility (IVDMD), and concentrations of ergovaline1 in stockpiled tall fescue at three dates from November to May.

Date	Availability, lb DM/acre	Protein, %	ADF, %	IVDMD, %	Ergovaline, ppb[2]
22-Nov	3,213	13.8	21.7	82	384
30-Jan	2,666	8.5	36.7	49.3	266
13-May	3,596	12.8	33.5	66.5	383

[1]Measure of toxin in tall fescue.

[2]Parts per billion.

Table 2. Soil chemical components from tall fescue pastures managed in a twice weekly or twice monthly rotation schedule with calves weaned in mid-April or early June. – 2000-2003 summary.

	2 rotations/month		2 rotations/week			
Item	April	June	April	June	SE	Effect[a]
pH	6.1	6.1	6.0	6.0	0.06	r, Y
Organic matter, %	3.8	3.6	3.9	3.5	0.18	Y
Phosphorus, lb/acre	139	134	141	116	6.7	w
Potassium, lb/acre	308	322	283	234	19.8	r
Calcium, lb/acre	2,140	2,278	1,957	1,980	100.7	R, y
Magnesium, lb/acre	109	111	96	96	5.9	r
Applied fertilizer, lb/acre[b]						
P_2O_5	11	4	3	8	4.5	
K_2O	46	45	50	66	6.8	Y
Lime, ton/acre	0.3	0.2	0.3	0.3	0.03	R, Y

[a] w = weaning date effect ($P < 0.10$); R and r = rotation frequency effect ($P < 0.05$ and 0.10, respectively); Y and y = year effects ($P < 0.05$ and 0.10, respectively).

[b] Average amount of fertilizer applied annually based on soil test recommendations.

Table 3. Forage species composition of tall fescue pastures managed in a twice weekly or twice monthly rotation schedule with calves weaned in mid-April or early June. – 2000 - 2003 summary.

	2 rotations/month		2 rotations/week			
Item	April	June	April	June	SE	Effect[a]
No. observations	33	33	27	33		
Basal cover, %	38.3	37.3	36.4	33.2	2.31	R, w
	% of plant species					
Tall fescue, %	55.8	66.9	56.2	60.9	2.93	ns
Red clover, %	0.6	0.5	0.5	1.0	0.25	ns
White clover, %	0.5	0.5	0.3	1.1	0.23	ns
Lespedeza, %	4.8	4.0	2.5	5.3	1.15	ns
Crabgrass, %	13.5	10.8	13.3	5.9	2.26	ns
Other grasses, %	16.4	11.4	19.0	16.9	1.83	ns
Other broadleafs, %	8.4	6.0	8.2	9.0	1.46	ns

[a] R = rotation frequency effect ($P < 0.05$); w = weaning date effect ($P < 0.10$); ns = no differences were detected ($P < 0.10$).

Table 4. Forage species composition of tall fescue pastures managed in a twice weekly or twice monthly rotation schedule with calves weaned in mid-April or early June. Composition within season and year.[1]

Year	Month	Basal cover	Tall fescue	Red clover	White clover	Lespedeza	Crabgrass	Other grasses	Other broadleaf
		%	% of plant species						
2000	February	71.0	75.0	0.8	0.4	0.0	0.0	13.8	10.0
	July	29.8	58.4	4.0	3.2	9.9	7.7	8.7	7.9
	October	22.4	82.2	0.1	0.1	0.4	1.2	9.2	6.6
2001	April	37.2	62.4	0.1	0.2	0.2	6.6	6.0	24.3
	July	26.8	64.8	0.1	0.0	4.7	7.0	11.9	11.3
	October	32.1	42.7	0.0	0.1	1.1	28.8	19.0	8.2
2002	April	36.8	64.9	0.2	0.0	0.0	0.0	30.5	3.5
	July	37.2	45.2	0.3	0.1	10.9	24.3	18.9	0.2
	October	32.4	46.9	0.1	0.2	3.0	24.0	22.7	3.0
2003	April	37.2	67.0	0.5	0.3	0.3	6.2	13.6	12.1
	July	36.6	52.2	0.7	0.8	15.0	9.3	19.7	2.3
	SE[2]	1.65	3.79	0.3	0.3	1.21	2.63	2.50	1.66

[1]Data combined across grazing and weaning treatments.

[2]Pooled standard error of the overall interactive mean (date by year) with 11 pasture observations during the spring-fall of 2001 and 12 pasture observations beginning in the spring of 2002.

Contrasts:

a = linear year effect within spring sampling periods ($P < 0.05$).

b = linear year effect within summer sampling periods ($P < 0.05$).

c = linear year effect within fall sampling periods ($P < 0.05$).

d = quadratic year effect within spring sampling periods ($P < 0.05$).

e = quadratic year effect within summer sampling periods ($P < 0.05$).

f = quadratic year effect within fall sampling periods ($P < 0.05$).

Table 5. In vitro digestibility (%) of tall fescue pastures managed in a twice weekly or twice monthly rotation schedule with calves weaned in mid-April or early June. – 2000 - 2003 summary.

		2 rotations/month		2 rotations/week			
Month	Year	April	June	April	June	SE	Effect[a]
April	00	77.3	77.1	78.0	76.2	1.55	
May	00	57.3	58.0	57.5	54.5	3.14	
June	00	54.8	58.4	56.2	55.2	2.79	
July	00	64.0	61.1	57.7	62.3	2.73	
August	00	57.8	61.0	57.5	61.2	1.76	w
September	00	51.2	51.5	55.0	53.5	2.24	
October	00	56.4	50.4	59.4	57.8	2.42	r
November	00	62.4	63.8	62.1	63.6	2.12	
December	00	66.1	66.7	69.1	74.4	2.50	r
April	01	60.7	64.8	78.5	72.5	2.68	R
May	01	79.8	81.1	79.0	76.4	1.32	r
June	01	45.8	44.8	46.4	48.2	1.48	
July	01	58.8	55.7	54.7	61.4	2.84	
August	01	62.1	63.7	57.1	60.3	3.62	
October	01	67.5	70.7	67.9	75.6	4.56	
November	01	62.7[bc]	60.8[bc]	54.1[c]	67.9[b]	2.45	R*W
December	01	47.6[d]	56.5[c]	65.0[b]	57.6[c]	2.04	R*W
March	02	63.7	62.3	70.6	66.2	1.99	R
April	02	67.8	65.1	69.6	67.2	1.35	w
May	02	71.1	71.2	73.0	70.4	2.05	
June	02	46.6	48.0	49.7	49.2	1.91	
July	02	45.8	47.9	48.8	46.9	1.61	
August	02	47.1	47.1	48.2	47.0	3.86	
September	02	55.9	50.6	56.0	51.2	3.71	
October	02	49.4	56.8	52.9	52.2	3.21	
November	02	57.0	61.4	57.1	69.4	3.32	W
April	03	84.7	85.1	84.2	86.7	0.70	w
May	03	74.6	76.6	74.5	75.1	1.15	
June	03	60.4	60.4	59.0	61.9	1.54	
July	03	55.5	60.8	52.0	60.2	3.33	w

[a] W and w = weaning date effect ($P < 0.05$ and $P < 0.10$, respectively); R and r = rotation frequency effect ($P < 0.05$ and 0.10, respectively); R x W = rotation frequency by weaning date interaction ($P < 0.05$).

[bc]Means in a row without a common superscript letter differ ($P < 0.05$).

Table 6. Forage mineral concentrations from tall fescue pastures managed in a twice weekly or twice monthly rotation schedule with calves weaned in mid-April or early June. – 2000-2003 summary.

	2 rotations/month		2 rotations/week			
Item	April	June	April	June	SE	Effect[a]
Calcium, %	0.46	0.47	0.45	0.48	0.012	Y
Phosphorus, %	0.25[b]	0.26[b]	0.23[c]	0.26[c]	0.005	W,R*W,Y,y*r
Magnesium, %	0.19	0.2	0.19	0.2	0.004	Y
Potassium, %	2.65	2.66	2.68	2.79	0.068	Y
Sulfur, %	0.16	0.16	0.15	0.16	0.003	Y
Sodium, %	0.01	0.01	0.01	0.01	0.001	Y
Iron, mg/kg	80.8[d]	75.6[de]	69.8[e]	77.0[de]	2.96	Y, r*w
Manganese, mg/kg	100.0	98.7	102.0	123.1	6.37	Y,r
Zinc, mg/kg	19.7	18.1	17.5	18.3	0.79	Y
Copper, mg/kg	4.5	4.5	4.3	4.9	0.16	Y

[a] Y = year effects ($P < 0.05$); R x W and r x w = rotation frequency by weaning date interaction ($P < 0.03$ and $P < 0.10$, respectively); r = rotation frequency effect ($P < 0.10$); r x y = rotation frequency by year interaction ($P < 0.10$).

[bc] Means in a row without a common superscript letter differ ($P < 0.05$).

[de] Means in a row without a common superscript letter differ ($P < 0.10$).

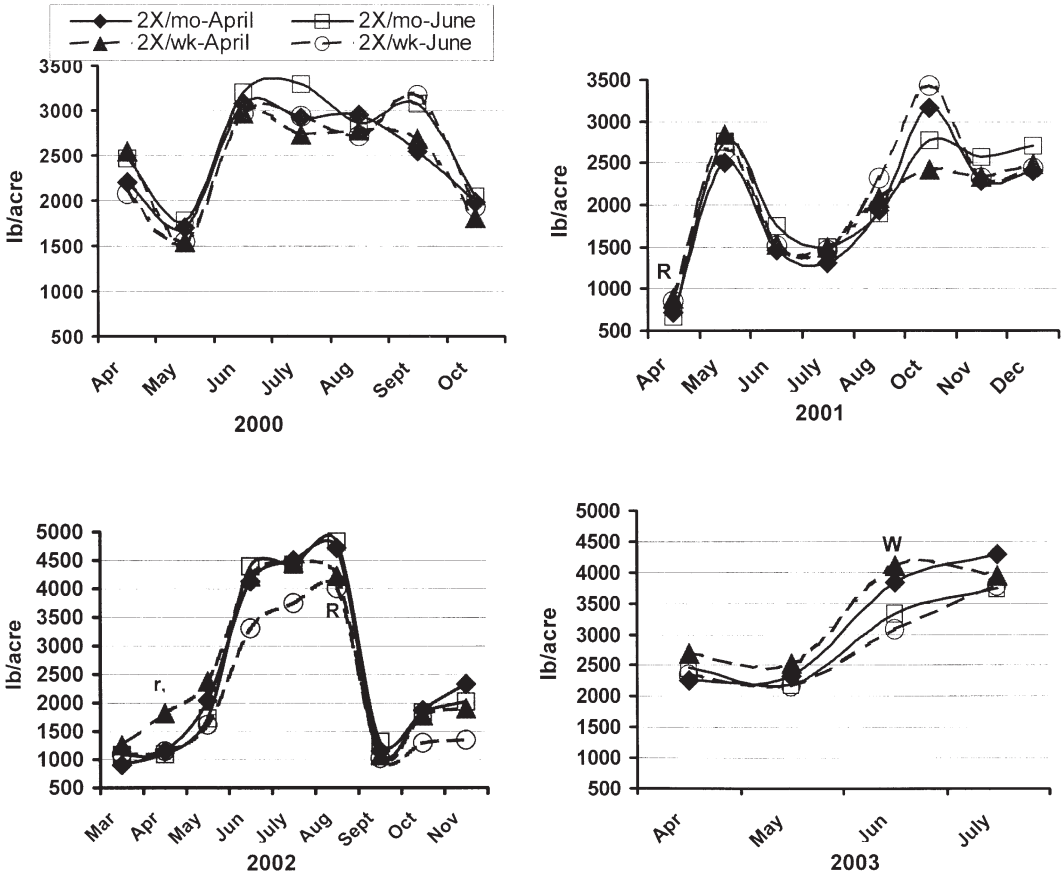

Fig. 1. Available forage (lb/acre) in tall fescue pastures managed in a twice weekly (2X/wk) or twice monthly (2X/mo) rotation schedule with calves weaned in early April or early June – 2000 - 2003 summary. W and w = weaning date effect ($P < 0.05$ and $P < 0.10$, respectively); R and r = rotation frequency effect ($P < 0.05$ and $P < 0.10$, respectively).

In Situ Digestibility of Tall Fescue Fertilized with Different Swine Manure Treatments and Harvested on Four Dates

J.L. Reynolds, R.Ogden, K.P. Coffey, C. Maxwell, and W.K. Coblentz[1]

Story in Brief

Forage digestibility varies across a growing season due to factors such as fertility and harvest date. Our objective was to evaluate dry matter digestibility (in situ) of tall fescue (*Lolium arundinacea*, Schreb.) fertilized with different swine manure treatments and harvested on different dates. Tall fescue ('GA-Jessup' variety) infected with a non-ergot alkaloid producing endophyte (Max-Q®) was either not fertilized (CONT) or fertilized (113 lb N/acre) with normal swine manure (NORM), swine manure from pigs fed phytase (PHY), or PHY treated with aluminum chloride (PHY+AL). Forage was allowed to accumulate before harvesting by clipping with hand shears (1-inch stubble height) on April 3, April 28, May 15, and June 23, 2003. Ruminally cannulated steers (n = 5; 1,208 lb BW) were used to evaluate these forages in situ. Degradation rate of DM was greater ($P < 0.05$) from NORM and PHY than from CONT and decreased ($P < 0.05$) with advancing harvest dates through the May 15 harvest. A fertility treatment by harvest date interaction was detected ($P < 0.05$) for most variables. The water soluble fraction and effective degradability were greater ($P < 0.05$) from fertilized than CONT fescue harvested April 3, but the improvement was not consistent across harvest dates for either measurement. Therefore, inclusion of phytase in swine diets along with subsequent treatment of the manure with aluminum chloride did not have consistent impacts on forage degradation compared with normal swine manure. Furthermore, fertilization with swine manure increased effective degradation of fescue initially, but the impact was not consistent at later harvest dates.

Introduction

Swine manure is used as a fertilizer for forages that may be used as pasture or harvested for later use. When swine manure is used as a source of N fertilizer, excess levels of phosphorus (P) are typically applied to the forage. The excess P can affect forage quality and, if extreme or poorly applied, can also pollute water sources due to runoff. Recent research has focused on methodology to limit the amount of P that is excreted from growing pigs. One such practice, feeding phytase, has been shown to improve P use by pigs and thereby reduce P excretion. This study was conducted to determine the impact of swine dietary or manure treatments on digestibility of tall fescue (*Lolium arundinacea*, Schreb.) fertilized with swine manure and harvested on different dates.

Experimental Procedures

Growing pigs were fed a normal growing and finishing ration, or a ration where phytase (0.03%) was added to the mixture. Phytase is an enzyme that breaks down phytate, which contains an indigestible form of P and is used to increase P availability. Manure was collected separately from pigs fed the normal and the phytase diets. Manure was analyzed, then applied to supply 113 lb N/acre to three of four experimental pastures. One pasture received no swine manure and served as a negative control (CONT). One pasture received normal manure (NORM), one pasture received the manure from pigs fed phytase (PHY), and one pasture received manure from pigs fed phytase with the manure treated with aluminum chloride (0.75%) at the time of application (PHY+AL). The manure was treated with aluminum chloride to chemically bind the P and prevent it from being solubilized and potentially leach into ground water. The experimental pastures were established originally from a field predominated by bermudagrass that was used as a hay meadow.

Representative sites within each pasture were chosen and enclosed with cattle panels bent into circles to protect those sites from grazing. Samples were collected on April 3, April 28, May 15, and June 23, 2003 to correspond to vegetative, boot, full bloom, and soft dough maturity stages. The forage was harvested by clipping with hand shears to a 1-inch stubble height. Samples were gathered at multiple locations on the April 3 sampling date prior to initiation of grazing. Thereafter, samples were clipped from one enclosure selected at random within each pasture. Samples were then dried to a constant weight under forced air (122°F) and ground through a 2-mm screen.

Five ruminally cannulated steers (1,208 lb BW) were used to determine the in situ ruminal degradation kinetics of the different tall fescue samples. Steers were adapted to a diet of alfalfa hay and concentrate mix for 10 days before initiation of the in situ study. Steers had ad libitum access to water.

Eight hundred (50/fertility x date) Dacron bags were filled with 5 g (0.18 oz) of dried forage and placed into separate mesh bags for each of nine time periods. Mesh bags were soaked in warm water prior to ruminal incubation to ensure accessibility of microorganisms to the samples. Bags were inserted simultaneously into the rumen of all steers prior to feeding. Bags were incubated for 3, 6, 9, 12, 24, 36, 48, 72, and 96 hours then placed into a washing machine and rinsed with cold water for 10 cycles consisting of a 1-minute agitation and 2-minute rinse. One bag for each forage and date combination was not inserted in the rumen but was washed as described above to determine the water-soluble fraction of each forage. Following rinsing, bags were dried to a constant weight under forced air (122°F), then weighed to determine forage degradation.

The forage fractions remaining in the in situ bags at the different time periods were analyzed using SAS (PROC NLIN; SAS Inst., Inc., Cary, N.C.) to determine degradation rate constants. These rate

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constants were used along with estimates of passage rate determined using an indigestible fraction of the diet to estimate effective ruminal degradation. Manure treatment and harvest date effects were analyzed as a randomized complete block design with a 4 x 4 (four treatments on four dates) factorial arrangement with steer as the experimental unit.

Results and Discussion

The water-soluble fraction of a forage represents the portion of the carbohydrates, protein, and minerals that are very rapidly solubilized and rapidly available for use by the rumen microorganisms and(or) the ruminant animal. The influence of fertility source on the water-soluble fraction varied across harvest dates (fertility by date interaction; Table 1). The water-soluble fraction of forage harvested on April 3 was lower ($P < 0.05$) from CONT than from forages fertilized with the swine manure treatments. On April 28, NORM had a greater ($P < 0.05$) water-soluble fraction than PHY + AL, and CONT and PHY were intermediate. Fescue fertilized with PHY had a higher ($P < 0.05$) water-soluble fraction on May 15 than the other forages. The water-soluble fractions of PHY and PHY+AL were higher ($P < 0.05$) on the June 23 harvest date compared with NORM, and CONT was intermediate and did not differ ($P > 0.10$) from the other treatments. The water-soluble fraction generally declined ($P < 0.05$) with advancing maturity within each fertility treatment. Therefore, the concentration of rapidly available nutrients declined with advancing maturity, but fertilizing with swine manure from pigs fed phytase appeared to help the forage maintain a higher level of rapidly available nutrients as the forage advanced in maturity.

Forage intake is generally limited by gut fill along with numerous other factors. A faster digestion rate of a forage means that gut fill will be reduced more rapidly following forage consumption, thereby allowing more room in the rumen for intake of a greater quantity of forage. In situ dry matter disappearance rate is a measure of the rate at which forage will be digested in the rumen and is directly proportional to forage intake.

The swine manure treatment by harvest date interaction was not significant ($P > 0.10$) for DM degradation rate. Degradation rate declined ($P < 0.05$) with advancing maturity through the May 15 harvest date but did not further decline ($P > 0.10$) through the June 23 harvest (Figure 1). Therefore, forage intake would likely decline through May 15, then level off. When averaged across harvest dates, DM degradation rate was greater ($P < 0.05$) from NORM and PHY than from CONT, and PHY+AL was intermediate and did not differ ($P > 0.10$) from the other fertility treatments (Figure 2). Therefore, it is possible that intake of NORM and PHY would be greater than that from CONT.

Effective ruminal degradation represents the ruminal digestibility of a particular forage. A fertility source by harvest date interaction was detected ($P < 0.05$) for effective ruminal degradation (Figure 3). Effective degradation decreased ($P < 0.05$) with each advancing harvest date within each fertility source, but the decrease over time was greater from fertilized forages (avg. 37% decline) compared with CONT (27% decline). Effective degradation was greater ($P < 0.05$) on April 3 from pastures fertilized with swine manure compared with CONT, but effective degradation did not differ ($P > 0.05$) among the three swine manure sources. Effective degradation did not differ ($P > 0.10$) among the four fertility treatments on April 28. By May 15, forage harvested from CONT had greater ($P < 0.05$) effective degradation than forage harvested from NORM and PHY+AL. On the June 23 harvest, effective degradation was greater ($P < 0.05$) from CONT and PHY than NORM, and PHY+AL was intermediate and did not differ ($P > 0.10$) from the other treatments. Changes in effective degradation over time are likely a result of differential plant maturity and seedhead formation. Fertilized plants appeared to produce greater leaf tissue, but likewise produced a greater number of stems per unit of area and the stems were much taller from fertilized plants. The shorter and less frequent stem production in the unfertilized pasture likely resulted in a greater leaf to stem ratio in those plants, resulting in increased digestibility of the whole plant at later maturity.

Implications

Addition of swine manure resulted in increases in the water-soluble components and effective ruminal degradation of tall fescue harvested at the late vegetative stage, but those improvements were not maintained as the forage advanced in maturity. Fescue fertilized with swine manure from pigs fed phytase appeared to maintain higher quality than fescue fertilized with other swine manure treatments. Therefore, impacts of maturity on forage quality were not reduced by increased fertilization with swine manure, and dietary manipulation to reduce phosphorus runoff may enhance forage quality.

Table 1. Water-soluble fraction of tall fescue forage fertilized with different types of swine manure and harvested on different dates.

	Fertility treatment[1]			
Date	CONT	NORM	PHY	PHY + AL
3-Apr-03	27.6 w[2] b[3]	31.5 w a	33.2 w a	31.8 w a
28-Apr-03	26.7 wx ab	27.4 x a	27.2 x ab	25.4 x b
15-May-03	24.9 x b	23.4 y b	27.4 x a	23.7 xy b
23-Jun-03	21.5 y ab	20.6 y b	23.4 y a	22.6 y a

[1] CONT = no swine manure applied, NORM = conventional swine manure applied, PHY = manure applied from pigs fed a diet with phytase; PHY+AL = manure applied from pigs fed phytase and then treated with aluminum chloride.

[2] w,x,y,z Means for harvest dates within a fertility treatment (column) that are not followed by a common letter differ ($P < 0.05$).

[3] a,b,c Means for fertility treatments within a harvest date (row) that are not followed by a common letter differ ($P < 0.05$).

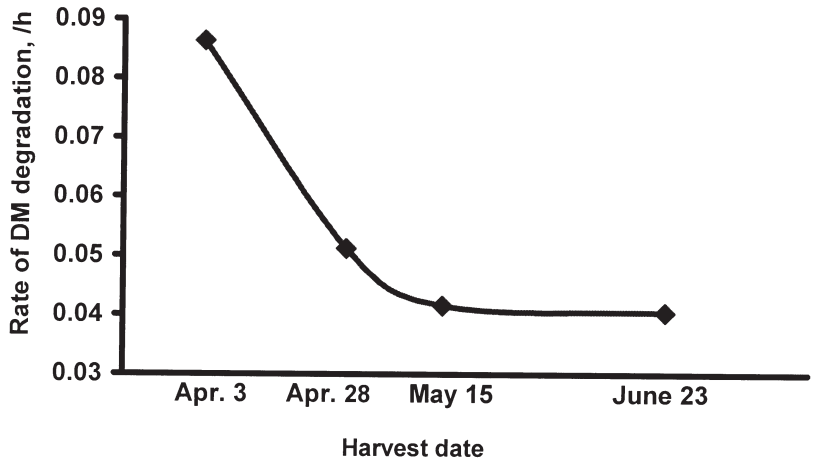

Fig. 1. Rate of ruminal DM degradation of tall fescue harvested on different dates. Means represent an average across different swine manure fertility treatments.

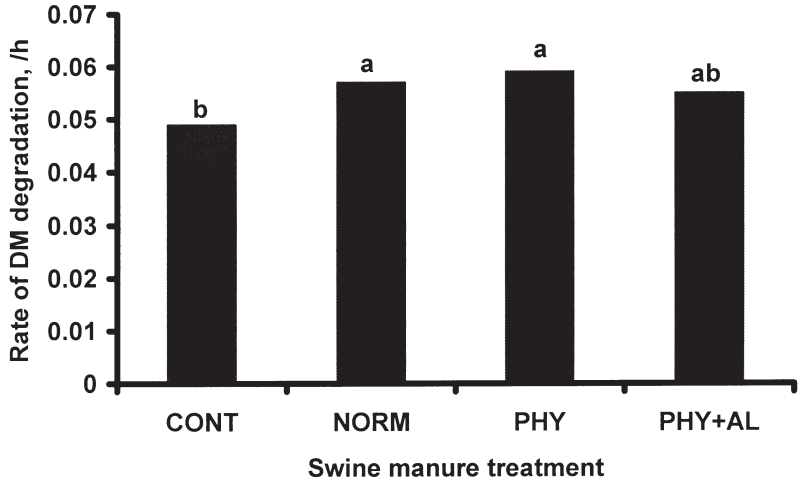

Fig. 2. Rate of ruminal DM degradation of tall fescue fertilized with different swine manure fertility treatments. Means represent an average across forage harvested on different dates. Means without a common superscript letter differ (P < 0.05). CONT = no swine manure applied, NORM = conventional swine manure applied, PHY = manure applied from pigs fed a diet with phytase, PHY+AL = manure applied from pigs fed phytase and then treated with aluminum chloride.

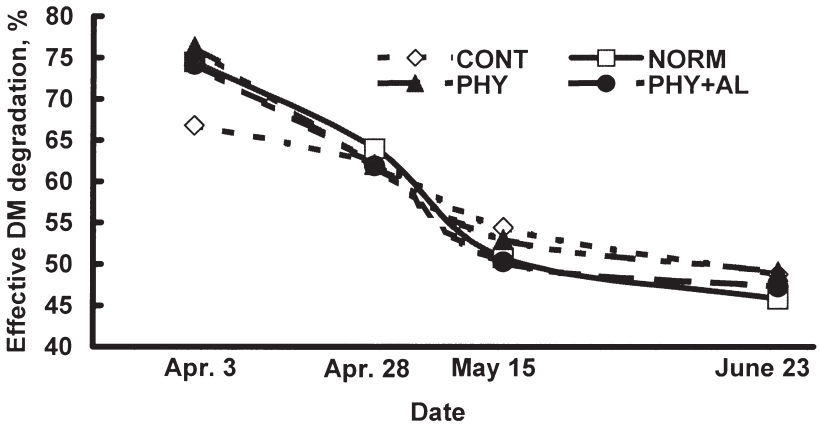

Fig. 3. Effect of swine manure treatment on effective ruminal DM degradation of tall fescue forage harvested on different dates. Means within a swine manure treatment differed (P < 0.05) with each advancing harvest date. CONT = no swine manure applied, NORM = conventional swine manure applied, PHY = manure applied from pigs fed a diet with phytase, PHY+AL = manure applied from pigs fed phytase and then treated with aluminum chloride.

Growth-Performance of Heifers Grazing Wheat and Ryegrass Pastures Sod-Seeded into Bermudagrass with Different Tillage Intensities and Seeding Dates

K.P. Coffey[1], G. Montgomery[2], W.K. Coblentz[1], W. Whitworth[2], and P. Francis[2]

Story in Brief

A total of 120 Gelbvieh x Angus crossbred heifers (552 ± 2.5 lb initial BW) were stratified by weight and allocated randomly to one of eight 5-acre pastures of common bermudagrass overseeded with wheat and ryegrass for a 3-year study beginning in December 2001 to compare the effect of seeding dates and tillage intensities on heifer growth performance. 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 were disked once (1x) and the other half were disked twice (2x) before seeding. Grazing began Dec. 20, 2001 on each pasture for year 1, Nov. 20, 2002 on all EARLY pastures and Dec. 5, 2002 on all LATE pastures in year 2, and Dec. 12, 2003 on all EARLY pastures and Jan. 8, 2004 on all LATE pastures in year 3. Grazing continued through May 11, 2002 in year 1, April 25, 2003 in year 2, and May 10, 2004 in year 3. Initial and average forage mass was greater ($P < 0.05$) from EARLY than from LATE seeded pasture. Three-year average BW and gain did not differ ($P > 0.10$) between seeding dates or tillage intensity, but winter animal gains varied with respect to treatment across years. Based on 3 years of grazing animal performance data, producers in south Arkansas 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 of winter annuals and more intensive tillage of the bermudagrass sod to determine if those practices would promote more fall forage growth, allowing for earlier grazing or greater animal gains.

Experimental Procedures

A total of 120 Gelbvieh x Angus crossbred heifers (552 ± 2.5 lb initial BW) grazed one of eight 5-acre pastures of common bermudagrass during the winters of 2002 through 2004 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 broadcast seeded during the first week of September (EARLY) and half were broadcast seeded in mid-October (LATE) of each year. Within each seeding date, half of the pastures were disked once (1x) and the other half were 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 to provide 50 lb/acre each 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.

Within each year, heifers were stratified by weight and allocated in a random stratified manner to each pasture. Grazing began Dec. 20, 2001 on all pastures and continued until May 11, 2002 in year 1. During year 2, grazing began Nov. 20, 2002 on EARLY pastures and on Dec. 5, 2002 on LATE pastures and continued until April 25, 2003. Grazing began Dec. 3, 2003 on EARLY and on Jan. 8, 2004 on LATE in year 3 and continued until May 10, 2004. Grazing was terminated at the specified dates so heifers could be co-mingled to facilitate breeding. 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. For purposes of statistical analysis, initial forage mass was the amount of forage available when grazing was initiated on the EARLY pastures. Initial, final, and average forage mass, along with cattle production measurements were analyzed as a 2 x 2 factorial arrangement of a repeated measures experiment using SAS (SAS Inst., Inc., Cary, N.C.) PROC MIXED. Year was treated as a repeated measurement.

Results and Discussion

A seeding date by year interaction was detected ($P < 0.05$) for forage mass at the time grazing began on EARLY pastures, implying that these trends were not consistent over years. However, the decision of an appropriate seeding date should be based on an average across years to account for differential weather patterns across years. When averaged across the three-year study, forage mass measured on the day grazing was initiated on EARLY pastures was 880 lb greater ($P < 0.05$) from EARLY than from LATE pastures (Table 1). However, based on visual appraisal, a portion of this forage mass was residual bermudagrass that grew after cattle removal and seeding of the EARLY forages. This was validated in the first 2 years by an approximately five percentage unit lower crude protein concentration in the initial forage samples from EARLY (data not shown).

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Available forage mass averaged across the monthly samplings was greater ($P < 0.05$) from EARLY than from LATE pastures. Available forage mass did not differ ($P > 0.10$) between seeding dates or tillage intensity when grazing was terminated.

Although year and year by seeding date interactions were detected ($P < 0.10$) for certain heifer performance measurements, the overall mean is considered to be the criteria of importance. No significant differences were detected ($P > 0.10$) among tillage intensity and seeding date combinations for heifer gains or daily gains (Table 2). Overall, heifer gains were good and averaged 2.13 lb/d across treatment combinations. Total heifer gains were highest numerically from EARLY seeded pastures disked twice and lowest from heifers grazing LATE seeded pastures. Trends were for daily gains during the winter annual grazing period to be greatest numerically from heifers grazing LATE seeded pastures. Although LATE pastures provided fewer ($P < 0.05$) total grazing days per acre, less dilution of LATE pastures with dormant bermudagrass may have resulted in higher quality forage, thereby supporting slightly greater animal gains. Because of later initiation of grazing in two of the three years, heifers grazing LATE required approximately 165 lb more hay per heifer than heifers grazing EARLY. We observed no effect of tillage intensity or seeding date on the subsequent bermudagrass stand.

Implications

Sod-seeded winter annuals continue to be a viable feed source for developing heifers during most years. Because of a high degree of variability in early fall weather patterns including uncertainty of rainfall to stimulate germination of the winter annuals, and possible periods of extended hot dry weather following germination, it might be advantageous for producers to split acreage and seed some of the acreage early and some later in the fall to hedge against this variability in weather patterns.

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 (1X) or two (2X) diskings – 3-year average.

	1X		2X			
	EARLY	LATE	EARLY	LATE	SE	Effect[a]
Initial mass, lb/acre[b]	2,109	1,100	1,997	1,222	139.6	S,Y,S*Y
Final mass, lb/acre	1,866	1,919	2,275	1,874	294.2	ns
Average mass, lb/acre	1,656	1,247	1,728	1,315	117.8	S

[a] S = seeding date effect ($P < 0.05$); Y = year effect ($P < 0.05$); S*Y = seeding date by year interaction ($P < 0.05$); ns = no significant differences were detected ($P > 0.10$).

[b] Initial forage mass represents the forage mass measured on Dec. 18, 2001, Nov. 20, 2002, and Dec. 3, 2003.

Table 2. Growth performance by heifers grazing sod-seeded winter annuals planted in early September (EARLY) or mid-October (LATE) after one (1X) or two (2X) diskings – 3-year average.

	1X		2X			
	EARLY	LATE	EARLY	LATE	SE	Effect[a]
Initial wt, lb[b]	556	553	552	547	3.6	Y
Final wt, lb	825	829	852	815	26.1	y,s*y
Total gain, lb[c]	268	277	300	268	24.0	s*y
Daily gain, lbc	1.93	1.98	2.15	1.92	0.17	s*y
Winter annual[d]						
Gain, lb	268	271	300	267	22.6	S*Y
Daily gain, lb	2.93	2.23	2.15	2.20	0.18	ns
Grazing days/acre	153	136	153	136	0.0	S
Hay offered, lb/head	138	303	138	303	0.0	S,Y,S*Y

[a] Y and y = year effects ($P < 0.05$ and 0.10, respectively); S*Y and s*y = seeding date by year interaction ($P < 0.05$ and 0.10, respectively); ns = no significant differences were detected ($P > 0.10$).

[b] Initial weight is the weight at which grazing began for the EARLY group. LATE calves grazed dormant bermudagrass pastures or were fed hay until they were allocated to their respective pastures.

[c] Total gain and daily gain from the time EARLY began grazing.

[d] Gain, daily gain, and grazing days per acre while cattle were grazing winter annual pastures only.

Performance of Market Cows Grazing Stockpiled Tall Fescue

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Story in Brief

Forty-two crossbred, non-pregnant cows (mean age = 4.3 ± 0.2 yr) were purchased from local auction barns to determine the effect of supplementation on performance, reproduction, and economics of market cows grazing stockpiled, endophyte-infected tall fescue. Cows were assigned to one of six paddocks (two paddocks/treatment) of stockpiled tall fescue for 160 d and supplemented with 2 lb/d of either soyhulls (SH), corn:soybean meal (CSB), or not supplemented (control). Cows were exposed to bulls and palpated for pregnancy. Cows were weighed and body condition scored (BCS) every month. Cows weighed 884 ± 16 lb and had a BCS of 4.3 ± 0.2 at the initiation of the study. At the termination of the experiment, cows were sold at local auction. Supplementation tended (P = 0.11) to influence ADG of cows. Control cows gained 1.1 ± 0.1 lb/d while both SH and CSB cows gained 1.5 ± 0.2 lb/d. Change in body condition was greater (P < 0.05) for SH (1.9 ± 0.1 units increase) and CSB cows (1.5 ± 0.2 units increase) than control cows (1.0 ± 0.1 units increase). Reproductive performance was similar (P > 0.10) among supplementation treatments. When cows were sold, SH (1,110 ± 24 lb) and CSB cows (1,108 ± 27 lb) tended (P = 0.11) to be heavier than control cows (1,049 ± 21 lb). Selling price and net return was similar (P > 0.10) among supplementation treatments. Supplementation of market cows grazing stockpiled tall fescue can increase performance but may not increase farm profitability.

Introduction

Tall fescue (*Festuca arundinacea*) is the cool-season forage most commonly stockpiled in Arkansas because it has increased growth and retains nutritional content during winter months (Hitz and Russell, 1998). Further, Jennings (2002) reported that stockpiling fescue reduced winter feed costs by $14/cow and $20 to $27/stocker calf in Arkansas when compared to conventional winter supplementation practices. Quantity of endophyte affects performance of cattle grazing tall fescue. Fescue toxicosis is usually less severe in winter, and concentrations of ergovaline are reduced during the cooler months (Looper et al., 2004).

Supplemental feeding of market cows can increase body condition score (Apple et al., 1999) and potentially increase profits to the producer (Apple, 1999). The performance of market cows grazing stockpiled tall fescue has not been investigated. Therefore, objectives of this study were to determine the effects of supplementation on performance, reproduction, and economics of market cows grazing stockpiled, endophyte-infected tall fescue.

Experimental Procedures

Forages. To initiate the stockpile of tall fescue, paddocks were clipped to a 4 -inch height on September 23 and fertilized on October 1 with 12-20-20 (36 lb N/acre). Paddocks were fertilized again on March 5 with 20-10-10 (60 lb N/acre). Fescue paddocks were characterized three times (November 22, January 30, and May 13) during the experiment to determine the quantity and quality of stockpiled forage. Forage availability was evaluated using a disk meter. Crude protein (CP), acid detergent fiber (ADF), and in vitro dry matter digestibility (IVDMD) were determined on forage samples. Endophyte infection rates of all tall fescue paddocks were approximately 90%, and there were about 90% of the fescue tillers producing ergot alkaloids. To determine toxicity potential of the fescue paddock, plant samples were harvested and sent to the College of Veterinary Medicine, Oregon State University, to quantify ergovaline concentration.

Cattle. All animal procedures used in this study were approved by the committee for animal welfare at the Dale Bumpers Small Farms Research Center, Booneville, Ark. Forty-two crossbred (≤ 1/4 Brahman-influence), non-pregnant cows of similar biological type (mean BW = 884 ± 16 lb; mean BCS = 4.3 ± 0.2; mean age = 4.3 ± 0.2 yr) were purchased at local auction barns. Cows were assigned to one of six paddocks (two paddocks/treatment) of stockpiled tall fescue for 160 d (November 20 to April 29) at a constant stocking rate of one cow/2 acres. Cows were supplemented with either soyhulls (SH; crude protein = 10.6%; n = 12), corn:soybean meal (CSB; crude protein = 18%; n = 12), or not supplemented (control; n = 18). Supplements were fed at 2 lb/d per cow prorated to be fed 3 d/wk. Body weight and BCS were collected every month. Cows were exposed to bulls for 112 d and palpated for pregnancy at the termination of the experiment. Cows were sold at a local auction (Waldron Livestock Auction, Waldron, Ark.) on May 8, 2003 and selling price was recorded.

Statistical Analyses. Analysis of covariance was used to determine the effects of supplementation on ADG, BW, BCS, selling price and net income of market cows using the GLM procedure of SAS (SAS Inst. Inc., Cary, N.C.). Beginning BW and BCS were used as covariates. Chi-square analysis, using the FREQ procedure of SAS, was used to determine influence of supplementation on pregnancy rate of cows. Treatment means were compared using the PDIFF statement of SAS when protected by a significant (P < 0.05) treatment effect.

Results and Discussion

Forage availability was not limiting during the experiment, and averaged 3,213 lb DM/acre at the initiation of the experiment (November 22) and decreased to 2,666 lb DM/acre by January 30

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(Table 1). A total of 12 round bales of fescue hay (approximately 1,100 lb/bale) were fed to cows during the experiment due to snow cover. Forage characteristics for the three collection dates are shown in Table 1. Crude protein, ADF, and IVDMD averaged 12, 31, and 66%, respectively, throughout the experiment. Concentrations of ergovaline ranged from 266 to 384 parts per billion (ppb; Table 1). The protein and total digestible nutrient (TDN) requirements of a 1,200 lb, mid-gestation cow are 49% TDN and 6.9% CP (NRC, 1984). The nutritive content of the stockpiled tall fescue in the current study was 66% digestible dry matter and 12% CP, indicating that if dry matter intake is adequate, forage alone could meet the nutritional requirements of cows. Concentrations of ergovaline (mean = 344 ppb) were below the quantity of published values that may induce fescue toxicosis in cattle. Researchers at Oregon State University suggest fescue toxicosis may be possible in cattle when concentrations of ergovaline are between 400 to 750 ppb.

This is an initial report of data on increasing the value of market cows with the end result of selling pregnant cows. To date, most market cow research has investigated the effects of feeding high energy diets to cattle and harvesting carcass data. Additional feeding of market cows can increase BCS, carcass value, carcass characteristics (Apple et al., 1999; Funston et al., 2003), and potentially increase profits to the producer (Apple, 1999).

The ADG of market cows grazing stockpiled tall fescue tended ($P = 0.11$) to be affected by supplementation with SH and CSB at 0.2% BW compared with no supplementation (Table 2). A common recommendation associated with market cows is to feed thin cows to take advantage of compensatory gain. Cows in the current experiment had a mean initial BCS of 4.3 ± 0.2, and supplemented cows gained 1.5 lb/d. Likewise, market cows grazing stockpiled tall fescue and fed either SH or CSB had increased ($P < 0.05$) final BCS and BCS change compared with non-supplemented, control cows (Table 2). Supplemented cows tended ($P = 0.11$) to be heavier at the time of selling (final BW) compared with control cows (Table 2). Pregnancy rates did not differ ($P > 0.10$) among supplementation treatments and averaged 86% (Table 2).

Beginning with healthy market cows is one of most critical components in the success of adding value to market cows. In the current study, one cow died and one cow was removed from the study due to health problems reducing profitability. Feed cost was \$0.06/lb for SH (\$19.32/cow for the 160 d) and \$0.08/lb for CSB (\$25.76/cow for the 160 d). A partial budget with costs associated with supplemental feeding of market cows grazing stockpiled, endophyte-infected tall fescue is shown in Table 3. Selling price of cows and net income were similar ($P > 0.10$) among supplementation treatments (Table 3). The mean net income was \$137.42/cow. Data collected from 1995-2003 by the USDA, National Agricultural Statistics Service (NASS, 2003) showed seasonal affects on the selling price of market beef cows. Prices generally are lowest during the months of November and December while the highest prices received for market cows are during March, April, and May. A majority (86%) of cows in the current study were pregnant and sold during May allowing for higher selling prices relative to other times during the year.

Implications

The sale of pregnant market cows may be a significant source of income for Arkansas producers. Supplementation of market cows grazing stockpiled tall fescue may enhance performance and increase value of market cows. However, if availability of stockpiled fescue is adequate, supplementation of cows may not be cost-effective.

Acknowledgments

The authors gratefully acknowledgment L. Huddleston, USDA-ARS, for daily animal management, N. and T. Preston, Booneville, Ark., for supplying cattle, and personnel at Waldron Livestock Auction, Inc., Waldron, Ark., for collection of cattle sale data.

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Table 1. Forage availability (lb DM/acre), crude protein, acid detergent fiber (ADF), *in vitro* dry matter digestibility (IVDMD), and concentrations of ergovaline[1] in stockpiled tall fescue at three dates from November to May.

Date	Availability, lb DM/acre	Protein, %	ADF, %	IVDMD, %	Ergovaline, ppb[2]
November 22	3,213	13.8	21.7	82.0	384
January 30	2,666	8.5	36.7	49.3	266
May 13	3,596	12.8	33.5	66.5	383

[1]Measure of toxin in tall fescue.
[2]Parts per billion.

Table 2. Influence of supplementation on final BW and BCS, BCS change, ADG, and pregnancy rate of market cows fed supplemental diets and grazing stockpiled tall fescue for 160 d.

Item	Control	Soyhulls	Corn:SBM	S.E.
Initial BW	864	911	877	16
Initial BCS	4	4.3	4.7	0.2
Final BW	1,049[a]	1,110[b]	1,108[b]	17
Final BCS	5.3[c]	6.1[d]	5.8[d]	0.1
BCS change	1.0[c]	1.9[d]	1.5[d]	0.1
ADG, lb	1.1[a]	1.5[b]	1.5[b]	0.1
Pregnant, %	83	83	92	--

[a,b]Means in a row with no superscript in common differ (P = 0.11).
[c,d]Means in a row with no superscript in common differ (P < 0.05).

Table 3. Partial budget[1] of costs, gross income, and net income associated with market cows fed supplemental diets and grazing stockpiled tall fescue for 160 d.

Item	Control	Soyhulls	Corn:SBM
Purchase price	372.72	392.92	397.42
Feed costs	0.0	19.32	25.76
Grazing costs[a]	13.15	13.15	13.15
Bull lease	20.0	20.00	20.00
Labor costs[b]	10.35	31.05	31.05
Freight costs[c]	10.00	10.00	10.00
Misc. costs[d]	8.20	8.20	8.20
Total Costs	434.42	494.64	505.58
Gross Income (selling price)	597.12	612.27	637.50
Net Income[e]	162.70	117.63	131.92

[1]In dollars on a per cow basis.
[a]$15/acre per year with a stocking rate of one cow/2 acres.
[b]Labor costs $9.00/hr. Feeding required 1 hr for 3 d/wk for 23 wk (160 d) for each feeding treatment; control cows were observed once weekly [1 hr for 23 wk (160 d)].
[c]Freight from and to auction barn.
[d]Miscellaneous costs includes hay fed during snow cover, dewormer, and vaccinations.
[e]Means in a row do not differ (P > 0.10).

Estrous Behavior and Pregnancy Rate of Brahman-influenced Beef Cows after Treatment with Progesterone and Prostaglandin $F_{2\alpha}$

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Story in Brief

Eighty-four multiparous, crossbred cows (1/4 to 3/8 Brahman) were utilized to evaluate the effects of progesterone (P_4) and prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) on estrous behavior and pregnancy rate. Cows grazed common bermudagrass throughout the breeding season. Cows received either a controlled internal drug-releasing (CIDR) insert containing P_4 for 7 d on d 1 of the breeding season or no CIDR (control). On d 7, CIDRs were removed and cows receiving CIDRs were administered $PGF_{2\alpha}$. Cows were exposed to bulls and fitted with a HeatWatch transmitter to record estrous activity during the first 30 d of the breeding season. Thirty-seven percent of cows were anestrus at breeding. Duration of estrus (mean = 7.3 ± 0.8 h) and quiescence between mounts (mean = 2.3 ± 0.3 h) were similar ($P > 0.10$) between cows with and without CIDR-$PGF_{2\alpha}$. However, cows treated with CIDR-$PGF_{2\alpha}$ had an increased ($P < 0.05$) number of mounts (25.4 ± 2.3) compared with cows without CIDR-$PGF_{2\alpha}$ (17.0 ± 2.9). Fifty-seven percent of cows administered CIDR-$PGF_{2\alpha}$ exhibited estrus within 72 h after CIDR removal. Treatment with CIDR-$PGF_{2\alpha}$ tended ($P = 0.12$) to increase the number of anestrous cows exhibiting estrus during the first 30 d of the breeding season. Pregnancy rate was similar between cows with or without CIDR-$PGF_{2\alpha}$. The number of mounts of cows treated with CIDR-$PGF_{2\alpha}$ was increased, and the percentage of anestrous cows that initiated estrous cycles during the first 30 d of the breeding season tended to increase when cows were treated with P_4 followed by $PGF_{2\alpha}$.

Introduction

Resumption of estrus and luteal activity by 85 d post-calving is necessary to maintain a yearly calving interval. Most postpartum cows have transient increases in progesterone (P_4) prior to resumption of normal luteal activity. This increase in P_4 prior to estrus may enhance subsequent luteal function (Looper et al., 2003a).

Use of a controlled internal drug-releasing (CIDR) insert containing P_4 has been effectively utilized for synchronization of ovulation in heifers (Martinez et al., 2002). Likewise, conception and pregnancy rates of dairy heifers were increased with CIDRs in combination with GnRH and $PGF_{2\alpha}$ compared with GnRH or $PGF_{2\alpha}$ alone in non-timed artificial insemination protocols (Richardson et al., 2002).

Treatment with a CIDR induced more anestrous suckled beef cows to ovulate with subsequent normal luteal activity than anestrous cows treated with melengestrol acetate (MGA) (Perry et al., 2004). The influence of a CIDR followed by $PGF_{2\alpha}$ treatment on estrous behavior of Brahman-influenced cows has not been fully elucidated. Therefore, our objectives were to evaluate the influence of P_4 for 7 d, via a CIDR, followed by $PGF_{2\alpha}$ administration on 1) estrous behavior and pregnancy rate of Brahman-influenced beef cows, and 2) initiation of estrous cycles in anestrous cows.

Experimental Procedures

All animal procedures used in this study were approved by the committee for animal welfare at the Dale Bumpers Small Farms Research Center, Booneville, Ark. Eighty-four multiparous (1/4 to 3/8 Brahman; mean BW = 1,226 ± 143 lb; mean BCS = 6.3 ± 0.8; mean d postpartum = 79 ± 1.9 d) cows were utilized. All cows grazed common bermudagrass [*Cynodon dactylon* (L.) Pers] pastures throughout the breeding season. Three weeks before the start of the breeding season, weekly blood samples were collected from each cow and concentrations of P_4 were quantified by radioimmunoassay (Coat-A-Count®, Diagnostic Products, Los Angeles, Calif.) to determine luteal activity. Intra- and interassay coefficients of variation were 1 and 1%, respectively. Luteal activity was defined as concentrations of $P_4 \geq 1$ ng/mL in two consecutive blood samples. Thirty-seven percent (31/84) of the cows were determined to be anestrus at the start of the breeding season. Cows with luteal activity were randomly assigned to one of two treatment groups: 1) controlled internal drug-releasing insert containing P_4 (CIDR; 1.38 g of P_4; Pharmacia & Upjohn Co., Kalamazoo, Mich., n = 29) for 7 d followed by administration of prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$), or 2) no CIDR or $PGF_{2\alpha}$ (control, n = 24). Of the anestrous cows, 18 were randomly assigned to receive CIDR-$PGF_{2\alpha}$ and 13 were assigned to the control group. Overall, 47 cows were administered CIDR-$PGF_{2\alpha}$ and 37 cows did not receive CIDR-$PGF_{2\alpha}$ (control).

A CIDR was inserted into the vagina of each cow in the treatment group on d 1 of the breeding season and was removed on d 7. Additionally, all cows in the treatment group were administered $PGF_{2\alpha}$ (Lutalyse®, 25 mg, intramuscular, Pharmacia & Upjohn Co., Kalamazoo, Mich.) on the day of CIDR removal.

On d 1 of the breeding season, all cows were fitted with a Heatwatch® (DDx Inc., Denver, Colo.) transmitter, and estrous activity was recorded during the first 30 d of the breeding season. Cows were exposed to a bull during the first 30 d of the breeding season (1 bull/21 cows). To determine pregnancy rate, all cows were palpated 43 d after a 75-d breeding season.

Duration of estrus, quiescence, or the longest interval between each successive mount, and the number of mounts received were analyzed with a one-way ANOVA using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). Means were separated using pre-

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planned pairwise comparisons generated with the PDIFF statement of SAS when protected by a significant ($P < 0.05$) treatment effect. Chi-square procedures of SAS were used to compare pregnancy rate and percentage of anestrous cows displaying estrus following treatment with CIDR-$PGF_{2\alpha}$.

Results and Discussion

Mean BW, BCS and days postpartum was similar ($P > 0.10$) between CIDR-$PGF_{2\alpha}$-treated and control cows. Likewise, mean duration of estrus and mean quiescence (longest interval) between mounts were similar ($P > 0.10$) between CIDR-$PGF_{2\alpha}$-treated and control cows (Table 1). Mean duration of estrus was 7.3 ± 0.8 h and quiescence between mounts averaged 2.3 ± 0.3 h for both CIDR-$PGF_{2\alpha}$-treated and control cows. Cows treated with CIDR-$PGF_{2\alpha}$ had increased ($P < 0.05$) number of mounts (25.4 ± 2.3) compared with control cows (17.0 ± 2.9). Mean duration of estrus was reported to be 14.0 h and mean number of mounts was 40 in crossbred Brahman heifers following CIDR removal and $PGF_{2\alpha}$ administration (Lemaster et al., 1999). In the current study, 57% of cows (both estrous and anestrous cows) administered CIDR-$PGF_{2\alpha}$ exhibited estrus within 72 h after CIDR removal (Table 2), whereas only 19% of control cows (both estrous and anestrous) exhibited estrus within the same time period ($P < 0.05$). Synchronization of estrus among cows with CIDR-$PGF_{2\alpha}$ may explain the increased number of mounts. Treatment of cows with CIDR-$PGF_{2\alpha}$ will influence the number of cows exhibiting estrus simultaneously. Mounting activity per cow is increased when four or more cows are in estrus concurrently (Hurnik et al., 1975). Although control cows were not synchronized, clearly, fewer control cows were displaying estrus within the same 72 h time period compared with cows treated with CIDR-$PGF_{2\alpha}$ (Figure 1). Cows exhibiting estrus and subsequently becoming pregnant earlier in the breeding season may result in older, heavier calves at weaning and allow cows more time to return to estrus the following year.

Cows were palpated 43 d after a 75-d breeding season to determine pregnancy rate. Overall, pregnancy rate for the 75-d breeding season was similar ($P > 0.10$) between the CIDR-$PGF_{2\alpha}$ and control cows (Table 2). Pregnancy rate averaged 90% for both groups.

Thirty-seven percent of cows, in the current study, were anestrus at the initiation of the breeding season. Treatment of anestrous cows with CIDR-$PGF_{2\alpha}$ tended ($P = 0.12$) to increase the percentage of cows exhibiting estrus compared with control cows (Table 3). Our results are in agreement with Lucy et al. (2001) who found more anestrous cows (various breed types) treated with a CIDR and $PGF_{2\alpha}$ were detected in estrus during the first 3 d of the breeding season compared with anestrous cows treated with $PGF_{2\alpha}$ alone or control cows. Further, treatment with a CIDR induced more early (30 d postpartum) anestrous Angus x Hereford crossbred cows to ovulate and initiate estrous cycles compared with cows treated with MGA (Perry et al., 2004). Looper et al. (2003b) recently demonstrated the quantity of messenger RNA for LH β subunit in the pituitary gland was increased when anestrous cows were treated with P_4. Increased synthesis of LH β could increase pituitary content of LH thereby causing a LH surge and ovulation to occur sooner after calving (Looper et al., 2003b). Exposure of anestrous cows to P_4 similar to concentrations observed during the estrous cycle may initiate estrous cycles which will aid in maintenance of a yearly calving interval.

Implications

Treatment of Brahman-influenced beef cows with exogenous P_4 via a CIDR for 7 d followed by $PGF_{2\alpha}$ may influence estrous behavior and initiate estrus in anestrous cows. Resumption of luteal activity with CIDR-$PGF_{2\alpha}$ may allow cows more time to return to estrus and maintain a yearly calving interval.

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Table 1. Estrous behavior of Brahman-influenced beef cows after treatment with progesterone via a controlled internal drug releasing (CIDR) insert for 7 d followed by prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) or non-treated control cows.

	Treatments		
Item	CIDR-$PGF_{2\alpha}$	Control	S.E.[1]
No. of cows	47	37	-
Duration of estrus, h	7.7[a]	6.8[a]	0.8
Quiescence between mounts, h[2]	2.3[a]	2.4[a]	0.3
No. of mounts	25.4[a]	17.0[b]	2.6

[1]Pooled standard error.
[2]Longest interval between each successive mount.
[a,b]Means in a row with no superscript in common differ ($P < 0.05$).

Table 2. Synchronization (within 72 h) and pregnancy rate of Brahman-influenced beef cows after treatment with progesterone via a controlled internal drug releasing (CIDR) insert for 7 d followed by prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) or non-treated control cows.

	Treatment	
Item	CIDR-$PGF_{2\alpha}$	Control
Synchronization rate, %	57[a]	19[b]
Pregnancy rate, %	91[c]	89[c]

[a,b,c] Percentages in a row with no superscript in common differ ($P < 0.05$).

Table 3. Percentage of anestrous, Brahman-influenced beef cows exhibiting estrus after treatment with progesterone via a controlled internal drug releasing (CIDR) insert for 7 d followed by prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) or non-treated control cows.

	Treatment	
Item	CIDR-$PGF_{2\alpha}$	Control
No. of anestrous cows	18	13
% Estrus[1]	88[a]	64[b]

[1] Estrus during the first 30 d of the breeding season.

[a,b] Percentages in a row with no superscript in common differ ($P = 0.12$).

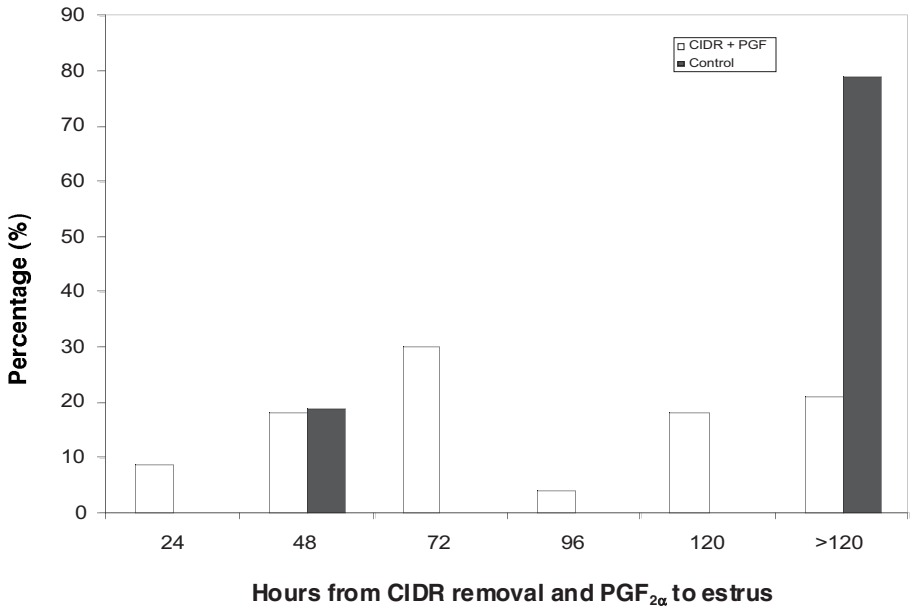

Fig. 1. Percentage of Brahman-influenced beef cows exhibiting estrus at various times after treatment with progesterone via a controlled internal drug releasing (CIDR) insert for 7 d followed by prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) or non-treated control cows.

