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Department Report • 2001

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Editors

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ARKANSAS ANIMAL SCIENCE DEPARTMENT REPORT • 2001

JOHNSON AND KELLOGG

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DIVISION OF AGRICULTURE

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No findings, conclusions, or reports regarding any product or any process that is contained in any article published in this Report should imply endorsement or non-endorsement of any such product or process.

INTRODUCTION

The faculty and staff of the Animal Science Program are pleased to present the fourth edition of the Arkansas Animal Science Department Report.

By the time this is published, construction of our new swine finishing facilities should be completed and the facility filled with new pigs. This facility, provided through state appropriated funds, greatly expands our total program in swine management including emphasis on environmental issues.

Development of new pasture systems for the forage research area and the equine unit has resulted in an attractive setting for the north entrance to the campus. Reaction from the community and alumni has been most positive. A quality herd of brood mares and a stallion has been assembled through donations during the past year. Student interest has been high as projected. Extension and service programs in both youth and adult education were expanded to meet the increased demand for equine education. The department continues to develop new courses and adjust the curriculum to meet an increasingly non-traditional student base.

Distance education took on added importance. A graduate course in Advanced Livestock Management was taught via compressed interactive video by faculty from the campus and also from the Southwest Research and Extension Center in Hope. Students from these two locations, as well as students from Little Rock and Batesville, took the class. In Fall 2001 for the first time, a senior beef production course will be taught via compressed interactive video to students on the campus and at one or more Research and Extension Centers in the state. The lead instructor will be an Animal Science faculty member at the Southwest Research and Extension Center in Hope.

Animal Science Extension programs are broad-based and include beef cattle, dairy cattle, horses, forages and grazing management and 4-H youth activities. The Arkansas Beef Improvement Program uses an integrated resource management team approach to enhance the efficiency and profitability of cattle producers. The Feedout Program provided a method for cow-calf producers to obtain feedlot and carcass data. With the assistance of the Livestock Market Reporters, livestock auction data were collected to determine factors affecting the selling price of feeder cattle. The Beef Quality Assurance Program addressed management factors that affect the quality of the cattle producers' product. The overall goal of the program is to encourage the consistent production of high quality cattle.

Extension programs helped dairy producers and the related industry to identify areas needing improvement to enhance production efficiency. Producers were assisted with integrating management practices such as waste management, sire selection, nutrition, reproductive management, and financial management to increase profitability.

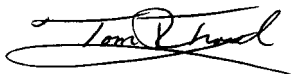
Forage and grazing management are extremely important components of any grazing livestock system. Arkansas Grazing Schools were designed to teach management options to improve efficiency of forage utilization. Forage demonstrations included using stockpiled forages to reduce hay feeding and improving pasture quality and quantity through pasture renovation.

4-H livestock programs are a very important educational effort of Animal Science. Over 8,000 youth enrolled in beef, dairy, sheep, swine and horse 4-H programs. These programs teach lifetime skills in the areas of animal and veterinary science through demonstrations, livestock judging and exhibition of animals at county, district and state levels.

We are committed to ensuring that our programs in research, teaching and extension are effectively meeting the needs of the Arkansas livestock industry.

Sincerely,

Keith Lusby
Department Head



Tom Troxel
Section Leader

INTERPRETING STATISTICS

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

Most data will be presented as means or averages of a specific group (usually the treatment). Statements of probability that treatment means differ will be found in most papers in this publication, in tables as well as in the text. These will look like ($P < 0.05$); ($P < 0.01$); or ($P < 0.001$) and mean that the probability (P) that any two treatment means differ entirely due to chance is less than 5, 1, or .1%, respectively. Using the example of $P < 0.05$, there is less than a 5% chance that the differences between the two treatment averages are really the same. Statistical differences among means are often indicated in tables by use of superscript letters. Treatments with the same letter are not different, while treatments with no common letters are. Another way to report means is as mean ± standard error (e.g., 9.1 ± 1.2). The standard error of the mean (designated SE or SEM) is a measure of how much variation is present in the data—the larger the SE, the more variation. If the difference between two means is less than two times the SE, then the treatments are usually not statistically different from one another. 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.

Some experiments will 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 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.

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

COMMON ABBREVIATIONS

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

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Cover photo: Dean Scarbrough, Ph.D. student and research associate, conducting forage research.

Instruction in Milk Production Using a Tour of Diverse Farms

D. W. Kellogg[1]

Story in Brief

The popular Milk Production course involves travel to a variety of dairy farms so students can observe different facilities and study various management styles. Milking and handling facilities range from small, inexpensive herringbone and trigon milking parlors to large, automated parlors that require huge capital investments. Relatively new parallel parlors with rapid exit technology are observed. Two New Zealand innovations are included on the tour: 1) a 64-cow, low-technology, herringbone milking parlor in a barn that is open (has no walls) on three sides and 2) a high-technology, 40-cow rotary milking system. Housing systems vary from cows on pasture and in southwestern-style dry lot corrals to cows maintained in new free-stall barns. Managers and owners explain their management styles, discuss their problems, and demonstrate animal handling facilities. Students express their appreciation for the "hands-on" learning made available by traveling to the dairy farms.

Introduction

In 1997 Dr. Charles Rosenkrans and Dr. A. Hayden Brown led a group of students on a tour of farms to demonstrate various styles of dairy farming in the region. After that first trip was evaluated, it was decided that the idea was worth pursuing to instruct interested students. The only major frustration that surfaced was the need for students to gain some basic information before leaving the campus so they could understand terminology used by dairy producers and could ask intelligent questions. For the past 4 years, Dr. Kellogg has directed the course and included a 4-day farm tour in three states. Other faculty members, extension specialists, private consultants, and dairy producers have assisted with the instruction. Students have given excellent evaluations of the course, and many suggestions for its improvement have been incorporated to improve the course. The goals of the milk production course are to provide a basic understanding and specific vocabulary of dairy farming, to observe different facilities for milking and housing cattle, and to study various management styles of well-managed dairy farms for advanced undergraduate students.

Experimental Procedures

Three, 3-hour lecture sessions were scheduled to present an overview of nutrition, reproduction, genetics, record systems, herd health, and marketing.

Separate sessions were offered on two evenings for consecutive weeks to encourage attendance. The video, "From Feed to Milk: Understanding Rumen Function" (Heinrichs et al., 1996), was selected to present dairy cattle nutrition and management to the class. Slide presentations titled, "Survey of management practices used for the highest producing DHI herds in the United States" (Kellogg et al., 2001) and, "Optimal genetic improvement for the high producing cow", (Cassell, 2001) were used to present management and genetics. Dr. A. H. Brown served as a guest lecturer on genetic improvement and selection of cows. Material was provided by Dr. Rick Rorie for the presentation on reproductive management and artificial insemination of cows.

Pasture-based dairy farming was demonstrated at Double D Dairy Farm near Rudy (AR), Simon Family Dairy Farm near Conway (AR), Green Acres Dairy Farm near Greenbrier (AR), Helms Dairy Farm near Arkadelphia (AR), Pine Star Farm near Sulphur Springs (TX), and Alexis Roulet Dairy near Evansville (AR) on the most recent tour. To show students the techniques used for intensive housing of dairy cows, tours were arranged at Ark-Tenn Dairy Farm near Center Ridge (AR), Rose-Ark Dairy near Rosebud (AR), Jack Kempanaar Dairy Farm near Sulphur Springs (TX), Johnston Dairy Farm near Comanche (TX), and Alan Richey Dairy near Durant (OK). Herds with open corral systems were the Leo and Christina Ruyne's Farm near Sulphur Springs (TX) with wading ponds to cool cows and the Juan Escobar Dairy Farm near Comanche (TX) with shades to cool cows. The herds also represented a selected sample of different milking parlors used in the region, including varying levels of automation. All six breeds of dairy cattle were represented on the farms. Different styles of management included milking two vs. three times daily, grouping cows by production vs. grouping cows by stage of lactation, and registered vs. grade (or commercial purebred) cows.

Students were required to keep a journal of the trip and to record their impressions of each farm. Students were instructed in advance to select a topic about dairy farming that interested them on the tour. After returning to campus,

[1]Author is associated with the Department of Animal Science, Fayetteville.

they were required to find an article published about that topic, and write a brief report supporting, or refuting, the practice that they found being used on a dairy farm.

Students were asked to evaluate the course, emphasizing written responses to each aspect of the course.

Results and Discussion

The video was a superb presentation of dairy cattle nutrition and included thorough discussion of carbohydrate ratios, protein digestion, and rumen buffers. An additional benefit of the video was presentation of feeding management and dairy farming in the Northeast United States where colder winter temperatures require different cattle housing and management compared to the South and Southwest. It was of particular assistance in keeping the attention of students during a 3-hour, evening lecture session. The two sets of slides also helped to break the long sessions into interest areas. All the materials helped introduce vocabulary used by dairy farmers and assisted in meeting the goal of preparing students to learn from the producers, extension specialists, and consultants they would encounter on the tour.

Farms with pasture systems.

Double D Dairy Farm, owned by Charles and DeWite DeShazo, had over 200 cows on pasture, but grain was supplemented at several computerized feeding stations. The computer was re-programmed regularly so the Holstein cows received amounts of grain appropriate for their production level. Constant maintenance of the system allowed expression of genetics for high production by cows receiving bovine somatotropin (BST) even though cows grazed pasture when grass was available. Students were allowed to observe the milking parlor and equipment closely and to ask questions about each phase of the farm's management.

Simon Family Dairy Farm milked over 100 Holstein and Jersey cows. Cows were on pasture, but they supplemented cows by feeding a total-mixed ration (TMR) based on grass silage that they raised and commodities that they purchased. A commodity barn allowed them to purchase truckload lots of grains and soybean meal to mix with the grass silage. Their milking parlor was new, but incorporated some used equipment to reduce initial investment costs.

Green Acres Dairy Farm near Greenbrier is owned by Chris Acre's family. Their 114 registered Holstein cows have routinely been among the top-producing herds in Arkansas, and the animals are often shown at fairs and other competitive events. Their cows were on pasture but also received corn silage and grain supplements to support high milk production.

Helms Dairy Farm is located near Arkadelphia. The family farm had air-tight silos and an auger feeding system for corn silage, haylage, and high-moisture grain that they raised. In addition to the automated feeding system, their cows grazed pasture in season.

A "New Zealand style" dairy farm (Pine Star Farm owned by Robbie and Susie Bean) had capability to manage 1000 cows on pasture with a simplified double 32-stall, herringbone, milking parlor that was open (no walls) to the west, south, and east, an unusual (for the United States) parlor design. Cows were fed a grain mixture immediately after milking. Two large troughs allowed twice as much time to eat as it takes to milk cows. The cows relied heavily on pasture during the growing season. Excess pasture was harvested as hay to provide supplemental feed when pastures did not produce enough feed for the cows.

The Alexis Roulet Dairy Farm near Evansville featured a remodeled old barn containing a new "trigon" milking parlor. The three herringbones had 12 milking stalls and allowed the person to move in a tight circle while milking rather than walking back and forth in a conventional double herringbone parlor. Some grain was supplemented in a separate feeding barn, but the farm did not emphasize high milk production. The herd of about 70 registered Brown Swiss cows grazed pasture, although hay was fed due to the limited availability of grass.

All six of the dairy farms that relied heavily on pasture approached supplementation of pasture differently depending upon their goals. The tour allowed students to see that high milk production is possible with pasture by combining an economical means of supplementation. It also shows the necessity of planning carefully to alternate with stored forages when pasture is not growing or when the quality of pasture is low.

Farms with intensive management of cows.

Ark-Tenn Dairy Farm is located near Center Ridge. The entire farm was constructed and began milking cows in December, 1998. They had over 1000 cows of three breeds—Holstein, Brown Swiss, and Ayrshire—and plan to demonstrate several styles of management. Cows were milked three times daily. In addition to the free-stall barn for 900 cows fed a TMR based on corn silage, some cows were on pasture. The corporation owned a feed mill, but they maintained some commodities on the farm. The concrete side of a bunker silo doubled as the back wall of the commodity shed. The waste disposal system of large lagoons was approved for 2100 milking cows.

Rose-Ark Dairy near Rosebud, owned by Ricky Strain, was a new farm with a rotary milking parlor for 1200 cows. Although the farm existed on a smaller scale for many years, they began milking in the new parlor during April, 2000. The cows voluntarily entered and left the parlor very efficiently, although exiting meant they had to back off the moving platform. The cows were housed in six free-stall barns. Cows were fed a TMR based on small-grain silage.

The farm of Leo and Christina Ruyne near Sulphur Springs, Texas, had a covered feeding barn and an outdoor feeding area for a TMR. Cows had access to large "pasture" areas, but the paddocks served basically as exercise lots because of the number of animals. Part of a lake was used to cool cows that submerge themselves in the water during hot weather, and cows could enter or leave the water to go to the feeding area when they choose.

The Jack Kempanaar Dairy Farm near Sulphur Springs

had excellent management of a large herd in free-stalls that was fed grass silage. The farm had a unique system of collecting flush water from seven large free-stall barns. The solid material was removed before effluent enters a large irrigation pond, and the solids are dried for use as bedding in the free stalls. The Holstein herd was bred artificially to outstanding sires, and the quality of cows was evident from their appearance and high production (usually over 80 lb/cow/day).

The Escobar Dairy Farm near Comanche, Texas, had a 400-cow Holstein herd with cows maintained in open corrals with shades—a style typically used in warm, arid regions. Cows were feed a TMR in covered feeding troughs in the corrals.

In contrast, Ray Johnston had an 1800-cow dairy farm near Comanche with free stalls that were scraped rather than flushed. Manure was collected, loaded, and moved to compost piles on the farm. A large machine stirred the rows of drying compost, and it was ultimately sold or used for fertilizer in fields of corn silage. A double-20 stall, parallel parlor was completely automated with a new computerized system that maintained records on the milking parlor operations. The cows typically produced over 80 lb per day.

The Alan Richey Dairy in Oklahoma, managed by Dave Allenson, was a very attractive farm featuring new technology to milk 3200 cows. They produced much of their own feed on the large farm, including 2400 acres of silage corn. The TMR also used wheat silage and chopped alfalfa hay that was grown locally. A large calf barn housed calves in individual stalls.

Student evaluations.

Some of the typical comments, criticisms, and suggestions of the students after the course were as follows:

What I liked most about the course:

– "The information was relevant and applicable to dairy production. Having different topics covered by 'experts' in their area was also beneficial."
– "I enjoyed the trip! That was the best part. Actually seeing the farms working was incredible, especially the rotary."
– "I loved this class! The lectures were very informative and kept me interested in learning. The dairy tour was great! It was so nice to get some hands-on experience about modern dairy practices."
– "The course gave some very good knowledge and insight into the dairy industry. Many different styles, aspects, sizes, and attitudes towards milk production were seen through the tour of the many different dairies and operators."
– "The trip was excellent. What a great way to apply lecture material to the real world. Talking with the actual producers provided true insight into the ups and downs in the dairy industry."
–"A lot of fun, and I learned a lot."
–"I learned more in this class than I have in any other University ANSC course."
–"The course is good to see the real world of dairy operation and problems."

Suggested improvements:

– "Maybe visit more diverse, more common (smaller) dairies."
– "I think the paper needed to be a little longer."
– "None."
– "I don't really have any suggestions. The class and trip were very well organized and informational, and entertaining."
– "More information on current production schemes, methods used for increasing milk production, and dairy nutrition and forages."
– "Shorten the trip to three days."
– "I wouldn't change a thing."
– "I would have retained more information if the class were one hour per week prior to the trip."

Implications

The tour permits an excellent learning environment for students in milk production and helps compensate for the lack of a dairy farm at the University.

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Demographics and Academic Success of Animal Science Graduate Students

C. F. Rosenkrans, Jr., Z. B. Johnson, and W. K. Coblentz[1]

Story in Brief

The purpose of this study was to determine if there are quantifiable indicators of an undergraduate's potential as a graduate student. We evaluated 54 state assistantship supported graduate students from 1990 to 1998. Overall those students had an undergraduate GPA of 3.17, graduate GPA of 3.47, and graduation rate of 72%. Effects of gender were noted on the GRE quantitative score and percentage of students in the Ph.D. program, both lower for women than men. Students receiving their undergraduate degree from the University of Arkansas had the lowest graduation rate (52%) compared with students from other institutions graduating at greater than 80%, although graduate GPA was not different. The best predictor of graduate GPA was a combination of undergraduate GPA and GRE quantitative score. We found that graduate student graduation rate was not successfully modeled by the quantitative information that we collected, indicating that graduate student success may depend more on collective intangible items and determination than past academic record.

Introduction

Land-grant universities fulfill their mission using three approaches, education, research, and extension/outreach. Educating graduate students is an integral component of that mission. Nationally, the number of graduate students peaked during the early 1990's and has declined by as much as 2% per year in the last few years. That decline has been particularly true for the biological sciences, the general category in which agriculture and Animal Science programs exist. However, at the University of Arkansas our graduate student enrollment has been increasing during the last few years. Those students have gone on to impact the animal industries and scientific community; thereby, enhancing and building our national and international reputation.

One of the more difficult decisions for a faculty member is whether or not to accept the responsibility of mentoring a graduate student. Once the decision is made that monetary commitments can be made for an incoming student, then the decision is: Which student? How do we decide which student to accept as an advisee? Once we have a match in personalities and research interests, are there quantitative factors that could indicate a student's potential success in graduate school? Our objective was to determine if an undergraduate's academic record could be used as predictor of that person's potential as a graduate student.

Procedures

Our data set contained information from 54 graduate students who were on state assistantship during 1990 to 1998. The information collected was gender, undergraduate institution and cumulative grade point average (GPA), graduate record examination (GRE) scores, graduate degree (M.S. or Ph.D.) they were seeking, graduate GPA, and graduate school graduation (yes or no). The data set excluded all currently enrolled students. Data were analyzed to determine gender, undergraduate institution, and GRE effects on graduate student GPA and graduation percentage. In addition, regression analyses were used to determine which factors most accurately predicted graduate GPA and graduation rate.

Results and Discussion

Overall demographic profile of our data set was as follows: gender was split with 22 women and 32 men. Forty students were seeking the master of science degree and 14 were pursuing the doctorate of philosophy. Their average undergraduate GPA was 3.17 and their graduate GPA was 3.47 on 32 hours. Graduate GPA was correlated with undergraduate GPA ($r = 0.23$; $P = 0.1$); GRE quantitative score ($r = 0.47$, $P = 0.02$); and number of graduate hours ($r = 0.35$, $P = 0.01$). Those simple correlations suggest that a graduate student's academic performance was related to their undergraduate academic record as well as their math skills on a standardized test. Lastly, students completing a greater number of graduate hours, typically a Ph.D. student, have a higher GPA than those not taking as many hours.

Table 1 presents the means separated by gender. The two significant ($P < 0.05$) effects of gender were on GRE quantitative score and percentage in the Ph.D. program, both of which were lower for women students. Those results are consistent with observations at other universities and disciplines in the biological sciences. However, neither graduate

[1]Authors are associated with the Department of Animal Science, Fayetteville.

GPA or graduation rates were affected by gender.

The school the graduate student attended as an undergraduate was coded into one of four categories: University of Arkansas, other land-grant schools, non-land grant schools, and international. Table 2 presents the means separated by undergraduate school. The most striking and significant finding in that analysis was the graduation percentages. Students attending the University of Arkansas as undergraduates had the lowest graduation rate (52%); whereas, international students had the highest graduation rate (100%). Those findings were quite troubling, but when undergraduate academics were evaluated, the University of Arkansas students ranked well in each category. Our interpretation is that students who move schools and even to other countries are probably more committed to completing their graduate education; whereas, those who stayed at home might move on to other employment opportunities as the rigor of graduate school increased.

Twenty-five (46%) of our graduate students in this data set took the GRE. It is the general policy of the University of Arkansas' Graduate School to require students who do not have an acceptable undergraduate GPA for unconditional admittance to take a standardized test (i.e. GRE). Therefore, it was not surprising to find that students who had taken the GRE had a lower ($P < 0.05$) undergraduate GPA (3.32 vs. 3.00) and a greater ($P < 0.05$) number of graduate hours (36 vs. 28). Graduate GPA (3.49 vs. 3.46) and graduation percentages (80 vs. 66, respectively, for *yes* and *no* GRE score) were not different when analyzed by GRE. The mean overall GRE score for our students was 1500 with subscores of 523, 573, and 404, respectively, for analytical, quantitative, and verbal. Mean GRE score for 159 graduate students taking the GRE at the University of Arkansas in 1998-99 was 1559 with mean subscores of 552, 535, and 472, respectively, for analytical, quantitative, and verbal. For that same year nationally, 700 animal science majors took the GRE with a total mean of 1582, and subscores of 577, 560, and 445, respectively, for analytical, quantitative, and verbal. When comparing our students with their norms, we find that our students were at least 10% below their colleagues on the analytical and verbal scores, but scored higher than their contemporaries on the quantitative subscore. That interpretation agrees with our faculty's general consensus. That is: our graduate students need more development of their analytical/interpretive and communication skills as a part of their educational plan of study.

Our overall graduation rate for these graduate students was 72%. Sixty-three percent of the master of science students graduated; whereas, 100% of the doctoral students completed their degrees and graduated. Those numbers add credence to the interpretation that commitment to their graduate program is a determining factor in whether or not students complete their graduate program. Generally speaking, a Ph.D. student is older, more mature, and more certain (committed) that graduate education is a part of their future than are most entering M.S. students.

Regression analyses on the determinants of graduate GPA revealed that undergraduate GPA and GRE quantitative score were the best quantitative indicators of graduate GPA. We also used logistic regression to determine if the quantitative information that we collected could be used to predict graduation rates of our graduate students. Those results indicated that we could not use quantitative information to predict graduation rate.

Our data set was limited due to the small number of students, but our results confirm what many have thought. Graduate student academic success may in fact be modeled by the undergraduate academic record; however, actual completion of their degree requirements and graduation may be more dependent on less tangible factors. Some of those factors include graduate advisement, personal commitment, family obligations, and job opportunities. In this era of shrinking enrollments in graduate schools, particularly in the biological sciences, we are fortunate to have maintained and in fact increased our graduate student enrollment in the Department of Animal Science. Our results suggest we need to survey our former students and determine why they left without completing their degrees so that we can continue to expand our program and its influence on the animal industries and scientific community.

Table 1. Relationships between gender and academic records

Item	Women	Men
Number	22	32
Undergraduate GPA	3.22	3.14
Graduate GPA	3.47	3.48
Graduate Record Exam		
Analytical	552	514
Quantitative[1]	512	593
Verbal	450	389
Masters program,%	48	52
Doctoral program,%[1]	21	79
Overall program,%	41	59
Graduation rate,%	73	72

[1]Means and percentages are different (P < 0.05).

Table 2. Relationships between undergraduate school and academic records.

	Undergraduate Institution			
Item	Univ. of AR	Land-grant	Non-Land grant	International
No. of students	23	8	15	8
Undergrad GPA	3.19	3.15	3.23	3.03
GRE total	1,490	1,545	1,522	1,468
Graduate hours	27	30	35	41
Graduate GPA	3.67	3.64	3.5	3.56
Graduation,%[1]	52	88	80	100

[1]Percentages are different (P < 0.05) by Chi-square.

Efficacy of Mannan Oligosaccharide (Bio-Mos®) as a Complete or Partial Replacement for Zinc Oxide in the Diets of Weanling Pigs

E. Davis, D. Brown, S. Singh, C. Maxwell, and Z. Johnson[1]

Story in Brief

A total of 216 barrows (1/2 Large White x 1/4 Duroc x 1/4 Landrace; 21 ± 2 d of age; 12.3 ± 0.01 lb BW) were fed six treatments to determine the potential for Bio-Mos® to replace pharmacological additions of zinc oxide. Pigs were blocked by BW and penned in groups of six (six pens per treatment). Treatments were arranged as a 2 x 3 factorial with two dietary concentrations of Bio-Mos® (0 and 0.3%) and three dietary concentrations of zinc (165, 500, and 2,465 ppm). Experimental diets were fed throughout the study, however zinc was reduced to 165 ppm in all diets during Phase 3 (d 21 to 35). Blood samples were obtained to measure lymphocyte proliferation on d 21, 22, 26, and 27. From d 7 to 21 after weaning (Phase 2), ADG was greater ($P < 0.05$) when pigs were fed 2,465 ppm zinc compared to those fed 165 or 500 ppm. Pigs fed 2,465 ppm zinc had greater ($P < 0.05$) ADFI than pigs fed 165 ppm and lower ($P < 0.05$) F/G than pigs fed 500 ppm zinc. Bio-Mos® improved ($P = 0.02$) F/G during Phase 2, and improved ($P < 0.03$) ADG and F/G from d 21 to 28 after weaning. Lymphocyte proliferation of unstimulated cell cultures was reduced ($P = 0.03$) in cells isolated from pigs fed Bio-Mos® when compared to those from pigs fed diets without Bio-Mos®. Proliferation of cell cultures stimulated by pokeweed mitogen and phytohemagglutinin was greater when cells were isolated from pigs fed 165 ppm zinc without Bio-Mos® supplementation than when pigs were fed the same level of zinc with Bio-Mos® supplementation. However, proliferation did not differ regardless of Bio-Mos® supplementation when the diets contained 500 and 2,465 ppm. This resulted in a Bio-Mos® x zinc interaction ($P < 0.05$). This study indicates that pharmacological concentrations of zinc improve ADG and ADFI during Phase 2, while Bio-Mos® improves ADG and F/G during the last week of Phase 3.

Introduction

Bio-Mos® (Alltech, Nicholasville, KY) is a mannan oligosaccharide derived from the cell wall of yeast that has resulted in improved weight gain and feed efficiency when added to the diets of weanling pigs. Previous research comparing Bio-Mos® and the addition of pharmacological levels of zinc oxide has resulted in significant ADG and F/G responses to Bio-Mos® (Davis et al., 2000). Environmental restrictions in Europe have limited the amount of zinc that can be added in swine diets to 500 ppm. Research assessing pig response to dietary zinc oxide additions report no benefit when supplementing zinc at lower levels (250 to 500 ppm) over adding zinc to meet the pigs' dietary requirement (Kornegay et al., 1993; Hill et al., 2001). This study was conducted to determine the efficacy of Bio-Mos® to serve as a replacement for pharmacological additions of zinc, and to determine if Bio-Mos® addition in diets containing 500 ppm zinc would improve gain and efficiency responses to a level comparable to supplementation with pharmacological levels of zinc. In addition, the effect of dietary treatment on the pigs' immunocompetence was evaluated by measuring lymphocyte proliferation in response to mitogens administered in vitro.

Experimental Procedures

A total of 216 weanling barrows (1/2 Large White x 1/4 Duroc x 1/4 Landrace; 21 ± 2 d of age; 12.3 ± 0.01 lb BW) were obtained from a single source and transported to the University of Arkansas off-site nursery facility. Pigs were sorted by weight and divided into six weight groups (blocks). Pigs within each weight group were allotted into equal subgroups (six pigs per pen), and treatments were randomly assigned to pens (subgroups) within each of the weight groups.

Six dietary treatments were fed consisting of two levels of Bio-Mos® (0 and 0.3%) and three concentrations of inorganic zinc (165, 500, and 2,465 ppm) in a 2 x 3 factorial arrangement of treatments. The specific treatment diets fed during the first 7 d after weaning (Phase 1) consisted of the following: 1) a negative control diet containing zinc at 165 ppm from zinc oxide, 2) the negative control diet plus 335 ppm zinc as zinc oxide, 3) the negative control diet plus 2,300 ppm zinc as zinc oxide, 4) as 1), supplemented with 0.3% Bio-Mos®, 5) as 2), supplemented with 0.3% Bio-Mos®, and 6) as 3), supplemented with 0.3% Bio-Mos® (Table 1). Substitutions in all diets were made at the expense of corn. Phase 1 diets were fed for a period of 7 d after weaning. Upon completion of Phase 1, pigs were fed a Phase 2 diet (1.35%

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lysine) from d 7 to 21 after weaning and a Phase 3 diet (1.20% lysine) from d 21 to 35 after weaning (Table 1). Zinc was maintained at 165 ppm in diets fed during Phase 3, resulting in two dietary treatments (0 and 0.3% Bio-Mos®) during this phase of the experiment. Pig BW and feed intake were determined at the initiation of the study, and weekly thereafter to evaluate ADG, ADFI, and F/G.

Pigs were housed in an off-site nursery facility in pens with two nipple waterers and a five-hole feeder. Pigs had *ad libitum* access to feed and water. For the first week of the trial, the nursery was maintained at 85°F and decreased 1°F each week.

In vitro cellular immune response was measured using a lymphocyte blastogenesis assay (Blecha et al., 1983). A total of 72 pigs (18 pigs per treatment) were sampled across four days of the experiment (d 21, 22, 26, and 27). Phytohemagglutinin (PHA) and pokeweed mitogen (PWM) were used as mitogens at a concentration of 50 and 25 mg/ml, respectively to stimulate lymphocyte proliferation in vitro. Uptake of [3]H-thymidine served as the measurement of cell proliferation.

Data were analyzed as a randomized complete block design with pen as the experimental unit and blocks based on initial BW. Analysis of variance was performed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC). The effects of block, zinc, Bio-Mos®, and the Bio-Mos® x zinc interaction were evaluated. When a significant interaction was observed, least square means were generated and separated using the PDIFF option. Main effect means were evaluated when the interaction was not significant.

Results and Discussion

Main effect means in response to dietary supplementation with Bio-Mos® and zinc oxide are presented in Table 2. There was no effect on ADG, ADFI, or F/G in response to either Bio-Mos® or zinc supplementation during the Phase 1 period.

During the first week of Phase 2 (d 7 to 14) and in the overall Phase 2 period (d 7 to 21), ADG was greater ($P < 0.05$) when pigs were fed diets containing 2,465 ppm zinc when compared to pigs fed diets containing 165 and 500 ppm zinc, and ADFI was greater ($P < 0.05$) when pigs were fed 2,465 ppm zinc when compared to pigs fed 165 ppm zinc. Also, F/G was improved ($P < 0.05$) when pigs were fed diets containing 2,465 ppm zinc compared to pigs fed diets containing 500 ppm zinc. During the second week of Phase 2 (d 14 to 21) and in the overall Phase 2 period (d 7 to 21), F/G improved when pigs were supplemented with Bio-Mos® when compared to those fed diets devoid of Bio-Mos®.

During the first week of Phase 3 (d 21 to 28), pigs fed Bio-Mos® had greater ($P = 0.02$) ADG and improved ($P = 0.009$) F/G when compared to pigs fed diets without Bio-Mos®. Pigs previously fed diets containing 500 ppm zinc during Phase 1 and 2 had greater ($P < 0.05$) ADG during the first week of Phase 3 (d 21 to 28) than pigs previously fed 2,465 ppm zinc. During the second week of Phase 3 (d 28 to 35), pigs fed 165 ppm zinc had greater ($P < 0.05$) ADG and improved ($P < 0.05$) F/G when compared to pigs previously fed 500 ppm zinc during Phase 1 and Phase 2. In the overall experiment (d 0 to 35), pigs fed diets containing Bio-Mos® had improved ($P = 0.03$) F/G when compared to pigs fed diets devoid of Bio-Mos®.

Several studies evaluating the effects of zinc supplementation have determined that pigs do not usually respond to pharmacological levels of dietary zinc during the first week of supplementation. However, as observed in this experiment, supplementing zinc for 2 weeks following weaning elicits an improvement in ADG, ADFI, and F/G during the second week after weaning (Carlson et al., 1999; Woodworth et al., 1999a, 1999b). There was no benefit to supplementing 500 ppm zinc in the diet over providing zinc to meet the pigs' dietary requirement, as corroborated by Kornegay et al. (1993) and Hill et al (2001), with or without Bio-Mos® supplementation. As observed in a previous experiment (Davis et al., 2000), response to Bio-Mos® was most pronounced during Phase 2 and Phase 3 of the experiment. When pharmacological levels of zinc were removed from the diet during Phase 3, pig performance decreased when compared to pigs fed the control diet. Contrary to the observations in this experiment, Carlson and coworkers (1999) observed either a similar response or an improvement in response when pigs were previously fed pharmacological levels of zinc compared to pigs fed a diet containing only enough zinc to meet the pigs' requirement.

Proliferation of lymphocytes in unstimulated cultures was less ($P = 0.03$) when cells were isolated from pigs fed Bio-Mos® than when cells were isolated from pigs fed diets without Bio-Mos® (Table 2). A Bio-Mos® x zinc oxide interaction ($P < 0.05$) was observed for lymphocyte proliferation in response to both PHA and PWM (Figures 1 and 2, respectively). Lymphocyte proliferation in response to PHA and PWM was greater ($P < 0.05$) when cells were isolated from pigs fed 165 ppm zinc without Bio-Mos® in the diet than when cells were isolated from pigs fed the same level of zinc with Bio-Mos® supplementation. However, proliferation responses did not differ regardless of Bio-Mos® supplementation when diets contained 500 and 2,465 ppm zinc. Bio-Mos® supplementation seems to suppress lymphocyte proliferation response in unstimulated as well as stimulated cell cultures. Since mounting an immune response is a metabolically expensive process resulting in adverse effects on feed intake and growth, the improvement in growth and efficiency observed when pigs were fed Bio-Mos® could be a result of a suppression in immune responses that would otherwise be amplified needlessly. In a study conducted by Dritz et al. (1995), feeding dietary β-glucan (a feed additive similar to Bio-Mos®) improved the gain and feed intake of weanling pigs. However, mortality was greater when pigs were fed diets containing β-glucan and administered a disease challenge, indicating that the improved growth response may be due to a suppression of the immune response. Similarly, the mechanism by which Bio-Mos® improves growth and efficiency in weanling pigs may be a result of its suppressive effect on the pigs' cell mediated immune response.

Implications

Although pharmacological levels of 2,465 ppm zinc fed to nursery pigs did elicit an improvement in pig performance, there was no benefit from supplementing 500 ppm zinc over feeding the pigs' dietary requirement for zinc. Also, there was no improvement in pig response when Bio-Mos® was included with 500 ppm zinc over that observed when pigs were fed diets containing 165 ppm zinc. Bio-Mos® supplementation improved efficiency during Phase 2, gain and efficiency during the first week of Phase 3, and suppressed lymphocyte proliferation in unstimulated cultures and when cells isolated from pigs fed 165 ppm zinc were stimulated with PHA and PWM.

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Table 1. Composition of basal diets (as-fed basis).[a]

Item, %	Phase 1	Phase 2	Phase 3	
Yellow corn	39.17	48.07		62.325
Steam rolled oats	5.00	-		-
Deproteinized whey	17.50	10.00		-
Processed soy protein	6.75	-		-
Soybean meal, 48% CP	10.00	28.30		30.00
Spray dried blood cells	2.00	2.00		-
Spray dried animal plasma	3.75	-		-
Select menhaden fish meal	8.50	4.00		-
Fat	-	-		4.00
Soybean oil	4.00	4.00		-
Ethoxyquin	0.03	0.03		0.03
Lysine HCl	-	-		0.16
Threonine	0.05	-		-
Methionine	0.15	0.12		0.07
Neoterromycin 10/5	1.00	1.00		-
Tylan-40	-	-		0.125
Mineral premix (NB-8557B)[b]	0.15	0.15		0.15
Vitamin premix (NB-6157B)[c]	0.25	0.25		0.25
Dicalcium phosphate	1.30	1.40		1.88
Calcium carbonate	0.10	0.38		0.61
Salt	0.30	0.30		0.40
Calculated composition				
Lysine	1.50	1.35		1.20
Threonine	0.98	0.87		0.77
Tryptophan	0.27	0.26		0.24
Met + Cys	0.90	0.82		0.72
Ca	0.90	0.80		0.80
P	0.80	0.70		0.70
Metabolizable energy, kcal/lb	1533	1542		1557
Lactose	14.53	8.30		-

[a]During Phase 1 and Phase 2, basal diets were supplemented with 0.30% Bio-Mos® and 0.05% and 0.32% zinc oxide to provide two levels of Bio-Mos® (0 and 0.30%) and 3 levels of zinc oxide (0, 500, and 2,465 ppm) to provide six dietary treatments. During Phase 3, Bio-Mos® was supplemented at 0 and 0.30% to provide two dietary treatments.
[b]Mineral levels met or exceeded NRC (1998) recommendations.
[c]Vitamin levels met or exceeded NRC (1998) recommendations.

Table 2. Bio-Mos® and zinc main effect treatment means.

	Bio-Mos®, %				Zinc, ppm				
	0	0.3	SE	P-value	165	500	2,465	SE	P-value
Phase 1 (d 0 to 7)									
ADG, lb	0.31	0.33	0.02	0.485	0.32	0.33	0.32	0.02	0.919
ADFI, lb	0.48	0.50	0.02	0.346	0.48	0.50	0.48	0.02	0.582
Feed:gain	1.60	1.58	0.09	0.907	1.58	1.56	1.63	0.11	0.884
Phase 2 (d 7 to 14)									
ADG, lb	0.53	0.51	0.03	0.543	0.49[b]	0.46[b]	0.61[a]	0.03	0.008
ADFI, lb	0.80	0.73	0.03	0.072	0.72[b]	0.75[a,b]	0.82[a]	0.03	0.065
Feed:gain	1.58	1.49	0.07	0.352	1.54[a,b]	1.71[a]	1.35[b]	0.08	0.019
Phase 2 (d 14 to 21)									
ADG, lb	1.00	1.02	0.02	0.642	0.99	1.01	1.03	0.03	0.595
ADFI, lb	1.38	1.32	0.03	0.199	1.31	1.35	1.40	0.04	0.252
Feed:gain	1.39	1.31	0.02	0.015	1.32	1.35	1.37	0.03	0.506
Phase 2 (d 7 to 21)									
ADG, lb	0.77	0.76	0.02	0.897	0.74[b]	0.73[b]	0.82[a]	0.03	0.053
ADFI, lb	1.08	1.02	0.03	0.096	1.00[b]	1.05[a,b]	1.10[a]	0.03	0.098
Feed:gain	1.43	1.35	0.02	0.024	1.38[a,b]	1.44[a]	1.35[b]	0.03	0.073
Phase 3 (d 21 to 28)									
ADG, lb	0.90	0.99	0.02	0.022	0.94[a,b]	1.00[a]	0.90[b]	0.03	0.084
ADFI, lb	1.60	1.63	0.04	0.501	1.62	1.67	1.56	0.04	0.210
Feed:gain	1.78	1.66	0.03	0.009	1.74	1.68	1.73	0.04	0.506
Phase 3 (d 28 to 35)									
ADG, lb	1.03	1.04	0.03	0.869	1.10[a]	0.98[b]	1.01[a,b]	0.04	0.102
ADFI, lb	1.92	1.93	0.06	0.850	1.92	1.92	1.93	0.07	0.990
Feed:gain	1.91	1.87	0.06	0.683	1.74[b]	2.00[a]	1.94[a,b]	0.08	0.065
Phase 3 (d 21 to 35)									
ADG, lb	0.97	1.01	0.02	0.151	1.02	0.99	0.96	0.03	0.249
ADFI, lb	1.76	1.78	0.04	0.694	1.77	1.80	1.74	0.05	0.794
Feed:gain	1.83	1.76	0.03	0.158	1.73	1.82	1.83	0.04	0.209
Overall (d 0 to 35)									
ADG, lb	0.75	0.78	0.02	0.380	0.77	0.75	0.77	0.02	0.814
ADFI, lb	1.24	1.23	0.03	0.811	1.21	1.25	1.25	0.03	0.687
Feed:gain	1.66	1.59	0.02	0.035	1.59	1.66	1.61	0.03	0.202
Lymphocyte Proliferation, cpm									
Unstimulated	388	265	40.2	0.035	276	314	389	50.8	0.277

[a,b] Means within a main effect in a row with no letters in common differ (P< 0.05).