The Effects of Method of Castration, and/or Implantation on Cow/Calf Performance when Creep Grazing Either Tall Fescue or Crabgrass

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Story in Brief

Starting on June 2 or 3, 2003, one hundred twenty cow/calf pairs were creep grazed on tall fescue or crabgrass pastures for 92 days. Bull calves were randomly picked to be in three groups. Each group received one of the three following treatments 1) castrated at 3 months of age; 2) castrated and implanted with 36 mg zeranol at 3 months of age; or 3) not castrated until weaning. Heifer calves were randomly picked to either be implanted with 36 mg zeranol at 3 months of age or not implanted. After weaning, calves were placed in a feedlot for a 28-day weaning trial, and then placed on K-31 tall fescue pasture for 170 days. The purpose of this study was to evaluate the effects of these treatments on pre- and post-weaning calf performance. There were no significant differences ($P > 0.09$) in body weight gain due to creep-treatment or castration/implantation treatment at weaning on August 22, after the weaning period on October 20, or after grazing tall fescue for 170 days.

Introduction

The castration of bull calves intended for beef production is a common practice in the US. Siedeman et al. (1982) reported that non-castrated male calves grow more rapidly, are more efficient at utilizing feed, and produce a higher-yielding carcass with less fat and more edible product than castrated male calves. This supports observations reported by Marlowe and Gaines (1958) who found that bulls grew 5% faster from birth to weaning than steers. However, carcasses from intact males have repeatedly been inferior in quality grade and palatability (Worrell et al., 1987). Gregory and Ford (1983) suggest that many of the advantages of intact vs. castrated males may be expressed by about one year of age and the disadvantages begin at about the same time, approximately at puberty.

When given estrogenic growth stimulants castrated calves have similar weight gains compared to intact bull calves (Bagley et al., 1989). The use of growth promoting implants is also a common practice in the US. Implants can be administered to cattle of any age from suckling to the finishing stage. Results from previous studies have been inconsistent. Laudert et al. (1981) reported that implanting calves during the growing phase of beef production reduced finishing ADG; however, Mader et al. (1985) reported that implanting during the growing phase did not reduce finishing ADG. The purpose of this study was to evaluate the effects of castration and implantation of steers and implantation of heifers on pre- and post-weaning calf performance.

Experimental Procedures

Three 6.0 acre pastures located at the SWREC Beef Cow Unit were sprayed with Roundup, and then disked to prepare a seedbed. The pastures were planted to crabgrass (Digitaria ischaemum, cv Red River; Lorenz's OK Seeds, Okeene, Okla.) using a Vicon broadcast spreader on May 13, 2003 at a rate of 2.5 lb/acre. Triple 17 (17-17-17) was mixed with the crabgrass seed at a rate of 8.5 lb N, phosphorus (P), and potassium (K)/acre to produce a more even spread of crabgrass seed. Three 6.0-acre pastures, planted to tall fescue (*Festuca arundinacea* Schreb., MaxQ; Pennington Seed, Inc.; Madison, Ga.) in the fall of 2002 were used as comparison pastures. Cows were restricted from creep graze areas by electric fencing.

All animal procedures were approved by the University of Arkansas Institutional Animal Care and Use Committee. On June 2 or 3, 2003, 120 crossbred beef cow (average BW = 927 ± 24.3 lb)/calf pairs were weighed, body condition scored (using a standard 1 to 9 scale), and left in breeding groups on six previously assigned 12.0 acre bermudagrass pastures. Pairs had ad libitum access to mineral throughout the trial. A 17-17-17 blended fertilizer was also applied at a rate of 50 lb each of N, P, and K /acre on June 3. Pairs were separated into pasture groups at a rate of 20 cow/calf pairs per pasture, breeding bulls were removed, and the herd was allowed access to creep pastures three days a week (M, W, F) on June 23-24. The bull calves were divided into thirds and received a treatment of either castration + implant (Ralgro®, 36 mg of zeranol, Shering-Plough Animal Health, Union, N.J.), castration only, or left as bulls. One half of the heifers received implants. On July 1, creep access was initiated with cows having limited access to the creep pastures.

Pastures also were fertilized with ammonium nitrate at a rate of 50 lb actual N/ acre on July 1. Picloram + 2,4-D (Dow AgroSciences, Indianapolis, Ind.) was sprayed at a rate of 1 quart/acre onto both bermudagrass and creep pastures on July 22 to control Spiny Pigweed. On July 29, crabgrass pastures were cut for hay to stimulate new growth of a higher quality forage. Crabgrass hay harvested from the plots was analyzed to contain 11.6 % CP and 49.5 % TDN. Quality of fescue pastures was not measured during the study. Ivermectin (Schering Plough, Union, Ind.) pour-on was administered to cows on August 4 or 5 to control both internal and external parasites. On August 12 to 18, cows were put on tall fescue pastures to flash graze the forage because forage had matured. This was done to stimulate new growth.

Calves were weaned on September 22 and transported to a small feedlot facility. Bull calves that were still intact were banded (Callicrate Bander™, No Bull Enterprises, St. Francis, Kan.) to determine if late castration has an affect on weight gains after weaning. Calves were penned by pasture groups from the previous part of this experiment. Calves were fed a concentrate diet consisting of soybean hulls, cracked corn, soybean meal, QLF Pasture Plus

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(Quality Liquid Feeds, Dodgeville, Wisc.), a mixture of ammonium sulfate, limestone, salt, and water at a percentage of 17.8, 36.9, 10.8, 9.7, 1.7, and 4.2% of the total diet on an as-fed basis, respectively. Warm season grass hay containing 10.05% CP and 55.1% TDN was milled with the concentrate diet to make up the remaining 19.1 % of the total diet on an as-fed basis. Calves were introduced to the milled diet by initially adding it to a long-stemmed bermudagrass hay containing 10.9% CP and 54% TDN at a rate of 5 lb/calf/day. The proportion of the milled diet was gradually increased until September 30. Calves were then fed approximately 12 lb milled diet/day (as fed). Final calf weights were collected on October 20.

After finishing on October 20, calves were placed on an endophyte infected tall fescue (K-31) pasture. Calves had ad libitum access to bermudagrass hay, mineral, and 2 lb corn/ head/ day until weighed on April 7, 2004.

Data were separated by animal gender and analyzed using PROC MIXED (SAS Inst. Inc., Cary, N.C.) as a split plot design with creep-treatment as the whole plot and castration/implant treatment as the subplot and the covariates of cow age and calving date in the model. The experimental unit was pasture or pen.

Results and Discussion

Treatment had no affect on cow body weights (BW; $P > 0.19$) or body condition score (BCS; $P > 0.17$) regardless of calf gender as shown in Tables 1and 2. There was also no creep by implant treatment interaction for cow BW ($P > 0.42$) or BCS ($P > 0.43$). Bull calf BW (Table 3) did not differ across castration/implant combinations ($P > 0.15$) at initial turn out on June 23. At weaning on September 22, implanted steer calves weighed 46 lb heavier ($P = 0.03$) than non-implanted steers, while intact bull calves weighed 18 lb more ($P = 0.37$) than non-implanted steers. Bagley et al. (1989) found that leaving bulls intact for a period of time had no affect on weight gains. This contradicts reports by Gregory and Ford (1983) who reported that leaving males intact for up to a year old increased finishing gains when compared to castrated males, regardless of implant treatment. The slight effect of castration treatment was due to the weight gain advantage shown by calves that were castrated and implanted. Castration/implant-treatments ($P = 0.18$) had no effect on body weight during the 28-d weaning period. Mader et al. (1985) reported that implanting during the growing phase had no subsequent effect on finishing phase performance. There was also no castration/implant treatment effect ($P = 0.21$) on calf body weights during the 170 d grazing period of endophyte infected (K-31) tall fescue.

Heifer calves (Table 4) showed similar characteristics throughout the trial. At weaning, body weights were not affected by implant treatment ($P = 0.9$). Nor was there any statistical difference in body weights due to implant treatment after a 28-d weaning period ($P = 0.52$) or after the 170 d K-31 pasture grazing period ($P = 0.47$). Creep treatments (Table 5) had no effect on calf BW, regardless of gender, at weaning ($P = 0.79$), after the 28-d weaning period ($P = 0.61$), or after grazing endophyte infected K-31 tall fescue ($P = 0.28$).

Implications

This study provides evidence that calves, regardless of gender, castration treatment, or implant treatment, showed no increase in body weight gains when creep grazing either Max Q tall fescue or crabgrass. Nor did any treatment have an affect on calf performance during a 28-day weaning period or after grazing K-31 tall fescue for 170 days. Castration of bull calves after weaning did not affect post weaning performance, and performance pre-weaning was not increased compared to steers without implants.

Acknowledgments

The authors wish to thank Pat Capps, Josh Loe, and Clint Cornelius. These people were highly supportive in the successful completion of the study.

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Table 1. Body weight (BW) and body condition scores (BCS) for cows with male calves.

	Treatment[a]						
Item	Castrate at weaning	Castrate + implant	Castrate only	Crabgrass creep	Continuous	Fescue creep	SE
BW 6-23, lb	899	903	898	897	890	912	25.2
BCS 6-23	5.11	5.09	5.22	5.19	5.19	5.04	0.11
BW 8-6, lb	952	973	945	982	924	963	22.2
BCS 8-6	5.18	5.16	5.25	5.35	5.04	5.21	0.11
BW 9-23, lb	960	977	950	973	949	966	24.1
BCS 9-23	5.15	5.05	5.28	5.16	5.16	5.17	0.094

[a] No significant treatment effects were found ($P > 0.05$).

Table 2. Body weight (BW) and body condition scores (BCS) for cows with female calves.

	Treatment[a]					
Item	No implant	Implant	Crabgrass creep	Continuous	Fescue creep	SE
BW 6-23, lb	964	957	982	953	947	32.9
BCS 6-23	5.23	5.2	5.25	5.17	5.23	0.097
BW 8-6, lb	1018	1014	1040	1004	1004	32.3
BCS 8-6	5.23	5.32	5.37	5.11	5.36	0.125
BW 9-23, lb	1007	1011	1017	1015	994	31.7
BCS 9-23	5.18	5.28	5.31	5.1	5.29	0.119

[a] No significant treatment effects were found (P > 0.05).

Table 3. Body weights (BW) and gain of male calves pre- and post-weaning.

	Treatment[a]			
Item	Castrate at weaning	Castrate + implant	Castrate only	SE
BW 6-23, lb	247	268	244	9.3
BW 9-22, lb	407	435	389	14.4
Pre-wean gain, lb	163	166	153	6.4
BW 10-20, lb	436	462	432	12.2
Feedlot gain, lb	25	28	29	5.3
BW 4-7, lb	614	639	600	15.3
Pasture gain, lb	178	177	168	9.4

[a] No significant treatment effects were found (P > 0.05).

Table 4. Body weight (BW) and gain of female calves pre- and post-weaning.

	Treatment[a]		
Item	No implant	Implant	SE
BW 6-23, lb	242	235	7.2
BW 9-22, lb	391	389	10.6
Pre-wean gain, lb	153	154	5.0
BW 10-20, lb	420	410	10.8
Feedlot gain, lb	17	21	3.6
BW 4-7, lb	559	545	13.0
Pasture gain, lb	139	138	9.7

[a] No significant treatment effects were found (P > 0.05).

Table 5. Pooled analysis of creep graze treatments across gender.

	Treatment[a]			
Item	Crabgrass creep	Continuous	Fescue creep	SE
BW 6-23, lb	243	249	247	6.7
BW 9-22, lb	400	395	405	10.0
Pre-wean gain, lb	159	155	158	4.7
BW 10-20, lb	425	438	427	9.8
Feedlot gain, lb	21	27	22	3.6
BW 4-7, lb	588	601	572	12.3
Pasture gain, lb	166	155	145	10.0

[a] No significant treatment effects were found (P > 0.05).

Arkansas Beef Improvement Program: Whole-farm program[1]

T.R. Troxel, M.S. Gadberry, J.A. Jennings, D.E. Kratz, G.V. Davis, and W.T. Wallace[2]

Story in Brief

The Arkansas Beef Improvement Program (ABIP) uses an integrated resource management approach to balance ranch resources and to enhance efficiency and profitability of cattle producers. Production and financial parameters were measured over a 5-year period to evaluate progress with whole farms. Since 1992, 15 cooperators completed the ABIP whole-farm program. Analysis across all completed whole ABIP farms revealed that herd break-even decreased 28.2% ($0.52 ± 0.12 to $0.37 ± 0.14. lb; $P < 0.03$), average specified cost/animal unit (AU) tended to decrease ($226.35 ± 108.05 to $174.42 ± 79.16; $P = 0.19$), mature cow calf crop percent tended to increase (84.6 ± 11.15% to 93.3 ± 5.24%; $P = 0.14$), and return over specified cost/AU increased 121.7% ($98.50 ± 62.43 to $218.35 ± 92.31; $P < 0.05$) from year 1 to year 5. The ABIP accomplished its educational objectives and made an impact on the Arkansas cattle industry.

Introduction

Technology transfer from land grant institutions to agricultural producers may create awareness, but seldom leads to adoption (Beverly, 1988). This is evident because 53.6% of operations have no set calving season, 51.9% do not use individual calf identification, 91% do not laboratory test feedstuffs (hay), and only 22% reported they calculated a balanced diet (NAHMS, 1997). It is not the discovery of new technology but rather the adoption of proven technology that can greatly influence the profitability of a cow-calf operation. Economical cow-calf management is an impossible task if a logical and practical approach has not been developed for collecting and analyzing information, evaluating plans, and directing daily operations. Management practices change over time and from farm to farm, region to region and state to state. The decision-making process to select the appropriate management practice, however, does not change. Therefore, the Arkansas Beef Improvement Program (ABIP) was designed to use multiple educational methods to teach decision-making skills and beef cattle and forage management practices. The objective of this paper is to document progress in the ABIP whole-farm program.

Experimental Procedures

The goal of the ABIP program was to balance ranch resources to enhance the efficiency and profitability of Arkansas cattle production. The ABIP decision-making process involves setting goals, evaluating resources, and selecting the management practices to achieve those goals. An ABIP team was established for each farm and consisted of specialists, the local Extension agent and cooperator. This team worked together to identify the cooperator's goals, recognize resource limitations and establish a plan of work to achieve those goals. The Extension agent was a critical member of the team. He/She worked directly with the cooperator, monitored changing conditions, scheduled activities with specialists and assisted with data collection.

The ABIP whole-farm program required a 5-year commitment. Seven management practices were implemented on the whole-farm demonstrations. They included completing a cow-calf budget, forage testing, soil testing, cow herd performance, enrolling steers in the Arkansas Steer Feedout Program, pasture inventories and completing production calendars. Benchmark data were collected during year 1. Beginning year 2, a plan of work was established to reach the cooperator's goals. Information was collected annually to document change due to management.

During March and April, the ABIP team visited with each cooperator to evaluate the accomplishments of the past year, discuss new data, review the plan of work and cooperator's goals, and establish management plans for the coming year. Additional farm visits were made by the ABIP team members (either together or individually) throughout the year. Since 1992, 15 cooperators completed the ABIP whole-farm program. In any given year, three to four farms were active in the whole-farm program.

Cow-Calf Budget Description. The budget included herd inventory, number of animal units (AU), production information, income and expenses. The herd inventory reflected the number of animals as of January 1 of the budget year. It included mature cows (a female pregnant with at least her second calf), growing heifers (weaned heifers that had not conceived), first-calf heifers (heifers that were pregnant or nursing their first calf but were not pregnant with their second calf), bulls for breeding the mature cow herd and heifers, and growing bulls (6 to 16 mo of age). Total number of AU in the cow herd was calculated based on metabolizable energy requirements as described by Gadberry and Troxel (1999).

Production information was separated into four groups – mature cows, growing heifers, pregnant heifers and bulls. The production information was a summary of calf crop percentage, pregnancy rate, culling percentage, replacement rate, death loss, number of females exposed to the bull and useful life of a bull. All calf crop percentages were determined by dividing the number of calves weaned by the number of females exposed to the bull. Death loss was determined by dividing the number of dead animals (cows, heifers, etc.) by the total number of animals.

[1] This material is based upon work supported by the Cooperative State Research, Education, and Extension Service, U. S. Department of Agriculture, and the Cooperative Extension Service, University of Arkansas, under Agreement No. 2002-45033-01408. Any opinions, finding, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U. S. Department of Agriculture.

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Income summary included the number of head sold, average BW/head and average price/cwt. Included in the income section were calculated values for total pounds sold, total gross income, average selling price for the entire herd, total pounds sold/AU and gross income/AU. Budgets were completed each year. Year 1 budgets served as the baseline, and for comparisons of budget in subsequent years, the selling price established in the baseline year was used to determine income in subsequent years to prevent market price changes from confounding the results.

The specified expenses included salt and mineral, supplemental feed, veterinarian costs, growth implants, fly control, sales commission, hauling, day labor, pregnancy testing, bull cost or AI, breeding soundness examinations, replacement heifer or cow purchase, grazing lease, fertilizer, lime, purchased hay, herbicide and miscellaneous. No overhead items such as family expenses, machinery, depreciation, etc., were included in the budget. Summarized values included total specified cost, total specified cost/AU, herd break-even/pound (specified cost divided by pounds of beef sold), return over specified cost, and return over specified cost/AU. Comparisons were also made across farms on an AU basis.

Analysis. Where statistical analysis was not appropriate, means ± SD were used to describe the data. The t-test as described by Freund and Wilson (1993) was used to determine if the percent change in production items was different from a zero percent change within the whole-farm program. An analysis of variance was performed with the GLM procedure of SAS (SAS Inst., Inc., Cary, N.C.) to analyze production-level differences in the whole-farm programs.

Results and Discussion

The most common goal expressed by the cooperator was to improve beef cattle production efficiency. Although the whole farm was managed with an integrated resource philosophy, improving beef cattle production efficiency meant concentrating on specific limited resources for each farm. For example, some ABIP teams identified beef cattle genetics or pasture conditions as limiting, and those received concentrated management efforts. As time progressed, the ABIP team (including the cooperator) identified additional limiting resources, and management efforts shifted.

The average number of mature cows during the first year of the whole-farm program was 68 ± 46.7 head. Of the 15 whole-farm cooperators, four had a herd size of 30 head or less. The number of mature cows increased by an average of 34.1% ($P < 0.06$) from year 1 to 5 (91 ± 81.6 head). Increasing the number of mature cows was a goal for eight cooperators. Additional land was not obtained, but pasture and soil fertility management was implemented to improve forage resources.

Herd break-even/pound of beef sold was used to measure beef production efficiency. The average herd break-even decreased ($P < 0.01$) from year 1 ($0.52 ± 0.12/lb) to 5 ($0.37 ± 0.14/lb). The decrease in herd break-even was 28.2% ($P < 0.03$). Major factors that influenced herd break-evens were increased beef production, reduced specific production cost, or both.

Beef sold/AU (lb/AU) during year 1 averaged 436 ± 159.8 lb. Beef cattle sold included steers, heifers not kept for replacements, and market bulls and cows. Beef sold increased by 23.6% to 539 ± 345.7 lb by year 5. Since the goal for a number of cooperators was to increase the number of mature cows, it was common for beef sold/AU to decrease in year 2 and 3. Working with a cow herd for 5 years was not enough to document completely the financial impact of this major management change.

Specified cost/AU tended to decrease 22.9% ($P = 0.19$) from year 1 to 5. The average specified cost/AU tended to decrease ($P = 0.14$) from year 1 ($226.35 ± 108.05) to year 5 ($174.42 ± 79.16). Along with a tendency to decrease specified costs/AU, variability in costs decreased 27%. When evaluating specified cost/AU, three general circumstances existed. The first was excessively high specified cost/AU; therefore, cost-reducing measures were taken without reducing cattle performance. The second was that specified cost/AU actually increased but resulted in cost-effective improvements in beef production. The third circumstance was the specified cost/AU was not changed, but funds were reallocated to more cost-effective expenses.

The average mature cow calf crop percentage in year 1 was 84.6 ± 11.15% and tended to increase ($P = 0.14$) to 93.3 ± 5.24% by year 5. This tendency may not be expected to be highly significant because calf crop percentages above 93% may be close to the biological maximum (e.g., 100% is not a realistic maximum). The percentage change in calf crop was significant ($P < 0.01$). Improving mature cow reproductive rates was an accumulation of a number of management practices such as culling non-productive cows, improving nutrition and mineral supplementation, etc. Improving mature cow reproduction rates from 84.6 to 93.3% while reducing specified cost/AU by 22.9% was important to improving beef production efficiency.

Overall, economic return over specified cost/AU increased 121.7% ($P < 0.05$). Return over specified cost/AU in year 1 averaged $98.50 ± 62.43 and increased ($P < 0.04$) to $218.35 ± 92.31 by year 5. In year 5, each AU contributed an average of $218.35 to pay overhead and family expenses. This documents that ABIP improved efficiency, improved return above specified cost and achieved the cooperators' goals. Record keeping was critical to document changes due to management. Many cooperators stated that the budget was the most challenging item to complete, but it was the item from which they learned the most.

Harvested forages (hay) were analyzed for nutritional value from all cuttings from all hay meadows each year. During year 1, hays were analyzed, and cooperators fed their normal supplement during the winter period. This was done to document the baseline forage quality and supplemental feeding cost. Beginning in year 2, management practices to improve hay quality and enhance supplemental feeding were implemented. Supplemental feed was defined as purchased feed (corn, cottonseed meal, protein supplements, etc.) and did not include hay cost. The average supplemental feed cost/AU during year 1 was $48 ± 52.51. Supplemental feed cost was reduced to $24 ± 13.88/AU by year 5. Analyzing the forage for nutritional value demonstrated the importance of harvesting hay that meets the nutritional requirement of the herd. Cooperators realized that the greater the hay quality, the fewer supplements were required. Cutting interval, weather, soil fertility, forage variety, etc., can affect hay quality. Managing the small details apparently resulted in improved hay quality and reduced supplemental feeding cost.

Soil samples were analyzed for all hay meadows and pastures. On some farms, the soil nutrient profile (pH, phosphorus (P), and potassium (K)) was acceptable, and a maintenance fertilizer program was recommended. Historically, use of chicken and/or turkey litter for fertilizer resulted in some farms having fields with greater P levels. For those situations, commercial fertilizer blends providing N and K were recommended. For example, the soil P level for a whole-farm pasture in year 1 was 537 lb/acre and 427 lb/acre by year 5. Another example demonstrated how soil fertility was used to address a thinning stand of Tifton 44 bermudagrass. It was determined that K levels were too low (60 lb/acre). It was recommended that soil K should be above 200 lb/acre. A fertilization program was implement-

ed to increase soil K. By year 5, soil K improved to 278 lb/acre, and the percentage of Tifton 44 bermudagrass improved from 83 to 93%. Open ground decreased from 10 to 0%.

Calves were weighed to determine 205-d adjusted BW and ratios according to Beef Improvement Guidelines (BIF, 2002). Where the cow herd performance data were used to make culling and selection decisions, beef cattle performance improved. One cooperator's cow herd started with an average 205-d adjusted BW of 445 lb and cow efficiency (205-d calf adjusted BW divided by the cow's BW times 100) of 46.5%. By year 5, the average 205-d adjusted BW and cow efficiency improved to 501 lb and 49.7%, respectively. This cooperator collected cow herd performance data even after completing the ABIP. After 8 years of cow herd performance, average 205-d adjusted BW and cow efficiency improved to 557 lb and 50.1%, respectively.

Although enrolling steers in the Arkansas Steer Feedout Program was a requirement for the ABIP whole-farm cooperators, not all farms participated. Three of 15 cooperators were purebred cattle operations, one cooperator was already retaining ownership to the feedyard, and six cooperators failed to participate in the Feedout program. Therefore, only five whole-farm cooperators participated in this program. One cooperator increased the percentage of cattle grading USDA Choice from 30 to 70%. Sire selection to complement his cow herd and using carcass EPD's as part of the sire selection process were the keys to improving the percentage grading USDA Choice.

Each cooperator was asked to record major production practices (weaning, fertilizer application, breeding season, etc.) implemented on the farm and the month they were conducted during year 1. In some cases, the cooperator was implementing proper management practices but at the wrong time of year. This was especially true with practices such as fertilizer application and weed control. Suggestions made by the ABIP team to change the timing of some practices resulted in a greater benefit from the respective practice. In addition to the initial documentation of when management practices were implemented, during the annual winter ABIP team visit, a projected plan for the coming year was developed that identified when management practices were to be implemented by month.

Implications

The Arkansas Beef Improvement Program is an integrated resource management educational program that demonstrated cost-effective beef cattle and forage management practices. It attempts to pull together fragmented management technology to aid in the decision-making process to achieve producers' goals. This educational approach provided was successful in improving beef production efficiency.

Acknowledgments

The authors would like to express their sincere appreciation to the Extension agents, Extension specialists and cooperators and their families who have participated and supported ABIP.

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Arkansas Beef Improvement Program: Workshop and Program Evaluation

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Story in Brief

The Arkansas Beef Improvement Program (ABIP) is an Extension educational program using an integrated resource management approach to convey knowledge of beef cattle and forage management systems to producers. One educational method used to transfer ABIP knowledge included workshops. Workshops were offered through county Extension offices and consisted of two, 2.5-h programs. The teaching objectives of the workshop were to: (1) demonstrate the importance of establishing goals, (2) teach the importance of a cow-calf budget, (3) demonstrate the use of a forage analysis to determine supplementation needs, (4) demonstrate the value of cattle production records for selecting replacement and marketing cows, and (5) evaluate forage management practices to achieve production goals. An evaluation was conducted following each workshop to determine if the workshop achieved its educational objectives. Overall, participants responded that the ABIP workshop was very meaningful to their cattle operations, and 100% of the respondents liked the way the workshop was taught. An ABIP survey of all county agents and cooperators who participated in the ABIP whole farm program or any of the ABIP special projects was completed to determine of ABIP was achieving its educational objectives. A majority of cooperators and Extension agents thought their ABIP experience was most valuable (66% and 57%, respectively), and 100% and 97% of the cooperators and Extension agents, respectively, stated ABIP fulfilled their expectations. The ABIP accomplished its educational objectives and made an impact on cooperators and Extension agents. Surveys affirmed that ABIP should be a high priority Extension program.

Introduction

Technology transfer from land grant institutions to agricultural producers may create awareness, but seldom leads to adoption (Beverly, 1988). Oftentimes, it is not the discovery of new technology but the adoption of proven technology that can greatly influence the profitability of a cow-calf operation. Economical cow-calf management is an impossible task if a logical and practical approach has not been developed for collecting and analyzing information, evaluating plans, and directing daily operations. Successful Extension programs have taught integrated resource management, where all ranch resources are evaluated before a decision is implemented (Troxel and White, 1996). This program was typically taught in 2- to 8-d workshops and attempted to teach decision-making skills rather than demonstrating specific beef cattle and forage management technologies. Appropriate management practices change over time and from farm to farm, region to region, and state to state, but the decision-making process does not change. Practicing decision-making skills in an educational workshop format is more efficient in terms of Extension resources than demonstrating decision-making skills on individual producers' farms. Therefore, the objective of this paper is to document the educational value of the county ABIP workshops, and to conduct a survey to determine if ABIP whole farms and special projects were valuable educational programs.

Experimental Procedures

The Arkansas Beef Improvement Program (ABIP) was implemented in 1992. From 1992 to 2003, 45 of the 75 counties (60%) in Arkansas implemented at least one ABIP educational method (Figure 1). The goal of the program was to balance ranch resources to enhance the efficiency and profitability of Arkansas cattle production in an integrated resource management approach. The ABIP decision-making process involved setting goals, evaluating resources, and selecting the management practices to achieve those goals.

The ABIP used multiple educational methods to demonstrate cost-effective beef cattle and forage management practices. These methods included whole-farm programs, special projects, workshops, Extension agent training, and other educational methods (field days, newsletters, popular press articles, etc.).

Workshops were offered through county Extension offices and consisted of two, 2.5-h programs. The workshops were developed to meet the needs of both full- and part-time producers whether operating a small or large operation. Management teams such as husbands and wives, fathers and sons, owners and managers, etc., were encouraged to attend the workshop together. Workshops were limited to a maximum of 25 participants.

The workshop was a means to transfer knowledge gained from the ABIP whole-farm program and special projects. The teaching objectives of the workshop were to: (1) demonstrate the importance of establishing goals, (2) teach the importance of a cow-calf budget, (3) demonstrate the use of a forage analysis to determine supplementation needs, (4) demonstrate the value of cattle production records for selecting replacements and marketing cows, and (5) evaluate forage management practices to achieve production goals. The workshop was taught using problem-solving examples from ABIP experiences. The workshop teaching outline is given in Figure 2. An evaluation survey was completed following each workshop.

ABIP Survey. Seventy-four surveys (43 cooperators and 31 Extension agents) were mailed to past ABIP cooperators (whole-farm and special project cooperators) and Extension agents. Three weeks following the mailing of the survey, another survey was

[1] This material is based upon work supported by the Cooperative State Research, Education, and Extension Service, U. S. Department of Agriculture, and the Cooperative Extension Service, University of Arkansas, under Agreement No. 2002-45033-01408. Any opinions, finding, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U. S. Department of Agriculture.

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mailed to those who had not returned the first survey. Because cooperators and Extension agents attended and participated in ABIP educational activities, separate surveys were developed for each group.

Analysis. Where statistical analysis was not appropriate, means ± SD were used to describe the data. An analysis of variance was performed with the GLM procedure of SAS (SAS Inst., Inc., Cary, N.C.) to analyze responses to the ABIP workshop survey. Chi-square (Cochran and Cox, 1957) was used to analyze survey data to determine if cooperators or Extension agents shared more information about what they learned from ABIP.

Results and Discussion

Twenty ABIP workshops were conducted with an average attendance of 24. Although the responses for some questions were different ($P < 0.05$) across counties (cow-calf budget, mineral supplementation and cow herd performance) and across years (cow-calf budget, supplemental feeding, mineral supplementation and cow herd performance), the data were pooled and are summarized in Table 1. Even though there were significant differences in the responses for these questions (across counties and across years), all of the means were greater than 4.2 (1 = none to 5 = very). Therefore, these differences of means were deemed insignificant in terms of program delivery and producer acceptance. There were no differences in response for the other questions across counties or across years ($P > 0.10$). When asked how meaningful the topics to their cattle operation were, responses averaged > 4.4. When asked if they liked the way the workshop was taught, 100% of the respondents indicated "yes." The workshop participants were also asked if they planned to implement the management practices taught in the workshop (Table 1). The responses to implementing the practices taught in the workshop were very high (66 to 91%). The workshop participants who had implemented these management practices prior to attending the ABIP workshop answered "yes" to these questions. In addition, no effort was made to contact workshop participants to determine if the management practices were actually implemented. Some of the participants responded "no" to those management practices that did not apply to their operation. It was interpreted that the workshop evaluation documented that participants enjoyed and gained from participating in the ABIP workshops.

ABIP Survey. The survey response rate was 79.7% (67.4% cooperator response rate and 96.8% Extension agent response rate). The results of the survey are reported in Tables 2, 3, and 4. Summary of questions and results that were common between the cooperator survey and Extension agent survey are presented in Table 2. Summaries of those questions and results that were unique to the cooperator survey and Extension agent survey are given in Tables 3 and 4, respectively. No differences were noted between the responses of cooperators and Extension agents as to the type of ABIP information shared with others except that Extension agents shared more information about the Arkansas Steer Feedout Program than did cooperators ($P < 0.05$). Since all cooperators in ABIP did not participate in the Arkansas Steer Feedout Program, it would be expected that fewer cooperators would share this information than Extension agents. Overall, a majority of cooperators and Extension agents thought their ABIP experience was most valuable (66% and 57%, respectively), and 100% and 97% of the cooperators' and Extension agents' ABIP expectations were fulfilled.

The unique questions asked cooperators are reported in Table 3. Overall, the ABIP experience helped build cooperator confidence, which should improve their chances for success.

Extension agents used ABIP results in a variety of educational methods (Table 4). The most common methods used were county programs (87%) and county newsletters (80%). Although a majority of Extension agents used ABIP results at a field day (60%), not all Extension agents had a field day associated with their ABIP activity. The Extension agents in the current study (82%) and in a Texas study (88%; Troxel and White, 1996) agreed that the integrated resource management educational experience helped them to become a more effective Extension employee. Extension personnel in the Texas study (Troxel and White, 1996) and in the current study indicated that these types of programs should be a high priority for Extension Services.

Implications

The ABIP workshops were very successful in conveying ABIP knowledge. Educational methods that included hands-on problem solving were appreciated by producers and Extension personnel. Overall, the ABIP verification programs (whole farms and special projects) were successful. This educational approach provided learning opportunities for the producer and Extension personnel. Extension personnel affirmed that these types of programs should be a high priority for Extension Service.

Acknowledgments

The authors would like to express their sincere appreciation to the extension agents, extension specialists and cooperators and their families who have participated and supported ABIP.

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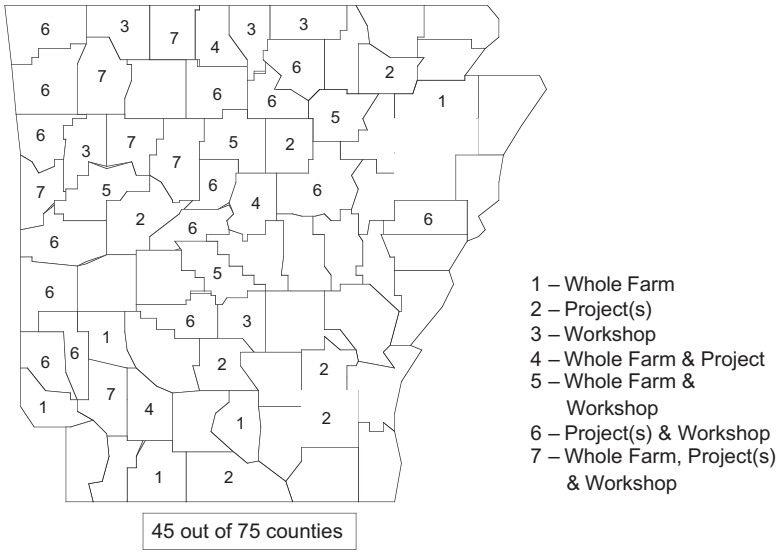

Fig. 1. ABIP Participation by County.

Session 1
Cow-Calf Budgets
- Establish goals
- Monitor changes in the herd composition
- Complete a cow-calf budget
- Measure returns and direct costs of a cow-calf operation

Nutrition: Supplemental Feeding
- Identify the nutritional requirements of different groups of cattle
- Formulate feed supplements based on forage analysis
- Determine the cost of supplemental feeding

Nutrition: Minerals and Vitamins
- Mineral and vitamin requirements
- Identify mineral and vitamin deficiencies of forages and supplements
- Design a mineral-vitamin supplement
- Recommendations for feeding mineral-vitamin mixes

Session 2
Cow Herd Performance
- Overview of the cow herd performance testing program
- Identify the requirements for participating in cow herd performance program
- Use cow herd performance records to select heifers and cull cows

Management Calendar
- Controlled breeding season – managing cattle by production status
- Nutrition, reproduction, health and genetic management

Pasture Management
- Identify seasonal forage requirements of the cow herd
- Forage production practices to meet forage demands
- Identify principles of designing a flexible grazing system

Figure 2. Teaching outline for the ABIP workshops.

Table 1. Summary of the ABIP workshop evaluations.

How meaningful were the following topics to your cattle operation?		
Cow-calf budget	233 [a]	4.4 ± .8[b, c]
Forage testing	229	4.5 ± .7
Supplemental feeding	220	4.5 ± .7
Mineral supplementation	233	4.5 ± .7
Cow herd performance	203	4.4 ± .7
Forage production planning	197	4.6 ± .7
Grazing systems	202	4.5 ± .7
Controlled breeding season	208	4.4 ± .7
Timing of management practices	204	4.4 ± .7

Do you plan to implement one or more of the management tools that were taught?[d]

Topic:	Yes (%)	No (%)	Maybe (%)
Cow-calf budget	70.6	2.8	26.6
Forage test	81.5	1.2	17.3
Supplemental feeding	81.9	3.2	14.9
Mineral supplementation	91.1	2.4	6.5
Cow herd performance	66.1	2.4	31.5
Forage production planning	78.4	1.4	20.2
Grazing system	78.6	2.8	18.5
Controlled breeding season	78.2	2.4	19.4
Timing management practices	73.4	1.2	25.4

[a] Number responding.
[b] Mean ± SD.
[c] 1 = none to 5 = very.
[d] Number responding = 248.

Table 2. ABIP survey questions and results common to both cooperators and Extension agents.

Item:	Cooperators	Extension agents
How many years were you involved in ABIP?	3.1 ± 1.54[a]	3.1 ± 1.42
What information have you shared with other producers that you learned from ABIP?		
a. have not shared information with others	0%	0%
b. importance of budget information	35%	43%
c. steer feedout information	17%[b]	43%[b]
d. importance of planning	62%	53%
e. importance of establishing ranch or production goals	52%	57%
f. importance of pasture/hay meadow management	72%	67%
g. importance of forage testing	76%	90%
h. importance of soil testing	66%	67%
i. importance of beef cattle nutrition	69%	70%
j. importance of cow herd performance	55%	70%
With hindsight, how valuable was your participation in ABIP?		
a. no value at all	0%	0%
b. some value	0%	0%
c. about average value	4%	11%
d. better than average value	30%	32%
e. most valuable	66%	57%
Did ABIP fulfill your expectations?		
Yes	100%	97%
No	0%	4%

[a] Mean ± SD.

[b] Value for cooperators differed from value for Extension agents ($P < 0.035$).

Table 3. Survey questions and results unique to cooperators.

Item:	Response
How has ABIP affected your outlook on ranching?	
a. improved changes for success	3.9 ± 0.74[a,b]
b. satisfaction with accomplishments	4.3 ± 0.54
c. more realistic expectations	4.0 ± 0.92
d. enjoy ranching more	3.8 ± 0.91
e. can improve ranch resources	4.1 ± 1.00
f. improve pride of management	4.2 ± 0.71
g. daily activities have purpose	3.7 ± 1.08
h. involve family more with ranching	3.6 ± 1.36

[a] 0 = not sure; 1 = low outlook to 5 = high outlook.

[b] Mean ± SD.

Table 4. Survey questions and results unique to extension agents.

Item:	Response
How have you used ABIP results in your Extension program?	
a. newsletters	80%
b. field days	60%
c. newspaper articles	57%
d. radio	43%
e. county programs	87%
Has participating in ABIP helped you be a more effective Extension employee?	4.1 ± 0.8[a,b]
What priority should Extension place on ABIP verification-type programs?	4.6 ± 0.7[c]
How many years have you been an Extension employee?	17.1 ± 9.4

[a] 0 = not sure; 1 = no to 5 = very.

[b] Mean ± SD.

[c] 0 = not sure; 1 = none to 5 = high.

Arkansas Beef Improvement Program: Special Projects[1]

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Story in Brief

The Arkansas Beef Improvement Program (ABIP) uses an integrated resource management approach to gain and transfer knowledge about beef cattle and forage management. Special projects included establishing breeding and calving seasons, replacement heifer development, hay quality, forage testing and supplemental feeding, stockpiled forages, pasture renovation, cow herd performance, and market cow management. Production and financial data were measured to evaluate the progress of each project. The average number of years it took to reduce breeding and calving seasons to 90 d was 4.3 ± 0.58 yr. In the replacement heifer special project, heifers reached over 100% of their expected breeding weight at a cost of gain of $0.32/lb. During the hay quality special project, hay yields improved by an average of 52 ± 8.0%, and production costs decreased by an average of 33 ± 12.6%. The average production cost per large round bale of hay was $17.13 ± 0.24. When comparing the cost of stockpiling forage to the cost of hay and supplement to achieve the same level of cattle performance, stockpiling saved an average of $17.92 ± 14.17/head and $11.29 ± 21.79/head for fescue and bermudagrass, respectively. The net return of wintering market cows from the fall to the spring was $48/head. The ABIP special projects were excellent educational methods to demonstrative cost effective beef cattle and forage management practices.

Introduction

Extension demonstrations are very effective educational methods, but can be time consuming. Because of the success of the Arkansas Beef Improvement Program (ABIP) whole farm program, which required a 5-yr commitment, special projects were developed that looked at specific beef cattle and forage management practices. Three advantages for implementing ABIP special projects were: 1) more counties could get involved in the ABIP program; 2) special projects would last 2 to 3 yr; and 3) specific beef cattle and forage management practices could be better evaluated. The objective of this paper is to document the ABIP special project educational processes and share knowledge gained with the Arkansas cattle industry.

Experimental Procedures

Breeding and Calving Seasons Special Project. The objective was to demonstrate the beef cattle management changes necessary to convert a year-long breeding and calving season to a short breeding and calving season (< 90 d) and to assess the impact of those changes. From the benchmark calving distribution, a plan of work was developed to reach the cooperator's desired breeding and calving season. Supplemental feeding, mineral supplementation, breeding soundness examinations for bulls, and other management factors that could affect reproduction rates were reviewed and, if necessary, changes were made.

Replacement Heifer Development Special Project. The objective of the replacement heifer development special project was to demonstrate the management necessary to develop heifers from weaning to first breeding. Heifers were individually identified and weighed at weaning to establish a beginning BW. Data such as hip height measurements and muscle scores also were recorded. Projected target BW (65% of mature BW) and date for breeding were determined, and harvested forages were tested. A least-cost supplement was calculated to obtain the appropriate gain necessary to reach the target BW at the projected breeding date. Two blood samples were collected 10 d apart to assess progesterone levels and to determine estrous cycle activities prior to the breeding season. Heifers were individually weighed every 30 to 45 d and at the beginning of the breeding season.

Hay Quality Special Project. The objective was to demonstrate proper fertilization and harvesting practices to improve hay quality. Soil analysis and pasture inventories were conducted annually on each hay meadow. Data such as harvest information (harvest conditions, tonnage, etc.), rainfall, inputs (including fertilizers, agricultural limestone, chemicals, etc.), and hay analysis from each harvest date were collected.

Forage Testing and Supplemental Feeding Special Project. The objective was to develop supplements based on forage analysis for wintering beef cattle. A representative sample of each cutting of harvested forage was analyzed to determine nutritional value. A supplement was formulated based on the results of the forage test, nutritional requirements of beef cows (NRC, 1996), and locally available feedstuffs. Data collected included supplementation cost, cost of historical supplementation practice, and cattle performance (BW, body condition scores, etc.).

Stockpiled Forages Special Project. The objective was to demonstrate the practice of stockpiling forage in the fall for winter grazing. Stockpiling pastures had at least 50% cover of fescue or bermudagrass. Nitrogen fertilizer was applied (50 to 60 lb/acre) in late summer or early fall, and forage growth was allowed to accumulate. Forage samples were collected to determine nutrient value and nitrate-N concentration in October, d 1 of cattle grazing, and once monthly until forage availability became limiting. Yield was estimated on d 1 of cattle grazing by clipping a 0.2 m^2 area of forage to 4.0 cm. Samples were dried and weighed. Data collected included number of cattle grazing, cattle performance (BW, body condition scores, etc.), pasture size, number of days grazed, cost associated with stockpiling, and cost associated with hay and supplement (if necessary) to obtain similar cattle performance as achieved from stockpiling forage.

[1] This material is based upon work supported by the Cooperative State Research, Education, and Extension Service, U. S. Department of Agriculture, and the Cooperative Extension Service, University of Arkansas, under Agreement No. 2002-45033-01408. Any opinions, finding, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U. S. Department of Agriculture.

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Pasture Renovation Special Project. The objective was to demonstrate effective pasture improvement by matching recommendations with the producer's goals. Producer goals were to increase stocking rates, utilize rotational grazing, have forage available year-round, reduce hay feeding to 60 d, and eliminate the need for a designated hay meadow so all pastures could be harvested (grazing or hay). Pasture fields were soil tested each year, and inventories were completed in the spring and summer for forage species, weeds, and bare ground percentage. Recommendations for fertilizer, weed control, and grazing and hay management were based on results of these assessments. To improve forage growth and to establish legumes, target fertility levels were set at a soil pH of 6.0, phosphorus of 60 lb/acre and potassium of 200 lb/acre. Fertilizer application was timed to stimulate growth of remnant patches of warm-season grasses for summer grazing in some pastures and to encourage establishment and growth of legumes in others. Rotational grazing was used to improve legume persistence and to extend available forage during summer months. Annual lespedeza and clover were overseeded in selected pastures during winter to improve forage quality.

Cow Herd Performance Special Project. The objective was to demonstrate the improvement of economically important traits in a beef cattle herd through selection of high performing females for herd replacements and the removal of low performing females. Cooperators were required to individually identify cows and calves, maintain a breeding season (< 90 d), record calving dates, participate in the Arkansas Steer Feedout Program, and weigh cows and calves to determine 205-d adjusted weights, weight ratios, and Most Probable Producing Ability (BIF, 2002). Cow efficiency was defined as the 205-d adjusted BW divided by the dam's BW at the time of weaning. The Arkansas Steer Feedout Program provided the opportunity to acquire postweaning performance (feedlot ADG, etc.) and carcass characteristics (USDA Quality Grades, yield grades, etc.) data. With input from the cooperator, low-performing cows were marketed, and heifers were selected for replacements.

Market Cow Management Special Project. The objective of the market cow management special project was to demonstrate the management necessary to improve the value of market (cull) cows. Cows were selected for culling and were individually identified and weighed in the fall at weaning time. When the cows were selected for culling, the value of the market cows was determined by a USDA certified livestock reporter. Body condition scores (BCS; 1 to 9 scoring system) were recorded, and a feeding program determined to improve condition. At the time of marketing, cull cows were individually weighed and BCS recorded.

Analysis. Income and specified expenses were recorded and analyzed as described by Gadberry and Troxel (1999). Where statistical analysis was not appropriate, means ± SD were used to describe the data. The t-test as described by Freund and Wilson (1993) was used to determine if the percent change in production items was different from a zero percent change within special projects. An analysis of variance was performed with the GLM procedure of SAS (SAS Inst., Inc., Cary, N.C.) to analyze production level differences in special projects.

Results and Discussion

Breeding and Calving Season Special Project. Five farms were enrolled in this special project with an average of 53 ± 46.6 cows. The average number of years it took to reach the cooperator's desired breeding and calving season goals was 4.3 ± 0.58 yr. The percentage of cows calving during the desired calving season in the baseline year (yr = 0) was 36.5 ± 12.2%. The percentage of cows calving in the desired calving season increased from the baseline year to 40.5 ± 7.2%, 46.7 ± 16.6%, 67.0 ± 31.6%, 87.0 ± 22.5% and 100 ± 0.0% for yr 1, 2, 3, 4 and 5, respectively. The average length of the calving season decreased to 281.5 ± 57.0, 230.8 ± 69.4, 217.0 ± 109.0, 133.75 ± 72.2, 100.0 ± 45.8 and 96.7 ± 4.7 d for yr 1, 2, 3, 4 and 5, respectively. When averaged across all farms, break-even (specified cost divided by pounds of beef sold) decreased 38% from $0.50 ± 0.08/lb to $0.31 ± 0.07/lb in yr 3. Specified cost/AU dropped from $180.19 ± 62.24 to $121.89 ± 7.10 from yr 0 to yr 3, respectively. Income over specified cost improved 75% from $77.65 ± 63.73/AU in yr 0 to $135.53 ± 44.58 in yr 3. This demonstrated that the farms were able to increase beef production efficiency due to decreasing the breeding and calving season. This project was very successful, but required a cattle cooperator who was committed to reducing the breeding and calving season and would stay with the program for 4 to 5 years.

Replacement Heifer Development Special Project. Six cooperators participated in the 2-yr project with an average of 18.0 ± 9.3 heifers. It was discovered that most cooperators were overfeeding because they thought high rates of gain were necessary. In yr 1, the average heifer reached 103.3 ± 11.2% of their target BW, and in yr 2 the average heifer reached 102.5 ± 7.3% of their target BW. The number of heifers exhibiting estrous cycles prior to the breeding season improved from 60.0 ± 13.9% in yr 1 to 82.2 ± 8.3% in yr 2. The feed cost/lb of gain for yr 1 and 2 were $0.48 ± 0.33/lb and $0.32 ± 0.08/lb, respectively. The total cost/lb of BW gain for yr 1 and 2 were $0.69 ± 0.20/lb and $0.50 ± 0.20/lb, respectively. The total cost of raising heifers to breeding (including the value of the heifer) ranged from $732 to $782/head.

Hay Quality Special Project. The four farms enrolled in the hay quality improvement project were already producing good-quality hay. Therefore, it was difficult to make great quality improvements. When averaged across the farms completing the project, crude protein (CP) and total digestible nutrient (TDN) content of hay did not change; however, one farm improved CP percentage by 20% and TDN by 7%. Forage maturity at harvest has the greatest influence on hay quality. Seasonal weather variations such as delayed harvest during wet spring weather and extended harvest intervals during summer drought influenced hay maturity and quality. Producers did benefit from recommendations through increased hay yields and lesser production costs. Across farms, hay yields improved by an average of 52 ± 8.0%, and production costs decreased by an average of 33 ± 12.6%. The average production cost per large round bale (4 X 5 foot) of hay was $17.13 ± 0.24. This information has helped producers to determine the value of hay being sold or produced.

Forage Testing and Supplemental Feeding Special Project. Eleven cow-calf cooperators with an average of 41 ± 35.3 cows and three stocker cattle cooperators with an average of 134 ± 107.1 stockers participated in this special project. When working with the cow-calf cooperators, three situations were experienced. The first situation was the hay quality was sufficient so no additional protein or energy supplementation were needed. One cooperator discovered that hay quality was 12.9% CP (DM basis) and 63.2% TDN (DM basis) which was sufficient to meet the protein and TDN requirements (NRC, 1996) of his cows. A second producer saved $14.24/head because the hay met CP and TDN requirements. The range meal he usually fed was not necessary. In some cases, the supplemental feed cost did not change. For example, a cooperator was spending $1.45/head/d (cost includes hay and supplement) on supplemental feed but was purchasing the wrong kind of feed (soybean hulls and a liquid feed supplement). As a result of the forage analysis, the liquid feed was discontinued and additional soybean hulls were fed, resulting in a feed cost of $1.46/head/d. A third situation

occurred where the hay quality was low and supplemental feed cost increased. Because of the additional supplement, average cow BCS improved from 4.5 to 5.0, and the cooperator was pleased with overall cow performance. In conclusion, supplemental rations when hay quality was average or better resulted in a reduction of $3.50 to $12.00/head in winter feed costs. In contrast, when hay quality was poor, cattle were reported (by the producers) to improve in condition when steps were made to implement feeding recommendations designed to maintain or improve body condition. On average, winter feed costs were $0.61 ± 0.07 head/d when hay quality met animal requirements and $1.32 ± 0.20 head/d when hay quality did not meet animal requirements.

Two extremes were experienced with the stocker cattle cooperators. One stocker cattle operator had high-quality hay (18.5% CP and 66.4% TDN; DM basis). A corn and soybean hull pellet mixture was recommended resulting in BW gains of 1.0 to 1.25 lb/d at a cost of $0.43/lb. A second stocker cooperator had lesser quality hay (11.9% CP and 51.8% TDN) but was expecting calves to gain 1.0 to 1.25 lb. It was recommended that 4 lb of corn be supplemented, which he chose not to feed.

Stockpiled Forages Special Project. Ten cooperators (8 stockpiled fescue and 2 stockpiled bermudagrass) with an average of 35 ± 19.9 cows participated in this special project. The average cost of stockpiling fescue and bermudagrass was $13.90/acre and $21.00/acre, respectively. The average production per acre of stockpiled growth for fescue and bermudagrass was 2,031 ± 554.6 lb/acre and 2,531 ± 997.2 lb/acre, respectively. The number of days cattle grazed the stockpiled fescue and bermudagrass was 50 ± 27.3 d and 117 ± 52.3 d, respectively. When comparing the cost of stockpiling to the cost of hay and supplement to achieve the same level of cattle performance, stockpiling saved an average of $17.92 ± 14.17/head and $11.29 ± 21.79/head for fescue and bermudagrass, respectively.

Quality of stockpiled fescue was consistently high across farms and years (Figure 1). Mean concentration of CP and TDN declined during the winter, but generally met or exceeded the requirements for a lactating 1,100 lb cow until late winter. Average CP and TDN of hay sampled on each farm was 12.4 ± 2.2% and 55.3 ± 4.8%, respectively, which was less than that of most stockpiled fescue samples.

Pasture Renovation Special Project. After yr 3, percentage of the pasture covered by legumes increased by 6% and warm-season grasses increased to 45% across the farm. Bare ground percentage decreased from 21% to less than 5% across the farm. The number of grazing days increased by 51%, and the number of winter hay feeding days decreased by 43%. The designated hay meadow was eliminated, and all fields were grazed or harvested for hay as needed due to increased forage productivity. The cost of pasture improvement including inputs for fertilizer, lime, herbicide and seed averaged $28.15 acre/yr. Results indicated that pastures could be effectively improved without total renovation by accurately assessing pasture conditions, then matching recommendations with those assessments and producer goals.

Cow Herd Performance Special Project. Three farms with an average of 47 ± 19.6 calf records per year participated in the cow herd performance special project. All farms showed an increase in 205-d adjusted BW from yr 1 to the final year. The increase in 205-d adjusted BW from yr 1 to the final year for farms 1, 2, and 3 were 44 lb, 79 lb and 27 lb, respectively. In addition, BCS generally increased, specified cost/AU decreased 79% and specified cost divided by lb of beef sold dropped 41% from yr 1 to yr 5. This project showed dramatic results, especially when the average 205-d adjusted BW of the cooperator's herd was low. It did, however, take at least 4 to 5 yr to change cow herd genetics to the point where herd averages were impacted.

Market Cow Management Special Project. Only one farm with six market cows participated in this project. The average BW, live value/cwt., and value per head on December 4, 2002 were 1,070 ± 98.7 lb, $29.33 ± 2.25, and $315.56 ± 53.61, respectively. The average BW for market cows on sale date (March 1, 2003) was 1,107 ± 8.26 lb. All market cows sold for $35.00/cwt or an average $388/head. The cost of wintering the market cows was $26/head (hay, supplemental feed, mineral and salt). This resulted in a return of $48/head. Retaining ownership of market cows from the fall to the spring has been a profitable practice 20 out of the last 21 years (Cattle-Fax, 2001); the average net return/head was $36.32, $46.80 and $54.07, for the five-yr, 10-yr, and overall averages, respectively. The return experienced in this special project was similar to the norms reported by Cattle-Fax (2001).

Implications

The Arkansas Beef Improvement Program special projects have demonstrated cost-effective beef cattle and forage management practices. Most of the practices demonstrated can be implemented by the Arkansas beef cattle industry regardless of farm size. This educational approach provided learning opportunities not only for the producer but also the participating Extension personnel.

Acknowledgments

The authors would like to express their sincere appreciation to the extension agents, extension specialists and cooperators and their families who have participated and supported ABIP.

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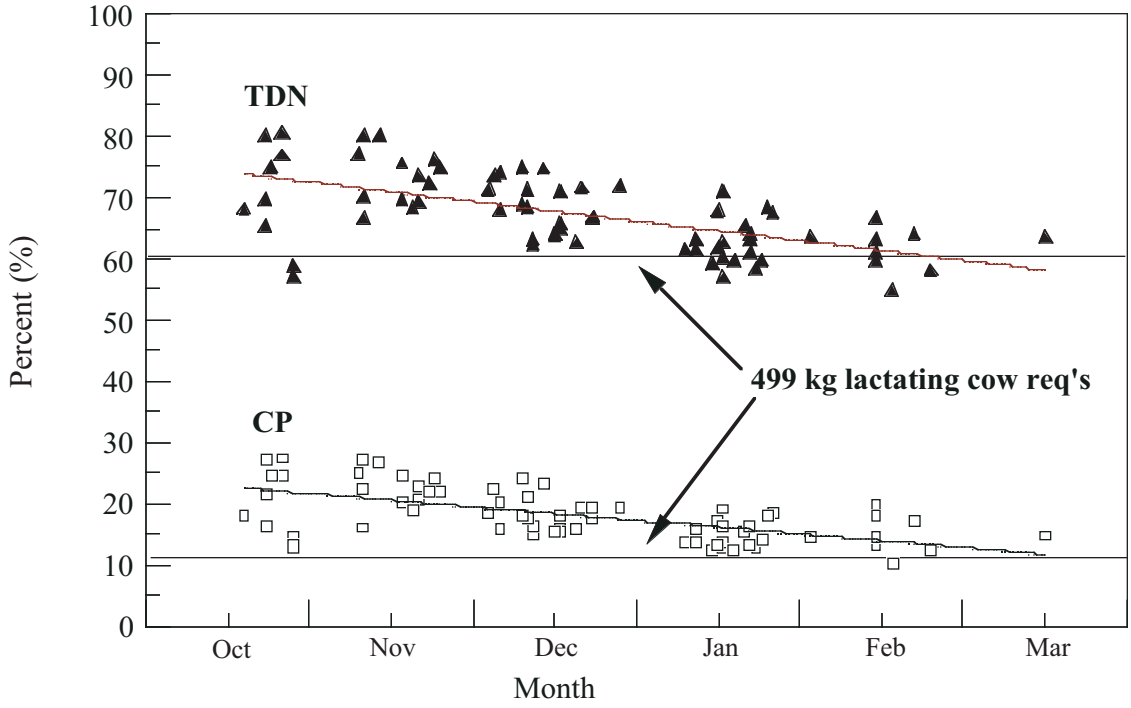

Fig. 1. Crude protein (CP) and total digestible nutrient (TDN) percentage of stockpiled fescue samples collected from ABIP project farms.

Arkansas Steer Feedout Program 2002-2003

T.R. Troxel, S. Gadberry, S. Cline, G.V. Davis, and D.E. Kratz[1]

Story in Brief

The objective of the Arkansas Steer Feedout Program is to provide cow-calf producers information about the postweaning performance and carcass characteristics of their calves. For the 2002-2003 feedout, hot carcass weight, quality grade, days on feed, yield grade, dressing percentage, medicine cost, and feed cost of gain were significant factors that affected the feedlot return over specified cost. Cow-calf producers who participated in this program can use the information to better evaluate their cattle breeding programs.