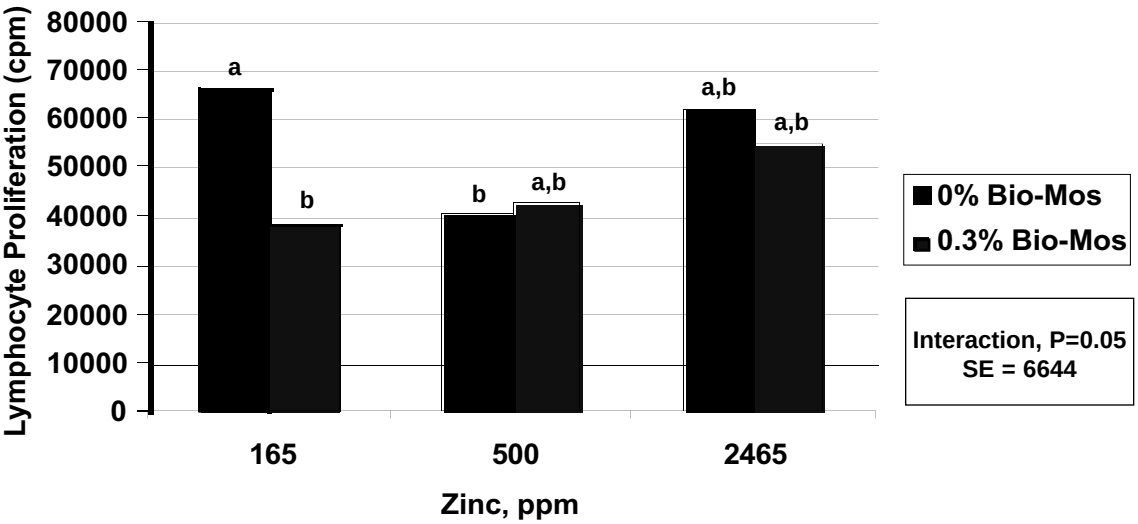

Figure 1. Lymphocyte proliferation response to phytohemagglutinin administered in vitro to cells isolated from nursery pigs fed Bio-Mos® and zinc oxide. a,b Bars (representing least-squares means) with no letter in common differ (P < 0.05).

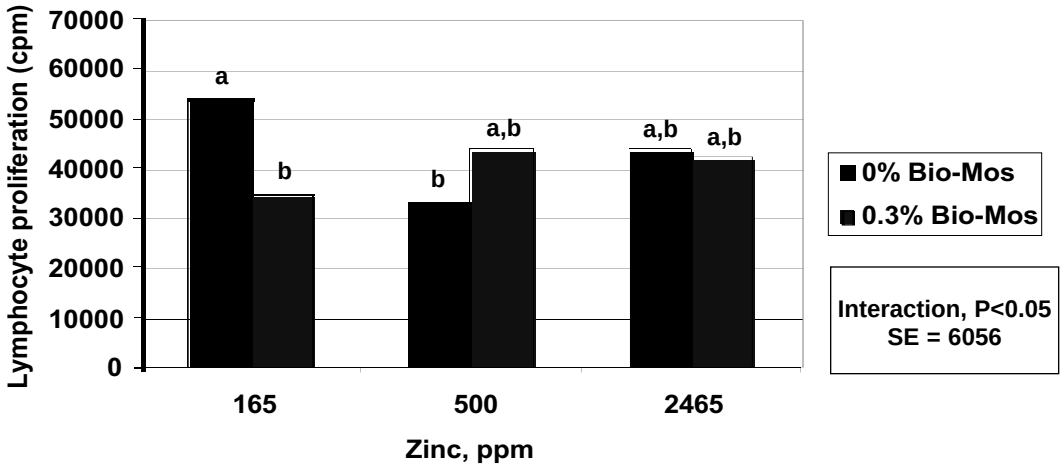

Figure 2. Lymphocyte proliferation response to pokeweed mitogen administered in vitro to cells isolated from nursery pigs fed Bio-Mos® and zinc oxide. a,b Bars (representing least-squares means) with no letters in common differ (P < 0.05).

Efficacy of Mannan Oligosaccharide (Bio-Mos®) Addition With and Without Copper Sulfate in the Diets of Growing-Finishing Pigs

E. Davis, D. Brown, B. de Rodas, C. Maxwell, and Z. Johnson[1]

Story in Brief

An experiment involving 144 crossbred barrows and gilts was conducted to determine the efficacy of Bio-Mos® in improving performance of growing-finishing pigs fed diets devoid of antibiotics and with and without growth promoting levels of copper sulfate. Pigs were sorted by BW and divided into six weight groups with 24 pigs in each group. Pigs within each group were allotted into four pens (six pigs/pen) and stratified by sex and litter. Treatments were randomly assigned to pens within each weight group (six pens/treatment). Dietary treatments were fed throughout the starter (44 to 71 lb BW), grower (71 to 151 lb BW), and finisher (151 to 234 lb BW) phases. Diets consisted of two levels of copper sulfate (10 ppm in starter, grower, and finisher diets vs. 185 ppm in starter and grower diets and 135 ppm in finisher diets) with and without Bio-Mos® (0 vs. 0.2% in starter, 0.1% in grower, and 0.05% in finisher). Average daily gain and F/G improved (P = 0.02) in the starter phase when pigs were fed diets containing 185 ppm of additional copper compared to pigs fed 10 ppm copper. Feed/gain improved (P = 0.01) in the grower phase when pigs were fed 185 ppm copper compared to pigs fed 10 ppm copper. During the finisher phase, ADG improved with the addition of Bio-Mos® in pigs fed 10 ppm copper, but decreased when Bio-Mos® was supplemented in diets with 135 ppm of additional copper (interaction, P = 0.04). This study indicates that copper sulfate addition to the diets of growing-finishing pigs at pharmacological levels improves gain and efficiency, while response to Bio-Mos® addition was dependent upon the level of copper in the diet.

Introduction

Growth promoters such as antibiotics and pharmacological levels of copper are commonly added to the diets of growing swine to improve health and performance. Copper sulfate is often added to the diets of growing-finishing pigs as a growth promoter, however the high concentrations of copper in manure applied to land has prompted concern about soil copper toxicity. Concerns about environmental problems that accompany additions of high levels of trace minerals in swine diets have challenged the swine industry to explore alternative products to promote growth. Bio-Mos® (Alltech, Nicholasville, KY) is a mannan oligosaccharide derived from the cell wall of the yeast *Saccharomyces cerevisiae* that has resulted in improved gain and efficiency when added to the diets of weanling pigs (Davis et al., 1999; Davis et al., 2000). The response to Bio-Mos® in the diets of growing-finishing pigs has not been explored. This experiment was conducted to assess the potential of Bio-Mos® to promote gain and efficiency in growing-finishing pigs to levels comparable to the addition of pharmacological levels of copper.

Experimental Procedures

A total of 144 crossbred barrows and gilts were moved from nursery facilities, sorted by BW, and divided into six weight groups (blocks) with 24 pigs in each group. Pigs within each weight group were allotted into four equal subgroups (six pigs per pen) with stratification based on sex and litter. Dietary treatments were randomly assigned to pens within each of the six weight groups (six pens per treatment). Pigs were fed in three phases with transition from starter to grower phase occurring 3 weeks from the initiation of the experiment. Transition from grower to finisher occurred when the mean weight of each weight block reached approximately 150 lb, and the study was terminated by weight group as each block reached an average of 235 lb.

Four dietary treatments were arranged as a 2 x 2 factorial and fed throughout the starter (44 to 71 lb BW), grower (71 to 151 lb BW), and finisher (151 to 234 lb BW) phases (Table 1). Diets consisted of two levels of inorganic copper (10 ppm in the starter, grower, and finisher diets vs. 185 ppm in starter and grower diets followed by 135 ppm in finisher diets) with and without the addition of Bio-Mos® (0 and 0.2, 0.1, and 0.05% in the starter, grower, and finisher phases, respectively). Pigs received a corn-soybean meal diet formulated to contain 1.10%, 0.96%, and 0.85% lysine during the starter, grower, and finisher phases, respectively. Substitutions in all diets were made at the expense of corn.

Pig BW and feed intake were determined at the initiation and termination of each phase to determine ADG, ADFI, and F/G. Data were analyzed as a randomized complete block design with pen as the experimental unit and blocks based on

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initial BW. Analysis of variance was performed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC). The effects of copper, Bio-Mos®, and copper x Bio-Mos® interaction were evaluated. When a significant interaction was observed, treatment means were separated using the PDIFF option of the LSMEANS statement in PROC GLM. Main effect means were evaluated when the interaction was not significant.

Results and Discussion

Main effect means in response to Bio-Mos® and copper supplementation are presented when no Bio-Mos® x copper interaction was observed (Table 2), while treatment means are presented when a significant interaction occurred (Table 3). Average daily gain increased (P = 0.02) and F/G improved (P = 0.01) when pigs were fed diets containing 185 ppm copper during the starter phase compared to pigs fed diets containing 10 ppm copper. During the grower phase, ADG increased (P = 0.06) and F/G improved (P = 0.01) when pigs were fed 185 ppm copper compared to pigs fed diets containing 10 ppm copper during the finishing phase. Average daily gain improved with the addition of Bio-Mos® in diets containing 10 ppm copper, but decreased when Bio-Mos® was supplemented in diets with supplemental copper (Table 3). This resulted in a Bio-Mos® x copper interaction (P = 0.04). Average daily gain was greater (P < 0.10) when pigs were fed diets supplemented with Bio-Mos® or 135 ppm copper than when pigs were fed the control diet during the finisher phase. Average daily gain was similar among pigs fed copper sulfate, Bio-Mos®, or the combination of copper sulfate and Bio-Mos® (P > 0.10). In the overall experiment, ADG and F/G improved (P = 0.03) when pigs were fed diets containing 185 ppm copper during the starter and grower phases and 135 ppm during the finisher phase compared to pigs fed diets containing 10 ppm copper. Pig BW at the termination of starter, grower, and finisher phases was greater (P < 0.03) when pigs were fed diets containing additional copper compared to pigs fed diets containing 10 ppm copper.

The response to copper addition in this study is consistent with earlier documented research (Hawbaker et al., 1961; Braude and Ryder, 1973; Castell et al., 1975) in which copper sulfate addition to the diets of growing-finishing pigs improved gain and efficiency. However, our results do not concur with the findings of Bunch et al. (1965) and Lillie et al. (1977) in which additions of high concentrations of copper sulfate depressed performance. The response to Bio-Mos® in the diets of growing-finishing pigs was much less pronounced than the responses observed in prior experiments with weanling pigs (Davis et al., 2000; Davis et al., 1999). There was a tendency for an improvement in ADG during the finisher phase when pigs were fed Bio-Mos® and 10 ppm copper compared to pigs fed low copper without Bio-Mos® addition. The response to Bio-Mos® and 135 ppm copper was similar during the finishing period. This suggests that Bio-Mos® as an alternative to copper supplementation during the finishing period should be further investigated.

Implications

Copper sulfate addition at pharmacological concentrations improved gain, efficiency, and final pig weight when supplemented in the diets of growing-finishing pigs. Bio-Mos® supplementation did not result in gain and efficiency comparable to pigs fed pharmacological levels of copper sulfate during the starter and grower period. Although there was an improvement in ADG during the finisher phase in response to Bio-Mos®, addition to diets containing 10 ppm copper, gain was intermediate between pigs fed 10 ppm and 135 ppm copper without Bio-Mos® supplementation.

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Table 1. Composition of basal diets (as-fed basis).[a]

Item, %	Starter	Grower	Finisher
Yellow corn	62.00	67.20	71.215
Soybean meal, 48% CP	30.75	25.60	21.90
Fat	4.00	4.00	4.00
Ethoxyquin	0.03	0.03	0.03
Mineral premix (NB-8557B)	0.10	0.10	0.10
Vitamin premix (NB-6157B)	0.25	0.15	0.125
Dicalcium phosphate	1.55	1.65	1.45
Calcium carbonate	0.82	0.77	0.68
Salt	0.50	0.50	0.50
Calculated composition			
Crude protein	20.17	18.11	16.67
Lysine	1.10	0.95	0.85
Threonine	0.78	0.70	0.64
Tryptophan	0.24	0.21	0.19
Met + Cys	0.67	0.61	0.57
Calcium	0.80	0.80	0.70
Phosphorus	0.65	0.65	0.60
Metabolizable energy, kcal/lb	1567	1568	1576

[a] Basal diets were supplemented with 175 ppm of copper sulfate in the starter and grower phases and 125 ppm of copper sulfate in the finishing phase (so that diets contained 185 and 135 ppm copper, respectively), as well as 0.2, 0.1, and 0.05% Bio-Mos® in the starter, grower, and finisher phases, respectively, resulting in four dietary treatments.

Table 2. Main effect means in response to dietary Bio-Mos® and copper sulfate.

	Bio-Mos®				Copper Sulfate			
	-	+	SE	P-value	-	+	SE	P-value
Starter								
ADG, lb	1.27	1.28	0.04	0.857	1.21	1.35	0.04	0.017
ADFI, lb	3.02	2.97	0.06	0.559	2.94	3.05	0.06	0.206
Feed:gain	2.37	2.32	0.05	0.452	2.44	2.26	0.05	0.014
Grower								
ADG, lb	1.99	2.03	0.05	0.605	1.93	2.09	0.05	0.063
ADFI,lb	5.06	5.08	0.12	0.902	4.96	5.18	0.12	0.191
Feed:gain	2.55	2.50	0.02	0.182	2.57	2.48	0.02	0.012
Overall								
ADG, lb	1.96	1.98	0.04	0.646	1.90	2.03	0.04	0.028
ADFI, lb	5.24	5.37	0.11	0.447	5.23	5.38	0.11	0.351
Feed:gain	2.68	2.71	0.03	0.444	2.74	2.65	0.03	0.027
Weight, lb								
Initial	43.9	43.9	0.01	0.292	43.9	43.9	0.01	0.458
Starter	70.7	70.9	0.78	0.844	69.3	72.3	0.78	0.015
Grower	149.7	151.6	2.55	0.606	146.3	155.0	2.55	0.029
Finisher	232.9	235.3	3.42	0.616	228.3	239.9	3.42	0.029

Table 3. Treatment means in response to dietary Bio-Mos® and copper sulfate during the finishing phase.

	Treatment					
Bio-Mos®	-	-	+	+		Probability value
Copper sulfate	-	+	-	+	SE	Bio-Mos® x $CuSO_4$
ADG, lb	2.21[b]	2.42[a]	2.35[a]	2.30[a,b]	0.05	0.040
ADFI, lb	6.75	7.06	7.15	7.04	0.27	0.437
Feed:gain	3.07	2.92	3.04	3.05	0.10	0.435

[a,b]Means within a row with no letter in common differ (P < 0.10).

Effects of Dietary Magnesium and Halothane Genotype on Performance and Carcass Traits of Growing-Finishing Swine

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Story in Brief

Halothane-negative (NN) and halothane-carrier (Nn) pigs were assigned randomly to one of three dietary treatments: 1) control corn-soybean meal diets; 2) control diets supplemented with 1.25% magnesium mica (MM); or 3) control diets supplemented with 2.5% MM. When the lightest block averaged 240 lb, pigs were harvested at a commercial pork slaughter plant, and bone-in pork loins were captured, vacuum-packaged and transported back for measurement of pork quality traits. The NN pigs had greater average daily gain (ADG) during the grower ($P < 0.03$) and finisher ($P < 0.06$) periods than Nn pigs. Although MM had no effect ($P > 0.14$) on ADG, pigs fed 1.25% MM had a lower ($P < 0.05$) feed-to-gain ratio (F/G) during the grower phase than pigs fed 2.5% MM; whereas, pigs fed control diets had an intermediate F/G. Carcasses from Nn pigs were leaner ($P < 0.01$) and heavier ($P < 0.01$) muscled than carcasses from NN pigs. In contrast, a greater ($P < 0.01$) percentage of carcasses from Nn pigs received color scores characteristic of the pale, soft, and exudative (PSE) condition. Although there were distinct genotype effects on performance and carcass traits, long-term supplementation of diets with MM had no beneficial, or deleterious, effects on carcass quality or yield.

Introduction

The halothane gene affects the stress susceptibility/resistance of swine, and pigs homozygous positive (nn) typically produce pork of inferior quality when compared to homozygous negative (NN) pigs. Research has shown that heterozygous (Nn) pigs produced carcasses with lower muscle pH, greater moisture loss, less marbling, and a higher percentage of pale, soft, and exudative (PSE) pork than carcasses from NN pigs (Simpson and Webb, 1989; Leach et al., 1996).

Supplementing swine diets with magnesium (Mg) has improved pork quality traits, especially muscle color and drip loss (D'Souza et al., 1998, 1999). However, the magnitude of responses to supplemental Mg on pork quality traits appears related to the stress-susceptibility, or resistance, of the pigs being studied. For example, Schaefer et al. (1993) reported that improvements in pork quality, in response to short-term supplementation of Mg aspartate, were for only confirmed heterozygous carriers of the halothane gene.

Magnesium mica (MM) is an inorganic, layered silicate product, containing approximately 8% Mg, that has been used primarily as a pellet binder in the feed milling industry. In the first of two experiments from our laboratory (Apple et al., 2000), long-term supplementation of swine diets with MM improved pork color and reduced the proportion of carcasses with quality traits characteristic of pale, soft, and exudative (PSE) pork; however, in the second experiment, dietary MM had no appreciable effects on any pork quality trait measured. Diets for both experiments were identical, but pig populations had changed from a herd of unknown halothane-genotype to an almost exclusively halothane-negative herd in the year between experiments. Therefore, the aim of this experiment was to test the effects of feeding MM during the growing-finishing period on the performance and pork quality traits of halothane-carrier and homozygous-negative pigs.

Experimental Procedures

Prior to breeding, hair samples from a population (n = 30) of Yorkshire x Landrace females were collected, packaged, and shipped to Pig Improvement Company headquarters in Franklin, KY, where hair-samples were analyzed for halothane-genotype by their laboratory. All females that were homozygous dominant (NN), or negative, for the halothane-gene were selected and mated to either Duroc x Hampshire males (Line TT, The Pork Group, Rogers, AR), tested and guaranteed to be homozygous dominant for the halothane-gene, or to synthetic-breed males (Pig Improvement Company, Franklin, KY), tested and guaranteed to be homozygous recessive (nn) for the halothane-gene. Pigs generated from these matings were either homozygous dominant/negative (NN) or heterozygous (Nn) carriers of the halothane-gene.

Halothane-negative (n = 45) and halothane-carrier (n = 75) barrows and gilts, with an average initial body weight (BW) of 38.3 ± 7.0 lb, were moved from the University of Arkansas Nursery to the University of Arkansas Swine

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Growing-Finishing Facility and blocked by BW into four blocks. Pigs were then allotted randomly to pens (six pens/block) based on sex and litter origin/genotype, with at least one NN pig/pen. A total of 24 pens (five pigs/pen) were assigned randomly to one of three treatments: 1) a negative control corn-soybean meal starter, grower, and finisher diets devoid of supplemental magnesium; 2) the control starter, grower, and finisher diets supplemented with 1.25% MM (Micro-Lite, Inc., Chanute, KS); or 3) the control starter, grower, and finisher diets supplemented with 2.5% MM (Table 1). Pigs were fed a three-phase diet with transition from starter to grower when the average block BW was 74.8 lb, and from the grower to finisher when the mean block BW was 150 lb. Within the MM-supplemented diets, MM was added at the expense of corn. All diets were formulated to meet, or exceed, NRC (1998) requirements for growing-finishing swine, and starter, grower, and finisher diets contained 1.10, 0.95, and 0.85% lysine, respectively (Table 1). Individual pig weights were measured weekly, and feed disappearance was recorded during each phase to calculate average daily gain (ADG), average daily feed intake (ADFI), and feed-to-gain ratio (F/G).

When the lightest block of pigs averaged 240 lb, all pigs were transported approximately 10 h to a commercial pork harvest/fabrication plant (Seaboard Farms, Inc., Guymon, OK). After a brief 45-min rest period, pigs were harvested according to industry-accepted procedures, and carcasses were chilled rapidly for 1 to 2 h at -15°F, followed by a "tempering" period where temperature was gradually increased from 26° to 36°F. Approximately 24 hr post-harvest, fat and longissimus muscle (LM) depths were measured on-line with a Fat-O-Meater® automated probe, and trained personnel recorded carcass backfat measurements. Carcasses were then fabricated into subprimal cuts, and bone-in pork loins were vacuum-packaged, boxed, loaded into a refrigerated truck and shipped back to the University of Arkansas Red Meat Abattoir for pork quality measurements.

Upon arrival at the Abattoir (approximately 48 h after harvest), loins were removed from the vacuum-bags, and the pork tenderloin was removed. Then, the blade was removed perpendicular to the length of the loin and discarded. Beginning at the cranial end of the loin, two 1-in thick LM chops were cut for color evaluations and two 1.5-in. thick LM chops were removed for drip loss, pH, and moisture determinations.

After a 30-min "bloom" period at 39°F, the 1-in thick LM chops were visually evaluated for marbling (1 = devoid [1% intramuscular lipid] to 10 = abundant [10% intramuscular lipid]; NPPC, 1999), firmness (1 = very soft and watery to 5 = very firm and dry; NPPC, 1991), and color based on both the American (1 = pale, pinkish gray to 6 = dark purplish red; NPPC, 1999) and Japanese color standards (1 = pale gray to 6 = dark purple; Nakai et al., 1975). Furthermore, L*, a*, and b* values were determined from a mean of four random readings (two readings from each of the 2.5-cm thick LM chops) made with the Hunter MiniScan XE (model 45/0-L, Hunter Associates Laboratory, Reston, VA) using illuminant C and a 10° standard observer. Drip loss, a measure of the water-holding capacity of the LM, was determined according to the suspension procedure described by Apple et al. (2000). Additionally, LM moisture was measured following the freeze-drying procedure outlined in Apple et al. (2000).

All data were analyzed as a split plot design with pen as the experimental unit for performance data and pig as the experimental unit for all carcass data. Analysis of variance was generated using the PROC MIXED procedure (SAS Institute, Inc., Cary, NC), with the main effects of genotype and dietary MM, as well as the genotype x MM interaction. The random error term used to test MM effects was generated using the pen x block x MM interaction; whereas, genotype and the genotype x MM interaction were tested for significance using the random residual. Least squares means were computed for the main and interactive effects, and were separated statistically using the probability of difference (PDIFF) option. Frequencies of American and Japanese color scores were analyzed using the frequency procedure (SAS Institute, Inc., Cary, NC). There were no significant ($P < 0.10$) genotype x MM interactions discovered; therefore, only main effects are reported.

Results and Discussion

The effects of halothane-genotype and MM on live animal performance are reported in Table 2. Although ADG was similar among NN and Nn pigs during the starter phase, NN pigs had higher ADG during the grower ($P < 0.03$) and finisher ($P < 0.06$) phases, as well as over the entire feeding trial ($P < 0.01$) than Nn pigs. Because each experimental unit (pen) contained both NN and Nn pigs, it was impossible to calculate and report ADFI and F/G.

Supplementing the diets of growing-finishing swine with MM did not ($P > 0.05$) affect ADG or ADFI during the starter, grower, or finisher phases, as well as over the entire length of the feeding trial. Pigs fed the control diet and 1.25% MM during the starter phase had lower ($P < 0.05$) F/G than pigs fed the diet supplemented with 2.5% MM. However, during the grower phase, pigs fed 1.25% MM were more ($P < 0.05$) efficient than pigs fed 2.5% MM, with pigs consuming the control diet having F/G intermediate to those of the MM-fed pigs. Feed-to-gain ratios were similar ($P > 0.10$) among treatments during the finisher phase and over the duration of the trial.

O'Quinn et al. (2000) reported that ADG, ADFI, and G:F were not affected by inclusion of Mg sulfate in the diets of finishing pigs. Similarly, the long-term inclusion of MM in swine diets had no effect on ADG, ADFI, or G:F during the starter, grower, or finisher phases, or during the entire trial (Apple et al., 2000). Thus, the lack of a reduction in ADG in pigs fed diets supplemented with MM in this, and a previous study (Apple et al., 2000), as well as the reduced F/G in pigs fed 1.25% MM during the grower phase, may suggest an improvement in overall energy efficiency.

Carcasses from Nn pigs had less ($P < 0.01$) fat opposite the first rib, last rib, and last lumbar vertebra, as well as less ($P < 0.01$) average backfat, than carcasses from NN pigs

(Table 3). Moreover, carcasses of Nn pigs had considerably less ($P < 0.01$) fat at the tenth rib (0.87 vs. 1.28 in.), and greater ($P < 0.01$) LM depth (2.35 vs. 2.00 in.) than carcasses from NN pigs.

Eikelenboom et al. (1980) reported that carcasses from Nn pigs had less average backfat than carcasses from NN pigs. Other studies, however, have shown that carcasses from NN and Nn pigs had similar midline backfat measurements and tenth rib fat depths (Leach et al., 1996; Sather and Jones, 1996). Moreover, Simpson and Webb (1989) and Jones et al. (1988) found that carcasses from Nn pigs were actually fatter than carcasses from NN pigs.

As for carcass muscling, results from the present study are comparable to those of Sather and Jones (1996) and Jones et al. (1988), who reported that carcasses from Nn pigs had greater LM depth and a higher percentage muscle than carcasses from NN pigs. In contrast, Leach et al. (1996) failed to denote differences in LM area or depth and carcass muscle percentage among carcasses from NN and Nn pigs.

Supplementation of swine diets with MM had no effect ($P > 0.10$) on midline backfat measurements, tenth rib fat depth, LM depth, or percentage muscle (Table 3). These results are consistent with those of Schaefer et al. (1993) and D'Souza et al. (1998; 1999), who failed to note an effect of supplemental Mg on any fat or muscle measurement of pork carcasses; however, these authors fed Mg aspartate for a brief 5-day period before harvest. In the first experiment, Apple et al. (2000) reported no effect of long-term supplementation of MM on pork carcass composition, but, in the second experiment, they reported a 0.07 to 0.17 in. reduction in tenth rib fat depth, and a 0.89 to 1.44% increase in percentage muscle of carcasses from pigs fed 2.50 and 1.25% MM, respectively.

Although LM pH was not affected ($P > 0.81$) by halothane genotype, drip loss percentages were higher ($P < 0.01$), and LM moisture content was lower ($P < 0.01$), in pork from Nn pigs compared to NN pigs (Table 4). The LM from Nn pigs received lower ($P \leq 0.02$) marbling, firmness, and color scores than the LM from NN pigs. Moreover, pork from Nn pigs was lighter ($P < 0.01$), less ($P < 0.01$) red, and less ($P < 0.01$) yellow compared to that from NN pigs, and a higher proportion of carcasses from Nn pigs received American and Japanese color scores indicating PSE pork (Table 5).

Our results are in agreement with those of Sather and Jones (1996) and Leach et al. (1996), who found that Nn pigs produced lighter, less desirable colored pork with greater drip loss than pork from NN pigs. Moreover, Simpson and Webb (1989) reported a higher percentage of pork carcasses from Nn pigs were PSE than carcasses from NN pigs, which is consistent with results from the present study.

The pH of the LM was not affected ($P > 0.10$) by inclusion of MM in the diets of growing finishing pigs (Table 4). Moreover, dietary MM had no effect ($P > 0.10$) on drip loss percentages or moisture contents of the LM. Results of the present study confirm previously published information from our laboratory that long-term supplementation of swine diets with MM did not affect LM pH, drip loss, or moisture content. However, several authors have reported that feeding diets fortified with Mg shortly before harvest increased initial and/or ultimate muscle pH (D'Souza et al., 1999; 1998; Schaefer et al., 1993) and reduced drip loss percentages (D'Souza et al., 1999; 1998; Schaefer et al., 1993).

Both subjective color scores and objective color measurements of the LM were similar ($P > 0.10$) among carcasses from pigs fed 0.0, 1.25 and 2.50% MM (Table 4). Moreover, dietary MM had no effect ($P > 0.49$) on the percentage of carcasses with color scores characteristic of PSE pork (Table 5). Neither O'Quinn et al. (2000) or D'Souza et al. (1999) found a difference in pork color among pigs fed diets containing supplemental Mg. On the other hand, D'Souza et al. (1998) reported lower L* values, and Schaefer et al. (1993) reported higher a* values, for LM chops from pigs supplemented with Mg aspartate 5 days before slaughter. Similarly, the percentage of PSE, or PSE-like, carcasses was greatly reduced by short-term (D'Souza et al., 1998) or long-term (Apple et al., 2000) Mg supplementation.

Implications

Results from this study indicated that homozygous negative pigs had greater growth rates and superior pork quality traits than their heterozygous contemporaries, yet carcasses of the homozygotes were lighter muscled and fatter than the heterozgyous pigs. Even though inclusion of magnesium mica in the diets of growing-finishing pigs had no effect on pork color or any other pork quality attribute, the economic benefits realized from enhanced feed efficiency and lower diet costs (Apple et al., 2000) makes magnesium mica supplementation an attractive management decision for today's swine industry.

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Table 1. Composition of experimental diets.

	Starter diets			Grower diets			Finisher diets		
Ingredient (%)	0.00	1.25	2.50	0.00	1.25	2.50	0.00	1.25	2.50
Corn	61.78	60.28	59.10	66.98	65.73	64.30	71.12	69.87	68.62
Soybean meal (48% CP)	30.75	31.00	30.90	25.60	25.60	25.75	21.90	21.90	21.90
Animal and vegetable fat	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Dicalcium phosphate	1.55	1.55	1.60	1.65	1.65	1.70	1.45	1.45	1.50
Magnesium mica	0.00	1.25	2.50	0.00	1.25	2.50	0.00	1.25	2.50
Calcium carbonate	0.82	0.82	0.82	0.77	0.77	0.77	0.68	0.68	0.68
Salt	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Mineral premix	0.15	0.15	0.15	0.15	0.15	0.15	0.10	0.10	0.10
Vitamin/trace mineral premix	0.25	0.25	0.25	0.15	0.15	0.15	0.13	0.13	0.13
Tylosin-40	0.13	0.13	0.13	0.13	0.13	0.13	0.05	0.05	0.05
Copper sulfate	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Ethoxyquin	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Calculated composition (%)									
Crude protein (CP)	20.17	20.16	20.01	18.11	18.00	17.95	16.67	16.56	16.45
Lysine	1.10	1.10	1.10	0.95	0.95	0.95	0.85	0.85	0.85
Methionine	0.32	0.32	0.32	0.29	0.29	0.29	0.27	0.27	0.27
Methionine and cysteine	0.67	0.67	0.67	0.61	0.61	0.61	0.57	0.57	0.57
Threonine	0.78	0.78	0.78	0.70	0.70	0.70	0.64	0.64	0.64
Tryptophan	0.24	0.24	0.24	0.21	0.21	0.21	0.19	0.19	0.19
Magnesium	0.18	0.28	0.38	0.18	0.28	0.38	0.18	0.28	0.38
Calcium	0.80	0.80	0.80	0.80	0.80	0.80	0.60	0.60	0.60
Phosphorus	0.65	0.65	0.65	0.65	0.65	0.65	0.60	0.60	0.60
Metabolizable energy (kcal/kg)	712.2	703.3	694.3	712.9	704.1	695.1	716.3	707.5	698.7

Table 2. Effects of halothane genotype and magnesium mica on performance of growing-finishing swine.

	Halothane genotype[a]		Magnesium mica (%)		
Trait	NN	Nn	0.0	1.25	2.5
Starter phase (38.3 – 74.8 lb)					
ADG (lb/d)	1.36 ± 0.037	1.33 ± 0.031	1.43 ± 0.042	1.32 ± 0.042	1.28 ± 0.042
ADFI (lb/d)	---	---	3.01 ± 0.066	2.87 ± 0.066	2.93 ± 0.066
F/G	---	---	2.11^{y} ± 0.041	2.17^{y} ± 0.041	2.30^{x} ± 0.041
Grower phase (74.8 – 150.0 lb)					
ADG (lb/d)	2.09^{x} ± 0.040	1.97^{y} ± 0.031	2.07 ± 0.042	2.02 ± 0.042	1.96 ± 0.042
ADFI (lb/d)	---	---	5.13 ± 0.117	4.89 ± 0.117	5.01 ± 0.117
F/G	---	---	2.48^{xy} ± 0.031	2.41^{y} ± 0.031	2.55^{x} ± 0.031
Finisher phase (150.0 – 240.0 lb)					
ADG (lb/d)	1.98^{x} ± 0.046	1.86^{y} ± 0.037	1.89 ± 0.047	1.90 ± 0.047	1.92 ± 0.047
ADFI (lb/d)	---	---	5.99 ± 0.099	5.99 ± 0.099	6.04 ± 0.099
F/G	---	---	3.18 ± 0.044	3.16 ± 0.044	3.15 ± 0.044
Overall (38.3 – 240.0 lb)					
ADG (lb/d)	1.87^{x} ± 0.029	1.77^{y} ± 0.022	1.83 ± 0.026	1.80 ± 0.026	1.79 ± 0.026
ADFI (lb/d)	---	---	4.98 ± 0.066	4.87 ± 0.066	4.95 ± 0.066
F/G	---	---	2.71 ± 0.023	2.70 ± 0.023	2.77 ± 0.023
Weights (lb)					
Initial	38.8 ± 0.37	38.0 ± 0.29	38.3 ± 0.02	38.4 ± 0.02	38.3 ± 0.02
Starter phase	75.8 ± 1.14	74.0 ± 0.90	76.8 ± 1.19	74.2 ± 1.19	73.4 ± 1.19
Grower phase	153.5^{x} ± 2.00	147.5^{y} ± 1.54	153.8^{x} ± 1.65	149.6$_{xy}$ ± 1.65	146.6^{y} ± 1.65
Finisher phase	246.3^{x} ± 3.23	234.9^{y} ± 2.51	242.7 ± 3.04	238.6 ± 3.04	236.8 ± 3.04

[a]NN = halothane-negative pigs and Nn = halothane-carrier pigs.

^{x,y}Within a row and within a main effect, least-squares (±SE) means lacking a common superscript letter differ ($P < 0.05$)

Table 3. Effects of halothane genotype and magnesium mica on carcass yield characteristics.

	Halothane genotype[a]		Magnesium mica (%)		
Trait	NN	Nn	0.0	1.25	2.5
Backfat measurements (in.)					
First rib	2.20[x] ± 0.055	1.77[y] ± 0.043	2.01 ± 0.059	2.01 ± 0.059	1.97 ± 0.059
Last rib	1.50[x] ± 0.043	1.26[y] ± 0.031	1.46 ± 0.047	1.42 ± 0.043	1.30 ± 0.043
Last lumbar vertebra	1.50[x] ± 0.043	1.10[y] ± 0.035	1.30 ± 0.047	1.34 ± 0.047	1.22 ± 0.047
Average backfat	1.73[x] ± 0.035	1.38[y] ± 0.028	1.57 ± 0.039	1.57 ± 0.039	1.50 ± 0.039
10th rib fat depth (in.)	1.28[x] ± 0.033	0.87[y]± 0.026	1.07 ± 0.036	1.08 ± 0.036	1.07 ± 0.035
Longissimus muscle depth (in.)	2.00[y] ± 0.036	2.35[x] ± 0.029	2.20 ± 0.040	2.15 ± 0.40	2.19 ± 0.039
Percentage muscle[b]	46.6[y] ± 0.38	52.1[x] ± 0.30	49.4 ± 0.42	49.0 ± 0.41	49.5 ± 0.40

a NN = halothane-negative pigs and Nn = halothane-carrier pigs.

b Percentage muscle = ((2.827 + (0.469 x hot carcass wt, lb) + 9.824 x [10th rib fat depth, mm x 0.0393701]) – (18.47 x [LM depth, mm x 0.0393701])) ÷ hot carcass wt, lb) x 100 (Seaboard Farms, Inc.).

[x,y]Within a row and within a main effect, least-squares means (± SE) lacking a common superscript letter differ (P < 0.05).

Table 4. Effects of halothane genotype and magnesium mica on pork quality characteristics.

	Halothane genotype[a]		Magnesium mica (%)		
Trait	NN	Nn	0.0	1.25	2.5
Longissimus muscle pH	5.70 ± 0.04	5.71 ± 0.03	5.73 ± 0.04	5.67 ± 0.04	5.71 ± 0.04
Drip loss (%)	2.26[y] ± 0.31	3.63[x] ± 0.24	3.07 ± 0.35	2.72 ± 0.34	3.05 ± 0.32
Moisture content[b] (%)	72.3[x] ± 0.18	71.4[y] ± 0.18	71.6 ± 0.22	71.9 ± 0.22	72.0 ± 0.21
American color score[c]	3.4[x] ± 0.12	2.4[y] ± 0.09	2.8 ± 0.13	3.1 ± 0.13	2.8 ± 0.12
Japanese color score[d]	3.0[x] ± 0.11	2.1[y] ± 0.09	2.5 ± 0.12	2.7 ± 0.12	2.5 ± 0.12
Marbling score[e]	2.2[x] ± 0.12	1.5[y] ± 0.09	1.9 ± 0.13	1.9 ± 0.13	1.8 ± 0.12
Firmness score[f]	2.9[x] ± 0.12	2.6[y] ± 0.10	2.7 ± 0.15	2.7 ± 0.15	2.9 ± 0.14
Hunter CIE values[g]					
L*	53.9[y] ± 0.64	59.3[x] ± 0.48	57.1 ± 0.71	55.9 ± 0.68	56.9 ± 0.65
a*	8.0[x] ± 0.21	7.3[y] ± 0.16	7.7 ± 0.25	7.8 ± 0.24	7.5 ± 0.23
b*	18.3[x] ± 0.27	17.7[y] ± 0.20	17.9 ± 0.31	17.8 ± 0.29	17.7 ± 0.29

a NN = halothane-negative pigs and Nn = halothane-carrier pigs.

b Longissimus muscle moisture content determined by freeze-drying.

c American color score: 1 = pale pinkish gray and 6 = dark purplish red (NPPC, 1999).

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

e Marbling score: 1 = devoid and 10 = abundant (NPPC, 1999).

f Firmness score: 1 = very soft/very watery and 5 = very firm/very dry (NPPC, 1991).

g L* = measure of darkness to lightness (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 yellow color).

[x,y]Within a row and within a main effect, least-squares means (± SE) lacking a common superscript letter differ (P < 0.05).

Table 5. Effect of halothane genotype and magnesium mica level on the frequency (%) of American[a] and Japanese[b] color scores.

	Halothane genotype[c]		Magnesium mica (%)		
Trait	NN	Nn	0.0	1.25	2.5
American color scores[d,e]					
1	0.00	12.04	3.70	3.70	4.63
2	5.56	25.93	12.04	9.26	10.19
3	18.52	21.30	14.81	9.26	15.74
4	13.89	2.78	2.78	10.19	3.70
Japanese color scores[f,g]					
1	0.93	18.52	6.48	7.41	5.56
2	12.04	31.48	15.74	10.19	17.59
3	22.22	12.04	11.11	13.89	9.26
4	2.78	0.00	0.00	0.93	1.85

aAmerican color score: 1 = pale pinkish gray and 6 = dark purplish red (NPPC, 1999).
bJapanese color score: 1 = pale gray and 6 = dark purple (Nakai et al., 1975).
cNN = halothane-negative pigs and Nn = halothane-carrier pigs.
dChi-Square statistic for halothane genotype = 30.981 ($P < 0.001$).
eChi-square statistic for magnesium mica level = 8.971 ($P < 0.175$).
fChi-square statistic for halothane genotype = 28.22 ($P < 0.001$).
gChi-square statistic for magnesium mica level = 5.468 ($P < 0.485$).

Effects of Supplemental Manganese on Performance and Pork Quality of Growing Finishing Swine

W. J. Roberts, J. K. Apple, C. V. Maxwell, L. K. Rakes, J. N. Leach, J. R. Jimenez, and C. B. Boger[1]

Story in Brief

A total of 120 crossbred gilts and barrows were used to test the effects of manganese (Mn) supplementation level (350 ppm versus 700 ppm Mn) and Mn source (Mn sulfate versus AvailaMn-80,), fed during the growing-finishing periods, on ADG, ADFI, and F/G, as well as on carcass yield and quality traits. Neither Mn source, nor supplementation level, had any effect ($P > 0.10$) on ADG, ADFI, or F/G. Additionally, dietary Mn did not ($P > 0.10$) impact any measurements of carcass fatness and muscling. Even though dietary Mn did not ($p > 0.10$) influence drip loss percentages and marbling or color scores, pork from pigs fed diets containing 350 ppm of Mn from AvailaMn-80, was darker ($P < 0.05$) than pork from pigs fed 700 ppm of Mn from AvailaMn-80,. Results from this study suggest that supplementing swine diets with 350 ppm AvailaMn-80, may improve pork color without affecting live animal performance.

Introduction

The dietary requirements for manganese (Mn) in swine diets are quite low and not well established. Manganese requirements for growing-finishing swine are largely based on research conducted 30 years ago with inorganic sources of Mn. Grummer et al. (1950) observed improvements in ADG and F/G in pigs fed supplemental Mn at levels of 40, 80, and 160 ppm. On the other hand, neither Plumlee et al. (1956) nor Leibholz et al. (1962) found a difference in ADG and F/G between pigs fed diets supplemented with or without Mn. Although not statistically significant, Svajgr et al. (1969) noted that F/G tended to be improved by including 100 ppm of manganese in swine diets.

The aforementioned studies did not report the effects of supplemental Mn on any carcass characteristics. Furthermore, little, if any, data is available comparing the effects of inorganic and organic sources of Mn on live animal performance or carcass traits. Therefore, the objective of this study was to test the effects of Mn source and level on the performance and carcass characteristics of growing-finishing swine.

Experimental Procedures

One hundred twenty crossbred gilts and barrows were moved from the nursery unit to the University of Arkansas Swine Farm, and blocked by weight, litter, and sex and randomly allotted to 25 pens (five pigs/pen) at an average weight of 57.5 lb. Pigs were fed a four-phase diet with transition from starter to grower I phase, grower I phase to grower II phase, and from grower II phase to finisher occurring when the mean weight of each block reached approximately 80, 150, and 200 lb, respectively. Pens, within blocks, were randomly allotted to one of five treatments: 1) control corn-soybean meal based starter, grower, and finisher diets devoid of supplemental Mn; 2) control diets supplemented with 350 ppm Mn from manganese sulfate; 3) control diets supplemented with 700 ppm Mn from manganese sulfate; 4) control diets supplemented with 350 ppm Mn from AvailaMn-80; 5) control diets supplemented with 700 ppm Mn from AvailaMn-80. During each feeding phase, farm personnel recorded ADG, ADFI, and F/G information weekly. All diets were formulated to meet, or exceed, NRC (1998) requirements for growing-finishing swine. Starter, grower I, grower II, and finisher diets contained 1.16, 0.95, 0.66, and 0.531% lysine, respectively. Control diets contained approximately 44 ppm of Mn, and to achieve supplemental levels of an additional 350 and 700 ppm of Mn, 0.11 and 0.22% of Mn sulfate, as well as 0.44 and 0.88% AvailaMn-80, were added to control diets, respectively, at the expense of corn starch.

When the lightest block averaged 265 lb, all pigs were transported approximately 275 miles to a commercial pork harvest/fabrication facility (Fineberg Packing, Co. Inc., Memphis, TN). After a traditional 24-hr chilling period, carcasses were fabricated and bone-in pork loins were collected. Fat depth was measured at the first rib, last rib, and last lumbar vertebra, for determination of average backfat. Bone-in loins were subsequently paper wrapped, boxed and transported by refrigerated truck to the University of Arkansas Red-Meat Abattoir for further carcass quality measurements.

At approximately 48 hr postmortem, tenderloins were removed, loins were separated between the 3rd and 4th thoracic vertebra (to remove the blade region), and immediately anterior to the hip bone (to remove the sirloin region) to achieve center loins. Loin chops were removed from the anterior end, perpendicular to the length of the loin in the follow-

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ing order: 1) 1.5-inch thick chop; 2) 1 inch thick chop; and 3) 1.5-inch thick chop.

The two 1.5-inch thick chops were used for drip loss determinations following modifications to the suspension procedure of Honikel et al. (1986). A 1.5-inch diameter core was removed from each 1.5-inch thick chop, weighed, and suspended on a fishhook (barb removed) mounted to the lid of a plastic container (18 in. deep x 15 in. wide x 24 in. long) and stored at 34°F. After 48 hr, each core was blotted with a paper towel and reweighed. The loss in weight due to drip and evaporation was divided by the original weight, multiplied by 100 and reported as drip loss percentage. Furthermore, a 2 g sample of longissimus muscle was excised after core removal for muscle pH determination following the protocol outlined by Bendall (1973).

A 1 inch thick bone-in chop was removed from the loin, over-wrapped with PVC film, and, after a 45 minute bloom period, chops were evaluated by a three-person panel for marbling (1 = 1% intramuscular fat and 10 = 10% intramuscular fat; NPPC, 1999), firmness (1 = very soft/watery and 5 = very firm/dry; NPPC, 1991), and color based on both the 6-point American (1 = pale, pinkish gray to 6 = dark purplish-red) and Japanese (Nakai et al., 1975) color scale. The Japanese color standards system is composed of six plastic disks with meat-like texture and appearance developed from objective colorimetry, and scores range from 1(pale gray) to 6 (dark purple). Also, CIE (1976) L*, a*, b* values were determined from a mean of three or four random readings made with the Hunter MiniScan XE (model 45/0-L, Hunter Associates Laboratory, Reston, VA) using illuminant C and a 10° standard observer.

Data were analyzed using the general linear model (GLM) procedure of SAS (SAS Inst., Cary, NC), with pen as the experimental unit for all performance data and loin as the experimental unit for all carcass data. Least squares means were generated and separated statistically by PDIFF option of GLM.

Results and Discussion

Neither Mn source or supplementation level had an effect ($P > 0.10$) on ADG, ADFI, or F/G (Table 1). Our results concur with those of Plumlee et al. (1956) and Leibholz et al. (1962), who reported that ADG and F/G were not affected in pigs fed diets supplemented with Mn. However, Grummer et al. (1950) observed improvements in ADG and F/G in pigs fed supplemental Mn at levels of only 40, 80, and 160 ppm.

The effects of Mn on carcass characteristics are presented in Table 2. Backfat depth at the first rib, last rib, and last lumbar vertebra, as well as average backfat depth, loin eye area, drip loss percentage, ultimate pH, Japanese color, American color, marbling, or a* values were not ($P > 0.10$) affected by Mn supplementation. However, pork from pigs fed diets containing 350 ppm Mn from AvailaMn-80 was darker (lower L* values; $P < 0.05$) than pork from pigs fed diets containing 700 ppm Mn from AvailaMn-80.

Implications

Results from this study confirm that supplementing the diets of growing-finishing swine with excess manganese does not affect live animal performance. Even though drip loss, marbling, or subjective color scores were not influenced by elevated dietary manganese, supplemental manganese at a level of 350 ppm may have beneficial effects on L* values.

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Table 1. Effects of manganese source and level on performance of growing-finishing swine.

	Manganese sulfate			AvailaMn-80		
Item	Control	350 ppm	700 ppm	350 ppm	700 ppm	SE
Starter phase (57.5 to 80.0 lb)						
ADG, lb/d	1.07	1.03	0.98	1.02	0.98	0.052
ADFI, lb/d	2.02	2.15	2.17	2.17	2.02	0.114
F/G	1.92	2.18	2.22	2.15	2.14	0.580
Grower I phase (80.0 to 150.0 lb)						
ADG, lb/d	1.83	1.81	1.67	1.76	1.75	0.059
ADFI, lb/d	4.83	4.71	4.78	4.74	4.61	0.161
F/G	2.64	2.61	2.90	2.70	2.63	0.013
Grower II phase (150.0 to 200.0 lb)						
ADG, lb/d	1.99	2.01	2.08	2.09	2.03	0.084
ADFI, lb/d	6.24	6.09	6.23	6.48	5.96	0.212
F/G	3.15	3.03	3.01	3.10	2.94	0.083
Finisher phase (200.0 to 265.0 lb)						
ADG, lb/d	2.10	2.22	2.22	2.06	2.08	0.116
ADFI, lb/d	11.10	11.47	11.12	11.42	11.08	0.453
F/G	5.30	5.24	5.04	5.61	5.29	0.140
Initial	57.6	57.6	57.6	57.6	57.5	0.02
Starter phase	88.5	86.4	85.7	87.1	85.9	1.52
Grower I phase	166.3	165.1	156.6	162.7	160.3	3.17
Grower II phase	209.5	206.9	199.3	206.1	202.3	4.31
Finisher phase	270.6	272.0	263.9	266.2	263.6	5.98

Table 2. Effects of manganese source and level on carcass cutability traits and pork quality characteristics.

	Manganese sulfate			AvailaMn-80	
Item	Control	350 ppm	700 ppm	350 ppm	700 ppm
Backfat thickness, in.					
First rib	1.53 ± 0.064	1.67 ± 0.078	1.46 ± 0.070	1.61 ± 0.068	1.56 ± 0.063
Last rib	1.03 ± 0.042	1.12 ± 0.051	0.98 ± 0.047	1.06 ± 0.044	1.06 ± 0.041
Last lumbar vertebra	0.99 ± 0.045	0.98 ± 0.055	0.88 ± 0.049	0.95 ± 0.047	0.99 ± 0.043
Average backfat	1.19 ± 0.042	1.25 ± 0.051	1.11 ± 0.047	1.19 ± 0.045	1.20 ± 0.042
Loin eye area, sq. in.	7.40 ± 0.293	7.36 ± 0.333	7.12 ± 0.285	6.90 ± 0.291	7.31 ± 0.274
Drip loss, %	3.79 ± 0.419	2.95 ± 0.488	3.34 ± 0.462	3.41 ± 0.458	3.95 ± 0.420
Muscle pH	5.89 ± 0.110	5.92 ± 0.134	5.89 ± 0.121	5.95 ± 0.120	5.74 ± 0.107
Japanese color score[a]	2.3 ± 0.13	2.3 ± 0.16	2.5 ± 0.15	2.8 ± 0.14	2.4 ± 0.13
American color score[b]	2.8 ± 0.12	2.9 ± 0.15	3.0 ± 0.14	3.2 ± 0.14	2.9 ± 0.12
Marbling score[c]	2.9 ± 0.16	2.7 ± 0.20	2.5 ± 0.18	2.8 ± 0.18	2.7 ± 0.16
Firmness score[d]	3.1 ± 0.12	3.2 ± 0.15	3.0 ± 0.13	3.3 ± 0.13	2.9 ± 0.12
CIE color values[e]					
L*	54.56[x] ± 0.78	54.46[x] ± 0.95	54.08[xy] ± 0.86	51.86[y] ± 0.87	55.33[x] ± 0.76
a*	6.45 ± 0.26	6.05 ± 0.32	6.15 ± 0.29	6.32 ± 0.29	6.45 ± 0.26
b*	14.77 ± 0.31	14.72 ± 0.38	14.52 ± 0.34	13.93 ± 0.34	15.17 ± 0.30

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

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

[c] Marbling score: 1 = devoid and 10 = abundant (NPPC, 1999).

[d] Firmness score: 1 = very soft/very watery and 5 = very firm/very dry (NPPC, 1995).

[e] L* = measure of darkness to lightness (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 yellow color).

[x,y] Within a row, least-squares means (± SE) lacking a common superscript letter differ ($P < 0.05$).

Effect of Feather Meal on Live Animal Performance and Carcass Quality and Composition of Growing-Finishing Swine

C. B. Boger, J. K. Apple, D. C. Brown, C. V. Maxwell, W. J. Roberts, Z. B. Johnson, L. K. Rakes, and J. Stephenson[1]

Story in Brief

Crossbred barrows and gilts (n = 120; BW = 55.77 ± 0.02 lb) were used to assess the effects of supplementing valine with hydrolyzed feather meal plus blood (FM) in growing-finishing swine. Pigs were blocked by weight, segregated within blocks, and assigned randomly to 24 pens (five pigs/pen), and pens within blocks were assigned randomly to one of four treatments; 1) positive control corn-soybean meal-based starter, grower, and finisher diets (PC); 2) negative control starter, grower, and finisher diets consisting of corn-soybean meal, and wheat middlings as a low-valine protein source (NC); 3) corn-SBM diet supplemented with 3% FM (3FM); and 4) corn-SBM diet supplemented with 6% FM (6FM). Feather meal was included in the diets at the expense of wheat middlings. During the starter phase the pigs fed the PC diets had higher ($P < 0.05$) ADG and lower ($P < 0.05$) F/G than pigs fed NC or valine supplemented diets. Pigs on the PC diets had a higher ($P < 0.05$) BW at the end of the starter period than pigs fed the NC, 3FM, or 6FM diets. Carcass composition traits were unaffected ($P > 0.10$) by inclusion of FM in the diets. Pigs on the PC diets had lower ($P < 0.05$) Hunter a*, b* and chroma values than pigs fed the NC or valine supplemented diets. The PC pigs also exhibited a larger hue angle ($P < 0.05$) than the pigs fed the other three diets.

Introduction

Feather meal plus blood (FM) is a major byproduct of poultry processing. Recently feather meal has been of interest to the swine industry because of its high protein content (80-85%). Feather meal is relatively inexpensive and it is an excellent source of valine and sulphur containing amino acids such as cystine, methionine, and threonine. However, its use in growing-finishing swine diets has been limited due to concerns about variability in quality and the fact that the lysine content is quite low. Inferior pork quality, particularly pale, soft, and exudative (PSE) pork, has quickly become a major economical problem facing the pork industry. The incidence of inferior pork quality is genetically linked to muscularity, so pork producers are trying to combat the problem nutritionally. Chiba et al. (1995) found that feeding finishing hogs diets supplemented with FM greatly enhanced pork carcass composition, but no pork quality measurements were taken. Preliminary data from our laboratory indicate that inclusion of FM in the diets of growing pigs improved feed efficiency by approximately 3.6% (Brown et al., 2000). Southern and co-workers (2000) recently evaluated FM as a source of valine in lactating sows and found that supplying 0.1% of the total supplemental valine from FM had no effect on sow productivity. However, FM was included in diets at a level of only 2.5% and the valine content of the control diet, devoid of FM, exceeded recommended levels. Therefore, the objective of this study was to test the effects of valine level on carcass traits and live animal performance of growing-finishing swine.

Experimental Procedures

Materials. Hydrolyzed FM containing 8% blood was obtained from Tyson's Foods, Inc. Protein Plant in Noel, MO. The FM was processed as follows, fresh poultry feathers were spread evenly on a conveyer, passed through a metal detector (to remove harmful metals), and hydrolyzed in a batch hydrolyser for 30 min at a pressure of 30 to 40 psi and a temperature of 170°F. Feathers were hydrolyzed in a batch hydrolyser to break down keratin (long chain proteins) into more digestible, smaller chain proteins and to reduce microorganisms on the feathers. Blood was coagulated and added to the hydrolyzed feathers in the batch hydrolyser to increase the protein level of the product. This product was then dried in a direct contact drier (natural gas fire dryer), milled through a mesh screen and shipped to the producer.

Allotment of pigs. Crossbred gilts and barrows (n = 120) were moved from the University of Arkansas nursery unit to the University of Arkansas Swine Farm, sorted by weight, and divided into six weight groups (blocks) with 20 pigs in each block. Pigs within each block were allotted into equal subgroups (five pigs/pen) with stratification based on sex. Treatments were then randomly assigned to pens within each of the weight groups.

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Experimental treatments. The four treatments consisted of: 1) negative control (NC) starter, grower, and finisher diets consisting of corn, soybean meal, and wheat middlings as a low-valine protein source 2) positive control (PC) corn-soybean meal based starter, grower and finisher diets; 3) The NC diets supplemented with 3% FM (3FM) on an equal lysine basis; 4) the NC diets supplemented with 6% FM (6FM) on an equal lysine basis. All diets were formulated to meet, or exceed, NRC (1998) requirements for growing-finishing swine, and starter, grower-I, grower-II, and finisher diets contained 1.00, 0.91, 0.80, and 0.66% lysine, respectively, and 1,548, 1,521, 1,525, and 1,529 Kcal of ME/lb, respectively. Additionally, the valine content of the PC, NC, 3FM, and 6FM diets during the starter phase was 0.89, 0.75, 0.90, and 1.06%, respectively, during the grower-I phase was 0.83, 0.69, 0.85, and 1.00%, respectively, during the grower-II phase was 0.75, 0.62, 0.77, and 0.93, respectively, and during the finisher phase was 0.66, 0.52, 0.68, and 0.85, respectively (Table 1).

Pigs were fed a four-phase diet with transition from starter to grower-I phase occurring as each block reached approximately 80 lb; transition from grower-I to grower-II occurring when each block reached a mean weight of 150 lb; and transition from grower-II to finisher when each block averaged approximately 200 lb. Pig weights and feed disappearance were recorded weekly to calculate ADG, ADFI, and F/G.

When the lightest block of pigs averaged 240 lb, pigs were transported approximately 250 miles to a commercial pork packing plant (Excel Corp., Marshall, MO). Pigs were harvested according to industry-accepted procedures, and 10th rib fat and loin depth were measured on-line with a Fat-O-Meater, automated probe (SFK Technology A/S, Cedar Rapids, IA) and hot carcass weight was recorded. Following a 24-hour spray-chill, midline backfat depth opposite the first rib, last rib and last lumbar vertebra was recorded, and loins were marked between the 10th and 11th ribs in order to measure loin eye area upon arrival at the University of Arkansas Red Meat Abattoir. Carcasses were then fabricated into primal cuts, and bone-in hams, from the left sides, were analyzed for lean composition using a TOBEC, unit. Prediction equations to calculate lean composition from the TOBEC, and Fat-O-Meater, measurements could not be obtained because they are the intellectual property of Cargill Red Meat Sector. Additionally, bone-in pork loins from left sides were collected, vacuum-packaged, boxed, and transported back to the University of Arkansas for pork quality data collection.

Quality data. At approximately 48-h post-mortem, a 2-in portion of the loin (blade end) was removed, and a 2 g sample was excised for pH measurement following the protocol outlined by Bendall (1973). Loin chops were removed perpendicular to the muscle fiber orientation in the following order: 1) 1-in thick loin chop; 2) 1.5-in thick loin chop; 3) 1-in thick loin chop; 4) 1.5-in thick loin chop. Additionally, each loin was separated at the mark between the 10th and 11th ribs, and each loin eye was traced onto acetate paper and loin eye area was measured, at a later date, using a compensating planimeter.

The two 1.5-in thick chops were used for drip loss determination. A 1.5-in core was removed from each 1.5-in thick chop, weighed and suspended on a fishhook (barb removed) mounted to the lid of a plastic container (18 in deep X 15 in wide X 24 in long), and stored at 34°F. After 48 h, each core was blotted, with a paper towel and reweighed. The loss in weight due to drip and evaporation was divided by the original weight, multiplied by 100, and reported as drip loss percentage. Two additional 1-in thick chops were removed from the loin and, after a 30-min bloom period, American (NPPC, 1999) and Japanese color (Nakai et al., 1975) scores, as well as marbling (NPPC, 1999) and firmness (NPPC, 1991) scores, were recorded. Also, L*, a*, and b* values were determined from the mean of four readings from a Hunter MiniScan XE (Hunter Associates Laboratory, Inc., Reston, Virginia) using illuminant C and a 10° observer. The hue angle, representing a change from the true red axis, was calculated as: tan-1(b*/a*); whereas, the chroma, representing the color intensity of loin chops, was calculated as: .

Statistical Analysis. Performance and carcass cutability and quality data were analyzed as a randomized complete-block design with pen as the experimental unit and blocks based on initial body weight. Analysis of variance was performed using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC). Least-squares means were calculated and separated statistically by the PDIFF option.

Results and Discussion

Live animal performance results are presented in Table 2. During the starter phase, pigs fed the PC starter-diets had greater ($P < 0.05$) ADG than pigs fed either the FM-supplemented or the NC diets. Although ADFI was similar ($P > 0.05$) among diets, PC-fed pigs had lower ($P < 0.05$) F/G than pigs fed the NC, 3FM, and 6FM diets. Neither ADG, ADFI, or F/G were affected ($P > 0.05$) by dietary valine level during the grower I and II, and finisher phases of the feeding trial, nor did dietary valine level affect ($P > 0.05$) live pig performance over the entire length of the trial. The higher ADG achieved by pigs fed the PC starter-diet led to a higher mean weight for these pigs at the end of the starter phase. Furthermore, the effect was carried over into the grower-I phase where the final weights for the pigs fed the PC-diet tended to be higher ($P < 0.10$) than pigs fed either the NC-diet, or the valine supplemented diets. Results from this study confirm those of Brown et al. (2000), who observed a similar increased ADG and decreased F/G during the starter phase in pigs fed control diets compared to pigs fed diets supplemented with 3 or 6% FM. Moreover, Chiba et al. (1995; 1996) showed that inclusion of up to 6% FM in swine diets had no adverse affect on ADG, ADFI, or final BW.

Carcass cutability traits were not affected by valine supplementation (Table 3). These results contradict previous research (Brown et al., 2000) that reported an increase in average backfat and carcass fat measurements for pigs fed 3% FM. Furthermore, other studies have reported that inclusion of FM in swine diets enhanced leanness in finishing pigs

(Chiba et al., 1995) and reduced abdominal fat in broilers (Cabel et al., 1987).

Pork quality results are presented in Table 4. The level of dietary valine supplementation had no effect ($P > 0.05$) on drip loss, pH, Japanese or American color scores, marbling or firmness scores. Although valine level had no affect ($P > 0.05$) on the L* star values, pigs fed the NC diets had the highest ($P < 0.05$), and pigs fed the PC diets had the lowest ($P < 0.05$) a* (indicating a redder color) and chroma (indicating a more vivid color) values; pork from pigs fed the FM-supplemented diets had a* and chroma values intermediate to the those from pigs fed either NC or PC. Moreover, pigs fed the PC diet had lower ($P < 0.05$) b* scores (less yellow), and higher hue angles (indicating a greater shift from true red color) than pigs fed either the NC diets or the valine supplemented diets. There are no published reports of the effects of dietary valine content on pork quality attributes; however, it is plausible that the observed pork color differences between the PC starter-diet and the NC starter-diet is not a response to valine content, but may be related to the high wheat middlings content of the NC diets compared to the exclusively corn-soybean PC diets.

Implications

Results indicate that valine level has little to no effect on overall pig performance or carcass cutability and quality traits. In addition, the lack of improvement in pork quality traits associated with diets formulated to provide required, and elevated levels of valine may have been overshadowed by the increased wheat middlings included in those diets. More research is required to first elicit the effects of wheat middlings on pork quality traits, before assessing the effects of altering dietary valine levels on pork quality traits.

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Table 1. Calculated amino acid and energy content of experimental diets[a].

Item	PC	NC	3FM	6FM
Starter phase (50 – 80 lb)				
Crude protein, %	18.62	16.11	18.03	20.05
Lysine, %	1.00	1.00	1.00	1.00
Methionine, %	0.30	0.28	0.27	0.28
Methionine & Cysteine, %	0.63	0.58	0.68	0.80
Valine, %	0.89	0.75	0.90	1.06
Threonine, %	0.70	0.65	0.67	0.77
Metabolizable energy, Kcal/lb	1548	1548	1548	1548
Grower-I phase (80-150 lb)				
Crude protein, %	17.43	14.94	16.90	18.91
Lysine, %	0.91	0.91	0.91	0.91
Methionine, %	0.28	0.25	0.26	0.27
Methionine & Cysteine, %	0.60	0.53	0.66	0.78
Valine, %	0.83	0.69	0.85	1.00
Threonine, %	0.65	0.59	0.63	0.73
Metabolizable energy, Kcal/lb	1521	1521	1521	1521
Grower-II phase (150 – 200 lb)				
Crude protein, %	15.89	13.40	15.37	17.39
Lysine, %	0.80	0.80	0.80	0.80
Methionine, %	0.26	0.23	0.24	0.25
Methionine & Cysteine, %	0.55	0.49	0.61	0.74
Valine, %	0.75	0.62	0.77	0.93
Threonine, %	0.59	0.52	0.57	0.67
Metabolizable energy, Kcal/lb	1525	1525	1525	1525
Finisher phase (200 – 240 lb)				
Crude protein, %	13.84	11.34	13.32	15.34
Lysine, %	0.66	0.66	0.66	0.66
Methionine, %	0.24	0.20	0.21	0.22
Methionine & Cysteine, %	0.51	0.43	0.56	0.68
Valine, %	0.66	0.52	0.68	0.83
Threonine, %	0.51	0.43	0.49	0.59
Metabolizable energy, Kcal/lb	1528	1528	1528	1528

[a]Experimental diets are abbreviated: PC = positive control = NRC requirements; NC = negative control – valine deficient; 3FM = negative control diets supplemented with 3% hydrolyzed feather meal plus blood (FM); and 6FM = negative control diets supplemented with 6 % FM.

Table 2. Effects of valine supplementation on performance traits.

	Valine treatments[a]				
Item	NC	PC	3FM	6FM	SE
Starter phase					
ADG	1.19[c]	1.41[d]	1.23[c]	1.23[c]	.044
ADFI	3.06	3.23	3.21	3.17	.099
F/G	2.61[c]	2.30[d]	2.6[c]	2.61[c]	.095
Grower I phase					
ADG	1.98	2.02	2.00	1.98	.070
ADFI	5.35	5.37	5.57	5.43	.086
F/G	2.71	2.66	2.8	2.79	.120
Grower II phase					
ADG	2.27	2.13	2.27	2.35	.121
ADFI	7.24	6.60	7.28	7.41	.273
F/G	3.21	3.12	3.24	3.17	.072
Finisher phase					
ADG	2.16	2.16	1.93	2.07	.123
ADFI	7.90	7.94	7.72	7.96	.354
F/G	3.72	3.73	4.03	3.86	.205
Overall trial					
ADG	1.87	1.94	1.89	1.87	.040
ADFI	5.65	5.59	5.76	5.68	.092
F/G	3.01	2.89	3.05	3.03	.063
Weights, lb					
Initial	55.77	55.77	55.79	55.75	.026
Starter	80.89[b]	85.95[c]	82.61[b]	82.17[b]	1.09
Grower I	156.60[d]	163.28[e]	159.24[de]	158.84[de]	1.676
Grower II	204.80	209.73	208.30	207.00	2.875
Finisher	237.86	242.66	239.43	237.29	3.071

[a] Valine treatments are valine deficient – negative control (NC); NRC requirement – positive control (PC); 3% hydrolyzed feather meal plus blood (3FM); and 6% feather meal (6FM).

[bc]Within a row, means lacking a common superscript letter differ ($P < 0.05$).

[de]Within a row, means lacking a common superscript letter differ ($P < 0.10$).

Table 3. Effects of valine supplementation in carcass cutability traits.

	Valine treatments[a]				
Item	NC	PC	3FM	6FM	SE
Hot carcass wt, lb	172.47	176.53	175.48	172.31	3.059
Backfat thickness, in					
First rib	1.55	1.52	1.50	1.57	.054
Last rib	1.03	1.07	1.03	.98	.045
Last lumbar vertebra	1.00	.93	.92	.95	.051
Average	1.19	1.17	1.20	1.17	.043
10th rib fat depth, in	.92	.90	.90	.89	.043
LM depth, in	1.96	1.97	2.01	1.96	.049
LM area, in^2	5.93	5.95	5.83	5.94	.166
Carcass muscle[b], %	49.95	50.05	50.48	50.36	.539
Ham wt, lb	20.56	21.09	20.51	20.13	.305
Ham lean wt, lb	12.82	14.18	13.21	12.98	.475
Ham lean[b], %	63.26	67.46	64.45	64.53	1.902

[a]Valine treatments are valine deficient – negative control (NC); NRC requirement – positive control (PC); 3% hydrolyzed feather meal plus blood (3FM); and 6% feather meal (6FM).

[b]Formulas for percent carcass muscle and ham lean are the confidential property of Excel Corp., Marshall, MO.

Table 4. Effects of valine supplementation in carcass quality traits.

	Valine treatments[a]				
Item	NC	PC	3FM	6FM	SE
Drip loss, %	3.92	3.08	3.94	3.75	.066
Japanese color score[b]	3.10	3.08	3.17	2.99	.063
American color score[c]	3.40	3.45	3.37	3.26	.070
PH	5.62	5.74	5.69	5.62	.036
Marbling score[d]	2.09	2.03	2.03	1.86	.107
Firmness score[e]	3.66	3.68	3.71	3.56	.087
Hunter L*[f]	52.42	51.61	51.64	52.88	.470
Hunter a*[f]	7.12[i]	6.06[j]	6.71[k]	6.63[k]	.123
Hunter b*[f]	14.74[i]	13.83[j]	14.37[i]	14.50[i]	.179
Chroma[g]	16.39[i]	15.14[j]	15.87[i]	15.96[i]	.188
Hue Angle[h]	64.27[i]	66.43[j]	65.03[ij]	65.49[jk]	.388

[a] Valine treatments are valine deficient – negative control (NC); NRC requirement – positive control (PC); 3% hydrolyzed feather meal plus blood (3FM); and 6% feather meal (6FM).

[b] 1=pale gray and 6=dark purple (Nakai et al., 1975).

[c] 1=pale pinkish gray and 6=dark purplish red.

[d] 1=practically devoid (1% intramuscular fat) and 10=abundant (10% intramuscular fat).

[e] 1=very soft (weepy) and 5=very firm (dry).

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

[g] Chroma is a measure of total color (larger number indicates a more vivid color).

[h] Hue Angle represents a change from red to yellow color (larger number indicates a “lighter” red).

[ijk]Within a row, means lacking a common superscript letter differ ($P < 0.05$).

Maternal Effects for Performance Test Data of Four Breeds of Swine

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Story in Brief

The objective of this study was to investigate the importance of maternal genetic effects on performance traits of Yorkshire, Landrace, Duroc and Hampshire breeds of swine. Data consisted of performance test records collected in a commercial swine operation from 1992 to 1999. Pigs were weighed at the beginning (WT100) and end of a 77-day performance test, and backfat (BF) and loin eye area (LEA) were measured over the 12th rib by ultrasound. Daily feed intake (ADFI) was calculated for boars, and ADG was calculated for all animals. Genetic parameters were estimated for each breed and trait using multiple-trait DFREML procedures (MTDFREML). Fixed effects were contemporary groups and either initial or final test age as a covariate. Four models were examined: Model 1 included only the additive genetic effect of the animal; Model 2 added the common litter environmental effect; Model 3 added the maternal genetic value assumed to be uncorrelated with additive genetic effects; and Model 4 was the same as Model 3 with additive and maternal genetic effects assumed to be correlated. All models were two-trait models including WT100, and ratios of likelihoods were used to compare models. Maternal effects were important ($P < 0.05$) for WT100 in all breeds; ADG in Landrace, Yorkshire and Duroc; ADFI in Landrace; and LEA and BF in Landrace and Yorkshire. In summary, maternal effects are important for some traits for some breeds and may need to be included in models to obtain unbiased estimates of direct breeding values.

Introduction

Genetic progress depends on accurate estimates of variances and heritabilities for traits of selection. Accurate estimates of these variances and heritabilities depend on application of the appropriate model for those traits. Estimates may be biased by failure to account for appropriate genetic or environmental sources of variation, such as maternal effects. If maternal genetic effects are important for performance traits, a model containing these effects along with direct genetic effects should provide more precise predictive ability of future progeny performance than a model that contains only direct genetic effects. The objective of this study was to investigate the importance of maternal genetic effects on performance traits of Landrace, Yorkshire, Duroc and Hampshire breeds of swine.

Materials and Methods

Data for this study consisted of performance test records of Landrace, Yorkshire, Duroc and Hampshire pigs collected in a commercial swine operation from 1992 to 1999. Two indexes (breeding values) for each animal were calculated at birth. One was a maternal index based on number born alive, farrowing interval, and litter weaning weight. The other was based on growth rate, leanness, and feed efficiency (Grow-Fin). These were combined into an overall ranking depending on the breed. For Landrace equal emphasis was given to both indexes; for Yorkshire more emphasis was given to the maternal index; for Duroc more emphasis was given to the Grow-Fin index; and for Hampshire the emphasis was totally on the Grow-Fin index. Boars from approximately 60% of the litters for each breed were culled at weaning based on that breed's index. Remaining boars and all females were grown to 100 days of age. At this time all pigs were weighed (WT100) and a second culling event occurred with recalculated indexes using any new information collected on animals in the breed. Fifty to sixty percent of the females and around 20 to 25% of the remaining boars were put on performance test for approximately 77 days. A slightly higher percentage (37%) of Landrace boars were performance tested. Boars were individually penned in 2.79 m^2 pens on slatted concrete floors and fed for *ad libitum* consumption a pelleted corn-soybean meal diet that was 1.14% lysine, 19% protein, and 3,344 mcal/kg ME. Exact composition of the diet varied due to ingredient cost. Gilts were fed this same diet in groups of eight to ten pigs in a pen with each pig having an area of 1.2 m^2. All pigs were weighed at the end of the 77-day performance test, and backfat (BF) and loin eye area (LEA) were measured over the 12th rib using B-mode ultrasound equipment. Average daily feed intake (ADFI) was calculated for boars, and ADG was calculated for all animals.

Contemporary group was defined as all pigs of the same sex reared in the same house and started on test within a 3-month period (quarter of a year). Data sets were edited to remove records of animals with missing sire or dam identification. Records were omitted if any trait measurement was

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greater than four standard deviations away from the overall mean. The number of records for various traits, along with means and standard deviations is given in Table 1.

Genetic parameters were estimated for each breed and trait using multiple-trait DFREML procedures (MTDFREML; Boldman et al., 1993 and Boldman and Van Vleck, 1991). Fixed effects were contemporary group and initial test age as a covariate for ADG and ADFI. Final test age was the covariate for BF and LEA. Four models were examined: Model 1 included only the additive genetic effect of the animal; Model 2 added the common litter environmental effect; Model 3 added the maternal genetic value assumed to be uncorrelated with additive genetic effects; and Model 4 was the same as Model 3 with additive and maternal genetic effects assumed to be correlated. Initially, a single-trait model was used for WT100. After the appropriate model for WT100 was determined, this trait and model were included in the analysis of each other trait in a series of two-trait models in an attempt to remove bias due to selection at 100 days of age; not all pigs weighed at 100 days of age were performance tested. Ratios of likelihoods as described by Ferraz and Johnson (1993) and Irgang et al. (1994) were used to compare models. The negative of twice the difference between two log likelihoods (reduced model vs. an unreduced model) is asymptotically distributed as chi-square with degrees of freedom equal to the difference in the number of parameters in the two models. Genetic parameters for the appropriate models were obtained and are reported.

Results and Discussion

Means, standard deviations, number of observations, and minimum and maximum value for each trait by breed are presented in Table 1. Numerically, Landrace pigs had the largest average WT100, followed by Yorkshire, Duroc and Hampshire. Mean ADG was lowest for Hampshire (1.83 lb), followed by Landrace (1.88 lb), Yorkshire (1.91 lb), and Duroc (1.95 lb). Mean LEA was greatest for Hampshire (6.5 in^2), followed by 6.3 in^2 for Yorkshire and 6.1 in^2 for the other two breeds. and similar for the other three breeds (approximately 40 cm2). Mean BF was largest for Duroc pigs (0.72 in), followed by Landrace (0.67 in), Yorkshire (0.65 in), and Hampshire (0.59 in). Mean ADFI ranged from 5.39 lb for Hampshire to 5.89 lb for Duroc.

Likelihood-ratio tests (Table 2) indicated that litter environmental effects (Model 1 vs. Model 2) were important ($P < 0.01$) for all five traits in all four breeds. Maternal effects (Model 2 vs. Model 3) were important for WT100 for all breeds ($P < 0.01$), for BF only in Yorkshire ($P < 0.01$), for LEA only in Landrace and Yorkshire ($P < 0.05$), and for ADG only in Duroc ($P < 0.05$). The correlation between direct and maternal effects (Model 3 vs. Model 4) was important for all traits but WT100 in Landrace ($P < 0.01$) and for all traits but ADFI in Yorkshire ($P < 0.05$ or $P < 0.01$). Among traits in the other two breeds, this correlation was important ($P < 0.01$) only for WT100 in Hampshire.

Estimated genetic parameters for WT100 using single-trait analyses and appropriate models are presented in Table 3. Effects found to be unimportant (Table 2) were not estimated and are reported as 0. Estimates of heritability of direct additive effects were 0.18 for Landrace, 0.14 for Yorkshire, 0.05 for Duroc and 0.20 for Hampshire (Table 3). Estimates of heritability of maternal genetic effects were 0.05, 0.06, 0.05 and 0.11, for Landrace, Yorkshire, Duroc, and Hampshire, respectively. The correlation between direct additive effects and maternal genetic effects (ram) was negative for the two breeds for which this effect was important (–0.25 for Yorkshire and –0.68 for Hampshire). Common environmental litter effects (c^2) explained from 20 to 25% of the phenotypic variance.

Estimates of genetic parameters for WT100 in the two-trait analyses with other traits (Table 3) were similar to those obtained in the single-trait analyses. Genetic correlations of WT100 with ADG were consistent for Landrace, Yorkshire, and Hampshire (0.43 to 0.46), but lower for Duroc (0.17). Genetic correlations for WT100 with ADFI followed the same pattern ranging from 0.47 to 0.60 for Landrace, Yorkshire and Hampshire, and lower for Duroc (0.14). Lower genetic correlations, ranging from 0.17 to 0.31, were found between WT100 and LEA. A correlation of 0.31 between WT100 and BF was obtained for Landrace and Yorkshire breeds, with higher correlations observed for Duroc (0.57) and Hampshire (0.45). Estimates of common environmental litter effects were consistent in all analyses, explaining from 21 to 26% of the phenotypic variance.

The covariance between litter environmental effects (r_c) for WT100 and ADG was 0.12 and 0.09 for Landrace and Yorkshire, respectively, and higher for Duroc and Hampshire (0.24 and 0.22, respectively). The covariance between litter environmental effects for WT100 and ADFI ranged from 0.31 to 0.42. For LEA, r_c was similar for Landrace, Yorkshire, and Duroc (0.43 or 0.44), but higher for Hampshire (0.64). For backfat, this covariance ranged from 0.28 for Landrace to 0.39 for Hampshire.