Introduction

The Steer 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, nor is it 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 are warranted.

Experimental Methods

On November 7, 2002, 170 steer calves from 23 Arkansas producers representing 16 counties, were placed on feed at Oklahoma Feeders Inc., Coyle, Okla. Upon arrival, steers were eartagged, weighed, and processed (Ivomec, Component, Covexin, ResProMune 4, and *pasteurella bacterin*). An Arkansas Livestock Market Reporter placed an arrival value on all calves. Steers were sorted into two pens based upon weight, frame, and condition. Management factors such as processing, medical treatments, and rations were the same as for the other cattle in the feedyard. The feedyard manager and Extension specialist selected individual steers (from either pen) for slaughter when they reached the weight and condition regarded as acceptable for the industry and market conditions. Calves were slaughtered in two groups (April 15 and May 20, 2003). 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. Steer carcass values for Choice-Yield Grade 2 carcasses were $132.03 and $134.70 for April 15 and May 20 harvest dates, respectively.

Descriptive statistics were computed to describe general program results. Of the 170 steers delivered in the fall, three died (2.8% death loss), four carcasses were used by IBP (Iowa Beef Processors) for quality control checks; and therefore, carcass data were not obtained from these animals. These steers were not included in the statistical analyses. The final data set analyzed consisted of feedlot and carcass data from 163 steers.

Carcasses of steers also were grouped according to whether they fit an industry standard for carcass merit (at least Choice, yield grade < 3.5, and 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 carcass value, ADG and net return were determined using the GLM procedure of SAS (SAS Inst. Inc., Cary, N.C.). Least-squares means were computed and reported.

Calves were sorted into the top or bottom 25% category based upon their feedlot return (income minus feedlot direct expenses). Factors affecting feedlot return for the top 25% steers and the bottom 25% steers were determined using the Stepwise method of PROC REG of SAS (SAS, Inst., Inc., Cary, N.C.). 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 per 100 lb of hot carcass weight; and dressing percentage. The cow-calf producer recorded the breeding percentages (percentage of Brahman, English and Continental).

Results and Discussion

The financial summary is reported in Table 1. Average steer gross income per head was $945.59 (range = $451 to $1,221). The steer feedlot return averaged $571.50, whereas the calculated returns (accounted for the initial value of the calf at arrival) averaged $97.81 (range = $-129 to $279).

The sick rate was very low with eight calves (4.7%) treated for sickness. The average medicine cost per sick calf was $48.13. In the judgment of the feedlot manager there were a number of unthrifty looking calves in one pen where a preventive treatment was initiated. Calves with a body temperature between 101.5° F and 102.5° F received a preventive treatment of Baytril and Banimine, and calves with a body temperature of greater than 102.5° F received a preventive treatment of NuFlor. Calves with a normal body temperature (101.5° F) did not receive a treatment. Fifty-two calves received the preventive treatment with an average cost of $24.23 per head. Only three calves that received the preventive treatment required additional medical attention (NuFlor and Banimine). The overall average medicine cost (n = 170 steers) was $10.01.

The health status of cattle in the feedyard usually has a major impact on performance and profit. Healthy steers had higher feedlot returns ($610) than steers that became sick ($483; $P < 0.001$). In addition, healthy steers had higher initial weights (689 vs. 632 lb; P

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< 0.06), higher initial values per head ($501 vs. $452; P < 0.01), fewer days on feed (174 vs. 186; P < 0.05), lower total cost of gain ($0.69 vs. $0.78; P < 0.01), and higher carcass weights (761 vs. 713 lb; P < 0.01) than steers that became sick. Sickness also impacted the calves' ability to grade Choice. More healthy steers graded Choice (56%) than steers that were treated for sickness (25%) or received the preventive treatment (47%). The percentages that graded Select for healthy steers, steers that received the preventive treatment, and sick steers were 35%, 53% and 62%, respectively (P < 0.03). This vividly points out the need to adhere to a sound health management plan. Implementing a sound vaccination program at the farm of origin, and thus keeping calves healthy, will play an important role in allowing calves to express their genetic potential.

Variability in health is built into the calf market. Buyers factor this into what they are willing to pay for calves. There are cattle feeding operations that are willing to pay more for good quality cattle that have been properly immunized and properly backgrounded. The amount they are willing to pay is dictated by the increase in the added value of benefits and the quantity of similar type cattle, which can be purchased and managed as a unit.

The steer average off-the-truck arrival weights were 660 lb (range = 444 to 876). The steer average daily gain, average days on feed, feed cost per lb of gain, and total cost per lb of gain were 3.01 lb (1.62 to 4.28), 176 days (156 to 190), $0.60 ($0.41 to $0.91), and $0.69 ($0.46 to $1.01), respectively.

The average steer carcass weight, ribeye area, dressing percentage, yield grade, and fat thickness were 741 lb (440 to 925), 12.6 in2 (8.6 to 16.6), 62.2% (56.3% to 66.8%), 2.72 (1.05 to 4.49), and 0.42 in. (0.20 to 0.84), respectively. Fifty-one percent of the carcasses graded Choice whereas 41% and 6% graded Select and Standard, respectively. Only 1% of the carcasses graded Prime.

Listed below are the significant factors that affected the feedlot return over specified costs for the steers in the 2002-2003 Steer Feedout Program. Factors are listed from the most important to the least important.

Factors Affecting Returns Over Specified Cost

1. Hot Carcass Weight
2. Quality Grade
3. Days on Feed
4. Yield Grade
5. Dressing Percentage
6. Medicine Cost
7. Feed Cost of Gain

1. Hot Carcass Weight - The relationship between hot carcass weight and feedlot net return was positive. As hot carcass weight increased, so did feedlot net return. The more carcass pounds that were sold, the greater the gross income and feedlot net return. Table 2 shows the relationship between hot carcass weight, total cost of gain, average daily gain, feedlot net return and calculated return. Hot carcass weight discounts were observed for carcasses weighing less than 550 lb and greater than 950 lb.

Factors that affect hot carcass weight include frame size, muscle thickness and backfat. Muscle thickness is a major factor that relates to carcass weight. Thickness, depth and fullness of quarter, and width (without excessive fat) of back, loin and rump are indications of muscling. Muscling is inherited through the sire and dam.

2. Quality Grade - Cattle that graded Choice, Select, Standard and Dark Cutter had feedlot net returns of $643, $528, $502 and $490 per head (P < 0.001), respectively. Marbling is the primary 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) ration. Some cattle breeds report marbling EPDs in their sire summaries. Carcass traits such as marbling are highly heritable; therefore, selecting high marbling EPD bulls can be effective for improving the marbling ability of their calves. Breed also can influence a calf's ability to grade Choice.

3. Days on Feed - Cattle were sold on either April 15 or May 20, 2003. A negative relationship existed between days on feed and feedlot net return. That means that on the average, the longer the steers were on feed the lower the net returns (Table 3). A factor that affected the relationship between days on feed and feedlot net return was the price difference between Choice and Select quality grades. On April 15, a price spread of $7.00 per cwt existed between Choice and Select Yield Grade 3 carcasses, and by May 20, the spread increased to $14.00 per cwt. Generally, there is a seasonal pattern for price spreads between Choice and Select. Often, the spread between Choice and Select is very low early in the year, starts to widen during the late spring months and usually continues to widen into early fall. The Choice-Select spread is usually widest during the late fall and winter period. It was interesting to note that although the price of Choice Yield Grade 3 carcasses from April 15 to May 20 remained about the same ($130 to $132 per cwt), feedlot net return decreased. This was because fewer steers harvested on May 20 graded Choice compared to the steers harvested on April 15. Consequently, more of the May 20th harvested steers graded Select, No Roll or Standard or were discounted for light carcasses.

4. Yield Grade - As yield grade increased from 1 to 3, feedlot net return decreased ($599, $570 and $616 per head for yield grades 1, 2 and 3, respectively). There were no significant differences between feedlot net returns for Yield Grades 1 and 3, but feedlot net returns for Yield Grades 1 and 3 were significantly higher than the feedlot net return for Yield Grade 2. Backfat, ribeye area, hot carcass weight and percentage of kidney, pelvic and heart fat determine yield grade. As yield grade (1 to 4) increases, the amount of fat increases in relation to the amount of lean.

5. 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. The top 25% of steers (based on feedlot return) had a dressing percentage of 63.1% compared to 61.4% for the steers in the bottom 25% (P < 0.05).

6. Medicine Cost - Healthy calves outperformed sick calves. A good preconditioning vaccination program will not guarantee a healthy feedyard calf, but it is the best management tool available. Healthy calves had a higher feedlot net return ($610 vs. $483 per steer) than calves that were treated for illness. A higher percentage of healthy steers graded Choice than did the sick calves.

7. Feed Cost of Gain – Feed costs were allocated based on initial weight and final ADG, and feed cost of gain takes into account many different factors such as average daily gain, health, feed cost, feed efficiency, frame score, muscle score, etc. Generally, feed cost of gain is inversely related to average daily gain. That is, as average daily gain increases feed cost of gain decreases. Therefore, as feed cost of gain goes down, feedlot net return increases.

Table 4 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 higher feed and medicine costs, lower 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. Fifty-one percent of the steers in the

2002-2003 Steer Feedout Program met the industry standards. The breed makeup of the steers that met the industry standards were 57% English, 8% Brahman and 35% Continental. Steers that met the industry standards averaged $115 more per head than those that did not fit the industry standards ($P < 0.01$). They had higher carcass values ($1.34 vs. $1.21; $P < 0.01$) 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). Steers that met the industry standards had higher average daily gains (3.10 vs. 2.96; $P < 0.03$) than steers that did not meet the industry standards.

Implications

Extremes in feedlot returns are due to health costs, feedlot performance factors and carcass parameters. Value-based marketing at all levels of the industry is rapidly becoming a reality. A producer's goal should be to produce a product that meets the needs of all segments of the beef industry, and those who do this will be more competitive in the market place.

Table 1. Financial summary 2002-03 Arkansas steer feedout program.

Item	Average	Range
Gross income	$945.59	$451 to $1,221
Expenses		
Feed	$312.35	$109 to $399
Medicine	$10.01	$0 to $96
Freight, processing, yardage, interest, etc	$35.30	$24 to $40
Total feedlot expenses	$357.41	$155 to $437
Feedlot return	$571.50	$211 to $805
Steer calf in value	$471.34	$386 to $654
Calculated return	$97.81	$-129 to $279

Table 2. Summary of hot carcass weight, total cost of gain, average daily gain (ADG), feedlot net return and calculated return.

Hot carcass weight (lb)	Total cost of gain ($)	ADG (lb)	Feedlot net return per steer ($)	Calculated return per steer ($)
< 600	0.70	2.1	346	-50
600-699	0.66	2.8	520	78
700-799	0.69	3.0	586	95
800-899	0.70	3.3	676	139

Table 3. Effect of days on feed on average daily gain, total cost of feed, carcass value and feedlot net return.

Slaughter Date	Days on feed	ADG (lb)	Total cost of gain ($)	Carcass value per lb ($)	Feedlot net return per steer($)
15-Apr	156	3.2	0.71	1.3	637
20-May	190	2.9	0.67	1.25	549

Table 4. The performance of the bottom 25%, average and top 25% steers based on feedlot returns.

Item	Bottom 25%	Top 25%	Average
Number of steers	41	42	163[a]
In weight (lb)	590[b]	730[c]	600
Muscle score	1.8[d]	1.5[e]	1.6
Frame score			
Large	59%[b]	93%[c]	82%
Medium	41%[b]	7%[c]	18%
Final weight (lb)	1,113[b]	1,280[c]	1,191
Average daily gain (lb)	2.84[b]	3.29[c]	3.01
Gross income	$819[b]	$1,078[c]	$946
Carcass value per lb	$1.20[b]	$1.34[c]	$1.27
In value per head	$446[b]	$529[c]	$471
Hot carcass weight (lb)	684[b]	808[c]	741
Dressing percentage	61.4%[b]	63.1%[c]	62.20%
Medicine	$18.92[f]	$3.63[g]	$10.01
Total feed cost per head	$290[b]	$337[c]	$312
Total expense	$341	$378	$357
Feedlot returns	$421[b]	$701[c]	$572
Calculated returns	$-24[b]	$172[c]	$98
Days on feed	187[b]	167[c]	176
Feed cost per lb of gain	$0.57[b]	$0.62[c]	$0.60
Total cost per lb of gain	$0.67	$0.69	$0.69
Ribeye area (in^2)	11.8[b]	13.2[c]	12.6
Fat thickness (in.)	0.36[b]	0.47[c]	0.42
Quality grade			
Prime	0%	2%	0.60%
Choice	5%[b]	93%[c]	51%
Select	73%[b]	5%[c]	41%
No Roll	20%[b]	0%[c]	6%
Standard	2%	0%	0.60%
Yield grade	2.00[h]	2.29[i]	2.72

[a]Seven calves were not used in this data set. Three calves died and four were used as IBP quality control checks.

[b,c]Values within rows with unlike superscripts are different ($P < 0.01$).

[d,e]Values within rows with unlike superscripts are different ($P < 0.06$).

[f,g]Values within rows with unlike superscripts are different ($P < 0.02$).

[h,i]Values within rows with unlike superscripts are different ($P < 0.03$).

Sire Breed Effects on Preweaning Traits of Crossbred and Purebred Calves from Angus or Hereford Dams

E.L. Oxford, A.H. Brown, Jr., Z.B. Johnson and D.W. Kellogg[1]

Story in Brief

The objective of this research was to evaluate variation in calf performance from birth to weaning due to breed of sire (BRS), breed of dam (BRD), sex of calf and all interactions. Records from 2,352 calves born at the Pinetree Research unit of the Arkansas Experiment Station were utilized in the study. The physical environment and the available production resources make this location one of the more challenging environments for feeder calf productions in the state. Calves resulted from mating Angus and Hereford dams to Angus, Hereford, Charolais, Santa Gertrudis, Red Poll, Brown Swiss, or Holstein sires. Data collected were birth weight (BWT), preweaning average daily gain (ADG), weaning weight (WWT), weaning grade (WGR), and weaning body condition score (WBCS). Year, BRD and BRS were significant ($P < 0.01$) for all traits studied. Sex of calf was significant for BWT, ADG, WWT, and WGR, but not for WBCS. The interaction of BRS x BRD affected ($P < 0.01$) all traits studied except ADG and WBCS. This interaction indicated that there were differences in calf performance between the two dam breeds depending on the sire breed of calf. These data indicated breed differences exist for preweaning performance of two-breed-cross calves produced in an Eastern Arkansas production environment.

Introduction

The future potential of the Arkansas cattle industry for production is limited only by the ability of the industry to adapt the state's herds to the available resource base. The state resources, including land areas, soils, forages, labor, management, financial capital, etc., all have the potential to be better utilized. Matching the animal to those inputs is essential to achieving the goal of maximizing their utilization. In recent years, many producers have made crossbred matings in an effort to achieve their goals. Crossbred matings offer the opportunity to take advantage of hybrid vigor in certain traits in the offspring, and seek combinations of traits that may not occur together in the purebred parent stock. Thus, possible crosses must be evaluated before decisions can be made as to which offer the greatest advantages. In more recent years, the price structure in the industry is encouraging production with some marginal resources, and there has been moderation of mature size in the state's cow herd, thus a revisit of some earlier obtained data for evaluation of breed crosses seems appropriate. Therefore, the objective of this study was to evaluate birth weight, growth, and weaning traits of calves from two dam breeds and seven sire breeds for feeder calf production in eastern Arkansas.

Experimental Procedures

Records on 2,352 calves born from 1965 through 1977, representing two dam breeds and seven sire breeds, were utilized in this study. Angus and Hereford dams were mated to seven sire breeds: Angus, Hereford, Brown Swiss, Charolais, Holstein, Santa Gertrudis and Red Poll. A distribution of the two-breed-cross calves for each breed of dam by breed of sire combination is presented in Table 1. All animals were located at the Pinetree Station in the University of Arkansas Agricultural Experiment Station System. The station is located approximately 45 miles due west of Memphis, Tenn., and 4 miles west of Colt, Ark., in St. Francis County in the L'Arguille river drainage system. The topography is relatively flat and the soils for pasture production are poorly drained. For the study period, mean annual low and high ambient temperatures were 50.2°F and 73.0°F, respectively, and mean annual ambient temperature was 61.5°F. Mean annual rainfall at this location was approximately 55 inches (National Climatic Data Center, Asheville, N.C.). Each year, during the spring and early summer ecto- and endo-parasite populations were considerably above the economic threshold. Also, it was common to count 30 to 40 horse files per cow during the peak of the horse fly season. The incidence of anaplasmosis was high. The Pinetree Station represents the most environmentally challenging area for feeder calf production in the state.

In each year of the study, pastures consisted of approximately a 60:40 ratio of unimproved pasture to improved pasture. The unimproved pasture consisted of stands of little blue stem grass and other native species. The improved pastures were stands of Kentucky 31 tall fescue which was approximately 80% infected with a fungal endophyte. Cows grazed unimproved pastures in the warm season and the improved pastures in the cool season. Fescue stands were fertilized in the fall according to the soil test recommendations. Stocking rate on the warm season grass was one cow-calf unit per 3.71 acres and stocking rate on the fescue was one cow-calf unit per 1.25 acres. Cows were fed a liquid protein supplement free-choice from a tank through the use of a lick wheel in the late fall and during the winter until grass was available the following spring. The liquid protein supplement consisted of approximately 45% wood molasses, 29% molasses/urea mix, 20% condensed corn distillers solubles, and 6% mineral and vitamins (Southern Farmers Association Cooperative, Little Rock, Ark.). Cows received approximately 14 lb/d (air dry basis) of a medium quality bermudagrass hay during the late fall, winter and early spring. Calves received no creep feed.

All animals were managed similarly and management practices during the study period were consistent with those for commercial beef production in Arkansas. Cows were exposed for natural service mating in single sire pastures in a 120-day breeding period from

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January 15 through May 15 of each year. Bulls were tested via a breeding soundness evaluation approximately 60 days prior to the start of the breeding period. Within sire breed group assignment, bulls were rotated among pastures to improve mating performance. Calving started around November 1 and ended around March 1 of each year. Within 24 hours of birth, calves were ear tagged, tattooed, weighed (BWT) and male calves were castrated. Calves were weighed and weaned in late August. Weaning body condition score (WBCS) and weaning grade (WGR) were independently determined by trained personnel. Data for these observations were the mean of the independently determined scores and grades for each calf. The same personnel evaluated all calves in the study. Weaning grades were based on the 17-point Arkansas Beef Improvement Program grading chart and weaning body condition scores were based on the 7-point system of the same program (Table 2). Birth weight and weaning weight (WWT) were adjusted for age of dam and sex of calf based on adjustment factor information from the Beef improvement Federation (BIF, 1996). Data were analyzed by least squares analysis of variance with unequal subclass numbers. Sources of variation in birth weight and weaning traits were separated with a mathematical model that included terms for an overall mean, year, sex of calf, breed of sire, breed of dam, the two-way interactions of sex of calf x breed of sire, sex of calf x breed of dam and breed of sire x breed of dam and the three-way interaction of sex of calf x breed of sire x breed of dam and residual using the GLM procedure of SAS (SAS Inst. Inc., Cary, N.C.). In a preliminary analysis, age of calf and the three-way interaction of sex of calf x breed of sire x breed of dam were non-significant and were deleted from the model. Least squares means were calculated and separated using the PDIFF option of LSMEANS.

Results and Discussion

The fixed effects of year, sex of calf, breed of sire and breed of dam were significant for all preweaning traits, except that sex of calf was not significant for WBCS. Sex of calf affected BWT, ADG, WGR, ($P < 0.01$) and WWT ($P < 0.05$). Steer calves were heavier at birth (67.3 lb versus 62.7 lb) and gained more rapidly (1.41 lb/day versus 1.31 lb/day) to a heavier weaning weight (448.8 lb versus 407.2 lb) than the heifer calves. Steer calves received on average a weaning grade of almost a half of a point higher than did the heifer calves (11.90 and 11.55, respectively). Our results are in agreement with Crockett et al. (1978) who reported that sex of the calf was significant for birth and weaning weight, but not significant for weaning body condition scores in crosses utilizing Hereford, Angus and Brahman breeds.

Breed of dam was a significant source of variation for calf ADG and WBCS. Least squares means and standard errors are shown in Table 3 for these traits. Calves raised by Angus dams gained more to weaning ($P < 0.05$), and had a higher ($P < 0.05$) WBCS than did calves with Hereford dams. Gregory et al. (1978) found similar results for Hereford and Angus dams when mated to Hereford, Angus, Red Poll and Brown Swiss sires.

Breed of sire was a significant source of variation for ADG and WBCS. Table 3 shows the least squares means and standard errors for these traits. Charolais sired calves had the highest ($P < 0.05$) mean value for ADG (1.46 lb/day), but there was no difference ($P > 0.05$) between ADG for Charolais and Santa Gertrudis or Santa Gertrudis, Brown Swiss and Holstein sired calves. Angus and Hereford sired calves had the lowest ($P < 0.05$) ADG (1.29 and 1.28 lb/day, respectively) although not significantly different from Holstein or Brown Swiss. Calves from Charolais sires had the highest ($P < 0.05$) mean WBCS (3.90) compared to all other calves. Holstein and Brown Swiss sired calves had the lowest ($P < 0.05$) mean WBCS (3.25 and 3.41, respectively). No difference ($P > 0.05$) was observed for WBCS of calves sired by Santa Gertrudis, Red Poll, Hereford and Angus bulls, but were intermediate to Charolais, Brown Swiss and Holstein sired calves.

The interaction of BRS x BRD was significant for BWT and WWT ($P < 0.01$) and for WGR ($P < 0.05$). Least squares means and standard errors for BWT, WWT and WGR are presented in Table 4. When Angus and Hereford cows were mated to Angus, Charolais, Santa Gertrudis, and Brown Swiss sires, Hereford dams had calves with greater ($P < 0.05$) BWT than Angus dams. When Angus and Hereford dams were mated to Hereford Sires, Angus dams produced calves with greater ($P < 0.05$) BWT when compared to BWT of calves by Hereford dams. When Angus and Hereford dams were mated to Red Poll and Holstein sires there was no difference ($P > 0.05$) in mean BWT of calves produced.

Across all sire breeds except Angus, mean WWT was greater ($P < 0.05$) in all BRS x BRD combinations involving Angus dams vs. Hereford dams. There was no difference ($P > 0.05$) in mean WWT of calves from Angus and Hereford dams mated to Angus sires (414.1 ± 2.0 vs. 405.2 ± 5.2 lb)

Angus dams weaned calves with higher ($P < 0.05$) mean WGR than did Hereford dams when crossed with Angus, Hereford, Charolais, Red Poll, Santa Gertrudis, and Holstein sires; conversely, calves of the Brown Swiss x Hereford combinations had higher ($P < 0.05$) mean WGR than calves of the Brown Swiss x Angus combination.

Implications

Significant changes can be accomplished through proper sire selection to complement the cow herd. Proper sire selection should result in improved efficiency through increased average daily gain and larger weaning weights with minimal increase in birth weight. Both sires and dams can influence production potential of the cow herd, so both contributions must be considered in crossbreeding decisions. These results suggest that two-breed-cross calves demonstrated greater production potential over their straightbred contemporaries under this particular production environment at the Pinetree Station in the University of Arkansas Agricultural Experiment Station System.

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Table 1. Distribution of two-breed-cross calves for each breed of dam by breed of sire combination.

	Breed of dam	
Breed of sire	Angus	Hereford
Angus	755	109
Hereford	130	599
Charolais	81	80
Brown Swiss	35	18
Holstein	64	11
Santa Gertrudis	123	103
Red Poll	154	90

Table 2. Scoring scenario[a] for weaning grade and weaning body condition.

Weaning grade		Weaning body condition score	
Score	Definition	Score	Definition
17	Fancy +	7	Very fat
16	Fancy	6	Fat
15	Fancy -	5	Average +
14	Choice +	4	Average
13	Choice	3	Average -
12	Choice -	2	Thin
11	Good +	1	Very Thin
10	Good		
9	Good -		

[a]Table taken from Brown et al. (1970).

Table 3. Least squares means and standard errors for preweaning average daily gain, and weaning body condition score by breed of dam and breed of sire.

	Preweaning ADG, lb/day	Condition score[a]
Dam		
Angus Angus	1.44 ± 0.01[b]	3.76 ± 0.03[b]
Hereford Hereford	1.28 ± 0.01[c]	3.48 ± 0.04[c]
Sire		
Charolais	1.46 ± 0.02[b]	3.90 ± 0.05[b]
Santa Gertrudis	1.43 ± 0.02[bc]	3.77 ± 0.05[c]
Brown Swiss	1.37 ± 0.04[bcde]	3.41 ± 0.10[d]
Hereford	1.28 ± 0.02[e]	3.68 ± 0.03[c]
Holstein	1.34 ± 0.05[cde]	3.25 ± 0.11[d]
Red Poll	1.37 ± 0.03[d]	3.68 ± 0.04[c]
Angus	1.29 ± 0.02[e]	3.66 ± 0.03[c]

[a] 7 = Very fat, 6 = Fat, 5 = Average +, 4 = Average, 3 = Average -, 2 = Thin, 1 = Very thin

[bcde] Means in the same column, within subclass, with different superscripts differ ($P < 0.05$)

Table 4. Least squares means and standard errors for birth weight, weaning weight and weaning grade for the interaction of breed of sire with breed of dam.

	Preweaning trait		
Group[a]	Birth weight, lb	Weaning weight, lb	Weaning grade[b]
A x A	57.4 ± 0.4^{h}	414.1 ± 2.0^{hi}	12.21 ± 0.04^{d}
A x H	60.1± 0.8^{g}	405.2 ± 5.2^{i}	11.52 ± 0.12^{fgh}
H x A	64.9 ± 0.8^{f}	431.2 ± 4.8^{fg}	12.21 ± 0.11^{d}
H x H	61.6 ± 0.4^{g}	381.1 ± 2.2^{j}	11.68 ± 0.05^{fg}
C x A	69.1 ± 0.9^{de}	477.6 ± 5.9^{c}	12.73 ± 0.13^{c}
C x H	71.9 ± 0.9^{c}	431.0 ± 5.9^{fg}	12.13 ± 0.13^{d}
S x A	68.6 ± 0.8^{de}	473.9 ± 4.8^{cd}	12.04 ± 0.11^{de}
S x H	71.5 ± 0.8^{c}	423.5 ± 5.3^{gh}	11.48 ± 0.12^{fhi}
R x A	60.5 ± 0.8^{g}	441.1 ± 4.4^{ef}	11.80 ± 0.10^{eg}
R x H	60.7 ± 0.8^{g}	403.1 ± 5.5^{i}	11.21 ± 0.12^{fhij}
B x A	66.0 ± 1.5^{ef}	455.0 ± 8.8^{de}	11.26 ± 0.20^{hij}
B x H	71.3 ± 2.2^{cd}	410.1 ± 13.2^{gi}	12.01 ± 0.30^{def}
HO x A	62.5 ± 1.3^{g}	449.7 ± 7.0^{e}	11.14 ± 0.16^{ij}
HO x H	64.5 ± 2.5^{fg}	396.2 ± 15.6^{hij}	10.68 ± 0.35^{j}

[a] Breed groups: A = Angus, B = Brown Swiss, C = Charolais, H = Hereford, HO = Holstein, R = Red Poll and S = Santa Gertrudis (sire breed listed first)

[b] 17 = Fancy+, 16 = Fancy, 15 = Fancy-, 14 = Choice+, 13 = Choice, 12 = Choice -, 11 = Good+, 10 = Good, and 9 = Good-

[cdefghij] Means in the same column with different superscript differ ($P < 0.05$).

Postpartum Maternal Behavior Score in Six Breed Groups of Beef Cattle

B.A. Sandelin, A.H. Brown, Jr., Z.B. Johnson, J.A. Hornsby, and R.T. Baublits[1]

Story in Brief

The objective of this study was to determine the effects of fixed sources of variation on postpartum maternal behavior score (MBS) in six breed groups of beef cows. Postpartum MBS were determined on 5,447 births involving the progeny of 142 sires and 145 maternal grandsires used in the purebred herds of the University of Arkansas Agricultural Experiment Station over a 25-year period. Breed groups included Angus (n = 2,250), Charolais (n = 585), Hereford (n = 738), Heritage Angus (n = 497), Polled Hereford (n = 1,013), and Red Poll (n = 364). Within 24 hours of birth, a MBS was assigned as the handler obtained birth weight and body condition of each calf. Postpartum MBS were: 1) very aggressive, 2) very attentive, 3) indifferent, 4) apathetic. Variation in MBS across breed was partitioned using a model that included terms for an overall mean, year, breed, age of dam, sex of calf, body condition of calf, sire of calf, and maternal grandsire of calf. Across breed, important sources of variation ($P < 0.01$) in MBS were year, age of dam, body condition of calf at birth, breed, sire within breed and sire of dam within breed. Dams giving birth to calves in thin body condition had higher ($P < 0.01$) mean MBS than dams giving birth to calves in average or fat body condition (2.34 vs 2.24 or 2.19, respectively). These results suggest MBS is influenced by several sources of variation and should be considered when evaluating maternal behavior in selection programs.

Introduction

Maternal behavior is an important part of efficient beef production. It is so important that the producer usually intervenes to ensure survival of the offspring. The consequence of centuries of this type of intervention has been the removal of natural selection pressures that maintained maternal behavior within narrow limits. Once the forces of natural selection were eliminated by husbandry, the genetic basis for maternal behavior became quite variable. Thus, some cows display a remarkable repertoire of maternal responses at birth, and others show no interest in their offspring, with graduations between the extremes. Temperament score at calving, a reported indicator of this part of maternal ability, was shown to differ among beef breeds in New Zealand, although heritabilities for behavioral traits were generally low (Morris et al., 1994). Grandin (1998) and Houpt (1998) suggested that postpartum maternal behavior is related to temperament in subsequent phases of production; however, Houpt (1998) stated that our knowledge of the biological basis of maternal behavior is sketchy at best. The objective of this study was to determine the effects of year, breed, age of dam, sex of calf, calf body condition score, and sire of calf within breed and sire of dam within breed on post partum maternal behavior score.

Experimental Procedures

Postpartum maternal behavior scores were recorded for Angus, Charolais, Hereford, Polled Hereford, and Red Poll cows in the herd of the Agricultural Experiment Station, University of Arkansas over a 25-year period. The pedigree of each cow was recorded in the herd book of its respective breed association. The Angus cows consisted of two different biological types: Angus and Heritage Angus. The Heritage Angus was a small breeding group of cows similar to those popular in the 1950s that were retained for experimental observations because they were early-maturing to a small mature size.

Cattle were maintained in Ozark Upland native grass pastures with only containment fences separating the breeding units. The range area provided approximately 3 acres of unimproved open upland and 3 acres of woodland per cow-calf unit. The chief grasses were common bermudagrass (*Cynodon dactylon* L.[Pers.]), tall fescue (*Festuca arundinacca* Shreb.), and native annual species. After heifer calves were weaned, they received about 6 lb/d of supplemental concentrate mix (corn and cottonseed meal) in addition to pasture and(or) hay free-choice until grass was available the following spring. Management of heifers was such that prior to 1990 heifers were managed to calve first at 3 years of age, and from 1990 to 1998 they were managed to calve at 2 years of age. Supplemental feeding of cows and 2-year-old heifers was limited to the winter season and consisted of prairie hay and range cubes (American Milling Company, Fayetteville, Ark.; CP = 20%). Supplementary prairie hay and range cubes (fortified with Vitamin A) were fed between December and April in amounts as required to maintain a body condition score of 5 to 6 in the scoring system of 1 to 9 described by Herd and Sprott (1986). A complete mineral mix was available through out the study period.

Most heifers produced in the breeding groups were retained as replacements. Criteria of selection in breeding groups were established in earlier years, and the primary criterion was reproductive performance (Johnson, 1990). Cows were checked for pregnancy by rectal palpation when calves were weaned in October. Before 1988 most matings were by natural service in an annual breeding period from May 20 to July 20. After 1988, approximately 20% of the matings were by artificial insemination (AI) and the remainder by natural service. All matings were between cows and bulls of the same breed. Approximately one-third of the natural matings were by bulls originating outside the herd; all other natural matings were by bulls produced within the herd. All bulls were chosen on the basis of performance test records or expected progeny differences (EPDs). No direct selection was practiced for postpartum maternal behavior score in the history of the breed groups studied. Although occasion-

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ally matings were made that resulted in inbreeding, these were relatively small in number, and average coefficients of inbreeding did not exceed 5% in any of the breed groups (Buddenburg et al., 1989).

Maternal behavior scores were determined after parturition. Scores were assigned at the time the handler determined birth weight, calf body condition, and tattooed and ear-tagged each calf. Calf body condition scores were; 1 = fat, 2 = average, 3 = thin. In most cases intervention was after the calf had stood and attempted to nurse. Cows that experienced dystocia were not scored. Each year all scores were determined by one individual (herdsman). The arbitrary scale used for assigning maternal behavior scores is presented in Table 1. The distribution of cows by breed group and maternal behavior score is presented in Table 2.

Data for analysis included postpartum maternal behavior scores on 5,447 births involving the progeny of 142 sires and 145 maternal grandsires used over the 25-year period. Data were analyzed by methods of least squares with unequal subclass numbers. Variation in maternal behavior score was partitioned with a model that included terms for an overall mean, year, breed group, age of dam, sex of calf, body condition of calf, sire of calf, and maternal grandsire of calf, and error. The possible interaction effects were found non-significant in a preliminary analysis and deleted from the model used. All analyses were conducted using the general linear model (GLM) procedure of SAS (SAS Inst. Inc., Cary, N.C.). Least squares means were separated using the PDIFF option of the LSMEANS procedure of SAS. Calf survivability was calculated as the percentage of cows that raised a calf from birth to weaning and was tested with a Chi-Square statistic. No empirical data was available to determine when loss occurred.

Results and Discussion

Year, age of dam, calf condition, breed, sire of calf within breed and maternal grandsire of calf within breed were all important ($P < 0.0001$) sources of variation in postpartum maternal behavior score. Sex of calf was not significant for postpartum maternal behavior score.

Least squares means and standard errors for postpartum maternal behavior score by age of dam are presented in Table 3. Three-year-old cows had the highest ($P < 0.05$) (least favorable) mean numerical postpartum behavior score (2.48 ± 0.03), however, the mean postpartum maternal behavior score of the 3-year-old cows did not differ ($P > 0.05$) from the postpartum maternal behavior score of the 2-year-old cows (2.41 ± 0.04). Also, there was no difference ($P > 0.05$) in mean postpartum behavior scores of 4- and 9-year-old cows. Generally there was no difference ($P > 0.05$) in mean postpartum maternal behavior scores of 5- to 10-year old cows. In a slightly different design, Murphey et al. (1981) found that age was an important factor on investigative behavior with the younger cows being more investigative than their older counterparts. However, Morris et al. (1994) found no differences in temperament scores at calving due to age of dam.

Least squares means and standard errors for postpartum maternal behavior score by body condition score of calf are presented in Table 4. Cows giving birth to calves with body condition score of three (thin) had the highest (least favorable) ($P < 0.05$) mean postpartum maternal behavior score (2.31 ± 0.03); conversely, cows giving birth to calves with body condition score of one (fat) had the lowest (most favorable) ($P < 0.05$) mean postpartum maternal behavior score (2.19 ± 0.03). Cows giving birth to calves in body condition score of two (average) were intermediate ($P < 0.05$) for mean maternal behavior score (2.24 ± 0.03).

Least squares means and standard errors for postpartum maternal behavior score by breed group are presented in Table 5. Of the breed groups evaluated, Red Poll cows had the highest (least favorable) mean numerical score (2.51 ± 0.11), but the mean maternal behavior score of Red Poll cow was not different ($P > 0.05$) from those of the Hereford or Polled Hereford (2.23 ± 0.06 and 2.39 ± 0.08, respectively) breed groups. Angus and Heritage Angus breed groups had the lowest (most favorable) numerical mean value for postpartum maternal behavior score (2.13 ± 0.05 and 2.13 ± 0.10, respectively), but mean maternal behavior scores of these two breed groups did not differ ($P > 0.05$) from mean maternal behavior scores of the Charolais (2.18 ± 0.09) and Hereford (2.23 ± 0.08) breed groups. Individual animal differences in several measurements of docility have been reported in the Limousin breed (Le Niedre et al., 1995). Murphey et al. (1980) found no differences in approachability between Charolais and nine other breed types consisting of *Bos indicus* x *Bos Taurus* crosses, as well as purebreds of different breed types.

Implications

These data suggest that age of dam, breed group, sire of calf, maternal grandsire of calf and perhaps calf body condition should be considered when evaluating postpartum maternal behavior in selection programs. Other areas need to be explored to determine the effects of temperament on economically important traits. Genetic parameter estimates need also be determined in order to implement these practices into breeding and selection programs.

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Table 1. Arbitrary scale used for assigning maternal behavior scores.

Value	Description
1	Very aggressive; cow was willing and did fight the handler to protect calf
2	Very attentive; cow remained in close proximity with mild aggression, but did not fight the handler to protect calf
3	Indifferent; cow remained in proximity but showed no aggression toward handler, but remained in sight of calf
4	Apathetic; cow showed no emotion toward calf in presence of handler, grazed away or moved out of proximity

Table 2. Distribution of dams by breed group and postpartum maternal behavior score.

	Postpartum maternal behavior score[a]				
Breed	1	2	3	4	Total
Angus	204	1,485	548	13	2,250
Charolais	52	309	220	4	585
Hereford	4	427	305	3	738
Polled Hereford	14	578	409	3	1,813
Red Poll	8	155	206	1	364
Heritage Angus	45	335	114	2	497
Total	328	3,298	1,756	25	5,447

[a]1 = Very aggressive, 2 = Very attentive, 3 = Indifferent, 4 = Apathetic

Table 3. Least squares means and standard errors for postpartum maternal behavior score by age of dam.

Age of dam	Number of observations	Maternal behavior score[a]
2	377	2.41 ± 0.04^{b}
3	1,038	2.48 ± 0.03^{b}
4	853	2.31 ± 0.03^{c}
5	734	2.20 ± 0.03^{d}
6	657	2.16 ± 0.03^{d}
7	556	2.18 ± 0.04^{d}
8	452	2.17 ± 0.04^{d}
9	373	2.23 ± 0.04^{cd}
10	407	2.18 ± 0.04^{d}

[a]1 = Very aggressive, 2 = Very attentive, 3 = Indifferent, 4 = Apathetic

[bcd] Means with no superscripts in common differ ($P < 0.05$)

Table 4. Least squares means and standard errors for postpartum maternal behavior score by body condition score of calf.

Body condition score[a]	Number of observations	Maternal behavior score[b]
1	682	2.19 ± 0.03[e]
2	3,945	2.24 ± 0.03[d]
3	781	2.31 ± 0.03[c]

[a]1 = Fat, 2 = Average, 3 = Thin

[b]1 = Very aggressive, 2 = Very attentive, 3 = Indifferent, 4 = Apathetic

[cde]Means with different superscripts differ ($P < 0.05$)

Table 5. Least squares means and standard errors for postpartum maternal behavior score by breed.

Breed group	Number of observations	Maternal behavior score[a]
Angus	2,250	2.13 ± 0.05[d]
Charolais	585	2.18 ± 0.09[cd]
Hereford	783	2.23 ± 0.08[bcd]
Polled Hereford	1,813	2.39 ± 0.06[bc]
Red Poll	364	2.51 ± 0.11[b]
Heritage Angus	497	2.13 ± 0.10[d]

[a]1 = Very aggressive, 2 = Very attentive, 3 = Indifferent, 4 = Apathetic

[bcd] Means with no superscripts in common differ ($P < 0.05$).

Identification of Polymorphisms in the Enhancer Region of the Bovine Prolactin Gene

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Story in Brief

Prolactin (PRL) stimulates mammary development and promotes the formation and action of the corpus luteum during the female reproductive cycle in some mammals. The compounds associated with fescue toxicosis depress the levels of PRL in cattle, reduce milk yield, and lower reproductive efficiency. Studies have shown that administering other hormones may alleviate these symptoms by raising PRL levels in *Bos indicus* (Brahman) but not *Bos taurus* (Angus) cattle. This research project attempts to locate polymorphisms in the enhancer region of the PRL gene and correlate this to Brahman and Angus parentages. Two polymorphisms were found at positions –1161 and -1286. Genomic DNA from 73 Angus, Brahman, and Angus/Brahman crossed cows was analyzed for these single nucleotide polymorphisms (SNPs). Both SNPs showed allelic frequency variation between the Brahman and Angus populations. On the polymorphism at -1286, Brahmans were the predominant carriers with fewer carriers in the Angus population. This SNP has an allele frequency of 0.507. The polymorphism at -1161 showed even more variation in that the Brahmans appear to be the only carriers of the allele, with a frequency of 0.137. Results demonstrate that the enhancer region of the bovine prolactin gene has sequence differences that appear to be associated with Brahman cattle.

Introduction

Prolactin (PRL) is a protein hormone that stimulates production of milk proteins. Serum concentrations of prolactin vary considerably due to breed, seasonal, and environmental effects. Fescue toxicosis is associated with a decrease in serum concentrations of prolactin; however, that fescue effect is less in Brahman cattle. The enhancer element of a gene serves as an attachment region for transcription factors that augment or repress basal levels of transcription. This sequence starts from approximately 1.5 kilobases to 300 base pairs before the PRL coding region. Polymorphisms, changes in the DNA base sequence, in this enhancer region could potentially alter the binding of promoter or enhancer elements, thus affecting expression of PRL in cattle. In a preliminary study of 13 cows (seven Brahman, six Angus) we found that the PRL enhancer region had two single nucleotide polymorphisms (SNPs) of interest. Therefore, this study was designed to determine the distribution of the two SNPs within a herd of cattle that contained both *Bos indicus* (i.e. Brahman) and *Bos taurus* (i.e. Angus) cattle.

Experimental Procedures

Polymerase Chain Reaction (PCR). Genomic DNA was obtained from 17 Brahman (BB), 12 Brahman/Angus (BA), 21 Angus/Brahman (AB), and 23 Angus (AA) cows. Based on the NCBI Nucleotide sequence X16641 of PRL, primers were designed to amplify a 500 base pair fragment from positions –892 to –1392. Primer +PRL 892 (AAGTCCCCATAAGCACACTTGG) and primer –PRL 1392 (CTAACTTTAGGGAGTTCATACTG) were synthesized and supplied by Sigma – Genosys (Saint Louis, Mo.). The conditions for all PCRs were: 1x Buffer, 1.5mM MgCl2, 0.2 mM dNTPs, 0.2 µM of each primer, 0.08 µl Biolase TAQ polymerase (Biolase USA, Inc., Randolph, Mass.). Fifteen µl of this mixture was added to 5 µl of each cow's DNA at 20 ng/µl. Each well was covered with a protective layer of mineral oil, and the plate enclosed by a plastic cover. The PCR program used for this reaction consisted of an initial 205°F for 2 minutes, then 35 cycles of 205°F for 30 seconds, 122°F for 30 seconds, 154°F for 1 minute. The reaction was completed with 10 minutes at 154°F, and then held at 46°F. A small portion of the PCR product was analyzed on a 1% agarose gel to determine if the PCR products were present.

Enzyme Digestion. The SNPs of interest occurred at two distinct restriction enzyme sites. The first site was digested by *Xba* I (TCT AGA) and the second site was digested by *Hsp*92II (CATG). Restriction enzymes were obtained from Promega (Madison, Wis.) and used to digest the PCR products. Ten microliters of PCR fragments was digested with 10 µl of *Xba* I according to manufacturer's instructions for 2 hours at 99°F, and another 10 µl was digested with *Hsp*92II according to manufacturer's instructions for 2 hours at 99°F. After digestion, the *Xba* I samples were analyzed on a 1% agarose gel to identify fragment sizes. The *Hsp*92II samples were analyzed on a 1.65% synergel because of the close size differences between the fragments.

Results and Discussion

Single Nucleotide Polymorphisms. The SNPs identified in the initial sequencing were tested on 93 DNA samples to assess the frequency of the polymorphisms. Of the 93 test samples 73 were successfully amplified and restriction digested with *Hsp*92II and *Xba* I. If the allele had the SNP at –1286 (TTTAGA), the *Xba* I did not digest at this designated site, but the original sequence would be digested (TCTAGA). If the allele had the SNP at –1161 (CGTG), the *Hsp*92II did not digest at this position; yet if the allele was CATG, the enzyme did digest. Because cows have two alleles for every

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gene, one on each chromosome, the digestion site could occur on both, one, or neither of the alleles possessed by the cow. The alleles that were digested by the restriction enzymes were coded as 'W' for *Xba* I and 'Y' for *Hsp*92II. Those alleles that were not digested by the enzymes were labeled as 'X' for *Xba* I and 'Z' for *Hsp*92II.

*Hsp*92II. For the –1161 SNP, samples were homozygously cut (alleles YY), or heterozygous for the cut (alleles YZ), but no samples were completely digested (alleles ZZ). Table 1 presents the allelic frequency of animals by breed composition, showing that breed did affect the distribution of *Hsp*92II alleles ($P < 0.001$). Additional analysis showed that paternal breed had a significant affect on the distribution of alleles with Brahman sires associated with 80% of the YZ alleles. The maternal breed was not a significant source of variation of frequencies of this *Hsp*92II allele. The sequences that contained the Z allele were either crossbred or Brahman DNA samples. That distribution contributes to the low allele frequency of 0.137 for this population.

Xba I. For the –1286 SNP, samples were homozygously cut (alleles WW), heterozygous (alleles WX), or homozygous uncut (alleles XX). The allelic distributions are presented in Table 2. A significant dependence between breed composition and the allelic frequencies was found. Both maternal and paternal breed were important ($P < 0.05$ maternal, $P < 0.01$ paternal). The frequencies of alleles show a near perfect distribution between W and X.

Allelic Interaction. Polymorphism frequencies of both SNP sites analyzed together reveals a significant effect of breed composition (Table 3). Those interactions demonstrate that several possible allele combinations are not present in the population. One interesting omission is that the heterozygous *Hsp*92II alleles (YZ) did not combine with the homozygous undigested *Xba* I alleles (XX).

At the *Hsp*92II site, the Brahman-sired cows were more likely to be heterozygous for the SNP than those sired by Angus. That finding suggests that the CGTG allele (Y) originated in the Brahman population. For the *Xba* I restriction site, there was variation in the frequency of alleles between the purebred Angus (AA) and the purebred Brahman (BB). In the AAs, only 8.7% of the samples were homozygous for the uncut allele (XX), while the BBs had 47% homozygous for the same allele. This indicates that the TTTAGA allele exists in the Angus population, but at a lower frequency than in the Brahman population.

Looking at the data from both enzymes, several patterns emerge. The only cows to be cut by both *Hsp*92IIand *Xba* I were purebred Angus, while the Brahman influence provided the alleles for heterozygosity. It is also worth noting that there were no *Xba* I uncut samples (XX) that are *Hsp*92II heterozygous (YZ). Due to the proximity of these SNPs, which were only 125 base pairs apart, it is highly probable that their frequencies are not independent. Together these polymorphisms provide a genetic marker for the *Bos taurus* and *Bos indicus* subspecies on the enhancer region of the PRL gene.

Implications

With further research, these single nucleotide polymorphisms could provide genetic markers for production and reproductive traits related to prolactin synthesis. These single nucleotide polymorphisms may account for differences in prolactin concentrations and milk production between Brahman and Angus cattle. The polymorphic regions, if linked to prolactin concentrations and(or) function, could explain part of the advantage of using Angus x Brahman cows over either of the purebreds.

Table 1. Allele frequencies of *Hsp* 92II restriction site by breed composition.

Breed[1]	YY[2]	YZ	ZZ
AA	23	0	0
AB	17	4	0
BA	5	7	0
BB	8	9	0

[1] Breed designations are AA = purebred Angus; AB = sire was Angus, dam was Brahman; BA = sire was Brahman, dam was Angus; BB = purebred Brahman.

[2] Allele YY represents the samples that were homozygous for the restriction site allele (CATG), YZ represents the heterozygous cows, and ZZ allele represents the samples that were homozygous for the SNP (CGTG).

Table 2. Allele frequencies of *Xba* I restriction site by breed composition.

Breed[1]	WW[2]	WX	XX
AA	8	13	2
AB	1	19	1
BA	3	6	3
BB	1	8	8

[1] Breed designations are AA = purebred Angus; AB = sire was Angus, dam was Brahman; BA = sire was Brahman, dam was Angus; BB = purebred Brahman.

[2] Allele WW represents the samples that were homozygous for the restriction site allele (TCTAGA), WX represents the heterozygous cows, and XX allele represents the samples that were homozygous for the SNP (TTTAGA).

Table 3. Allelic combinations based on breed composition.

Xba I	WW[1]			WX			XX		
Hsp 92II	YY	YZ	ZZ	YY	YZ	ZZ	YY	YZ	ZZ
Breed[2]									
AA	8	0	0	13	0	0	2	0	0
AB	0	1	0	16	3	0	1	0	0
BA	0	3	0	2	4	0	3	0	0
BB	0	1	0	0	8	0	8	0	0

[1]Allele WW represents the samples that were homozygous for the restriction site allele (TCTAGA), WX represents the heterozygous cows, and XX allele represents the samples that were homozygous for the SNP (TTTAGA). Allele YY represents the samples that were homozygous for the restriction site allele (CATG), YZ represents the heterozygous cows, and ZZ allele represents the samples that were homozygous for the SNP (CGTG).

[2] Breed designations are AA = purebred Angus; AB = sire was Angus, dam was Brahman; BA = sire was Brahman, dam was Angus; BB = purebred Brahman.

A Study of Selected Environmental Factors on Feed Intake of Performance-Tested Beef Bulls

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Story in Brief

Feed intake data from 52 140-d feeding trials and selected environmental data were analyzed to define more precisely the relationship between environmental factors and feed intake of performance-tested beef bulls. Feed intake data originated from bulls (n = 2,002) in University of Arkansas Cooperative Bull Tests at Fayetteville, Hope and Monticello from 1978 to 1990. Bulls were given a 21-d adjustment period, then individually full-fed a total mixed ration (TMR) twice daily in the same stall for 140 d. Initial age and weights were recorded at the beginning of each test and at 28-d intervals. Environmental data were obtained from the National Climatic Data Center (Asheville, N.C.). Data were pooled, divided into five 28-d periods with each period analyzed separately. Feed intake was influenced by initial age in all periods ($P < 0.01$) and initial weight in periods 3 through 5 ($P < 0.01$). Initial weight x breed interactions ($P < 0.01$) were present in periods 1 and 2. Thermal Heat Index (THI) x breed interactions ($P < 0.01$) were evident in all periods. Relative humidity from 0600 to 1000 h (RH6-10) influenced intake ($P < 0.01$) in period 2, with RH6-10 x breed interactions ($P < 0.01$) evident during periods 3 and 4. A rainfall x breed interaction ($P < 0.01$) also existed during period 4. Results suggest that environmental effects on feed intake are strongly influenced by breed, and that initial age and weight of cattle when placed on feed affect intake throughout the feeding period.

Introduction

Level of feed intake is perhaps the most important factor regulating performance of beef cattle. Because weight gain is dependent on nutritional intake, it is advantageous for cattle to maintain a consistently high intake throughout the feeding period. However, environmental effects can contribute to intake variation. No meteorological effect on cattle is more thoroughly documented than temperature; although, Hahn (1985) indicated that temperature alone is inadequate to represent impacts of weather on beef cattle. Feed intake by confined beef cattle fed finishing diets did not generally increase during cold stress and was often less during winter than other seasons (Stanton, 1995). Long-term production benefits to heat stress reduction techniques are elusive to measure due to the animal's ability to exhibit compensatory growth following exposure to heat stress conditions. Temperature, environment, photoperiod, animal, and perhaps management differences contribute to seasonal intake patterns, and separate effects are difficult to measure. Therefore, the objective in this study was to define, more precisely, the relationship between feed intake and selected environmental factors of performance-tested beef bulls.

Experimental Procedures

Diet, Feeding and Weighing Procedures. Feed intake data originated from bulls in University of Arkansas Cooperative Bull Tests at Fayetteville, Hope, and Monticello. After a 21-d adjustment period, bulls were individually full-fed a total mixed ration (TMR) twice daily (0800 to 1000 and 1500 to 1700) in the same stall for 140 d. As formulated, the diet contained 0.75 megacalories per lb of net energy for maintenance (Mcal/lb NE_m), 0.46 megacalories per lb of net energy for gain (Mcal/lb NE_g) and 12% CP on a DM basis (Table 1). Individual intake was measured by weighing feed and orts each day. Weights were taken at the beginning of each test and at 28-d intervals. All weights were partially shrunk as bulls were weighed immediately before the morning feeding and had not been allowed access to water since the evening feeding of the previous day.

Climatic Data. Climate data for the period January 1977 to December 1990 were obtained from the National Climatic Data Center (Asheville, N.C.). Data corresponding to animal testing periods included: dry bulb temperature, dew point temperature, and rainfall. Rainfall data were analyzed as the total amount during each 28-d period. Relative humidity percentage was calculated from dry bulb and dew point temperatures. After calculation, relative humidity percentage from 0600 to 1000 h (RH6-10) was extracted for analysis as this represented a 4-h window of interest immediately prior to, and including, the morning feeding period. This period was of interest because daily relative humidity values are often highest early in the morning and may affect feeding patterns. Temperature-humidity index (THI) values were calculated using the Thom (1959) equation:

$$THI = (0.81 \times DBT) + (RH \times (DBT - 014.4)) + 46.4$$

where DBT is dry bulb temperature (°C) and RH is relative humidity in decimal form.

Statistical analysis. Feed intake data from 52 individual performance tests over a 13-yr study period were pooled, divided into five 28-d periods beginning with the start of each test, and data from each period were analyzed separately. Feed intake was regressed on the continuous environmental variables. Non-significant predictors were removed sequentially until an adequate fit was obtained. Analysis of covariance techniques were used to determine if the coefficients of the remaining predictors differed by breed. All statistical analyses were carried out using SAS (SAS Institute, Inc., Cary, N.C.).

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Results and Discussion

The effects of initial weight, initial age, THI, RH6-10 and rainfall in five 28-d periods on feed intake during 52 individual 140-d feedlot performance tests are summarized in Table 2. Feed intake was influenced by initial age ($P < 0.01$) in all periods, and initial weight ($P < 0.01$) in periods 3 through 5. An initial weight x breed interaction ($P < 0.01$) was evident in periods 1 and 2. The finding that feed intake was influenced by initial age and weight agrees with numerous reported findings that older animals typically consume more feed per unit BW than younger ones. A broad range in initial age and weight existed in this study, with animals ranging in age from 160 to 430 d whereas initial weight ranged from 310 to 1,045 lb. Assuming cattle started on feed at heavier BW are generally older, age-related effects on feed intake are partly responsible for the positive relationship between initial weight on feed and dry matter intake (NRC, 1987). The NRC (1987) also noted possible breed-specific effects, and indicated that genetic selection for feed efficiency could produce animals with increased feed intake potential, suggesting that genetic potential for growth may affect feed intake. Intake differences among beef cattle breeds and their crosses may be largely accounted for by their differences in mature size. However, environmental conditions likely affect feed intake among different breeds differently and breed differences have not been clearly defined. This may possibly explain the initial weight x breed interaction noted in Periods 1 and 2.

Hahn (1985) indicated that temperature alone is inadequate to represent the impacts of weather on beef cattle. Therefore, we chose THI values in order to consider combined effects of both temperature and humidity on feed intake. Thermal heat index values averaged in the normal (≤ 74) range during all five periods. However, there were THI x breed interactions present in all periods ($P < 0.01$; Table 2). The numerous breeds of cattle used in today's beef industry represent many diverse biological types that likely perform differently in a given environment. Variations in frame size, coat color and genotype likely lead to differing levels of feed intake in response to environmental conditions. The THI x breed interaction present throughout this study suggests a wide variation in response to environmental conditions from the diverse genotypes and phenotypes of bulls even though THI values remained normal for all periods. It is possible that individual animals may have been affected to varying degrees by short-term meteorological events within each period (cold front passage, heat waves, storms, etc.) for which animal data were not available (depending on prior conditioning). Without prior conditioning, a relatively low level of an environmental stressor (heat or cold) can cause a relatively large effect on feed intake until the animal becomes acclimated to its changing dynamic thermal environment. It also appears that feed intake changes due to environmental conditions vary with changes in the animal's critical temperature (the point at which it must increase or decrease heat production to maintain a normal body temperature). Critical temperature is different among different breeds of cattle, and will likely vary even among different animals within the same breed. The various breeds of bulls and the number of animals per breed represented in the 52 individual 140-d feeding trials are reported in Table 3. Table 3 is also representative of the regression analysis of feed intake on continuous variables during each of the five 28-d periods allowing for breed.

Relative humidity at or near feeding time may influence feed intake. We chose a 4-h window (0600 to 1000) that included the 2 h prior to feeding and the 2-h morning feeding period. There was a RH6-10 effect ($P < 0.01$) during period 2, and RH6-10 x breed interactions ($P < 0.01$) in periods 3 and 4 (Table 2). However, no humidity effect or humidity x breed interaction existed in periods 1 or 5. It is not entirely clear why relative humidity was highly significant throughout the middle portion of the feeding period, yet, was not a significant factor during periods 1 or 5. Bulls were younger, and, therefore, lighter during period 1. Perhaps this prevented a relative humidity effect, which developed later as the animals increased in age and weight. However, this does not explain the lack of an effect in period 5 when the bulls were older and heavier than at any other time. Cattle on feed become conditioned to environmental surroundings during a feeding period, although it is unknown if conditioning contributed to lack of a relative humidity effect in period 5.