Estimates of heritability of direct additive effects for ADG were 0.28 for Landrace, 0.26 for Yorkshire, 0.14 for Duroc, and 0.17 for Hampshire (Table 4). Estimates of maternal heritability for ADG were low, being unimportant (reported as 0) for Hampshire, 0.02 for Landrace and Yorkshire, and 0.03 for Duroc. Correlations between direct additive and maternal effects were reported as 0 for Duroc and Hampshire, and were negative being –0.62 and –0.33 for Landrace and Yorkshire, respectively. Litter environmental effects explained approximately 15% (14 to 17%) of the phenotypic variation. Additive direct heritability for ADFI ranged from 0.20 for Duroc to 0.34 for Landrace. Maternal heritability of ADFI was important ($P < 0.05$) for Landrace pigs and was estimated as 0.05 for this breed with a negative correlation of –0.62 between direct additive and maternal genetic effects. The proportion of common litter environmental effects ranged from 0.20 for Yorkshire to 0.24 for Duroc and Hampshire.

Estimates of additive direct heritability of LEA varied for breeds, ranging from 0.25 for Hampshire to 0.48 for Landrace. Estimates of maternal heritability are reported as 0

for Duroc and Hampshire and are low for Landrace and Yorkshire (0.06 and 0.04, respectively) with correlations between direct and maternal effects found to be unimportant for Duroc and Hampshire and –0.67 for both Landrace and Yorkshire breeds. The proportion of common litter environmental effects ranged from 0.09 for Landrace to 0.18 for Hampshire.

For backfat, estimates of direct heritability were 0.63, 0.65, 0.35 and 0.31 for Landrace, Yorkshire, Duroc and Hampshire, respectively. Estimates of maternal heritabilities of BF were 0.07 for Landrace and 0.06 for Yorkshire and were unimportant for Duroc and Hampshire (Table 3). Correlations between direct and maternal effects were negative and similar for Landrace and Yorkshire (-0.66 and –0.69, respectively). Common environmental litter effects explained from 8 to 12% of the phenotypic variance for BF.

In summary, the importance of maternal effects differed by breed and trait. They were important ($P < 0.01$) for WT100 for all breeds, although the correlation between direct and maternal effects was unimportant for Landrace and Duroc. Maternal effects were important ($P < 0.05$) for ADG in Duroc, and the correlation between direct and maternal effects were important ($P < 0.01$) for ADG in Landrace and Yorkshire. The correlation between direct and maternal effects was important ($P < 0.05$) for ADFI in Landrace. Maternal effects were important ($P < 0.05$) for LEA in Landrace and for both LEA ($P < 0.05$) and backfat ($P < 0.01$) in Yorkshire. The correlation between direct and maternal effects was important ($P < 0.01$) for both LEA and BF in Landrace and Yorkshire. Perhaps these results are related to the selection program for each breed. No emphasis is given to maternal traits for Hampshire, less emphasis on maternal traits for Duroc, equal emphasis with grow-finishing traits for Landrace, and more emphasis is given to maternal traits for Yorkshire.

Implications

Maternal effects may be important for some traits in some breeds of swine and should be examined in large commercial herds. If important, they need to be included in genetic prediction programs to get unbiased estimates of direct breeding values. Improvement of maternal response in addition to direct response can lead to greater overall response to selection in a trait.

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Table 1. Mean,standard deviation, minimum and maximum values for performance traits of four breeds of swine

Trait	n	Mean	SD	Minimum	Maximum
			Landrace		
Age at 100 d	15594	98.67	2.93	71.00	109.00
Weight at 100 d, lb	15594	101.23	16.84	36.00	168.00
ADG, lb	7951	1.88	0.32	0.61	3.10
ADFI, lb	2523	5.85	0.80	3.22	8.71
LEA, in2	7942	6.13	0.89	2.89	9.65
Backfat, in	7946	0.67	0.18	0.22	1.40
Age at 177 d	7951	175.66	4.13	146.00	188.00
Weight at 177 d, lb	7951	252.45	31.47	149.00	375.00
			Yorkshire		
Age at 100 d	55497	99.34	2.90	71.00	117.00
Weight at 100 d, lb	55497	97.74	16.94	31.00	165.00
ADG, lb	27656	1.91	0.30	0.69	3.13
ADFI, lb	3953	5.69	0.86	3.00	8.72
LEA, in2	27638	6.34	0.94	2.71	10.96
Backfat, in	27647	0.65	0.19	0.18	1.42
Age at 177 d	27656	176.37	3.83	146.00	207.00
Weight at 177 d, lb	27656	251.61	28.78	136.00	366.00
			Duroc		
Age at 100 d	12267	98.98	2.83	62.00	118.00
Weight at 100 d, lb	12267	92.71	17.14	26.00	155.00
ADG, lb	5240	1.95	0.28	0.83	3.01
ADFI, lb	998	5.89	0.82	3.14	8.34
LEA, in2	5230	6.14	0.77	3.66	9.23
Backfat, in	5235	0.72	0.17	0.28	1.42
Age at 177 d	5240	175.98	3.87	160.00	199.00
Weight at 177 d, lb	5240	250.80	27.13	146.00	353.00
			Hampshire		
Age at 100 d	9782	100.09	2.94	70.00	132.00
Weight at 100 d, lb	9782	86.20	16.18	26.00	150.00
ADG, lb	3615	1.83	0.29	0.71	2.87
ADFI, lb	1094	5.39	0.76	3.05	7.64
LEA, in2	3613	6.50	0.87	3.79	9.57
Backfat, in	3615	0.59	0.14	0.18	1.14
Age at 177 d	3615	177.17	4.03	145.00	209.00
Weight at 177 d, lb	3615	236.60	29.29	132.00	354.00

Table 2. Values of minus two times the differences between the likelihood functions[a] of two different animal models[b] for weight at 100 d (WT100), ADG, average daily feed intake (ADFI), loin eye area (LEA) and backfat thickness (BF) for four breeds of swine.

Breed	Trait	Model 1 vs. Model 2	Model 2 vs. Model 3	Model 3 vs. Model 4
Landrace	WT100	1,181.76**	17.57**	1.89
	ADG	209.15**	.01	8.40**
	ADFI	102.20**	.01	9.42**
	LEA	159.80**	5.70*	26.71**
	Backfat	123.62**	2.71	20.87**
Yorkshire	WT100	3,772.44**	122.24**	5.37*
	ADG	941.97**	3.25	5.39*
	ADFI	127.57**	1.04	3.71
	LEA	859.31**	4.33*	58.24**
	Backfat	572.89**	14.58**	73.46**
Duroc	WT100	882.81**	24.00**	3.59
	ADG	150.73**	5.50*	0.01
	ADFI	33.56**	.70	1.24
	LEA	117.80**	.10	1.47
	Backfat	112.47**	0	0.27
Hampshire	WT100	1,079.38**	10.44**	11.73**
	ADG	133.32**	0	1.29
	ADFI	41.69**	0	0.44
	LEA	220.27**	0	0.01
	Backfat	62.08**	0	0.01

[a] Asymptotically distributed as chi-square with 1 degree of freedom.

[b] Model 1 includes direct additive genetic effects only; Model 2 includes additive direct genetic and common litter environmental effects; Model 3 includes direct genetic effects, litter environmental effects and maternal genetic effects; Model 4 is Model 3 with the correlation between additive direct and maternal genetic effects added. A single-trait model was used for WT100. Analyses of all other traits were two-trait models including WT100. Landrace and Duroc used Model 3 for WT100 and Yorkshire and Hampshire used Model 4 for WT100.

* $P < 0.05$.

** $P < 0.01$.

Table 3. Estimated genetic parameters for weight at 100 d of age (WT100) using the appropriate single-trait model[a] and two-trait models with ADG, average daily feed intake (ADFI), loin eye area (LEA) and backfat for Landrace, Yorkshire, Duroc and Hampshire pigs.

	Breed			
Item[b]	Landrace	Yorkshire	Duroc	Hampshire
Single-trait analysis				
h^2a	0.18	0.14	0.05	0.20
h^2m	0.05	0.06	0.05	0.11
r_{am}	0	-0.25	0	-0.68
c^2	0.20	0.21	0.21	0.25
With ADG				
h^2a	0.19	0.14	0.05	0.17
h^2m	0.04	0.05	0.05	0.10
r_{am}	0	-0.20	0	-0.60
c^2	0.21	0.21	0.21	0.25
r_{ga}	0.46	0.44	0.17	0.43
r_c	0.12	0.09	0.24	0.22
With ADFI				
h^2a	0.20	0.14	0.05	0.18
h^2m	0.03	0.05	0.05	0.10
r_{am}	0	-0.23	0	-0.61
c^2	0.21	0.21	0.21	0.25
r_{ga}	0.47	0.50	0.14	0.60
r_c	0.35	0.32	0.42	0.31
With LEA				
h^2a	0.19	0.14	0.06	0.18
h^2m	0.03	0.05	0.05	0.08
r_{am}	0	-0.17	0	-0.57
c^2	0.21	0.21	0.21	0.26
r_{ga}	0.26	0.17	0.26	0.31
r_c	0.43	0.43	0.44	0.64
With Backfat				
h^2a	0.19	0.16	0.05	0.19
h^2m	0.04	0.06	0.05	0.08
r_{am}	0	-0.30	0	-0.58
c^2	0.21	0.21	0.21	0.26
r_{ga}	0.31	0.31	0.57	0.45
r_c	0.28	0.32	0.29	0.39

[a] The model for Landrace and Duroc included additive direct effects, litter environmental effects and maternal genetic effects. The correlation between additive direct and maternal genetic effects is reported as 0 since this effect was found to be unimportant for WT100 (See Table 2). The model for Yorkshire and Hampshire included the correlation between additive direct and maternal genetic effects.

[b] Notation: heritability for additive direct effects (h^2a); heritability for maternal genetic effects; (h^2m); correlation between direct and maternal effects (r_{am}); and proportion of common litter environmental effects (c^2); genetic correlation of WT100 with each other trait (r_{ga}); and covariance between litter environmental effects for WT100 and each other trait (r_c).

Table 4. Estimated genetic parameters for ADG, average daily feed intake (ADFI), loin eye area (LEA), and backfat using appropriate two-trait models[a] that included weight at 100 d of age (WT100) for each breed.

	Breed			
Item[b]	Landrace	Yorkshire	Duroc	Hampshire
		ADG		
h^2a	0.28	0.26	0.14	0.17
h^2m	0.02	0.02	0.03	0
r_{am}	-0.62	-0.33	0	0
c^2	0.14	0.17	0.15	0.18
		ADFI		
h^2a	0.34	0.31	0.20	0.23
h^2m	0.05	0	0	0
r_{am}	-0.73	0	0	0
c^2	0.22	0.20	0.24	0.24
		LEA		
h^2a	0.48	0.39	0.26	0.25
h^2m	0.06	0.04	0	0
r_{am}	-0.67	-0.67	0	0
c^2	0.09	0.14	0.12	0.18
		Backfat		
h^2a	0.63	0.65	0.35	0.31
h^2m	0.07	0.06	0	0
r_{am}	-0.66	-0.69	0	0
c^2	0.08	0.10	0.12	0.10

[a] Models for each trait included effects that were found to be important (Table 2). When maternal genetic effects or the correlation between additive direct and maternal genetic effects were found to be unimportant, these effects are reported as 0.

[b] Notation: heritability for additive direct effects (h^2a); heritability for maternal genetic effects; (h^2m); correlation between direct and maternal effects (r_{am}); proportion of common litter environmental effects (c^2).

Effect of Treatment to Temporarily Block Germinal Vesicle Breakdown on Porcine Oocyte Maturation and Subsequent Parthenogenetic Development

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Story in Brief

Porcine oocytes matured in vitro undergo nuclear maturation more rapidly than cytoplasmic maturation. Treatment or procedures to synchronize the completion of nuclear and cytoplasmic maturation might enhance oocyte developmental competence. These studies assessed the effectiveness of various treatments to prevent or slow nuclear progression for a period of 20 h without detrimental effects to subsequent maturation and cleavage. Cumulus-oocyte complexes (COC's) were aspirated from sow ovarian follicles and assignment across treatments. Experiment 1 compared the effect of timing of follicle stimulating hormone (FSH) and luteinizing hormone (LH) on nuclear maturation. Experiment 2 compared the effectiveness of various treatments [dexamethasone (DEX), dimethylaminopurine (DMAP) and dibutyryl cyclic adenosine monophosphate plus testosterone (dbcAMP + T)] to temporarily block nuclear maturation without detrimental effects on subsequent development. In both experiments, oocyte nuclear maturation was assessed at 20 and 46 h of culture. Also, oocytes were chemically activated and then cultured to assess parthenogenetic cleavage and development to the blastocyst stage. Results of Experiment 1 indicate that delaying FSH and LH supplementation until after 20 h of maturation reduced maturation of oocytes to metaphase II (MII) and cleavage. Experiment 2 showed that DMAP irreversibly blocked nuclear maturation, resulting in few oocytes maturing or cleaving after activation. Both DEX and dbcAMP + T treatments appeared to be reversible and resulted in similar rates of maturation to MII and cleavage. When compared to the control group, all treatments reduced cleavage.

Introduction

In order to achieve developmental competence, porcine oocytes must undergo both nuclear and cytoplasmic maturation. Nuclear maturation results from breakdown of the germinal vesicle (GV) and progression of meiosis to metaphase II (MII). Cytoplasmic maturation is the accumulation, within the oocyte's cytoplasm, of products necessary for fertilization, cleavage and development, prior to activation of the embryonic genome. In vitro studies show that porcine oocytes require a maturation period of about 44 h in vitro to achieve adequate cytoplasmic maturation for developmental competence. However, nuclear maturation to metaphase II occurs within the first 24 h of culture (Day & Funahashi, 1996). This suggests that nuclear maturation events undergo aging while awaiting adequate cytoplasmic maturation, which in turn may decrease developmental competence.

Better synchrony between nuclear and cytoplasmic maturation might be achieved by temporarily blocking the spontaneous nuclear maturation that occurs when oocytes are removed from follicles and placed into culture. This might be achieved through the use of chemical blocking agents or altering the timing of addition of hormones to maturation medium. The present studies were conducted to determine if the presence or absence of gonadotropins (FSH and LH) during the first or second half of in vitro maturation affected porcine oocyte maturation to M II and subsequent cleavage. Also, the studies assessed the effectiveness of various chemical treatments to prevent porcine oocyte germinal vesicle breakdown (GVBD) for a period of 20 h without detrimental effects to subsequent maturation and cleavage.

Experimental Procedures

Sow ovaries were collected from an abattoir and 3 to 7 mm follicles were aspirated to recover cumulus-oocyte complexes (COC's). Recovered COC's were rinsed three times and held in M-199 medium supplemented with 10 mM HEPES and 50 µg/ml gentamicin until assignment to maturation treatments. In Experiment 1, the base in vitro maturation (IVM) medium was M-199 supplemented with 0.1 mM glutathione, 10% fetal calf serum and 50 µg/ml gentamicin. The COC's were matured for a total of 46 h. In Treatment 1, the base medium was supplemented with FSH and LH for the first 20 h and no hormones the last 26 h of maturation. In Treatment 2, FSH was used the first 20 h and LH the last 26 h of maturation, while in Treatment 3, no hormones were used the first 20 h, but FSH and LH were added the last 26 h of maturation. The FSH and LH used were each supplemented at 0.05 NIH units/ml.

In Experiment 2, the base IVM medium for 0 to 20 h was M-199 medium, supplemented with 0.1 mM glutathione, 10% FCS, 50 µg/ml gentamicin, and 0.05 NIH units/ml of FSH. This medium was used alone (Control), or was supplemented with either 10 mg/ml dexamethasone (DEX), 2 mM dimethylaminopurine DMAP, or 1 mM dibutyryl cyclic adenosine monophosphate plus 1 µM testosterone (dbcAMP

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+ T; Petr et al., 1996). After the initial 20 h of culture, COC's in each treatment were rinsed and cultured to 46 h in M-199 medium supplemented with 0.1 mM glutathione, 10% FCS, 50 µg/ml gentamicin, and 0.05 NIH units of LH.

In both Experiments 1 and 2, approximately one-third of the COC's in each treatment were removed from culture after the initial 20 h of culture, stripped of cumulus cells, and then fixed and stained to assess stage of nuclear maturation. At the termination of culture (46 h), the remaining COC's were recovered and cumulus cells were mechanically removed. Half of the resulting denuded oocytes were fixed and stained to assess nuclear maturation, while the other half were chemically activated and cultured to assess parthenogenetic cleavage.

Oocytes in each treatment group were chemically activated by exposure to NCSU-23 medium containing 50 µM calcium ionophore A23187 for 3 min (Wang et al., 1999). After exposure to activation treatment, the oocytes were rinsed and placed into 4-well culture plates containing NCSU-23 medium and cultured in a humidified atmosphere of 5% CO2 in air at 39 ºC. Forty-eight hours after activation, embryos were evaluated for cleavage and uncleaved oocytes were discarded. On day 7, development to the morula and/or blastocyst stage was assessed.

Experiment 1 and 2 were each replicated three times. The JMP program, (SAS Institute Inc. Cary, NC) was used for statistical analysis. Analysis of variance for a randomized block design (blocked on replicate) was used with the response variables being the percentage of GV, MII, cleaved and morula/blastocysts, transformed by the angular transformation. Pairwise comparisons of treatments were done by multiple t-tests at the 5% level of probability.

Results and Discussion

The sequence of FSH and LH supplementation had no effect on the percentage of oocytes remaining at the GV stage at 20 h of culture (Table 1). Across treatments, the percentage of oocytes maturing to MII at 46 h ranged from 38 to 61%. Addition of both FSH and LH to culture medium after 20 h of culture reduced maturation, when compared with other treatments. Previous studies report that FSH supports estradiol production by cumulus cells in the absence of significant levels of LH and estradiol slows nuclear progression (Richter and McGaughey, 1979). Luteinizing hormone promotes luteinization of cumulus cells and a shift in steroid synthesis from estradiol to progesterone. Progesterone in turn, promotes nuclear progression (Eroglu, 1993). Therefore, we had expected that the addition of FSH the first 20 h and LH the second 26 h of maturation would slow or delay nuclear maturation and allow both nuclear and cytoplasmic maturation to be completed at approximately the same time. However, it would appear that deletion of LH from maturation medium the first 20 h of culture is not enough to delay GVBD.

Oocyte cleavage after activation ranged from approximately 29 to 50% (Table 2). As with maturation, addition of both FSH and LH to culture medium after the initial 20 h of culture reduced subsequent cleavage. These results tend to confirm a previous study reporting that the presence of FSH and LH during the last 20 h period of culture reduces the oocytes' ability to properly mature (Funahashi et al., 1994). There were no differences among treatments for the percentage of embryos developing into morulae and blastocysts. However, adding FSH the first 20 h and LH the remaining 26 h numerically increased the number of blastocysts, when compared with all other treatments. While this difference was not statistically significant, it would likely be of economic benefit in labs producing porcine embryos.

Based on the number of oocytes remaining at the GV stage at 20 h of IVM, all of the chemical treatments more effectively blocked GVBD than the control treatment (Table 3). The DMAP and dbcAMP + T treatments were equally effective in blocking nuclear maturation. The DEX treatment was less effective than DMAP but similar to dbcAMP + T in blocking GVBD. Both DEX and dbcAMP + T treatments appeared to be reversible and resulted in similar rates of maturation to MII after removal from the maturation medium. The DMAP treatment appeared to have an irreversible effect on subsequent nuclear maturation. All treatments reduced subsequent cleavage after parthenogenetic activation when compared with the control treatment. The DMAP treatment was most detrimental to subsequent maturation, cleavage and development. The mean number of cells per developing embryo were similar among treatments and within the range reported for parthenogenetic embryos.

The objective of our studies was to block GVBD for a period of 20 h, without detrimental effects to subsequent maturation and cleavage. Blocking nuclear maturation at the germinal vesicle stage has proven to be beneficial for development to the blastocyst stage. A previous study reported that the presence of dbcAMP during the first 20 h of culture for maturation, induces a more synchronous meiotic progression of porcine oocytes and improves the rate of early embryonic development to the blastocyst stage after fertilization (Funahashi et al., 1997). In our study, oocytes were parthenogenetically activated rather than fertilized. Further study is planned to determine if dbcAMP and testosterone treatment can be used in oocyte maturation regimens to improve developmental competence after fertilization.

Implications

It may be possible to improve porcine developmental competence by synchronizing nuclear and cytoplasmic maturation in vitro. The most effective method to synchronize maturation is through use of chemical agents to delay GVBD. Both DEX and dbcAMP + T treatments appeared to be reversible and resulted in similar rates of maturation to MII and cleavage. Additional studies are needed to assess developmental competence of oocytes exposed to these treatments after fertilization, rather than activation and parthenogenetic cleavage.

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Table 1. Effect of hormone supplementation on germinal vesicle breakdown and subsequent nuclear maturation to metaphase II (MII).

Hormone added, 0 to 20 h	Hormone added, 20 to 46 h	No(%) oocytes with cleavage	No(%) morula & blastocyst
FSH + LH	None	54/124 (43.5)[a]	80/134 (59.7)[ab]
FSH	LH	64/124 (51.6)[a]	69/112 (61.6)[b]
None	FSH+LH	69/113 (61.1)[a]	45/118 (38.1)[a]

[a,b]Within the same column, values with different superscripts differ (P < 0.05).

Table 2. Effect of hormone supplementation on subsequent parthenogenetic cleavage and embryo development to the morula/blastocyst stage.

Hormone added, 0 to 20 h	Hormone added, 20 to 46 h	No(%) oocytes with cleavage	No(%) morula & blastocyst
FSH + LH	None	86/171 (50.3)[b]	14/86 (16.3)[a]
FSH	LH	74/164 (45.1)[b]	19/74 (25.7)[a]
None	FSH+LH	48/163 (29.4)[a]	10/48 (20.8)[a]

[a,b]Within the same column, values with different superscripts differ (P < 0.05).

Table 3. Effect of chemical treatments to block germinal vesicle breakdown and subsequent nuclear maturation to metaphase II (MII).

Maturation treatment	No(%) oocytes, GV stage @ 20h	No(%) oocytes, M II stage @ 46h
Control	63/128 (49.2)[c]	74/106 (69.8)[a]
DEX	96/142 (67.6)[b]	93/123 (75.6)[a]
dbcAMP + T	86/103 (83.5)[ab]	101/136 (74.3)[a]
DMAP	119/128 (93.0)[a]	16/119 (13.4)[b]

[a,b,c]Within the same column, values with different superscripts differ (P < 0.05).

Table 4. Effect of chemical treatments on subsequent parthenogenetic cleavage and embryo development to the blastocyst stage.

Maturation treatment	No(%) oocytes with cleavage	No(%) cleaved to blastocyst	Mean cell number per blastocyst
Control	69/153 (45.1)a	8/69 (11.59)[a]	31[a]
DEX	51/163 (31.3)b	2/51 (3.92)[ab]	22[a]
dbcAMP + T	51/158 (32.3)b	3/51 (5.88)[a]	36[a]
DMAP	26/181 (14.4)c	0/26 (0.0)[b]	---

[a,b]Within the same column, values with different superscripts differ (P < 0.05).

Genetic Parameter Estimates of Yearling Live Animal Ultrasonic Measurements in Brangus Cattle

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Story in Brief

The objective of this study was to estimate genetic parameters for real-time ultrasound measurements of longissimus muscle area (LMAU), 12th-rib back fat thickness (FTU), percent intra-muscular fat (PFAT), and yearling weight (YW) for 1,299 yearling Brangus bulls and heifers. A single ultrasound technician took all measurements. Number of observations was 1,298, 1,298, 1,215, and 1,170 for LMAU, FTU, PFAT, and YW, respectively. Genetic parameters were estimated for each trait using single- and multiple-trait DFREML procedures (MTDFREML). Each trait was analyzed as a single-trait, then in combination with each other trait in a series of two-trait models. Means for LMAU, FTU, PFAT, and YW were 11.13 ± 2.25 in^2, 0.22 ± 0.10 in, 3.27 ± 0.92 %, and 1030.51 ± 188.23 lb, respectively. Heritabilities obtained from single-trait analysis of LMAU, FTU, PFAT and YW were 0.31, 0.26, 0.16, and 0.53, respectively. Average heritabilities from the two-trait analyses for LMAU, FTU, PFAT, and YW were 0.31, 0.27, 0.15, and 0.53, respectively. Genetic correlations for LMAU and FTU, LMAU and PFAT, LMAU and YW, FTU and PFAT, FTU and YW, and PFAT and YW were -0.09, -0.25, 0.44, 0.36, 0.42, and 0.31, respectively. These data suggest a substantial additive genetic effect for YW, FTU, and LMAU implying a strong relationship between phenotypic value and breeding value for these traits.

Introduction

Collection of ultrasound measurements is faster, easier, and more economical than traditional methods of collecting carcass data that include harvesting of animals. Green (1996) stated the amount of useful carcass data that can be easily and economically collected is unlimited. Some beef cattle breed associations collect yearling live-animal ultrasound measurements of carcass traits for purebred bulls and heifers. These measurements are to be used in collaboration with genetic performance records already used by seedstock and commercial cattle breeders. Research and literature reporting on analysis of genetic parameters for carcass trait measurements taken by live-animal ultrasound techniques is plentiful. Before these data can be effectively utilized, each association must state proven heritabilities and correlations for their respective breeds for ultrasound measurements of these carcass traits. The objective of this research was to obtain accurate estimates of heritabilities and genetic correlations for carcass traits of yearling bulls and heifers in the Brangus breed.

Experimental Procedures

Animals and Data Collection. Purebred Brangus cattle (n = 1,299) had real-time ultrasound (RTU) measurements taken for inclusion in this study. Of these animals 226 were heifers and 1,073 were yearling bulls. All animals were scanned by a single ultrasound technician, and were taken in accordance to the Beef Improvement Federation guidelines (BIF, 1996). At the time of ultrasounding, measurements were taken of the 12th-rib longissimus muscle area (LMAU), 12th-rib fat thickness (FTU), percent intra-muscular fat (PFAT), and yearling weight (YW). Other data collected included location of ranch, sex of animal, age of animal, and animal registration number in accordance with the International Brangus Breeders Association (IBBA; San Antonio, TX). All animals included in the study had pedigrees traced back to paternal and maternal grandparents.

The equipment used in the collection of data was the Aloka 500V system (distributed by Aloka USA, Inc., Wallingford, CT) along with a superflab to ensure proper fit of the transducer to the curvature of the animal's natural body shape. The software used was the Critical Vision (CVIS) software (Critical Vision, Inc., Atlanta, GA). Placement of the transducer was determined by palpating the left side of the animal between the 12th and 13th ribs. Once the scanning area was determined, the location was oiled, curried free of dirt and debris, and oiled again before transducer placement. The transducer was placed toward the midline and parallel to the 12th and 13th rib bones and moved laterally until the longissimus muscle came into full view on the screen. Fat thickness was estimated at the 3/4 position from the chine bone end of the longissimus muscle (U.S.D.A. beef carcass grade standards) using the cross sectional ribeye image. A

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single longitudinal image of the longissimus muscle was taken (included the 11-12-13th ribs) for calculation of PFAT. The CVIS software predicts the percentage of intramuscular fat (ether extractable equivalent) from the longitudinal LMA image.

Data Editing. Only purebred Brangus bulls and heifers intended to be used in the future as seedstock or replacement animals were retained in the data set. Pedigrees were formulated by the IBBA database and went back two generations. Live-animal ultrasound measurements that predated 1995 were scanned using the Aloka 210DX (Corometrics Medical Systems, Wallingford, CT) equipped with a 3.0MHz, 12.5 cm transducer. This transducer requires that the technician take two scans of the longissimus muscle area and merge them together. This technique leaves room for technician error compared to the Aloka 500V; therefore, all data scanned with the Aloka 210DX were excluded.

In order to agree with the IBBA guidelines, yearling animals were considered 365 ± 45 days of age. For animal measurements to be included for this study they must have met the yearling requirements set by the IBBA. Animals included in the study were put into contemporary groups. Contemporary group was determined as animals of the same sex, same breeding season, and same environment. Contemporary groups containing only one sire were also eliminated. Represented in this study were progeny of 309 sires and 170 paternal grandsires in 23 contemporary groups. Table 1 presents descriptive statistics of number of records, means and standard deviations for traits in the edited data set used for analysis.

Model. Prior to variance component estimation, the MIXED procedures of SAS (SAS Inst. Inc., Cary, NC) were used to determine the significance of fixed effects for contemporary group (CG), days of age (DOA), and the interaction of CG x DOA for inclusion into the final animal model. In addition, starting variance components for the Multiple Trait Restricted Maximum Likelihood (MTDFREML) program of Boldman et al. (1993) and Boldman and Van Vleck (1991) were also estimated using MIXED procedures. Contemporary group was significant ($P < 0.001$), the linear effect of DOA was significant ($P < 0.001$), but the interaction of CG x DOA was not significant ($P > 0.05$). Therefore, CG was included in single and multiple-trait animal models as a fixed effect, and DOA was included in the models as a covariate.

Single-trait animal models were used to estimate starting variances for subsequent multiple-trait analysis. All possible combinations of multiple-trait analysis were performed two traits at a time. This procedure fits an additive genetic effect for animals with records as well as all parents analyzed in the pedigree database. The MTDFREML program used does not provide information on standard errors of estimated genetic parameters. The relationship matrix (A) contained 4,134 records.

Results and Discussion

Variance and covariance estimates for all traits achieved from MTDFREML are presented in Table 2. Heritabilities for single-trait analysis of LMAU, FTU, PFAT, and YW were 0.31, 0.26, 0.16, and 0.53 respectively. The heritabilities for the two-trait analysis for LMAU, FTU, PFAT, and YW were 0.31, 0.27, 0.15 and 0.53, respectively (Table 3).

Heritabilities. As stated previously the heritability obtained for LMAU in this study was 0.31. This moderate heritability indicates that the longissimus muscle should be under genetic control, and could be affected by selection for this trait.

A heritability of 0.27 was found for FTU in this study. In the literature it was found that heritabilities for fat thickness ranged from 0.04 to 0.52 for ultrasound measures. The heritability found in this study (0.27) was also in the middle range of those pertaining to ultrasound measures for Brangus cattle. The difference in heritabilities estimated in this research might be attributed to the smaller sample size used in this study. The difference could also be accounted for by the accuracy obtained from using only one technician. Even though there is a great deal of variability among estimates of heritability of fat thickness, the moderate measure in this study suggests that even with the great deal of environmental control there is also a great deal of genetic control associated with this trait, and selection could be a beneficial tool in reducing fat thickness.

The estimation of genetic parameters for the ultrasonic measurement of PFAT was one of the main concerns of this research. Information on the direct measurement of intramuscular fat (marbling) by ultrasound technology is not prevalent in the literature. The estimate of heritability for PFAT (0.15) is in the low range, and suggests that PFAT is dependent on circumstances other than direct genetic influence. The estimation of heritability for PFAT found in this study does differ from the heritability estimates of marbling scores previously published. Estimates of heritability for marbling score ranged from 0.26 to 0.47.

Genetic and Phenotypic Correlations. Genetic and phenotypic correlations are presented in Table 3. Genetic correlations between LMAU and FTU, LMAU and PFAT, and LMAU and YW were -0.09, -0.25, and 0.44 respectively. Phenotypic correlations of LMAU and FTU, LMAU and PFAT, and LMAU and YW were 0.16, -0.08, and 0.44, respectively. These correlations indicate that one could select for increased muscling without having to increase the amount of external fat an animal would put on. Genetic correlations between FTU and PFAT, and FTU and YW were 0.36, and 0.42, respectively. The moderate correlation between FTU and PFAT indicates that if selection is done to reduce the amount of fat thickness there will most likely be a reduction in the amount of marbling, which would be an adverse affect.

There was also a positive correlation between FTU and YW of 0.42. This indicates that as one selects for increased growth (post-weaning) there is also a chance of increasing external fat. Information was not found in the literature comparing the correlations of ultrasonic PFAT with that of other carcass traits. A correlation of 0.34 was obtained for between measurements of PFAT and YW in this study. This correlation is moderate and suggests that there could be some increase in the amount of intramuscular fat associated with increased post-weaning gain. However, while selecting for gain one must use caution so that the amount of external fat is not unknowingly increased.

Implications

Ultrasound technologies have the ability to provide producers and breed associations with efficient methods of collecting carcass data for inclusion in their genetic records. However, more research is needed to ensure the proper heritabilities and correlations are achieved using modern technology. More research is also needed to substantiate estimates of heritabilities obtained from direct ultrasound measurements of percent intramuscular fat, and uniform collection methods from technician effects to hardware and software used.

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Table 1. Descriptive statistics for ultrasound data.

Trait[a]	Number of records	Mean	Standard deviation
LMAU, in^2	1298	11.13	2.25
FTU, in	1298	0.22	0.10
PFAT, %	1215	3.27	0.92
YW, lb	1170	1030.51	188.23

[a]LMAU = 12th-rib longissimus muscle area, ultrasonically measured on live yearling bulls and heifers; FTU = 12th to 13th-rib back fat thickness, ultrasonically measured on live yearling bulls and heifers; PFAT = Percent intramuscular fat from 12th-rib longissimus muscle area, ultrasonically measured on live yearling bulls and heifers; YW = Live weight of yearling bulls and heifers taken at time of ultrasound.

Table 2. Genetic and phenotypic (co)variance[a] estimates for yearling live-animal ultrasonic measurements for carcass traits.

Measurement[b]	LMAU	FTU	PFAT	YW
LMAU	19.664	-0.041	-0.327	57.710
	(43.862)			
FTU	0.276	0.010	0.011	1.226
		(0.027)		
PFAT	-0.184	-0.014	0.091	2.592
			(0.494)	
YW	82.170	1.322	-1.715	841.982
				(753.894)

[a]On diagonal, additive genetic variance with residual variance below diagonal in parentheses. Above diagonal direct additive (co)variance, below diagonal residual (co)variances.

[b]LMAU = 12th-rib longissimus muscle area, ultrasonically measured on live yearling bulls and heifers; FTU = 12th to 13th-rib back fat thickness, ultrasonically measured on live yearling bulls and heifers; PFAT = Percent intramuscular fat from 12th-rib longissimus muscle area, ultrasonically measured on live yearling bulls and heifers; YW = Live weight of yearling bulls and heifers taken at time of ultrasound.

Table 3. Two-trait Heritabilities and Correlations[a] for Estimates of Ultrasonic Carcass Characteristics.

Measurement[b]	LMAU	FTU	PFAT	YW
LMAU	0.31	-0.09	-0.25	0.44
FTU	0.16	0.27	0.36	0.42
PFAT	-0.08	0.17	0.15	0.31
YW	0.44	0.33	0.03	0.53

[a]Heritability estimates on diagonal, genetic correlations above diagonal, phenotypic correlations below diagonal.

[b]LMAU = 12th-rib longissimus muscle area, ultrasonically measured on live yearling bulls and heifers; FTU = 12th to 13th-rib back fat thickness, ultrasonically measured on live yearling bulls and heifers; PFAT = Percent intramuscular fat from 12th-rib longissimus muscle area, ultrasonically measured on live yearling bulls and heifers; YW = Live weight of yearling bulls and heifers taken at time of ultrasound.

Breed-Type x Forage Interaction for Mature Weight and Rate of Maturing for Angus, Brahman, and Reciprocal Cross Cows

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Story in Brief

Mature weight (A) and rate of maturing (k) were estimated in 177 Angus, Brahman, and reciprocal cross cows grazing Bermudagrass (BG) or endophyte-infected tall fescue (E+) to evaluate breed-type x forage interactions. Data were collected every 28 d until approximately 18 mo of age and then at prebreeding, postcalving, and weaning of calf. Mature weight and k were estimated using Brody's model. Data were pooled over year and analyzed by the general linear model (GLM) procedure of SAS. Models for A and k included the independent variables of breed-type, forage and breed-type x forage interaction. There was a significant ($P < 0.01$) breed-type x forage interaction for A, but not for k. Angus cows had greater ($P < 0.01$) mean A on E+ than did Angus x Brahman cows on BG. Angus x Brahman cows grazing BG had lower ($P < 0.05$) mean A than did Brahman x Angus cows grazing BG or E+ and Brahman cows grazing BG. Angus cows had a slower ($P < 0.05$) mean k than Angus x Brahman and Brahman x Angus cows, and Angus x Brahman cows had a faster ($P < 0.05$) mean k than Brahman x Angus and Brahman cows. These data suggest that the choice of breed-type is important for maintaining a crossbreeding program, in that mature size and rate of maturing are critical to the match of animal requirements to available production resources.

Introduction

The growth parameters of mature weight (A) and rate of maturing (k) have been shown to be of biological importance to the efficiency of beef production. These parameters are major determinants of the amount of energy needed to grow and mature properly. The availability of adequate production resources often hinders the level of efficiency needed to sustain this level of energy. These parameters may be useful to producers who are trying to find the ideal animal to match available resources. There have been numerous papers that deal with the calculation of A and k in many breeds of cattle, however, a review of literature found a limited amount of growth curve data for crossbred cattle. Problems associated with endophyte-infected tall fescue (E+) have been extensively documented. The objective of this study was to look at the interaction of breed-type x forage for the growth parameters of A and k in Angus, Brahman, and reciprocal cross cows grazing common bermudagrass or endophyte-infected tall fescue.

Experimental Procedures

Base Herd Development. Eighty purebred Angus and 80 purebred Brahman heifers born in the spring of 1985 were purchased from approximately 20 different sources per breed in the fall of 1985 and winter of 1986. Of these heifers, 32 and 30 different sires were represented in Angus and Brahman breeds, respectively. Heifers were stratified according to source and assigned at random to one of four 36-acre BG pastures and one of four 36-acre 'Kentucky-31' E+ pastures.

Stocking rate for each pasture within forage environment ranged from 19 to 24 head, with approximately equal numbers of Angus and Brahman. Heifers were managed as commercial replacement heifers to gain approximately 0.80 lb/d by supplementing with cottonseed meal, corn, and E+ or BG hay according to visual estimates of forage DM availability and normal quality curves for either BG or E+. Normally, supplemental feed was provided from late November to late April for both forage treatment types; supplemental grain (2.0 lb per animal per day) was continued in the E+ treatment into late fall and early spring in an attempt to moderate potential toxicity from the forage. Minerals were fed free choice throughout the year.

Heifers were bred as 2-yr-olds to calve at 3 yr of age to preclude introducing parity differences into the study due to the low percentage of purebred Brahman reaching sexual maturity at 15 mo of age. They were bred during 75 d breeding seasons. Five sires of each breed were used in this study. Sires were rotated among breeding pastures in both forage treatments to prevent confounding of sire and forage effects, and breed of sire was alternated in a breeding pasture to facilitate sire of calf identification.

Study Animals. Calves were born from late February to late May each year. Weights were taken, and calves were tagged at birth. The post-weaning backgrounding environments were designed to imitate two commercial situations: 1) a warm season, dormant forage environment (BG) and 2) a cool-season forage environment (E+) where growing forage is available for a portion of the evaluation period and supple-

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mental feed can be reduced.

Calves were weaned in October at an average of 204 d of age. After weaning, calves were penned for 2 wk and fed BG hay and 2.2 lb/d of commercial mixed feed. Subsequently, calves were moved back to their preweaning forage environment (i.e. BG or E+). Calves were managed postweaning for moderate gains consistent with a common backgrounding program by supplementing with cottonseed meal, corn, and (or) a commercial mixed feed. Tall fescue or BG hay was provided free choice for calves on E+ or BG, respectively. Supplemental feed (same as above) was provided from weaning to late October and was continued to April of the following spring. Amounts of supplemental feed were adjusted based on visual estimates of forage availability and ambient temperatures

Growth parameters of A and k were estimated on 177 Angus (AA), Brahman (BB), Angus x Brahman (AB) and Brahman X Angus (BA) heifers born from 1988 to 1991 using the three-parameter growth curve model as described by Brody (1945). Data were collected every 28 d until approximately 18 mo and then at prebreeding, postcalving, and weaning of calf. In a preliminary analysis, year was not a significant source of variation, therefore data were pooled over year and analyzed by the general linear model (GLM) procedure of SAS (SAS Inst. Inc., Cary, NC). Included in the models for A and k were the independent variables of breed-type, forage and breed-type x forage interaction. Sire of calf was not included in the model due to the fact that sires were rotated among breeding pastures in both forage treatments to prevent confounding of sire and forage effects.

Results and Discussion

There was a significant ($P < 0.01$) breed-type x forage interaction for mature weight in this study. Presented in Table 1 are the least squares means and standard errors for estimated mature weight by breed-type and forage environment. There was no difference ($P > 0.05$) in mature weight of straightbred Angus cows on either forage with means of 1,298 and 1,344 lb, respectively, for BG and E+ forages. These estimated values for Angus cows are higher than those reported by Stewart and Martin (1983) and Brown et al. (1972) who reported mean A values of 1,067 and 970 lb, respectively. Angus x Brahman cows grazing E+ were heavier ($P < 0.05$) at 1,283 lb than were their counterparts grazing BG at 1201 lb. It is not entirely clear why these Angus x Brahman cows which grazed BG had smaller A values than the mean of their parental breed-types, however, this could be due to an interaction between the direct breed effects of the Angus cattle and the maternal breed effects on the Brahman cows grazing this BG forage. There were no differences ($P > 0.05$) in mean A values for the Brahman x Angus cows on either forage. The Brahman cows seemed to have a difficult time coping with the negative effects of the E+ forage as they had a mean A value of only 1,120 lb which is smaller ($P < 0.05$) than all other breed-type x forage combinations with the exception of the Angus x Brahman crosses on BG at 1,201 lb. Determining the ideal weight for maximum animal production is an important question that needs an answer. Stewart and Martin (1983) reported that in Angus cows, their optimum estimated mature weight in order to achieve maximum maternal performance was 1,045 lb. This weight was considerably lower than our estimated mature weights of 1,298 to 1,344 lb, however, Kapps et al. (1999) reported similar values for mature weight in Angus cows of 1,320 lb.

Shown in Table 2 are the least squares means and standard errors for k by breed-type. There was no breed-type x forage interaction for k in this study. Angus x Brahman crosses had the earliest ($P < 0.05$) rate of maturing of all breed-types maturing at a rate of 0.053. There were no differences ($P > 0.05$) between the k values between straightbred breed-types with Angus at 0.039 and Brahman at 0.042. These values of k are considerably lower than values reported in the literature. There was however a difference between the two reciprocal crosses with Brahman x Angus cows maturing at a slower ($P < 0.05$) rate than did the Angus x Brahman (0.049 vs 0.053). This increase in rate of maturing over the purebred cattle can be expected due to the effect that heterosis has on this trait. Nelson et al. (1982) reported a percentage heterosis increase in maturing rate of 3.5 % in Brahman x Angus cross cattle thus supporting our results. In a growth curve study by Tawah and Franke (1985), they used 574 straightbred and crossbred cows and reported results stating that generation one crossbred cows had a 0.034 greater k value than did the straightbred cattle.

Implications

These results suggest that the growth parameters of A and k differ by breed-type. These differences are of importance to the biological and economical efficiency of beef production and need to be carefully considered when attempting to correctly match breed-type to available production resources. Further research is needed in this area, particularly in the field of crossbreeding to help producers deal with different biological types of animals in a wide variety of production environments, including those with limited resources.

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Table 1. Least-squares means and standard errors of estimated mature weight (lb) for genotype x forage interaction.

	Genotype[a]			
Forage	AA	AB	BA	BB
Bermudagrass	1298 + 37^{bcdef}	1201 + 35^{fgh}	1373 + 42^{b}	1316 + 44^{bcde}
Fescue	1344 + 37^{bcd}	1283 + 40^{bcdefgh}	1351 + 48^{bc}	1120 + 46^{h}

[a] AA = Angus x Angus, AB = Angus x Brahman, BA = Brahman x Angus and BB = Brahman x Brahman.

^{bcdefgh} Means with different superscripts differ ($P < 0.05$).

Table 2. Least-squares means and standard errors for rate of maturing by genotype.

	Genotype[a]			
Forage	AA	AB	BA	BB
Rate of maturing	0.039 + 0.002^{d}	0.053 + 0.002^{b}	0.049 + 0.002^{c}	0.042 + 0.002^{d}

[a] AA = Angus x Angus, AB = Angus x Brahman, BA = Brahman x Angus and BB = Brahman x Brahman.

^{bcd} Means with different superscripts differ ($P < 0.05$).

Supplementation of Beef Cows and Heifers Consuming High Quality Fescue Hay

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Story in Brief

Seventy-six spring calving, cross-bred cows and heifers of mostly Angus breeding were used to determine the impact of pre- and post-partum supplementation on post-partum reproductive performance when consuming harvested high-quality cool-season forages. Forage used in the study was tall fescue hay having 16.05% CP and 58.4% TDN. Cows and heifers received either no supplement (Control), 2 lb of Corn (Corn) or 2 lb of a 17% CP corn-soybean meal supplement (Corn-Soy). Cows and heifers were placed on supplement before calving and continued on the same supplement into the post-partum period. Control (non-supplemented) heifers had greater weight loss in the post-partum period ($P < 0.01$), lower weaning weights ($P < 0.10$) and ADG ($P < 0.08$) by nursing calves than Corn or Corn-Soy supplemented heifers. Cows receiving the Corn-Soy supplement had a shorter calving interval ($P = 0.10$) than Control cows. Reproductive performance was poor in all treatment groups, suggesting that intake of forage in all groups was not adequate to meet nutritional requirements.

Introduction

Feed costs constitute 60 to 70% of the annual cost of maintaining a beef cow and a large part of feed cost is represented by the cost of supplements. Recent data (Davis, 2000) indicate that 89% of the hay samples assayed in Arkansas were adequate in protein for a dry gestating cow and 59% of samples had adequate protein for lactating cows. In the same study, TDN was adequate for dry gestating cows in 75% of the hay tested, while only 28% of the samples had adequate TDN for lactating cows. These data suggest that dry gestating cows and, in some instances, lactating cows can be maintained on forage alone or on an energy supplement alone since protein is adequate in many cases. It is well established that adequate nutrition of the cow in the pre- and post-partum period is a critical factor in achieving successful post-partum reproduction (Richards et al., 1986; Selk et al., 1988). It has also been demonstrated that excessively high dietary protein intake has been associated with decreased fertility (Jordan and Swanson 1979; Kaim et al., 1983; Canfield et al. 1990). Since protein supplements are relatively high in cost compared to energy supplements and excess protein can have detrimental effects on reproductive performance, minimizing the supplemental protein fed may be beneficial to producers. The following study was conducted to compare the effects of no supplement, an energy supplement and a 17% CP supplement on the post-partum reproductive performance of beef cows consuming high quality tall fescue hay.

Experimental Procedures

Seventy-six spring calving, cross-bred cows and heifers with mostly Angus breeding were used to determine the impact of pre- and post-partum supplementation on post-partum reproductive performance of cows consuming harvested high-quality cool-season hay (Table 1). Before calving, animals were blocked by body weight, parity and body condition score (BCS) and randomly assigned to one of three treatment groups. Animals received either no supplement (Control), 2 lb of corn per animal per day (Corn), or 2 lb per animal per day of a 17% CP corn-soybean meal supplement (Corn-Soy). Supplementation was started at approximately 7 to 8 weeks pre-partum and animals remained on the same supplements until the start of the breeding season. Cows were maintained as a single group, and were sorted from calves once daily (Monday-Saturday) and fed supplement individually. Treatment groups remained together in the same pen or pasture at all times except at daily supplementation. Supplements were fed to all groups until the start of the breeding season. Ad libitum access to the mixed fescue hay, mineral supplement, and water was available at all times.

In order to evaluate the effects of supplements on body weight change and energy reserves, body weights and BCS were taken at the beginning of the trial and at the start of the 60-day breeding season. In order to access reproductive status via serum progesterone concentration, all animals were bled weekly beginning at 3 weeks post-partum and continuing until the start of the breeding season. Blood samples, collected by jugular venipuncture, were stored on ice and

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allowed to clot, and were then centrifuged at 2,000 x g. Serum was decanted and stored frozen at –20°C until analyzed for progesterone by radioimmunoassay.

Fertile bulls were placed with cows for 60 days beginning on May 15. Pregnancy status was checked by ultrasound at the end of the breeding season and non-pregnant animals and animals of less than 30 days of pregnancy were checked again by ultrasound at 30 days after the end of the breeding season.

Initial analysis of data indicated that the performance of heifers and their calves differed from that of cows for most variables measured; therefore, data for heifers and cows were analyzed separately with treatment as the only effect in the model. Differences between least squares treatment means were determined by multiple LSD tests. Percent pregnant and calving percentage were compared by Chi-Square test.

Results and Discussion

Heifers: Pre- and post-partum data for heifers by treatment is presented in Table 2. There were no differences ($P > 0.10$) in days pre-partum at the start of the experiment, initial body weight, or initial BCS for heifers among treatments. Body weight and BCS at the start of breeding and the change in BCS from the start of the experiment to the start of the breeding season did not differ ($P > 0.10$) among treatments. However, the decrease in body weight between the start of the experiment and the start of the breeding season was greater in the non-supplemented Control group than in the Corn or Corn-Soy groups. The reduction in body weight loss in the Corn and Corn-Soy treatments suggests that heifers benefited from the additional energy and protein provided by the supplements. The number of heifers cycling at the start of the breeding season, pregnancy rates at the end of the breeding season, pregnancy rates at 30 days after the end of the breeding season, and calving percentage were low in all treatment groups, but differences among treatments were not significant ($P > 0.10$). Calving interval was also not different ($P > 0.10$) among treatments. It appears that the amount of supplement fed prevented some weight loss in heifers, but was not adequate for acceptable reproductive performance.

Calf birth weight was not affected ($P > 0.10$) by treatment; however, calf weaning weight ($P < 0.10$) and ADG ($P < 0.08$) of calves from birth to weaning was greater in Corn and Corn-Soy treatments than in Controls. It is likely that the additional energy in the Corn treatment and the energy and protein in the Corn-Soy treatment increased milk production in heifers and therefore increased gains in calves in the supplemented groups.

Cows: Pre- and post-partum data for cows by treatment is presented in Table 3. There were no differences ($P > 0.10$) in days pre-partum at the start of the experiment, initial body weight, or initial BCS for cows among treatments. Body weight at the start of the breeding season and change in body weight between the start of the experiment and the start of the breeding season were not different ($P > 0.10$) among treatments. However, BCS at the start of the breeding season was higher ($P < 0.05$) in the Corn treatment compared to the Control or Corn-Soy treatments. Similarly, the change in BCS between the start of the experiment and the start of the breeding season was less ($P < 0.05$) for the Corn treatment, than for the Control and Corn-Soy treatments.

Similar to results in heifers, the number of cows cycling at the start of the breeding season, pregnancy rates at the end of the breeding season and at 30 days after the end of the breeding season, and calving percentage were low in all treatment groups, but were not different ($P > 0.10$) among treatments. Mean calving interval in days tended to be shorter in the Corn-Soy treatments compared to non-supplemented Controls ($P = 0.10$) Average calf birth weight, calf weaning and ADG from birth to weaning did not differ ($P > 0.10$) among treatments.

Forage intake was not monitored in this trial. However, the poor reproductive performance and low calf weaning weights in all treatment groups indicate that intake of forage may have been limited to such an extent that heifers and cows were not able to meet their nutritional requirements, even with the Corn or Corn-Soy supplements. Pregnancy rates in this cow herd in previous years have ranged from 75 to 90%. In previous years, forage was not analyzed, and cows were fed 4 lb per day of a supplement similar to the Corn - Soy treatment in this study. Crude protein and TDN supplied by the supplement in each treatment plus estimated forage intake and contribution of forage to CP and TDN is presented in Table 4 for heifers and Table 5 for cows, along with the NRC (1996) requirements. Forage intake for both cows and heifers was estimated by dividing 120 by the NDF percentage in the forage and expressing the result as a percent of body weight (1.6%). This estimate of intake was well below the NRC (1996) guide for both cows and heifers. Based on the analysis of hay (Table 1) used in this trial, cows without supplement (Control) should have been able to meet their CP and TDN requirements by consuming forage alone. The degree of weight loss observed in all treatment groups and the poor post-partum reproductive performance suggest that intake was well below NRC (1996) estimates and that nutrient requirements were not supplied in the available diet. Intake may have been limited by unknown factors. The forage may have contained fescue toxins which can limit intake; however, problems associated with fescue toxicosis have not been previously observed on this farm.

Implications

The poor reproductive performance of cows and heifers and poor post-partum performance of calves observed in all treatments in this study suggest that intake of forage can be a limiting factor in the ability of animals to meet their nutritional requirements when consuming relatively high quality harvested forage.

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Table 1. Proximate Analysis of Fescue Hay

Item[a]	Percent
DM	85.5
CP	16.05
ADF	39.5
NDF	73.
TDN	58.4

[a] DM = dry matter, CP = crude protein, ADF = acid detergent fiber, NDF = neutral detergent fiber, and TDN = total digestible nutrients.

Table 2. Pre- and post-partum data for heifers by treatment.

	Treatment			
Item	Control	Corn	Corn-Soy	SEM
Number of Animals	8	11	10	---
Days pre-partum	35.7	37.4	47.7	4.6
Initial body wt, lb	1,034	992	1,006	35.4
Initial BCS, 1–9[g]	5.3	5.3	5.4	0.2
Wt at start of breeding lb	835	846	854	32.9
BCS at start of breeding, 1-9	4.7	4.5	4.7	0.2
Change in body wt, lb	-199[a]	-146[b]	-152[b]	12.1
Change in BCS, 1-9	0.6	0.8	0.7	0.2
Cycling at start of breeding, no	0 of 8	0 of 11	1 of 11	---
Pregnant at end of breeding season, %	57.1	36.4	40	---
Pregnant at 30 d after breeding, %	57.1	45.4	60	---
Calving percentage, %	42.9	36.4	50	---
Calving interval, day	367	365	355	13
Calf birth wt, lb	60.8	61.6	64.3	2.8
Calf weaning wt, lbs	278[c]	319[d]	323[d]	16.8
Calf ADG birth-weaning, lb/day	0.96[e]	1.15[f]	1.21[f]	0.07

[ab]Means within a row with no superscript in common differ (P < 0.01).
[cd]Means within a row with no superscript in common differ (P < 0.10).
[ef] Means within a row with no superscript in common differ (P < 0.08).
[g] Body condition score (BCS) can range from 1 = very thin to 9 = very fat.

Table 3. Pre- and post-partum data for cows by treatment.

	Treatment			
Item	Control	Corn	Corn-Soy	SEM
Number of Animals	15	16	16	
Days pre-partum	56	50	59.5	3.8
Initial body wt,lb	1,202	1,217	1,196	26
Initial BCS, 1-9[g]	5.2	5.4	5.4	0.1
Wt at start of breeding, lb	1,045	1,081	1,059	26
BCS at start of breeding, 1-9	4.7[a]	5.3[b]	5[a]	0.2
Change in body wt, lb	-157	-138	-137	13
Change in BCS, 1-9	0.5[c]	0.1[d]	0.4[c]	0.1
Cycling at start of breeding, no	2 of 15	4 of 16	2 of 16	---
Pregnant at end of breeding seasons, %	31.3	43.7	56.2	---
Pregnant at 30 d after breeding, %	50	56.2	56.2	---
Calving percentage, %	50	50	56.2	---
Calving interval, day	361[d]	354[d]	345[e]	6
Calf birth wt, lb	73.8	75.6	74.4	2.9
Calf weaning wt, lb	332	352	349	15
Calf ADG birth-weaning, lb/day	1.25	1.31	1.37	0.07

[ab]Means within a row with no superscript in common differ (P < 0.03).
[cd]Means within a row with no superscript in common differ (P < 0.04).
[ef] Means within a row with no superscript in common differ (P < 0.10).
[g] Body condition score (BCS) can range from 1 = very thin to 9 = very fat.

Table 4. Estimated forage intake[a], nutrients available, and requirements[b] for heifers by treatment.

Treatment	Diet	Pounds DM fed or estimated intake	lb TDN available	lb CP available
Control				
	Savoy Fescue	16.50	9.64	2.65
	Total supplied	16.50	9.64	2.65
	Requirement	22.90	13.80	2.34
	Balance	-6.40	-4.16	0.31
Corn				
	Savoy Fescue	16.50	9.64	2.65
	Corn	1.76	1.58	0.17
	Total supplied	18.26	11.22	2.82
	Requirement	22.90	13.80	2.34
	Balance	-4.64	-2.58	0.48
Corn-Soy				
	Savoy Fescue	16.50	9.64	2.65
	Corn	1.32	1.18	0.13
	Soybean meal	0.45	0.39	0.22
	Total supplied	18.27	11.21	3.00
	Requirement	22.90	13.80	2.34
	Balance	-4.63	-2.59	0.66

[a]Estimated forage intake is calculated as 120 divided by the forage NDF expressed as a percentage times body weight.
[b]Nutrient requirements are from NRC (1996) based on heifers calving at 1000 lb with a mature cow weight of 1200 lb.

Table 5. Estimated forage intake[a], nutrients available and requirements[b] for cows by treatment.

Treatment	Diet	Pounds DM fed or estimated intake	lb TDN	lb CP
Control				
	Savoy Fescue	19.68	11.49	3.16
	Total supplied	19.68	11.49	3.16
	Requirement	26.80	15.70	2.71
	Balance	-7.12	-4.21	0.45
Corn				
	Savoy Fescue	19.68	11.49	3.16
	Corn	1.76	1.58	0.17
	Total supplied	21.44	13.07	3.33
	Requirement	26.80	15.70	2.71
	Balance	-5.36		0.62
Corn-Soy				
	Savoy Fescue	19.68	11.49	3.16
	Corn	1.32	1.18	0.13
	Soybean meal	0.45	0.39	0.22
	Total supplied	21.45	13.06	3.51
	Requirement	26.80	15.70	2.71
	Balance	-5.35	--	0.80

[a]Estimated forage intake is calculated as 120 divided by the forage NDF expressed as a percentage times body weight.
[b]Nutrient requirements are from NRC (1996), based on a mature cow weight of 1200 lb, with 20 lb of peak milk.

Growth-Performance and Shrink by Stocker Calves Grazing Bermudagrass Pastures and Fed Different Levels of Grain Sorghum

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

Story in Brief

A 48-day grazing study was conducted to evaluate the effect of feeding no supplemental grain sorghum or ground grain sorghum at 0.5 or 1% of body weight (BW) on growth-performance and shrink by stocker cattle grazing bermudagrass in the summer. A total of 72 mixed-breed stocker steers and heifers (490±8.4 lb) were allocated randomly by weight and sex into nine groups and grazed bermudagrass pastures from June 29 until August 16, 2000. Calves were fed 0, 2.5, or 5 lb/day of ground grain sorghum on Monday through Friday. Calves fed 5 lb/day of grain sorghum were heavier ($P < 0.10$) than calves from the other groups, and had faster ($P = 0.11$) weight gain (0.43 lb/day) than those fed no grain. Gain by calves fed 2.5 lb/day grain were numerically improved (0.12 lb/day) compared with calves fed no grain, and numerically lower (0.31 lb/day) than from calves fed 5 lb/day, but did not differ statistically ($P > 0.11$) from either group. Supplemental grain level did not affect ($P > 0.10$) calf shrink. Therefore, supplemental grain fed at 1% of BW may be used to improve weight gain by calves grazing bermudagrass during the summer, but conversion efficiencies should be considered to determine if the supplement is economical or not.

Introduction

Grains are often fed to grazing cattle to improve rate of gain. Calf gains may be improved substantially during late-season grazing of bermudagrass by supplementation with low levels of grain (Gunter and Phillips, 1998), but those gains may still be lower than desired. When supplemental grain levels reach approximately 0.5% of body weight, forage intake may be suppressed (Lusby and Horn, 1991), leading to inefficient conversion of the supplemental grain to additional body weight gain. However, without the additional energy supplementation, gains may not be adequate to reach marketing objectives of the producer. The objective of this study was to compare growth-performance by stocker cattle grazing bermudagrass and fed different levels of grain sorghum.

Experimental Procedures

Seventy-two mixed-breed stocker steers and heifers were received at the University of Arkansas Southeast Research and Extension Center in Monticello on June 16, 2000 and had received respiratory and clostridial vaccinations and a growth-promoting implant prior to arrival at the station. Calves initially grazed a bermudagrass pasture as a group. Calves were weighed on June 28 and 29 without prior removal from pasture and water, were stratified by weight and sex, and allocated randomly to one of nine groups. The groups were then allocated randomly to receive no grain sorghum (0GS), or 2.5 (2.5GS) or 5 lb/d (5GS) Monday through Friday of ground grain sorghum. These levels were chosen to represent feeding grain at either 0.5, or 1% of body weight. Groups of calves were then allocated randomly to one of nine bermudagrass pastures for a 48-day study.

All calves were offered free-choice access to a commercial mineral mix containing lasalocid. Pastures were fertilized with a complete commercial fertilizer to provide 50 lb/acre of each of N, P2O5, and K in late May and 50 lb/acre N in early July.

Calves were weighed on July 27 without prior removal from pasture and water for an intermediate weight. On August 16 beginning at 0700 h, calves on 2.5GS and 5GS treatments were fed their respective supplement amounts, were allowed to consume the supplement, and were then removed from pasture along with 0GS calves. They were immediately weighed, then placed in small pens without feed or water. Calves were weighed at 2-hour increments through the following 10-hour period to determine the impact of grain supplement level on subsequent shrink.

All animal weight and shrink data were analyzed statistically using SAS (SAS Institute, Inc., Cary, NC.) procedures for a completely randomized design.

Results and Discussion

Final body weight was heavier ($P < 0.10$) from calves fed 5GS than those on 0GS or 2.5GS treatments (Table 1). Total gain tended to be greater ($P = 0.11$) from calves fed 5GS than from those on 0GS, but gain from calves fed 2.5GS did not differ ($P > 0.11$) from those on either 0GS or 5GS. At

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these levels of gain, the conversion efficiencies were 14.9 and 8.3 lb of supplemental grain required to produce an additional pound of gain from 2.5GS and 5GS, respectively. These conversion efficiencies are somewhat better than observed in a previous study from feeding grain sorghum at 1% of BW (9.5 lb/lb; Galloway et al. 1993a), but are worse that from another study from feeding corn at .5% of BW to calves grazing bermudagrass pastures (6.1 lb/lb; Galloway et al. 1993b).

The rate of shrink (%/hour) during the period between 2 and 4 hours after removal from pasture was lower ($P < 0.10$) from calves on the 5GS treatment than from calves on the 0GS or 2.5GS treatments (Table 2). However, total weight loss over the entire 10-hour period (lb and % of initial body weight) did not differ ($P > 0.10$) among treatments.

Therefore, feeding supplemental grain sorghum to calves grazing bermudagrass pastures during the late grazing season improved weight gain, but conversion efficiencies were poor making the economic efficiency questionable. In order for the calves to gain approximately 2 lb/day during the late grazing season, it was necessary to feed them 25 lb of ground grain sorghum each week (5GS). Feeding grain sorghum prior to a period of feed and water deprivation did not impact cattle shrink over a 10-hour period.

Implications

In order to achieve body weight gains in excess of 1.5 lb/day in a typical summer grazing period from calves on bermudagrass pastures, supplements must be fed. Feeding at levels at or above 0.5% of body weight should improve animal gain, but conversion efficiencies may limit economic benefits of the supplementation. Feeding ground grain sorghum immediately prior to removing calves from bermudagrass pastures should have minimal impact on body weight loss during a period of feed and water deprivation.

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Table 1. Growth performance by stocker steers grazing bermudagrass pastures and fed different levels of ground grain sorghum.

	Level of ground grain sorghum, lb/day M-F			
Item	0	2.5	5	SE
Initial weight, lb	490	489	492	1.2
Weight – d 29, lb	523	522	535	4.2
Final weight, lb	562[b]	567[b]	584[a]	5.7
Total gain, lb	72[d]	78[cd]	92[c]	5.9
Daily gain, lb	1.49[d]	1.61[cd]	1.92[c]	0.123
Feed/additional gain, lb/lb	-	14.9	8.3	-

[a,b] Means within a row without a common superscript letter differ ($P < 0.10$).
[c,d] Means within a row without a common superscript letter differ ($P = 0.11$).

Table 2. Weight loss during a 10-h drylot shrink by stocker steers fed different levels of ground grain sorghum.

	Level of grain sorghum, lb/day M-F			
Item	0	2.5	5	SE
Shrink, %/h				
0-2 h	1.32	1.44	1.47	0.279
2-4 h	0.98[a]	1.06[a]	0.56[b]	0.127
4-6 h	1.13	0.84	1.38	0.207
6-8 h	0.61	0.63	0.62	0.112
8-10 h	0.17	0.53	0.31	0.153
Total weight loss, lb	45	51	49	1.7
Total weight loss, %	9.8	10.1	10.0	0.13

[a,b] Means within a row without a common superscript letter differ ($P < 0.10$).

Influence of Fish Oil Addition on Growth Performance and Immune Function of Grazing Cattle

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

Story in Brief

In the U.S., intake of n-3 fatty acids by humans is approximately 1.6 g/d, of which 1.4 g is α-linolenic acid (ALA; 18:3) and 0.1 to 0.2 g is eicosapentaenoic acid (EPA; 20:5) and docosahexanoic acid (DHA; 22:6). The predominant sources of EPA and DHA are fish and fish oils. Inclusion of fish oil in ruminant diets may fortify the fatty acid composition of meats and modulate the immune system. Therefore, an experiment was conducted to determine the effects of supplemental fish oil on growth performance and immune characteristics of beef calves. The experiment (78-d study) used 48 crossbred steers (509 ± 48.5 lb initial BW) grazing mixed grass pastures (n = 16). Steers were supplemented with 4 lb/d of one of four treatment supplements. Treatment supplements consisted of: 1) corn-based supplement; 2) corn-based supplement with 1.5% fish oil; 3) wheat midd-based supplement; and 4) wheat midd-based supplement with 1.5% fish oil. Fish oil supplementation had a negative impact on ADG when added to the corn-based supplement and no effect when added to the wheat midd-based supplement (3.0 vs. 2.6 and 2.8 vs. 2.7 lb/d, respectively; base-supplement x fish oil interaction, $P < 0.03$). Isolated lymphocytes from calves fed the corn-based supplement with fish oil had a greater response to stimulation with concanavalin A than lymphocytes from calves fed the corn-based supplement, and there was no effect of fish oil addition to the wheat midd-based supplement (base-supplement x fish oil interaction, $P < 0.01$). Fish oil supplementation in the current trial seemed to stimulate the immune system. However, the reduction in performance may limit its use as an immune stimulant and may limit the potential to use it for altering the fatty acid composition of meat.

Introduction

Fish industry by-products are potential sources of valuable nutrients. Therefore, methods of converting fish industry by-products into reliable sources of animal feeds would benefit both the fish and livestock industries. In the United States, intake by humans of n-3 fatty acids is approximately 1.6 g/d, of which 1.4 g is α-linolenic acid (ALA; 18:3) and 0.1 to 0.2 g is eicosapentaenoic acid (EPA; 20:5) and docosahexanoic acid (DHA; 22:6) (Kris-Etherton et al., 2000). The predominant sources of EPA and DHA are fish and fish oils. Recently, the dietary recommendation for the highly unsaturated n-3 fatty acids has increased, specifically EPA and DHA, from 0.15 to 0.65 g/d. To achieve this four-fold increase in consumption, consumers will either have to adjust their diets, or the nutrient content of certain foodstuffs may be able to be changed. However, feeding diets that alter the fatty acid content of meat may also affect other aspects of beef production. Theis et al. (1999) reported that dietary fish oils may have a negative impact on immune function and fatty acid composition in pigs. The objective of this study was to determine the effects of dietary fish oil addition on growth and immune function of cattle consuming a forage based diet.

Materials and Methods

Forty-eight steers (509 ± 48.5 lb initial BW) were obtained from the University Livestock and Forestry Branch Station in Batesville. Steers were shipped to the University of Arkansas Stocker and Receiving Unit in Savoy prior to the start of the study. Calves were weighed upon arrival, blocked by weight (four blocks) and randomly assigned to pens. There were three steers in each of the 16 pens, for a total of 12 animals per treatment. Pens were 1.1 acre mixed grass pastures. Supplements were fed at a rate of 4.0 lb/d. Treatment supplements (Table 1) consisted of: 1) corn-based supplement; 2) corn-based supplement with 1.5% fish oil; 3) wheat midd-based supplement; and 4) wheat midd-based supplement with 1.5% fish oil. The diets were mixed at approximately weekly intervals.

Steers were fed their respective diets for 78 d. Steers were weighed on day 0, 14, 28, 42, 56, and 78 and were observed daily for signs of clinical disease. Steers were weighed on consecutive days at d 0 and 78 to start and finish the trial. On d 78 of the study, all calves were bled by jugular venipuncture, and blastogenic response of peripheral lymphocytes to phytohemagglutinin (PHA; Sigma Chemical Co., St. Louis, MO), concanavalin A (CONA; Sigma Chemical Co.) and pokeweed mitogen (PWM; Sigma Chemical Co.)

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was measured using [^{3}H]thymidine. Triplicate cultures from each calf with each mitogen were supplemented with 25 ml of fetal bovine serum.

Weights, ADG, and lymphocyte blastogenesis data were analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC). The model included block, base supplement, fish oil and the base supplement by fish oil interaction.

Results and Discussion

Fish oil supplementation had a negative impact on ADG (Table 2) when added to the corn-based supplement and no effect when added to the wheat midd-based supplement (base-supplement x fish oil interaction, $P < 0.03$). This negative association could have been due to a decreased overall fiber digestibility due to the added starch and oil.

Isolated lymphocytes (Table 3) from steers fed the corn-based supplement with fish oil had a greater response to stimulation with CONA than lymphocytes from calves fed the corn-based supplement, and there was no effect of fish oil addition to the wheat midd-based supplement (base-supplement x fish oil interaction, $P < 0.01$). Isolated lymphocytes from steers fed the corn based supplement had a greater response to stimulation with PHA ($P < 0.05$) and PWM ($P < 0.01$) than lymphocytes from steers fed the wheat midds based supplements (base-supplement effect, $P < 0.05$). Fish oil supplementation increased the blastogenic response of lymphocytes to PHA ($P = 0.09$) and PWM ($P = 0.04$) over the basal supplemented steers. The stimulation in the immune system was unexpected since in previous studies in humans and rats it has been shown that fish oil supplementation modulates and/or decreases the activity of the immune system (Hankenson et al., 2000). Two more trials are currently being conducted to further elucidate the effects of fish oil supplementation on the immune system of cattle as well as to determine the fatty acid composition of the meat.

Implications

This study suggests that supplementing fish oil to grazing cattle may boost their immune response and therefore aid in the reduction of morbid cattle. However, the depression in growth may eliminate any additive effects of stimulating the immune system. The determination of the effects of supplementing fish oil to grazing cattle on carcass characteristics has yet to be determined.

Acknowledgements

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

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Table 1. Ingredient composition of supplements (%, DM basis).

Ingredient	Corn	Corn + oil	Wheat midds	Wheat midds + oil
Corn	47	43.25	29	23
Wheat midds	-	-	60.5	65.75
Cane molasses	2	2	2	2
Cottonseed hulls	27	29	-	-
Soybean meal	21	21.5	3.5	3.25
Dicalcium phosphate	0.25	0.26	-	-
Limestone	1.5	1.5	3.5	3.5
Salt	1	1	1	1
Fish oil	-	1.5	-	1.5
Vitamin premix[1]	+	+	+	+
Trace mineral premix[2]	+	+	+	+

[1]Premix supplied per lb of diet: 224.5 IU of vitamin A, 74.8 IU of vitamin D_3, and 0.075 IU vitamin E.

[2]Premix supplied: 20 ppm of Zn as ZnO, 8 ppm of Cu as $CuSO_4$, 0.10 ppm of Se as Na_2SeO_3, and 0.10 ppm of Co as $CoCO_3$.

Table 2. Effect of fish oil supplementation on performance of cattle grazing mixed grass pastures.

Item	Corn	Corn + oil	Wheat midds	Wheat midds + oil	SE
ADG, lb					
d 1 to 14[1]	4.0	3.3	3.7	3.3	0.14
d 15 to 28	3.0	3.4	3.4	3.1	0.27
d 29 to 42[2]	4.1[a]	2.8[b]	2.9[ab]	3.2[a]	0.29
d 43 to 56	1.5	1.3	1.4	1.3	0.31
d 57 to 78[1]	2.8	2.6	2.8	2.7	0.08
d 1 to 78[2]	3.0[a]	2.6[c]	2.8[b]	2.7b[c]	0.05

[1] Effect of fish oil addition ($P < 0.01$).

[2] Base-supplement X fish oil interaction ($P < 0.01$).

[abc]Within a row, means without a common superscript letter differ ($P < 0.05$).

Table 3. Effect of fish oil supplementation on lymphocyte blastogenic response (1000 X cpm).

Mitogen	Corn	Corn + oil	Wheat midds	Wheat midds + oil	SE
Unstimulated	2.4	3.5	4.7	2.4	1.1
CONA[1], 25 mg/mL	63[ab]	88[a]	80[b]	76[b]	4.6
PHA[2], 40 mg/mL	66	79	60	64	6.0
PWM[3], 15 mg/mL	55	63	51	53	5.3

[1] Concanavalin A (base-supplement x fish oil interaction, $P < 0.01$).

[2] Phytohaemagglutinin (fish oil supplementation effect, $P = 0.09$; and base-supplement effect, $P = 0.05$).

[3] Pokeweed mitogen (fish oil supplementation effect, $P = 0.04$; and base-supplement effect, $P < 0.01$).

[ab]Within a row, means without a common superscript letter differ ($P < 0.05$).

Influence of Supplementing Cobalt in the Receiving Ration on Performance of Heifers New to the Feedlot Environment

T. J. Wistuba, E. B. Kegley, D. L. Galloway, J. A. Hornsby, and S. M. Williamson[1]

Story in Brief

The influence of dietary cobalt concentration on performance of growing heifers was studied using 86 crossbred heifers (465.2 ± 36.4 lb) in a 42-d receiving trial. Treatments consisted of a control diet that had a calculated cobalt concentration of 0.1 ppm or the control diet with an additional 0.1 ppm supplemental cobalt/kg of DM from cobalt carbonate. Heifers were weighed on d 0, 7, 14, 28, and 42 and were observed daily for signs of clinical disease. For the entire 42-d study ADG (2.36 vs. 2.25, lb/d), ADFI (13.7 vs. 13.6 lb as fed), and feed/gain (5.80 vs. 6.04) did not differ (P > 0.10) for the control heifers vs. the heifers supplemented with cobalt, respectively. Supplemental cobalt tended to increase ADG (P = 0.07) and decrease feed/gain (P = 0.06) from d 8 to 14. However, from d 15 to 28 control calves tended to have increased ADG (P = 0.09) and decreased feed/gain (P = 0.07). Percentage morbidity was not affected (P > 0.10) by supplemental cobalt (65%) vs. control (76%), and neither were medication costs, $12.37 for cobalt supplemented calves vs. $12.57 for controls. Supplementing cobalt did not improve growth performance or lower medication costs for stressed heifers in the present study.

Introduction

The cobalt requirement for cattle is very low (0.1 ppm), but it is a crucial element for the formation of vitamin B12 by microorganisms in the rumen. Vitamin B12 requiring enzymes synthesize one-carbon units, making it very important in the metabolism of nucleic acids, proteins, carbohydrates and lipids. Furthermore, recent research has indicated that the immune response is depressed in cobalt deficient cattle suggesting that cobalt deficient animals have an increased vulnerability to disease and parasites. The objective of this study was to determine the effect of cobalt supplementation, an essential trace mineral, on feed intake, growth, feed conversion, morbidity, and medication costs of receiving cattle.

Materials and Methods

Eighty-six crossbred heifers weighing 465.2 ± 36.4 lb were purchased at sale barns and delivered to the Beef Cattle Research Facility in Savoy. Upon arrival, calves were branded with an electric iron, any horns were tipped, and calves were dewormed (Ivomec, Merial Limited, Iselin, NJ) and ear tagged. Calves were vaccinated against bovine respiratory syncytial virus, infectious bovine rhinotracheitus virus, bovine viral diahrrea, and parainfluenza –3 (BRSV – Vac 4, Bayer Corp., Shawnee Mission, KS). All calves were given a vaccine containing *Pasteurella haemolytica*, *Pasteurella multocida*, *Haemophilus somnus*, and *Salmonella typhimurium* (Poly-Bac-HS, Texas Veterinary Labs, San Angelo, TX) and a clostridial toxoid injection (Vision 7, Bayer Corp.). Calves were weighed upon arrival, blocked by weight (eight blocks), stratified by horn tipping and randomly assigned to pens (two pens per block, six heifers per pen in six pens and five heifers per pen in ten pens). Pens within a block were randomly assigned to a treatment. Heifers were kept in 12 ft X 98 ft dry lots and had *ad libitum* access to feed and water.

The dietary treatments included either a control diet or the control diet supplemented with 0.1 ppm of cobalt (Table 1). The diets were formulated to meet or exceed NRC (1996) recommendations. Calves were offered a small amount of long hay in addition to the dietary treatments for the first 5 d of the study. Throughout the experiment, each feedbunk was examined visually at 0800 h daily. The quantity of feed remaining in each bunk was determined and a decision was made on the amount of feed to be offered. The objective was to allow for a minimal accumulation of unconsumed feed (< 15 lb). Feed was offered once daily at approximately 0800 h. Daily feed offered and any refusals were recorded.

Heifers were fed their respective diets for 42 d. Heifers were weighed on d 0, 7, 14, 28, and 42 and were observed daily for signs of clinical disease. Any calves that were observed to be depressed were pulled and rectal temperature was measured. Consecutive weights were taken on d 0 and 42 to start and finish the trial. Calves with a rectal temperature greater than 104°F were treated with antibiotics according to a preplanned treatment protocol. On d 42 of the study all calves were sampled via jugular venipuncture to determine plasma vitamin B^{12} concentrations.

Weights, ADG, ADFI, feed/gain, medication costs,

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incidence of morbidity, serum vitamin B12 concentrations, and number of antibiotic treatments were analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC). The model included block and cobalt supplementation.