A rainfall x breed interaction ($P < 0.01$) was present in period 4 (Table 2). Period 4 was the wettest of all the test periods, and was also a relatively cold period during the majority of the tests. Wet weather occurring during colder seasons of the year may have affected the diverse Bos taurus and Bos indicus makeup of the bulls to differing degrees. Various breeds likely respond differently to rainfall, which may be associated with cold, damp conditions, wet hair coats, mud and possibly wind. Therefore, test-starting date cannot be ruled out as possibly influencing findings.

Feed intake increased during each of the five 28-d periods, although at a slower rate later in the 140-d trials. Mean feed intakes were 554 lb, 660 lb, 706 lb, 730 lb, and 737 lb for periods 1 through 5, respectively. The R-square values for predicting feed intake for periods 1 through 5 were 0.49, 0.55, 0.55, 0.49, and 0.38, respectively.

Implications

Findings suggest environmental conditions strongly influence feed intake of beef cattle. However, breed effects can make understanding the degree of influence difficult. Further research is warranted to characterize effects of climatic conditions and assist producers in determining potential of different breeds for specific climate conditions in beef production locations.

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Table 1. Ingredient and nutrient composition of diet fed during 140-d feedlot performance tests.

Item	Formula, DM basis
Ingredient	%
Cracked corn	42.4
Cottonseed hulls	33.0
Crimped oats	9.4
Cottonseed meal	7.1
Soybean meal	7.1
Calcium carbonate	1.0
Composition, as formulated	
Crude protein, %[b]	12.0
NE_m, Mcal/lb[b]	0.8
NE_g, Mcal/lb[b]	0.5
Calcium, %[c]	0.5
Phosphorus, %[c]	0.3
Potassium, %[c]	0.8

[a]2,200 IU/kg Vitamin A also added
[b]NRC, 1976
[c]NRC, 1996
NE_m = Net energy for maintenance
NE_g = Net energy for gain

Table 2. Summary of results from regression analysis of feed intake on continuous variables during 140-d feedlot performance tests.

Month on trial				
First	Second	Third	Fourth	Fifth
THI[a]	THI[a]	THI[a]	THI[a]	THI[a]
Initial Weight[a]	Initial Weight[a]	Initial Weight[b]	Initial Weight[b]	Initial Weight[b]
Initial Age[b]	Initial Age[b]	Initial Age[b]	Initial Age[b]	Initial Age[b]
-	RH6-10[b]	RH6-10[a]	RH6-10[a]	-
-	-	-	Rainfall[a]	-

[a]indicates effect on feed intake is breed dependent ($P < 0.01$)
[b]indicates effect on feed intake is not breed dependent ($P < 0.01$)
THI = Thermal Heat Index
RH6-10 = Relative Humidity from 0600 to 1000 h
Rainfall = Total rainfall for the 28-d period

Table 3. Parameter estimates (and SE) from regression analysis of feed intake on continuous variables during fourth month on trial allowing for breed.

Breed[a]	n	Thermal heat index (THI)		Relative humidity (RH6-10)		Rainfall, in	
Angus	315	1.56	(0.27)*	-118.71	(125.45)	5.71	(1.86)*
Beefmaster	63	0.83	(0.88)	-299.08	(407.59)	4.11	(4.92)
Brangus	103	0.82	(0.60)	-633.94	(200.74)*	9.12	(3.43)*
Charbray	42	3.71	(1.76)*	-63.97	(406.01)	19.39	(19.20)
Charolais	173	3.25	(0.44)*	-150.46	(143.21)	-1.29	(2.43)
Hereford	127	1.09	(0.57)*	127.12	(215.95)	0.99	(3.90)
Maine Anjou	69	2.26	(1.08)*	-503.76	(251.10)*	5.08	(6.12)
Polled Hereford	471	1.02	(0.34)*	44.15	(106.64)	1.59	(1.66)
Red Brangus	30	2.04	(1.07)	3,432.52	(1,247.49)*	-75.32	(24.18)*
Santa Gertrudis	65	4.56	(0.83)*	1,061.99	(317.80)*	1.46	(9.40)*
Simbrah	35	-0.96	(2.60)	750.98	(665.64)	32.57	(19.26)
Simmental	410	2.65	(0.32)*	-148.48	(87.72)	0.67	(1.46)*
South Devon	95	4.15	(0.54)*	361.80	(196.98)	-0.44	(3.99)

* Coefficient significantly different from zero at P = 0.05 level.

[a] Parameter estimates (and SE) for initial age and weight across all breeds were 0.34 (0.06) and 0.40 (0.02), respectively.

Utilization of Chemical Treatments to Reduce *Escherichia coli* O157:H7 in Cattle Manure

S.L. Krumpelman[1], J.K. Apple[1], E.B. Kegley[1], M.G. Johnson[2], and S.E. Watkins[3]

Story in Brief

A benchtop trial was conducted to determine the effects of various chemical treatments on the growth of *Escherichia coli* O157:H7 in autoclaved cattle manure. Five replications of five chemical treatments were applied: acetic acid, aluminum sulfate, cetylpyridinium chloride (CPC), lactic acid, or granulated sulfuric acid, and then compared with an inoculated, untreated control. Acetic acid, aluminum sulfate, lactic acid, and sulfuric acid were applied at a rate of 3.6% of the wet manure, whereas the CPC was applied at 1.4% of the wet manure. Manure was incubated at 98.6°F and sub-samples were taken at 4, 24, and 48 h for bacterial enumeration and determination of pH and moisture content. There were no treatment by time interactions ($P \geq 0.05$) for any trait measured. Application of lactic acid and CPC reduced ($P < 0.05$) *E. coli* O157:H7 by 1.98 and 1.99 $\log_{10}$ CFU/g, respectively, when compared to the untreated control. Application of aluminum sulfate, acetic acid, and sulfuric acid treatments did not significantly alter bacteria levels from those of the untreated control ($P > 0.05$). The most effective treatments in vitro to reduce *E. coli* O157:H7 in cattle manure were CPC and lactic acid.

Introduction

Escherichia coli O157:H7 is intermittently shed into the environment by cattle resulting in contamination of the hide at the time of slaughter and potentially leading to *E. coli* O157:H7 in the food chain. Sargeant et al. (2003) found that 95.9% of 73 feedlots, and 52% of 711 pens had at least one *E. coli* O157-positive fecal sample. Elder et al. (2000) suggested that there is a positive correlation between fecal and hide prevalence of *E. coli* O157 and carcass contamination.

Various chemical treatments (e.g., acetic acid, lactic acid, and cetylpyridinium chloride) have been used in the red meat and poultry industry to decrease bacteria on carcasses and trim (Hardin et al., 1995; Yang et al., 1998). Aluminum sulfate and granulated sulfuric acid are used in the grower phase of the poultry industry as litter amendments, and are effective in decreasing ammonia levels by altering the microbial population (McWard and Taylor, 2000; Sims and Luka-McCafferty, 2002). No information is available to determine if these products would be effective in reducing bacteria counts in the beef feedlot environment. Thus, the objective of this benchtop study was to find an effective chemical method to decrease *E. coli* O157:H7 in bovine manure prior to evaluating its effect in the feedlot environment.

Experimental Procedures

Collection and storage of feces. Two 900 ± 4.4-lb crossbred (Gelbvieh x Angus x Brangus) steers were fitted with fecal collection bags and offered alfalfa hay ad libitum and a grain supplement at 0.2% of body weight (91% cracked corn). Animal procedures were approved by the University of Arkansas Animal Care and Use Committee. Feces were collected from the calves and stored frozen until use.

Growth of bacteria. Two days prior to the start of the study, a pure culture of green fluorescent protein-labeled (GFP), ampicillin-resistant *E. coli* O157:H7 was grown in tryptic soy broth with ampicillin for 18 to 24 h in an incubator at 98.6°F. Bacterial cells were harvested by centrifugation (2056 x *g* for 10 min), washed twice, and re-suspended in 85 ml of 0.1% sterile peptone water. Cell populations of the *E. coli* O157:H7 were determined by plating on tryptic soy agar plates containing 100 mcg of ampicillin/ml (TSA-A; Remel, Lenexa, KS).

Inoculation of manure. Three days prior to the beginning of the study, manure was removed from the freezer and thawed overnight at 98.6°F. The following day approximately 14.3 lb of wet manure were weighed into a stainless steel bowl, autoclaved at 250°F for 20 min, and allowed to cool overnight. One day before commencing the study, 8.8 and 2.2 lb of manure were weighed into separate, sterile, two-gallon paint cans labeled inoculated control and uninoculated control, respectively. In the inoculated control can, 80 ml of *E. coli* culture (7 $\log_{10}$ CFU *E. coli* O157:H7/g of manure) were added, and in the uninoculated control manure, 20 ml of 0.1% sterile peptone water were added (1 ml 0.1% peptone water/50 g manure). Lids to each can were sealed, and then the cans were mixed by repeated inversion for 5 min. Manure was incubated in sealed cans at 98.6°F for 18 to 24 h.

Application of treatments. At the commencement of the study, 600 g of manure inoculated with *E. coli* O157:H7 were spread into each of six sterile, 9-inch diameter Pyrex pie pans (approximately 0.75 in depth) and 600 g of the uninoculated control manure were spread into one sterile Pyrex pie pan. The following treatments were prepared: 25% food grade lactic acid (PuracAmerica, Lincolnshire, Ill.), 25% food grade acetic acid (Wal-Mart, Bentonville, Ark.), 25% liquid aluminum sulfate (General Chemical Corporation, Parsippany, N.J.), and 10% cetylpyridinium chloride (CPC; Zeeland Chemicals, Zeeland, Mich.). Granulated sulfuric acid with Fullers earth and crystalline silica (OilDri, Chicago, Ill.) was applied as a

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dry application (22.4 g). One-hundred milliliters of each liquid treatment were applied randomly to one sample each using the treatment applicator (Figure 1) by the same person, and the dry application was sprinkled on the surface of the pie pan. Final dilution of treatments in manure was 3.6% of the wet manure, except for CPC which was 1.4%. Manure samples were incubated at 98.6°F and sub-samples were taken from each pie at 4, 24, and 48 h for bacterial enumeration, pH, and moisture content using separate sterile metal spoons between each pie pan. Each treatment was replicated five times over a period of 5 weeks.

Bacterial enumeration, pH, and moisture content. Twenty-five grams of manure were added to 225 ml of 0.1% peptone water in a sterile Whirl-Pak bag (Nasco, Ft. Atkinson, Wis.) and mixed in a Seward Stomacher (Seward, London, England) for 1 min at medium speed. Dilutions were prepared using 0.1% sterile peptone water, and 0.1-ml portions of each dilution were spread onto TSA-A plates which were incubated at 98.6°F for 48 h for the determination of *E. coli* O157:H7 counts. The GFP-labeled *E. coli* O157:H7 colonies were counted under an UV light at 365 nm. The detection level for *E. coli* O157:H7 on TSA-A was 100 CFU/g. The pH of the manure was determined by adding 5 g of manure to 50 ml of distilled water. The suspension was stirred for 5 min and then allowed to settle for 5 min. The pH of the liquid was determined with a Corning portable 314 meter (Corning, Inc., Corning, N.Y.). Moisture content of the manure was determined by drying 10 g of manure in a microwave oven, stirring between each minute, until there were three consecutive 1-minute readings with no change in weight.

Statistical methods. Microbiological data were converted to $\log_{10}$ CFU/g for statistical analysis. All calculations were performed using the MIXED model procedure of SAS (SAS Inst., Inc., Cary, N.C.). Analysis of variance was used for a completely randomized design with repeated measures across time of sub-sampling, and week of sampling as a covariate to determine if differences ($P < 0.05$) existed among the six treatments. When a treatment difference was detected, specific comparisons between treatment means at that time point were accomplished with the PDIFF option of LSMEANS.

Results and Discussion

Our study demonstrated that lactic acid and CPC can be effective compounds to decrease *E. coli* O157:H7 in cattle manure and, hopefully, in the feedlot environment. Application of CPC and lactic acid reduced ($P < 0.05$) *E. coli* O157:H7 from the inoculated, untreated control by 1.99 and 1.98 $\log_{10}$ CFU/g, respectively (Figure 2). Our results were similar to those of other studies. A 2% lactic acid spray applied to beef carcasses caused a 3.0 to 4.9 $\log_{10}$ CFU/cm² reduction in bacteria (Hardin et al., 1995). A 0.5% CPC spray applied to chicken carcasses reduced *Salmonella typhimurium* by 1.62 $\log_{10}$ CFU/carcass (Yang et al., 1998). Most studies apply CPC at a rate of 0.1 to 0.5% on food products because too much CPC residue may be harmful to humans. Our application rates of 3.6 and 1.4% of the wet manure for lactic acid and CPC, respectively, were higher than rates applied on food products because the composition of manure is better suited for bacterial growth. More research needs to be conducted to determine the most effective application rate of CPC and lactic acid and to ensure that application of these products in the feedlot are not harmful to the environment.

Aluminum sulfate, acetic acid, and granulated sulfuric acid reduced *E. coli* O157:H7 counts by 1.02, 0.56, and 0.67 $\log_{10}$ CFU/g, respectively, which did not differ from those for the inoculated, untreated controls (Figure 2). Aluminum sulfate, although able to decrease ammonia levels in poultry litter by altering of the microbial population, did not prove effective in reducing *E. coli* O157:H7 in cattle manure. Generally in the poultry industry, a solid form of aluminum sulfate is sprinkled over the litter and activated by spraying with water or incorporating into the litter (Sims and Luka-McCafferty, 2002). Use of the solid form of aluminum sulfate, in this study, may have resulted in an even smaller decrease of bacteria, similar to that of granulated sulfuric acid, a solid application. Hardin et al. (1995) used a 2% acetic acid rinse on beef carcasses and reduced *E. coli* O157:H7 by 2.4 to 3.7 $\log_{10}$ CFU/cm². In this study, the acetic acid caused a 0.56 $\log_{10}$ CFU/g reduction in *E. coli* O157:H7. A dilution of food grade acetic acid (vinegar) was used in this study, and it is possible that a more concentrated mixture would have been more bactericidal. Granulated sulfuric acid may have proven more effective if it could have been mixed with the manure. All the other treatments were liquid and were thus able to soak into the manure. During the study, no GFP-labeled *E. coli* O157:H7 colonies were found (data not shown) in the uninoculated control samples, and there were no treatment by time of sub-sampling interactions ($P \geq 0.05$).

All treatments caused a reduction ($P < 0.01$) in pH from the untreated inoculated control to varying degrees. Lactic acid and granulated sulfuric acid decreased pH the most (Table 1) yielding pH values of 4.42 and 4.68, respectively. The low pH (4.42) of lactic acid may be what caused the decrease in bacteria. In addition, lactic acid is a weakly ionized acid, thus able to penetrate bacterial cell membranes causing cell death. Treatment of manure with granulated sulfuric acid resulted in a low pH, similar to lactic acid, when sub-samples were homogenized. However, because granulated sulfuric acid was a dry application sprinkled over the top of each sample, it was not able to absorb into the manure like the liquid treatments and thus did not reduce bacteria counts as well as the liquid treatment. Another plausible reason why granulated sulfuric acid was not as effective as lactic acid could be that granulated sulfuric acid is a highly ionized acid, thus, unable to penetrate the negatively charged bacterial cell membrane. Aluminum sulfate treated manure had a pH around 6.08, whereas acetic acid and CPC maintained a higher ($P < 0.05$) pH at 7.22 and 7.13, respectively (Table 1). The ability of CPC to decrease bacteria could not have been due to a pH effect. Cetylpyridinium chloride is a quaternary ammonia compound that is a strong base derived from ammonium by replacement of hydrogen atoms with organic radicals. The organic radicals may be attaching to the bacteria, causing leakage of the cellular material, and leading to cell death.

Growth of most bacteria is favored by moist environments. Moisture content of the manure treated with granulated sulfuric acid did not differ ($P \geq 0.05$) from the inoculated, untreated control (Table 1). Granulated sulfuric acid was a dry application with no additional moisture added. In addition, other ingredients of granulated sulfuric acid are crystalline silica and Fullers earth which may have a drying effect on the manure. Manure treated with acetic acid, lactic acid, and aluminum sulfate had a higher ($P < 0.05$) moisture content than manure treated with granulated sulfuric acid, but the moisture content did not differ ($P \geq 0.05$) from the inoculated, untreated control (Table 1). Treatment with CPC resulted in the wettest manure, which did not differ ($P \geq 0.05$) from manure treated with lactic acid or acetic acid (Table 1).

The turnover of calves leaving the feedlot and a new lot entering is between 24 and 48 h, so we investigated what happens to the bacteria counts, moisture content, and pH over 48 h. The time the sub-samples were taken had no effect on bacteria counts or the moisture content of the manure, but pH of the manure was affected. The pH at 48 h (pH = 6.64) was higher ($P < 0.01$) than the pH at 4 and 24 h (6.03 and 6.13, respectively).

Implications

Finding a method or methods to reduce prevalence of *E. coli* O157:H7 in the feedlot environment may decrease the amount of pathogenic bacteria entering the slaughter facility and potentially entering the food chain. A method that decreases the prevalence of food-borne bacteria may also reduce exposure of disease-causing bacteria to the animal, leading to decreased use of antibiotics and better performing animals. Further research is needed to see if cetylpyridinium chloride and lactic acid would have the same effect in the feedlot environment where temperature and moisture are not as easily controlled.

Acknowledgments

This study was supported by a grant from the Arkansas Beef Council. The authors wish to thank Dr. Michael Doyle from the University of Georgia Center for Food Safety, Rex Thompson of Poultry Guard™, Rex Johns of General Chemical, Inc., and Zeeland Chemical for providing the GFP-labeled *E. coli* O157:H7, the granulated sulfuric acid, the aluminum sulfate, and the CPC, respectively. We appreciate the technical assistance provided by Wendy White, Natalee Echols, Angela Collins, and Shiloh Whiting in the laboratory, and by Jim Turner in fecal collections.

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Table 1. Effect of various chemical treatments on pH and moisture content after application to autoclaved cattle manure inoculated with E. coli O157:H7 (samples taken at 4, 24, and 48 h)[a].

Treatment	pH	Moisture content (%)
Control	8.09[e]	20.12[fg]
Acetic acid	7.22[d]	21.06[gh]
Aluminum sulfate	6.08[c]	20.52[g]
Cetylpyridinium chloride	7.13[d]	21.59[h]
Granulated sulfuric acid	4.68[b]	19.46[f]
Lactic acid	4.42[b]	20.84[gh]
SE	0.21	0.33

[a] Five replicates x three sub-sampling times (n = 15).
[bcde] Least-squares means within column with no superscripts in common differ (P < 0.01).
[fgh] Least-squares means within column with no superscripts in common differ (P < 0.05).

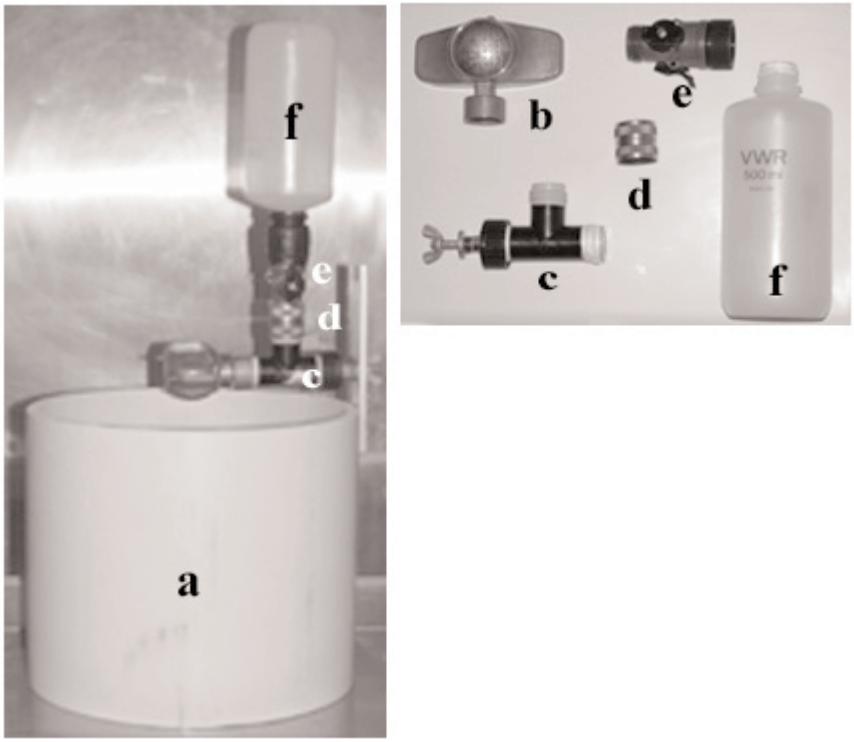

Fig. 1. Treatment applicator developed to apply liquid treatments used a 10-in diameter PVC pipe (a); a garden hose sprinkler (b); three garden hose adaptors (c, d, e), one of which had an on/off switch (e); and a 500 ml bottle (f). The sprinkler system was set at a height of approximately 10 in.

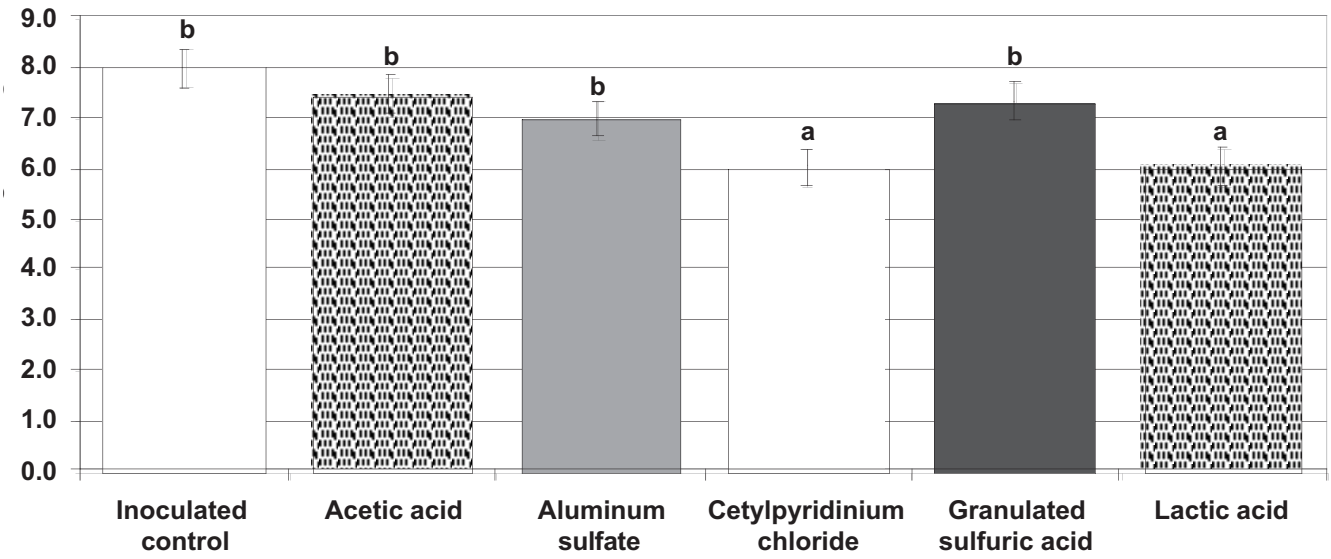

Fig. 2. Effect of chemical treatment (n = 10) application on GFP-labeled *E. coli* O157:H7 inoculated into autoclaved cattle manure.

[ab] Least-squares means with no letters in common differ (P < 0.05).

Use of Lactic Acid or Cetylpyridinium Chloride to Reduce *Escherichia coli* O157:H7 in Cattle Manure Incubated at 41.0 or 98.6°F

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Story in Brief

A benchtop trial was conducted to determine the effects of lactic acid or cetylpyridinium chloride (CPC) on the growth of *E. coli* O157:H7 in cattle manure. Wet manure samples were treated with surface sprays of lactic acid and CPC at a rate of 3.6 and 1.4%, respectively, and incubated at 41 or 98.6°F. Manure sub-samples were taken at 4, 24, and 48 h for enumeration of *E. coli* O157:H7, aerobic plate counts (APC), coliforms, and generic *E. coli*. Additionally, pH and moisture content were determined. Cetylpyridinium chloride caused the greatest reduction ($P < 0.05$) of *E. coli* O157:H7, APC, coliforms, and generic *E. coli* counts at 4 h followed by 24 and 48 h as compared to an inoculated control. Lactic acid reduced ($P < 0.05$) *E. coli* O157:H7, coliforms, and generic *E. coli* at 48 h, but not at 4 or 24 h as compared to an inoculated control. Lactic acid reduced ($P < 0.05$) APC bacteria counts at 4, 24, and 48 h. Cetylpyridinium chloride at both 41 and 98.6°F caused the greatest reduction ($P < 0.001$) in growth of APC, followed by lactic acid ($P < 0.01$) at 98.6°F and then lactic acid at 41°F ($P < 0.05$). Cetylpyridinium chloride was the most effective in vivo treatment to quickly reduce bacteria in cattle manure; whereas, the in vivo lactic acid treatment had a stronger bactericidal effect at 48 h than at 4 h.

Introduction

Escherichia coli O157:H7 is intermittently shed into the environment by cattle resulting in contamination of the hide at the time of harvest and potentially leading to carcass contamination and *E. coli* O157:H7 entering the food chain. A survey in 1999 conducted by the USDA National Animal Health Monitoring System found that 58.8% of 422 feedlot pens had at least one sample positive for *E. coli* O157 (USDA-APHIS, 2001). In that same survey, it was documented that cattle shed more *E. coli* O157 during the warmer months than in the cooler months (USDA-APHIS, 2001).

Various chemical treatments have been used in the post-harvest side of the red meat, poultry, and dairy industries to decrease bacteria. Krumpelman et al. (2004) found that lactic acid and cetylpyridinium chloride (CPC) were more effective than acetic acid, aluminum sulfate, and granulated sulfuric acid in reducing *E. coli* O157:H7 inoculated into autoclaved cattle manure incubated at 98.6°F. Thus, the objective of this benchtop study was to test the effectiveness of the treatments at a warm (98.6°F) and a cool temperature (41°F) on unautoclaved cattle manure after inoculation with green fluorescent protein (GFP)-labeled *E. coli* O157:H7.

Experimental Procedures

Collection and storage of feces. Two 900 ± 4.4-lb crossbred (Gelbvieh x Angus x Brangus) steers were fitted with fecal collection bags and offered alfalfa hay ad libitum and a grain supplement at 0.2% of body weight (91% cracked corn). Animal procedures were approved by the University of Arkansas Animal Care and Use Committee. Feces were collected from the calves and stored frozen until use.

Growth of bacteria. Two days prior to the study beginning, a pure culture of GFP-labeled, ampicillin-resistant *E. coli* O157:H7 was grown up in tryptic soy broth with ampicillin for 18 to 24 h in an incubator at 98.6°F. Bacterial cells were harvested by centrifugation (2056 x g for 10 min), washed twice, and re-suspended in 85 ml of 0.1% sterile peptone water. Cell populations of the *E. coli* O157:H7 were determined by plating on tryptic soy agar plates containing 100 mcg of ampicillin/ml (TSA-A; Remel, Lenexa, Kan.).

Inoculation of manure. Two days before commencement of the study, manure was removed from the freezer and thawed overnight at 98.6°F. The following day, 8.8 and 3.3 lb of manure were weighed into separate, sterile two-gallon paint cans labeled inoculated control and uninoculated control, respectively. In the inoculated control can, 80 ml of *E. coli* culture (7 $\log_{10}$ CFU *E. coli* O157:H7/g of manure) were added, and in the uninoculated control, 30 ml of 0.1% sterile peptone water were added (1 ml 0.1% peptone water/50 g manure). The cans were sealed, mixed by repeated inversion for 5 min, and incubated at 98.6°F for 18 to 24 h.

Application of treatments. At the commencement of the study, 600 g of manure inoculated with *E. coli* O157:H7 were spread into each of six sterile, 9-in diameter Pyrex pie pans (approximately 0.75 in depth) and 600 g of the uninoculated control manure were spread out into two sterile Pyrex pie pans. The following treatments were utilized in the study: a 25% food grade lactic acid (Purac America, Lincolnshire, Ill.) solution and a 10% cetylpyridinium chloride (CPC; Zeeland Chemicals, Zeeland, Mich.) solution. A single application (100-ml) of each liquid treatment was randomly applied to pie pans using the treatment applicator (Figure 1) by the same person. Final dilution of treatments in manure was 3.6% of the wet manure for the lactic acid and 1.4% for CPC. One pie pan of each treatment was incubated at 41 and 98.6°F and sub-samples from each pie pan were aseptically taken using sterile metal spoons at 4, 24, and 48 h for bacterial enumeration, and determination of pH and moisture

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content. Each treatment was replicated five times over a period of 5 weeks.

Bacterial enumeration, pH, and moisture content. Twenty-five grams of manure were added to 225 ml of 0.1% sterile peptone water in a sterile Whirl-Pak bag (NASCO, Ft. Atkinson, Wis.) and macerated in a Seward Stomacher (Seward, London, England) for 1 min at medium speed. Dilutions were prepared using 0.1% sterile peptone water, and 0.1-ml portions of each dilution were spread in duplicate onto TSA-A plates which were incubated at 98.6°F for 48 h to determine *E. coli* O157:H7 counts. Colonies that fluoresced green under 365 nm UV light were counted. One milliliter of each dilution was spread in duplicate on Petrifilm™ Aerobic Count Plate (APC; 3M, St. Paul, Minn.) and incubated at 95°F for 48 h. One milliliter of each dilution was spread in duplicate on Petrifilm™ *E. coli*/Coliform Count Plate (3M) and incubated at 95°F for 24 h to determine coliform counts and for 48 h to determine generic *E. coli* counts. The minimum detection level for the Petrifilm™ plates and for *E. coli* O157:H7 on TSA-A was 10 and 100 CFU/g of manure, respectively. The pH of the manure was determined by adding 5 g of manure to 50 ml of distilled water. The suspension was stirred for 5 min and then allowed to settle for 5 min. The pH of the liquid was determined with a Corning portable 314 meter (Corning, Inc, Corning, N.Y.). Moisture content of the manure was determined by drying 10 g of manure in a microwave oven, stirring between each minute, until there were three consecutive 1-minute readings with no change in weight.

Statistical methods. Microbiological data were converted to $\log_{10}$ CFU/g for statistical analysis. All calculations were performed using the MIXED model procedure of SAS (SAS Inst., Inc., Cary, N.C.). Analysis of variance was used for a completely randomized design with repeated measures across sub-sampling times and week of sampling as a covariate. The model included chemical treatment (uninoculated control, inoculated control, lactic acid, and CPC), incubation temperature (41 and 98.6°F), time of sub-sampling (4, 24, and 48 h) and the appropriate two- and three-way interactions. When a treatment difference was detected ($P < 0.05$), specific comparisons between any pair of treatment means at that time point were accomplished with the PDIFF option of LSMEANS.

Results and Discussion

With the exception of pH, there were no chemical treatment by time of sub-sampling by incubation temperature interactions ($P \geq 0.05$). There were chemical treatment by time of sub-sampling interactions ($P < 0.05$) for *E. coli* O157:H7, APC, generic *E. coli*, and coliform (Figure 2). Manure treated with CPC at 4 h had the greatest ($P < 0.05$) reduction in *E. coli* O157:H7 counts; however, numbers increased at 24 and 48 h, which did not differ from the manure treated with lactic acid at 48 h (Figure 2). *Escherichia coli* O157:H7 counts numerically decreased over the three sampling times for manure treated with lactic acid (Figure 2), however, these observations were non-significant ($P \geq 0.05$). *Escherichia coli* O157:H7 counts in manure treated 4 to 24 h earlier with lactic acid did not differ ($P \geq 0.05$) from the inoculated control counts (Figure 2). In a previous study by Krumpelman et al. (2004), CPC and lactic acid decreased *E. coli* O157:H7 by 1.99 and 1.98 $\log_{10}$ CFU/g of manure, respectively. In this study, CPC decreased *E. coli* O157:H7 by 4.8 $\log_{10}$ CFU/g at 4 h and by 2.6 $\log_{10}$ at 48 h post-treatment. The regrowth of *E. coli* O157:H7 may be due to revival of injured bacteria or the regrowth of the bacteria that survived. Lactic acid decreased *E. coli* O157:H7 by 0.6 $\log_{10}$ CFU/g at 4 h and by 1.4 $\log_{10}$ CFU/g at 48 h post-treatment. Similar trends of CPC decline and lactic acid increase in effectiveness were seen in the original study (Krumpelman et al., 2004), although, not significant. The ability of lactic acid to become more bactericidal may prove beneficial in the feedlot.

Manure samples treated with CPC showed the greatest reduction in aerobic plate counts ($P < 0.05$) at 4 h, but plate counts increased at 24 and 48 h, although they were still significantly lower ($P < 0.05$) than the APC of all other chemical treatments (Figure 2). The APC for lactic acid-treated samples were lower ($P < 0.05$) than the controls at all sub-sampling times (Figure 2).

Coliform counts in the manure were reduced ($P < 0.05$) the most by CPC after 4 h (Figure 2). Coliform counts increased in CPC-treated manure at 24 and 48 h, which did not differ ($P \geq 0.05$) from the 48 h sample from the lactic acid-treated manure (Figure 2). In manure treated with lactic acid no differences in coliform counts were observed (Figure 2). These coliform counts were similar to those in manure treated with CPC after 24 h (Figure 2). Coliform counts in the inoculated and uninoculated controls did not differ from each other or from lactic acid-treated manure samples taken at 4 and 24 h (Figure 2).

Generic *E. coli* counts were also reduced ($P < 0.05$) the greatest by CPC at 4 h (Figure 2). Numbers of generic *E. coli* in CPC-treated manure increased at 24 and 48 h, and counts in the 24-h sample did not differ from counts at any sampling time for lactic acid treated manure (Figure 2). Lactic acid-treated manure after 4 and 24 h did not differ from the inoculated or uninoculated controls (Figure 2).

Our study showed that lactic acid and CPC can be effective compounds to decrease bacteria in cattle manure by 0.4 to 3.2 $\log_{10}$ CFU/g. Cutter et al. (2000) demonstrated that a 1% CPC treatment applied to beef lean and adipose surfaces caused an immediate reduction in APC, *E. coli* O157:H7, and *Salmonella typhimurium* populations after being sprayed and packaged. More research is needed to determine the bactericidal duration of lactic acid and additionally to determine if the bacteria in CPC-treated manure continues to rise and for what length.

There was a chemical treatment by incubation temperature interaction for APC. No temperature effect was observed for CPC; however, APC counts for CPC-treated manure were lower ($P < 0.05$) than the other treatments (Figure 3). Lactic acid-treated manure at 98.6°F was more effective ($P < 0.05$) in reducing APC counts than at 41°F (Figure 3). No effect of temperature on APC was observed in the inoculated and uninoculated controls (Figure 3). In addition, there were no differences between bacteria counts for *E. coli* O157:H7, coliform, and generic *E. coli*, due to incubation temperatures (Table 1). Jiang et al. (2002) found that *E. coli* O157:H7 survived a shorter time (35 to 77 days) at 41°F than at warmer temperatures of 59 or 69.8°F (103 to > 226 days). Our study did not show a difference in counts due to incubation temperature for *E. coli* O157:H7, coliform, or generic *E. coli*; however, for APC, lactic acid-treated manure incubated at 98.6°F had a stronger ($P < 0.05$) killing effect than lactic acid at 41°F (0.7 $\log_{10}$ CFU/g).

No differences in moisture content due to chemical treatment or incubation temperature were observed; however, there were differences ($P < 0.05$) due to the time of sub-sampling. Moisture levels of sub-samples taken at 4 and 24 h were 21.7 and 20.7%, respectively. Neither moisture levels at 4 or 24 h differed from the 48 h sample (21.3% moisture content). The moisture content for samples treated with CPC, lactic acid, the inoculated control, and the uninoculated control were 21.1, 21.0, 21.3, and 21.4%, respectively (SE = 0.3).

A three-way interaction ($P < 0.05$) of treatment, time of sub-sampling, and incubation temperature was observed for pH (Figure 4). Lactic acid- treated manure had the lowest ($P < 0.05$) overall pH.

Jiang et al. (2002) found that *E. coli* O157:H7 survived longer in manure-amended autoclaved soil (> 226 d) than in manure-amended unautoclaved soil (up to 152 d). They postulated that this was due to the lack of competing indigenous bacteria in the autoclaved soil (Jiang et al., 2002). The combination of the indigenous bacteria and CPC in this study may have resulted in the increased killing effect by CPC, although there was a similar bactericidal effect for APC, coliform, and generic *E. coli*. The competition with the indigenous bacteria, may have decreased the immediate effectiveness of lactic acid; however, at 48 h, the manure treated with lactic acid continued to have a pH below 4.7, and thus continued to have a killing effect. Lactic acid is weakly ionized, enabling it to penetrate bacterial cell membranes and cause a bactericidal effect. The bactericidal effect of CPC is not a pH effect, due to its neutral pH of around 7.1. The killing mode of action for CPC may be due to the organic radicals attaching to the bacteria, causing cellular material to leak, and leading to cell death.

Implications

Our study indicates that cetylpyridinium chloride and lactic acid may be effective in decreasing *E. coli* O157:H7, APC, coliform and generic *E. coli* in the feedlot environment at both winter and summer temperatures. Cetylpyridinium chloride had a greater initial kill, whereas lactic acid had an increased kill over the 48 h. Further research is needed to test these compounds in the feedlot environment to confirm that cetylpyridinium chloride and lactic acid will decrease human and animal pathogens in the feedlot, which in turn may affect shedding rates of the cattle, both in the feedlot and at slaughter. If so, a healthier, better performing animal may be produced with less chance of causing food-borne illness or antibiotic residues in the meat.

Acknowledgments

This study was supported by a grant from the Arkansas Beef Council. The authors wish to thank Dr. Michael Doyle from the University of Georgia Center for Food Safety for providing the GFP-labeled *E. coli* O157:H7 and Zeeland Chemical for providing the CPC. We appreciate the laboratory assistance provided by Wendy White, Natalee Echols, Angela Collins, Colin Bible, Shiloh Whiting, Hernando Florez, Mike Ratcliff, and Shanna Hutchison, and fecal collection assistance provided by Jim Turner.

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Table 1. Mean bacteria counts (log_{10} CFU/g) in unautoclaved cattle manure incubated at 41 or 98.6°F (samples taken at 4, 24, and 48 h).

	Incubation temperature		
Bacteria[a]	41°F	98.6°F	SE
GFP-labeled *E. coli* O157:H7	5.49	4.98	0.19
Coliform	6.40	6.38	0.16
Generic *E. coli*	6.35	6.33	0.14

[a] Five replicates x four treatments x three sub-samples for each incubation temperature (n = 60).

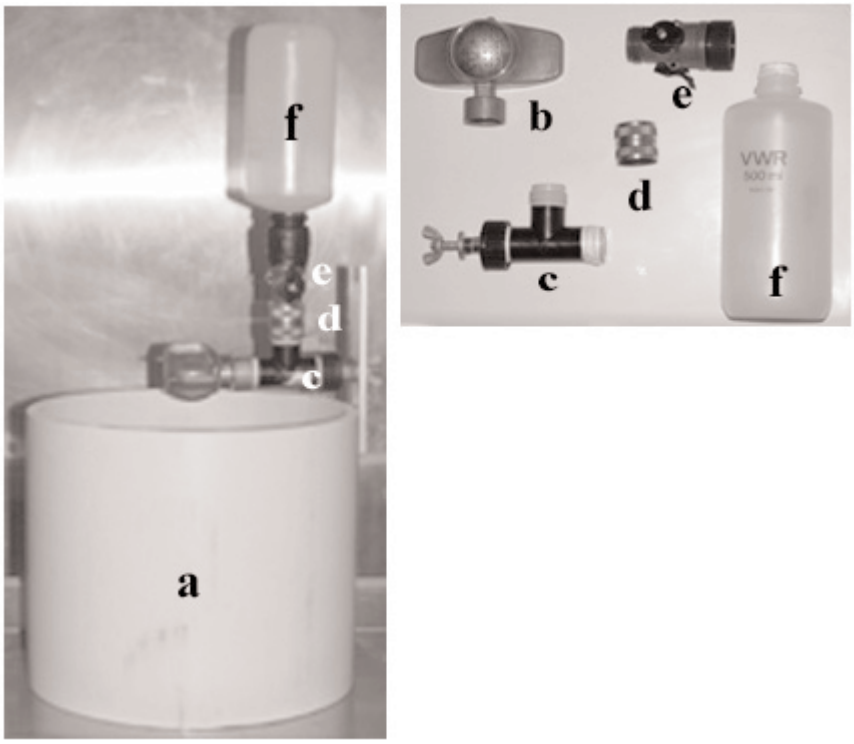

Fig. 1. Treatment applicator developed to apply liquid treatments used a 25 cm diameter PVC pipe (a); a garden hose sprinkler (b); three garden hose adaptors (c, d, e), one of which had an on/off switch (e); and a 500 ml bottle (f). The sprinkler system was set at a height of 10 in.

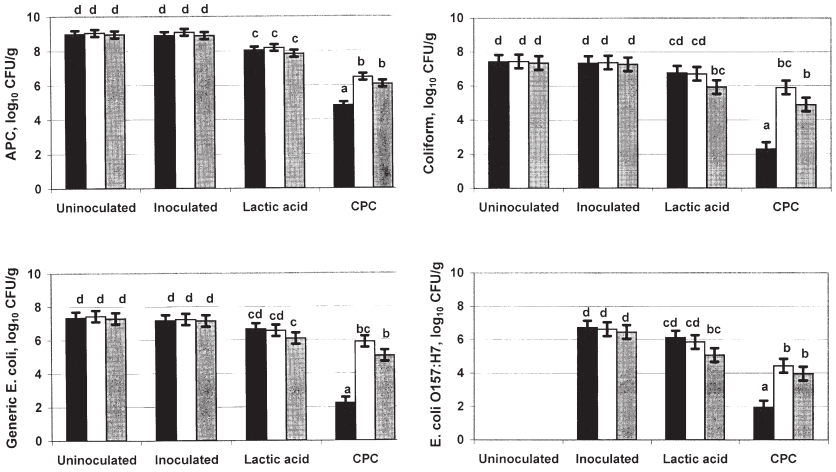

Fig. 2. Mean bacteria counts in unautoclaved cattle manure sub-samples (n = 10) taken at 4 (dark bar), 24 (white bar), and 48 (gray bar) h after application of each chemical treatment. Within each bacterial type, bacteria counts with no letters in common differ (chemical treatment x type of sub-sampling interaction, P < 0.05).

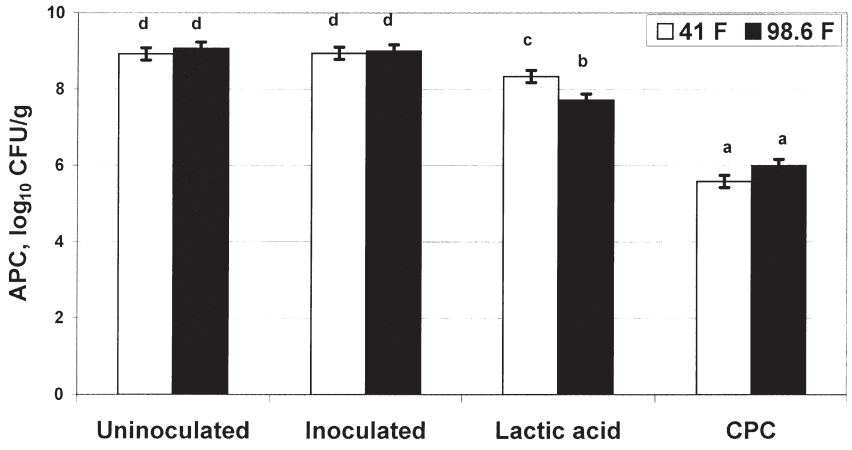

Fig. 3. Mean aerobic plate counts (APC) in unautoclaved cattle manure (n = 15) incubated at 41 or 98.6°F. Means with no letters in common differ (chemical treatment by incubation temperature interaction, P < 0.05).

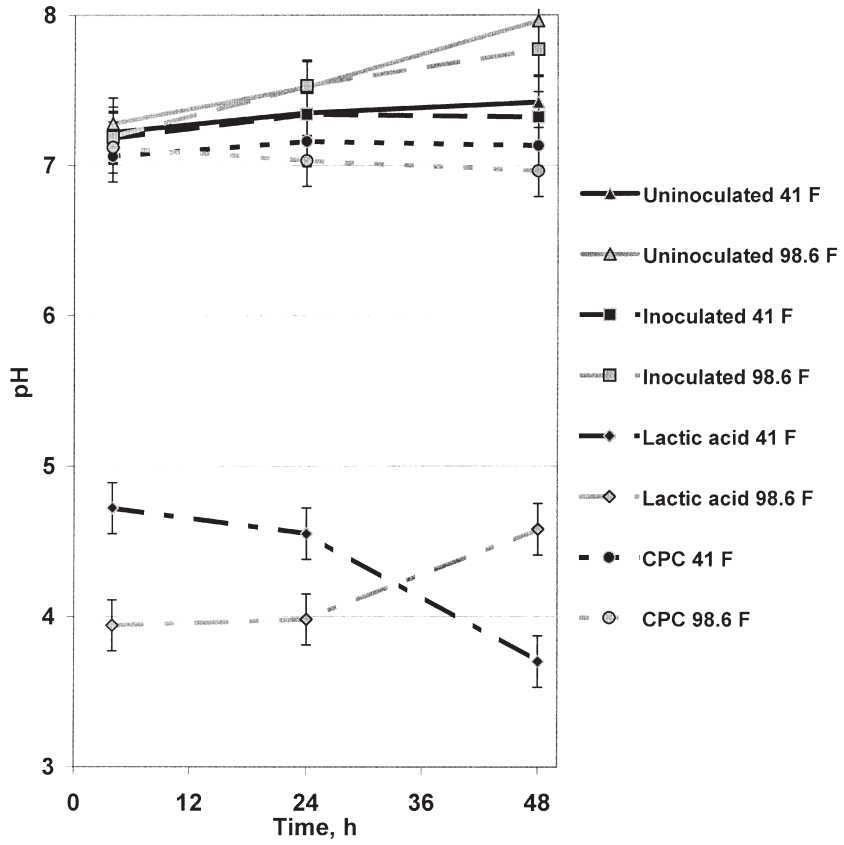

Fig. 4. The pH of each treatment group over time at 41 or 98.6°F (chemical treatment x incubation temperature x time of sub-sampling interaction, P < 0.02).

Incidence of Persistent Bovine Viral Diarrheal Infection in Arkansas Stocker Calves

J.G. Powell[1], M.D. Ratcliff[2], D.S. Hubbell, III[3], J.A. Hornsby[4]

Story in Brief

A study was conducted to determine the incidence of bovine viral diarrhea virus (BVD) persistent infections based on tissue samples obtained from stocker cattle originating from Arkansas sale barns. Tissue samples were collected from 221 stocker calves from the Livestock & Forestry Branch Station at Batesville, Ark., and 279 stockers from the Beef Cattle Research Facility at Savoy, Ark. The samples were shipped to the Oklahoma Animal Disease Diagnostic Laboratory for analysis. An immunohistochemistry test was performed on each sample to determine if the calf was persistently infected with bovine viral diarrhea virus. The incidence of the disease in the cattle that were tested was 0.8% (4 of 500).

Introduction

Persistent infection with bovine viral diarrhea (BVD) occurs in a calf that is born to a cow that became infected with BVD within the first 150 days of gestation (Brock, 2003). The calf is immunotolerant of the disease, and will carry the virus throughout its lifetime. A persistently infected calf will constantly shed the virus; serving as a principle source of infection for other cattle. Cattle that are persistently infected with BVD pose a costly economic concern to the industry. Other cattle that become exposed to BVD can exhibit various symptoms including abortion, congenital abnormalities, respiratory disease, acute enteritis, ulceration of mucosal surfaces, lameness, and immunosuppression. These conditions can lead to considerable decreases in performance, and greatly affect production related costs. In the upper Midwest, the estimated incidence of persistently infected (PI) cattle is 1.7% (Bolin et al., 1985). The objective of this project was to determine the incidence of PI calves in Arkansas, targeting weaning age calves that were obtained from sale barns in this state.

Experimental Procedures

Over the course of six months (July to December 2003), six groups of stocker cattle totaling 500 crossbred bull, steer, and heifer (BW 450 ± 50 lb; mostly Continental X English crosses) calves were obtained from Arkansas sale barns and received at the University of Arkansas Experiment Stations at Savoy (four groups; n = 279) and Batesville (three groups; n = 221). Soon after arrival, the cattle were individually weighed, treated for internal and external parasites, vaccinated against Clostridial diseases, infectious bovine rhinotracheitis, bovine viral diarrhea, parainfluenza-3, and bovine respiratory syncytial virus. Bulls were castrated, and horns were tipped. Calves were revaccinated with all vaccines 2 weeks after the initial doses of vaccine.

During initial processing or during the revaccination, skin tissue samples were collected via the ear notch method. Collected tissue samples were placed in individual containers and fixed in a formalin solution. All samples were sent to the Oklahoma Animal Disease and Diagnostic Laboratory to test for testing. An immunohistochemistry test was performed to determine the presence of a persistent infection with BVD (Broderson, 2004). Calves were observed daily for a 28-day receiving period at 8 AM for clinical signs of respiratory disease. Calves pulled for treatment had their temperature taken, and received appropriate antibiotics if their body temperature exceeded 104.0°F. All health and disease data were recorded.

Statistical analysis was performed on the data relative to morbidity rates so as to note correlation with PI BVD prevalence. The morbidity data were analyzed using the GLM procedure of SAS (SAS Inst., Inc., Cary, N.C.).

Results and Discussion

Four tissue samples out of the 500 (0.8%) submitted were positive for the disease (Table 1). One sample originated from a calf at the Batesville unit, and three samples originated from calves at the Savoy unit, in which two of the three calves were in the same group of cattle.

In the three groups that contained PI BVD calves, 42.6% of the calves were treated at least once for respiratory disease, and only 23.9% of those calves in non-PI BVD groups were treated at least once for respiratory disease ($P < 0.05$; Table 1). There was a significant difference between morbidity rates in groups that contain PI BVD calves versus groups that contained no PI BVD calves.

Implications

There was a 0.8% incidence rate of PI BVD infections in this population of Arkansas stocker cattle. A significant difference was noted between the numbers of calves treated for bovine respiratory disease in the groups of cattle that contained PI BVD calves compared to those groups that did not contain PI BVD calves. More research is needed to identify the economic impact that this disease has on cattle that are exposed to these PI calves.

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Acknowledgments

This study was funded by Boehringer Ingelheim Vetmedica, Inc. and the Division of Agriculture, University of Arkansas.

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Table 1. The number of PI BVD[1] calves and morbidity percentage for calves obtained from Arkansas livestock auctions.

Group	Location	Number of calves	Number of PI BVD calves	Morbidity %
1	Savoy	50	2	62.1[a]
2	Savoy	101	1	43.6[b]
3	Batesville	90	1	21.1[c]
4	Savoy	83	0	43.8[b]
5	Batesville	131	0	16.2[cd]
6	Savoy	45	0	4.4[d]

[1]Persistently infected (PI) with bovine viral diarrhea (BVD)
[abcd] Least-squares means within a column, with no superscripts in common, differ ($P < 0.05$)

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Poultry Fat Addition to Finishing Rations Influences the Fatty Acid Composition of Muscle Tissue and Adipose Tissue[1]

S. Hutchison[2], E.B. Kegley[2], J.K.Apple[2], T.J. Wistuba[3], and D.C. Rule[4]

Story in Brief

Poultry fat may be a more economical energy source than other by-products currently used. In cattle finishing diets; however, little research has quantified the effects of poultry fat on the fatty acid composition of beef. Therefore, a 112-d finishing study was initiated to determine the effects of dietary fat source (poultry or tallow) on the fatty acid profiles of the subcutaneous and intramuscular fat depots. Sixty Angus crossbred steers (903.8 lb initial body weight) were stratified by source, blocked by weight, and assigned to 15 pens (four steers/pen). Then, pens were assigned randomly within blocks to one of three dietary treatments consisting of: 1) a corn-soybean meal control diet devoid of added fat; 2) control diet formulated with 4% tallow; or 3) control diet formulated with 4% poultry fat. In the longissimus dorsi (LM), total saturated fats were similar ($P > 0.10$) among diets. Furthermore, total monounsaturated fatty acids (MUFA) were not ($P > 0.10$) affected by diet. The LM from the steers fed poultry fat had increased ($P < 0.05$) 18:2 and total polyunsaturated fatty acids compared to that of the steers consuming the other two diets. Conversely, the LM of the tallow fed steers had lower ($P < 0.05$) concentrations of 20:3 than steers consuming the other two diets. The only changes noted in subcutaneous fat were that the steers consuming the control diet had greater 17:1 concentrations than the ($P < 0.05$) steers that consumed the poultry fat diet. Therefore, poultry fat may serve as an alternative energy source in finishing cattle diets without compromising fatty acid composition of beef.

Introduction

Ruminants have the ability to utilize by-products from numerous industries as nutrients. Poultry industry by-products are potential sources of valuable nutrients, including energy and protein. Therefore, methods of converting poultry industry by-products into reliable sources of animal feeds would benefit both the beef and poultry industries by providing a market for the poultry fat and an economical energy source for cattle diets. Currently poultry fat is not widely utilized by the cattle industry.

Typically fat is limited to <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. Recent research, however, has indicated that increasing the proportion of omega-3 fatty acids in ruminant diets modifies the fatty acid composition of their muscle tissue, indicating that all dietary fatty acids are not completely hydrogenated in the rumen. In the future, there may be considerably more emphasis placed on the modification of the fatty acid composition of beef in efforts to produce healthier beef products. The objective of this study was to determine the effects of adding poultry fat to finishing diets on fatty acid composition of edible lean and fat of cattle.

Experimental Procedures

Sixty Angus crossbred steers were obtained from the Livestock and Forestry Branch Station in Batesville, and the University of Arkansas Cow/Calf unit in Savoy. Steers were adapted to a high concentrate diet by feeding a 20% cottonseed hull growing diet for 55 d. The finishing study was initiated on December 5, 2002 and the initial body weight was 903.8 lb. Steers were stratified by source, blocked by weight, and assigned to 15 pens (four steers/pen). Then, pens were assigned randomly within blocks to one of three dietary treatments (Table 1) consisting of: 1) a corn-soybean meal control diet devoid of added fat; 2) control diet formulated with 4% tallow; or 3) control diet formulated with 4% poultry fat. Diets were mixed at approximately 2-wk intervals. Steers were allowed ad libitum access to feed and water for the 112-d study. Steers were weighed on consecutive days at d 0 and 112 to start and finish the trial, and interim weights were collected on d 28, 55, and 83.

Steers were transported approximately 360 miles to a commercial beef packing plant, and harvested after a 12-h rest period. After a 24-h conventional spray-chill, carcass yield and quality grade data were collected. Wholesale ribs from the left sides were captured and boxed, and then transported under refrigeration back to the University of Arkansas Red Meat Abattoir for further processing.

Two samples from each animal's adipose and LM tissues were taken for fatty acid analysis. Two 150-mg samples of each tissue were subjected to transesterification by incubating in 2.0 mL of 0.2 *M* methanolic KOH according to methods of Murrieta et al. (2003). Fatty acid methyl esters were transferred to gas liquid chromatograph vials that contained a 1.0-mm bed of anhydrous sodium sulfate. Separation of fatty acid methyl esters was achieved by gas liquid chromatography with a 100-m capillary column. Identification of peaks was accomplished using purified standards.

Analyses of variance were conducted on adipose and LM tissue using the MIXED procedure of SAS (SAS Inst., Inc., Cary, N.C.) with pen as the experimental unit. The model for the data included dietary treatment with block as a random variable. When treatment was significant ($P < 0.05$), then a F-protected student's t-test (PDIFF option) was used to separate means.

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Results and Discussion

Total fatty acid profiles are reported in Table 2. In the LM, total saturated fatty acids (SFA) were similar ($P > 0.10$) among diets. Furthermore, total monounsaturated fatty acids (MUFA) were not ($P > 0.10$) affected by the addition of fat, regardless of source, to finishing diets. However, the LM from the steers fed poultry fat had increased ($P < 0.05$) 18:2 and total polyunsaturated fatty acids (PUFA) over the LM of the steers fed the control or tallow diets. Scollan et al. (2001) reported feeding *n-3* PUFA supplements, such as bruised linseed or fish oil, resulted in significant increases in their deposition in muscle lipids. The *n-3* fatty acids are those with the first double bond at the third carbon from the carbonyl end of the fatty acid.

The LM of steers consuming tallow had lower ($P < 0.05$) concentrations of 20:3 than the steers fed the control or poultry fat diets. Rule et al. (1994) indicated that increasing the proportion of 18:0 and 18:1 would be beneficial to the beef industry because these fatty acids are hypocholesteremic in humans. Even though not statistically significant, these fatty acids concentrations were increased in the LM of steers consuming the poultry fat diet.

The effects of addition of poultry fat on fatty acid composition of subcutaneous fat are reported in Table 3. The only changes detected in subcutaneous fat were steers that consumed the control diet had greater 17:1 concentrations than ($P < 0.05$) steers fed poultry fat. However, diet did not ($P > 0.10$) affect total SFA, MUFA, PUFA, omega-6, or trans fatty acids. Subcutaneous fat from tallow-fed steers had lower ($P < 0.05$) conjugated linoleic acid concentrations than fat from controls and poultry fat-fed steers. It has been reported by Bauman (1999) and others that conjugated linoleic acid can reduce body fat accretion and have antidiabetic effects. Therefore, it is possible to change the fatty acid composition of beef to produce a healthier, value-added, end product with the addition of certain dietary fats.

Implications

Feeding poultry fat in the current study had no detrimental effects on the fatty acid composition of the subcutaneous and intramuscular fat depots when compared to diets formulated with or without beef tallow. Therefore, adding poultry fat as an energy source can replace tallow without negatively altering the fatty acid composition of beef.