Results and Discussion

Average daily gain for the entire 42-d study (Table 2) was not affected (P > 0.10) by dietary supplementation of cobalt. Gains during the period from d 8 to 14 tended to be greater in calves supplemented cobalt (P = 0.07) compared with those fed no supplemental cobalt; however, from d 15 to 28 control calves tended to have increased ADG (P = 0.09). Stangl et al. (1999) found that a cobalt deficiency did not have any significant effect on energy metabolism in calves fed a cobalt deficient diet for 43 weeks. These authors did find that there was a marked reduction in serum triodothryonine.

The ADFI (Table 2) for d 1 to 42 did not differ (P > 0.10) among treatments. These results are consistent with those of Mburu et al. (1992) who found that cobalt deficiency had no effect on feed intake of small east African goats. Supplemental cobalt did decrease feed/gain (P = 0.06) from d 8 to 14 ; although, from days 15 to 28 control calves had a lower feed/gain (P = 0.07) compared with calves fed supplemental cobalt.

Percentage morbidity was not affected (P > 0.10) by supplemental cobalt (65%) vs. control (76%). Supplemental cobalt also had no effect (P > 0.01) on medication costs, $12.37 for cobalt supplemented calves vs. $12.57 for controls. Plasma vitamin B12 was not affected by cobalt supplementation. Judson et al. (1997) found that plasma vitamin B12 concentration was increased for up to 28 weeks due to the supplementation of a single cobalt pellet over that of control cows.

Implications

Supplementing cobalt in the present study did not improve growth performance or lower medication costs for stressed heifers. In addition, cobalt supplementation did not improve plasma vitamin B12 concentrations.

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

Ingredient	%
Corn	55.42
Cottonseed hulls	30.00
Soybean meal	11.20
Cane molasses	2.00
Dicalcium phosphate	0.4
Limestone	0.85
Salt	0.15
Bovatec[1]	+
Cobalt carbonate[2]	- / +
Vitamin premix[3]	+
Trace mineral premix[4]	+

[1]Added to provide 15.2 mg lasalocid/lb of diet DM

[2]Added to provide 0 or 0.1 ppm Co of diet DM

[3]Premix supplied per lb of diet: 224.5 IU of vitamin A, 74.8 IU of vitamin D_3, and 0.075 IU vitamin E.

[4]Premix supplied: 20 ppm of Zn as ZnO, 10 ppm of Mn as MnO, and 0.10 ppm of Se as Na_2SeO_3

Table 2. Effect of supplemental cobalt on growth performance, plasma vitamin B^{12} concentration, morbidity, and medicine cost.

Item	Control	Cobalt	SE	P=
Average daily gain, lb				
Day 1 to 7	0.68	0.49	0.295	NS
Day 8 to 14	3.11	4.12	0.337	0.07
Day 15 to 28	2.23	1.96	0.214	0.09
Day 29 to 42	2.93	2.45	0.207	NS
Day 1 to 42	2.36	2.25	0.132	NS
Daily feed intake, lb				
Day 1 to 7	7.91	8.20	0.220	NS
Day 8 to 14	12.65	13.43	0.441	NS
Day 15 to 28	13.67	13.93	0.419	NS
Day 29 to 42	17.13	16.07	0.794	0.07
Day 1 to 42	13.69	13.60	0.441	NS
Feed/Gain				
Day 1 to 7	11.63	16.73	2.651	NS
Day 8 to 14	4.07	3.26	0.513	0.06
Day 15 to 28	6.13	7.11	0.495	0.07
Day 29 to 42	5.85	6.56	0.421	NS
Day 1 to 42	5.80	6.04	0.157	NS
Plasma vitamin B_{12}, pg/mL, d 42	137.59	250.92	59.96	NS
Morbidity, %	76.00	65.00	7.6	NS
Medicine cost, $/heifer	12.57	12.37	1.8	NS

The Effect of Tasco™ Inclusion in the Prepartum Diet and Time of Sampling on the Proportions of Bovine Leukocyte Populations in Blood and Mammary Gland Secretions

T. J. Wistuba,[1] E. B. Kegley,[1] T. K. Bersi,[2] D. W. Kellogg,[1] and G. F. Erf[2]

Story in Brief

The effects of Tasco™ inclusion in the diet during the last 21 d of gestation on the proportion of bovine leukocyte populations in blood and mammary gland secretions (MGS) was investigated using flow cytometric analysis. Thirty Holstein cows were stratified by parity and randomly assigned to the Tasco™ (170 g/d) supplemented group or control diet. Tasco™ is a product derived from Ascophyllum nodosum, a brown seaweed that grows along the coast of Nova Scotia. Treatments were initiated 21 d prior to expected parturition and fed until calving. Blood samples and MGS from cows and blood samples from calves were obtained at parturition and at d 1 post partum. Proportions of bovine leukocyte populations in cows were affected by dietary treatment, but not time of sampling. In cows, supplementation of Tasco™ increased the proportion of B lymphocytes ($P = 0.05$) in the blood. However, Tasco™ supplementation decreased the proportion of T-helper lymphocytes ($P = 0.04$) and tended to decrease the proportion of gd T lymphocytes ($P = 0.13$). The percentage of B lymphocytes tended to increase ($P = 0.13$) from parturition to d 1 in the MGS. Proportions of granulocytes, macrophages/monocytes and B lymphocytes in the blood of calves increased from parturition to d 1 ($P < 0.04$). Dietary supplementation with Tasco™ and time of sampling altered proportions of bovine leukocyte populations. The impact of Tasco™ supplementation on cow and calf health requires further investigation.

Introduction

Trace mineral or vitamin supplementation has been shown to improve immune response and growth performance when animals are consuming deficient or marginal levels of trace minerals or vitamins. Tasco™ (Acadian Seaplants Ltd.; Dartmouth, Canada) is a product derived from Ascophyllum rodosum, a brown seaweed, that grows along the coast of Nova Scotia. The commercial product that has been developed contains high levels of trace minerals and vitamins. Initial work using Tasco™ at Virginia Tech, Mississippi State University, and Texas Tech has shown improvements in immune cell function and hair coat scores of calves grazing fescue but no significant improvements in growth performance (Allen et al., 2001; Fike et al., 2001; and Saker et al., 2001).

It has been well documented (Quigley and Drewry, 1998 and Wittum and Perino, 1995) that the passive transfer of immunoglobulins in colostrum is the most important source of immunologic protection available to neonatal calves. Inadequate intake and absorption of maternal antibody has been associated with increased risk of disease and death in neonatal calves (Wittum and Perino, 1995) The concentration of immunoglobulin G (IgG) in colostrum is important in determining the degree of passive immune transfer, being linearly related to the maternal IgG concentration in calves. The objective of this study was to determine the effects of Tasco™ inclusion in the prepartum diet on the proportion of bovine leukocyte populations and IgG concentrations in blood and mammary gland secretions.

Materials and Methods

Thirty Holstein cows were stratified by parity and randomly assigned to the Tasco™ (170 g/d) supplemented group or control diet. Treatments were initiated 21 d prior to expected parturition and fed until calving. Tasco™ supplemented cows were on the diet a minimum of 8 and a maximum of 42 d with a mean of 22 d. All cows were offered 21 lb of sorghum silage, ad lib hay, and 5 lb of a commercially prepared dry cow grain supplement.

Blood samples from cows and calves, as well as mammary gland secretion (MGS) samples were obtained at parturition and at d 1 post partum. After calving, the cow and calf were separated before the calf nursed. Approximately two liters of bulk colostrum were collected and fed to the calf immediately after the calf was sampled. One-half liter of bulk colostrum was obtained at parturition and one day later, and centrifuged at 1000 X g at room temperature for 10 min. The supernate was removed and the pelleted cells were washed twice in phosphate-buffered saline (PBS).

At parturition and one day later, peripheral blood was collected from cows and calves into vacutainer tubes containing acid citrate dextrose as an anticoagulant. Mononuclear cells were isolated by lysis of red blood cells with Tris-buffered ammonium chloride and washed twice in PBS.

Samples of washed milk cells and peripheral blood mononuclear cells (1×10^6/sample) were immunofluorescently labeled with a panel of mouse monoclonal antibodies specific for bovine leukocyte cell surface molecules using an

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indirect staining procedure and flow cytometric analysis (Park et al., 1992). The functions of each of the cell types measured are described in Table 1.

Cow and calf serum concentrations of IgG were measured 0 and 24 h post partum. Serum IgG was assessed using a commercial radial immunodiffusion kit (VMRD, Pullman, WA). Cow and calf serum concentrations of Cu and Zn were measured 0 and 24 hr post partum.

Analyses of variance were conducted on proportions of leukocyte populations, MGS and serum data using SYSTAT 9.0 software (SPSS Inc., Chicago, IL 60606). The model included Tasco™, sampling time, and the Tasco™ by sampling time interaction.

Results and Discussion

Where there were no dietary treatment by time of sampling interactions ($P > 0.10$), the main effects of dietary treatment and time of sampling will be discussed.

In cows, supplementation of Tasco™ increased the proportion of B lymphocytes ($P = 0.05$) in the blood (Table 2). Tasco™ decreased the proportion of helper T lymphocytes ($P = 0.03$) and tended to decrease the proportions of γδ T cells ($P = 0.13$) within the lymphocyte population. γδ T cells are T lymphocytes that are predominantly associated with immune function at epithelial and mucosal surfaces.

Proportions of bovine leukocyte populations in the MGS were affected by time of sampling and dietary treatment (Table 3). T lymphocytes migrate selectively into bovine milk. T cells in milk express cell surface markers that are characteristic of memory T cells (Taylor et al., 1994). Additionally, T cells in the milk are predominantly positive for cell surface markers (CD8+), suggesting cytotoxic function (Asai et al., 2000). B lymphocytes represent a minor population in milk when compared to peripheral blood. The proportion of B lymphocytes tended to increase from parturition to d 1 ($P = 0.13$). Tasco™ supplementation tended to increase the proportion of monocytes/macrophages in the mammary gland secretions ($P = 0.06$).

Proportions of B lymphocytes in blood from calves decreased ($P = 0.03$) due to Tasco™ supplementation (Table 4). Proportion of granulocytes and monocytes/macrophages in the blood of calves increased from parturition to d 1 ($P < 0.03$). The proportions of helper T lymphocytes tended to increase and B lymphocytes increased in the blood of calves from birth to d 1 ($P = 0.13$ and $P = 0.04$, respectively).

Tasco™ supplementation had no effect on the concentration of IgG (Table 5) in the serum of cows or MGS ($P > 0.10$). Mammary gland secretion IgG concentrations decreased from parturition to d 1 ($P < 0.01$). This finding is in agreement with previous reports that noted a decrease in MGS IgG concentration several days after parturition (Quigley and Drewry, 1998). Serum IgG concentrations from calves born to cows consuming the Tasco™ supplement did not increase as much from d 0 to d 1 as did the non-supplemented group (sampling time x Tasco™ interaction, $P < 0.01$; Figure 1).

In cows, supplementation of Tasco™ had no effect on the concentrations of Cu in the serum (Table 6). However, Tasco™ supplementation decreased ($P = 0.05$) serum Zn concentrations in the cows. Time of sampling significantly increased the Cu concentration in the serum of calves ($P < 0.01$) and tended to decrease the serum Zn concentration ($P = 0.09$).

Implications

Dietary supplementation with Tasco™ altered proportions of bovine leukocyte populations in blood and mammary gland secretions. The impact of Tasco™ supplementation on cow and calf health requires further investigation. Determining the basic mechanisms involved in passive immune transfer from the cow to the calf at parturition could be economically advantageous to the dairy cattle producer.

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Table 1. Description of each of the bovine leukocyte types determined by flow cytometric analysis.

Leukocyte type	Function
Granulocytes	Includes neutrophils, eosinophils, and basophils, important in inflammation and innate immunity
Monocytes/macrophages	Involved in the recognition, activation and effector phases of specific immunity
Lymphocytes	Mediate specific immune responses
Helper T lymphocytes	Recruit and activate inflammatory leukocytes
Cytotoxic T lymphoctes	Lyse cells that produce foreign antigens
γδ T lymphocytes	A subset of cytotoxic T cells associated with mucosal and epithelial surfaces
B lymphocytes	Production of antibodies

Table 2. The main effects of Tasco™ inclusion in the prepartum diet and time of sampling on the proportion among bovine leukocyte populations in the blood of cows.

	Time of Sampling			Dietary Treatment		
Cell type	Hour 0	Hour 24	P=	Control	Tasco	P=
% Granulocytes	12.4	17.6	NS	14.7	15.2	NS
% monocytes/macrophages	10.2	14.9	NS	12.6	12.4	NS
Lymphocytes						
% Helper T lymphocytes	26	24	NS	29	21	0.04
% Cytotoxic T lymphocytes	22	24	NS	22	24	NS
% γδ T lymphocytes	12	14	NS	15	11	0.13
% B lymphocytes	30	33	NS	27	35	0.05

Table 3. The main effects of Tasco™ inclusion in the prepartum diet and time of sampling on the proportion among bovine leukocyte populations in mammary gland secretions.

	Time of Sampling			Dietary Treatment		
Cell type	Hour 0	Hour 24	P=	Control	Tasco	P=
% Granulocytes	19.4	25.8	NS	22.6	23.5	NS
% monocytes/macrophages	43.6	49.4	NS	40.2	53.0	0.06
Lymphocytes						
% Helper T lymphocytes	26	21	NS	24	23	NS
% Cytotoxic T lymphocytes	33	32	NS	32	33	NS
% γδ T lymphocytes	24	24	NS	22	26	NS
% B lymphocytes	16	19	0.13	18	17	NS

Table 4. The main effects of Tasco™ inclusion in the prepartum diet and time of sampling on the proportion among bovine leukocyte populations in the blood of calves.

	Time of Sampling			Dietary Treatment		
Cell type	Hour 0	Hour 24	P=	Control	Tasco	P=
% Granulocytes	10.2	26.9	0.01	18.3	22.6	NS
% monocytes/macrophages	4.9	15.2	0.02	12.6	10.1	NS
Lymphocytes						
% Helper T lymphocytes	15	21	0.13	18	21	NS
% Cytotoxic T lymphocytes	26	23	NS	26	23	NS
% γδ T lymphocytes	33	33	NS	31	34	NS
% B lymphocytes	14	19	0.04	20	15	0.03

Table 5. The main effects of Tasco™ inclusion in the prepartum diet and time of sampling on IgG concentrations (mg/dL) in mammary gland secretions and serum.

	Time of Sampling			Dietary Treatment		
Item	Hour 0	Hour 24	P=	Control	Tasco	P=
Cow serum	3037	2948	NS	2956	3035	NS
MGS	13330	5037	0.01	8296	8668	NS

Table 6. The main effects of Tasco™ inclusion in the prepartum diet and time of sampling on serum concentrations (mg/L) of Cu and Zn.

	Time of Sampling			Dietary Treatment		
Item	Hour 0	Hour 24	P=	Control	Tasco	P=
Cow serum, Cu	0.80	0.84	NS	0.79	0.84	NS
Cow serum, Zn	0.68	0.65	NS	0.70	0.61	0.05
Calf serum, Cu	0.32	0.42	0.01	0.39	0.37	NS
Calf serum, Zn	1.35	1.10	0.09	1.22	1.18	NS

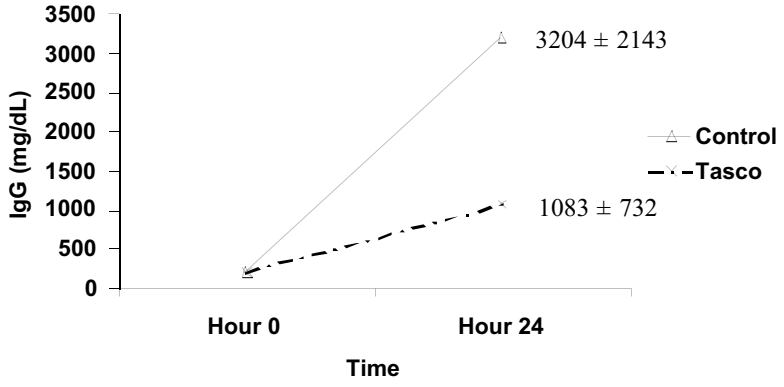

Figure 1. IgG Concentrations (mg/dL) in Calf Serum; Time X Dietary Treatment interaction (P < 0.01).

Clostridial Immune Response in Beef Cattle That Develop Lesions at the Injection Site[1, 2]

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Story in Brief

An experiment was conducted to compare the clostridial antibody response of beef heifers that do and do not develop injection-site lesions. Heifers were vaccinated (d = 0) with a 2-mL clostridial vaccine (Alpha-7) subcutaneous using the tented technique. Blood samples were collected on d 0, 28, 56, 84 and 112 to determine clostridial antibody titers. On d 28, heifers were visually inspected and palpated for injection-site lesions. Heifers with lesions (64.9%) were designated as the lesion group and those without were designated as the non-lesion group. The mean lesion size (diameter) was 2.2 ± 0.76 inches. The lesioned heifers had elevated antibody titers for *Cl. chauvoei* on d 28 ($P < 0.08$) and d 84 ($P < 0.07$) compared to the non-lesioned heifers. *Clostridium sordellii* and *perfringens* type D antibody titers were higher in the lesioned heifers than the non-lesioned heifers on d 28 and 56. These data indicated that antibody titers against clostridial diseases are enhanced when injection-site lesions develop. Therefore, the presence of an injection-site lesion following a clostridial vaccination may not have visual appeal but it does have positive implications for immune response.

Introduction

Clostridial diseases can affect beef cattle of all ages, but are a primary concern in cattle between 6 mo and 2 yr of age. Feeder cattle are marketed by the time they reach 2 yr of age, therefore, vaccinating for clostridial diseases is a matter for cow-calf producers, stocker cattle operators and feedlot managers. Although clostridial vaccinations are very effective, it has been demonstrated that 5-mL clostridial bacterins injected 376 and 255 d preslaughter produced lesion-site lesions in the sirloin butts of 92.7 and 79.5%, respectively (George et al., 1995). Therefore, the National Cattlemen's Beef Association's Beef Quality Assurance Task Force concluded that all products labeled for subcutaneous administration should be administered subcutaneous ahead of the point of the shoulder using the tented method (Executive Summary – 1995, NCBA). This method of administration for clostridial vaccines causes visible injection-site lesions (Beecher, 1995). The objective of this experiment was to compare the clostridial antibody response of calves that develop lesions at the injection site.

Experimental Procedures

Weaned crossbred heifers (approximately 8 mo of age) from two locations (Fayetteville, AR; 15 head and Greenbrier, AR; 22 head) were vaccinated with a 2-mL clostridial vaccine (Alpha-7®, Boehringer Ingelheim Vetmedica, Inc.). Alpha-7 bacterium-toxoid contains an oil adjuvant and is labeled for a single 2-mL injection. Injections were administered subcutaneous on the left side of the neck using the tented technique with a pistol-grip syringe. Enough toxoid was drawn into the syringe to vaccinate 10 head. Once the pistol-grip syringe was expended, the used 16-gauge, 3/4-inch needle was replaced with a new sterile needle and enough toxoid was withdrawn from the vial to vaccinate 10 additional head. If a needle became bent or burred, it was immediately replaced. The vaccination area was not cleaned and the hair was not clipped. On d 28, heifers were visually inspected and palpated for injection-site lesions. Heifers that developed lesions were designated as the lesion group and those that did not were designated as the non-lesion group. The heifers from the Greenbrier location had received clostridial vaccinations as preweaned calves but the heifers from Fayetteville had not. Heifers within each location were

[1] Mention of trade names, proprietary, or specific equipment does not constitute a guarantee of warranty of the product by the University of Arkansas and does not imply approval to the exclusion of other products that may also be suitable.

[2] Appreciation is expressed to Ron Everett for the use of his cattle and assistance.

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pastured and managed together according to acceptable management practices.

Blood was collected via jugular venipuncture from each heifer immediately before Alpha-7 injection (d 0) and on d 28, 56, 84, and 112. Blood samples were placed in crushed ice immediately after collection. Serum was harvested and stored at -20°C until assayed. Agglutination titers were determined for *Cl. chauvoei* by the serum agglutination test modified from Claus and Macheak (1972) and Troxel et al. (1997). Antitoxin units were determined for *Cl. perfringens* type D and *C. sordellii* by the antitoxin neutralization test as described by USDA:APHIS:VS (1993) and Troxel et al. (1997) and by USDA (1998), respectively.

Statistical Analysis. Heifers served as experimental units. *Clostridium chauvoei* was measured in microagglutination titers whereas the other clostridials were measured as antitoxin units. Therefore the term "titer" will be used to denote levels of the antibody response for all clostridials. The data were tested for normality by the Shapiro-Wilk test (SAS Inst., Inc., Cary, NC). The null hypothesis was rejected ($P < 0.05$). Therefore, we concluded that the data were not normally distributed around the mean. Because the data were not normally distributed, the variation around each mean value is not reported. Titers were transformed to a natural logarithm prior to analysis. This experiment was arranged in a completely randomized design with two locations. The GLM procedure of SAS was used to determine the effects of location, treatment and interactions. Non-transformed least square means are reported.

Results and Discussion

On d 28, 64.9% of the heifers (24 head) had developed injection-site lesions with an average lesion size (diameter) of 2.2 ± 0.76 inches. These calves were designated as the lesion group and those that did not develop injection-site lesions (13 head) were designated as the non-lesion group. There were no differences ($P > 0.10$) across locations in the number of heifers developing injection-site lesions or in lesion size. All heifers were examined again for injection-site lesions on d 112. Forty-five percent of the heifers still had detectable lesions with an average size of 1.3 ± 0.78 inches. Beecher (1995) reported an injection-site lesion percentage of 50, 50 and 30 on d 18, 33 and 54, respectively, on steer calves following Alpha-7 vaccination. In that study, all steers were vaccinated on the left side of the neck where no other vaccinations were given and a 3.0 inch square area of hair was removed with electric clippers. The area was cleansed with an alcohol soaked cloth, and the injection was administered with an 18-gauge, 1.0 inch needle that had been cleaned with alcohol. The tenting method for subcutaneous vaccinations was used. The majority of the lesions ranged between 0.80 to 2.4 inches. In the present study, the injection-site area was not clipped or cleansed with alcohol nor were the needles cleaned with alcohol between vaccinations. This could explain the higher incidence of injection-site lesions (64.9%), but even with using more sanitary techniques, a 50% injection-site lesion percentage on d 18 and 33 resulted (Beecher, 1995). Many clostridial vaccines require two injections at 4 to 6 wk intervals. It was reported that following the second injection, the percentage of injection-site lesions and injection-site swelling were more numerous and larger than those occurring after the first injection (Beecher, 1995).

Injection-site lesions may be caused by many factors. Some factors may include animal sensitivity to the clostridial vaccines, the vaccination injury itself, the adjuvant used to enhance the immune response and contamination (dirty needles, skin, etc.) at the time of vaccination. Oil adjuvant vaccines (like Alpha-7) are more successful in stimulating antibody production (Straw et al., 1986) and higher antibody titers have been associated with greater disease protection (Henry, 1983). Vaccines containing an oil adjuvant produce large and more persistent lesions in the muscle than vaccines produced with aluminum hydroxide (Straw et al., 1986).

Mean titers for *Cl. chauvoei*, Cl. sordellii and *Cl. perfringens* type D did not differ on d 0 between those with or without lesions (Table 1). Lesioned heifers had elevated antibody titer levels for *Cl. chauvoei* on d 28 ($P < 0.08$) and d 84 ($P < 0.07$) compared to the non-lesioned heifers. There were no differences between lesioned and non-lesioned heifers for d 56 and 112. *Clostridium chauvoei* (blackleg) is a soil-borne organism that causes sudden death and is more common with pastured cattle. *Clostridium sordellii* titers for the lesioned heifers were higher on d 28 ($P < 0.07$) and 56 ($P < 0.02$) compared with non-lesioned heifers, but no differences were detected for d 84 and 112. *Clostridium sordellii* can cause a fatal myositis and be identified as *Cl. chauvoei* or malignant edema. Titers for *Cl. perfringens* type D were enhanced for the lesioned heifers on d 28 ($P < 0.02$), 56 ($P < 0.04$) and 84 ($P < 0.07$) compared to the non-lesioned heifers but not on d 112. *Clostridium perfringens* type D, or pulpy kidney, can also cause sudden death especially in calves between 1 and 4 mo of age. It is a short-term inhabitant that does not usually persist in the soil for more than 1 yr.

The *Cl. chauvoei*, *Cl. sordellii* and *Cl. perfringens* type D immune antibody response between lesioned and non-lesioned heifers followed the same basic pattern. Serum antibody titer levels for all three clostridial diseases started at the same levels, but over time (d 0 to d 84) the heifers that developed injection-site lesions showed an enhanced antibody response. Although the clostridium antibody response for the non-lesioned heifers was not as high as the lesioned heifers, the immune response appeared to be adequate to protect them from a natural clostridium exposure. No heifers died during the experimental period.

There was a location effect for *Cl. chauvoei* on d 56 ($P < 0.05$) and 112 ($P < 0.06$) and a group by location interaction on d 112 ($P < 0.04$). In data not reported here tabular form, *Cl. chauvoei* titers were higher for the heifers at the Greenbrier location on d 56 and 112 compared to the heifers at the Fayetteville location (39.0 vs. 15.6 and 25.8 vs. 12.1, respectively). The group by location interaction on d 112 occurred due to the Greenbrier lesioned heifers having higher titers than the Fayetteville lesioned heifers (36.6 vs. 19.9, respectively). One possible explanation for these location

effects is that the heifers from the Greenbrier location were vaccinated for the clostridium diseases twice prior to the study. Therefore, their immune system was already prepared to respond to additional vaccinations.

There was a group by location interaction for *Cl. sordellii* on d 28 ($P < 0.005$), 56 ($P < 0.02$), and 84 ($P < 0.003$, Table 2). On d 28, the Greenbrier non-lesioned heifers had enhanced titers that were similar to the Fayetteville lesioned heifers. The Fayetteville lesioned heifers had enhanced titer levels, but it appeared that the Fayetteville non-lesioned heifers did not respond. On d 56, the Fayetteville lesioned heifers' titers were still elevated compared to the other three groups. It appeared that the Fayetteville lesioned heifers were the only group to respond with elevated *Cl. sordellii* titers and that the Greenbrier heifers (lesioned and non-lesioned) responded similarly to the vaccine. On d 84, the interaction ($P < 0.003$) occurred due to the Fayetteville lesioned heifers and the Greenbrier non-lesioned heifers having elevated titers compared to the Fayetteville non-lesioned and the Greenbrier lesioned heifers. It is not known what caused this response.

Implications

These results indicate that titers against clostridial diseases are enhanced when injection-site lesions develop. Lesions associated with an injection should not be a discounting factor when pricing cattle but rather a sign that the cattle were properly immunized. The success of a vaccination program depends upon management, proper timing of vaccination and using the product correctly.

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Table 1. Mean titers for *Cl. chauvoei, Cl. sordellii* and *Cl. perfringens* Type D in serum of calves with or without injection site lesions.

Time after vaccination, day	*Cl. chauvoei*			*Cl. sordellii*			*Cl. perfringens* Type D		
	L[a]	NL[b]	Significance level	L	NL	Significance level	L	NL	Significance level
0	5.0	5.7	NS[c]	0.05	0.05	NS	0.05	0.05	NS
28	46.7	19.9	$P < 0.08$	0.32	0.16	$P < 0.07$	0.17	0.08	$P < 0.02$
56	30.1	20.1	NS	0.20	0.10	$P < 0.02$	0.21	0.10	$P < 0.04$
84	38.1	15.7	$P < 0.07$	0.15	0.10	NS	0.30	0.12	$P < 0.07$
112	19.1	16.4	NS	0.08	0.08	NS	0.30	0.16	NS

[a]L = heifers that developed injection site lesions (n = 24).

[b]NL = heifers that did not develop injection site lesions (n = 13).

[c]NS = not significant ($P > 0.10$).

Table 2. Mean titers for *Cl. sordellii* in serum of calves with or without injection site lesions from the Fayetteville and Greenbrier locations.

Experimental location	Day 28		Day 56		Day 84		Day 112	
	L[a]	NL[b]	L	NL	L	NL	L	NL
Fayetteville	0.37	0.07	0.39	0.07	0.24	0.07	0.09	0.09
Greenbrier	0.24	0.37	0.16	0.16	0.09	0.16	0.08	0.09
Location by group interaction	$P < 0.005$		$P < 0.02$		$P < 0.003$		NS[c]	

[a]L = heifers that developed injection site lesions (Fayetteville, n = 8; Greenbrier, n = 16).

[b]NL = heifers that did not develop injection site lesions (Fayetteville, n = 7; Greenbrier, n = 6).

[c]NS = not significant ($P > 0.10$).

Long-Term Immune Response of Beef Heifers Injected with Either a Single or Multiple Dose Clostridial Toxoid

M. S. Gadberry,[1] T. R. Troxel,[1] D. L. Kreider,[2] P. Widel,[3] and I. Nicholson[3]

Story in Brief

The objective of this experiment was to evaluate the long-term immune response of weaned heifers vaccinated with either a single or multiple dose clostridial toxoid. Heifers (427 ± 63 lb) were randomly assigned to receive either a one-time injection of a 2-mL vaccine (Alpha-7, A7; n = 15) or the injection on days 0 and 28 with a 5-mL vaccine (Ultrabac 7, UB7; n = 15). All injections were administered subcutaneously in the neck region using the tented technique. Serum samples were analyzed for *Cl. chauvoei* (CC) agglutination titers and antitoxin units for *Cl. perfingens* type C (CPC) and D (CPD), *Cl. novyi* (CN), *Cl. septicum* (CSE) and *Cl. sordellii* (CS) on d 0 and every 28 d through d 112. Resulting titers and units lacked normality and were therefore transformed to a natural logarithm before statistical analyses. Agglutination titers of CC as well as antitoxin units of CPC, CPD, CN, CSE, and CS did not differ ($P > 0.10$) between the treatment groups before vaccination on d 0. *Clostridium chauvoei* titers, CPD and CN antitoxin units of A7 heifers were higher ($P < 0.05$) than UB7 heifers on d 28. No differences were detected for CPC, CSE or CS. At d 56, CC titers, CPC, CN and CS antitoxin units were higher ($P < 0.01$) in UB7 heifers than in A7 heifers. Antitoxin units did not differ between treatments on d 56 for CPD or CSE. Day 84 CPC and CS antitoxin units remained higher ($P < 0.01$) for UB7 heifers than for A7 heifers. By d 112, differences between treatments were only detectable for CPD with UB7 heifers having a lower antitoxin unit than A7 heifers. Alpha-7 invoked a greater immune response by d 28 for CC than UB7; however, the second injection of UB7 increased immunity for CC beyond A7 by d 56. At the completion of the trial, d 112, A7 and UB7 levels were similar.

Introduction

Some clostridial vaccines require revaccination 4 to 6 wk following the initial treatment. In reality, however, many cattle producers fail to gather their cattle for revaccination. With many stocker cattle grazing programs and feedlot feeding programs lasting 110 to 180 d, long-term single dose clostridial protection would therefore be very beneficial. The objective of this experiment was to evaluate the long-term immune response elicited by either single or multiple dose toxoid.

Materials and Methods

Thirty weaned stocker heifers (427 ± 63 lb) were randomly assigned to receive injections of either Alpha-7 (A7, n = 15) or Ultrabac 7 (UB7, n = 15, SmithKline Beecham Animal Health). Ultrabac 7 is labeled for 5-mL injections with revaccination in 4 to 6 wk and uses an aluminum hydroxide adjuvant. Both products protect beef cattle against *Cl. chauvoei* (CC, blackleg), *Cl. septicum* (CSE, malignant edema), *Cl. novyi* (CN, black disease), *Cl. perfringens* types C (CPC) and D (CPD), and *Cl. Sordellii* (CS) (Veterinary Pharmaceuticals and Biologicals, 1995-96). The heifers that received Alpha-7 (d 0) were administrated one 2-mL injection while the heifers that received Ultrabac 7 were administrated a 5-mL injection on d 0 and 28.

Blood was collected via jugular venipuncture from each heifer immediately before Alpha-7 or Ultrabac 7 injection (d 0) and on d 28, 56, 84, 112, 140, and 180. Blood samples were placed in crushed ice immediately after collection. Serum was harvested and stored at -20°C until assayed. Agglutination titers were determined for *Cl. chauvoei* by the serum agglutination test modified from Claus and Macheak (1972) and Troxel et al. (1997). Antitoxin units were determined for CPD and CS by the antitoxin neutralization test as described by USDA:APHIS:VS (1993) and Troxel et al. (1997) and by USDA (1998), respectively. Antitoxin units were determined for CPC, CN, and CSE by the antitoxin neutralization test as described by USDA:APHIS:VS (1985) and Troxel et al. (1997), USDA (1999) and British Pharmacopoeia (1993), respectively.

Statistical Analysis. Heifers served as experimental units. *Clostridium chauvoei* was measured in microagglutination titers whereas the other clostridials were measured as antitoxin units. Therefore, the term "titer" will be used to denote levels of the immune response for all clostridials. The

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data was tested for normality by the Shapiro-Wilk test (SAS Inst., Inc., Cary, NC) and the null hypothesis of normally distributed data was rejected ($P < 0.05$). Because the data were not normally distributed, the variation around each mean value is not reported. Titers were transformed to a natural logarithm before analysis. The experiment was set up as a completely randomized design, and data were analyzed using the GLM procedure of SAS. Non-transformed least-squares means are reported.

Results and Discussion

After d 112, titers for all clostridial disease units were below detectable levels and therefore are not reported. Titers for CC, CS, CPD, CN, CSE or CPC did not differ ($P > 0.10$) between A7 or UB7 groups prior to vaccination on d 0. *Clostridium chauvoei* ($P < 0.05$), PD ($P < 0.06$) and CN ($P < 0.06$) titers from the A7 heifers were higher than gpt UB7 heifers on d 28 (Tables 1 and 2). No differences were detected for CS, CSE or CPC. On d 56, CC ($P < 0.02$), CS ($P < 0.01$), CN ($P < 0.01$) and CPC ($P < 0.01$) titers were higher in UB7 heifers than in A7 heifers. This increased immune response was due to the second injection of UB7 on d 28. Titers did not differ between treatments on d 56 for CPD or CS. Day 84 CS and CPC titers remained higher ($P < 0.01$) for UB7 heifers. By d 112, differences between treatments were only detectable for CPD in which A7 heifers had higher ($P < 0.01$) levels than UB7 heifers.

Following labeled instructions for all vaccines is a critical component for vaccination success. Beef calves are often vaccinated for clostridial diseases with one injection even though the vaccination label states that two injections should be given 4 to 6 wk apart. Troxel et al. (1997) demonstrated that vaccinating beef calves at 50 d of age with one injection of UB7 and not again until d 170, may not provide adequate protection against clostridial diseases. In the current study, A7 seemed to cause an enhanced immune response as compared to the first UB7 injection, but the second UB7 injection on d 28 enhanced the titers for CC, CS, CN and CPC on d 56. Even with the enhanced immune response seen by the second UB7 injection, long-term immune response through d 112 was not improved. Therefore, one injection of A7 seemed to provide the same long-term protection as two injections (2 to 4 wk apart) of UB7.

Implications

With many cow-calf and stocker cattle producers not wanting to gather calves to administer a second clostridial vaccination, one injection of Alpha-7 appeared to provide the same length of protection as two injections of Ultrabac 7 given 4 to 6 wk apart.

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Table 1. Mean titers for *Cl. chauvoei*, *Cl. sordellii* and *Cl. perfringens* type D in serum of calves vaccinated with either Alpha-7 or Ultrabac 7.

Experimental	*Cl. chauvoei*			*Cl. sordellii*			*Cl. perfringens* type D		
period, d	A7[a]	UB7[b]	Significance level	A7	UB7	Significance level	A7	UB7	Significance level
0	6.7	5.7	NS[c]	0.05	0.05	NS	0.05	0.05	NS
28	61.4	13.6	P < 0.05	0.40	0.30	NS	0.30	0.10	P < 0.06
56	27.7	156.1	P < 0.02	0.40	1.80	P < 0.01	0.30	0.30	NS
84	42.5	37.3	NS	0.30	0.80	P < 0.01	0.30	0.20	NS
112	17.7	20.0	NS	0.10	0.10	NS	0.50	0.10	P < 0.01

[a]A7 = Alpha-7.
[b]UB7 = Ultrabac 7.
[c]NS = not significant (P > 0.10).

Table 2. Mean titers *Cl. novyi*, *Cl. septicum* and *Cl. perfringens* type C in serum of calves vaccinated with either Alpha-7 or Ultrabac 7.

Experimental	*Cl. novyi*			*Cl. septicum*			*Cl. perfringens* type C		
period, d	A7[a]	UB7[b]	Significance level	A7	UB7	Significance level	A7	UB7	Significance level
0	0.05	0.05	NS[c]	0.05	0.05	NS	0.08	0.09	NS
28	0.90	0.08	P < 0.06	0.70	0.90	NS	4.00	1.90	NS
56	0.60	2.10	P < 0.01	0.60	0.90	NS	3.50	8.40	P < 0.01
84	0.50	0.60	NS	0.50	0.60	NS	0.80	2.80	P < 0.01
112	0.25	0.10	NS	0.50	0.60	NS	0.60	1.40	NS

[a]A7 = Alpha-7.
[b]UB7 = Ultrabac 7.
[c]NS = not significant (P > 0.10).

Examination of Hospital Pen Management for Stocker Cattle Operations

J. Robins, S. Krumpelman, and D. H. Hellwig[1]

Story in Brief

Two experiments were conducted to examine the management of hospital pens in a stocker facility. Eighty-six calves (bulls and steers, 443 to 618 lb) and126 calves (bulls, steers and heifers, 213 to 415 lb) were used in experiments 1 and 2, respectively. For each experiment, the calves were blocked by weight and randomly assigned to 1.1-acre grass lots with 21 or 22 calves per lot. The calves were examined daily for signs of bovine respiratory disease (BRD), given a clinical illness score (CIS) and treated according to protocol. When each calf was treated for BRD, it was assigned to either group 1 or group 2 (alternately). Calves in group 1 were sent to a hospital pen after treatment, while calves in group 2 were returned to their home pen to recover. In either experiment, there were no significant differences between groups in percentage of treatment successes, treatment failures or relapses. In addition, there were no significant differences between groups for ADG, medication costs, and cost per pound of gain in either experiment.

Introduction

The goals of a stocker cattle or feedlot health program include reducing mortality due to disease, minimizing disease outbreaks, economically enhancing cattle performance and utilizing professional assistance with health and production management (Lechtenberg et al., 1998; Smith et al., 1993; USDA, 1999). Many operations will utilize a hospital facility for the treatment and recovery of sick animals. These facilities provide a place for animals to recover in a low-stress, non-competitive environment. It is convenient for the hospital manager to evaluate the animal's response to treatment as well as re-evaluating the therapy for treatment failures. There are however, disadvantages to using a hospital area. These include exposure of the animal to additional pathogens, the development of "seeder" calves that can bring new pathogens back to the home pen, the social adjustment of the calf in a new environment, and poorly managed pens that don't provide a stress-free environment for the recovering calf. The objective of these studies was to compare the use of a hospital pen against home pen replacement following treatment for bovine respiratory disease (BRD).

Experimental Procedures

Experiment 1. Eighty-six stocker calves (bulls and steers) with weights ranging from 443 to 618 lb were purchased from several salebarns in Central Arkansas and delivered as a group to the University of Arkansas Beef Cattle Research Facility in Savoy. All animals were initially processed within 24 hours of arrival. This included a modified-live viral vaccine (Frontier 4-Plus®, Bayer Corp., Shawnee Mission, KS), a multivalent clostridial bacterin (Vision-7®, Bayer Corp., Shawnee Mission, KS), and a tetanus toxoid. (Vision-CDT®, Bayer Corp., Shawnee Mission, KS). A pour-on endectocide (Eprinex®, Merial, Athens, GA), was used for parasite control. All animals were re-vaccinated with the same products 2 weeks after initial processing. At this time the bulls were castrated using a banding method and the horns were tipped.

All calves were weighed, blocked by weight (bulls were stratified through treatment groups to nullify any affects of castration 2 weeks after arrival) and randomly assigned to one of four grass lots (1.1-acres) with 21 or 22 calves per lot. The animals were initially offered a 16% pelleted protein supplement at a rate of 2 lb per head per day. This was gradually increased over one week to a maximum of 4 lb per head per day. This amount was offered daily until the end of the study (28 d). Grass hay was supplemented as necessary.

Calves with clinical signs of BRD (Table 1) were removed from their home pens and evaluated for treatment. Each calf was given a clinical illness score (CIS, Table 2), treated for BRD (Table 3) and alternately assigned to one of two groups. Calves from group 1 were sent to a hospital pen to recover and calves from group 2 were, upon treatment, sent back to the respective home pen for recovery. Treatment success was characterized by a CIS of < 2 accompanied by a reduction in body temperature by 20°F or < 104°F. No improvement in CIS and no reduction in body temperature were considered to be a treatment failure and the next successive (Table 3) treatment was initiated. A BRD relapse was defined as showing clinical signs of BRD within 21 days of recovery. There were designated hospital pens for first, second and third treatments.

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Examined were proportion of treatment successes, failures, BRD relapses, average medication cost, ADG and cost per pound of gain. The cost per pound of gain included feed cost, medication, processing and chute charges. Average daily gain, medication cost and cost per pound of gain were statistically analyzed by ANOVA (SAS Inst. Inc., Cary, NC). Differences in the percentage of treatment successes, failures and relapses for home and hospital pen were analyzed with a Goodness of Fit Test using the chi-square distribution.

Experiment 2. One-hundred-twenty-six stocker calves (heifers, bulls and steers) with weights ranging from 213 to 415 lb, were purchased from several salebarns in Central Arkansas and delivered as a group to the University of Arkansas Beef Cattle Research Facility in Savoy. Initial processing was identical to that for experiment 1, with the exception that no anthelmintic treatment was given. All treatments and randomizations were identical to experiment 1, however, the calves were only observed for illness for 14 days rather than 28 days. Statistical analysis was performed in a similar fashion to experiment one.

Results and Discussion

The probability of treatment success, treatment failure and relapse from BRD of animals recovering in the hospital pens did not differ from those that were returned to their home pen after initial treatment (Table 4; P = 0.30). The initial clinical illness scores were not statistically different between the groups indicating that the level of illness was about equal for each group (Table 5). Average medication cost, ADG and cost per pound of gain were not significantly different between the groups (Table 5). Results were the same for experiment 2 (Tables 6 and 7) in that there were no statistical differences between groups for any trait. There was a higher percentage of successes in the hospital group than the home group in experiment 1 (94% vs 76%), while in experiment 2 there was a higher percentage of successes in the home group than in the hospital group (84% vs 75%); however, these percentages were not statistically different between groups for either experiment.

The hospital pens at this facility were well managed, providing adequate space and optimum nutrition. In addition, the additional labor cost for sorting out animals from their home pen to assess treatment success was not calculated. Labor cost calculation would have been difficult since there were different numbers of people working each day and each person is at a different pay scale. It is speculated that if this could have been easily done, there may have been an economic advantage to keeping the animals in the hospital during recovery. The effect on morbidity to pen mates from sending treated animals back to their home pens was not evaluated. One also needs to consider there were only 21 animals in each lot. This provided adequate room and bunk space and translates into a relatively low stress situation. In a dry lot with 80 to 100 animals per pen the results may have been different. Additional studies would be indicated to assess these effects.

Implications

Results of this study indicate that in a small facility with well-managed hospital and home pens there is no advantage to maintaining a hospital facility. It should be noted, however, that there is an increased amount of labor involved with handling and re-handling of sick animals in the home pen. It is much easier to observe and re-treat animals that are kept in a hospital facility. Regardless of method used, there is no substitute for good management when it comes to enhancing treatment success for BRD in a stocker or feedlot facility.

Literature Cited

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Table 1. Criteria for evaluation of bovine respiratory disease.

Clinical signs	Depression
	Purulent ocular/nasal discharge
	Labored breathing
	Coughing
	Lameness
Rectal temperature	≥ 104°F

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

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

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

Table 3. Treatment Schedule for calves treated for BRD

Treatment 1: Micotil (10 mg/kg) SQ

•Check in 72 hours. If temperature has not dropped 2 degrees, then go to treatment 2. If temperature has not dropped 2 degrees but still is not <104°F, then give second dose of Micotil. If temperature has dropped below 104°F, then consider treatment a success and put animal back in the home pen.

Treatment 2: Nuflor (40 mg/kg) SQ

•Check in 48 hours. If temperature has not dropped 2 degrees, then go to treatment 3. If temperature has dropped 2 degrees but still is not <104°F, then give second dose of Nuflor. If temperature has dropped below 104°F, then consider treatment a success and put animal back in the home pen. Also for animals that recovered from treatment 1 and relapsed at a later date.

Treatment 3: Excenel (2.2 mg/kg) SQ

•Treat for 3 consecutive days. If temperature has dropped 2 degrees but is not <104°F, then give fourth dose of Excenel. If temperature has dropped below 104°F, then consider treatment a success and put animal back in the home pen. This treatment is also for animals that recovered from treatment 2 but relapsed at a later date.

Table 4. Experiment 1: Percentage of treatment success, failure, and relapse in stocker calves treated for bovine respiratory disease[a].

	Group	
Item	**Hospital Pen**	**Home Pen**
Treatment success (%)	94 (15/16)	76 (16/21)
Treatment failure (%)	6 (1/16)	14 (3/21)
Relapse (%)	0 (0/16)	10 (2/21)

[a]Chi-square for a 3 X 2 table. P = 0.30

Table 5. Experiment 1: Means of clinical illness score (CIS), ADG, medication cost, and cost per pound of gain in stocker calves treated for bovine respiratory disease.

	Group			
Item	**Hospital**	**Home**	**SE**	**P-value**
Average CIS[a]	2.5	2.6	0.14	0.63
ADG (lb/hd/d)	2.07	1.88	0.30	0.66
Average medical cost per head, $	8.68	15.58	1.67	0.15
Cost per pound of gain, $	0.59	-0.41	0.81	0.42

[a]Average CIS score when animals were initially pulled and put on study

Table 6. Experiment 2: Percentage of treatment success, failure, and relapse in stocker calves treated for bovine respiratory disease.[a]

	Group	
Item	**Hospital**	**Home**
Treatment success, %	75 (47/63)	83 (44/53)
Treatment failure, %	13 (8/63)	9 (5/53)
Relapse, %	13 (8/63)	8 (4/53)

[a]Chi-square for a 3 X 2 table, P = 0.53

Table 7. Experiment 2: Means of clinical illness score (CIS), ADG, medication costs, and cost/lb gain in stocker calves treated for bovine respiratory disease.

	Group			
Item	**Hospital**	**Home**	**SE**	**P-value**
Average CIS[a]	2.6	2.5	0.08	0.48
ADG (lb/hd/d)	1.82	1.86	0.16	0.85
Average medical cost per head, $	7.81	7.34	0.46	0.48
Cost per pound of gain, $	1.16	1.27	0.96	0.94

[a]CIS score when animals were initially pulled and put on study

Arkansas Steer Feedout Program 1999-2000

T. Troxel, G. Davis, S. Gadberry, S. McPeake, and W. Wallace[1]

Story in Brief

The objective of the Arkansas Steer Feedout Program is to provide cow-calf producers information about the post-weaning performance and carcass characteristics of their calves. Steers that were composed of more than 50% English, less than 50% Continental, and less than 25% Brahman breeding had a higher percentage that graded Choice than steers that did not satisfy the breed type description (65% vs. 35%). Hot carcass weight, days on feed, quality grade, yield grade, medicine cost, and dressing percentage were significant factors that affected the return over specified cost. With the information gained from this program, cow-calf producers can better evaluate their cattle breeding programs.

Introduction

The Feedout Program allows producers to learn more about the characteristics of their calf crop and the factors that influence value beyond the weaned-calf phase. The program is not a contest to compare breeds or breeders, or a retained ownership promotion program. It creates an opportunity for producers to determine how their calf crop fits the needs of the beef industry and provides information needed to determine if changes in genetics and/or management factors are warranted.

Experimental Procedures

On November 4, 1999, 309 calves (20 heifers and 289 steers) from 42 Arkansas producers representing 21 counties were placed on feed at Neill Cattle Company Feedyard at Welch, Oklahoma. Upon arrival, steers were eartagged, weighed, and processed (Synovex-S, Ivomec Plus, Vision 7 and Bovishield). An experienced order buyer placed an in value on all calves. Steers were sorted to two feeding pens based upon weight, frame and condition. Heifers were placed in a pen and fed separately from the steers. Management factors such as processing, medical treatments, and diets were the same as the other cattle in the feedyard. The feedyard manager selected animals for slaughter when they reached the weight and condition regarded as acceptable for the industry and market conditions. Calves were slaughtered in four groups (March 23, April 12, April 26 and May 17, 2000). The cattle were sold on a carcass weight basis with premiums and discounts for various quality grades, yield grades, and carcass weights. 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.

Descriptive statistics were computed to describe general program results. Because there were only 20 heifers, the heifer data was not used in the analysis. Of the 289 steers that started in the fall, two died and two were sold as realizers. Ten additional steers were sold after only 80 days on feed. These steers were exceptionally large and were sold to prevent large carcass discounts. These 14 steers were not included in the statistical analyses. Therefore, feedlot and carcass data from 275 steers were used in the analyses. Carcasses of steers that were at least 50% English, no more than 50% Continental and less than 25% Brahman were sorted into one group and those steers that did not satisfy the breed-type criteria were placed in a second group. Steers either fit the criteria or they did not, which resulted into two groups. The group main effect and interaction on the dependent variables yield grade, ribeye area, ribeye area/hot carcass cwt., ADG, dressing percentage, feed cost per pound of gain, and net return were determined using the PROC GLM procedure of SAS (SAS Inst. Inc., Cary, NC). Fat thickness was used as a covariant in the model.

Carcasses of steers were also grouped according to whether or not they fit an industry standard for carcass merit (at least Choice, yield grade # 3.5, with a hot carcass weight between 550 and 950 lb). Data were analyzed in the same manner as the breeding group analysis. Least-squares means were computed and reported.

Factors affecting feedlot return (gross income minus feedlot direct expenses) of the top 25% steers and the bottom 25% steers were determined using the Stepwise method of PROC REG. Independent variables included in weight; percentage Brahman, percentage English, and percentage Continental breeding; ADG; yield grade; quality grade; feed cost per lb of gain; hot carcass weight; days on feed; medicine cost; ribeye area; ribeye area/hot carcass cwt.; and dressing percentage.

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Results and Discussion

The steer and heifer financial reports are summarized in Tables 1 and 2, respectively. Average steer and heifer gross income per head was $878.05 (range = $593 to $1,102) and $821.01 (range = $614 to $1,008), respectively. The feedlot returns for steers and heifers averaged $616.52 and $555.11, respectively, whereas the calculated returns averaged $112.30 (range = $-138 to $259) and $130.35 ($-51 to $258), respectively.

The fall of 1999 was exceptionally dry and windy which may have contributed to an increase in sickness. A total of 45 calves (14.6%) were treated for sickness. The average medicine cost per sick calf was $31.86. The medicine cost for the entire group averaged $4.65 per head. The health status of cattle in the feedyard usually has a major impact on performance and profit. Healthy steers had higher feedlot returns ($631) than steers that became sick ($522; $P < 0.01$). In addition, healthy steers had a higher dressing percentage (64.2%) than steers that became sick (62.0%; $P < 0.001$). Significant differences ($P < 0.001$) were detected between healthy steers and steers that became sick for final weight (1,210 lb vs. 1,159 lb), average daily gain (3.37 lb vs. 3.03 lb), feed cost of gain ($0.40 vs. $0.44), days on feed (166 vs. 175), carcass weight (776 lb vs. 715 lb), carcass value ($888 vs. $813), total cost of gain ($0.47 vs. $0.58), and percent grading Choice (sick calves = 24% and healthy calves = 50%). Only 8% of the healthy calves graded Standard whereas 41% of the sick calves graded Standard.

The steer and heifer average off-the-truck arrival weights were 650 (range = 440 to 920) and 610 lb (range = 490 to 680), respectively. The steer average daily gain, average days on feed, feed cost per lb of gain, and total cost per lb of gain were 3.33 lb (1.57 to 4.77), 167 days (146 to 190), $0.41 ($0.30 to $0.75), and $0.49 ($0.35 to $0.99), respectively. The heifer average daily gain, average days on feed, feed cost per lb of gain, and total cost per lb of gain were 2.78 lb (1.93 to 3.78), 176 days, $0.46 ($0.39 to $0.60), and $0.56 ($0.45 to $0.83), respectively.

The average steer carcass weight, ribeye area, dressing percentage, yield grade, and fat thickness were 768 lb (567 to 1,021), 12.4 in^2 (9.0 to 16.1), 63.8% (54.5% to 70.8%), 2.93 (1.09 to 5.63), and 0.42 in. (0.12 to 1.16), respectively. Forty-six percent of the carcasses graded Choice whereas 40% and 13% graded Select and Standard, respectively. A few carcasses graded Prime (0.4%). Carcass value for Choice-Yield Grade 2 carcasses was $117.50, $119.00, $120.50, and $115.50 for March 23, April 12, April 26 and May10 harvest dates, respectively.

The percentage English, Continental and/or Brahman breeding was determined for each calf. Carcass of steers that were at least 50% English, no more than 50% Continental and less than 25% Brahman were sorted into one group and those steers that did not satisfy the breed-type criteria were placed in a second group (Table 3). Calves that fit the breed-type criteria graded 65% Choice compared to 35% Choice for the calves that did not fit the breed-type criteria. After reviewing the data, there appears to be enough evidence to support the recommendation that market cattle should be composed of at least 50% English, no more than 50% Continental, and less than 25% Brahman.

Listed below are six significant factors that affected the return over specified costs in the 1999-00 Feedout Program. Factors are listed from the most important to the least important.

Factors Affecting Returns Over Specified Cost

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

1. Hot Carcass Weight – The relationship between hot carcass weight and feedlot returns over specified cost was positive. That is as hot carcass weight increased so did feedlot returns. The more carcass pounds sold, the greater the gross income and feedlot returns. Table 4 shows the relationship between hot carcass weight, total cost of gain, average daily gain and feedlot returns over specified costs. Hot carcass weight discounts were observed for carcasses weighing less than 550 lb and greater than 950 lb.

2. Days on Feed – Cattle were sold on March 23, April 12, April 26 and May 10, 2000. There was a negative relationship between days on feed and returns over specified cost. This means that on the average, the longer that cattle were on feed the lower the returns (Table 5). A factor that affected the relationship between days on feed and feedlot return over specified costs was the price difference between Choice and Select quality grades on two slaughter days. Early in the spring, there was a $3 per carcass cwt. discount between Choice and Select but on May 10 the spread was $7 per carcass cwt.

3. Quality Grade – Cattle that graded Prime, Choice, Select, and Standard had feedlot returns of $560, $557, $507, and $399, respectively for the past two feedouts (1998-1999 and 1999-2000). Marbling is the main factor that affects a calf's ability to grade Choice. Three main factors that affect marbling are: (1) the genetic ability to marble; (2) the maturity, or the physiological age, not the chronological age; and (3) diet. Some cattle breed associations report marbling EPD's in their sire summary. Carcass traits such as marbling are highly heritable; therefore, selecting high marbling EPD bulls can impact the marbling ability of their progeny. Breed type can also influence a calf's ability to grade Choice.

4. Yield Grade – As yield grade increased from 1 to 4, feedlot return decreased ($565, $521, $523 and $414 for yield grades 1, 2, 3 and 4, respectively).

5. Medicine Cost – Healthy calves had higher dressing percentage (64.2% vs. 62.0%) and higher feedlot returns over specified costs ($631 vs. $523) than calves that were treated for illness. Healthy calves had a calculated return of $134 more than sick calves.

6. Dressing Percentage – The relationship between dressing percentage and feedlot net return was positive. As dressing percentage increased so did feedlot net return. Many of the factors that affect hot carcass weight also affect dressing percentage.

Table 6 summarizes the performance and carcass data from the steers that were in the bottom 25% and top 25% (based on returns over specified costs) and the average of all the steers. In summary, the calves in the bottom 25% had high feed and medicine cost, low dressing percentage and failed to grade Choice. The cattle that performed the best were medium to large framed, heavy muscled, gained well, had a high dressing percentage, did not get sick, and graded Choice.

The beef cattle industry has set the standard that quality grade should be Choice, yield grade should be < 3.5, and hot carcass weight between 550 and 950 lb. This year 37% of the steer calves fit all those requirements. Steers that met the industry standards had higher average daily gain (3.40 vs. 3.20 lb) and averaged $65 more per head than those that did not fit the industry standards ($P < 0.01$). They had higher carcass values ($1.18 vs. $1.06) 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).

Implications

Extremes in feedlot return over specified costs, health costs, performance factors and carcass parameters exist in the beef industry. A producer's goal should be to reduce these variables and produce a product that meets the needs of all segments of the beef industry. Value-based marketing at all levels of the industry is rapidly becoming a reality. Ranchers who produce a product that meets the demands will be more competitive in the market place.

Table 1. 1999-00 Arkansas steer feedout summary financial results.

Item	Average	Range
Gross income	$878.05	$593 to $1,102
Expenses		
Feed	$222.07	$151 to $274
Medicine	4.32	0 to 72
Freight,processing, yardage, interest, etc	35.14	31 to 39
Total feedlot expenses	$261.53	$182 to $342
Feedlot return	$616.52	$298 to $806
Steer calf in value	$504.22	$345 to $661
Return over specified cost	$112.30	$-138 to $259

Table 2. 1999-00 Arkansas heifer feedout summary financial results.

Item	Average	Range
Gross income	$821.01	$614 to $1,008
Expenses		
Feed	$222.74	$184 to $261
Medicine	5.11	0 to 40
Freight,processing, yardage, interest, etc	38.05	37 to 40
Total feedlot expenses	$265.90	$221 to $303
Feedlot return	$555.11	$360 to $707
Heifer calf in value	$424.76	$314 to $496
Return over specified cost	$130.35	$ -51 to $258

Table 3. Performance and carcass data of Arkansas steers that did or did not fit the breed-type criteria[1].

Item	Fit breed-type criteria	Did not fit breed-type criteria	Significance
Percent grading Choice	65%	35%	P < 0.01
Yield grade	2.1	1.8	P < 0.001
Ribeye area (REA), in^2	12.1	12.9	P < 0.001
REA per 100 lb carcass weight	1.60	1.69	P < 0.001
Average daily gain, lb	3.26	3.07	P < 0.01
Dressing percentage	63.1%	64.5%	P < 0.001
Hot carcass weight, lb	770	769	NS[2]
Carcass value	$114.88	$113.75	NS
Feed cost per lb of gain	$0.42	$0.46	P = 0.001
Feedlot return	$556	$547	NS
Percentage that met industry standards	57%	30%	P < 0.01

[1]At least 50% English, no more than 50% Continental and less than 25% Brahman.
[2]NS = Not significant.

Table 4. Summary of hot carcass weight, total cost of gain, average daily gain, feedlot returns, and calculated returns.

Hot carcass Weight, lb	Total cost of gain/lb	ADG, lb	Feedlot returns	Calculated return
<600	$0.66	2.2	$371	$-59
600-699	$0.57	2.6	$504	$52
700-799	$0.48	3.3	$601	$102
800-899	$0.46	3.8	$695	$152

Table 5. Effect of days on feed on average daily gain, total cost of gain, carcass value and feedlot returns, and calculated returns.

Slaughter dates	Days on feed	ADG, lb	Total cost of gain/lb	Carcass value	Feedlot return	Calculated return
March 23	146	3.5	$0.46	$115	$666	$111
April 12	162	3.7	$0.46	$117	$662	$161
April 26	176	3.0	$0.52	$116	$600	$137
May 17	190	3.1	$0.52	$111	$537	$86

Table 6. Performance of the bottom 25%, average and top 25% steers based upon feedlot returns.

	Bottom 25%	Average	Top 25%
Number of steers	69	275[a]	69
In weight, lb	587[b]	650	722[c]
Muscle score	1.3[d]	1.2	1.1[e]
Frame score			
Large	35%	41%	46%
Medium	65%	59%	54%
Final weight, lb	1,111[b]	1,202	1,306[e]
Average daily gain, lb	2.84[b]	3.33	3.82[e]
Gross income	$769[b]	$878	$983[e]
Carcass value per lb	$1.10[b]	$1.14	$1.17[e]
In value per head	$516	$504	$490
Hot carcass weight, lb	698[b]	768	841[e]
Dressing percentage	63.0%[b]	63.9%	64.0%[e]
Medicine	$12.89[b]	$4.32	$0.69[e]
Total feed cost per head	$226	$222	$221
Total expense	$275[b]	$262	$256[e]
Feedlot returns	$494[b]	$617	$727[e]
Calculated returns	$39[b]	$112	$172[e]
Days on feed	184[b]	167	153[e]
Feed cost per lb of gain	$0.45[b]	$0.41	$0.38[e]
Total cost per lb of gain	$0.55[b]	$0.48	$0.44[e]
Ribeye area, in^2	12.0[b]	12.4	13.0[e]
Fat thickness, in	0.42	0.42	0.40
Quality grade			
Prime	1%	0.4%	0%
Choice	23%[b]	46%	71%[e]
Select	45%[b]	31%	26%[e]
Standard	30%	31%	3%
Yield grade	2.04	2.10	1.94

[a] Fourteen calves were not used in this data set. Two calves died, two were sold as realizers and ten were sold early in the feeding period.

[b,c] Values within a row with no common superscripts differ ($P < 0.01$).

[d,e] Values within a row with no common superscripts differ ($P < 0.05$).

Small Grain Forage for Stocker Cattle Production

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Story in Brief

Seventy-two preconditioned, crossbred steers (average BW = 400 lb) were placed on 2-acre pastures containing various small-grain forage from October 23, 2000 until March 20, 2001 at a stocking density of 600 lb beef per acre. The pastures were seeded to 1) Delta King 9027 soft red winter wheat, 2) Elbon rye, 3) Bob Oats, 4) Marshall ryegrass, 5) Delta King 9027 wheat plus Elbon rye, 6) Delta King 9027 wheat plus Marshall ryegrass, 7) Elbon rye plus Marshall ryegrass and 8) Delta King 9027 wheat plus Elbon rye plus Marshall ryegrass. These treatments were replicated three times. Pastures were covered with ice from December 21 until January 24. Steers were fed bermudagrass hay during this period. No differences occurred in average daily gain (ADG), total gain (TG) or gain per acre (G/A) from October until December 19. However, from January 25 until March 20, pastures which contained rye produced significantly ($P < 0.05$) greater ADG, TG and G/A then did those which did not contain rye. Bob oats suffered severe winter kill and could not be grazed from January 25 to March 20. Regrowth of wheat and ryegrass was severely delayed compared to rye. These data suggest that rye is much more winter hardy, especially if ice covered for an extended time, than wheat, oats or ryegrass.

Introduction

Forage of small grains has been used as pasture for cattle in Arkansas for years. However, small grains have primarily been over seeded in bermudagrass sod during late September and October. Hubbell et al. (2000) seeded soft red winter wheat, rye, oat, ryegrass and combinations of these into a prepared seed bed in September. They observed no differences in average daily gain (ADG), total gain (TG) and gain per acre (G/A) in stocker cattle which grazed pastures of wheat, oats, rye or ryegrass or mixtures of these small grains. Steer performance was excellent with ADG of 2.87 lb, TG of 321 lb and G/A of 475 lb. However, the fall and winter during 1999-2000 was extremely mild. Therefore, the objective of this study was to continue evaluating small grains as forage for stocker cattle production.

Experimental Procedures

Twenty-four 2-acre pastures were seeded on September 10/11/2000 into a prepared seedbed as follows:

1. 120 lb/acre of Delta King 9207 soft red winter wheat
2. 120 lb/acre of Elbon rye
3. 120 lb/acre of Bob Oat
4. 40 lb/acre of Marshall ryegrass
5. 75 lb/acre of Delta King 9027 wheat plus 75 lb/acre Elbon rye
6. 90 lb/acre of Delta King 9027 wheat plus 20 lb acre Marshall ryegrass
7. 90 lb/acre of Elbon rye plus 20 lb/acre of Marshall ryegrass
8. 75 lb/acre of Delta King 9027 wheat plus 75 lb/acre Elbon rye plus 20 lb/acre of Marshall ryegrass

All pastures were fertilized at seeding according to soil analyses. Seventy-two preconditioned, commercial crossbred steers, averaging 400 lb BW, were placed on their respective pastures at a stocking density of 600 lb beef/acre (1.5 calves/acre) on October 23, 2000. Steers grazed continuously from October 23, 2000 until March 20, 2001 except when pastures were ice covered from December 21, 2000 until January 24, 2001. During this period of time, calves were fed bermudagrass hay plus 2 lb of corn per head per day. All calves were implanted with Ralgro® and were fed 2 lb of corn per head per day containing 70 mg/lb monensin. Calves were weighed using a 12-hour shrunk weight, initially and every 28 days thereafter. A commercial trace mineral vitamin salt mixture was fed free choice. The data were analyzed by ANOVA using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC).

Results and Discussion

There were no differences in ADG, TG or G/A of steers due to forage grazed from October 23, 2000 to December 21, 2000 when the ice storm occurred (Table 1). ADG ranged from 2.43 lb for ryegrass to 2.93 lb for wheat + rye + ryegrass. Total gain ranged from 141 lb to 170 lb for ryegrass and wheat, rye, ryegrass, respectively, and 211 lb to 255 lb of

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G/A for ryegrass and wheat + rye + ryegrass, respectively. Gains were limited from December 19, 2000 to January 24, 2001 when ice covered the forages and calves were fed hay, ranging from 0.54 lb to 1.11 ADG for wheat and rye + ryegrass, respectively. Daily high and low temperatures from December 21, 2000 to January 24, 2001 are given in Table 2. Pastures were ice covered from December 19, 2000 to approximately January 15, 2001 and were too muddy to graze until January 25, 2001. High temperature was 61°F on January 16, 2001, and low temperature was 6°F on December 21, 2000. Calves that grazed pastures containing rye had higher ($P < 0.05$) ADG, TG and G/A than those calves which grazed other small grain forage from January 25, 2001 to March 20, 2001. The combination of consecutive cold days and three consecutive weeks of ice cover caused severe winter kill of oat forage which eliminated grazing from January 25, 2001 to March 20, 2001 and considerable winter kill of wheat forage. Delayed growth of ryegrass also occurred. However, it appeared that rye was not greatly affected by the cold temperature. Average daily gain, TG and G/A for the duration of the study favored steers which grazed pastures containing rye ($P < 0.05$). Therefore, if grain is not important, it would reduce the risk of winter kill to plant rye or rye in combination with wheat or ryegrass.

Implications

Rye or rye in combination with wheat and/or ryegrass had little winter kill and produced good gains of stocker cattle during the severe winter. However, oat forage had nearly 100% winter kill, wheat had approximately 50% winter kill and spring growth of ryegrass was delayed considerably due to cold and ice cover. Rye appeared to have minimal winter kill. Therefore, if harvesting of grain is not important, rye should be planted or rye in combination with wheat and/or ryegrass for forage for stocker cattle.

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Table 1. Average daily gain, total gain and gain per acre of calves that grazed small grain pastures during 2000 – 2001.

Variety	10/23 – 12/20	12/21 – 1/24	1/25 – 3/20	Overall
		ADG, lb[1]		
Oats	2.82	0.59	--	--
Rye + ryegrass	2.74	1.11	1.41[a]	1.86[a]
Rye	2.54	0.77	1.90[a]	1.88[a]
Ryegrass	2.43	0.88	0.54[b]	1.36[b]
Wheat + rye	2.74	0.50	1.71[a]	1.83[a]
Wheat + ryegrass	2.72	0.65	0.58[b]	1.44[b]
Wheat + rye + ryegrass	2.93	0.51	1.55[a]	1.85[a]
Wheat	2.92	0.54	0.62[b]	1.51[b]
SE	0.20	0.20	0.22	0.09
		Total gain/steer, lb[1]		
Oats	163.33	20.56	--	--
Rye + ryegrass	159.06	38.89	77.51[a]	275.53[a]
Rye	147.33	26.78	104.44[a]	278.56[a]
Ryegrass	140.67	30.67	29.78[b]	201.11[b]
Wheat + rye	158.78	17.33	94.00[a]	270.11[a]
Wheat + ryegrass	157.89	22.67	32.11[b]	212.67[b]
Wheat + rye + ryegrass	170.11	17.89	85.33[a]	273.33[a]
Wheat	169.44	19.00	34.33[b]	222.78[b]
SE	11.62	6.96	11.88	13.68
		Gain/acre, lb[1]		
Oats	245.00	30.83	--	--
Rye + ryegrass	238.33	56.67	112.33[a]	407.33[a]
Rye	221.00	40.17	156.67[a]	417.83[a]
Ryegrass	211.00	46.00	44.67[b]	301.67[b]
Wheat + rye	238.17	26.00	141.00[a]	405.17[a]
Wheat + ryegrass	236.83	34.00	48.17[b]	319.00[b]
Wheat + rye + ryegrass	255.17	26.83	128.00[a]	410.00[a]
Wheat	254.17	28.50	51.50[b]	334.17[b]
SE	17.37	10.32	17.88	18.84

[a,b]Means in a column within trait with different letters differ ($P < 0.05$).

Table 2. Daily high and low temperatures for December 19, 2000 to January 24, 2001.

Date	High	Low
	-°F-	
December		
19		
31		
10		
20	31	10
21	33	24
22	31	6
23	37	12
24	35	19
25	33	17
26	29	21
27	33	28`
28	35	21
29	36	18
30	31	16
31	28	12
January		
1	27	16
2	32	7
3	27	10
4	50	24
5	55	35
6	61	27
7	53	34
8	49	33
9	43	24
10	49	19
11	42	32
12	42	33
13	43	36
14	54	40
15	53	29
16	50	29
17	43	31
18	39	33
19	39	31
20	39	19
21	44	17
22	55	23
23	52	29
24	51	33
Average	41.2	23.4

Evaluation of Cultivars of Soft Red Winter Wheat for Forage for Stocker Cattle Production

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Story in Brief

Forty-eight Angus x Gelbvieh steers, averaging 524 lb body weight, were randomly assigned on November 9, 2000 to 2-acre replicated pastures containing forage of either Coker 9704, Coker 9663, Coker 9543, Agri Pro Shiloh, Patton, Roane, Pioneer 2580 or Delta King 9027 cultivars of soft red winter wheat. The steers were allowed to continuously graze their respected wheat pasture from November 9, 2000 until March 20, 2001 except from December 23, 2000 until January 24, 2001 when the pastures were covered with ice and snow. During this period, the steers were fed bermudagrass hay and 2 lb corn per head per day. There were no differences in average daily gain (ADG), Total Gain (TG) or Gain/Acre (G/A) of steers due to cultivars from November 09, 2000 until December 23, 2000 or when they were fed hay (December 23, 2000 until January, 24, 2001). However, Patton, Pioneer 2580 and Delta King 9027 tended to produce higher ADG, TG and G/A from January 25, 2000 to March 20, 2001 and overall from November 9, 2000 to March 20, 2001 (P = 0.10 and 0.08, respectively), suggesting that these cultivars of soft red winter wheat are more cold and ice tolerant than others.

Introduction

Over one million acres of soft red winter wheat are planted each year in Arkansas for grain production. A large percentage of this wheat is planted on soil that is suitable for cattle production. The use of wheat forage for stocker cattle production in Arkansas is a unique and renewable economic resource (Daniels et al., unpublished data; Daniels et al., 2000b). Daniels et al. (2000a) reported that steers which grazed eight cultivars of soft red winter wheat forage beginning on November 17, 1999 for 161 days made excellent gains (ADG = 3.23 to 3.76 lb) and suggested a trend for cultivar differences (P = 0.09). Horn et al. (1994) reported differences in ADG of steers that grazed various cultivars of hard red winter wheat. Similar cultivar differences of hard red winter wheat have been reported by Gribble and Krenzer (1994). It was the objective of this study to evaluate cultivars of soft red winter wheat developed for grain production in Arkansas as forage for stocker cattle.

Experimental Procedures

Eight cultivars of soft red winter wheat were seeded at a rate of 120 lb/acre on September 13 and 14, 2000 in prepared seedbeds. The wheat was seeded in 2-acre pastures, and each cultivar was replicated. Cultivars planted were the most common ones planted for grain production in Arkansas. They were Coker 9704, Coker 9663, Coker 9543, Agri Pro Shiloh, Patton, Roane, Pioneer 2580 and Delta King 9027. All pastures were fertilized according to soil analyses. Forty-eight Angus x Gelbvieh steers, averaging 524 lb body weight, were assigned randomly to pastures at a stocking density of 1.5 steers per acre (786 lb/beef/acre) on November 9, 2000, and they grazed until March 20, 2001. Steers were fed bermudagrass hay from December 23, 2000 until January 24, 2000 due to the pastures being covered with ice and snow. All steers were born and raised on the Livestock and Forestry Branch Station and were weaned and preconditioned 30 days prior to grazing. Steers were implanted with Ralgro® and were fed 2 lb of corn containing 70 mg rumensin/lb for each animal per day. A commercial trace mineralized salt and vitamin mixture was fed free choice. Steers were weighed using a 12-hour shrunk weight, initially and at 28-day intervals. The data were analyzed using GLM procedures of SAS (SAS Inst., Inc. Cary, NC).

Results and Discussion

The average daily gain (ADG), total gain (TG) and gain per acre (G/A) of steers which grazed forage of the various cultivars from November 9 to March 20 are given by periods in Table 1. There were no difference in ADG, TG or G/A due to cultivars from November 9, 2000 until December 22, 2000 or from December 23, 2000 until January 24, 2001 when pasture were covered with ice and bermudagrass hay was fed. The present data differs from that reported by Horn et al. (1994) and Gribble and Krenzer (1994), who observed differ-

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ences in ADG and TG of steers that grazed forage of different cultivars of hard red winter wheat but agrees with Daniels et al. (2000a) who observed a trend for cultivar differences (P = 0.09) for ADG or TG of steers grazing forage of various cultivars of soft red winter wheat. Even though differences were small, Patton, Pioneer 2580 and Delta King 9025 tended to produce higher ADG, TG and G/A than other cultivars tested from January 24, 2001 until March 20, 2000 and for the overall duration of the study from November 9, 2000 until March 20, 2001 (P = 0.10 and 0.08, respectively). Average daily gains were 2.00 and 1.64 lb/day for Patton, 1.59 and 1.53 lb/d for Delta King 9027; 1.55 and 1.89 lb/d for Pioneer 2580; 1.72 and 1.48 lb/d for Agri Pro Shiloh; 1.43 and 1.29 lb/d for Coker 9543; 0.81 and 1.27 lb/d for Roane; 0.89 and 1.19 lb/d for Coker 9704 and 0.53 and 0.97 lb/d for Coker 9663, for periods from January 25, 2001 to March 20, 2001 and overall duration of the study from (November 9, 2000 to March 20, 2001), respectively. These data suggest that Patton, Pioneer 2580 and Delta King 9029 recovery from the ice was much faster than the other cultivars tested and thus they may have more tolerance to ice cover.

Implications

These data show that soft red winter wheat cultivars, Delta King 9027, Pioneer 2580, Patton, Agri Pro Shiloh, Roane, Coker 9663, Coker 9543 and Coker 9074 provide excellent forage for stocker cattle. It appears that some cultivars such as Patton, Pioneer 2580 and Delta King 9027 may be more winter hardy and recover quicker after being ice and snow covered for 4 weeks.

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Table 1. Average Daily Gain (ADG), Total Gain (TG) and Gain per Acre (G/A) of stocker cattle which grazed various cultivars of soft red winter wheat forage between November 9, 2000 until March 20, 2001.

Variety	Period 1 11/9 to 12/22	Period 2 12/23 to 1/24	Period 3 1/25 to 3/20	Overall 11/9 to 3/20
		ADG, lb[1]		
Coker 9543	1.83	0.36	1.43	1.29
Coker 9663	1.79	0.63	0.53	0.97
Coker 9704	2.13	0.45	0.89	1.19
Delta King 9027	2.04	0.76	1.59	1.53
Patton	2.03	0.54	2.00	1.64
Pioneer 2580	2.54	0.42	1.55	1.59
Roane	2.35	0.65	0.81	1.27
Agri Pro Shiloh	1.78	0.67	1.72	1.48
SE	0.20	0.17	0.32	0.13
		Total gain/steer, lb[1]		
Coker	78.50	11.83	78.67	169.00
Coker 9663	77.17	20.67	29.33	127.17
Coker 9704	91.67	15.00	49.00	155.67
Delta King 9027	87.67	25.17	87.33	100.17
Patton	87.17	17.67	110.00	199.62
Pioneer 2580	109.17	13.83	85.33	208.33
Roane	101.00	21.50	44.33	166.83
Agri Pro Shiloh	76.67	22.17	94.50	193.33
SE	8.58	5.45	17.34	17.35
		Gain/Acre, lb[1]		
Coker 9543	117.75	17.75	118.00	253.50
Coker 9663	115.75	31.00	44.00	190.75
Coker 9704	137.50	22.50	75.50	233.50
Delta King 9027	131.50	37.75	131.00	300.25
Patton	130.75	26.50	165.00	322.25
Pioneer 2580	163.75	20.75	128.00	312.50
Roane	151.50	32.25	66.50	250.25
Agri Pro Shiloh	115.00	33.25	141.75	290.00
SE	12.87	8.17	26.00	26.03

[1]No significant differences among varieties at any time (P > 0.10) although gains for period 3 and overall approached significance (P = 0.10 and P = 0.08, respectively).

The Effects of Nitrogen Fertilization and Time of Year On The Quality and Quantity of Soft Red Winter Wheat Forage

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Story in Brief

The quality and quantity of soft red winter wheat forage, fertilized with different levels of nitrogen were determined at different times of the year in pasture clippings and masticate samples. The quality of the wheat forage was determined by measuring organic matter (OM), crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), and in-vitro organic matter disappearance (IVOMD). The quantity of forage was estimated by clipping all vegetative (alive and dead) forage within four -m^2 frames selected from random locations throughout each site. The percent dry matter decreased ($P < 0.01$) with the addition of nitrogen fertilization but there were no differences in dry matter yield due to nitrogen fertilization. There were no differences in the quality indicators (OM, CP, ADF, NDF or IVOMD) due to nitrogen fertilization except CP increased ($P < 0.01$) as nitrogen fertilization increased. All quality indicators were lower ($P < 0.01$) in the masticate samples than in the pasture clippings. Percent dry matter changed ($P < 0.01$) at different times of the year. Forage dry matter yield increased ($P < 0.01$) during the year. There was a highly significant effect ($P < 0.01$) on forage quality indicators due to time of the year in both pasture clippings and masticate samples. Pasture clippings or masticate samples were not affected by time of year. Forage quantity increased but forage quality decreased from December through March.