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 thank C. M. Murrieta for expert assistance with fatty acid analysis, and L. Rakes and K. Anschutz for assistance of preparation of fatty acid analysis.

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

Ingredient	Control	Tallow	Poultry fat
		%	
Corn, cracked	78.2	73.3	73.3
Cottonseed hulls	10	10	10
Soybean meal	8.2	9.1	9.1
Molasses	2	2	2
Dicalcium phosphate	0.1	0.1	0.1
Limestone	1.35	1.35	1.35
Salt, white	0.15	0.15	0.15
Vitamin premix[a]	0.075	0.075	0.075
Trace mineral premix[b]	+	+	+
Rumensin premix[c]	+	+	+
Tallow	0.0	4.0	0.0
Poultry fat	0.0	0.0	4.0

[a]Premix supplied per pound of diet: 225 IU of vitamin A, 75 IU of vitamin D3, and 0.15 IU vitamin E.
[b]Premix supplied: 20 ppm of Zinc as ZnO, 10 ppm of Manganese as MnO, 0.10 ppm of Selenium as Na_2SeO_3, and 0.10 ppm of Cobalt as $CoCO_3$.
[c]Premix supplied 20 ppm monensin.

Table 2. Influence of fat source on the fatty acid composition of longissumus dorsi muscle tissue.

Fatty acid mg/g (wet tissue basis)	Control	Tallow	Poultry fat	SE
Saturated fatty acids	17.10	17.70	19.59	1.600
14:0	1.15	1.22	1.39	0.135
15:0	0.20	0.19	0.19	0.026
16:0	10.35	10.64	11.60	0.969
17:0	0.48	0.47	0.43	0.058
18:0	4.93	5.17	5.97	0.449
Monounsaturated fatty acids	18.95	17.95	19.43	1.580
14:1	0.20	0.18	0.23	0.026
16:1	1.18	1.15	1.24	0.096
17:1	0.35	0.29	0.27	0.030
18:1$^{trans-9}$	0.069	0.073	0.122	0.023
18:1$^{trans-11}$	1.28	1.14	1.85	0.276
18:1^{cis-9}	15.20	14.48	15.06	1.190
18:1^{cis-11}	0.68	0.64	0.67	0.485
Polyunsaturated fatty acids	1.92^{y}	1.97^{y}	2.20^{x}	0.059
18:2$^{cis-9,12}$	1.43^{y}	1.49^{y}	1.68^{x}	0.049
18:3^{n-3}	0.066	0.071	0.078	0.007
CLA	0.07	0.08	0.10	0.011
20:3	0.10^{x}	0.09^{y}	0.10^{x}	0.003
20:4	0.26	0.25	0.24	0.015
Omega-6[a]	1.79^{y}	1.82^{y}	2.02^{x}	0.059
Total Trans fatty acids	1.42	1.29	2.08	0.307
n-6:n-3 Ratio[b]	29.4	26.3	26.7	3.220

^{xyz} Within a row, means lacking a common superscript letter differ ($P < 0.05$).

[a] Omega-6 fatty acids are 18:2$^{cis-9,12}$, 20:3 and 20:4.

[b] n-3 fatty acids are those fatty acids with the first double bond at the third carbon from the carbonyl end of the fatty acid; n-6 fatty acids are those unsaturated fatty acids with the first double bond at the sixth carbon from the carbonyl end of the fatty acid molecule.

Table 3. Influence of fat source on the fatty acid composition of adipose tissue.

Fatty acid mg/g (wet tissue basis)	Control	Tallow	Poultry fat	SE
Saturated fatty acids	309.41	287.48	315.06	25.55
14:0	22.53	22.94	25.66	2.35
15:0	4.17	3.94	3.94	0.407
16:0	183.41	165.81	184.51	13.80
17:0	11.18	9.48	8.42	1.13
18:0	88.12	85.30	92.52	8.45
Monounsaturated fatty acids	360.97	307.50	336.72	26.90
14:1	5.26	5.05	5.31	0.597
16:1	25.41	21.86	24.80	2.00
17:1	7.41^{x}	5.89^{xy}	4.96^{y}	0.709
18:1$^{trans-9}$	1.99	2.00	2.98	0.474
18:1$^{trans-11}$	30.88	27.71	39.74	4.85
18:1^{cis-9}	278.21	235.19	247.74	19.79
18:1^{cis-11}	11.81	9.80	11.20	0.926
Polyunsaturated fatty acids	17.84	16.46	18.51	2.06
18:2$^{cis-9,12}$	13.44	12.70	14.35	1.71
18:3^{n-3}	1.66	1.63	1.42	0.214
CLA	2.74^{x}	2.14^{y}	2.73^{x}	0.25
Total Trans fatty acids	35.61	31.85	45.44	5.51
n-6:n-3 Ratio[a]	8.33	8.25	10.47	1.01

[a] n-3 fatty acids are those fatty acids with the first double bond at the third carbon from the carbonyl end of the fatty acid; n-6 fatty acids are those unsaturated fatty acids with the first double bond at the sixth carbon from the carbonyl end of the fatty acid molecule.

^{xyz} Within a row, means lacking a common superscript letter differ ($P < 0.05$).

Effect of Poultry Fat Addition to Finishing Rations on Beef Quality During Retail Display and Sensory Panel Evaluations[1]

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Story in Brief

A 112-d finishing study was initiated to determine the effects of type of fat (poultry or tallow) on retail display and trained sensory panel evaluations of beef longissimus muscle (LM). Steers fed either a control finishing diet devoid of added fat or the control diet formulated with 4% beef tallow or poultry fat were harvested at a commercial beef packing plant. Wholesale, bone-in ribs were collected during carcass fabrication, and 1-in thick, boneless LM steaks were cut, weighed, placed on foam trays with an absorbent pad, and overwrapped with PVC film for display (deluxe warm white light; 1600 lx) in chest-type display cases (34°F). Two additional 1-in thick steaks were vacuum packaged and transported to Kansas State University for trained sensory panel analysis of cooked beef palatability. On d 1, 3, 5, and 7 of display, a three-person panel scored steak discoloration. Thiobarbituric acid reactive substances (TBARS) were measured on d 0 and 7 of display. Beef became less red (lower a* value; $P < 0.001$) and yellow (lower b* value) during the 7 d of retail display. Diet had no ($P > 0.10$) appreciable effect on the development of oxidative rancidity. Furthermore, diet had no effect ($P > 0.10$) on panel evaluations of cooked beef tenderness, juiciness, or flavor. Results of the present study indicated that replacing beef tallow with poultry fat in cattle finishing diets had no detrimental effects on beef quality during retail display or on beef palatability.

Introduction

Typically fat is limited to less than 5% of the diet in order to minimize negative effects on ruminal fiber digestion, and tallow is the preferred added energy source in feedlot diets. Poultry fat has been shown to have no effects on performance, carcass quality and yield grades Hutchison et al. (2003).

Because of the high level of polyunsaturation, poultry fat fed cattle may produce meat that will be more susceptible to lipid rancidity and discoloration, resulting in a reduced shelf-life. On the other hand tallow is very high in saturated fatty acid content, and its feeding may produce meat that will be less susceptible to these detrimental effects on shelf-life. Although Hutchison et al. (2003) reported significant differences in Warner-Bratzler shear force values, the differences were small and may not be perceived by consumers. Additionally little is known about the effect of dietary fat source on other palatability traits (i.e., juiciness, flavor, or off-flavors) of cooked beef. Therefore, the objective of this study was to determine the effects of adding poultry fat to finishing diets on shelf-life and sensory evaluations of beef.

Experimental Methods

Sixty Angus crossbred steers were obtained from the Livestock and Forestry Branch Station in Batesville, and the University of Arkansas Cow/Calf unit in Savoy. Steers were fed a 20% cottonseed hull growing diet for 55 d before changing to a high concentrate diet (10% cottonseed hull). The finishing study was initiated on December 5, 2002 and the initial body weight was 903.8 lb. Steers were stratified by source and blocked by weight, and assigned to 15 pens (four steers/pen). Then, pens were assigned randomly within blocks to one of three dietary treatments consisting of: 1) a corn-soybean meal control diet devoid of added fat; 2) the control diet formulated with 4% tallow; or 3) the control diet formulated with 4% poultry fat.

After the finishing period, steers were transported approximately 360 miles to a commercial beef packing plant, and harvested after a 12-h rest period. Carcasses were individually identified and hot carcass weights were recorded. After a 24-h conventional spray-chill, wholesale ribs from the left sides were captured and were then transported under refrigeration back to the University of Arkansas Red Meat Abattoir for further processing. Growth performance, carcass characteristics, and fatty acid composition of muscle and fat have been previously reported (Hutchison et al., 2003, 2004).

At approximately 48 h postmortem, six steaks 1-in thick were cut from each wholesale rib. Two steaks were used for shear force evaluation (Hutchison et al., 2003). Two steaks were vacuum packaged and transported to Kansas State University for trained sensory panel analysis. Two steaks were weighed, placed individually on foam trays, over-wrapped with an oxygen-permeable PVC film, and allotted randomly to 0 or 7 d of retail display (chest display cases with an average temperature of 34°F and under a 1,600 lx of warm, white light). On d 0, 1, 3, 5, and 7 of display, L* (a measure of darkness to lightness; a larger number indicates a lighter color), a* (a measure of redness; a larger number indicates a redder color), and b* (a measure of yellowness; a larger number indicates a more yellow color) values were determined from a Hunter MiniScan XE (model 45/0-L; Hunter Associates Laboratory, Reston, Va.) using illuminat C. Additionally, the hue angle (angle, in degrees, from the true red axis) was calculated as: $\tan^{-1}$ (b*/a*); whereas, chroma (a measure of

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vividness of color) was calculated as: $(a^{*2} + b^{*2})^{1/2}$. The ratio of reflectance measured at 630 nm to 580 nm was used to estimate oxymyoglobin concentration of steaks during retail display.

On d 0 and 7, one steak/animal was removed from the packaging material, re-weighed, and the difference between steak weights was divided by the initial (d 0) weight to calculate moisture loss percentage. In addition, approximately 2 g of pulverized longissimus muscle (LM) were used to measure 2-thiobarbituric acid reactive substances (TBARS; a measure of lipid oxidation) according to the procedures of Witte et al. (1970). Values for TBARS are reported as mg of malendehyde/kg of muscle.

At Kansas State University, sensory steaks were thawed for 18 to 24 h at 38°F, and cooked in a Blodgett forced air convection oven set at 325°F. Thermocouple wires were inserted in the steaks and internal temperature was monitored using a Doric Minitrend 205. Steaks were turned at 104°F and removed from the oven at 158°F. Cooked steaks were cut into 1 in x 0.5 in x 0.5 in cubes and evaluated by their trained sensory panel. Cubes were placed in double boilers and held on burners set to 212°F until serving. In a random order, each panelist received two cubes from each steak. The panelists sampled no more than eight samples per session. Each steak was sampled by five to seven panelists (an average of 6.1 panelists/steak). Samples were rated for myofibrillar tenderness, juiciness, flavor intensity, connective tissue amount, and overall tenderness and off flavor intensity. An eight-point scale was used to score samples with 8 being most desirable and 1 being least desirable.

Analyses of variance were conducted using the MIXED procedure of SAS (SAS Inst., Inc., Cary, N.C.). The model for TBARS and color data included dietary treatment, day, and the day by treatment interaction as fixed effects, and block and block by treatment as random effects. The model for the sensory evaluation included dietary treatment as a fixed effect and block, block by treatment interaction, and panelist as random effects. If dietary treatment was significant ($P < 0.05$), then a F-protected student's t-test (PDIFF option) was used to separate means.

Results and Discussion

There were no ($P > 0.05$) dietary fat source x day interactions; therefore, only main effects will be reported. Steaks from steers fed the tallow and the poultry fat diets were darker (lower L* value; $P < 0.05$) than controls (Table 1). However, dietary treatments did not ($P > 0.10$) affect other beef color or discoloration scores during retail display (Table 1). Beef became less red (lower a* value; $P < 0.001$) and yellow (lower b* value $P < 0.001$) during the 7 d of retail display (Table 2).

Concentrations of TBARS were numerically higher in the LM of steers consuming diets formulated with fat (0.54, 0.53, and 0.34 mg/kg for poultry fat, tallow, and control diets, respectively; Table 1); yet these differences were not significant ($P > 0.10$). By d 7 of retail display the TBARS concentration of the LM of all steers was 0.78 mg/kg (Table 2). As the TBARS concentration nears 1.0 mg/kg the product becomes less accepted by the consumer. With the onset of lipid oxidation meat typically becomes discolored. Lipid and pigment oxidation are closely coupled in beef; an increase in one of these results in a similar increase for the other (Faustman and Cassens, 1990). Although TBARS increased numerically in beef from steers fed the fat diets, there were no corresponding increases in beef discoloration during 7 d of retail display.

To our knowledge there have been few color studies of beef from cattle fed different fat sources. However, Wistuba et al. (2002) found that color was not affected by addition of fish oil to finishing cattle diets. Ponnampalam et al. (2001) reported that the only changes noted in color with the addition of elevated omega-3 and omega-6 fatty acids in the diet was a rapid decrease in a* values over time.

Cooked LM steaks from steers fed poultry fat did not ($P > 0.10$) differ in juiciness and flavor from steaks of steers fed the control or tallow diets (Table 3). The panelists were also not able to find any differences in the myofibrilar or overall tenderness of the steaks, even though Hutchinson et al. (2003) reported Warner-Bratzler shear force values from steers fed poultry fat or tallow were greater than controls.

While some studies show that there can be differences in flavor of fat supplemented beef and other products, the current study reported no differences ($P > 0.10$) in flavor or off flavor intensity as a result of added dietary fat. Moreover, there were no negative effects on shelf-life of steak found with the addition of poultry fat to the diet. Thus, results of the present study indicated that replacing beef tallow in finishing diets with a more economical energy source, poultry fat, has no detrimental effects on beef quality or palatability during retail display.

Implications

Feeding poultry fat in the current study had no effect on shelf stability of the product or sensory panel assessments when compared to the control or tallow diets. The addition of poultry fat in cattle finishing diets, therefore, can be a more cost efficient energy source without compromising the shelf-life or palatability of the beef produced.

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 like to thank Sally Stroda for conducting the taste panel. The authors would also like to acknowledge L. Rakes for her expert technical assistance, and Wendie Wallis-Phelps for assistance in the laboratory.

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Table 1. Effects of dietary fat supplementation on beef quality traits of the longissimus muscle during retail display.

Quality trait	Control	Beef tallow	Poultry fat	SEM	P-value
Lightness (L*)	39.09^{x}	37.82^{y}	38.21^{y}	0.252	0.02
Redness (a*)	20.08	19.1	19.18	0.339	0.12
Yellowness (b*)	18.04	17.44	17.54	0.199	0.11
Hue angle	42.3	43.08	42.96	0.355	0.3
Chroma	27.04	25.94	26.05	0.372	0.1
a*:b*	1.11	1.08	1.09	0.011	0.29
630/580 nm	4.94	4.63	4.81	0.125	0.28
Delta E	3.82	4.86	4.27	0.338	0.15
Discoloration score	5.9	5.9	5.74	0.13	0.53
TBARS mg/kg	0.34	0.53	0.54	0.1	0.21

^{x,y} Within a row, means without a common superscript letter differ (P < 0.05).

Table 2. Effects of retail display duration on beef quality traits of the longissimus muscle during retail display.

	Display day						
Quality trait	0	1	3	5	7	SE	P-value
Lightness (L*)	38.01	38.07	38.33	38.58	38.87	0.295	0.18
Redness (a*)	20.96^{w}	20.91^{w}	20.79^{w}	19.16^{x}	15.45^{y}	0.396	0.001
Yellowness (b*)	18.65^{w}	18.46^{w}	18.54^{w}	16.93^{x}	15.78^{y}	0.244	0.001
Hue angle	41.74^{x}	41.54^{x}	41.74^{x}	41.64^{x}	47.25^{w}	0.458	0.001
Chroma	28.07^{w}	27.91^{w}	27.88^{w}	25.59^{x}	22.24^{y}	0.438	0.001
a*:b*	1.12^{w}	1.13^{w}	1.13^{w}	1.13^{w}	0.95^{x}	0.015	0.001
630/580 nm	5.43^{x}	6.09^{w}	4.37^{y}	4.53^{y}	3.53^{z}	0.162	0.001
Delta E	---	2.63^{y}	3.51^{xy}	3.94^{x}	7.18^{w}	0.39	0.001
Discoloration score	---	6.54^{w}	6.11^{x}	5.76^{x}	5.00^{y}	0.145	0.001
TBARS mg/kg	0.16	---	---	---	0.78	0.086	0.001

^{w,x,y} Within a row, means without a common superscript letter differ (P < 0.05).

Table 3. Sensory panel evaluation results.

Trait[a]	Control	Tallow	Poultry fat	SE	P-value
Juiciness	5.8	5.7	5.7	0.13	0.94
Flavor intensity	5.9	5.9	5.9	0.01	0.75
Off-flavor	7.8	7.6	7.7	0.09	0.13
Connective tissue	7.0	6.8	6.9	0.13	0.31
Myofibrillar tenderness	5.5	5.4	5.5	0.13	0.73
Overall tenderness	5.8	5.7	5.7	0.14	0.74

[a]For the traits listed: 1 = extremely dry, bland, intense, abundant, extremely tough, and extremely tough; and 8 = extremely juicy, intense, none, none, extremely tender, and extremely tender; respectively.

Performance of Yearling Stocker Cattle of Different Biological Types Developed under a Rotational Management-intensive Grazing System

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Story in Brief

Yearling beef heifers (n = 36) and steers (n = 33) representing four biological types typical of commercial cattle in Northwest Arkansas were evaluated for growth performance on cool-season annual pastures. A management-intensive grazing system in a 112-day trial during the spring of 2003 was replicated three times. A variable stock density was used with daily paddock allocation based on forage availability. Twenty-three animals in each replication grazed an average of 8.2 acres for a stocking rate of 2.2 animal units/acre. Forages included annual ryegrass, wheat, and white clover. Overall mean crude protein (CP) was 15.26% and forage availability was 2,776 lb/acre. The four biological types included the potential for 1) large-framed, late maturing (LL; n = 15), 2) medium-framed, late maturing (ML; n = 18), 3) medium-framed, intermediate maturing (MI; n = 18) and 4) medium-framed, early maturing (ME; n = 18) calves. Animal performance measures including weight, hip height, body depth, body condition score, and temperament score were taken approximately every 28 d. Overall ADG was 2.2 lb/d but showed a sex by biological type interaction ($P < 0.05$). The ADG of LL steers was 2.6 lb/d, whereas LL heifers gained only 1.9 lb/d. The LL animals had greater ($P < 0.05$) hip height than the ML, with the ML being greater ($P < 0.05$) in hip height than both MI and ME in measurement period 1. In period 2, there were no differences in biological type ($P > 0.05$) between steers and heifers, but mean hip height was greater ($P < 0.05$) for heifers than steers. Body condition score did not vary by biological type or sex of calf. Steers had greater ($P < 0.05$) body depth measures than heifers in period 3. Animal temperament may have been a factor in gain since steers were less excitable ($P < 0.05$) than heifers. Total animal gain was 706 lb/acre in addition to 3,740 lb DM/acre of harvested forage in the form of ensiled haylage. These data suggest that biological type and sex should be considered in production systems involving yearling beef cattle under management-intensive grazing.

Introduction

More variation among animals of a particular breed can exist than between breeds. Biological type is defined as a classification for animals with similar genotypes for traits of interest (Bourdon, 1997). Animal performance measures that reflect traits of interest are of importance in comparing biological types, particularly under a specific nutritional system.

Management-intensive grazing is a rotational grazing system in which animal nutrient demand is balanced with forage supply and available forage is allocated based on animal requirements (Martz et al., 1999). Paddock sizes can be flexible using temporary fencing, forages can be kept more vegetative by quick grazing rotations through paddocks, and forages that reach maturity before grazing can be mechanically harvested.

The objective of this study was to evaluate growth and performance of yearling commercial cattle differing in biological types in Northwest Arkansas on cool-season annual pastures utilizing a rotational management-intensive grazing system.

Experimental Procedures

The study began February 27, 2003 and continued for 112 d, concluding June 19, 2003. Commercial beef cattle from 9 to 12 mo of age (n = 69) had an incoming mean weight of 580 lb ± 2.4 and included steers and heifers. Four biological types were represented: 1) Medium-framed, early maturing (ME; n = 18), 2) medium-framed, intermediate maturing (MI; n = 18), 3) medium-framed, late maturing (ML; n = 18), and 4) large-framed, late maturing (LL; n = 15). Biological types were assigned by experienced University of Arkansas personnel, using the equation set forth by McCurley et al. (1980). Each biological type was evenly represented with heifers and steers, with the exception of the LL type. The LL biological type was represented by six steers and nine heifers.

The experimental design was a 4 x 2 x 3 factorial, with four biological types, two sexes, and three replications. The design featured three spatial pasture replications in which all biological types and sexes were evenly distributed, with the exception of the LL type. The LL type had two steers per replication.

Animal performance measurements included weight every 28 days with a total of four weigh periods. Initial weights were taken upon arrival and subsequent weights were taken without withholding food or water. Other measurements included hip height, body depth, body condition score (1 = emaciated to 9 = obese), and temperament score (1 = docile to 3 = excitable) which were recorded three times during the trial. Hip height and body depth measures were taken with incremented calipers. One person subjectively assigned body condition score based on palpation of fat covering at each measurement period. Temperament scores were assigned in the same manner based on animal behavior within the chute and exiting the chute. A score of 1 indicated a very calm animal with slow exit from the chute. A score of 3 was given to animals that were agitated in the chute and exited by leaping or running upon the opening of the headgate.

Pasture size was approximately 8.2 acres per replication. Pastures were subdivided into paddocks with electric polywire based

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on forage availability. Dry matter needs were based on the mean weight of the animals per replication and allocated at 3.5% of the mean BW. A grazing management goal of a 3-in residual stubble height was to allow for adequate forage regrowth. Animals were moved to new paddocks daily and paddock size adjusted daily based on residual forage height. Biweekly laboratory dry matter measures helped to confirm adequate visual appraisal of availability.

Availability was measured every 2 weeks with a disk meter. Just prior to grazing in each replication, forage was clipped within a 2.7 ft² frame to a stubble height of 3 in. Samples were dried in a forced air oven at 122°F for 48 h and weighed to determine dry matter.

Additionally, several laboratory samples for nutrient analyses were also collected in paddocks just prior to grazing. Analyses included protein, NDF, ADF, ash, and in-vitro dry matter digestibility (IVDMD) levels. Protein was analyzed with an Elementar Nitrogen Analyzer (Elementar Americas, Inc., Mt. Laurel, N.J.). NDF, ADF, and IVDMD were analyzed with the ANKOM system (ANKOM Technology Corp., Fairport, N.Y.).

Mixed pastures consisted of cool-season annual forages including annual ryegrass, wheat, and white clover. Mean botanical composition over the three pastures was 39% ryegrass, 27% wheat, 22% white clover, and 12% other, using the step-point method of species frequency. Other forages included tall fescue and weeds, and bare soil percentage. Diet consisted of forages and ad libitum access to minerals and salt.

Statistical Analyses. PROC GLM of SAS (SAS Inc., Cary, N.C.) was used to analyze data by analysis of variance with unequal subclass numbers. The mathematical model used in the animal performance analyses (weight, hip height, body depth, body condition score, temperament) included terms for overall mean, biological type, sex of calf, initial weight, and error for each measurement period. Initial weight was included as a covariate. Means were separated with the PDIFF option.

Results and Discussion

Overall mean dry matter for the trial was 2,776 lb/acre. Paddock sizes ranged from 0.38 acres to 1.8 acres/replication group depending on forage availability. The stock density was considered variable due to the differing paddock sizes, but consistently there were 23 animals on the 0.38 acre to 1.8 acre paddocks. At 0.8 animal units (AU), stocking rate was 2.2 AU/acre and stock density ranged from 5.8 AU/acre to 1.2 AU/acre. Overall, average forage analyses for all replications during the trial was 15.3% CP, mean 54.4% NDF, 27.9% ADF, and 79.8% IVDMD.

Mean gain during the 112-d trial was 251 lb and there was a sex by biological type interaction ($P < 0.05$). Table 1 reflects those interactions and indicates that steers had a higher ($P < 0.05$) ADG than heifers. Mean increase in hip height was 2.4 in. Table 2 indicates hip height differences ($P < 0.05$) in biological types and sex of calf depending on measurement period. Measurement period 1, initial measure at the beginning of the trial, indicates LL animals were significantly taller than the other biological types. By measurement period 2, there were differences ($P < 0.05$) in steers and heifers in that heifers had a taller hip height than steers. This rate of skeletal growth rate difference may reflect earlier maturing of heifers than steers generally.

Despite a mean gain of 251 lb, body condition score increased by only an average 0.5 points due to skeletal and muscle growth during this growth phase compared to fat deposition. Steers had more ($P < 0.05$) body depth in both measurement periods 2 and 3 as detailed in Table 3. Differences ($P < 0.05$) in temperament score are also indicated in Table 3. Steers were generally more docile throughout the trial than heifers, but temperament improved over time. This may be a reflection of daily exposure to humans through movement to new paddocks.

Total animal growth was 17,375 lb ($n = 69$) over the 112 d trial. This was accomplished on 24.6 acres to yield 706 lb/acre animal growth. Despite efforts to keep up with rapid forage growth by frequent movements to new paddocks, some forage needed to be mechanically harvested due to forage maturity. Therefore, 22 (4' X 4') round bales of ensiled haylage were harvested from 5 acres within pastures. Dry matter estimates per bale were 850 lbs to total 3,740 lb DM/acre. Additionally, 3.2 acres of the harvested acreage were regrazed by animals before the end of the trial.

Implications

These data suggest that biological type and sex of calf should be considered in production systems involving yearling beef cattle under management-intensive grazing. Large-framed, late maturing steers and medium-framed, early maturing heifers excelled in this growth phase compared to other biological types. Yearling stocker cattle can perform adequately on high quality cool-season annual pastures in Northwest Arkansas. Additionally, management-intensive grazing allows for high forage production and utilization and should be considered for high production per acre.

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Table 1. Overall ADG (lb) with sex by biological type interaction.

	Biological type[a]				
Sex	LL	ML	MI	ME	Means
Steers	2.6[b]	2.3[c]	2.3[c]	2.4[bc]	2.4
(difference)	(0.7)	(0.2)	(0.3)	(0.2)	(0.4)
Heifers	1.9[cd]	2.1[c]	2.0[cd]	2.1[c]	2.0
Means	2.3	2.2	2.2	2.2	2.2
SE	0.05	0.04	0.04	0.04	0.04

[a]Biological types: ME =medium-framed, early maturing; MI = medium-framed, intermediate maturing; ML = medium-framed, late maturing; and LL = large-framed, late maturing.

[bcd] Row means with no superscripts in common differ (P < 0.05).

Table 2. Hip height (in) by biological type and sex interactions.

	Biological type[a]					
	LL	ML	MI	ME	Means	SE
Period 1	48[b]	46[c]	45[c]	45[c]	46.0	0.9
Period 2						
Steers	48	47	47	47	47.3[e]	1.4
Heifers	49	48	48	48	48.3[d]	1.4
Period 3	49	49	48	48	48.5	0.4

[a]Biological types: ME =medium-framed, early maturing; MI = medium-framed, intermediate maturing; ML = medium-framed, late maturing; and LL = large-framed, late maturing.

[bc]Row means with no superscripts in common differ (P < 0.05).

[de] Column means with no superscripts in common differ (P < 0.05).

Table 3. Body condition score, body depth (in), and temperament score by measurement periods and sex effects.

	Period 1	Period 2	Period 3
Body condition score [a]			
Steers	4.8	5.1	5.5
Heifers	4.8	5	5.4
Body depth, in			
Steers	21.0	22.0[c]	23.0[c]
Heifers	21.0	21.0[d]	22.0[d]
Temperament score [b]			
Steers	1.3[c]	1.2	1.0[c]
Heifers	1.7[d]	1.4	1.3[d]

[a]Body condition score: 1 = emaciated to 9 = obese.

[b]Temperament score: 1 = docile to 3 = excitable.

[cd] Column means within subclasses with no superscripts in common differ (P < 0.05).

Ultrasound and Carcass Measures of Different Biological Types of Beef Cattle Developed under a Rotational Management-Intensive Grazing System

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Story in Brief

Yearling beef steers (n = 33) representing four biological types, typical of commercial cattle in northwest Arkansas, were evaluated for muscle and fat deposition using real-time ultrasound measurements and carcass traits. Biological types included large-framed, late maturing (LL; n = 6), medium-framed, late maturing (ML; n = 9), medium-framed, intermediate maturing (MI; n = 9) and medium-framed, early maturing (ME; n = 9) steers. Steers grazed cool-season and warm-season forages, using a rotational management-intensive grazing system. Steers were rotated to new paddocks daily. Target BW and body condition score at harvest were 1,000 lb and 6.0 (1 to 9 scale), respectively. Average number of days before harvest was 300 ± 13 with a mean harvest BW of 1,020 ± 17 lb and a 5.9 ± 0.5 body condition score. Overall BW gain was 489 lb ± 22 at a rate of 1.6 lb/d ± 0.05. Generally, carcass data were correlated with the final ultrasound readings. Marbling score was greater ($P < 0.05$) for ME than LL steers (Slight 46 vs. Trace 39), but there was no difference ($P > 0.05$) in marbling score for MI and ML steers. There was an interaction ($P < 0.05$) between biological types and days on grass until harvest for ribeye area. Days on grass did not affect ($P > 0.05$) other carcass traits. Based on marbling scores, ME steers best match the all-forage diet utilizing a rotational management-intensive grazing system.

Introduction

Differences in genetic potential for growth rate, mature size, milk production, and lean:fat ratio have been identified by grouping cattle into biological types (Cundiff, 1993). Carcass composition is affected by sex, age, genotype, nutrition, and BW (Bruns et al., 2004). The development and deposition of tissues is in the order of skeleton, muscle, and fat, whereas the sequence of fat deposition is internal first, intermuscular, subcutaneous, and intramuscular fat last. Duckett et al. (1993) reported that intramuscular fat, or marbling, increases in a quadratic manner, increasing at a decreasing rate as days on feed increase.

A goal of rotational management-intensive grazing is to provide animals vegetative, nutrient dense forages to meet nutritional requirements for growth and development. Muscle and fat deposition during many stages of growth have been assessed by viewing animals with real-time ultrasound imaging as a tool to estimate carcass traits, to group for efficient feeding, and for genetic selection. Correlation between ultrasound measures and actual carcass measurements can vary greatly. One factor is the amount of time between ultrasound scanning and carcass data collection. Additionally, few U.S. studies have evaluated muscle and fat deposition by ultrasonic imaging of beef cattle developed on grazed forages. The objective of this study was to evaluate muscle and fat deposition over time for steers developed on an all-forage diet using rotational management-intensive grazing with predominantly high-quality annual forages.

Experimental Procedures

Yearling commercial beef steers (n = 33) representing four biological types were evaluated for muscle and fat deposition using real-time ultrasound measurements and carcass traits. Trained, experienced personnel from the University of Arkansas assigned steers to one of four biological types: 1) large-framed, late maturing (LL; n = 6), 2) medium-framed, late maturing (ML; n = 9), 3) medium-framed, intermediate maturing (MI; n = 9) and 4) medium-framed, early maturing (ME; n = 9) steers. Steers averaged 529 lb at the beginning of the trial, February 2003, and steers were harvested at a target BW of 1,000 lb and a body condition score of 6.0 (1 = emaciated to 9 = obese) to meet grassfed beef market demand. Performance measurements included weight, hip height, body depth, body condition score, and temperament score (1 = docile to 3 = excitable).

Steers grazed annual ryegrass, wheat, rye, and white clover during the spring and fall of 2003. Steers grazed warm-season forages in the summer, consisting of a mix of brown-midrib (BMR) sorghum-sudan hybrid, non-BMR sorghum-sudan hybrid, bermudagrass, crabgrass, and white clover. Steers were rotated to new paddocks daily and paddock size was adjusted based on forage availability. Dry matter availability was based on 3.5% of the mean group BW to help ensure animals of various weights and frame sizes had access to adequate intake. Forage DM was measured in the University of Arkansas laboratory by drying clipped forage samples. Samples were also chemically analyzed for nutrient content. Steers had access to minerals and salt *ad libitum*.

Ultrasonic images were taken five times during the trial. Images were taken by one technician using an Aloka 500V ultrasound unit (Corometrics Medical Systems, Wallingford, Conn.) equipped with a 3.5-MHz, 17.2-cm scanning width, linear array transducer. Hair was clipped and blown from the palpation site for the first date of data collection. Vegetable oil was applied to promote acoustical contact between animal and transducer. Copious amounts of oil were applied to the palpated area, which was curried until it was free of dirt and debris and then oiled again for optimum image registration according to the method of Perkins (1992). The transducer was placed between the 12th and 13th rib, lateral to the vertebral column. Cross-sectional images taken between the 12th to 13th ribs (with stand-off pad) were used to measure ribeye area (REA) and fat thickness. Longitudinal images taken about $^{3}/_{4}$ position from the chine bone end (without a stand-off pan) across the 11th to 13th ribs were used to determine percentage of fat (PFAT). A longitudinal measure

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was taken slightly above a line from the hook and pin bones, in line with the shaft of the ileum to measure rump fat. Images were recorded to the computer hard drive and later analyzed using Beef Image Analysis computer software (Designer Genes, Harrison, Ark.). Ultrasound measurements reported included REA, fat thickness, percent intramuscular fat in the ribeye, ribeye area ratio, ribeye area/cwt, rump fat, ribeye shape, ribeye depth, and ribeye length.

Steers were harvested over a 5-month period following the last ultrasound date in September, 2003. A total of nine harvest dates occurred. Steers were weighed directly off pasture without withholding feed and water prior to weighing, and steers were transported to abattoirs and humanely slaughtered following normal industry procedures. Carcasses were weighed immediately after evisceration. Carcass data for USDA yield and quality grades were collected by one University of Arkansas personnel 24 h after chill. REA was measured at the 12th and 13th rib interface, along with hot carcass weight, dressing percentage, fat thickness, kidney, pelvic, and heart fat percentage, yield grade, maturity, marbling, and quality grade.

Statistical Analyses. Data were analyzed using PROC GLM of SAS (SAS Inst. Inc., Cary, N.C.), with initial BW included as a covariate. Means were separated by the PDIFF option of LSMEANS. The model included biological type and initial weight and days on grass as covariates, as well as the biological type x days on grass interaction. When biological type x days on grass interactions were significant, each biological type was analyzed separately to get individual regression coefficients. PROC CORR of SAS was used to determine relationships between final ultrasound data and pooled carcass results.

Results and Discussion

Days on grass before harvest averaged 300, with a mean harvest BW of 1,020 lb and a 5.9 body condition score. Overall BW gain was 489 lb at a 1.6 lb ADG. All steers were harvested by approximately 19 to 22 mo of age. Large-framed, late maturing steers weighed more ($P < 0.05$) and had larger REA than the other maturity types at the final ultrasound date (Table 1). However, fat thickness, REA ratio, REA/cwt, rump fat, percent fat, or REA shape, depth, and length were similar ($P > 0.05$) among the four biological types.

Medium-framed, early maturing steers developed more ($P < 0.05$) marbling than the large-framed, late maturing steers (Table 2). As predicted by the final ultrasound scan, the numerical trend continued with carcass data in that large-framed, late maturing steers weighed more and had larger REA than other biological types at harvest, but not statistically different.

There was an interaction ($P < 0.05$) between biological type and days on grass for actual carcass REA. Regression of ribeye area on days on grass by biological type illustrated ($R^2 = 0.50$) that as days on grass increased, ME steers showed a slight negative regression coefficient ($b = -0.2 \pm 0.11$) with carcass REA. The regression coefficient was slightly positive ($b = 0.1 \pm 0.07$) for LL steers. The ME steers did not benefit from more days on grass in regards to REA. Days on grass did not affect ($P > 0.05$) other carcass traits.

Pooled carcass data over all harvest dates and final ultrasound measure correlations are presented in Table 3. Despite the amount of time between the final ultrasound scan and the final carcass data collection, many correlations were significant and moderate (0.4 +), indicating that ultrasound scans were a useful predictive tool to estimate final carcass traits.

Implications

Time to fully develop steers on pastures under a rotational management-intensive grazing system varies with biological type. In this study, medium-framed, early maturing steers developed more marbling than the large-framed, late maturing steers, yet had comparable carcass ribeye areas. Large-framed, late maturing steers may have benefited from more days on grass and a higher harvest weight in regards to marbling. Numerically, more days were required to fully develop the medium-framed, early maturing steers on grass, but harvest before 24 mo of age is possible under this grazing system. Additionally, real-time ultrasound scanning can be used as a predictive tool to estimate final carcass traits for commercial cattle developed on pasture.

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Table 1. Final ultrasound least squares means for measured traits by biological type.

	Biological Type[a]				
Trait	ME	MI	ML	LL	Pooled SE
Weight, lb	792.5[c]	858.3[c]	811.0[c]	952.8[b]	3.9
Ribeye area, in^2	8.4[c]	8.6[c]	8.3[c]	9.9[b]	0.3
Fat thickness, in	0.15	0.15	0.15	0.14	0.01
Ribeye area ratio	0.59	0.54	0.56	0.55	0.01
Ribeye area/cwt	1.06	1.00	1.03	1.05	0.03
Fat, %	4.15	4.57	4.02	3.60	0.25
Rump fat, in	0.16	0.17	0.17	0.18	0.03
Ribeye shape[d]	2.59	2.48	2.95	2.71	0.24
Ribeye depth[d]	2.11	2.1	2.16	2.27	0.06
Ribeye length[d]	3.79	3.9	3.83	4.13	0.09

[a] Biological types: ME =medium-framed, early maturing; MI = medium-framed, intermediate maturing; ML = medium-framed, late maturing; and LL = large-framed, late maturing.

[bc] Means within rows with no superscripts in common differ ($P < 0.05$).

[d] Propietary measures.

Table 2. Carcass data least squares means by biological type.

	Biological Type[a]				
Trait	ME	MI	ML	LL	Pooled SE
Days on grass	321	312	289	277	13.5
Liveweight, lb	1017	1004	1014	1037	16.7
Hot carcass weight, lb	557	538	560	564	11.8
Dressing percentage	54.8	53.6	55.2	54.4	0.6
Ribeye area, in^2	9.8	9.2	9.5	9.9	0.4
Fat thickness, in	0.17	0.15	0.2	0.18	0.03
Kidney, pelvic, and heart fat, %	1.59	1.45	1.64	1.4	0.1
Yield grade	2.2	2.3	2.4	2.2	0.1
Maturity[b]	166.0	168.6	171.2	163.9	4.1
Quality grade[c]	613.2	564.2	541.6	540.9	22.4
Marbling[d]	345.6[e]	285.2[ef]	253.1[ef]	239.0[f]	24.6

[a] Biological types: ME =medium-framed, early maturing; MI = medium-framed, intermediate maturing; ML = medium-framed, late maturing; and LL = large-framed, late maturing ML=medium frame, late maturing, LL=large frame, late maturing.

[b] Maturity: 100-199=A maturity.

[c] Quality grade: Standard=500-599, Select=600-699.

[d] Marbling score: 100-199 = Practically devoid; 200-299 = traces; and 300-399 = slight.

[f] Standard degree of marbling=100-299, Select degree of marbling=300-399.

[ef] Means within a row with no superscripts in common differ ($P < 0.05$).

Table 3. Correlations[a] between pooled carcass data and final ultrasound measurements.

	Carcass[b]											
Ultrasound [c]	DOG	ADG	Live Wt	HCW	DP%	REA	FT	KPH	YG	MAT	MARB	QG
Weight	-0.87*	0.26	0.68*	0.64*	0.23	0.17	0.01	0.22	-0.06	-0.09	-0.16	-0.19
REA	-0.64*	0.16	0.71*	0.79*	0.48*	0.43*	0.01	0.12	-0.14	-0.11	0.11	0.06
FT	-0.21	-0.05	0.33	0.29	0.07	-0.01	0.54*	0.46*	0.38*	0.11	0.02	0.20
REA RATIO	-0.01	-0.01	0.22	0.31	0.28	0.23	0.18	0.18	-0.01	0.06	0.28*	0.14*
REA/cwt	0.28	-0.19	0.11	0.32	0.48*	0.47*	-0.01	-0.13	-0.17	-0.05	0.48*	0.44*
PFAT	-0.02	-0.32	0.02	0.01	-0.02	0.12	-0.06	0.17	-0.2	-0.29	0.28	0.23
RF	-0.48*	0.12	0.59*	0.53*	0.13	0.23	0.19	0.32	-0.01	-0.12	0.18	-0.11
REA SHAPE	-0.12	0.15	0.31	0.40*	0.32	0.25	0.28	0.34	0.04	-0.02	0.22	0.05
REA DEPTH	-0.49*	0.25	0.62*	0.77*	0.58*	0.43*	0.09	0.08	-0.06	0.01	0.16	0.04
REA LENGTH	-0.52*	0.26	0.41*	0.47*	0.32	0.22	-0.1	-0.08	-0.09	-0.08	-0.11	-0.09

[a]* $P < 0.05$.

[b]DOG = days on grass, ADG = average daily gain, HCW = hot carcass weight, DP% = dressing percentage, REA = ribeye area, FT = fat thickness, KPH = kidney, pelvic, and heart fat, YG = yield grade, MAT = maturity, MARB = marbling, and QG = quality grade.

[c] REA = ribeye area, FT = fat thickness, REA RATIO = ribeye area ratio, REA/cwt = ribeye area/ hundred lbs, PFAT = percent fat, and RF = rump fat.

Sensory Characteristics of Beef from Three Biological Types of Cattle Grazing Cool-Season Forages Supplemented with Soyhulls

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Story In Brief

The effects of soyhull supplementation to divergent biological types of cattle on forage-based dietary regimens were studied to observe the impact on sensory beef palatability. Over two consecutive years, weaned calves (n = 107) classified as large-, medium-, or small-framed, and of intermediate rate of maturing were allocated to fescue without supplementation (Control), or fescue or orchardgrass pasture with soyhull supplementation. Sensory evaluation of longissimus steaks from the cattle revealed that soyhull supplementation reduced ($P < 0.05$) the grassy flavor intensity compared to the Control. There were no differences ($P > 0.05$) among dietary treatments for juiciness or tenderness; however, beef from all three dietary regimens was rated "slightly tender" on the sensory scale. Biological type revealed little influence on sensory flavor or palatability characteristics under these dietary regimens. These results indicate that although soyhull supplementation may not greatly impact beef flavor, it can aid in reduction of the grassy flavor characteristic commonly associated with forage-fed beef.

Introduction

Utilizing a forage-based feeding regimen potentially allows for beef with a more admirable fatty acid profile and improved leanness, thereby potentially providing a healthier beef product to consumers. However, forage-feed beef often is inferior to concentrate-fed beef in terms of carcass muscling and quality grade. Additionally, forage-fed beef can impart different flavor characteristics, particularly a more intense grassy flavor. Often, these flavor differences are partly due to volatiles from fat oxidation and from chlorophyll derivatives (Griebenow et al., 1997). Supplementing concentrates to cattle on a forage-based feeding regimen can improve gains, increase carcass weights, and improve quality grades. Additionally, supplementing concentrates can also reduce the grassy flavor intensity. However, concentrate supplementation can cause decreased forage utilization (Dixon and Stockdale, 1999), and since maximal utilization of available forages is one objective of a forage-based feeding program, alternative supplemental feedstuffs could be considered. In addition, allocating appropriate types of cattle to forage-based feeding regimens can allow for improved performance and carcass characteristics, and the rate of growth exhibited by cattle has been stated to influence tenderness (Aberle et al., 1981). The impact of cattle biological type on flavor characteristics is less clear. Therefore, the objective of this study was to observe the effects of supplementing soyhulls, a highly digestible fiber source, to divergent biological types of forage-fed cattle on sensory taste characteristics.

Experimental Procedures

Animals. British, and British x Continental fall- and winter-born beef steers and heifers from two consecutive years (n = 108) of small (n = 35; SI), medium (n = 36; MI), or large (n = 36; LI) frame size and intermediate maturing rate were selected from a commercial cow herd at the University of Tennessee Experiment Station, Springhill, Tenn., be utilized in this study. Biological types were estimated using the equation set forth by McCurley et al. (1980). This study was replicated over two consecutive years with 54 animals utilized each year. One small-framed intermediate maturing heifer was removed from the first year's study due to chronic illness.

The randomly chosen calves were stratified across either orchardgrass (*Dactylis glomerata*) predominated pasture supplemented with pelleted soyhulls (Orchard), tall fescue (*Festuca arundinacea* Schreb.) pasture with soyhull supplementation (Fescue), or fescue pasture with no supplementation, for the control (Control). A commercial salt and mineral mix was available to all animals throughout the study. Six animals (two from each biological type) were allocated to a paddock, replicated three times within each treatment, each year (n = 36 per treatment). There were equal numbers of steer and heifer calves represented within each biological type, within each treatment. Utilizing a rotational system, each paddock allowed for 0.5 acre/calf in the fall and spring, and 1.0 acre/calf in the winter. Pelleted soyhulls were fed to the supplemented treatments and were allocated at 1% BW/calf/day. Adjustments to supplementation were performed every 28 d when the cattle were reweighed. Grazing continued into the summer months (mean days-of-age = 555), until forage availability started to diminish, whereupon all cattle, within a year, were sent to a commercial slaughtering facility (carcass results from these cattle were reported by Baublits et al., 2003).

After carcasses had chilled for 48 h, a three-rib section (10^{th} – 12^{th} ribs) of the wholesale rib from the right side of each carcass was removed, vacuum-sealed, transported back to the University of Arkansas and aged for an additional 5 d before subsequent analyses.

Taste-panel. Sensory characteristics of longissimus steaks were obtained by a professional six-member descriptive taste-panel at Texas A & M University, College Station, Texas. A sub-sample consisting of 24 steaks per treatment (72 steaks total) was utilized for determination of sensory characteristics. A six-member taste panel determined aromatic, feeling-factor, taste and aftertaste, and textural sensory characteristics. The aromatic, feeling factor, taste and aftertaste sensory characteristics were scored on a 15-point scale (0 = not

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detected; 15 = extremely intense). Textural sensory characteristics were scored on an 8-point scale (1 = extremely dry, extremely tough, abundant, extremely bland; 8 = extremely juicy, extremely tender, none, extremely intense).

Statistical analysis. The experiment was set up as a split-plot design with random effects of year and replicate within year, and fixed effects of treatment and biological type. The whole plot consisted of forage treatment, and the sub-plot consisted of biological type. The three-way interaction of year x replicate x treatment was the error term for the whole plot, and the four-way interaction year x replicate x treatment x biological type was the error term for the sub-plot and for the interaction of treatment x biological type. Although year is generally considered to have a significant effect on performance, it is likely due to temporary environmental effects causing pasture conditions to vary between years (Vallentine, 1990). Due to this, and that year was considered a random effect, all interactions pertaining to year were not included in the final model. Days-of-age of individual animals was included in the final model as a covariate for all variables analyzed. Data were analyzed using the MIXED procedure of SAS (SAS Inst., Inc., Cary, N.C.). Means were generated using LSMEANS and separation was performed using the PDIFF option.

Results and Discussion

The treatment x biological type interaction was not significant for any of the sensory characteristics. Therefore, sensory results of longissimus samples by treatment and biological type are reported in Table 1. The Control samples exhibited a more intense ($P < 0.05$) grassy aroma than the supplemented groups, indicating a reduced grassy intensity associated with soyhull supplementation. The exact cause of this is unknown; however, it could be related to differences in phyt-2-ene, a volatile derivative of chlorophyll oxidation. Larick et al. (1987) reported a positive correlation between phyt-2-ene and grassy flavor intensity. Although not measured in the present study, the Control cattle could have deposited more chlorophyll in the fat depots due to increased forage ingestion with the exclusion of soyhull supplementation at 1 % / BW that the other groups received. The differences in the grassy flavor intensity could also be related to differences in fatness between the carcasses from the dietary regimens. Smith et al. (1983) discussed a minimal threshold fat thickness value of 0.3 in, to attenuate the grassy flavor characteristic. This could possibly explain the observed differences in the grassy descriptor in the present study. Although a treatment x biological type interaction was significant for fat thickness, all biological types in the Control treatment had less than 0.3 in backfat, whereas all biological types in the Fescue and Orchard treatments had greater than 0.3 in backfat (except Orchard-SI, which had 0.26 in backfat; Baublits et al., 2003). Biological type did not have a significant influence on flavor except for differences in the sweet sensory descriptor. Beef from the SI cattle had a more intense ($P < 0.05$) sweet characteristic than beef from MI. The exact cause of this is unknown. There were no significant differences between biological types for marbling, and although the treatment x biological type interaction was significant for fat thickness, SI generally did not differ from MI within each dietary regimen or LI within the Control and Fescue dietary regimens (Baublits et al., 2003). Interestingly, there were no differences in juiciness between dietary regimens, even though beef from the two supplemented treatments had significantly more marbling than the Control (Small vs. Practically Devoid marbling scores, respectively; Baublits et al., 2003). There were no differences ($P > 0.05$) in sensory tenderness ratings between treatments or biological types. Overall tenderness sensory ratings illustrated that longissimus samples from all three treatments were scored in approximately the "slightly tender" category, which is slightly above the median value on the sensory evaluation scale.

Implications

Supplementing forage-fed cattle soyhulls did not seem to greatly influence beef flavor or tenderness, but can decrease grassy flavor intensity. Biological type, within these types of production systems does not seem to have substantial influence on beef flavor or palatability.

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Table 1. Least squares means for sensory characteristics of longissimus muscle by treatment and biological type(n = 72)[a].

	Treatment[b]			Biological Type[c]		
Item	Control	Fescue	Orchard	LI	MI	SI
Aromatics [d]						
Beef/brothy	4.46 ± 0.10	4.73 ± 0.10	4.80 ± 0.10	4.66 ± 0.08	4.66 ± 0.08	4.68 ± 0.09
Beef fat	1.42 ± 0.07	1.58 ± 0.07	1.62 ± 0.07	1.50 ± 0.06	1.51 ± 0.06	1.61 ± 0.07
Serumy/bloody	1.49 ± 0.10	1.62 ± 0.10	1.60 ± 0.10	1.47 ± 0.10	1.59 ± 0.10	1.65 ± 0.11
Grainy/cowy	0.09 ± 0.03	0.04 ± 0.03	0.03 ± 0.03	0.04 ± 0.03	0.03 ± 0.02	0.09 ± 0.03
Cardboard	0.11 ± 0.03	0.07 ± 0.03	0.10 ± 0.03	0.08 ± 0.03	0.09 ± 0.03	0.10 ± 0.03
Painty	0.00	0.00	0.00	0.00	0.00	0.00
Fishy	0.00	0.00	0.00	0.00	0.00	0.00
Liver	0.27 ±0.06	0.21 ± 0.06	0.27 ± 0.06	0.28 ± 0.06	0.18 ± 0.06	0.28 ± 0.06
Soured	0.00	0.00	0.00	0.00	0.00	0.00
Browned/burnt	0.73 ± 0.10	0.82 ± 0.10	0.93 ± 0.10	0.93 ± 0.10	0.84 ± 0.10	0.71 ± 11
Grassy	1.11 ± 0.09[w]	0.80 ± 0.09[x]	0.77 ± 0.09[x]	0.92 ± 0.09	0.99 ± 0.09	0.77 ± 0.10
Milky/oily	0.62 ± 0.07	0.63 ± 0.07	0.68 ± 0.07	0.71 ± 0.07	0.70 ± 0.07	0.52 ± 0.08
Old/Putrid	0.09 ± 0.03	0.02 ± 0.03	0.05 ± 0.03	0.03 ± 0.03	0.06 ± 0.03	0.08 ± 0.03
Feeling Factors [d]						
Metallic	2.68 ± 0.04	2.81 ± 0.04	2.76 ± 0.04	2.74 ± 0.04	2.74 ± 0.04	2.76 ± 0.05
Astringent	2.37 ± 0.04	2.45 ± 0.04	2.42 ± 0.04	2.42 ± 0.03	2.42 ± 0.03	2.41 ± 0.04
Tastes [d]						
Salt	1.99 ± 0.02	2.04 ± 0.02	2.00 ± 0.02	1.99 ± 0.02	2.02 ± 0.02	2.01 ± 0.03
Sour	2.51 ± 0.06	2.52 ± 0.06	2.51 ± 0.05	2.51 ± 0.05	2.57 ± 0.05	2.55 ± 0.06
Bitter	2.45 ± 0.06	2.42 ± 0.06	2.39 ± 0.06	2.47 ± 0.06	2.39 ± 0.06	2.39 ± 0.06
Sweet	0.40 ± 0.04	0.50 ± 0.04	0.45 ± 0.04	0.44 ± 0.04[wx]	0.38 ± 0.04[x]	0.53 ± 0.04[w]
Aftertastes [d]						
Sour	1.01 ± 0.07	0.93 ± 0.07	1.01 ± 0.07	0.94 ± 0.07	1.01 ± 0.07	1.01 ± 0.08
Acid	1.27 ± 0.10	1.26 ± 0.10	1.15 ± 0.10	1.39 ± 0.09	1.19 ± 0.09	1.10 ± 0.11
Bitter	0.90 ± 0.09	0.94 ± 0.09	0.82 ± 0.09	0.97 ± 0.09	0.83 ± 0.09	0.86 ± 0.10
Liver	0.09 ± 0.03	0.03 ± 0.03	0.06 ± 0.03	0.08 ± 0.03	0.06 ± 0.03	0.04 ± 0.03
Browned/Burnt	0.14 ± 0.06	0.14 ± 0.06	0.20 ± 0.06	0.19 ± 0.06	0.17 ± 0.06	0.11 ± 0.06
Metallic	1.72 ± 0.10	1.89 ± 0.10	1.91 ± 0.10	1.86 ± 0.08	1.89 ± 0.08	1.76 ± 0.08
Grassy	0.26 ± 0.09	0.11 ± 0.09	0.10 ± 0.09	0.10 ± 0.06	0.22 ± 0.06	0.15 ± 0.06
Milky/Oily	0.30 ± 0.07	0.38 ± 0.07	0.37 ± 0.07	0.33 ± 0.07	0.37 ± 0.07	0.36 ± 0.07
Textures [e]						
Juiciness	4.93 ± 0.13	5.11 ± 0.13	5.07 ± 0.13	5.01 ± 0.13	4.96 ± 0.13	5.14 ± 0.14
Myofibrillar Tenderness	5.29 ± 0.21	5.44 ± 0.22	5.42 ± 0.22	5.32 ± 0.21	5.28 ± 0.21	5.56 ± 0.23
Connective Tissue	6.10 ± 0.22	6.26 ± 0.23	6.01 ± 0.23	6.06 ± 0.22	5.96 ± 0.22	6.35 ± 0.24
Overall Tenderness	5.29 ± 0.21	5.44 ± 0.22	5.40 ± 0.22	5.32 ± 0.21	5.24 ± 0.21	5.58 ± 0.23

[a] Sample consisted of sub-sample (n = 24 for each treatment or biological type).
[b] LI = large-framed, intermediate-maturing; MI = medium-framed, intermediate-maturing; SI = small framed, intermediate-maturing.
[c] 0 to 15: 0 = absent, 15 = extremely intense.
[d] 1 to 8: 1 = extremely dry, extremely tough, abundant, extremely bland; 8 = extremely juicy, extremely tender, none, extremely intense.
[wx] Within treatment or biological type, and within row, means without a common superscript differ (P < 0.05).

Chemical, Fatty Acid, and Tenderness Characteristics of Beef from Three Biological Types of Cattle Grazing Cool-Season Forages Supplemented with Soyhulls

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Story in Brief

Over two consecutive years, the effects of allocating large-, medium-, or small-framed cattle, all of intermediate rate of maturing (n = 107), to fescue without supplementation (Control), or fescue or orchardgrass pasture with soyhull supplementation on shear, chemical, and fatty acid characteristics were investigated. There were no differences ($P > 0.05$) in shear force between dietary treatments. Cattle from the two supplemented treatments produced beef that had increased ($P < 0.05$) percentage lipid and decreased ($P < 0.05$) proportions of polyunsaturated (PUFA) and n-3 fatty acids (those fatty acids with the first double bond at the third carbon from the carbonyl end of the fatty acid) compared to the Control. However, supplementation did not decrease proportions of conjugated linoleic acid (CLA) present in the longissimus, which can commonly occur when forage-fed cattle are supplemented concentrates. Additionally, even though the proportion of n-3 fatty acids was reduced with supplementation, the n-6/n-3 ratio (n-6 fatty acids are those unsaturated fatty acids with the first double bond at the sixth carbon from the carbonyl end of the fatty acid molecule) was below five in all three treatments, which could potentially aid in reduced atherosclerosis and inflammation. Biological type did not appear to be a significant source of variation for most traits analyzed in this study. These results suggest that supplementation of soyhulls to cattle grazing forage may not decrease CLA proportions, and although it might elicit a reduction in proportions of PUFA and n-3 fatty acids present in the longissimus, the n-6/n-3 ratio still may be maintained below the recommended ratio of four to five.

Introduction

A forage-based feeding regimen offers an alternative marketing approach for producers. Furthermore, forage-based beef often exhibits fatty acid profiles that offer positive health characteristics; thus, providing a healthier beef product to consumers. Typically, forage-fed beef contains higher proportions of conjugated linoleic acid (CLA), which exhibits anticarcinogenic properties, and can reduce body fat. Furthermore, forage-fed beef can exhibit a reduced n-6 /n-3 fatty acid ratio (n-6 fatty acids are those unsaturated fatty acids with the first double bond at the sixth carbon from the carbonyl end of the fatty acid molecule; n-3 fatty acids are those fatty acids with the first double bond at the third carbon from the carbonyl end of the fatty acid), which has been shown to exhibit positive health effects. These positive health effects, related to anti-atherogenicity and anti-inflammatory processes, have been associated with an n-6/n-3 ratio of five or less (Innis, 1996; Lee et al., 1989). However, forage-fed beef can experience decreased flavor acceptance due to volatiles from fat oxidation and from chlorophyll derivatives (Griebenow et al., 1997). Additionally, forage-fed cattle often are inferior to grain-fed cattle, in terms of carcass merit. Supplementation to cattle on forage-based rations can improve flavor acceptance and carcass merit; however, inclusion of grain in the diet can negatively impact the fatty acid profile of forage-fed beef. Furthermore, the rate of growth exhibited by cattle has been stated to influence tenderness (Aberle et al., 1981) and allotting appropriate types of cattle to a forage-based system could impact the palatability of the beef. Therefore, the objective of this study was to observe the effects of supplementing soyhulls, a highly digestible fiber source, to divergent biological types of forage-fed cattle on shear, chemical and fatty acid characteristics.

Experimental Procedures

Animals. British, and British x Continental fall- and winter-born beef steers and heifers from two consecutive years (n = 108) of small (n = 35; SI), medium (n = 36; MI), or large (n = 36; LI) frame size and intermediate maturing rate were selected from a commercial cow herd at the University of Tennessee Experiment Station, Springhill, Tennessee to be utilized in this study. Biological types were estimated using the equation set forth by McCurley et al. (1980). This study was replicated over two consecutive years with 54 animals utilized each year. One small-framed intermediate maturing heifer was removed from the first year's study due to chronic illness.

The randomly chosen calves were stratified across either orchardgrass (*Dactylis glomerata*) predominated pasture supplemented with pelleted soyhulls (Orchard), tall fescue (*Festuca arundinacea* Schreb.) pasture with soyhull supplementation (Fescue), or fescue pasture with no supplementation, for the control (Control). A commercial salt and mineral mix was available to all animals throughout the study. Six animals (two from each biological type) were allocated to a paddock, replicated three times within each treatment, each year (n = 36 per treatment). There were equal numbers of steers and heifers represented within each biological type, within each treatment. Utilizing a rotational system, each paddock allowed for 0.5 acre/calf in the fall and spring, and 1.0 acre/calf in the winter. Pelleted soyhulls were fed to the supplemented treatments and were allocated at 1% BW/calf/day. Adjustments to supplementation were performed every 28 d when the cattle were reweighed. Grazing continued into the summer months (mean days-of-age = 555), until forage availability started to diminish, whereupon all cattle, within a year, were sent to a commercial slaughtering facility (carcass results reported in Baublits et al., 2003). After carcasses chilled for 48 h, a

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three-rib section (10th – 12th ribs) of the wholesale rib from the right side of each carcass was removed, vacuum-sealed, transported back to the University of Arkansas and aged for an additional 5 d before subsequent analyses.

Warner-Bratzler shear force. For Warner-Bratzler shear force (WBS) analysis, longissimus steaks (1 in thick) were cooked in a convection oven until the internal temperature of each steak was 158°F. After cooking, steaks were allowed to cool to room temperature for approximately 2 h. Upon cooling, five 0.5 in-diameter cores were removed from each steak for WBS. Each core was sheared with a Warner-Bratzler attachment using an Instron (Canton, Mass.) Universal Testing Machine.

Cooking loss. Cooking loss of the steaks was determined during the cooking process for WBS. After steaks were removed from the vacuum-sealed pouches, each steak was weighed on a balance prior to cooking. Upon completion of cooking, a final weight was obtained for cooking loss calculations.

Moisture percentage. Percent moisture was obtained by dicing the longissimus muscle of a steak and utilizing approximately a 50 g sample to represent a homogenous portion. Samples were freeze-dried for approximately 96 h. After drying moisture percentage was calculated and samples were placed in a commercial blender, ground and stored in a freezer at - 10°F for later determination of total lipids and fatty acid profiles.

Total lipids. Total lipids were obtained using the method as described by Rule (1997). Tissue samples weighing 200 mg were utilized and lipid extraction was performed with chloroform-methanol, followed by chloroform removal and evaporation to yield the lipid fraction.

Fatty acid profiles. For fatty acid analysis, total lipids were extracted by the same method previously described. Fatty acid methyl esters (FAME) were prepared by transmethylation utilizing methanol and HCl as described by Murrieta et al. (2003). Tridecanoic acid (13:0; 1 mg) was used as the internal standard for all samples. Fatty acid methyl esters were analyzed using a Hewlett-Packard 5890 gas chromatograph (Hewlett-Packard, Avondale, Pa.) equipped with a flame ionization detector and a 60 -m x 0.25 -mm fused silica capillary column (SP-2380; Supelco, Bellefonte, PA).

Statistical analysis. The experiment was set up as a split-plot design with random effects of year and replicate within year, and fixed effects of treatment and biological type. The whole plot consisted of forage treatment and the sub-plot consisted of biological type. The three-way interaction of year x replicate x treatment was the error term for the whole plot, and the four-way interaction year x replicate x treatment x biological type was the error term for the sub-plot and for the interaction of treatment x biological type. Although year is generally considered to have a significant effect on performance, it is likely due to temporary environmental effects causing pasture conditions to vary between years (Vallentine, 1990). Due to this, and that year was considered a random effect, no interactions pertaining to year were included in the final model. Days-of-age of individual animals was included in the final model as a covariate for all variables analyzed. The treatment x biological type interaction was not significant for any traits in this study; therefore, the interaction was pooled into the error term and subsequent main effect means are reported. Data were analyzed using the MIXED procedure of SAS (SAS Inst., Inc., Cary, N.C.). Means were generated using LSMEANS and separation was performed using the PDIFF option.

Results and Discussion

There were no differences ($P > 0.05$) among treatments for longissimus cooking loss or WBS (Table 1). Longissimus percentage lipid was greater ($P < 0.05$) for the supplemented treatments than the Control, and the Control had greater ($P < 0.05$) percentage moisture than both supplemented groups (Table 1). Biological type effects revealed no differences ($P > 0.05$) in tenderness, or percentage lipid or moisture (Table 1), indicating that under these dietary conditions, biological type had little influence on the aforementioned traits.

Fatty acid profiles of longissimus tissue, by biological type and treatment, are presented in Table 2 and Table 3, respectively. Other than the SI cattle having lower ($P < 0.05$) proportions of 16:1*cis*-9 and 18:2*cis*-9, *trans*-11 (conjugated linoleic acid; CLA), there were no differences among biological types for fatty acid profiles.

Longissimus muscle samples from the Control had lower ($P < 0.05$) proportions of 16:0 and 18:1*cis*-9, and higher ($P < 0.05$) proportions of 18:3*cis*-9,12,15, 20:4*cis*- 5,8,11,14, 20:5*cis*-5,8,11,14,17, 22:5*cis*-7,10,13,16,19 and 22:6*cis*-4,7,10,13,16,19 than those from Fescue or Orchard (Table 3). There were no differences between dietary treatments for CLA (18:2*cis*-9, *trans*-11), indicating that soyhull supplementation did not decrease CLA, which commonly occurs with concentrate supplementation to forage-fed cattle. Although there were no differences ($P > 0.05$) among treatments for saturated fatty acids (SFA), the Control had greater ($P < 0.05$) proportions of polyunsaturated fatty acids (PUFA) and a greater ($P < 0.05$) PUFA / SFA ratio than Fescue and Orchard, with Fescue having lower ($P < 0.05$) proportions of PUFA and a lesser ($P < 0.05$) PUFA / SFA than Orchard. The Control samples exhibited an improved n-6/n-3 fatty acid ratio, which was less ($P < 0.05$) than Fescue or Orchard. The increased proportions of PUFA and improved n-6/n-3 ratio exhibited by the Control samples could have been largely due to increased forage ingestion. Forages typically have large amounts of 18:2*cis*-9,12 and 18:3*cis*-9,12,15 present in the form of glycolipids. Additionally, these two fatty acids serve as precursors for the endogenous synthesis of many of the 20- and 22-carbon polyunsaturates (Innis, 1996). Thus, the Control could have obtained higher proportions of longissimus 18:2*cis*-9,12 and 18:3*cis*-9,12,15 through increased forage digestion with the exclusion of soyhull supplementation that the Fescue and Orchard treatments received. This could have potentially allowed for direct increased PUFA absorption and increased substrate for synthesis of the 20- and 22-carbon polyunsaturates as well. Although longissimus samples from the control cattle had greater proportions of PUFA and an improved n-6/n-3 fatty acid ratio, the ratios for steaks from the supplemented treatments were below the recommended ratio five, and there were no differences ($P > 0.05$) between treatments for CLA.

Implications

Supplementing forage-fed cattle soyhulls does not seem to influence shear force. Biological type does not seem to have a large influence on shear force, or composition or fatty acid characteristics under these dietary regimens as well. Decreased longissimus polyunsaturated and n-3 fatty acids occurred as a result of supplementing soyhulls. However, the n-6/n-3 ratio was acceptable and the CLA proportions were not decreased, which can typically result from supplementing concentrates to forage-fed cattle; thus indicating soyhull

supplementation might be an effective approach to maintain some of the positive fatty acid characteristics associated with forage-fed cattle.

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Table 1. Least squares means for longissimus cooking loss, lipid percentage, moisture percentage and Warner-Bratzler shear force by treatment and biological type (n = 107).

	Treatment[a]			Biological type[b]		
Item	Control	Fescue	Orchard	LI	MI	SI
Cooking loss[c]	27.75 ± 1.03	27.09 ± 1.03	28.61 ± 1.04	27.83 ± 0.89	27.87 ± 0.86	27.75 ± 0.90
Lipid %[d]	2.55 ± 0.28^{x}	4.72 ± 0.28^{w}	5.02 ± 0.28^{w}	4.04 ± 0.29	3.95 ± 0.28	4.30 ± 0.29
Moisture %[e]	74.43 ± 0.27^{w}	71.92 ± 0.26^{x}	71.69 ± 0.27^{x}	72.69 ± 0.27	72.76 ± 0.26	72.60 ± 0.28
Shear, lb	10.32 ± 0.48	11.44 ± 0.22	11.33 ± 0.22	11.33 ± 0.23	11.13 ± 0.22	10.67 ± 0.23

[a] Control = fescue pasture with no supplementation; Fescue = fescue pasture with 1 % BW soyhull supplementation; Orchard = orchardgrass pasture with 1 % BW soyhull supplementation.
[b] LI = large-framed, intermediate-maturing; MI = medium-framed, intermediate-maturing; SI = small-framed, intermediate-maturing.
[c] Cooking loss expressed as percent; calculated as: (Fresh weight – Cooked weight) / Fresh weight x 100.
[d] Lipid percentage calculated as: Lipid weight / Tissue weight x (100 – percent moisture).
[e] Moisture percentage calculated as: (Wet weight – Dry weight) / Wet weight x 100.
[wx] Within treatment or biological type, within a row, means without a common superscript letter differ ($P < 0.05$).

Table 2. Least squares means for individual fatty acids of longissimus muscle by biological type (n = 107).

	Biological type[a]		
Fatty acid[b]	LI	MI	SI
12:0	0.29 ± 0.08	0.36 ± 0.11	0.22 ± 0.11
14:0	1.36 ± 0.08	1.37 ± 0.08	1.22 ± 0.08
14:1*cis-9*	0.79 ± 0.13	0.85 ± 0.18	0.74 ± 0.14
15:0	1.94 ± 0.16	1.94 ± 0.16	1.96 ± 0.16
15:1*cis-9*	0.25 ± 0.02	0.26 ± 0.02	0.28 ± 0.02
16:0	24.33 ± 0.34	24.10 ± 0.33	24.15 ± 0.34
16:1*cis-9*	3.07 ± 0.09[w]	3.03 ± 0.09[w]	2.76 ± 0.09[x]
16:1*trans-9*	0.82 ± 0.04	0.79 ± 0.04	0.73 ± 0.04
17:0	1.74 ± 0.16	1.85 ± 0.15	2.00 ± 0.16
17:1*cis-9*	0.95 ± 0.03	0.94 ± 0.03	0.89 ± 0.03
18:0	13.16 ± 0.24	13.01 ± 0.23	13.45 ± 0.24
18:1[c]	33.35 ± 0.49	33.52 ± 0.48	33.70 ± 0.50
18:2*cis*-9,12	6.83 ± 0.31	6.90 ± 0.30	6.72 ± 0.31
18:2*cis*-9, *trans*-11 (CLA)	0.70 ± 0.02[w]	0.70 ± 0.02[w]	0.62 ± 0.02[x]
18:3*cis*-6,9,12	0.05 ± 0.01	0.05 ± 0.01	0.05 ± 0.01
18:3*cis*-9,12,15	1.47 ± 0.08	1.54 ± 0.08	1.56 ± 0.09
20:4*cis*-5,8,11,14	2.81 ± 0.15	2.92 ± 0.15	2.97 ± 0.16
20:5*cis*-5,8,11,14,17	0.69 ± 0.04	0.70 ± 0.04	0.77 ± 0.04
22:0	0.94 ± 0.07	0.80 ± 0.07	0.82 ± 0.07
22:5*cis*-7,10,13,16,19	1.06 ± 0.06	1.09 ± 0.06	1.18 ± 0.06
22:6*cis*-4,7,10,13,16,19	0.10 ± 0.01	0.11 ± 0.01	0.12 ± 0.01
PUFA	12.42 ± 0.48	12.53 ± 0.48	13.10 ± 0.49
SFA	42.64 ± 0.36	43.26 ± 0.36	43.52 ± 0.36
PUFA /SFA	0.29 ± 0.01	0.29 ± 0.01	0.30 ± 0.01
n-3	3.20 ± 0.14	3.24 ± 0.14	3.48 ± 0.15
n-6	8.41 ± 0.40	8.48 ± 0.40	8.93 ± 0.41
n-6 / n-3	2.80 ± 0.12	2.82 ± 0.12	2.87 ± 0.13

[a] LI = large framed, intermediate maturing; MI = medium framed, medium intermediate; SI = small framed, intermediate maturing.

[b] Fatty acid percents expressed as proportion of all peaks observed by GLC
PUFA = Fatty acids with 2 or more double bonds;
SFA = Fatty acids with no double bonds;
n-3 = 18:3*cis*- 9,12,15; 20:5*cis*-5,8,11,14,17; 22:5*cis*-7,10,13,16,19; 22:6*cis*-4,7,10,13,16,19;
n-6 = 18:2*cis*-9,12, 18:3*cis*-6,9,12, 20:4*cis*-5,8,11,14.

[c] Includes all *cis*- and *trans*- isomers.

[wx] Within treatment or biological type, within a row, means without a common superscript letter differ ($P < 0.05$).

Table 3. Least squares means for individual fatty acids of longissimus muscle by treatment (n = 107).

	Treatment[a]		
Fatty acid[b]	Control	Fescue	Orchard
12:0	0.29 ± 0.10	0.32 ± 0.10	0.25 ± 0.11
14:0	1.20 ± 0.07	1.42 ± 0.08	1.33 ± 0.08
14:1*cis-9*	0.52 ± 0.18	1.00 ± 0.18	0.85 ± 0.18
15:0	2.56 ± 0.24^{w}	1.44 ± 0.24^{x}	1.84 ± 0.24^{x}
15:1*cis-9*	0.33 ± 0.02^{w}	0.18 ± 0.02^{x}	0.28 ± 0.02^{w}
16:0	22.77 ± 0.38^{x}	25.29 ± 0.38^{w}	24.53 ± 0.38^{w}
16:1*cis-9*	2.77 ± 0.09^{x}	3.13 ± 0.09^{w}	2.96 ± 0.09^{wx}
16:1*trans-9*	0.94 ± 0.05^{w}	0.68 ± 0.04^{x}	0.71 ± 0.05^{x}
17:0	1.97 ± 0.16^{wx}	1.52 ± 0.15^{x}	2.11 ± 0.16^{w}
17:1*cis-9*	1.00 ± 0.03^{w}	0.92 ± 0.03^{wx}	0.84 ± 0.03^{x}
18:0	13.65 ± 0.23	13.02 ± 0.23	12.96 ± 0.24
18:1[c]	30.99 ± 0.56^{x}	34.98 ± 0.56^{w}	34.60 ± 0.57^{w}
18:2*cis*-9,12	7.18 ± 0.32	6.47 ± 0.32	6.81 ± 0.32
18:2*cis*-9, *trans*-11 (CLA)	0.69 ± 0.02	0.70 ± 0.02	0.63 ± 0.02
18:3*cis*-6,9,12	0.04 ± 0.01	0.06 ± 0.01	0.05 ± 0.01
18:3*cis*-9,12,15	2.12 ± 0.09^{w}	1.28 ± 0.09^{x}	1.18 ± 0.09^{x}
20:4*cis*-5,8,11,14	3.55 ± 0.15^{w}	2.54 ± 0.15^{x}	2.61 ± 0.15^{x}
20:5*cis*-5,8,11,14,17	1.26 ± 0.04^{w}	0.38 ± 0.04^{x}	0.51 ± 0.04^{x}
22:0	1.00 ± 0.08	0.70 ± 0.08	0.85 ± 0.08
22:5*cis*-7,10,13,16,19	1.52 ± 0.06^{w}	0.80 ± 0.06^{x}	1.02 ± 0.06^{y}
22:6*cis*-4,7,10,13,16,19	0.15 ± 0.01^{w}	0.08 ± 0.01^{x}	0.09 ± 0.01^{x}
PUFA	15.05 ± 0.48^{w}	10.02 ± 0.48^{x}	12.98 ± 0.48^{y}
SFA	43.08 ± 0.36	43.40 ± 0.35	42.95 ± 0.36
PUFA /SFA	0.35 ± 0.01^{w}	0.23 ± 0.01^{x}	0.30 ± 0.01^{y}
n-3	4.87 ± 0.14^{w}	2.21 ± 0.14^{x}	2.84 ± 0.14^{y}
n-6	9.36 ± 0.40^{w}	7.03 ± 0.40^{x}	9.43 ± 0.41^{w}
n-6 / n-3	1.93 ± 0.13^{x}	3.19 ± 0.13^{w}	3.36 ± 0.13^{w}

[a] Control = fescue pasture with no supplementation; Fescue = fescue pasture with 1 % BW soyhull supplementation; Orchard = orchardgrass pasture with 1 % BW soyhull supplementation.

[b] Fatty acid percents expressed as proportion of all peaks observed by GLC
PUFA = Fatty acids with 2 or more double bonds;
SFA = Fatty acids with no double bonds;
n-3 = 18:3*cis*- 9,12,15; 20:5*cis*-5,8,11,14,17; 22:5*cis*-7,10,13,16,19; 22:6*cis*-4,7,10,13,16,19
n-6 = 18:2*cis*-9,12, 18:3*cis*-6,9,12, 20:4*cis*-5,8,11,14.

[c] Includes all *cis*- and *trans*- isomers.

[wxy] Within treatment or biological type, within a row, means without a common superscript letter differ ($P < 0.05$).

Interactive Effects of Ractopamine and Dietary Fat Source on Quality Characteristics of Fresh Pork Loins and Bellies

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Story in Brief

Crossbred pigs (n = 216) were used to test the interactive effects, if any, of ractopamine (RAC) and dietary fat source on quality characteristics of fresh pork loins and bellies. After receiving a common diet devoid of RAC for 1 wk, pens (six pigs/pen) were assigned randomly to one of four treatments arranged in a 2 x 2 factorial design with 5% fat (beef tallow or soy oil) and RAC (0 or 10 ppm). The longissimus muscle (LM) from pigs fed RAC received higher American (P = 0.010) and Japanese (P = 0.041) color scores, and was less red (P = 0.002) and yellow (P = 0.005) than the LM from pigs fed diets devoid of RAC. Moreover, pigs fed RAC and tallow had higher marbling scores than all other treatment combinations (RAC x fat source; P < 0.040). Neither subjective (bar-suspension) nor objective (compression test) measurements of belly firmness were affected by RAC; however, bellies from pigs fed soy oil were softer (P < 0.013) than bellies of pigs fed tallow. Additionally, RAC did not affect (P > 0.11) fat or lean color of bellies, but pigs fed tallow had lighter (P = 0.036) and redder (P = 0.023) belly fat than soy oil fed pigs. Results indicate that feeding pigs 10 ppm RAC improved quality characteristics of the longissimus muscle (LM), but did not affect fresh belly quality; conversely, dietary fat source had little to no impact on fresh loin quality, but, as expected, markedly affected the firmness of fresh pork bellies.

Introduction

Soft pork fat and bellies are an economical concern to today's pork processors, resulting in carcass handling and fabrication difficulties, reduced bacon yields, unattractive products, reduced shelf-life, and discrimination by importers of U.S. pork. The increase in the incidence of soft fat in the U.S. has resulted from the adoption of leaner genetics and increased use of polyunsaturated fat sources (i.e., poultry fat, restaurant grease, etc.) as more cost effective energy sources. More importantly, it is apparent that pork fat becomes softer as carcasses become leaner.

Dietary inclusion of ractopamine hydrochloride (RAC; Elanco Animal Health, Greenfield, Ind.) in swine finishing diets has repeatedly been shown to improve growth rate and carcass lean meat yields without detrimental effects on longissimus muscle (LM) quality. Even though Jeremiah et al. (1994) and Stites et al. (1991) demonstrated that RAC did not affect fresh belly thickness or cooking properties, palatability or consumer acceptance of bacon, some pork processors are concerned about belly quality because RAC has been shown to increase polyunsaturation of pork fat (Perkins et al., 1992). Therefore, the objective of the present study was to determine the interactive effects, if any, of RAC and dietary fat source on quality characteristics of fresh pork loins and bellies.

Experimental Procedures

Crossbred barrows and gilts (n = 216) from the mating of line 348 sows to EB boars (Monsanto Choice Genetics, St. Louis, Mo.) were blocked by weight (24 pigs/block) and allotted randomly to pens within blocks (six pigs/pen). After a one-week adjustment period when all pigs were fed a common finishing diet (devoid of ractopamine), pens within blocks were assigned randomly to one of four dietary treatments arranged in a 2 x 2 factorial design, with two ractopamine (RAC) levels (0 or 10 ppm) and 5% fat from two sources (beef tallow or soy oil). For more details concerning diet composition, feeding protocols, and swine housing, please refer to Apple et al. (2004).

At completion of the finishing period, pigs were transported to a commercial pork packing plant (Bryan Foods, West Point, Miss.), and slaughtered according to industry-accepted procedures. After a standard, 24-h spray-chilling period, carcasses were fabricated, and fresh pork bellies and bone-in loins were collected, wrapped in parchment paper, boxed, and transported under refrigeration to the University of Arkansas Red Meat Research Abattoir for pork quality data collection.

Upon arrival, loins were fabricated into three 1.0-in and two 1.5-in thick loin chops. After a 30-min bloom period, two 1.0-in chops were visually evaluated for marbling (1 = devoid to 10 = abundant; NPPC, 1999) and color based on both the American (1 = pale, pinkish gray to 6 = dark purplish-red; NPPC, 1999) and Japanese (1 = pale gray to 6 = dark purple; Nakai et al., 1975) standards. Also, L*, a*, and b* values were determined from a mean of four random readings (two readings for each chop) made with a Hunter MiniScan XE using illuminate C and a 10° standard observer.

The two 1.5-in thick LM chops were used to measure drip loss according to a modified suspension procedure of Honikel et al. (1986). Additionally, a 2-g sample of LM 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.

Subjective belly firmness was measured using the bar-suspension method by measuring the distance between belly ends when the length of the belly was suspended perpendicular (skin-side down and skin-side up) and parallel (skin-side up) to a 0.75-in diameter bar. Additionally, color (L*, a*, and b* values) of the *rectus abdominus* and belly fat was measured, and two 2.0-in diameter cores were removed from the center of each belly to objectively measure belly firmness. Briefly, belly cores were compressed 50% their thickness

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with an Instron testing machine equipped with an 880-lb load cell and a crosshead speed of 100 mm/min.

Data were analyzed as a randomized complete block design with treatments arranged in a 2 x 2 factorial design, with individual loin or individual belly as the experimental unit. Analysis of variance was generated using the GLM procedure of SAS (SAS Inst., Inc., Cary, N.C.) with RAC level (0 vs 10 ppm), dietary fat source (beef tallow vs soy oil), and the RAC x fat source interaction included in the model as main effects. Least-squares means were computed and separated statistically using pair-wise t-tests (PDIFF option) when a significant F-test ($P < 0.10$) was observed.

Results and Discussion

Fresh loins. The 48-h pH of the LM was elevated ($P = 0.011$) in loins from pigs fed RAC (Table 1). Including 10 ppm RAC in the diet of finishing pigs resulted in loin chops receiving higher American ($P = 0.010$) and Japanese ($P = 0.041$) color scores than chops from pigs fed 0 ppm RAC. Additionally, LM chops from non-RAC-fed pigs were redder (higher a* value; $P = 0.002$) and more yellow (higher b* value; $P = 0.005$) than those from RAC-fed pigs.

Several researchers have demonstrated that including RAC in swine finishing diets has no appreciable effect on pork quality traits. Stoller et al. (2003) reported that L* values were not affected by RAC inclusion in swine diets, and Uttaro et al. (1993) demonstrated that pork from pigs fed diets devoid of RAC was redder and more yellow than pork from RAC -fed pigs. Conversely, Watkins et al. (1990) found that pork color was actually improved over controls when 10 to 20 ppm RAC was included in the finishing diet.

Interestingly, the LM of pigs fed diets containing RAC and beef tallow received higher ($P < 0.05$) marbling scores than all other treatment combinations (RAC x dietary fat source; $P = 0.040$; Figure 1). Uttaro et al. (1993) reported that intramuscular fat content was reduced by the addition of RAC in the diet, whereas several other researchers have observed no effect of RAC on marbling scores (Stoller et al., 2003). However, results of the present study align closely to results of Watkins et al. (1990), who reported that the LM from RAC-fed pigs received higher marbling scores than pork from control pigs.

Ultimate (48-h) pH tended to be higher ($P = 0.089$) in the LM of pigs fed soy oil than beef tallow, and chops from pigs fed soy oil received higher ($P = 0.048$) American color scores (Table 1). Additionally, LM chops from pigs fed soy oil tended to be darker (lower L* value; $P = 0.064$) than chops from tallow-fed pigs; however, dietary fat source did not affect drip loss percentage ($P = 0.761$), Japanese color scores ($P = 0.189$) or a* ($P = 0.679$) or b* ($P = 0.105$) values. In general, results of the present study are in agreement with those of Engel et al. (2001), who failed to observe an effect of dietary fat source on color, marbling, and water-holding capacity of fresh loin chops. However, Miller et al. (1990) reported that feeding canola oil to finishing pigs resulted in softer loins with significantly less marbling.

Fresh pork bellies. Belly thickness was not affected by RAC ($P = 0.116$) or dietary fat source ($P = 0.372$; Table 2). Even though there was a tendency for bellies from RAC-fed pigs to be softer ($P = 0.068$) when suspended skin-side down, belly firmness was not affected by RAC when measured skin-side up ($P = 0.583$) or lengthwise ($P = 0.476$). Moreover, compression values were similar ($P = 0.608$) between bellies from pigs fed 0 or 10 ppm RAC. On the other hand, subjective measures of belly firmness were greater ($P < 0.003$) for bellies from pigs fed beef tallow than soy oil. In support of the subjective firmness measures, bellies from tallow-fed pigs required over 20 lb more force to compress 50% their thickness than bellies from soy oil-fed pigs.

Neither RAC nor dietary fat source affected L* ($P = 0.573$ and 0.364, respectively), a* ($P = 0.114$ and 0.607, respectively), and b* ($P = 0.801$ and 0.471, respectively) values of the *rectus abdominus* (Table 2). Moreover, there was no effect of RAC on L* ($P = 0.755$), a* ($P = 0.768$), and b* ($P = 0.956$) values for belly fat. However, bellies from pigs fed beef tallow were lighter (higher L* values; $P = 0.036$) and redder (higher a* values; $P = 0.023$) than bellies from pigs fed soy oil; yellowness (b*) values were similar ($P = 0.334$) between bellies from soy oil and tallow fed pigs.

Results are consistent with previous research showing that RAC did not affect fresh belly thickness or firmness (Stites et al., 1991). Miller et al. (1990) found that feeding unsaturated fats resulted in softer bellies, which were unacceptable for bacon production. However, when comparing poultry fat (a more polyunsaturated fat source) and choice white grease (a more saturated fat source) in swine diets, Engel et al. (2001) reported that dietary fat source did not affect bar-suspension belly firmness, belly compression values, or L*, a*, and b* values of belly lean and fat.

Implications

Results of the present study indicate that quality characteristics (i.e., marbling and visually-evaluated color) of fresh pork loins may actually be improved by feeding 10 ppm ractopamine, whereas dietary fat source had little to no effect on pork loin quality. Conversely, ractopamine did not alter belly firmness; however, feeding swine diets with 5% soy oil caused fresh bellies to become considerably softer, which may render bellies unacceptable for bacon production.

Acknowledgments

The authors wish to express their appreciation to Elanco Animal Health, a division of Eli Lilly and Company, for financial support of this experiment, and Darling International for donation of beef tallow. Additionally, the authors gratefully acknowledge the assistance of Jerry Stephenson and the staff at the University of Arkansas Red Meat Research Abattoir for assistance in loin and belly quality data collection.

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Table 1. Main effects of ractopamine and dietary fat source on fresh loin (longissimus muscle; LM) quality.

	Ractopamine			Fat source			
Trait	0 ppm	10 ppm	*P-value*	Soy oil	Tallow	*P-value*	SEM
48-h pH	5.81	5.87	0.011	5.86	5.82	0.089	0.018
Drip loss, %	2.69	2.50	0.384	2.56	2.63	0.761	0.160
American color[a]	3.3	3.6	0.010	3.6	3.4	0.048	0.07
Japanese color[b]	3.0	3.3	0.041	3.2	3.1	0.189	0.07
Lightness (L*)[c]	53.40	52.68	0.200	52.52	53.56	0.064	0.403
Redness (a*)[c]	6.64	6.04	0.002	66.30	6.38	0.679	0.136
Yellowness (b*)[c]	13.90	13.32	0.005	13.44	13.77	0.105	0.146

[a] 1 = pale pinkish gray to 6 = dark purplish red (NPPC, 1999).
[b] 1 = pale gray to 6 = dark purple (Nakai et al., 1975).
[c] 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 a more intense yellow color).

Table 2. Main effects of ractopamine and dietary fat source on fresh pork belly quality.

	Ractopamine			Fat source			
Trait	0 ppm	10 ppm	*P-value*	Soy oil	Tallow	*P-value*	SEM
Thickness, in	1.02	1.05	0.116	1.04	1.02	0.374	0.015
Firmness, in[a]							
Skin-side down	5.73	4.93	0.068	4.59	6.06	0.001	0.311
Skin-side up	7.67	7.44	0.583	6.92	8.19	0.003	0.294
Parallel	7.14	6.86	0.476	6.31	7.68	<0.001	0.257
Average	6.85	6.39	0.211	5.94	7.29	<0.001	0.243
Compression, lb	107.2	102.9	0.608	94.6	115.4	0.013	5.84
Lean color							
Lightness (L*)[b]	45.11	44.87	0.573	44.80	45.18	0.364	0.310
Redness (a*)[b]	12.58	12.20	0.114	12.33	12.45	0.607	0.174
Yellowness (b*)[b]	12.52	12.59	0.801	12.45	12.65	0.471	0.198
Fat color							
Lightness (L*)[b]	80.71	80.78	0.755	80.53	80.96	0.036	0.150
Redness (a*)[b]	3.58	3.54	0.768	3.40	3.72	0.023	0.100
Yellowness (b*)[b]	12.40	12.41	0.956	12.49	12.49	0.334	0.131

[a] Bar-suspension method that measures the distance between belly ends when bellies are suspended across a 0.75-in diameter bar (larger number indicates a firmer belly).
[b] 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 a more intense yellow color).

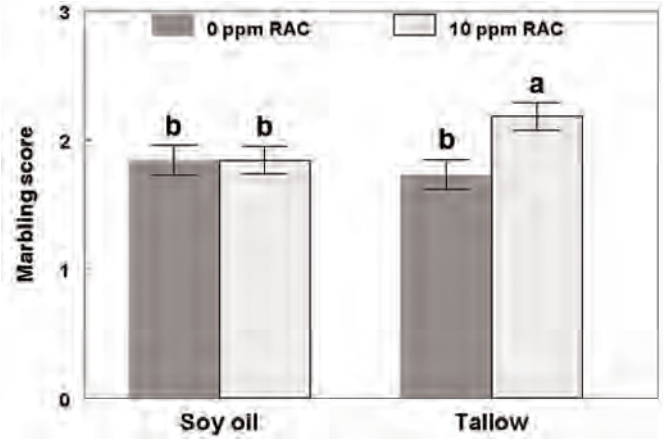

Fig. 1. Interactive effect of ractopamine (RAC) and dietary fat source (P = 0.040) on marbling scores (1 = devoid to 10 = abundant; NPPC, 1999) of fresh loins. Bars lacking a common superscript letter differ (P < 0.05).

Interactive Effects of Ractopamine and Dietary Fat Source on Performance and Carcass Traits of Finishing Swine

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Story In Brief

Crossbred pigs (n = 216) were used to test the interactive effect, if any, of ractopamine (RAC) and dietary fat source on the performance and carcass traits of finishing swine. Pigs were blocked by BW and allotted randomly to pens (six pigs/pen), and, after receiving a common diet devoid of RAC for 1 wk, pens within blocks were assigned randomly to one of four treatments arranged in a 2 x 2 factorial design with 5% fat (beef tallow or soy oil) and RAC (0 or 10 ppm). Individual pig weights and feed disappearance were recorded weekly to calculate ADG, ADFI, and feed-to-gain ratio (F:G). At the conclusion of the 35-d feeding period, pigs were slaughtered at a commercial pork packing plant, and carcass weight, 10th rib fat and longissimus muscle (LM) depths, and fat-free lean yield (FFLY) were recorded prior to chilling. Across the entire feeding trial, ADG was increased ($P < 0.001$), and F:G was decreased ($P < 0.001$), by feeding RAC; yet, dietary fat source did not affect ($P > 0.10$) pig performance. Carcass weight, LM depth, and FFLY were increased ($P < 0.002$), whereas fat depth was decreased ($P < 0.06$), in carcasses from RAC-fed pigs. Conversely, carcass composition measures were similar ($P > 0.10$) between pigs fed tallow or soy oil. Results indicate that feeding 10 ppm RAC will improve the rate and efficiency of gain and carcass leanness; however, dietary fat source had no impact on pig performance or carcass composition.

Introduction

It has been repeatedly shown that including ractopamine hydrochloride (RAC; Elanco Animal Health, Greenfield, Ind.) in swine finishing diets results in improved growth rates. In a summary of six research trials, Watkins et al. (1990) reported that feeding RAC improved ADG, regardless of dietary concentration, and Jones et al. (2000), summarizing results of 20 trials, also demonstrated that dietary inclusion of RAC increased ADG over untreated controls.

It is evident that increasing dietary energy improves feed efficiency in non-RAC-fed pigs. Moreover, research has shown that increasing energy density of swine finishing diets containing RAC resulted in improved feed efficiency (Dunshea et al., 1998). Yet, in the aforementioned study, a single fat source was used to elevate dietary energy density, and little information is available comparing different fat sources in diets also including RAC. Therefore, the objective of this study was to determine the interactive effects, if any, of RAC and dietary fat source on the performance and pork carcass composition of finishing pigs.

Experimental Procedures

Crossbred barrows and gilts (n = 216) from the mating of line 348 sows to EB boars (Monsanto Choice Genetics, St. Louis, MO) were blocked by weight (171.8 ± 14.3 lb) into nine blocks (24 pigs/block) and allotted randomly to pens within blocks (six pigs/pen). After a 1-wk adjustment period when all pigs were fed a common finishing diet (devoid of ractopamine), pens within blocks were assigned randomly to one of four dietary treatments arranged in a 2 x 2 factorial design, with two ractopamine (RAC) levels (0 or 10 ppm) and 5% fat from two sources (beef tallow or soy oil). Soy oil and beef tallow diets contained 1.63 and 1.61 Mcal/lb of metabolizable energy (ME), respectively; however, level was adjusted to keep the lysine-to-energy ratio (3.1 g lysine/Mcal of ME) constant for the two fat sources (Table 1). All diets met, or exceeded, NRC (1998) requirements for 175 to 240 lb pigs. Pigs were housed in a curtain-sided building with slatted floors, and each pen was equipped with a single-opening feeder and nipple waterer which allowed ad libitum access to diets and water throughout the trial. Individual pig weights and feed disappearance were recorded at 7-d intervals during the 35-d feeding trial to calculate ADG, ADFI, and feed-to-gain ratio (F:G).

At completion of the finishing period, pigs were transported to a commercial pork packing plant (Bryan Foods, West Point, Miss.), and slaughtered according to industry-accepted procedures. Carcass weight was recorded, and 10th rib fat and longissimus muscle (LM) depths were measured on-line with a Fat-O-Meater® and used to calculate fat-free lean yield (FFLY).

Performance and carcass composition data were analyzed as a randomized complete block design with treatments arranged in a 2 x 2 factorial design, with pen as the experimental unit. Analysis of variance was generated using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC) with the main effects of RAC level (0 vs 10 ppm) and dietary fat source (beef tallow vs soy oil), as well as the RAC x fat source interaction, included in the statistical model. Least-squares means were computed and separated statistically using pair-wise t-tests (PDIFF option) when a significant F-test ($P < 0.10$) was observed.

Results and Discussion

There were no ($P > 0.10$) RAC x dietary fat source interactions for any live pig performance or carcass composition measure; thus, only main effects are reported. Pigs fed RAC had greater ADG during the first ($P < 0.001$) and second ($P = 0.032$) weeks of the feeding trial (Table 2); however, ADG was lower in the second week on trial

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because of an outbreak of viral diarrhea. During the third week of the feeding trial, ADG was dramatically increased, but pigs fed 0 ppm RAC had higher (P = 0.031) ADG than pigs fed 10 ppm RAC because the onset of the diarrhea was later, and persisted longer, in pigs fed the RAC diet. By the fourth week (21 to 28 d), RAC-fed pigs had greater (P = 0.012) ADG than pigs fed the finishing diet devoid of RAC. Although ADG was not affected (P = 0.862) by RAC during the last week on feed, feeding RAC to finishing pigs improved (P < 0.001) growth rate by 0.21 lb/d across the entire 35-d feeding trial. Conversely, dietary fat source did not affect weekly ADG (P > 0.35) or overall ADG (P = 0.111).

Results of the present study confirm previously published results indicating that ADG is improved by including RAC in swine finishing diets (Watkins et al., 1990; Jones et al., 2000). Moreover, several studies have demonstrated that dietary fat source, when included in diets at similar levels, had no appreciable effects on growth rate of finishing pigs (Engel et al., 2001; Leszczynski et al., 1992; McDonald and Hamilton, 1976).

Even though pigs fed RAC tended to consume less (P = 0.086) feed during the last week on feed, ADFI was not (P = 0.318) affected by RAC during the first 28 d or across the entire feeding period (Table 2). Yet, RAC-fed pigs were more efficient during the first (P < 0.001) and fourth (P = 0.067) weeks of the feeding trial, as well as over the entire 35-d feeding period (P < 0.001). Even though there was a numerical advantage in F:G during the second week in pigs consuming the RAC-diet, the numbers were exaggerated because of the outbreak in viral diarrhea. Moreover, as previously mentioned, pigs fed 0 ppm RAC were more efficient (P = 0.023) during the third week (14 to 21 d) because they responded to treatment quicker than pigs fed 10 ppm RAC.

Previous research has failed to consistently show an effect of feeding RAC on feed intake (Watkins et al., 1990; Jones et al., 2000), which is in agreement with results of the present study. On the other hand, the dramatic improvements in growth rate observed with RAC, coupled with little to no change in feed intake, resulted in improved feed efficiency. Even though Dunshea et al. (1998) reported that increasing energy density of swine finishing diets containing RAC resulted in improved feed efficiency, there was no interactive effect of energy density and RAC on feed efficiency.

There was a trend for pigs fed soy oil to have lower (P = 0.071) ADFI than pigs fed beef tallow during the third week on feed; however, ADFI was similar between pigs fed soy oil or tallow during the first and last two weeks on feed (P > 0.28) and over the entire 35-d feeding period (P = 0.550; Table 2). It is evident that increasing the energy density of swine diets improves feed efficiency, even though dietary energy level may or may not affect ADFI (Southern et al., 1989). Conversely, results of the current study are consistent with results of McDonald and Hamilton (1976) and Leszczynski et al. (1992), who failed to detect differences in ADFI and F:G between pigs fed different fat sources.

Pigs fed RAC were heavier (P < 0.022) at each weigh period (except on d 0; P = 0.552) than pigs fed 0 ppm RAC, but pig weights were not (P > 0.24) affected by dietary fat source (Table 2). Moreover, inclusion of RAC in swine finishing diets resulted in heavier (P < 0.001) carcasses, greater (P < 0.001) LM depths, and reduced (P = 0.056) fat depths, which resulted in a higher (P = 0.014) FFLY (Table 3). However, carcass weight and measures of fatness and muscling were similar (P > 0.18) between pigs fed soy oil or tallow.

These results confirm the consensus of published results that including RAC in swine finishing diets increases carcass leanness and muscling. It is generally accepted that RAC has the ability to repartition dietary nutrient intake towards increased protein synthesis and muscle accretion, while simultaneously stimulating lipolysis and inhibiting lipogenesis.

It is widely accepted that pork carcass fatness increases in response to elevating dietary energy density or energy intake, with little to no change in carcass muscling. However, neither fat depth, LM area nor percent muscle was different between pigs fed choice white grease or poultry fat (Engel et al., 2001), full-fat soybeans or beef tallow (Leszczynski et al., 1992), and rapeseed oil or beef tallow (McDonald & Hamilton, 1976).

Implications

Results of the present study indicate that including ractopamine in the diets of finishing swine increases the rate and efficiency of growth, as well as improves pork carcass leanness. Moreover, the improvements in pig performance and carcass leanness associated with ractopamine were independent of the dietary fat source.

Acknowledgements

The authors wish to express their appreciation to Elanco Animal Health, a division of Eli Lilly and Company, for financial support of this experiment, and Darling International for donation of beef tallow. Additionally, the authors gratefully acknowledge the assistance of Ashley Hays and the staff at the University of Arkansas Swine Research Farm for animal care and assistance in performance data collection.

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Table 1. Composition of experimental diets (on an as-fed basis).

	0 ppm ractopamine		10 ppm ractopamine	
Ingredient, %	Soy oil	Tallow	Soy oil	Tallow
Corn	65.795	65.825	65.745	65.775
Soybean meal, 48%	27.00	27.00	27.00	27.00
Beef tallow	0.00	5.00	0.00	5.00
Soy oil	5.00	0.00	5.00	0.00
Paylean™ 9[a]	0.00	0.00	0.05	0.05
Calcium carbonate	0.50	0.50	0.50	0.50
Salt	0.50	0.50	0.50	0.50
Tylan 40	0.05	0.05	0.05	0.05
Dicalcium phosphate	0.65	0.65	0.65	0.65
Vitamin premix[b]	0.125	0.125	0.125	0.125
Mineral premix[c]	0.10	0.10	0.10	0.10
Ethoxyquin	0.03	0.03	0.03	0.03
Lysine	0.17	0.15	0.17	0.15
Methionine	0.04	0.04	0.04	0.04
Threonine	0.04	0.03	0.04	0.03
Total composition, %				
Crude protein	18.49	18.47	18.49	18.47
Lysine	1.10	1.12	1.10	1.12
Methionine	0.33	0.33	0.33	0.33
Methionine & cysteine	0.65	0.65	0.65	0.65
Threonine	0.73	0.72	0.73	0.72
Tryptophan	0.21	0.21	0.21	0.21
Calcium	0.45	0.45	0.45	0.45
Phosphorus	0.49	0.49	0.49	0.49
ME, Mcal/kg	3.59	3.55	3.59	3.55

[a] Ractopamine hydrochloride (Elanco Animal Health, a division of Eli Lilly and Company, Greenfield, Ind.).

[b] Premix consisted of 909,091 IU vitamin A, 136,364 IU vitamin D, 3,636 IU vitamin E, 3.6 mg vitamin B_{12}, 364 mg vitamin K, 818 mg riboflavin, 2,727 mg d-pantothenic acid, and 4,546 mg niacin per kg (NB-6157B; Nutra Blend Corp., Neosho, Mo.).

[c] Premix consisted of 11.0% iron, 11.0% Zn, 2.6% Manganese, 1.1% Copper, 0.02% iodine, and 0.02% selenium (NB-8557B; Nutra Blend Corp., Neosho, Mo.).

Table 2. Main effects of ractopamine and dietary fat source on live pig performance.

	Ractopamine			Fat source			
Trait[a]	0 ppm	10 ppm	*P-value*	Soy oil	Tallow	*P-value*	SEM
ADG, lb							
0 to 7 d	1.33	1.70	<0.001	1.51	1.52	0.883	0.058
7 to 14 d	0.52	1.08	0.032	0.68	0.92	0.357	0.173
14 to 21 d	2.65	2.25	0.031	2.40	2.49	0.605	0.123
21 to 28 d	1.32	1.84	0.012	1.62	1.54	0.662	0.137
28 to 35 d	2.44	2.41	0.862	2.37	2.48	0.566	0.130
0 to 35 d	1.65	1.86	<0.001	1.72	1.79	0.111	0.030
ADFI, lb							
0 to 7 d	3.98	3.95	0.835	3.99	3.94	0.690	0.085
7 to 14 d	2.99	3.17	0.404	3.05	3.10	0.806	0.150
14 to 21 d	4.98	5.09	0.385	4.92	5.15	0.071	0.083
21 to 28 d	5.15	4.95	0.318	5.11	4.99	0.525	0.139
28 to 35 d	5.48	5.24	0.086	5.29	5.44	0.286	0.097
0 to 35 d	4.51	4.48	0.652	4.47	4.52	0.550	0.059
F:G[b]							
0 to 7 d	3.12	2.42	<0.001	2.83	2.71	0.461	0.166
7 to 14 d	10.57	4.18	0.139	6.60	8.16	0.711	2.941
14 to 21 d	1.95	2.38	0.023	2.21	2.12	0.632	0.117
21 to 28 d	3.68	2.89	0.067	2.94	3.63	0.106	0.292
28 to 35 d	2.35	2.25	0.576	2.33	2.26	0.681	0.104
0 to 35 d	2.68	2.43	<0.001	2.57	2.54	0.500	0.031
Weights, lb							
0 d	177.8	178.2	0.552	178.2	177.8	0.524	0.39
7 d	187.1	190.1	0.002	188.7	188.5	0.758	0.61
14 d	190.7	197.6	0.002	193.5	194.9	0.509	1.42
21 d	209.3	213.4	0.022	210.3	212.3	0.245	1.17
28 d	218.5	226.3	<0.001	221.7	223.1	0.504	1.43
35 d	235.6	243.1	<0.001	238.3	240.4	0.264	1.31

[a] There were no ractopamine x fat source interactions (P > 0.10) for any performance trait.
[b] Feed-to-gain ratio.

Table 3. Main effects of ractopamine and dietary fat source on carcass composition measures.

	Ractopamine			Fat source			
Trait[a]	0 ppm	10 ppm	*P-value*	Soy oil	Tallow	*P-value*	SEM
Carcass wt, lb	177.5	184.7	<0.001	180.2	181.9	0.186	0.97
Fat depth, in	0.72	0.67	0.056	0.70	0.70	0.973	0.018
LM depth, in	2.1	2.3	<0.001	2.2	2.2	0.986	0.03
FFLY, %[b]	51.4	52.6	0.014	52.0	52.0	0.952	0.34

[a] There were no ractopamine x fat source interactions for any performance trait.
[b] Fat-free lean yield = ((15.3098 – (31.2796 x fat depth, in) + (3.8132 x LM depth, in) + (0.5096 x carcass wt, lb)) ÷ carcass wt, lb) x 100.

Effects of Supplemental Manganese on the Performance and Pork Carcass Composition of Growing-Finishing Swine

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Story in Brief

To investigate the effects of manganese (Mn) on live animal performance and pork quality, crossbred pigs (n = 168) were assigned randomly to one of six dietary treatments arranged in a 2 x 3 factorial design with Mn present or absent in the basal diet and 0 or 350 ppm of supplemental Mn from either Mn sulfate ($MnSO_4$) or AvailaMn-80. When the lightest block of pigs averaged 250 lb, pigs were harvested at a commercial pork packing plant. Prior to chilling, hot carcass weight was recorded, and 10th rib fat and longissimus muscle (LM) depths were measured online with an automated probe and used to calculate fat-free lean yield (FFLY). Immediately prior to carcass fabrication, backfat depth opposite the last rib and last lumbar vertebrae was measured. During the grower-II phase, pigs fed basal diets including Mn consumed less feed ($P < 0.02$) and tended to be more efficient ($P < 0.09$) than pigs fed basal diets devoid of Mn. However, across the entire feeding trial, dietary or supplemental Mn did not alter ($P > 0.10$) ADG, ADFI, or F/G. Carcasses from pigs fed basal diets with Mn tended to be heavier ($P = 0.10$) and had deeper ($P < 0.05$) LM than pigs fed basal diets devoid of Mn. Results suggest that increasing dietary Mn levels above maintenance requirements of growing-finishing swine does not beneficially impact live pig performance or carcass composition.

Introduction

Manganese (Mn) is a divalent, transition metal cation that functions as a co-factor of several enzymes crucial for carbohydrate, lipid and protein metabolism; however, the dietary requirements for Mn in swine diets are quite low and not well established. Until recently, little has been known about the effects of supplemental Mn on pork carcass composition or quality. In the first of two studies, Roberts et al. (2001) found that including 350 ppm Mn from either manganese sulfate ($MnSO_4$) or AvailaMn (a Mn amino acid complex) in diets of growing-finishing swine did not affect ADG, ADFI, or F/G. Yet, when lower dietary Mn inclusion levels (0 to 320 ppm) of AvailaMn were included in swine diets, Apple et al. (2003) noted improvements in pig performance, especially feed efficiency, with 40 and 320 ppm supplemental Mn.

In both previous studies, Mn was removed from the vitamin-mineral premix included in the basal diets, and the use of AvailaMn as the sole source of Mn in the diet may not be cost effective. However, if significant improvements in economically important traits (i.e., performance and pork quality) could be achieved by supplementing diets with Mn from AvailaMn above maintenance levels already in the diet, then it could be a cost-effect production practice. Therefore, the objectives of this study were to determine the effect of supplementing two different basal diets (diets devoid of Mn vs diets formulated to meet Mn maintenance requirements) with 0 or 350 ppm Mn from either $MnSO_4$ or AvailaMn (AvMn) on the performance and carcass composition of growing-finishing swine.

Experimental Procedures

Crossbred barrows and gilts (n = 168) from the mating of line 348 sows to EB boars (Monsanto Choice Genetics, St. Louis, Mo.) were blocked by weight and randomly allotted within blocks to pens (six pigs/pen in blocks 1, 2, 5, and 6, whereas there were only four pigs/pen in blocks 3 and 4) at an average weight of 48.8 lb. Within blocks, pens were assigned randomly to one of six dietary treatments arranged in a 2 x 3 factorial design: 1) negative control (NC) starter, grower, and finisher diets devoid of Mn in the basal diet; 2) NC diets supplemented with 350 ppm Mn from manganese sulfate ($MnSO_4$); 3) NC diets supplemented with 350 ppm Mn from AvailaMn-80 (a Mn amino acid complex; Zinpro Corp., Eden Prairie, Minn.); 4) positive control (PC) starter, grower, and finisher diets with Mn included in the basal diet; 5) PC diets supplemented with 350 ppm Mn from $MnSO_4$; or 6) PC supplemented with 350 ppm Mn from AvailaMn-80 (AvMn). Pigs were fed a four-phase diet with transition from the grower-I to grower-II, grower-II to finisher-I, and finisher-I to finisher-II phases occurring when the mean block weight reached 80, 150, and 200 lb, respectively. Diets were formulated to be isonitrogenous and isocaloric (Table 1). Grower-I, grower-II, finisher-I, and finisher-II diets contained 1.16, 0.95, 0.72, and 0.57% lysine, respectively. To achieve supplemental levels of 350 ppm Mn, 0.11 and 0.44% $MnSO_4$ and AvMn were added to diets, respectively, at the expense of cornstarch.

Pigs were housed in a curtain-sided building with slatted floors, and each pen was equipped with a single-opening feeder and nipple waterer, which allowed ad libitum access to diets and water throughout the trial. Individual pig weights and feed disappearance were recorded weekly to calculate ADG, ADFI, and feed-to-gain ratio (F/G).

When the lightest block of pigs averaged 250 lb, all pigs were transported to a commercial pork packing plant (Bryan Foods, Inc., West Point, Miss.), and slaughtered according to industry-accepted procedures. Carcass weight was recorded, and 10th rib fat and longissimus muscle (LM) depths were measured online with a Fat-O-Meater® automated probe. Carcasses were subsequently subjected to a conventional spray-chilling system for 24 h. Prior to carcass fabrication, backfat depth opposite the last rib and last lumbar vertebrae were measured.

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Data were analyzed as a randomized complete block design with treatments arranged in a 2 x 3 factorial design. Analysis of variance was generated using the GLM procedure of SAS (SAS Inst., Inc., Cary, N.C.) with pen as the experimental unit for performance and pork carcass composition data analyses. Dietary treatment was the lone fixed effect in the model for all performance and carcass composition data. Least squares means were computed, and orthogonal contrasts were used to make specific comparisons between the PC and NC diets, Mn sources ($MnSO_4$ vs AvMn), and presence or absence of Mn in the basal diet.

Results and Discussion

Pig performance was not ($P > 0.65$) affected by dietary or supplemental Mn during the grower-I phase (Table 2). Growth rate was not ($P > 0.44$) affected by supplemental Mn; however, during the grower-II phase, pigs fed basal diets including Mn consumed less ($P < 0.02$) feed than pigs fed basal diets devoid of Mn. Additionally, there was a tendency for pigs fed diets including Mn to be more efficient ($P < 0.09$) during the grower-II phase than those fed basal diets devoid of Mn. Even though pig performance was not affected ($P > 0.22$) during the early finishing (finisher-I) phase, pigs fed basal diets containing Mn grew faster (higher ADG; $P = 0.054$) and consumed more ($P < 0.047$) feed than pigs fed basal diets lacking Mn during the late-finishing (finisher II) phase. Moreover, during the finisher II phase, ADFI tended to be decreased ($P < 0.09$) in AvMn-supplemented compared to $MnSO_4$-supplemented pigs. Across the entire growing-finishing period, however, ADG, ADFI, and F/G were not ($P > 0.22$) affected by basal diet Mn level or supplemental Mn source.

Grummer et al. (1950) reported improvements in ADG and F/G in pigs fed supplemental Mn, but neither Plumlee et al. (1956) nor Leibholz et al. (1962) observed an effect of supplemental Mn on ADG or F/G of growing-finishing pigs. In a comparison of supplementation levels of 350 and 700 ppm Mn from either $MnSO_4$ or AvMn, Roberts et al. (2001) did not detect an effect of supplementing swine diets with Mn on pig performance, regardless of level or source. On the other hand, Apple et al. (2003) found that supplementing swine diets with 40 and 320 ppm Mn from AvMn increased ADG and reduced F/G during the grower-II phase, which is consistent with results of the present study. In contrast to current results, however, they reported a trend for F/G to be less in pigs fed diets containing 320 ppm Mn from AvMn.

Neither Mn inclusion in the basal diet nor Mn supplementation altered ($P > 0.14$) backfat depths opposite the last rib, last lumbar vertebrae, or the LM at the 10th rib interface (Table 3). However, carcasses of pigs fed basal diets including Mn tended to be heavier ($P = 0.104$), and had greater ($P < 0.04$) 10^{th} rib LM depths, than carcasses of pigs fed basal diets devoid of Mn. Even though fat-free lean yield (FFLY) estimates were numerical higher in carcasses from pigs fed basal diets with Mn, FFLY estimates were not ($P > 0.24$) affected by dietary or supplemental Mn.

Roberts et al. (2001) found that neither Mn source or supplementation level affected average midline backfat depth or LM area. Moreover, when Mn was included in swine diets, midline backfat depths, 10^{th} rib fat depth, LM depth, and estimated FFLY were similar across the dietary inclusion range of 0 to 320 ppm.

Implications

Results of the present study indicate that supplementing swine diets with manganese above their maintenance requirements has no appreciable impact on pig performance. Moreover, feeding manganese to meet maintenance requirements for growing-finishing swine is sufficient to optimize carcass composition.

Acknowledgments

The authors wish to express their gratitude to Zinpro Corporation, Eden Prairie, Minn., for financial support of this study. Moreover, the authors are appreciative of Ashley Hays and the staff at the University of Arkansas Swine Research Farm for animal care and assistance with performance data collection.

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Table 1. Composition of finisher-II diets (on an as-fed basis).

	Basal diet without Mn[a]			Basal diet with Mn[a]		
Ingredient, %	NC	NC + 350 ppm $MnSO_4$	NC + 350 ppm AvMn	PC	PC + 350 ppm $MnSO_4$	PC + 350 ppm AvMn
Corn	76.905	76.905	76.905	76.905	76.905	76.905
Wheat midds	15.00	15.00	15.00	15.00	15.00	15.00
Soybean meal, 48%	5.55	5.55	5.55	5.55	5.55	5.55
Calcium carbonate	0.90	0.90	0.90	0.90	0.90	0.90
Vitamin premix[b]	0.125	0.125	0.125	0.125	0.125	0.125
Monocalcium phosphate	0.25	0.25	0.25	0.25	0.25	0.25
Corn starch	0.44	0.33	0.00	0.44	0.33	0.00
Mineral premix[c]	0.10	0.10	0.10	0.00	0.00	0.00
Mineral premix[d]	0.00	0.00	0.00	0.10	0.10	0.10
Manganese sulfate	0.00	0.11	0.00	0.00	0.11	0.00
AvailaMn-80	0.00	0.00	0.44	0.00	0.00	0.44
Salt	0.50	0.50	0.50	0.50	0.50	0.50
Lysine	0.15	0.15	0.15	0.15	0.15	0.15
Tylan 40	0.05	0.05	0.05	0.05	0.05	0.05
Ethoxiquin	0.03	0.03	0.03	0.03	0.03	0.03
Calculated composition, %						
Crude protein	11.5	11.5	11.5	11.5	11.5	11.5
Lysine	0.57	0.57	0.57	0.57	0.57	0.57
Threonine	0.40	0.40	0.40	0.40	0.40	0.40
Tryptophan	0.11	0.11	0.11	0.11	0.11	0.11
Methionine and cysteine	0.44	0.44	0.44	0.44	0.44	0.44
Calcium	0.45	0.45	0.45	0.45	0.45	0.45
Total Phosphorus	0.44	0.44	0.44	0.44	0.44	0.44
Crude fat	3.78	3.78	3.78	3.78	3.78	3.78
Manganese, ppm						
Dietary (basal)	50	50	50	76	76	76
Supplemental	0	350	350	0	350	350

[a] NC = negative control (basal diet devoid of manganese (Mn)); $MnSO_4$ = manganese sulfate; PC = positive control; and AvMn = AvailaMn-80.

[b] Supplies 3,000 IU vitamin A, 450 IU vitamin D_3, 11.8 IU vitamin E, 1.2 mg vitamin K, 7.5 mg pantothenic acid, 13.6 mg niacin, 2.25 mg riboflavin, and 10.45 μg vitamin B_{12} per lb of feed.

[c] Supplies 110 ppm iron, 110 ppm zinc, 0.2 ppm selenium, 11 ppm Copper, and 0.2 ppm iodine.

[d] Supplies 26.4 ppm Mn, 110 ppm iron, 110 ppm zinc, 0.2 ppm selenium, 11 ppm copper, and 0.2 ppm iodine.

Table 2. Effect of manganese (Mn) in the basal diet and Mn supplementation on performance of growing-finishing swine.

	Basal diet without Mn[a] (-Mn)			Basal diet with Mn[a] (+Mn)				*P*-value[b]		
	NC	350 ppm $MnSO_4$	350 ppm AvMn	PC	350 ppm $MnSO_4$	350 ppm AvMn	SEM	PC vs NC	$MnSO_4$ vs AvMn	+Mn vs -Mn
Grower-I (48 to 80 lb)										
ADG, lb	1.44	1.38	1.44	1.43	1.45	1.38	0.057	0.846	0.915	0.924
ADFI, lb	2.65	2.56	2.57	2.64	2.61	2.52	0.084	0.949	0.658	0.998
F/G	1.86	1.86	1.79	1.90	1.81	1.86	0.055	0.598	0.847	0.890
Grower-II (80 to 150 lb)										
ADG, lb	2.01	1.89	1.93	1.99	1.89	1.86	0.031	0.590	0.672	0.260
ADFI, lb	4.64	4.57	4.57	4.67	4.30	4.13	0.139	0.883	0.558	0.018
F/G	2.32	2.39	2.37	2.41	2.28	2.22	0.074	0.393	0.561	0.085
Finisher-I (150 to 200 lb)										
ADG, lb	2.51	2.59	2.40	2.50	2.38	2.49	0.075	0.935	0.591	0.410
ADFI, lb	7.39	7.36	7.24	7.57	7.51	7.40	0.178	0.479	0.517	0.393
F/G	3.02	2.95	3.03	3.05	3.16	2.99	0.072	0.793	0.564	0.228
Finisher-II (200 to 250 lb)										
ADG, lb	2.34	2.23	2.25	2.39	2.56	2.37	0.112	0.756	0.440	0.054
ADFI, lb	8.40	8.16	8.15	8.51	9.11	8.23	0.247	0.758	0.083	0.047
F/G	3.60	3.67	3.65	3.56	3.62	3.50	0.119	0.833	0.537	0.392
Overall (48 to 250 lb)										
ADG, lb	2.04	1.98	1.94	2.04	2.02	1.98	0.035	0.937	0.516	0.555
ADFI, lb	5.48	5.38	5.37	5.51	5.53	5.25	0.117	0.861	0.223	0.893
F/G	2.69	2.73	2.72	2.73	2.74	2.65	0.042	0.527	0.230	0.432

[a] NC = negative control (basal diet devoid of Mn); $MnSO_4$ = manganese sulfate; PC = positive control; and AvMn = AvailaMn-80.

[b] Significance of orthogonal contrasts for: positive control (PC) vs. negative control (NC); manganese sulfate ($MnSO_4$) vs. AvailaMn-80 (AvMn); AvailaMn-80 (AvMn); and basal diets containing Mn (+Mn) vs. basal diets absent of Mn (-Mn).

Table 3. Effect of manganese (Mn) in the basal diet and Mn supplementation on carcass composition measures.

	Basal diet without Mn[a] (-Mn)			Basal diet with Mn[a] (+Mn)				*P*-value[b]		
	NC	350 ppm $MnSO_4$	350 ppm AvMn	PC	350 ppm $MnSO_4$	350 ppm AvMn	SEM	PC vs NC	$MnSO_4$ vs AvMn	+Mn vs -Mn
Backfat depth, in										
Last rib	1.09	1.09	1.14	1.04	1.12	1.06	0.056	0.528	0.929	0.142
Last lumbar vertebra	0.93	0.96	1.10	0.98	1.11	1.01	0.059	0.522	0.660	0.445
Carcass wt, lb	188.6	187.1	191.1	194.1	196.3	190.5	4.00	0.295	0.791	0.104
10th rib fat depth, in	0.85	0.79	0.86	0.79	0.87	0.78	0.044	0.310	0.799	0.503
LM depth, in[c]	2.1	2.1	2.0	2.1	2.2	2.1	0.06	0.493	0.170	0.034
FFLY, %[d]	51.4	52.4	51.1	52.6	51.7	52.6	0.69	0.232	0.808	0.248
Marbling[e]	1.8	2.3	2.0	2.2	2.0	1.9	0.15	0.123	0.220	0.918

[a] NC = negative control (basal diet devoid of Mn); $MnSO_4$ = manganese sulfate; PC = positive control; and AvMn = AvailaMn-80.

[b] Significance of orthogonal contrasts for: positive control (PC) vs. negative control (NC); manganese sulfate ($MnSO_4$) vs. AvailaMn-80 (AvMn); and basal diets containing Mn (+Mn) vs. basal diets absent of Mn (-Mn).

[c] 10th rib longissimus muscle depth

[d] Fat-free lean yield = ((15.3098 – (31.2796 x fat depth, in) + (3.8132 x LM depth, in) + (0.5096 x carcass wt, lb)) ÷ carcass wt, lb) x 100.

[e] 1 = devoid to 10 = abundant (NPPC, 1999).

Effects of Supplemental Manganese Source on the Pork Quality During Seven Days of Retail Display

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Story in Brief

Loins from 168 crossbred pigs were used to test the effects of supplemental manganese (Mn) on pork quality during 7 d of retail display. Loins were from pigs assigned randomly to one of six dietary treatments arranged in a 2 x 3 factorial design with Mn present (+Mn) or absent (-Mn) in the basal diet and 0 or 350 ppm of supplemental Mn from either Mn sulfate ($MnSO_4$) or AvailaMn-80 (AvMn). Bone-in loins were collected during fabrication and shipped to Oklahoma State University for quality data collection. Loins were cut into longissimus muscle (LM) chops and placed in a modified atmosphere package (80% O2:20% CO_2) for 7 d of retail display. Chops from pigs fed diets supplemented with $MnSO_4$ received higher ($P < 0.05$) lean color scores, were redder, and more vivid than chops from pigs fed diets supplemented with AvMn. Moreover, chops from pigs fed basal diets +Mn and supplemental $MnSO_4$ received higher ($P < 0.05$) color scores than all other treatment combinations, and were darker ($P < 0.05$) than chops from pigs fed the basal diet -Mn or the basal +Mn and supplemented with AvMn. Discoloration was reduced over the last 3 d of retail display by inclusion of Mn in the basal diets and supplemented with $MnSO_4$. Results suggest that supplementing 350 ppm Mn from $MnSO_4$ to swine diets formulated to meet maintenance Mn requirements improves pork color and reduces discoloration during retail display.

Introduction

Manganese (Mn) is a divalent, transition metal cation that functions as a co-factor of several enzymes crucial for carbohydrate, lipid and protein metabolism; however, the dietary requirements for Mn in swine diets are quite low and not well established, and, until recently, little was known about the effects of supplemental Mn on pork carcass composition or quality. In the first of two studies, Roberts et al. (2002) found that including 350 ppm Mn from AvailaMn (a Mn amino acid complex) in diets of growing-finishing swine improved pork color. However, when lower dietary Mn inclusion levels (0 to 320 ppm) from AvailaMn were included in swine diets, Apple et al. (2003) noted no beneficial effects on pork quality during retail display.

In both previous studies, Mn was removed from the vitamin-mineral premix included in the basal diets. Therefore, the objectives of this study were to determine the effect of supplementing two different basal diets (diets devoid of Mn vs diets formulated to meet Mn maintenance requirements) with 0 or 350 ppm Mn from either Mn sulfate ($MnSO_4$) or AvailaMn (AvMn) on pork quality of growing-finishing swine.

Experimental Procedures

Crossbred barrows and gilts (n = 168) from the mating of line 348 sows to EB boars (Monsanto Choice Genetics, St. Louis, Mo.) were blocked by weight and randomly allotted within blocks to pens (six pigs/pen in blocks 1, 2, 5, and 6, whereas there were only four pigs/pen in blocks 3 and 4) at an average weight of 48.8 lb. Within blocks, pens were assigned randomly to one of six dietary treatments arranged in a 2 x 3 factorial design: 1) negative control starter, grower, and finisher diets devoid of Mn in the basal diet; 2) the negative control diets supplemented with 350 ppm Mn from manganese sulfate ($MnSO_4$); 3) negative control diets supplemented with 350 ppm Mn from AvailaMn-80 (a Mn amino acid complex; Zinpro Corp., Eden Prairie, Minn.); 4) positive control starter, grower, and finisher diets with Mn included in the basal diet; 5) positive control diets supplemented with 350 ppm Mn from $MnSO_4$; or 6) positive control diets supplemented with 350 ppm Mn from AvailaMn-80 (AvMn). For more details concerning feeding regimen, diet composition, and pig housing refer to Apple et al. (2004).

When the lightest block of pigs averaged 250 lb, all pigs were transported to a commercial pork packing plant (Bryan Foods, Inc., West Point, Miss.), and slaughtered according to industry-accepted procedures. After a 24-h spray-chilling period, carcasses were fabricated, and right-side, bone-in pork loins were collected, paper-wrapped, boxed, and transported to the Oklahoma State University Meat Laboratory (Stillwater, Okla.) for pork quality data collection.

Upon arrival, the blade and sirloin ends of each loin were removed, and the remaining center-cut portion of each loin was processed into 1-in thick longissimus muscle (LM) chops, weighed, and allowed to bloom for 15 min. Visual appraisal of color, firmness, and discoloration was evaluated by a five-person trained and experienced panel. Then, chops were packaged in a modified atmosphere (80% O_2:20% CO_2) and displayed in coffin-display cases under constant light (1,600 lx) at 34°F for 7 d. On each day of retail display, chops were visually evaluated for lean color (1 = pale pinkish gray to 6 = dark purplish red; NPPC, 1999), discoloration (1 = total (100%) discoloration to 8 = no (0%) discoloration), and firmness (1 = very soft/very watery to 5 = very firm/very dry; NPPC, 1991) by the trained, experienced panel. Additionally, on d 0 and 7 of display, L*, a*, and b* values were determined from a mean of four readings made with a Minolta Chromameter (Minolta Corp., Ramsey, N.J.) using D65 illuminant. The saturation index, or chroma (C*), was calculated as $C^* = (a^{*2} + b^{*2})^{1/2}$, and is a measure of the total color, or vividness of the color, of the LM.

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On d 0 and 7, thiobarbituric acid reactive substances (TBARS) were analyzed on duplicate samples according to the modified procedure of Witte et al. (1970) to measure the amount of oxidative rancidity. Furthermore, on d 7 of display, chops were removed from their packages and weighed, and the difference between the d 0 and d 7 weights was used to calculate moisture loss percentage.

Data were analyzed as a randomized complete block design with treatments arranged in a 2 x 3 factorial design. Analysis of variance was generated using the mixed model procedure of SAS (SAS Inst., Inc., Cary, N.C.) with individual loin as the experimental unit for pork quality data analyses. Dietary treatment, display day, and the treatment x display day were the fixed effects included in the repeated measures model for pork quality measures. Least squares means were computed, and statistically separated by the PDIFF option of SAS when $P < 0.05$. Additionally, preplanned contrasts were used to make specific comparisons between the positive and negative control diets, Mn sources ($MnSO_4$ vs AvMn), and presence or absence of Mn in the basal diet.

Results and Discussion

The main effects of dietary and supplemental Mn on pork quality traits are presented in Table 1. The LM from pigs fed diets supplemented with 350 ppm Mn from $MnSO_4$ received higher ($P = 0.022$) color scores than chops from pigs consuming diets supplemented with AvMn. Specifically, chops from pigs fed Mn in the basal diet and supplemented with $MnSO_4$ had higher ($P < 0.05$) color scores than all other treatment combinations. The LM of pigs consuming diets with Mn in the basal diet and supplemented with $MnSO_4$ was also darker (lower L* values; $P < 0.05$) than the LM from pigs fed the unsupplemented (NC and PC) diets, as well as from pigs fed basal diets containing Mn and supplemented with AvMn. Additionally, chops of pigs fed $MnSO_4$ were redder (larger a* values; $P = 0.022$) and more vivid ($P = 0.037$) than those of pigs fed AvMn. Neither firmness scores nor b* values were ($P > 0.10$) altered by either dietary or supplemental Mn.

There was a dietary treatment x display day interaction ($P = 0.038$) on discoloration scores (Figure 1). Discoloration scores were similar ($P > 0.10$) during the first 4 d of retail display. However, on d 5 and d 6 of retail display, chops from pigs fed basal diets including Mn and supplemented with $MnSO_4$ were less ($P < 0.05$) discolored than chops from pigs fed basal diets devoid of Mn or basal diets with Mn and supplemented with AvMn. Furthermore, chops from pigs fed Mn-diets supplemented with AvMn were more ($P < 0.05$) discolored on d 6 of display than chops from pigs fed diets lacking Mn and supplemented with either $MnSO_4$ or AvMn, as well as pigs fed basal diets including Mn. By d 7, chops from the pigs fed diets containing Mn and supplemented with $MnSO_4$ were still the least ($P < 0.05$) discolored, whereas chops from pigs fed the basal diet with Mn and supplemented with AvMn were discolored the most ($P < 0.05$), to the point of total consumer discrimination.

Roberts et al. (2002) reported that loin chops from pigs fed diets containing 350 ppm Mn from AvMn received higher American and Japanese color scores than pigs fed diets devoid of Mn or diets containing 350 ppm Mn from $MnSO_4$, as well as diets containing 700 ppm Mn from either AvMn or $MnSO_4$. Furthermore, these authors indicated that including 350 ppm Mn from AvMn tended to produce darker (lower L* values) and less yellow (lower b* values) LM chops. On the other hand, lower dietary inclusion levels (0 to 320 ppm) of Mn from AvMn did not affect subjective and objective color measures, nor was the amount of discoloration during retail display affected by dietary Mn level (Apple et al., 2003).

Moisture loss over the 7 d of retail display was not ($P > 0.27$) altered by either dietary or supplemental Mn (Table 1). However, chops from pigs fed basal diets devoid of Mn had lower ($P = 0.045$) TBARS values than chops of pigs fed basal diets with Mn.

Manganese is a co-factor of superoxide dismutase, a free-radical scavenging enzyme that catalyzes superoxide anion radicals into hydrogen peroxide and water. Ellis et al. (1971) found inhibited lipid oxidation when pork lard was treated with low levels of Mn chloride; however, when methyl linoleate (a lipid model) was treated with very high levels of Mn, lipid oxidation actually increased (Tjhio and Karel, 1969). Moreover, Roberts et al. (2002) noted that TBARS values for pork of pigs fed 350 ppm Mn from $MnSO_4$ were lower than pork from pigs fed control diets or supplemented with 700 ppm Mn from $MnSO_4$ or AvMn. It is important to note that TBARS values of chops in the present study were considerably lower than 1.0 mg/g, which is the threshold where humans detect rancidity; therefore, the statistical difference among the dietary treatments may not be detected by either trained evaluators or consumers.

Implications

Results of the present study indicate that pork color can be improved by supplementing swine diets with 350 ppm of manganese from manganese sulfate above maintenance requirements. More importantly, supplementing basal diets containing manganese with 350 ppm of manganese from manganese sulfate effectively delayed pork discoloration during retail display.

Acknowledgments

The authors wish to express their appreciation to the Zinpro Corporation (Eden Prairie, Minn., USA) for donation of Availa®Mn-80 and financial support of this project. Additionally, the authors gratefully acknowledge the assistance of Keith Richardson and the employees at Bryan Foods (West Point, Miss., USA) for their hospitality and assistance with pig slaughter, carcass fabrication, and pork loin procurement. Finally, the authors wish to thank Jennifer Leach, Juan Jimenez, Abby Keener, Wendy White, and Angela Collins for assistance in loin fabrication and data collection

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Table 1. Effect of manganese (Mn) in the basal diet and Mn supplementation on pork quality during retail display.

	Basal diet without Mn[a] (-Mn)			Basal diet with Mn[a] (+Mn)				*P*-value[b]		
Item	NC	350 ppm $MnSO_4$	350 ppm AvMn	PC	350 ppm $MnSO_4$	350 ppm AvMn	SEM	PC vs NC	$MnSO_4$ vs AvMn	+Mn vs -Mn
Lean color score[c]	3.2^{y}	3.2^{y}	3.2^{y}	3.1^{y}	3.4^{x}	3.1^{y}	0.06	0.209	0.022	0.939
Firmness score[d]	4.7	4.8	4.7	4.8	4.9	4.8	0.07	0.199	0.097	0.182
Lightness (L*)[e]	50.27^{x}	49.41^{xy}	49.01^{xy}	50.08^{x}	48.25^{y}	50.36^{x}	0.585	0.795	0.118	0.997
Redness (a*)[e]	7.47	7.71	7.46	7.57	8.07	7.25	0.234	0.732	0.022	0.638
Yellowness (b*)[e]	12.01	11.89	11.78	11.83	11.81	11.59	0.167	0.459	0.327	0.283
Chroma[f]	14.21	14.27	14.04	14.14	114.37	13.76	0.197	0.814	0.037	0.605
Moisture loss, %	7.76	6.15	6.08	6.34	5.75	6.52	0.993	0.279	0.698	0.537
TBARS, mg/g[g]	0.41	0.37	0.29	0.36	0.33	0.49	0.045	0.421	0.389	0.045

[a] NC = negative control (basal diet devoid of Mn); $MnSO_4$ = manganese sulfate; PC = positive control; and AvMn = AvailaMn-80.

[b] Significance of orthogonal contrasts for: positive control (PC) vs. negative control (NC); manganese sulfate ($MnSO_4$) vs. AvailaMn-80 (AvMn); and basal diets containing Mn (+Mn) vs. basal diets absent of Mn (-Mn).

[c] 1 = pale pinkish gray to 6 = dark purplish red (NPPC, 1999).

[d] 1 = very soft/very wet to 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 a more intense yellow color).

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

[g] TBARS = thiobarbituric acid reactive substances are representative of lipid oxidation (larger number indicates greater oxidative rancidity).

[x,y] Within a row, least squares means lacking a common superscript letter differ ($P < 0.05$).

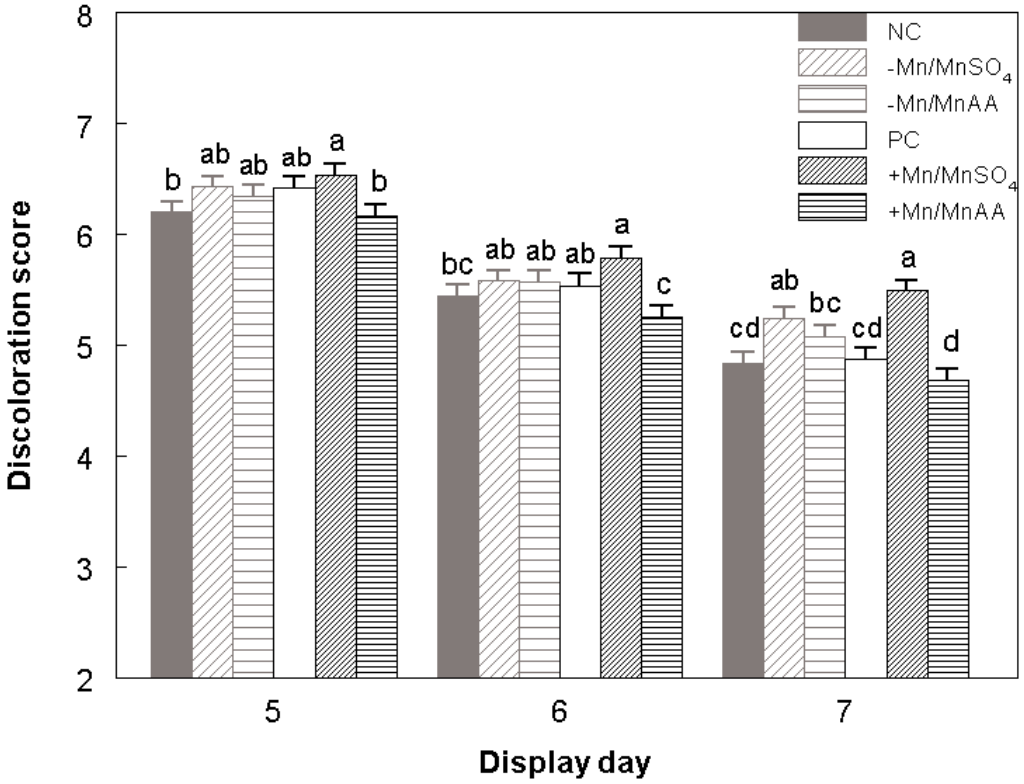

Fig. 1. Interactive effect of dietary and supplemental manganese (Mn) on longissimus muscle chop discoloration scores (1 = total (100%) discoloration to 8 = no (0%) discoloration) during 7 d of retail display (treatment x display day; P = 0.038). Within a display day, bars lacking a common letter differ (P < 0.05). Treatment abbreviations include: -Mn = no Mn included in the basal diet; +Mn = basal diet included Mn; NC = negative control diets; PC = positive control diets; $MnSO_4$ = manganese sulfate; and AvMn = AvailaMn-80 (a Mn amino acid complex).

Effect of Weaning Age and Commingling After the Nursery Phase on Growth Performance, Mortality Rate, and Behavioral Indicators of Welfare[1]

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Story in Brief

Age at weaning, as well as behavioral responses to management stressors, such as weaning and commingling after the nursery phase, impacts growth performance. This study evaluated the effects of weaning age and commingling after the nursery phase in wean-to-finish facilities on growth performance, mortality rate, and behavioral observations. A total of 216 pigs were weaned at 14 or 21 d of age, divided into older and younger age groups (108 pigs/group) and penned 12 pigs/pen. Pigs were fed common Phase 1 (d 0 to 14) and Phase 2 (d 14 to 34) diets during the nursery phase. At the end of the nursery, one-half of the pigs in each age group were removed, re-randomized, and commingled for the finishing phase, whereas the other half of the pigs remained in their original pens. Pigs were fed a four-phase common diet with transitions at 100, 150, and 198 lb. The study was terminated when pigs averaged 235 lb. Pigs weaned at an older age were heavier throughout the nursery period; and the BW difference between younger and older pigs increased from 4.4 lb at the start to 13.2 lb at the end of the nursery period. Younger pigs seemed to be more active (standing or walking vs. lying recumbent) than older pigs. However, pigs weaned at 14 d of age grew faster during the growing/finishing period and reached a common body weight (230 lb) 4 days sooner than older pigs. In conclusion, pigs weaned at 14 d of age grew slower than pigs weaned at 21 d of age during the nursery phase; however, younger pigs gained more than older pigs later in the finishing period. Commingling of pigs following the nursery phase did not affect ADG; however, the effects of commingling on ADFI were dependent on age at weaning, in that commingling decreased feed intake only in pigs weaned at 21 d of age.

Introduction

Pigs produced in conventional swine production systems are routinely weaned at 21 d of age, and as early as 10 to 14 d of age in segregated early weaning systems. Although there are no restrictions on weaning age in the US, the practice of weaning at an age earlier than 21 d of age is discouraged in some countries and prohibited in others. Additionally, commingling pigs following the nursery phase is a common management practice in the swine industry, and imposes an additional social stress upon the young pig. The advent of wean-to-finish facilities has potentially alleviated commingling after the nursery phase. However, the wasted space of placing weanling pigs in pens with space allowances for market hogs has led to the practice of double-stocking pens at weaning and later moving half of the pigs to another pen (DeDecker et al., 2002), and again introducing a commingling stress.

Many food service companies have come under scrutiny from animal-rights and animal-welfare organizations for the humane care and use of the meat animals from which their products are derived. It is imperative that decisions about animal welfare are based on scientific evaluation of pig well-being as well as effects on pig growth performance. The objective of this study was to determine the impact of weaning age and of rearing pigs in the same pen in an all-in-all-out wean-to-finish facility vs. commingling pigs after the nursery phase on growth performance, mortality rate, and behavioral indicators of welfare.

Experimental Procedures

Allocation of Animals. Pigs from one farrowing of 30 litters (DeKalb Line 348 dam mated to EB sires) over a 10-d period were weaned when the average age was approximately 17 d. Pigs were divided into equal age groups (14 and 21 d of age) representing the older and younger group of pigs (108 pigs in each group). Pigs within each age group were sorted into three categories based on weight (36 pigs/block). Pigs from each weight category within age group were then randomly allocated to pens within block in a double-stocked wean-to-finish facility (12 pigs/pen). This provided a total of nine replications of each age group for the nursery study. At the completion of the nursery phase, one-half of the pigs in each age category were removed from the double-stocked pens and re-randomized, blocked by weight and commingled for the growing-finishing component of the study. One-half of the pigs remained in the same wean-to-finish pens. This arrangement of treatments permitted evaluation of the effects of weaning age in pigs double-stocked in a wean-to-finish facility as well as effects of post-nursery commingling on well-being and performance. All pigs were housed and cared for in compliance with Animal Care and Use Protocol #01015 for swine experimentation issued by the University of Arkansas Animal Care and Use Committee.

Experimental Management. Pigs were housed in a wean-to-finish facility in totally slatted pens (5 ft x 10 ft) equipped with radiant heaters, a two-hole nursery feeder and wean-to-finish cup waterers. The pigs were offered ad libitum access to a Phase I nursery diet for the 0 to 14 d post-weaning period and a Phase II diet for the 14 to 34 d post-weaning period (Table 1). On the day of completion of the nursery phase, the pigs were started on the growing-finishing phase of the study. Pigs were fed a four-phase diet with transition from starter to grower I, from grower I to grower II and from grower II to finisher occurring when the mean weight of each block reached approximately 100 lb, 150 lb, and 200 lb, respectively (Table 2). All diets met or exceeded NRC (1998) requirements for all nutrients and were formulated to simulate diets typical of those used in the swine industry. The study was terminated when the lightest block reached an average weight of 235 lb.

[1] Research was supported by a grant from the National Pork Board.

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Measurements and Observations. Pig BW and feed disappearance were determined at the change of each dietary phase during the nursery and growing-finishing period, and ADG, ADFI, and F/G were calculated. Beginning at weaning, after pigs had been allotted to their respective pens, pigs in four pens/treatment were monitored with mounted camera surveillance equipment for 24 h to observe initial behaviors following weaning. Time-lapse videos were viewed at a later date in 2-h increments (1 AM h and 1 PM h), and the following behaviors were recorded: 1) acts of aggression (head-to-head and head-to-tail body knocks, tail-biting, ear-chewing, pushing and aggressive circling), 2) feeding, 3) drinking, 4) lying, and 5) moving. The duration of time spent by each pig engaged in these behaviors was recorded, and percentages of time were calculated based on the 2-h observation. This was replicated on d 7, 14, and 27 post weaning. Monitoring was continued on d 35 (after commingling at the end of nursery phase), 38, 44 and 65 of the growing-finishing period.

Experimental Design. Performance and behavioral data were analyzed as a 2 X 2 factorial with two weaning ages and two post-nursery management systems, with pen as the experimental unit, and day of observation as a repeated measure using PROC MIXED of SAS (SAS Inst., Inc., Cary, N.C.). When significant day x treatment interactions were observed, analysis of variance for each day was performed using PROC GLM of SAS. Mortality rate was analyzed by Chi-square analysis in SAS.

Results and Discussion

Growth Performance. During the nursery phase of the experiment (Table 3), pigs weaned at 21 d of age had greater ($P < 0.01$) ADG and ADFI during Phase 1, Phase 2, and in the overall nursery period than pigs weaned at 14 d of age. Pigs weaned at 14 d of age were more efficient ($P < 0.01$) than pigs weaned at 21 d of age during Phase 2 of the nursery and throughout the overall nursery period (Phase 1-2). At the commencement of the experiment, pig body weight was greater ($P < 0.01$) when pigs were weaned at 21 d of age compared to pigs weaned at 14 d of age, and as expected the older pigs continued to be heavier ($P < 0.01$) throughout the nursery period; however, the difference in body weight increased from 4.7 lb at the initiation of the experiment to approximately 12.8 lb at the end of the nursery period. In addition, nursery mortality was greater when pigs were weaned at 14 d compared to pigs weaned at 21 d of age (12% vs. 1%; Chi-square, $P < 0.01$).

During the growing/finishing phase of the experiment, ADG, ADFI and F/G did not differ between pigs weaned at 21 d of age or those weaned at 14 d of age during Phase 1, Phase 2, or Phase 4 (Table 4). However, during Phase 3, pigs weaned at 14 d of age had greater ($P < 0.05$) ADG and ADFI, and improved ($P < 0.05$) F/G. During the overall growing-finishing period, pigs weaned at 14 d of age had greater ($P < 0.01$) ADG and improved ($P < 0.01$) F/G compared to pigs weaned at 21 d of age. The removal and commingling of one half of the pigs from each pen at the end of the nursery period and resorting for the growing/finishing phase of the experiment did not affect ADG, F/G, or pig body weight (Table 5). However, ADFI decreased during Phase 3 ($P < 0.05$) when pigs weaned at 21 d of age were mixed and resorted compared to those that remained in original pens, while there was no difference in ADFI of pigs weaned at 14 d of age regardless of whether they were mixed and resorted or were left in their original pens (interaction, $P = 0.08$; Figure 1). Mixing and resorting pigs following the nursery phase of the study had no effect on the number of days for pigs to reach a common market weight of 230 lb (data not reported). However, age of pigs at weaning did impact days to market, such that pigs weaned at 14 d of age reached a common weight of 230 lb four days sooner than pigs weaned at 21 d of age ($P < 0.05$; Figure 2).

Behavioral Observations. Pigs weaned at 21 d of age spent a greater ($P < 0.05$) percentage of time lying recumbent on the day of weaning (d 0 post-weaning) than pigs weaned at 14 d of age (Table 6). Although the percentage of time spent standing or moving did not differ between pigs of different weaning ages at any observation day during the nursery period, pigs weaned at 14 d of age spent a greater ($P < 0.05$) percentage of time standing or moving during the overall nursery phase than pigs weaned at 21 d of age (Table 7). Although there was no difference in the percentage of time that pigs weaned at either age were engaged in aggressive behavior on any of the sampling days, the frequency of times aggressive behaviors were observed was greater (15.6 vs. 7.2 ± 4.4 actions; $P < 0.05$) at weaning (d 0) than on any other observation day. During the growing/finishing period, the effect of weaning age and post-nursery commingling on feeding behavior was dependent upon the day of observation (weaning age x mixing x date interaction, $P < 0.05$; Figure 3). On d 35 of the growing/finishing period, pigs that were weaned at 14 d of age and remained unmixed after the nursery period spent a greater ($P < 0.05$) percentage of time engaged in feeding activity than 14 d old pigs that were mixed, or pigs weaned at 21 d of age regardless of commingling. The percentage of time spent feeding did not differ among pigs of either weaning age or post-nursery mixing treatment on d 38 or d 44 post-weaning; however, on d 65 post-weaning, pigs that were weaned at 21 d of age and mixed and pigs weaned at 14 d and unmixed exhibited a greater ($P < 0.05$) proportion of time engaged in feeding behavior than pigs in the other two treatments.

General Discussion. The lower growth rate during the nursery period of pigs weaned at 14 d of age compared to older pigs is in contrast to other studies that reported either an improvement in ADG of early-weaned (10 d) pigs compared to late-weaned (30 d) pigs (Hohenstall et al., 2000) or no effect of weaning age on rate of the growth in the overall nursery period (Dritz et al., 1996). It is difficult to determine why the younger pigs performed poorly compared to the older pigs during the nursery phase in this study. Behavioral observations indicate that younger pigs spent less time lying recumbent on the day of weaning and more time standing or walking during the overall nursery phase, suggesting that younger pigs were less apt to settle into their new environment than older pigs. This nervousness and unrest may have contributed to the lower weight gains observed in young pigs compared to older pigs in the nursery phase of the study, although a disease challenge, as evidenced by mortality percentages, likely contributed to the decrease in gain as well. Increased feeding behavior of pigs weaned at 14 d of age supports the observed increase in feed intake and gain of the younger pigs during the growing-finishing period compared to pigs weaned at 21 d of age.

Implications

The results of this study indicate that weaning age affects growth performance in a wean-to-finish facility, as well as behavioral responses to weaning and commingling after the nursery phase. Management strategies should be further explored to optimize the benefits of early-weaning without the detrimental effects on health, as observed during the nursery period in this study.

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Table 1. Composition of Phase 1 (d 0 to 14) and Phase 2 (d 10 to 34) diets fed to pigs during the nursery phase (as-fed).

Item, %	Phase 1	Phase 2
Yellow corn	27.82	46.51
Steam rolled oats	12.00	5.00
Dried whey	20.50	8.00
Lactose	-	5.00
Soy protein concentrate	8.00	-
Soybean meal, 48% CP	11.00	20.00
Spray-dried plasma protein	6.00	1.75
Select menhaden fish meal	8.00	7.00
Soybean oil	4.00	-
Fat		4.00
Ethoxyquin	0.03	0.03
Lysine HCl	0.15	0.17
Threonine	0.08	0.07
Methionine	0.10	0.07
Isoleucine	0.02	-
Antibiotic [a]	0.10	0.25
Mineral premix	0.15	0.15
Vitamin premix	0.25	0.25
Zinc oxide	-	0.25
Copper sulfate	-	0.07
Dicalcium phosphate	1.12	0.65
Calcium carbonate	0.38	0.38
Salt	0.30	0.40

[a] Neo-Terramycin and Mecadox were provided in the diets during Phase 1 and Phase 2, respectively.

Table 2. Composition of Phase 1, Phase 2, Phase 3, and Phase 4 diets fed to pigs during the growing/finishing period (as-fed).

Item, %	Phase 1	Phase 2	Phase 3	Phase 4
Yellow corn	71.865	75.10	80.00	83.19
Soybean meal, 48% CP	23.00	18.10	13.50	10.50
Fat	2.30	4.00	4.00	4.00
Ethoxyquin	0.03	0.03	0.03	0.03
Lysine	0.15	0.15	0.15	0.15
Threonine	0.02	0.02	0.02	-
Dicalcium phosphate	0.94	0.95	0.75	0.755
Calcium carbonate	0.77	0.80	0.70	0.60
Mineral premix	0.15	0.15	0.15	0.125
Vitamin premix	0.15	0.15	0.15	0.125
Tylosin-40	0.125	0.05	0.05	0.025
Salt	0.50	0.50	0.50	0.50

Table 3. Average daily gain, average daily feed intake, and feed:gain of pigs in response to weaning age during the nursery period.

	Weaning Age, d			
Trait	14	21	SE	P-value
ADG, lb				
Phase 1	0.58	0.84	0.03	<0.001
Phase 2	1.07	1.35	0.03	<0.001
Phase 1-2	0.88	1.15	0.03	<0.001
ADFI, lb				
Phase 1	0.60	0.90	0.04	<0.001
Phase 2	1.36	1.93	0.06	<0.001
Phase 1-2	1.04	1.52	0.05	<0.001
Feed:gain				
Phase 1	1.091	1.063	0.011	0.09
Phase 2	1.300	1.431	0.022	< 0.01
Phase 1-2	1.238	1.323	0.015	< 0.01
Weight, lb				
Initial	9.96	14.70	0.57	<0.001
Phase 1	18.01	26.59	0.99	<0.001
Phase 2	40.54	53.35	1.59	<0.001

Table 4. Average daily gain, average daily feed intake, and feed:gain of pigs in response to weaning age during the finishing period.

	Weaning Age, d			
Trait	14	21	SE	P-value
ADG, lb				
Phase 1	1.68	1.70	0.04	0.59
Phase 2	2.23	2.16	0.04	0.26
Phase 3	2.29	1.90	0.04	< 0.01
Phase 4	1.94	1.90	0.09	0.72
Phase 1-4	2.01	1.92	0.02	< 0.01
ADFI, lb				
Phase 1	3.44	3.55	0.07	0.20
Phase 2	5.36	5.07	0.11	0.08
Phase 3	6.08	5.71	0.13	0.04
Phase 4	6.68	6.35	0.18	0.19
Phase 1-4	4.98	5.07	0.09	0.51
Feed:gain				
Phase 1	2.048	2.084	0.026	0.34
Phase 2	2.394	2.345	0.040	0.40
Phase 3	2.681	3.036	0.075	< 0.01
Phase 4	3.745	3.394	0.291	0.40
Phase 1-4	2.868	3.475	0.051	< 0.01

Table 5. Average daily gain, average daily feed intake, and feed:gain of pigs that were mixed and resorted at the initiation of the finishing period or remained unmixed during the finishing period.

	Finishing Treatment			
Trait	Mixed	Unmixed	SE	P-value
ADG, lb				
Phase 1	1.68	1.70	0.04	0.60
Phase 2	2.25	2.16	0.04	0.24
Phase 3	2.03	2.13	0.04	0.15
Phase 4	1.90	1.94	0.09	0.67
Phase 1-4	1.94	1.96	0.02	0.61
ADFI, lb				
Phase 1	3.51	3.48	0.07	0.69
Phase 2	5.31	5.09	0.11	0.17
Phase 3	5.82	5.97	0.13	0.35
Phase 4	6.42	6.64	0.18	0.36
Phase 1-4	5.03	5.05	0.09	0.83
Feed:gain				
Phase 1	2.091	2.041	0.03	0.19
Phase 2	2.375	2.364	0.04	0.85
Phase 3	2.868	2.849	0.07	0.85
Phase 4	3.437	3.701	0.29	0.53
Phase 1-4	3.159	3.185	0.05	0.71

Table 6. Behavioral data (presented as percentage of time engaged in each respective behavior) collected on each of four observation days during the nursery phase from pigs weaned at either 14 or 21 d of age.

	Observation d								
	Weaning (d 0)		d 7 post-weaning		d 14 post-weaning		d 27 post-weaning		
Age at weaning:	14	21	14	21	14	21	14	21	SE
Observation, %									
Lying	26.2[b]	45.5[a]	32.5	36.6	34.2	37.9	48.3	63.2	6.4
Standing/ moving	32.8	32.0	35.4	29.6	25.8	21.4	27.7	13.5	5.2
Drinking	1.9	3.2	1.3	1.5	1.5[b]	4.5[a]	1.8	1.1	0.8
Feeding	1.8	0.0	9.1	8.9	12.6	11.5	13.3	7.6	2.9
Aggression	3.1	3.3	3.7	1.8	1.8	1.0	1.9	2.0	1.6

[a,b] Means within each action in each observation day with differing superscripts are different ($P < 0.05$).

Table 7. Summary of behavioral data (presented as percentage of time engaged in each respective behavior) collected during the overall nursery phase from pigs weaned at either 14 or 21 d of age.

	Age at weaning, days			
Observation, %	14	21	SE	P=
Lying	36.1	46.1	4.00	0.130
Standing/moving	30.1	22.6	2.23	0.054
Drinking	1.7	2.5	0.47	0.255
Feeding	11.2	9.1	1.69	0.399
Aggression	2.9	2.1	0.61	0.387

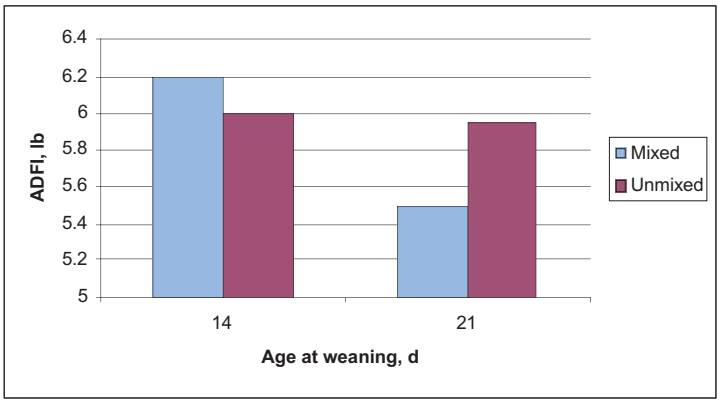

Fig. 1. Effect of mixing and age at weaning on average daily feed intake of pigs (ADFI) during Phase 3 of the growing/finishing period (interaction, P = 0.08; a,b P< 0.05).

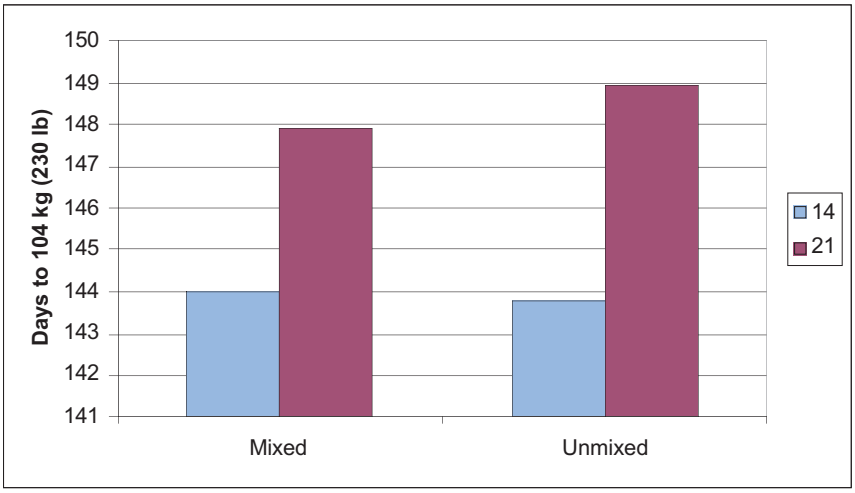

Fig. 2. Effect of mixing and age at weaning on the number of days for pigs to reach 230 lb. Effect of weaning age; P < 0.05.

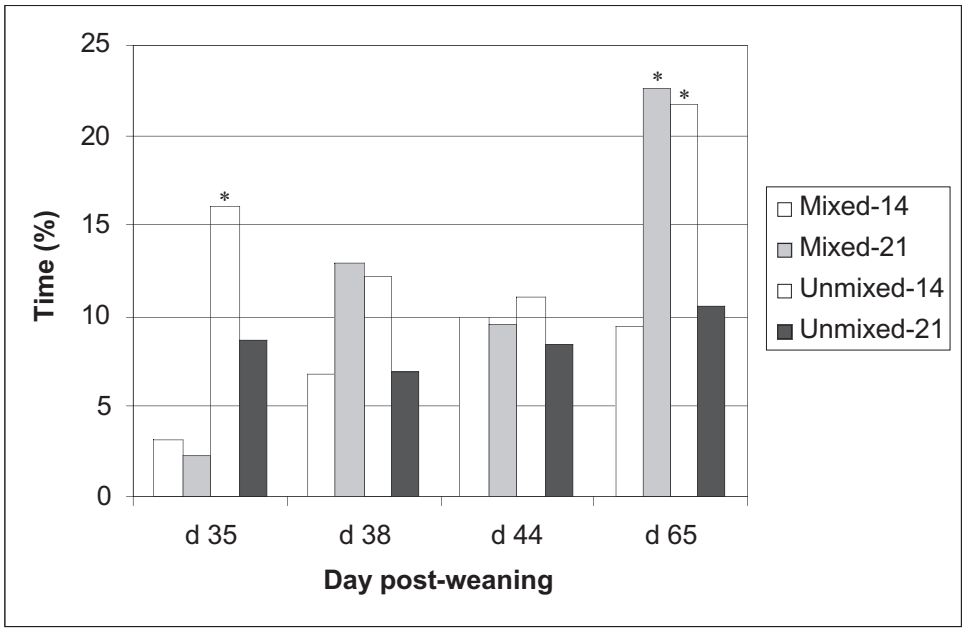

Fig. 3. Percentage of time spent engaged in feeding behavior during the growing/finishing phase by pigs weaned at either 14 or 21 d of age and either subjected to mixing and resorting following the nursery phase or remaining in original pens (weaning age x mixing x date interaction, P < 0.05). Bars with an asterisk differ from other bars without asterisks within day post-weaning (P < 0.05).

Efficacy of NuPro in Nursery Diets

C.V. Maxwell[1], M.E. Davis[1], D.C. Brown[1], R. Dvorak[2], R. Musser[3], and Z.B. Johnson[1]

Story in Brief

A total of 216 weanling pigs (Dekalb line 348 sired by Dekalb EB boars) were used to evaluate the efficacy of NuPro 2000 as an alternative to plasma protein in nursery diets. Pigs were sorted into three weight blocks, and pigs within each weight block were randomly assigned to pens of six pigs. Dietary treatments fed from d 0 to 7 (Phase 1) included a control complex nursery diet containing 4.25% plasma protein or the control diet with 50 or 100% of the plasma protein replaced with NuPro. In phase 2 (d 7 to 21), plasma protein was reduced to 2% in the control diet and NuPro replaced 50% of the plasma protein in treatment 2 and 100% in treatments 3 and 4. During phase 3 (d 21 to 42), treatments 1, 2 and 3 were fed a common diet whereas treatment 4 received a diet containing 1.3% NuPro. Phase 1 and 2 diets were complex nursery diets prepared by Hubbard Feeds, Inc., and basemixes were provided for phase 3 diets. Diets were formulated to meet currently acceptable ideal protein requirements and were formulated to simulate diets typical of those used in the integrated industry. During Phases 1 and 2, no differences ($P > 0.10$) were observed among the four dietary treatments with regard to ADG, ADFI, or F:G. From d 21 to 28 of the experiment (first week of Phase 3), pigs previously fed the diet containing NuPro at the 100% replacement level and those continuing to receive NuPro had higher ($P < 0.05$) ADG and ADFI than pigs previously fed NuPro at the 50% replacement level. These results suggest NuPro is an effective substitute for up to 100% of the plasma on an equal weight basis during the first 21-d post-weaning. Therefore, NuPro may offer an effective vegetable-based protein source for the early-weaned pig.

Introduction

Pigs produced in conventional, intensively-managed swine production systems are routinely weaned as early as 19 to 21 d of age, and potentially as early as 10 to 14 d of age in some off-site, segregated early-weaning systems. At these ages, pigs are very sensitive to the source of dietary protein. Many dietary proteins produce allergic reactions, resulting in diarrhea, reduced growth and increased mortality (Bimbo and Crowther, 1992). Various protein sources have been tested in early-weaned pig diets in an attempt to overcome these problems. Spray-dried plasma protein is a protein source that has consistently improved performance of early-weaned pigs when included in Phase 1 (d 0 to 14 postweaning) diets at the expense of dried skim milk (Hansen et al., 1993; Kats et al., 1994; de Rodas et al., 1995), soybean meal (Fakler et al., 1993; Coffey and Cromwell, 1995; de Rodas et al., 1995), and whey (Hansen et al., 1993). Select grade menhaden fish meal has also been a widely utilized protein source due to a combination of consistent quality and competitive price. Demand for plasma protein is high and supply is limited; therefore, plasma is an expensive protein source for nursery diets. Similarly, increased demand and decreased supply of fish meal has resulted in increased price volatility and relatively high current prices.

Nucleotides may be important nutrient sources for maintaining gut integrity during the early nursery period. NuPro 2000 is a protein source high in crude protein (51 to 55%) and digestible amino acids that has potential as a possible alternative protein source in nursery diets. NuPro 2000 also is high in glutamic acid and is an excellent source of nucleotides. Several specialty feed ingredients have been developed to compete against the animal plasma and fish meal market share. However, NuPro 2000 is a vegetable-based peptide product which may have greater international market appeal compared to products originating from animal by-products, and the high level of nucleotides may be uniquely beneficial to the early-weaned pig. Therefore, the objective of this experiment was to evaluate the efficacy of NuPro 2000 as an alternative to plasma protein in nursery diets. In addition, the effect on subsequent performance during the grow/finish phase was evaluated.

Experimental Procedures

Allotment of pigs. A total of 216 weanling pigs (Dekalb line 348 sired by Dekalb EB boars) were sorted by weight, and divided into three weight groups (blocks). Pigs within each weight group were allotted into equal subgroups (six pigs/pen), with stratification based on sex and litter. Treatments were randomly assigned to pens (subgroups) within each of the weight groups (nine pens/treatment).

Dietary treatments. The study was designed as a randomized complete block. Four dietary treatment regimens were imposed during Phase1 (0 to 7 d) and Phase 2 (7 to 21 d) of the nursery period. Dietary treatments were a control diet containing 4.25% spray-dried plasma or the control diet with 50 or 100% of the plasma protein replaced with NuPro 2000. During Phase 2 of the nursery, pigs were fed treatment diets consisting of a control diet with 2% plasma or the control diet with 50 or 100% of the plasma protein replaced with NuPro 2000. Finally, during Phase 3 of the nursery, pigs received either a common late nursery diet or a diet containing 1.3% NuPro for an additional week (21 to 28 d). A common late nursery diet was fed to all pigs for the remainder of Phase 3 (28 to 42 d). The diet containing NuPro for the additional 7 d of Phase 3 was formulated to the same nutrient specification as the common late nursery diet utilizing the same basemix, but with 1.3% NuPro replacing amino acids from soybean meal or synthetic amino acids. During the growing/finishing period, all pigs received a common diet.

Performance measurements and observations. Pigs were individually weighed on d 7, 21 and 42 and at the completion of each growing/finishing period. Feed disappearance from each pen was calculated as the difference between feed added and feed weighed

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back for each of the following periods: 0 to 7 d, 7 to 21 d, 21 to 28 d, 28 to 42 d, 21 to 42 d, 0 to 42 d, starter I, starter II, grower I, grower II, finishing I and finishing II. Feed:gain for each period was then calculated.

Lighting was natural lighting with supplemental lighting provided only when pigs were being observed. Incidence of scours was evaluated on a pen basis on d 5 and 9 postweaning. A scour score of 1 indicated no evidence of loose stools in the pen, a score of 2 indicated there was evidence of two loose stools in a pen, a score of 3 was indicative of three to five loose stools in a pen, a score of 4 was indicative of loose stools at the front and back of the pen, and a score of 5 was recorded when there was evidence of loose stools over the entire pen floor.

Animal care. Except for weighing the pigs, adding feed daily, and recovering any leftover at the end of each test period, pigs in this study were cared for following typical commercial management procedures. This experiment was carried out in accordance with the Animal Care Protocol # 01015 for swine experiments issued by the University of Arkansas Animal Care Committee. Any animal suffering from minor illness was reported to the Study Director, treated, and all medical treatments were recorded.

Statistical analyses. Data were analyzed using the GLM procedures of SAS (SAS Inst., Inc., Cary, N.C.). The model included block and diet regimen as main effects. Initial weight was used as a covariate. Since treatments 3 and 4 were identical through Phase 2, data from Phase 1 and 2 were analysed as three treatments. Least squares means were computed and separated by the LSMEANS and PDIFF options of PROC GLM.

Results And Discussion

During Phases 1 and 2, no differences ($P > 0.10$) were observed among the dietary treatments with regard to ADG, ADFI, or G:F (Table1). These results suggest NuPro is an effective substitute for up to 100% of the plasma on an equal weight basis during the first 21 d post-weaning. Therefore, NuPro may offer an effective vegetable-based protein source for the early-weaned pig. From d 21 to 28 of the experiment (first week of Phase 3), pigs previously fed the diet containing NuPro at the 100% replacement level and those continuing to receive NuPro had higher ($P < 0.05$) ADG and ADFI than pigs previously fed NuPro at the 50% replacement level, and ADFI was also numerically higher ($P > .05$) than for pigs fed the control diet. During the first week of Phase 3, pigs previously fed NuPro at the 50% replacement rate were less efficient (higher F:G; $P < 0.05$) than pigs fed the other dietary treatments. This effect was reversed in weeks 2 and 3 of Phase 3 and F:G was similar ($P > 0.05$) across all 21 d of Phase 3. As might be expected from the gain data, pigs fed diets with 100% replacement of plasma protein with NuPro were heavier ($P < 0.05$) at the end of the first week of Phase 3 compared to those fed the 50% replacement diet. Weight of pigs fed plasma protein and those fed NuPro at the 100% replacement through Phase 2 and 1.3% NuPro for an additional week during Phase 3 were intermediary. Previous treatment during the nursery period had no significant effect on performance during any of the six growing/finishing Phases or on the overall growing/finishing performance (Table 3).

Although there was no ($P > 0.57$) effect of treatment on incidence of scours (Table 2), it should be noted that 25% of the pens on d 5 were scored a 4, or higher. However, the incidence of scours was reduced by d 9 to only 8 % of the pens exhibiting a scour score greater than 4.

Implications

The results of this study indicate that NuPro, a vegetable-based peptide product containing nucleotides, may be used as an alternative to spray-dried plasma protein when substituted on an equal weight basis in nursery pig diets.

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Table. 1 Effect of NuPro on nursery performance.

	Treatment					
Trait	Control	50% NuPro	100% NuPro	100% NuPro	SE	P > F
ADG, g						
Phase 1, d 0 – 7	47	45	33	-	7	0.4
Phase 2, d 7 – 21	399	402	417	-	8	0.34
Phase 1-2, d 0 – 21	282	283	289	-	6	0.78
Phase 3, d 21 – 28	467 [a]	350 [b]	466 [a]	466 [a]	31	0.02
Phase 3, d 28 – 42	702	711	706	699	16	0.96
Phase 3, d 21 – 42	623	590	626	621	12	0.78
Phase 1-3, d 0 - 42	451	437	461	450	8	0.2
ADFI, g						
Phase 1, d 0 - 7	118	113	108	-	5	0.51
Phase 2, d 7 - 21	473	475	481	-	11	0.9
Phase 1-2, d 0 - 21	355	354	357	-	8	0.98
Phase 3, d 21 - 28	803 [ab]	738 [a]	830 [b]	833 [b]	27	0.07
Phase 3, d 28-42	1113	1074	1140	1087	21	0.16
Phase 3, d 21- 42	1009	962	1037	1002	19	0.08
Phase 1-3, d 0 - 42	680	658	701	675	13	0.18
Feed:Gain						
Phase 1, d 0 - 7	2.44	2.68	3.41	-	0.54	0.29
Phase 2, d 7 - 21	1.18	1.18	1.15		0.02	0.14
Phase 1-2, d 0 - 21	1.25	1.24	1.22	-	0.02	0.28
Phase 3, d 21 - 28	1.75 [a]	2.19 [b]	1.81 [a]	1.86 [a]	0.11	0.04
Phase 3, d 28-42	1.60 [b]	1.51 [a]	1.62 [b]	1.58 [ab]	0.03	0.06
Phase 3, d 21- 42	1.62	1.63	1.66	1.64	0.02	0.72
Phase 1-3, d 0 - 42	1.51	1.51	1.52	1.51	0.01	0.88
Weight, kg						
Initial	6.45	6.45	6.45	-	0.003	0.93
Phase 1, day 7	6.78	6.77	6.68	-	0.05	0.41
Phase 2, day 21	12.37	12.39	12.51		0.13	0.77
Phase 3, day 28	15.63 [ab]	14.84 [b]	15.93 [a]	15.62 [ab]	0.30	0.09
Phase 3, day 42	25.44	24.79	25.81	25.51	0.34	0.22

[a,b] Means in a row with different superscripts differ (P < 0.05).

Table 2. Least squares means of scour scores.

	Level of Nupro			
	0 %	50 %	100%	P-value
Scour score 1 Day 5	2.89 ± 0.30	2.67 ± 0.30	2.94 ± 0.21	0.75
Scour score 2 Day 9	2.44 ± 0.26	2.22 ± 0.26	2.11 ± 0.18	0.57

Table 3. Effect of NuPro during the nursery period on subsequent growing/finishing performance.[a]

	Treatment					
Trait	Control	50% NuPro	100% NuPro	100% NuPro	SE	P > F
ADG, kg						
Phase 1	0.818	0.826	0.794	0.827	0.018	0.52
Phase 2	0.995	1.008	0.993	1.002	0.015	0.87
Phase 3	1.068	1.031	1.055	1.032	0.019	0.44
Phase 4	0.994	0.993	0.992	1.009	0.021	0.92
Phase 5	0.974	0.968	0.910	0.961	0.023	0.20
Phase 6	0.994	0.917	0.910	0.996	0.056	0.56
Phase 1-6	0.978	0.969	0.951	0.976	0.011	0.30
ADFI, kg						
Phase 1	1.445	1.454	1.426	1.522	0.067	0.77
Phase 2	2.014	2.062	2.015	2.018	0.043	0.83
Phase 3	2.394	2.300	2.443	2.344	0.054	0.29
Phase 4	2.714	2.579	2.657	2.612	0.040	0.11
Phase 5	3.083	3.006	2.984	2.989	0.041	0.31
Phase 6	3.293	3.105	3.062	3.086	0.067	0.08
Phase 1-6	2.459	2.386	2.407	2.402	0.033	0.44
Feed:Gain						
Phase 1	1.77	1.76	1.76	1.84	0.069	0.81
Phase 2	2.02	2.02	2.01	2.02	0.030	0.98
Phase 3	2.24	2.23	2.33	2.28	0.049	0.48
Phase 4	2.74	2.60	2.70	2.60	0.049	0.11
Phase 5	3.18	3.14	3.30	3.15	0.082	0.51
Phase 6	3.39	3.43	3.46	3.16	0.167	0.57
Phase 1-6	2.51	2.46	2.53	2.47	0.028	0.28
Weight, kg						
Initial	25.44	24.78	25.95	25.57	0.35	0.14
Phase 1	36.37	35.84	36.64	36.64	0.40	0.46
Phase 2	57.27	57.01	57.49	57.68	0.55	0.84
Phase 3	72.21	71.45	72.26	72.13	0.64	0.79
Phase 4	90.85	89.90	90.62	90.94	0.80	0.79
Phase 5	109.18	108.16	107.70	109.06	1.03	0.70
Phase 6	117.40	115.85	115.37	117.28	1.10	0.47

[a] No significant differences were observed.

Relationship Between Performance Test Traits and Subsequent Reproductive Performance of Yorkshire Females

Z.B. Johnson[1] and R.A. Nugent III[2]

Story in Brief

The objective of this study was to examine relationships between performance test traits of Yorkshire females and their subsequent reproductive performance. Performance test records were collected in a commercial swine operation from 1992 to 1999. All females in the breed were grown to 100 d of age (AGE100; n = 38,979). At this time pigs were weighed (WT100) and selected for performance testing based on a combination of maternal and performance indexes. Pigs were weighed at the end of the 77-d performance test (WT177) and ADG calculated. Backfat (BF), loin eye area (LEA), and body length (LEN) were measured. Reproductive traits were number born live (NBA) and weaning weight (WWL) of the first litter. Heritabilities and genetic correlations were estimated with multiple-trait DFREML procedures using an animal model with litter effects. Fixed effects for performance traits included contemporary group and appropriate age as a covariate. Estimates of heritability for NBA, WWL, WT100, WT177, ADG, BF, LEA, and LEN were 0.09 ± .03, 0.10 ± .03, 0.22 ± .01, 0.32 ± .02, 0.28 ± .02, 0.47 ± .02, 0.31 ± .02, and 0.23 ± .02, respectively. Genetic correlations for NBA with WT100, WT177, ADG, BF, LEA, and LEN were -0.43, -0.20, 0.06, 0.01, -0.17, and -0.11, respectively. Genetic correlations for WWL with WT100, WT177, ADG, BF, LEA, and LEN were 0.55, 0.14, -0.04, -0.05, -0.05, and 0.13, respectively. These correlations indicated that 100-d weight of the mother was more related to NBA and WWL than any performance trait measured. Females that weighed more at 100 d of age had smaller litter sizes, but greater weaning weight of the litter.

Introduction

Litter size (number born and number weaned) is an important economic component of sow productivity. Noguera et al. (2002) reported that long-term selection experiments for directly increasing litter size by means of conventional selection have not, in general, been successful. This may be due to low heritability or the difficulty of achieving high selection intensity in practice. It is important to know how selection for other traits may affect this trait. Using data from selection experiments on the Landrace breed, Noguera et al. (2002a,b) suggested that different parities should be considered as different traits. They also reported that selection for growth and backfat should result in very little correlated response in litter size. The objective of this study was to examine relationships between performance traits of Yorkshire females and their subsequent reproductive performance in the first parity.

Experimental Procedures

Data for this study consisted of performance test records of Yorkshire pigs collected in a commercial swine operation (The Pork Group, A Division of Tyson Foods, Inc., Rogers, Ark.) from 1992 to 1999. All females were grown to 100 days of age (AGE100; n = 38,979). At this time pigs were weighed (WT100) and selected for performance testing. Two indexes (breeding values) for each animal were calculated. 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 with more emphasis given to the maternal index and used to select females for performance testing. About 60 % of the females were performance tested for approximately 77 days.

Gilts 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 in groups of 8 to 10 pigs in a pen with each pig having an area of 1.2 m^2. Exact composition of the diet varied due to ingredient cost. 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. Barns were curtain-sided buildings that were tunnel ventilated in the winter. All pigs were weighed at the end of the 77-day performance test (WT177) and ADG was calculated. Backfat (BF), loin eye area (LEA), and body length (LEN) were measured. Body length was measured from the top of the tail to the point of the shoulder when the head is down.

Gilts were ranked on an overall index at the end of the test. Those ranking highest were examined for acceptable phenotype (leg structure, vulva, etc.) and then retained for great-grandparent replacements if of acceptable phenotype; the next tier was used for grandparent replacements. Approximately 13 % of the gilts were retained and bred to produce first parity litters. Reproductive traits were number born alive (NBA; n = 3,140 litters) and weaning weight (WWL; n = 2,892 litters) of the first litter.

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 set is given in Table 1. For the WT100 trait there were 74 contemporary groups, 548 sires, 3,747 dams and 10,982 litters.

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 two-trait models was conducted to estimate genetic correlations of performance test traits with NBA and WWL. Contemporary group

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was a fixed effect. Initial test age (AGE100) was a covariate for WT100, and final test age (AGE177) was a covariate for WT177, ADG, BF, LEA, and LEN. Age at weaning was included as a covariate for WWL.

Results and Discussion

Means and standard deviations are given in Table 2. Mean number born alive in a litter was 8.46 with a SD of 2.87. Mean weaning weight of the litter was 84.71 lb. Mean weight at the beginning of the performance test was 97.81 lb and at the end of the performance test was 246.85 lb.

Estimates of heritability were 0.09, 0.10, 0.22, 0.32, 0.28, 0.47, 0.31, and 0.23 for NBA, WWL, WT100, WT177, ADG, BF, LEA, LEN, respectively (Table 3). Estimates for the reproductive traits, NBA and WWL, were low but comparable to what is reported in the literature for these traits. Chen et al. (2003), using records from the National Swine Registry Swine Testing and Genetic Evaluation System, reported heritabilities of 0.10 and 0.05 for NBA and litter weight at 21 days, respectively for Yorkshire. Estimates of heritability for performance test traits were in the low to moderate range indicating that additive genetic variance does exist for these traits and progress in changing them could be made through selection. A previous publication reported estimates of heritability for WT100, ADG, LEA, and BF using a model that included maternal effects and a larger data set that included both males and females (Johnson et al., 2002).

Estimates of genetic correlation for WT100 with NBA and WWL were -0.43 and 0.55 indicating that gilts that weighed more at 100 d of age had smaller first litters, but higher weaning weights of the first litter. Genetic correlations of NBA and WWL with WT177 were lower but followed the same trend, being negative for NBA (-0.20) and positive for WWL (0.14). Genetic correlations of NBA and WWL with ADG and BF were low (near zero). Genetic correlations of NBA with LEA and LEN were negative (-0.17 and -0.11, respectively) indicating that females with larger LEA and longer body length also had a smaller litter size at first parity. Loin eye area was not correlated with WWL, but LEN had a positive correlation (0.13) with WWL. These correlations may indicate that high growth (as measured by WT100, WT177, LEA, and LEN) is not conducive to good maternal performance (as measured by NBA) in the first parity. No estimates of these correlations were found in the literature, although Estany et al. (2002a,b) with Landrace pigs suggested that selection for litter size is not expected to dramatically affect performance traits in the short-term and that selection for litter size can reduce the lean content in the carcass, though little or no short-term effects are expected concerning the joint weight distribution and meat and fat quality traits.

Common environmental litter effects were obtained from these analyses and are presented in Table 3. Common litter effects only explained 4% of the variation in NBA. They explained from 11 to 22 % of the phenotypic variance for other traits examined in this study.

Implications

Genetic correlations obtained in this study indicate that high growth of the gilt (as measured by weight at 100 and 177 days of age, loin eye area, and body length) may not be conducive to good maternal performance (as measured by number born alive) in the first parity. This indicates that indexes which involve some combination of the two types of traits should be utilized in a selection program for maximum progress.

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Table 1. Some description of the data[a].

Item	Number
Contemporary groups	74
Sires	548
Dams	3,747
Litters	10,982
Individuals in pedigree matrix (A^{-1})	56,943

[a] Numbers apply to observations for weight at 100 days of age. Number of observations per sire ranged from 1 to 656 and number of observations per dam ranged from 1 to 54.

Table 2. Means and standard deviations for traits in study.

Trait[a]	N	Mean	SD
Number born alive	3,140	8.46	2.87
Weaning age of litter, d	2,892	16.91	4.46
Weaning weight of litter, lb	2,892	84.71	43.23
Age100, d	38,979	99.30	2.86
WT100, lb	38,979	97.81	16.79
Age177, d	23,623	176.31	3.84
WT177, lb	23,623	246.85	26.09
ADG, lb	23,623	1.86	0.27
Backfat, in	23,619	0.65	0.19
Loin eye area, sq in	23,611	6.33	0.93
Body length, in	23,622	37.90	2.06

[a] WT100 is weight of the gilt at 100 days of age (AGE100); WT177 is weight at 177 days of age (WT177); ADG is average daily gain between WT100 and WT177; backfat, loin eye area, and body length were measured at the end of performance test.

Table 3. Genetic parameters for performance test traits and reproductive traits of number born alive and weaning weight of litter for Yorkshire females.

Trait[a]	Estimate of heritability	Genetic correlation with NBA	Genetic correlation with WWL	Common environmental litter effects
Number born alive	0.09 $\pm$ 0.03			0.04
Weaning wt of litter	0.10 $\pm$ 0.03			0.11
WT100	0.22 $\pm$ 0.01	-0.43	0.55	0.22
WT177	0.32 $\pm$ 0.02	-0.20	0.14	0.18
ADG	0.28 $\pm$ 0.02	0.06	-0.04	0.19
Backfat	0.47 $\pm$ 0.02	0.01	-0.05	0.11
Loin eye area	0.31 $\pm$ 0.02	-0.17	-0.05	0.14
Body length	0.23 $\pm$ 0.02	-0.11	0.13	0.20

[a] WT100 is weight of the gilt at 100 days of age; WT177 is weight at 177 days of age; ADG is average daily gain between WT100 and WT177; backfat, loin eye area, and body length were measured at the end of performance test.

The Use of Coal Combustion Products (Fly Ash) for Reducing Mud Problems in Heavy Use Areas for Cattle

K. VanDevender[1] and J.A. Pennington[2]

Story in Brief

Coal combustion products vary in reactivity and therefore ability to set into a firm load-supporting surface. Bottom ashes typically have already had water added, and have very little reactivity left, and should be thought of as a filler or bulking material to mix with fly ash. Fly ashes have not had water added and are therefore still reactive. The level of reactivity varies with both the supplier and time. The two basic approaches to using fly ashes to reduce mud problems in heavy use areas for cattle are to build a pad on the ground surface with a blend of ashes or to mix fly ash with the soil as an amendment. Due to the difficulty with soil mixing, that approach is not generally recommended. Ideally, the supplier of ashes should mix bottom ash and fly ash on a 70:30 volumetric basis. This mix makes a material with a soil-like consistency that is easy to transport and handle at the application site. Material can be mixed on site, and it is possible to use a clean soil material instead of a bottom ash blend; however the mix ratio should be changed to 50:50 volumetric. It is best to add moisture and compaction as the pad is built.

Introduction

Heavy use areas for cattle often become denuded and muddy when the soil has been exposed to numerous animals. The most popular options to strengthen the soil are concreting the lot or adding gravel to minimize the exposure of the cattle to the mud and perhaps pathogenic organisms in the mixture of soil, urine, and manure. The addition of by-products of coal combustion is another option for strengthening the soil.

Coal ash is produced from the burning of coal to generate electricity in power plants, and can be placed in a heavy use area to bond with soil or other fractions of ash due to the pozzolanic action of coal ash. The pozzolanic reaction causes the ash to set up like concrete when exposed to water. The strength of the final product depends on the initial chemical composition of the coal. The ash contains silica and alumina that react with calcium to respond much like cement or lime.

The objective of these demonstrations was to illustrate methods of utilizing coal combustion products in heavy use areas to reduce problems associated with mud.

Experimental Procedures

Options to Use Coal Ash. Coal ash was used by two methods: (1) mixed with the soil on site or (2) prepared as a bottom ash blend (BAB) of 70% bottom ash: 30% fly ash. The blend is easier to transport and apply compared to fly ash which is prone to blow in the wind due to its small particle size.

In-State Demonstrations. In the late 1990's, Arkansas dairies in Yell and Washington counties were the sites of demonstrations using coal ash to reinforce the soil in heavy use areas. On two sites, fly ash was mixed into the soil. At site 1, the soil ash mixture was about 18 inches deep on an equipment road. This site had traditionally failed to support a tractor and feed mix wagon when the soil was moist. Also at site 1, fly ash was incorporated with the soil for a pad depth of about 4 to 6 inches for a travel lane, an area in front of a commodity barn, and an area to support silage bags. At site 1, fly ash also was pneumatically applied to the muddy area around a waterer. The fly ash was not mixed because the truck and equipment could not get close to the muddy area. The total depth of the mixture was probably 18 inches but could not be determined because the area was saturated with water. At site 2 where ash and soil where mixed, a cattle travel lane was treated to a depth of about 8 inches. In both of these sites, the mixing was accomplished with a bulldozer. For shallower mix-depths, a plow could mix the material adequately. In terms of thorough mixing, a PTO powered tiller would be ideal. After mixing the material, it was watered and compacted.

On site 3 in Washington County, a combination of various types of ash (fly ash, bottom ash, and mixtures) was used to make an 8-inch pad for a cattle travel lane on a pre-prepared soil surface. On site 4 in Van Buren County, a lane to the milking parlor was built with 12 inches of a 70: 30 blend of bottom ash and fly ash. At site 4, pads were also built with extra BAB at a feeding area for hay and a storage site for hay, but were approximately 6 inches thick.

At site 5, a 70:30 blend of bottom ash and fly ash was also used to build a pad for a feeding area. The existing travel lane was narrowed, and an open lot that had previously served as a loafing area was covered with a 10-inch pad of a blend of bottom and fly ash. In addition, the loafing area was shaped to form a ridge so that 100 ft of feed bunks and two waterers could be installed along the ridge. The conversion of the loafing area to a loafing area with feed and water allowed the cattle to be kept out of the mud and prevented the cattle from creating muddy conditions elsewhere on the farm during wet weather. Before the pads were built, roof gutters were installed on a side of a hay barn that dumped clean rainwater onto the cattle travel area. The captured rainwater was piped under the travel lane to an adjunct pasture. Then the travel lane was scraped to remove accumulated manure and to get to firm soil. Dump trucks and a bulldozer were used to deliver, spread, and partially pack the ash blend. During the spreading of the ash, a water hose was used as needed to help control dust. As the soil was moist and rain was expected in the

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next couple of days, no effort was made to supply enough water to initiate the chemical reaction that causes the ash to set; however, prior to and after the rain a homemade water-filled cultipacker was used to smooth and pack the pad.

Results and Discussion

Cattle were able to walk on the packed pad surfaces immediately, even though they had not chemically reacted. After the pads absorbed water from the soil and rainfall, they reacted chemically and became a hard surface. The installation of the pads confirmed that readily available equipment like bulldozers, dump trucks, and tractors work well to apply the blend of bottom and fly ash. In addition it was determined that while ideally water should be added to the blended ash as it is being applied and packed, it will absorb the necessary water from the soil and rainfall to cure and form the desired hard surface. However, packing of the ash is critical.

Since treatment, the soil ash mixtures with at least 8 inches of pad at sites 1 and 2 have supported vehicle and cattle traffic, even under moist conditions. At site 1, fly ash was pneumatically applied to a muddy area around a waterer. The fly ash was not mixed because the truck and equipment could not get close to the muddy area, but the area has maintained a firm surface for 5 years. One pad at site 1 that was placed at the entrance to a commodity barn failed when the tractor broke through. This failure occurred when the 4-inch pad could not support a tractor when the soil under the pad became saturated. This failure emphasizes the importance of proper design and drainage, especially as pertains to depth of the pad. A geotextile fabric (that allows water movement but retards soil movement) under a pad of less than 8 inches might support the ash and allow the use of material less than 8 inches deep but this method was not attempted in these demonstrations.

On site 3, a combination of various types of ash used to make pads on the pre-prepared soil surface has supported traffic well, but the pad was at least 8-inches deep. A blend of bottom ash and fly ash, BAB, was used to build a pad for a cattle travel lane 12 inches deep on site 4 and 10 inches deep on site 5. This BAB proved to be very easy to work with. It also resulted in a very durable surface that has held up well to cattle traffic. One area of the pad did not hold up well and was an apparent sinkhole. This area had been a problem previously and was adjacent to the holding pen. It was suspected that it harbored a wet-weather spring. Finally, a 12’ X 20’ concrete pad was poured over the area, which started as a perhaps 2’ x 6’ spot. The feeding floor of 10-inch depth at site 5 has held up well. Overall, the bottom ash and fly ash of 10 to12 inches in depth has satisfactorily supported cattle and equipment.

At site 4, BAB that remained after building the travel lane to the holding pen was applied to a feeding area and area to store hay. These pads were approximately 6 inches deep and decreased the mud in the areas but would not have satisfactorily supported cattle or equipment travel as they broke up too easily and allowed weeds to grow. When weeds grow in the ash, water penetrates the mix and breaking usually follows.

Key concepts in utilizing coal ash products are outlined in Table 1. The ash blends have a pH of 10 or 11 which indicates that they should not be used in conditions where the unreacted ash can flow to ponds and creeks. Once the fly ash blend is set, there are no documented concerns regarding runoff and leachate water from the ash.

When these demonstrations were initiated in 1998, fly ash from Oklahoma and Arkansas was being hauled to Louisiana to utilize it. However, as additional uses have been developed for the fly ash, costs have risen and must be considered before deciding on its use. A primary factor in the costs of utilizing fly ash is the distance from the plant where it is produced since hauling of the ash to the farm may cost more than the ash.

Implications

Experiences from across the nation and the Arkansas demonstrations show the potential of coal ash to moderate the impacts of excessively muddy conditions in cattle operations. With proper design and use of coal ash, cattle heavy use areas can usually be reduced in size, and a better job of keeping cattle out of the mud can be accomplished. Coal ash products can be used to strengthen the soil of the heavy use area, either by mixing with the soil or by forming a pad of bottom ash blend to support cattle and equipment traffic. For most producers, a bottom ash blend may be more appropriate as it requires less equipment. Costs should be considered when utilizing ash.

Table 1. Key Concepts in Utilizing Coal Ash Products.

- The two basic approaches to using fly ashes are to build a pad on the ground surface or to mix with the soil as an amendment. Due to the difficulty with soil mixing and requirements for large land-moving equipment, that approach is not generally recommended.
- The problem with using pure fly ash is that it has the consistency of talcum powder that requires special pneumatic trailers to haul, and that makes it extremely dusty to work with.
- Ideally, the end user is better off to have the supplier mix bottom ash and fly ash on about a 70:30 volumetric basis. This mix makes a material with a soil-like consistency that is easy to transport and handle at the application site.
- If the supplier won't supply a premixed material, fly ash and soil can be mixed on site. It is possible to use a clean soil material instead of bottom ash; however the mix ratio should probably be changed to 50:50 on a volumetric basis.
- To build the pad, surface manure and mud need to be removed to get to a firm material. Generally, since the pad will bond together, a geo-textile filter fabric should not be required. However, on very weak soils and expected heavy loads such as mix wagons, filter fabric or an 18- to 24-inch pad may be required.
- Concerns about surface drainage need to be addressed and corrected before ash is applied. When finished, there should be positive drainage off the pad.
- During installation of the ash, adding water and compaction are critical. If adequate hydration and compaction do not take place, strength and life of the final pad can be significantly reduced.
- It is possible but very difficult to add too much water. The final moisture content should be about 25%. It should be moist to the touch, but you should not be able to squeeze out water. If too much water is added, either add more ash (preferred) or let the material dry a day or two before compacting. It is better to use slightly too much water than not enough.
- Compaction can be provided by tracked or rubber-tired equipment. Usually the rubber-tired equipment will pack better but may leave ruts unless care is taken. Water-filled cultipackers can be effective for packing and smoothing the surface. To help insure adequate compaction, the material should be packed in 6- to 8-inch layers.
- It is best to add moisture and compaction as the pad is built.
- If fence posts are to be placed in the treated area, it is strongly recommended that they be placed before the material cures.
- The material takes about a month to reach maximum strength; however, under dry weather conditions, cow and equipment traffic should be acceptable immediately after construction. For wet weather conditions, a 12 -to 24-hour cure or longer should be allowed.

Organic Burial Composting of Cattle Mortality

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Story in Brief

Effective May 1, 2004, composting was approved as a method of disposing carcasses or portions of carcasses of large animals (cattle, other ruminants, horses, and swine) unless otherwise directed by the state veterinarian. Although rendering, extrusion and incineration are approved as methods of large animal disposal, burial is the only method other than composting that is feasible for most cattle producers. Incineration or open burning may be used as long as the carcass is reduced to ash, but other local regulations may exclude burning. Burial guidelines designed to protect water quality limit the land available for burial. In addition timely access to equipment to bury mortality is often a challenge.

Introduction

Composting is the decomposition of organic materials under predominately aerobic conditions. While it occurs naturally under a wide range of conditions, in order to achieve rapid decomposition, specific conditions are required. These "proper" conditions are often thought of in terms of the compost "recipe". The primary consideration in determining the proper recipe is the carbon to nitrogen (C:N) ratio and the moisture content. Other factors that are used to define an ideal "recipe" are listed in Table 1.

Composting is accepted and approved as an environmentally sound method of mortality disposal that also addresses animal health and disease concerns. Normally, composting involves the use of primary and secondary bins with a fairly high degree of management. With these systems, management can be the limiting factor that affects decomposition. This slower decomposition rate results in a lower efficiency of the composting facility.

Composting with low management input is an effective mortality disposal method and can best be expressed as organic burial composting (OBC). In concept, it is simply the burial of mortality in a sufficient amount of carbon to ensure that decomposition takes place in a manner that is acceptable from an environmental and animal health perspective. The objective of this demonstration was to illustrate to cattle producers and the Arkansas Livestock and Poultry Commission the use of composting as a method of dead animal disposal.

Experimental Procedures

The total required volume of carbon material for OBC was based on the size of the composting animal plus additional material to absorb access water and malodors. Design calculations indicated that surrounding a 1,400-lb cow with 18 inches of sawdust exceeded the carbon requirements while providing the necessary moisture and odor control. However, for lower density and carbon sources with lower C:N ratios such as rice hulls and straw, a minimum of 24 inches of supplemental carbon source is required to ensure adequate carbon for decomposition to occur and adequate moisture and odor control.

On September 23, 2002, the carcass of a mature dairy cow was placed on an 18-inch pad of green sawdust. Due to reach limitations of the skid steer being used, it was not possible to place the T-posts and net wire around the carcass as planned. Instead, the carcass was covered without any structure to keep the sawdust from sliding down slope. Then, an existing fence and cattle panels were used to build a fence around the pile. While this approach covered the carcass and prevented animal access to the pile, it also increased the amount of sawdust needed to cover the carcass. This pile was located outside and exposed to the weather.

From October 24, 2002 to December, 2003, an additional 14 cows, mostly mature animals with a few heifers, were added to the pile. Initially, more sawdust was added with each additional mortality. After all available sawdust was used, other on farm carbon sources such as waste silage and waste hay were used. Typically the addition of the new mortality was accomplished by partially excavating the pile, adding the mortality, then covering the animal with a blend of existing compost and new carbon material.

Results and Discussion

On October 2, 2002, 9 days after the first carcass was placed, the pile temperature was 126°F. The temperature climbed to a recorded peak of 129°F on October 7. By October 24, the temperature had dropped to 119°F. On this date the pile was excavated in four separate locations that included the front leg area, the body cavity area, the tail/hip area, and the head area. In the front leg area only one large leg bone and hoof with some connective tissue was found. In the body cavity area the only identifiable pieces were a few hairs. In the tail/hip area only a few large bones were located. In the head area, the skull and some soft tissue were found. While excavating the pile, no excessive odors or flies were observed. In the 31 days since placement of the carcass, the decomposition process had almost completely processed the mortality.

If the pile is left undisturbed, decomposition will continue, but at a greatly reduced rate. If space is limited, the pile can be turned and mixed after the temperature drops back down to about 110°F. It should then reheat to the 130 to140°F range for a period of time. This turning helps to aerate and mix the material to accelerate the decomposition. If space is limited, it is possible to leave the compost undistributed in the pile or windrow, although it will require significantly more time to completely decompose the mortality.

From September, 2002 to December, 2003, 15 animals had been disposed of in the compost pile that had expanded from a 15 x 15 ft pile to a 15 x 45 ft windrow. The most rapid decomposition (31 days) took place with the first animal being placed in green sawdust (almost completely decomposed within 31 days). As more mortality was added to the pile and other carbon sources were used, the rate of

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decomposition decreased.

Additional Observations. On occasion when a fresh carcass was excavated or was not adequately covered, excessive odors did occur. However, the recommended layer of carbon material seemed to do a good job of filtering the odors to background levels. If the animal being composted is large and swells to the point of removing the compost, additional carbon material should be added to the compost pile to cover the animal.

Although there was easy access to the pile by dogs and wild animals, no indication was ever found that animals had dug into the pile. Dogs have dug into other compost piles; if this occurs, restrict the animals from gaining access to the compost.

Due to the concern for water to leach from the pile into ground and surface water, the ground surface down slope from the pile was regularly inspected for signs that the pile was leaching and potentially becoming a source of water contaminates. However, in spite of the fact that the pile was exposed to the weather, no signs of significant water and nutrient movement into the down slope vegetation were ever observed.

One problem observed was that sawdust was prone to blow and slide off the pile. This was addressed by putting a top layer of waste silage on the sawdust. Of the various carbon sources utilized in the demonstration, the green sawdust performed the best in terms of rapid decomposition; however, waste hay and waste silage also worked but at a significantly reduced rate.

The time required to decompose a carcass depends on the size of the carcass, the initial heat of the pile, and whether the pile is turned. Based on a demonstration in Maine, a mature cow placed on a pad of actively composting material (110+°F) should be mostly decomposed in 3 to 4 months. At this time, it may be turned and allowed to compost an additional 2 months. If the carcass is placed on a pad that has not yet started to heat, the decomposition will be slow and it may take up to 6 months before most of it is decomposed. At this point, turning the pile should complete the decomposition in an additional 2 months. If the pile is not turned, the total time to complete decomposition may take as long as 8 to12 months.

Once the decomposition is complete, up to half the compost may be reused as a source of active preheated carbon/compost. The remainder is suitable for land application. Any bone fragments that are left should be brittle and easily broken. The bone fragments may be added back in the next compost pile until decomposition is complete.

There are two basic approaches that apply to the outside composting of large mortality: pile/bin and windrow (Figures 1 and 2). Both approaches start as a pile, however new carcasses are added repeatedly to one end, forming a windrow in the windrow method. Both approaches can be done without the use of some type of sidewall, such as fencing or wooden walls. However, the use of sidewalls will reduce the volume of carbon material required, and help to ensure the 24 inches of cover. Walls will also help to prevent pets and other animals from digging into the pile.

Temperature in the compost pile varies, with the temperatures at the carcass tending to be the highest. One of the critical features of the disposal of animal mortality is disease control. Composting exposes disease-causing organisms to heat, the toxicity of decomposition products, and the microbial antagonism. Of these, heat is probably the most effective in destroying disease-causing organisms. It is generally considered that temperatures of 122 to140°F will kill most viruses. These temperatures also are effective in killing the bacteria that cause anthrax and tuberculosis. It should be noted that while these temperature will kill the anthrax bacteria, it would not kill spores of anthrax or prions associated with bovine spongiform encephalopathy (BSE). Some bacteria such as *clostridia* can survive these temperatures. For this reason, while elevated temperatures are generally effective in killing bacteria, composting sites should be isolated from the rest of the farm and properly managed. Proper management will help ensure elevated temperatures and prevent the access of disease vectors, such as flies and animals, to the composting mortality.

In the traditional method of determining the ratios of the compost ingredients, the ingredients are thoroughly and uniformly mixed. However, when composting animal mortality, it is not practical to grind the mortality to achieve a uniform mixture. Thus, for larger carcasses, there are pockets of low C:N ingredients (the mortality) buried in a larger volume of higher C:N ingredients (the carbon source material). The moisture content within the compost pile also is not uniformly distributed and tends to be highest within and around the mortality.

As a result of these conditions, there are likely to be pockets of anaerobic decompositions in and immediately around the mortality. There also may be a tendency for water from the mortality to saturate the carbon material adjacent to the mortality, resulting in moisture migration to the compost mixture. This means additional carbon material, above the requirements for an ideal recipe, needs to be placed under, to the side of, and on top of the mortality. The extra carbon material serves as a sponge to absorb excess water from the mortality. It also serves as a "biological" filter where odors and objectionable gases are treated prior to being released to the air.

In summary, the composting of large animal mortality should be considered above ground burial of animal carcasses in organic burial composting. The basic concept is to compost the morality in sufficient carbon material to provide the minimum C:N ratio needed for decomposition, absorb excess moisture from the mortality, and filter odors. In practice, it is simply placing the mortality in the center of a pile of carbon material and leaving it for an extended period of time. After building the compost pile, management will probably be limited to adding additional carbon material, to maintain a cover over the mortality. Mixing and re-piling is an option to increase the decomposition rate. However, it will probably only be done if there is limited area that can be dedicated to mortality disposal. After decomposition, the composted material is suitable for land application as soil amendment or reuse as a portion of the carbon material for the next mortality.

Implications

For infrequent mortality disposal such as on cow-calf operations, burial of the mortality in a carbon source such as waste hay at an appropriate site is recommended. This method allows for disposal in a legal, efficient, and economical manner. When composting is exposed to the weather, the compost material (carbon source) may be sawdust, hay, etc., **but may not contain manure**. When the compost is protected from the weather, compost material (carbon source) for the carcasses may be sawdust, hay, etc., **and may contain manure**. Composting involving manure must be done in a bin(s) that has a concrete floor to provide an all-weather base, roof to exclude excess moisture and rot-resistant bin construction to support the compost material and withstand stresses applied by tractor loader.

Literature Cited

On-Farm Composting Handbook, NRAES-54. 1992. Northeast Regional Agricultural Engineering Service, Ithaca, N.Y.

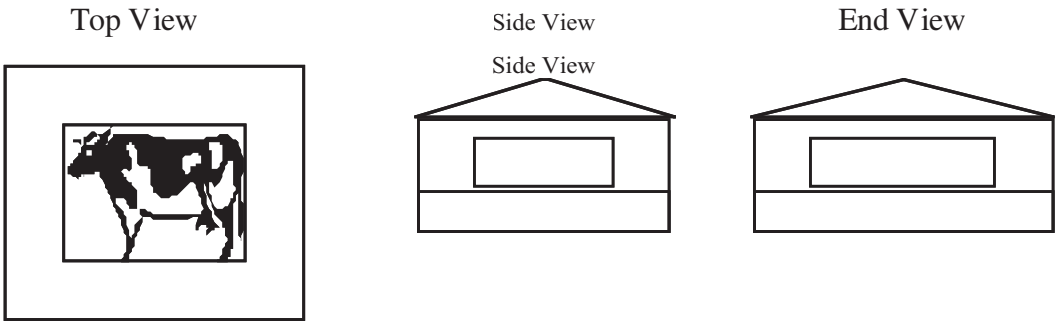

Fig. 1. Recommended organic burial composting (OBC) with Pile Method.

- Select the location of the compost pile. Ensure that the pile will be isolated from the rest of the farming operation on dry ground that is not in a drainage way, and will be accessible to equipment used to move the carcasses and carbon material. Ideally the site should not be visible, or conspicuous, to neighbors and the public.
- Make a 24-inch thick pad of carbon material that is large enough so that when the carcass is placed there will be at least 24 inches from the carcass to the edge of the pad. For a mature cow, this results in a pad that is about 9 x 10 ft.
- Add water to the pad as needed to ensure the pad has a moisture content of about 50%
- Place the carcass on the center of the pad. Consider that the animal may bloat and expand early in the composing process.
- (Optional) Some form of retaining walls can be used. One inexpensive method is to set a tee-post at each corner. Then wrap a 48-inch high net wire around the four posts and secure the wire to the posts. The posts will hold the wire in place until the enclosure is filled. The use of the fence will reduce the amount of carbon material needed to cover the carcass and reduce the chance of pets and wild animals digging into the pile. It will also reduce the land area required to compost.
- Cover the mortality with at least 24 inches of carbon material. Note that if a fence is not used, 24 inches of cover over the center of the carcass will likely result in less than 24 inches of cover part way down the slope. Therefore, more than 24 inches will be required at the top. When finished the pile should be mounded and shaped so that the amount of rainwater that infiltrates the pile is minimized.
- Maintain the carbon cover. It is likely that there will be shifting and settling of the cover material as the carcass decomposes. Therefore, additional material should be added as needed to maintain cover and water shedding ability. In some cases, the composting animal may bloat and extend extremities, including feet which will require additional sawdust, straws, or related material.
- After 3 to 4 months, the pile may be mixed and restacked for an additional 2 months. If the pile is not mixed and restacked, then the total duration of the composting needs to be 9 to12 months. If a compost thermometer is used, the pile should be turned and mixed when the temperature falls below 110°F if a faster decomposition rate is desired. The composting period is considered finished when there is no soft tissue remaining.
- Once the composting is complete, the mixture may be land applied or reused. When reusing the composted material, no more than half of the carbon source should be reused compost.

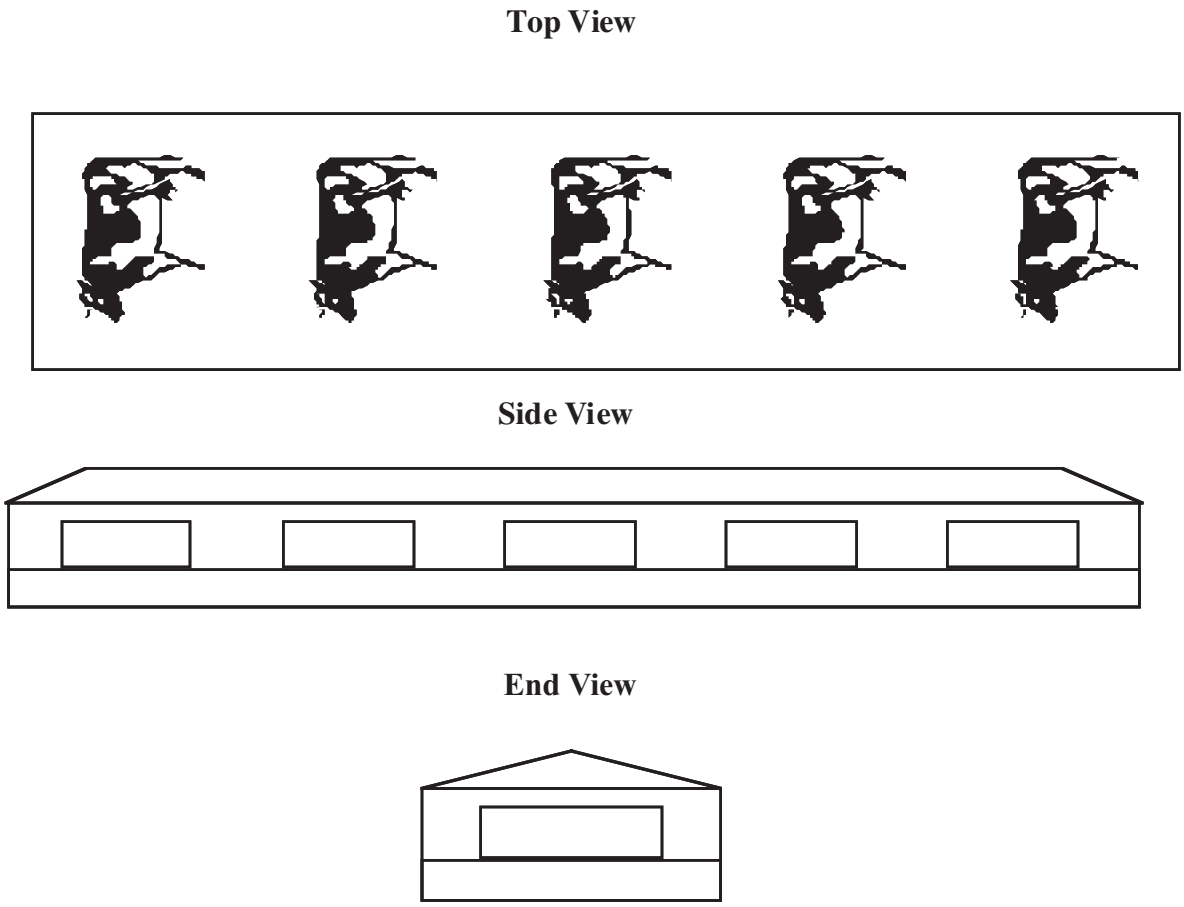

Fig. 2. Recommended organic burial composting (OBC) with Windrow Method.

- The windrow method of composing uses the same dimensions for pad thickness, edge distances, and moisture requirements as the pile method above. The advantage of using windrows is a possible savings in carbon material and a reduction in the land area required to compost several cows.
- Start the windrow with the process described for the pile approach above
- With each new dead animal, the "working" end of the pile is opened and reopened.
- If desired, some carbon material from the existing windrow can be pulled down to form a pad for the new mortality. Ideally, the earlier carcass is not disturbed, unless it is ready for mixing.
- Moisten the new pad as needed.
- Place the carcass in the center of the new pad
- (optional) Add two new tee-posts at the new corners of the pad then wrap additional net wire around the new length and end of the windrow.
- Cover the carcasses with the carbon source material.
- Maintain the cover,

Since a windrow is built over time, the original mortality will likely be decomposed and ready for disposal before the most recent mortality is decomposed. This provides the management options of (1) leaving the windrow alone until the last mortality is decomposed, then utilizing the compost or (2) starting at the original end of the windrow, then utilizing the completed compost.

Table 1. Range of conditions for rapid composting.

Condition	Reasonable range[a]	Preferred range
Carbon to nitrogen (C:N) ratio	20:1 – 40:1	25:1 – 30:1
Moisture content	40 – 65%[2]	50 – 60%
Oxygen concentrations	Greater than 5%	Much greater than 5%
Particle size, diameter in inches	1/8 – 1/2	Varies[b]
pH	5.5 – 9.0	6.5 – 8.0
Temperature, °F	110 – 150	130 – 140

[a] These recommendations are for rapid composting. Conditions outside these ranges can also yield successful results.

[b]Depends on the specific materials, pile size, and weather conditions.

Adapted from On-Farm Composting Handbook, NRAES-54. 1992 Northeast regional Agricultural Engineering Service. Ithaca, N.Y.

DairyMetrics for Arkansas Herds in 2004

J.A. Pennington[1]

Story in Brief

DairyMetrics, a benchmarking tool from Dairy Records Management Systems (DRMS), can compare 72 variables across herds, states, and regions for dairy herds on the Dairy Herd Improvement program. For each variable, DairyMetrics obtained the number of herds in the comparison, average of herds, standard deviation, and highest and lowest herds of the variables for Holstein herds and averages for all breeds in Arkansas. DairyMetrics also compared 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 (IOF$). Percentage of fat in milk had little effect on IOF$ per cow. Herds with less than 44% conception rate at first service had 18,098 lb milk rolling herd average and 5.40 IOF$ compared to 16, 298 lb milk rolling herd average and 4.70 IOF$ for herds with conception rates of greater than 44% at first service, illustrating the negative effect on conception rates of high-producing cows in early lactation. Arkansas dairy producers are now paid a premium for maintaining a herd somatic cell count (SCC) of less than 300,000. To illustrate the negative association of SCC and milk production, milk production of all herds in DRMS were summarized for different levels of SCC.

Introduction

DairyMetrics is a benchmarking tool that herds on the Dairy Herd Improvement (DHI) program can use to compare 72 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, production, reproduction, udder health and genetics. These comparisons 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 also compares 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.

Experimental Procedures

DairyMetrics was used to obtain the average, standard deviation, and low and high herds for various general, production, reproduction, udder health, and genetic variables in Table 1 for Holstein herds in the state (n = 28) plus the average for herds of all breeds (n = 41, or 13 additional herds) in Arkansas in May 2004.

DairyMetrics also was used to compare groups of Arkansas herds for selected variables (Table 2) to illustrate the importance of these variables on efficiency of milk production, using daily income-over-feed costs (IOF$) as the indicator of efficiency. Additionally, DairyMetrics for all herds in the DRMS was used to compare the level of milk production for varying levels of somatic cell count (SCC) in milk.

Results and Discussion

The average, standard deviation, low herd, and high herd for 72 variables from DairyMetrics for all herds and for the Holstein herds in Arkansas are shown in Table 1. Previously designated ranges of 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 mean for the herd 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).

As illustrated by the comparisons of Table 1, Holstein herds were the predominant herds on tests in Arkansas. Compared to last year, one of the most significant changes in the parameters is that milk blend price for all breeds increased from $11.98/cwt to $14.12/cwt (compared to $14.91 in 2001). This increase in milk price for all breeds was the primary cause of daily income minus feed costs increasing from $3.61/cow to $5.07 (compared to $5.18 in 2001). Feed costs/milk/cow increased from $2.97 in 2001 to $3.15 in 2002 to $3.24 in 2003.

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 percentage of cows in milk, lower feed costs per day with a higher IOF, greater rolling herd average for milk, and shorter calving intervals. Additionally, rolling herd average, calving interval, percentage of 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, these data illustrate 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 for Holstein herds were not greatly affected by percentage of fat in the milk. This relationship varies from year-to-year, but dairy producers are paid for additional fat. This year's relationship is positive for milk fat percentage in milk and income-over-feed cost, but milk per cow is often greater in lower fat herds. Additionally, herds with less than 44% conception rate at first service had 18,098 lb milk

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rolling herd average and 5.40 IOF$ compared to 16,298 lb milk rolling herd average and 4.70 IOF$ for herds with conception rates of greater than 44% at first service. This relationship also varies from year-to-year, but this year illustrates the negative effect on conception rates of high production in early lactation, even with relatively small herd numbers.

Table 3 illustrates the negative association of SCC with higher milk production and greater IOF$ in all DRMS herds. Data in Table 2 show a similar effect in Arkansas herds but additional herds were needed to show the relationship in smaller increments. DairyMetrics requires at least six herds in an average. Presently, Arkansas dairy producers are paid a premium for herds with an average SCC of less than 300,000 in milk on a monthly basis.

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. Additionally, it can be used 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. As expected, most variables related to routinely recommended management practices correlated with greater daily income-over-feed costs.

Table 1. DairyMetrics parameters for Holstein herds and averages for all herds.

Traits	Number of herds	Average of herds	SD	Lowest herd	Highest herd	Average for all breeds
GENERAL						
Number of cows	28	133	73	49	315	150
Change in herd size, %	28	-1.9	13.8	-59	28	-0.1
Number of 1st lactation cows	28	46	35	12	146	48
Number of 2nd lactation cows	28	31	18	6	86	36
Number of 3rd+ lactatuib cows	28	55	25	22	116	65
Percentage in milk on test day	28	88	6	69	99	88
Days in milk	28	207	33	161	279	203
Age of 1st lactation cows, mo	28	28	2	23	34	27
Percentage of cows left herd	27	28	8	12	47	29
Percentage of cows died	28	5	2	0	10	5
Daily value produced-milk cows, $	28	8.47	1.74	5.08	11.81	8.19
Daily feed cost-milk cows, $	24	3.35	0.77	2.4	7.6	3.24
Daily income/feed-milk cows, $	25	5.07	1.38	2.9	7.42	4.94
Daily feed cost/CWT, $	25	5.46	1.15	3.02	7.38	5.4
Milk blend, $	28	14	0.93	11.94	15.25	14.12
PRODUCTION						
Rolling milk, lb	28	17,314	3,387	11,750	23,970	16,625
Year change in rolling milk, lb	28	278	1,063	-2,146	1,889	33
Rolling protein, lb	28	538	102	347	737	526
Rolling fat, lb	28	618	126	421		602
Daily milk-milk cows, lb	28	60.9	10.1	42.6		59.1
Daily milk-all cows, lb	28	54	10.7	37.1	74.9	52.4
Daily fat, %	28	3.5	0.3	2.8	4.1	3.5
Daily protein, %	28	3.1	0.1	2.9	3.4	3.2
Summit milk 1st lactation, lb	28	57	9	40	76	55
Summit milk 2nd lactation, lb	28	72	11	50	97	69
Summit milk 3rd+ lactation, lb	28	77	12	57	97	74
Projected 305-day ME milk, lb	28	19,413	3,238	14,009	25,634	18,753
Standard 150-day milk, lb	28	65.8	9.6	46.4	80.6	63.6
REPRODUCTION						
Projected calving interval, d	28	15.5	1.5	12.8	19.4	15.4
Current actual calving interval, d	28	14.4	1	12.7	16.4	14.4
Days open-projected min-all	28	189	45	110	309	188
Days open-projected minimum-1st lactation	28	205	59	105	331	201
Days open-projected minimum-2nd lactation	28	187	49	106	321	184
Days open-projected minimum-3rd+ lactation	28	179	45	100	298	183
Voluntary waiting period (VWP), d	24	48	6	45	60	49
Days to 1st service (%herd < than VWP)	25	10	10	0	34	11
Days to 1st service (%herd VWP to 100 d)	25	51	16	22	83	51
Days to 1st service (%herd > 100 d)	25	37	19	3	75	37
Days 1st service-total herd	25	104	26	60	160	103
Conception rate for year-1st service	28	41	20	0	81	40
Conception rate for year-2nd service	28	42	21	0	87	42
Conception rate for year-3rd+ service	28	41	23	0	82	43
Heats observed for year, %	25	30	14	4	56	31
Number of abortions in past year	28	0	0	0	0	0
Number of calvings in past year	28	90	68	0	292	114

Table 1. DairyMetrics parameters for Holstein herds and averages for all herds. Continued…

Traits	Number of herds	Average of herds	SD	Lowest herd	Highest herd	Average for all breeds
Percent dry less than 40 days	27	13	8	1	31	14
Percent dry more than 70 days	28	38	15	15	74	35
UDDER HEALTH						
Somatic cell count (SCC) actual (x1000)	28	361	172	126	821	371
SCC score (SCCS)	28	3.1	0.6	2.3	4.6	3.2
Cows with SCCS of 0-3, %	28	59	10	33	75	57
Cows <41 d with SCCS > 4, %	28	20	17	0	56	21
1st lactation cows with SCCS of 0-3, %	28	65	12	35	88	63
2nd lactation cows with SCCS of 0-3, %	28	65	14	33	95	63
3rd lactation cows with SCCS of 0-3, %	28	51	14	16	76	50
Cows culled for mastitis, %	28	2	3	0	12	3
SCC score for 1st lactation cows	28	2.9	0.5	2	4	2.9
SCC score for 2nd lactation cows	28	2.8	0.7	1.4	4.6	2.9
SCC score for 3rd lactation cows	28	3.5	0.7	2.5	5.2	3.6
SCC score for cows 41-100 d	28	2.5	1.1	1.2	5.5	2.6
SCC score for cows 101-199 d	28	3	0.7	1.8	4.6	3
SCC score for cows 200-305 d	28	3.5	0.7	2.2	4.9	3.5
SCC score for cows 306+ d	28	3.7	0.5	2.6	5.1	3.8
Value of product lost from SCC, %	28	2	1	0	8	2
GENETICS						
Percentile rank of proven AI bulls	28	40	30	0	85	94
Percentile rank of young AI bulls	28	22	33	0	92	92
Herd bred to proven AI bulls, %	28	43	36	0	100	100
Herd bred to young bulls, %	28	8	14	0	51	55
Herd bred to non-AI bulls, %	28	36	38	0	100	100
Net merit$ for 1st lactation cows	23	101	74	-83	216	216
Net merit$ for heifers	24	103	78	-22	249	249
Net merit$ for all cows	24	62	93	-243	187	187
Heifers ID'd by sire, %	24	64	30	0	100	100
Cows ID'd by sire, %	28	52	40	0	100	100

Table 2. Comparison of Arkansas Holstein herds using DairyMetrics.

Trait for herds	Trait avg	RHA[a]-milk (lb)	Daily IOF[b] $	Calving Interval (mo)	% Cows left herd	SCC[c] (x1000)
Herds of 1-49 net merit, $	-25	15,714	4.93	16.2	29	394
Herds of > 50 net merit, $	118	17,672	5.16	14.9	28	333
Herds with < 169 days open	146	19,322	5.67	14.0	32	308
Herds with > 170 days open	214	16,198	4.78	16.3	26	390
Herds with < 86% in milk	79	15,861	4.77	15.3	28	385
Herds with > 85% in milk	91	17,710	5.16	5.5	28	354
Herds < $4.00 feed cost/day	3.02	16,276	5.00	15.5	30	388
Herds > $4.00 feed cost/day	4.31	19,814	5.14	15.0	24	331
Herds < 16,000 lb RHA milk	14,036	14,036	4.52	16.2	25	427
Herds > 16,000 lb RHA milk	19,435	19,435	5.43	15.0	30	318
Herds < 15 mo calving interval	14.0	19,322	5.67	14.0	32	308
Herds > 15 mo calving interval	16.3	16,198	4.78	16.3	26	390
Herds < 3.5% fat in milk	3.2	17,273	4.89	15.6	29	329
Herds > 3.5% fat in milk	3.7	17,355	5.25	15.3	28	393
Herds < 44% conception %	27	18,098	5.40	15.4	30	325
Herds > 44% conception %	59	16,268	4.70	15.6	27	409
Herds of 1-99 cows/herd	70	14,999	4.57	15.4	24	383
Herds of > 99 cows/herd	168	18,600	5.34	15.5	30	349
Herds < $5 IOF	3.82	15,197	3.82	15.7	25	440
Herds > $5 IOF[2]	6.22	18,710	6.22	15.1	31	307
Herds with < 30% cull rate	22	16,991	4.73	15.8	22	400
Herds with > 30% cull rate	37	18,044	5.53	15.0	37	310
Herds with < 300,000 SCC	220	18,194	5.76	14.9	33	220
Herds with > 300,000 SCC	467	16,654	3.41	15.9	25	467

[a]RHA = Rolling herd average (12 mo)

[b]IOF = Income-over-feed costs, $

[c]SCC = somatic cell counts

Table 3. Milk production and income-over-feed costs (IOF$) for different levels of somatic cell counts (SCC) for all herds in Dairy Records Management Systems (DRMS).

Herd Average SCC	Milk production, lb/year	IOF$
Less than 200,000 SCC	20,682	6.78
200,000-300,000 SCC	20,141	6.64
300,000-400,000 SCC	19,409	6.34
400,000-500,000 SCC	18,967	6.13
500,000-600,000 SCC	18,446	6.07
600,000-700,000 SCC	17,946	5.68
Greater than 700,000 SCC	16,792	5.17

2003 Dairy Herd Improvement Herds in Arkansas

J.A. Pennington[1]

Story in Brief

During 2003, 72 of the 260 dairy cattle herds in Arkansas were enrolled in the Dairy Herd Improvement (DHI) program and completed at least four DHI tests. These herds averaged 9.3 tests with rolling herd averages of 16,536 lb of milk, 620 lb of fat, and 526 lb of protein; mature equivalent averages were 18,470 lb of milk containing 3.6% fat and 3.2% protein. Average milk per cow was 13,008 lb/year on all cows in Arkansas during 2003. This indicates that non-DHI herds averaged less than 12,000 lb per cow since 30% of the cows participated in the DHIA program, compared to the 16,536 lb per cow for herds on DHI. This difference in milk yield of over 4,500 lb per cow affected annual income per cow by almost $550 or approximately $70,000 per herd. The quartile data of milk production for the Holsteins with DHI records also reinforced that income over feed costs was about $900 per cow greater for the highest producing quartile of herds compared to the lowest producing quartile of herds. Average income over feed costs were $1,139/cow, $95/cow greater than in 2002, and due primarily to improved milk prices. Improved udder health and reproduction were also associated with higher producing herds and contributed to this difference in income per cow. Opportunities exist for increasing 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. These 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 more milk nationally per year than herds not on DHI. Although many factors affect production per cow, this difference in production has a significant effect on net income for the dairies. Increased 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/her dairy to other dairies, so that areas of management that need improvement can be detected.

Experimental Procedures

Dairy cattle herds on test (n = 72) in Arkansas reported 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, protein and somatic cell count (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, Kan. Records were processed at Dairy Records Management Services (DRMS), Raleigh, N.C., and analyzed by the SAS system (SAS Institute, Inc., Cary, N.C.). State Management DART (Direct Access to Records by Telephone) was used to analyze data in previous years.

Results and Discussion

In December 2003, 72 of the 260 dairy cattle herds in Arkansas were enrolled in the DHI program and completed at least four DHI tests. These herds averaged 9.3 tests per year with a rolling hard average of 16,536 lb milk, 620 lb (3.6%) of fat, and 526 lb of (3.1%) protein; mature equivalent averages for the herds were 18,470 lb milk containing 3.6% fat and 3.2% protein.

Rolling herd averages for all breeds of 52 DHI herds on supervised tests are in Table 1. The 52 dairy cattle herds represented in Table 1 were less than the 72 dairy herds that were reported on DHI through other summaries. The primary reason for the difference in numbers was that herds reported in Table 1 had at least 10 test periods. Income minus feed cost averaged $1,139/cow this year for the Holstein herds compared to $1,044/cow last year. The increase in income minus feed cost primarily is related to slightly higher milk prices in 2003, but both 2002 and 2003 had lower milk prices than previous years. In 2000, Holstein herds averaged $1,184 in income minus feed costs. The Jersey herds averaged $1,116/cow/year for income minus feed costs; however, only two herds were included in the Jersey summary. Few non-Holstein herds were on DHI in Arkansas, but the Jersey herds showed similar yields to reports from other states. In the United States, 95% of cows on test are Holsteins and over 3% of cows on test are Jerseys.

Table 2 shows the Holstein DHI averages for herds with 10 tests by quartile of milk production. The quartile data for the Holstein herds illustrate the relationship of higher milk production to higher income minus feed costs. As expected, the high quartile of herds had higher peak milk levels than other herds and but also had lower somatic cell counts, fewer days to first service, less days open, and lower calving intervals than lower producing herds.

This year's analysis shows 6.1% of cows left the other herd for other dairies, 9.2% due to death loss, and 1.8% for disease. The percentages are similar to other years, except that death losses were greater than the 5 or 6% in most years.

For quartile data, the 23 Holstein herds were official herds with 10 tests during the year, a number less than the 35 herds last year.

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However, the total number of herds (n = 72) was about the same percentage of total farms as last year (79 of 312 herds). Herds may have been tested less frequently as a result of relatively low milk prices. There also were three goat herds on DHI. The list of 72 cow herds included any herd on DHI in 2003, including herds no longer on the DHI program. Additionally, two dairy cattle herds used the PCDART on-farm computer program for production testing and were not included in the 72 herds currently listed that were processed through DRMS. Still, only 28% of the 260 herds in 2003 were involved in the DHI program. If the cows from herds using PCDART are combined with the cows in the 72 DHIA herds, then over 30% of the cows in Arkansas were on test in 2003, and that achieves a goal that has been set for many years.

Herds on DHI averaged 16,536 lb milk/cow/year compared to the Arkansas average of 13,008 lb/milk/year, according to the Arkansas Agricultural Statistics Service. Omitting DHI herds from the state average indicated that the non-DHI herds averaged less than 12,000 lb milk/year. The difference of over 4,500 lb milk/cow/year affected income by almost $550/cow/year. This difference in milk income would be $70,000 per year in a 131-cow herd.

Implications

DHI program participation affords dairy producers an opportunity to maintain records of milk production on individual cows and other management practices. Herds utilizing DHI records averaged 16,536 lb milk/cow/year versus less than 12,000 lb/cow for herds not on DHI test. Producers should be encouraged to enroll in the DHI testing program.

Table 1. 2003 Arkansas Dairy Herd Improvement (DHIA) averages for all breeds.

Trait	No. herds	Mean	SD
Number of cows per herd	51	131.5	143.5
Rolling herd average for fat, lb	51	584	117
Rolling herd average for protein, lb	51	511	96
Peak milk, lb			
1st lactation cows	52	58.3	11.7
2nd lactation cows	52	74.0	13.1
SCC[a], average (x 1000)	51	422	181
SCC linear score	51	3.4	0.6
Days to 1st service	52	89	40
Days in milk, %	51	85	5
Days in milk, average	52	192	27
Cow index (PTA$[b])	46	43	108
Sire genetics (PTA$)			
1st lactation cows	52	22	25
2nd lactation cows	52	18	20

[a] Somatic Cell Count
[b] Predicted transmitting ability in $

Table 2. 2003 Arkansas DHI averages for official Holstein herds (n = 23).

Production trait	Quartile 1[a]	Quartile 2	Quartile 3	Quartile 4
Rolling herd average milk, lb	22,205	18,608	15,707	13,402
Peak milk, 1st lactation, lb	75.6	68.2	54.2	50.0
Peak milk, 2nd lactation, lb	91.0	78.8	70.5	63.0
Peak milk, 3+ lactation, lg	98.2	86.7	76.3	65.7
Peak milk avg, all lactations, lb	82.6	75.8	65.3	58.8
Somatic cell count x 1000	297	312	407	690
Days to 1st service	84	95	78	149
Days open	160	182	188	212
Projected calving interval, mo	14.5	15.2	15.4	16.2
Income minus feed cost, $	1,610	1,266	1,092	690

[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.