Introduction

Soft red winter wheat (*Triticum aestivum* L.) is an important crop in Arkansas with over a million acres planted each year. Daniels et al. (2000b) reported that stocker steers make excellent body weight gains when grazing soft red winter wheat forage from October through April. They also observed that if cattle are removed from the wheat forage by March 1, grazing of the forage does not decrease wheat grain production. Nitrogen fertilization has been shown to increase forage yields (Collins et al., 1990) while having no effect on concentrations of neutral detergent fiber (NDF) or acid detergent fiber (ADF). Collins and Balasko (1981) reported an increase in the digestibility of forage with increased nitrogen fertilization. However, Saibro et al. (1978) and Daniels et al. (2000a) reported that nitrogen fertilization had no effect on digestibility of forage.

Therefore, the objective of this study was to evaluate the quality and quantity of soft red winter wheat forage fertilized with different levels of nitrogen fertilization in pasture clippings and masticate samples taken from December through March.

Experimental Procedures

Delta King 9027 cultivar of soft red winter wheat was seeded in a 110 x 130 feet plot at the rate of 120 lb per acre into a prepared seedbed having no preliminary addition of fertilizer on October 1, 1999. The plot was divided into nine 10 feet by 100 feet subplots having 3 feet alleys separating each subplot. Subplots received either 0 lb N (control), 34 lb N or 68 lb N per acre on November 11, 1999 in the form of ammonium nitrate. The quantity of forage (alive and dead) was estimated by clipping forage in four -m^2 frames selected at random in each sub-plot on December 8, 1999, January 5, 2000, February 4, 2000, and March 1 and 28, 2000. Forage quality, using organic matter (OM, crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF) and in-vitro organic matter disappearance as indicators of quality, was determined on clipped pasture and rumen masticate samples taken on December 8, 1999, January 5, 2000, February 4, 2000 and March 1 and 28, 2000. Masticate samples were obtained using three ruminally fistulated steers fasted for 24 hours prior to sampling. Rumen contents were evacuated, and steers were allowed to graze the wheat forage for approximately 30 to 45 minutes before masticate samples were removed. Statistical analysis were conducted using PROC MIXED of SAS (SAS Inst. Inc, Cary, NC) for a split-plot design.

Results and Discussion

The effects of nitrogen fertilization on the percent dry matter and the pounds of dry matter per acre of soft red winter wheat forage are given in Table 1. The percent of dry matter of wheat forage decreased ($P < 0.01$) with an increase in

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nitrogen fertilization but there was no difference in the pounds of dry matter per acre due to nitrogen fertilization.

The effects of nitrogen fertilization on the quality of wheat forage in pasture and masticate samples are given in Table 2. In pasture samples, CP increased ($P < 0.01$) as nitrogen fertilization increased. However, nitrogen fertilization did not affect OM, IVOMD, NDF or ADF in pasture samples nor did it affect OM, CP, IVOMD, NDF or ADF in masticate samples.

The effects of time of year on the percent dry matter and pounds of dry matter per acre of wheat forage are given in Table 3. Percent dry matter and pounds of dry matter per acre increased ($P < 0.01$) from December 8, 1999 through March 28, 2000. This was due to the wheat becoming more mature. The effects of time of the year on the quality of wheat forage in pasture clippings and masticate samples are given in Table 4. Organic matter, NDF and ADF increased ($P < 0.01$) from December 8, 1999 through March 28, 2000, whereas CP and IVOMD decreased during the time period in pasture clippings. Organic matter in masticate samples of wheat forage increased ($P < 0.01$) from December 8, 1999 through March 28, 2000 but CP decreased ($P < 0.01$) during this time period. There were no differences due to time of year of masticate forage sample for IVOMD, ADF or NDF.

Implications

Nitrogen fertilization of soft red winter wheat forage increased CP and decreased DM concentration but had no effect on IVOMD, ADF or NDF. Time of year and associated maturity effects cause fiber concentrations of wheat forage to increase while CP and IVOMD decreased. These data provide a guide of the plant maturity effect on quality of the wheat forage.

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Table 1. The effects of nitrogen fertilization on percent dry matter and pounds of dry matter per acre of wheat forage.

	Nitrogen Level			
Variable	0	34 lb/acre	68 lb/acre	P–value
Percent dry matter	22.22	21.09	20.82	<0.01
Dry matter yield, lb/acre	3056	3445	3298	NS

Table 2. The effects of nitrogen fertilization on the quality of wheat forage in pasture and masticate samples.

		Nitrogen Level			
Sample	Variable	0	34 lb/acre	68 lb/acre	P-Value
Pasture[a]	OM	90.63	90.21	90.62	NS
	CP	19.90	22.02	23.15	<0.01
	IVOMD	77.86	77.03	78.83	NS
	NDF	49.88	50.82	49.46	NS
	ADF	24.00	24.50	23.53	NS
Masticate	OM	81.85	79.82	79.59	NS
	CP	23.11	25.02	23.72	NS
	IVOMD	57.98	56.15	58.64	NS
	NDF	62.21	66.25	64.40	NS
	ADF	33.79	33.00	36.61	NS

[a] Means between sampling techniques for each variable differ (P < 0.01).
NS Means within rows are not different (P > 0.05).

Table 3. The effects of time of year on percent dry matter and pounds of dry matter per acre of wheat forage.

	Time of year					
Variable	Dec 8	Jan 5	Feb 4	Mar 1	Mar 28	P-value
Percent dry matter	17.29	19.29	25.76	24.12	20.45	<0.01
Dry matter yield lb/acre	2215	2787	2988	3682	4690	<0.01

Table 4. The effects of time of year on the quality of wheat forage in pasture and masticate samples.

		Time of year					
Sample	Variable	Dec 8	Jan 5	Feb 4	Mar 1	Mar 28	P-value
				%			
Pasture	OM	89.00	89.49	90.84	90.65	92.46	<0.01
	CP	30.57	23.90	20.55	19.59	13.84	<0.01
	IVOMD	86.02	83.01	79.21	79.86	61.43	<0.01
	NDF	44.37	46.75	45.32	52.61	61.21	<0.01
	ADF	21.77	21.74	20.85	24.75	30.94	<0.01
Masticate	OM	76.31	77.60	83.32	75.50	87.38	<0.01
	CP	30.63	24.98	20.27	24.25	19.63	<0.01
	IVOMD	53.97	53.64	63.21	54.64	62.49	NS
	NDF	54.75	73.27	60.70	66.84	65.87	NS
	ADF	35.16	40.59	30.23	38.87	34.16	NS

Economics of Production Systems Involving Stocker Cattle and Soft Red Winter Wheat from 1996 through 1999[1]

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Story in Brief

Economics of two production systems were evaluated from 1996 through 1999. These included: (1) stocker cattle, which grazed soft red winter wheat forage from late October until late February, followed by harvesting wheat grain in June, or (2) stocker cattle that continuously grazed soft red winter wheat forage from late October until the end of April. Two cultivars of wheat (Hickory and Jaypee) fertilized at seedling emergence with 0 or 50 lb N/acre and two stocking densities (500 and 750 lb beef/acre) were used. Wheat was seeded on September 10 or 11 for 1996 and 1997 and September 18 or19, 1998. Average production costs for wheat cultivars were $151.17 and $147.93/acre for Hickory and Jaypee, respectively. Non-forage costs for cattle from October until March were $54.63 and $76.37/acre for steers stocked at 500 or 750 lb/acre respectively. For steers grazing wheat forage from October through April, non-forage costs were $72.98 and $101.90/acre for steers stocked at 500 and 750 lb/acre. Based on a selling price of $75.00/cwt for cattle and $3.50/bu for wheat grain, income over expenses ranged from $29.06 to $39.60/acre for cattle grazing from October through April, to $129.57 to $138.70 for cattle grazing from October through February and then harvesting wheat grain in June. When all production costs were charged to grain, income over expenses ranged from $6.33 and $9.59/acre. Grazing stocker cattle on wheat forage provided an economic advantage over harvesting for wheat grain only.

Introduction

Arkansas leads the nation in the production of soft red winter wheat, producing over 45 million bushels of grain annually (Klugh and Abbe, 1999) from about one million acres. Wheat farmers need a secondary source of net income from their land. One system that has been tried is to double crop wheat with soybeans. The viability of this system is limited because of a lack of soil moisture following the harvesting of wheat in mid to late June and because of possible frost damage to soybeans in the fall before the beans mature.

The production of stocker cattle from grazing hard red winter wheat forage in the Southern Plains is a unique and economical renewable resource. Income is derived from both grain and the increased value that is added as weight gain to growing cattle. This grain/livestock system has been a practice for many years in the Southern Great Plains (Horn, 1994; Horn et. al., 1994). Grazing soft red winter wheat forage in Arkansas may offer an alternative source of income to farmers.

Because of the even distribution and amount of rainfall and the warmer or milder winter temperature, soil and climate conditions favor the production of soft red winter wheat forage in the Southern United States over hard red winter wheat produced in the Southern Plains. Most of the land planted to soft red winter wheat in Arkansas will support grazing stocker cattle even though it may receive 14 to 15 in. of rainfall from October through April. Over 25 % of the nation's beef cows are located in the Southern United States (Taylor, 1994). Approximately, one million beef cows that produce nearly 875,000 calves annually are located in Arkansas (Klugh, 1999). Many of these calves are sold at weaning during the fall to cattlemen in the Southern plains and western states as stocker cattle and graze wheat forage before they are placed in feedlots. Arkansas has an ample supply of stocker cattle available to develop a sizable stocker cattle industry.

Therefore, it was the objective of a three-year study to evaluate the economics of production systems involving stocker cattle, and soft red winter wheat. The systems were: 1) grazing soft red winter wheat with stocker cattle from November until approximately March 1, followed by harvesting wheat grain in June, and 2) grazing soft red winter wheat forage with stocker cattle from November through April.

Materials and Methods

This research was conducted from 1996 through 1999 to evaluate the economics of production systems involving stocker cattle and soft red winter wheat at the Livestock and Forestry Branch Research Station, Batesville.

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Twenty-four 2 acre pastures, having a Peridge silt loam soil, were treated with Roundup® three times with 1/3 gallon/acre/treatment to kill existing vegetation. Soil test analyses were conducted for each pasture each year and the pastures were fertilized each year for wheat grain production according to the soil test. All fertilizer was applied by broadcasting with ground equipment. Each pasture was seeded with 120 lb/acre of either Hickory or Jaypee cultivar of soft red winter wheat on September 10 or 11 in 1996 and 1997 and September 18 or 19 in 1998 in a clean tilled prepared seedbed. After seeding the pastures were rolled with a cultipacker to preserve soil moisture. Half of the pastures of each cultivar received an additional 50 lb N/acre applied with ground equipment at seedling emergence.

A total of 360 crossbred commercial steers, averaging 500 lb body weight, were used as experimental animals for the three-year study. Sixty steers were randomly assigned to the pastures in October of each year, and 60 steers were randomly assigned on March 1 of each year at a stocking density of either 500 or 750 lb beef/acre. Treatments were replicated three times.

Two plots (12x20 feet) were fenced off in each pasture before grazing for an ungrazed control; two plots of the same size were fenced off at first hollow stems; and two when first jointing in ungrazed wheat occurred. Grain was harvested from each plot to estimate yield.

Records were kept relative to labor, tractor use, fencing, chemicals, fertilizer, seed, feed, etc. for economic analyses. Selling price of cattle was $75/cwt and selling price of wheat grain ranged from $2.50 to $3.50/bu. A scenario is also used for $75/cwt to $85 cwt for purchase cost of cattle.

Results and Discussion

Average production cost/acre for soft red wheat cultivars, Hickory and Jaypee, are presented in Table 1. These costs included soil preparation, seeding, fertilization, seed cost, chemicals, etc., harvesting and hauling. Total cost of production of Hickory and Jaypee were $151.17 and $147.93/acre, respectively. The difference was the cost of seed of the Hickory cultivar. These production costs/acre of wheat are similar to the cost of production/acre of soft red winter wheat grown for grain by the average wheat farmer in Arkansas.

The production costs/acre, excluding forage costs, for production of stocker cattle that grazed soft red winter wheat forage from October through February are shown in Table 2. Costs of labor and maintenance for the production of stocker cattle were $39.63 and $53.87 for stocking densities of 500 and 750 lb/acre, respectively. If the transportation costs of shipping cattle to the feedlot are included, costs of $15.00 and $22.50/acre for stocking densities of 500 and 750 lb/acre, should be added in the total cost of $54.63 and $76.37/acre for stocking densities of 500 and 750 lb beef/acre, respectively. Forage costs were $93.34 and $90.10 for Hickory and Jaypee cultivars, respectively (Table 3).

Economic analysis of stocker cattle production when soft red winter wheat forage was grazed from October through February during 1996-1999 is shown in Table 3. Income over the cost of forage and non-forage specified expenses/acre for stocker cattle ranged from $79.90 to $114.17 depending on cultivar of wheat and the stocking density of cattle. Average income over expenses/acre were $98.60 and $96.97 for Hickory and Jaypee, respectively. Average income above expenses for cattle having a stocking density of 500 and 750 lb/acre were $81.47 and $114.10, respectively. Income over expenses per head averaged $70.52 and $68.90 for Hickory and Jaypee, respectively whereas it was $70.60 and $68.82 for stocking densities of 500 and 750/acre. Cost per lb of gain averaged $0.465 for both for Hickory and Jaypee and $0.48 and $0.45 for stocking densities of 500 and 750 lb beef/acre.

Returns over specified expenses of wheat grain production are shown in Table 4. Since there were no significant differences in wheat grain yield due to time the cattle were removed from the wheat and wheat yields were essentially state average (45 bu/acre), 45 bushel/acre of wheat grain with a selling price of $3.50/acre were used in this economic scenario. Income over expenses/acre when all expenses were charged to grain was $6.33 for Hickory and $9.57 for Jaypee. If one received $2.50/bu for wheat grain, income over expenses would have been $-38.67 and $-35.43 for Hickory and Jaypee, respectively. If average wheat grain yields were increased to 55 bu/acre, income over expenses would have been $41.33 and $44.57 for Hickory and Jaypee, respectively, when selling price was $3.50/bu and $61.03 and $76.07 when the selling price of wheat was $4.00/bu. Therefore, there is a good potential of making money from stocker cattle when wheat grown for grain is grazed.

An economic analysis of stocker cattle wheat grain production system when steers grazed wheat forage from October through February, 1996-1999 and wheat grain was harvested in June is shown in Table 5. Selling price of cattle was $75/cwt and $3.50 per bu for wheat grain. Income over expenses/acre ranged from $179.57 for Jaypee stocked at 500 lb beef/acre to $214.70 for Jaypee stocked at 750 lb beef/acre. Average income above expenses for Hickory was $198.27/acre and for Jaypee was $197.14/acre. Income above expenses was $181.13 and $214.27/acre for stocking densities of 500 and 750 lb beef/acre. Thus, excellent returns were made when stocker cattle grazed soft red winter wheat forage from October through February and wheat was then harvested in June. Average income above expenses was $198.93/acre.

An economic analysis scenario looking at net returns from cattle grazing soft red winter wheat forage from October through February, 1996-1999 is shown in Table 6. Purchase cost of steers was based on either $85, $80 or $75/cwt and selling price of steers was $75/cwt and selling price of wheat grain was $3.50/bu. When purchase price of steers was $85/cwt, net return/acre ranged from $129.57 for Jaypee stocked at 500 lb beef/acre to $138.70 for Jaypee stocked at 750 lb beef/acre. Average net income/acre was $134.20/acre. When purchase cost of steers was $80/cwt, average net income/acre was $165.00, whereas when the purchase cost of

steers was $75/cwt, net income/acre averaged $196.70/acre. Thus, a wheat farmer having 200 acres of wheat has the potential to net from $26,840 to $39,340/year. Increase in selling price of cattle or wheat would change this scenario. Therefore, these data suggest that the potential to increase net income from wheat greatly increases if it is planted in early September and grazed with stocker cattle from October through February.

An economic analysis of stocker cattle that grazed soft red winter wheat from March through April 1997-99 with a selling price of steers of $75/cwt is shown in Table 7. Income over expenses/acre ranged from $59.66 for Hickory stocked at 500 lb beef/acre to $84.10 for Jaypee stocked at 750 lb beef/acre. Average return above expenses was $71.51 and $72.07/acre for Hickory and Jaypee, respectively and $59.85 and $83.75/acre for stocker densities of 500 and 750 lb beef/acre.

Economics of stocker cattle which grazed soft red winter wheat from October through April, 1996-99 based on a selling price of steer at $75/cwt is shown in Table 8. Income above specified expenses/acre ranged from $139.82/acre for Jaypee stocked at 500 lb beef/acre to $198.38/acre for Jaypee stocked at 750 lb beef/acre. Average income over expenses/acre was $171.01 and $169.10/acre for Hickory and Jaypee, respectively and $142.15 and $197.90 when stocked at 500 or 750 lb beef/acre respectively.

Given in Table 9 is a scenario of purchasing cattle at $85, $80 or $75/cwt, grazing soft red winter wheat forage form November through April and selling steers at $75/cwt. This scenario shows that net return is greatly influence by the purchase and selling price of cattle. Average net return/acre when cattle were purchased at $85, $80 and $75/cwt were $33.80, $96.07and $158.87/acre respectively.

Economics of harvesting soft red winter wheat forage with two sets of stocker cattle as compared to harvesting wheat forage with cattle from October through February and then harvesting wheat grain in June is given in Table 10. Harvesting wheat forage with cattle only was not as profitable as harvesting wheat forage with cattle plus harvesting wheat grain. Average net income when the purchase price was $85/cwt and the selling price was $75 cwt was $34.47/acre when wheat forage was harvested with cattle and $134.20/acre when wheat forage was harvested with cattle plus harvesting a wheat grain crop having a selling price of $3.50/bu. Price of cattle and or price of yield of wheat grain will change income over specified costs.

Implications

Stocker cattle grazing soft red winter wheat forage from October through February can enhance income over specified expenses. This provides an alternative for the wheat farmer to net more income from his wheat land.

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Table 1. Three year average cost of production of Hickory and Jaypee cultivars of soft red winter wheat for grain.

Labor and operating cost	Hickory	Jaypee
	----------$/acre ----------	
Disking	14.29	14.29
Fertilizer spreading	5.18	5.18
Grain drilling	8.11	8.11
Spraying	2.80	2.80
Rolling	4.26	4.26
Round-up	5.40	5.40
Wheat seed	19.20	15.96
Lime	11.60	11.60
Fertilizer	22.50	22.50
Subtotal	93.34	90.10
Spring urea	27.17	27.17
Fertilizer spreading	2.59	2.59
Custom combining	21.32	21.32
Custom hauling	6.75	6.75
Subtotal	57.83	57.83
Total	151.17	147.93

Table 2. Three year average cost for feed and maintenance of stocker cattle which grazed wheat forage having a stocking density of 500 and 750 lb beef per acre during October through February, 1996-1999.

Stocking Density	500 lb/acre	750 lb/acre
Expenses:[1]	----------$/acre----------	
Electric fence	5.00	5.00
Corn	15.75	23.66
Hay	4.48	6.72
Labor	3.20	3.20
Water	3.02	3.02
Minerals and Monensin	4.90	7.35
Vet and medical	3.28	4.92
Sub-Total	39.63	53.87
Hauling to feedlot	15.00	22.50
Total	54.631	76.371

[1] These costs do not include preconditioning or insurance.

Table 3. Economic analysis of stocker cattle production while grazing soft red winter wheat forage during October through February, 1996-1999 based on $75/cwt selling price of cattle.

Stocking density	Hickory		Jaypee	
	500 lb/acre	750 lb/acre	500 lb/acre	750 lb/acre
Economic parameters:				
Total gain, lb/acre	308.00	378.50	299.50	374.00
Gross income, $/acre	231.00	283.88	224.63	280.50
Total non-forage cost, $/acre	54.63	76.37	54.63	76.37
Return, $/acre	176.37	207.51	170.00	204.13
Forage cost, $/acre	93.34	93.34	90.10	90.10
Net income over specified expenses, $/acre	83.03	114.17	79.90	114.03
Net income over specified expenses, $/head	72.16	68.87	69.03	68.77
Cost per lb gain, $	0.48	0.45	0.48	0.45

Table 4. Economic analysis of soft red winter wheat which was grazed by stocker cattle from October through February, 1996-1999 and harvested for grain based on $3.50/bu, $3.00/bu, and $2.50/bu selling price of wheat grain and assuming all production costs were for grain.

Stocking density	Hickory		Jaypee	
	500 lb/acre	750 lb/acre	500 lb/acre	750 lb/acre
Economic parameters:				
Wheat grain yield, bu/acre[2]	45	45	45	45
Cost of production, $/acre	151.17	151.17	147.93	147.93
Gross income, $/acre ($3.50/bu)	157.50	157.50	157.50	157.50
Gross income, $/acre ($3.00/bu)	135.00	135.00	135.00	135.00
Gross income, $/acre ($2.50/bu)	112.50	112.50	112.50	112.50
Net income over specified expenses[1] ($3.50/bu)	6.33	6.33	9.57	9.57
Net income over specified expenses ($3.00/bu)	-16.17	-16.17	-12.93	-12.93
Net income over specified expenses ($2.50/bu)	-38.67	-38.67	-35.43	-35.43

[1]Specified cost did not include land use cost.

[2]Since yields were near state average in the study, state average (45 bu/acre) yields were used.

Table 5. Economic analysis of a stocker cattle – wheat grain production system where steers grazed wheat forage from November through February, 1996-1999 followed by harvesting wheat grain. Selling price of cattle was $75/cwt and wheat $3.50/bu.

Stocking density	Hickory 500 lb/acre	Hickory 750 lb/acre	Jaypee 500 lb/acre	Jaypee 750 lb/acre
Economic parameters:				
Income from cattle, $/acre	231.00	283.88	224.63	280.50
Income from wheat, $/acre				
$3.50/bu	157.50	157.50	157.50	157.50
$3.00/bu	135.00	135.00	135.00	135.00
$2.50/bu	112.50	112.50	112.50	112.50
Expenses: $/acre				
Non-forage	54.63	76.37	54.63	75.37
Cost of wheat production[1]	151.17	151.17	151.17	151.17
Return over specified expenses $/acre				
$3.50/bu	182.70	213.84	179.57	214.70
$3.00/bu	160.20	191.34	157.07	192.20
$2.50/bu	137.70	168.84	134.57	169.70

[1]Wheat production expenses do not include land use cost.

Table 6. Net return when cattle grazed soft red winter wheat forage from October through February, 1996-1999 with a purchase cost of steer being either $85, $80 or $75/ cwt as selling price of wheat grain being $3.50/bu.

Stocking density	Hickory 500 lb/acre	Hickory 750 lb/acre	Jaypee 500 lb/acre	Jaypee 750 lb/acre
Economic parameters:				
Gross income, $/acre				
Steers	606.00	846.38	599.63	843.00
Wheat grain	157.50	157.50	157.50	157.50
Total income	**763.50**	**1003.88**	**757.13**	**1000.50**
Expenses, $/acre				
Purchase of steers, $85/cwt	425.00	637.50	425.00	637.50
Purchase cost of steer $80/cwt	400.00	600.00	400.00	600.00
Purchase cost of steer, $75/cwt	375.00	562.50	375.00	562.50
Non-forage cost, $/acre	54.63	76.37	54.63	75.37
Grain & forage costs, $/acre[1]	151.17	151.17	147.93	147.93
Total cost feed, forage and grain $/acre	**205.80**	**227.54**	**202.56**	**224.30**
Net income over specified cost, $/acre				
Purchase cost of steers, $85/cwt	132.76	135.84	129.57	138.70
Purchase cost of steers, $80/cwt	157.70	173.34	154.57	176.20
Purchase cost of steers, $75/cwt	182.70	210.84	179.77	213.70

[1]Grain and forage costs do not include land use cost.

Table 7. Economics of stocker cattle that grazed soft red winter wheat forage from March through April, 1997-1999 based on a selling price of cattle of $75/cwt.

Stocking density	Hickory 500 lb/acre	Hickory 750 lb/acre	Jaypee 500 lb/acre	Jaypee 750 lb/acre
Economic parameters:				
Gain lb/acre	118.50	160.00	119.00	161.00
Income, $/acre	88.88	120.00	89.25	120.75
Expenses: $/acre[1]				
Urea	10.87	10.87	10.87	10.87
Corn	8.40	12.60	8.40	12.60
Fence	2.50	2.50	2.50	2.50
Labor	1.50	1.50	1.50	1.50
Water	1.50	2.50	1.50	2.50
Mineral	2.45	3.68	2.45	3.68
Vet and medical	2.00	3.00	2.00	3.00
Sub-Total	29.22	36.68	29.22	36.65
Income over specified expenses, $/acre	59.66	83.35	60.03	84.10
Income over specified expenses $/head	59.66	55.57	60.03	56.07

[1]Do not include preconditioning, costs or insurance.

Table 8. Economic analysis of a stocker cattle production system using soft red winter wheat forage from October through April based on $75/cwt selling price during 1996-1999.

Stocking density	Hickory 500 lb/acre	Hickory 750 lb/acre	Jaypee 500 lb/acre	Jaypee 750 lb/acre
Economic parameters:				
Income:				
Returns from cattle (fall) $/acre	232.80	284.24	224.52	280.50
Returns from cattle (Spring) $/acre	88.88	120.00	89.25	120.75
Total income	**321.68**	**404.24**	**313.77**	**401.25**
Expenses[1]:				
Non-forage cost (Fall) $/acre	54.63	76.37	54.63	76.37
Non-forage cost (Spring) $/acre	18.35	25.53	18.35	25.53
Forage cost (Fall) $/acre	93.34	93.34	90.10	90.10
Forage cost (Spring) $/acre	10.87	10.87	10.87	10.87
Total expenses	**177.19**	**206.71**	**173.95**	**202.87**
Net income over specified expenses $/acre	144.49	197.53	139.82	198.38
Net income over specified expenses $/h	144.49	131.69	139.82	132.25

[1]Do not include preconditioning, insurance or land use.

Table 9. Income over specified expenses per acre of stocker cattle which grazed soft red winter wheat forage from October through April.

Stocking density	Hickory		Jaypee	
	500 lb/acre	750 lb/acre	500 lb/acre	750 lb/acre
Economic parameters:				
Total income, $/acre	1069.88	1528.88	1063.88	1525.25
Expenses[1]:				
Forage costs, $/acre	115.08	115.08	111.84	111.84
Non-forage costs, $/acre	72.98	101.90	72.98	101.90
Animal purchase cost, $75/cwt	750.00	1125.00	750.00	1125.00
Animal purchase cost, $80/cwt	800.00	1200.00	800.00	1200.00
Animal purchase cost, $85/cwt	850.00	1275.00	850.00	1275.00
Income over specified expenses $/acre:				
Purchase cost $75/cwt	131.82	186.90	129.06	186.51
Purchase cost $80/cwt	81.82	111.90	79.06	111.51
Purchase cost $85/cwt	31.82	36.90	29.06	37.41

[1]Do not include preconditioning, insurance or land use.

Table 10. Economic scenario of harvesting soft red winter wheat forage from October through April with stocker cattle, harvesting winter wheat from October through February with stocker cattle and then harvesting wheat grain, or only harvesting wheat grain.

Stocking density	Hickory		Jaypee	
	500 lb/acre	750 lb/acre	500 lb/acre	750 lb/acre
Economic parameters[1]:				
Net income over specified expenses, $/acre				
Continuous grazing				
Purchase $85 cwt – selling $75 cwt	31.82	39.60	29.06	37.41
Purchase $80 cwt – selling $75 cwt	81.82	111.90	79.06	111.51
Purchase $75 cwt – selling $75 cwt	131.82	186.90	129.06	186.51
Grazing & wheat grain ($75 cwt selling)				
Wheat $3.50/bu	182.70	231.84	179.57	214.70
Wheat $3.00/bu	160.20	191.34	157.07	192.20
Wheat $2.50/bu	137.70	168.84	134.57	169.70
Wheat grain				
$3.50/bu	6.33	6.33	9.57	9.57
$3.00/bu	-16.17	-16.17	-12.93	-12.93
$2.50/bu	-38.67	-38.67	-35.45	-35.43

[1]Do not include land use cost, preconditioning or insurance.

Effects of Stockpiling Initiation Date and Nitrogen Fertilization Rate on the Yield of Stockpiled Bermudagrass Harvested Throughout the Fall and Winter

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Story in Brief

Limited information is available that describes the DM yield potential of stockpiled bermudagrass [*Cynodon dactylon* (L.) Pers.] during late fall and early winter. Well-established stands of 'Common' and 'Tifton 44' bermudagrass at Fayetteville and Batesville, AR, respectively, were chosen to evaluate the effects of stockpiling initiation date and nitrogen (N) fertilization rate on the dry matter (DM) yield potential of stockpiled bermudagrass forages throughout late fall and early winter. At Fayetteville, DM yields of stockpiled bermudagrass initiated on August 8 decreased ($P < 0.05$) between November 8 and November 29, but did not change ($P > 0.05$) between October 18 and November 8, or between November 29 and January 8. Yields for forage that began the stockpiling period later (September 6) were highest ($P < 0.05$) on November 8. At Batesville, DM yields of stockpiled bermudagrass initiated on August 10 and September 6 followed trends similar to those observed at Fayetteville. High temperatures and low moisture availability during the early fall, in addition to an early killing frost and unusual weather patterns during the sampling period probably limited the yield potential of stockpiled bermudagrass throughout the late fall and early winter.

Introduction

Beef cattle producers in Arkansas and the southeastern US face many economic obstacles, one of which is feeding mother cows throughout the winter. Many of these producers rely on bermudagrass [*Cynodon dactylon* (L.) Pers.] as a primary warm-season forage source during the growing season. Bermudagrass has the potential to produce high forage yields in response to fertilization with N (Doss et al., 1966; Hill et al., 1993). This growth has traditionally been used to support grazing livestock, but large quantities are also harvested as hay which is subsequently fed during the late fall and early winter after bermudagrass enters dormancy. However, costs associated with hay production, and adverse weather conditions during spring and summer make extended grazing systems attractive to producers. Recently, winter-feeding systems that involve stockpiling standing bermudagrass at the end of the growing season have received increased interest. Stockpiled bermudagrass can provide winter pasture for grazing livestock, thereby reducing the need for supplemental hay and its associated costs (D'Souza et al., 1990; Hitz and Russell, 1998). However, most agronomic research studies have focused on measuring DM yields of bermudagrass during the growing season (Burton et al., 1963; Jolliff et al., 1979). Little information is available that describes the DM yield potential of stockpiled bermudagrass forages. Therefore, the objectives of this study were to evaluate the effects of stockpiling initiation date and N fertilization rate on the DM yield potential of stockpiled 'Common' and 'Tifton 44' bermudagrass forages throughout late fall and early winter.

Experimental Procedures

Well-established stands of 'Common' and 'Tifton 44' bermudagrass were divided into four blocks consisting of eight plots each at Fayetteville and Batesville, AR, respectively, in July 2000. Half of the plots in each block received their final summer harvest on August 8 and 10 at Fayetteville and Batesville, respectively; the remaining plots were harvested for the last time during the growing season on September 6 at both locations. These two final harvest dates were used to create different initiation dates for autumn forage accumulation, which ultimately resulted in different plant ages throughout the accumulation and sampling periods of the trial. Nitrogen fertilizer treatments (0, 33, 66, or 99 lb N/acre) were applied as ammonium nitrate (34-0-0) to plots on each initiation date. Forage growth was allowed to accumulate until mid-October, when the sampling period of the trial was initiated. Plots were sampled (2-in stubble height) in 3-wk intervals between mid-October and late-November to determine DM yields. A fourth and final sampling date was delayed until early-January due to poor weather conditions that included substantial snow-fall events and subsequent

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ground cover. Forage samples were dried to a constant weight in a forced-air oven (55°C) and yields were expressed on a lb DM/acre basis.

Data for each location were analyzed independently as a split-plot design using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC). Whole plots were arranged in a 2 x 4 factorial design that included two initiation dates (August 8 or 10, September 6) and four fertilization rates (0, 33, 66, or 99 lb N/acre). The subplot treatment factor was fall harvest date (October 18 or 19, November 8 or 9, November 29 or 30, and January 8 or 9). Whole-plot sums of squares were partitioned to test for main effects of stockpiling initiation date and N fertilization rate, and to test for their associated interaction; the mean square for the stockpiling initiation date x N fertilization rate x block interaction was used as the error term. Fall harvest dates and all interaction terms with fall harvest date were tested for significance with the residual error mean square.

Results and Discussion

Mean daily air temperatures and monthly precipitation patterns are shown in Figures 1 and 2, respectively. Ambient air temperatures appeared to follow similar trends at both locations. Temperatures remained relatively high throughout the mid- and late-summer months and were coupled with very little rainfall (Figure 2), which resulted in droughty conditions during this time period. Total precipitation was higher at Fayetteville between August and November, which was the period when stockpiling occurred.

At Fayetteville, the stockpiling initiation date x fall harvest date interaction was significant ($P = 0.0002$); therefore, only interaction means are presented in Table 1. Dry matter yields of stockpiled bermudagrass initiated on August 8 decreased ($P < 0.05$) between November 8 and November 29, but did not change ($P > 0.05$) between October 18 and November 18 or between November 29 and January 8. Yields for forage that began the stockpiling period later (September 6) were greatest ($P < 0.05$) on the November 8 sampling date. At Batesville, the stockpiling initiation date x fall harvest date interaction was significant ($P < 0.0001$), while the main effect of N fertilization rate approached significance ($P = 0.057$). Therefore, main effect means of N fertilization are presented in addition to interaction means in Table 2. Previously, Hart et al. (1969) observed similar increasing trends for yields of stockpiled 'Coastal' bermudagrass in response to increased rates of N fertilization. Dry matter yields of stockpiled bermudagrass initiated on August 10 and September 6 followed trends similar to those observed for bermudagrass at Fayetteville.

Stockpiled bermudagrass yields on the initial sampling date in our study were lower than those reported for stockpiled bermudagrass harvested from early- to mid-November in Georgia (Hart et al., 1969). In addition, yields throughout the sampling period were lower than those reported by Coblentz et al. (1998) for stockpiled 'Greenfield' bermudagrass harvested during late fall and early winter in Arkansas. Unusually high temperatures and infrequent rainfall events during the early fall clearly influenced trends for yields of stockpiled bermudagrass throughout our study. Unusual weather patterns during the sampling period may have also contributed to unexpected trends for stockpiled bermudagrass yields. The approximate onset of fall dormancy for bermudagrass in Arkansas generally occurs in mid-October, after which little accumulation of bermudagrass forage is expected to occur. However, the first killing freeze at both experimental locations in our study occurred on approximately October 9; low temperatures on this date were 27 and 30°F at Fayetteville and Batesville, respectively. Therefore, high temperatures and low moisture availability during the early fall, coupled with an early killing frost probably limited the yield potential of stockpiled bermudagrass on the first sampling date. Dry matter yields were generally the highest at both locations on the early-November sampling date (Tables 1 and 2). This phenomenon was a result of increased temperatures and rain-fall events during the first sampling interval, which promoted renewed bermudagrass growth between mid-October and early-November.

Implications

Yields of stockpiled bermudagrass at Fayetteville and Batesville, AR remained relatively low throughout the late fall and early winter, never producing more than 1,565 lb of forage DM/acre. However, unusual weather events that occurred throughout late fall and early winter contributed to unexpected trends for stockpiled bermudagrass yields.

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Table 1. Dry matter yields of stockpiled 'Common' bermudagrass at Fayetteville, AR as affected by the interaction of stockpiling initiation date and fall harvest date.

	Harvest date				
Initiation date	Oct 18	Nov 8	Nov 29	Jan 8	SE[1]
	----------(lb DM / acre)----------				
Aug 8	1439.1[a]	1562.7[a]	1038.9[b]	963.8[b]	66.85
Sep 6	506.5[b]	1025.2[a]	572.0[b]	663.7[b]	66.85

[a,b]Within a row, means without a common superscript letter differ (P < 0.05).

[1] SE = standard error of the mean.

Table 2. Dry matter yields of stockpiled 'Tifton 44' bermudagrass at Batesville, AR, as affected by the interaction of stockpiling initiation date and fall harvest date, and by the main effect of N fertilization rate.

	Harvest date				
Initiation date	Oct 19	Nov 9	Nov 30	Jan 9	SE[1]
	----------(lb DM / acre)----------				
Aug 10	662.4[a]	595.3[a]	276.8[b]	305.2[b]	35.44
Sep 6	196.7[b]	316.8[a]	106.7[b]	165.1[b]	35.44
	N rate (lb N / acre)				
	0	33	66	99	SE[1]
DM Yield[2], (lb / acre)	226.5[b]	297.9[ab]	339.8[ab]	448.2[a]	54.05

[a,b]Within a row, means without a common superscript letter differ (P < 0.05).

[1] SE = standard error of the mean.

[2] Significance for the main effect of N fertilization rate on DM yield was P = 0.057.

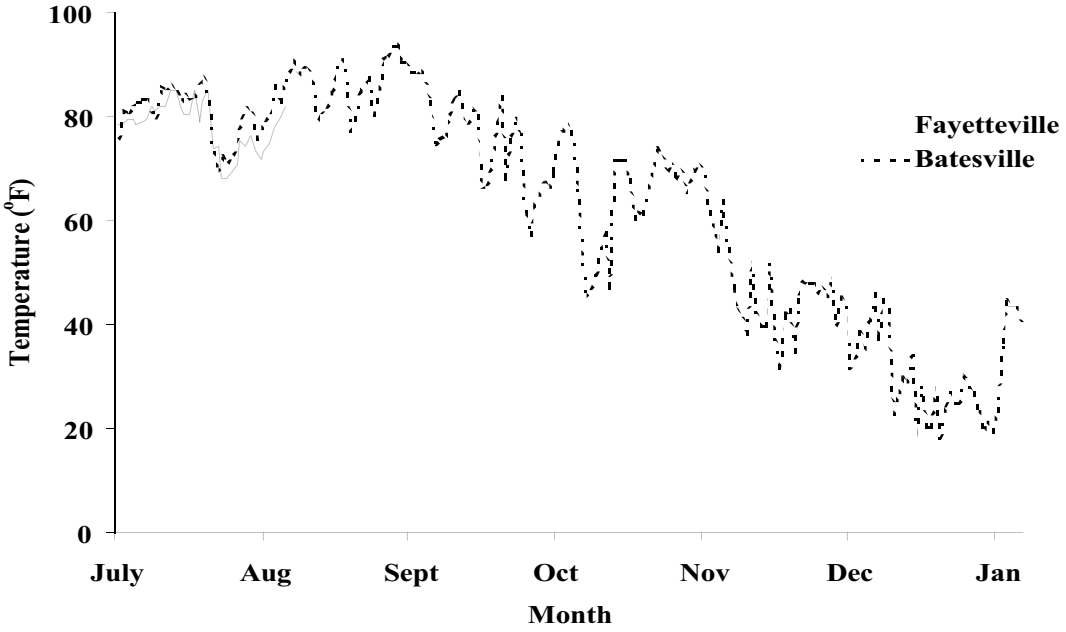

Figure 1. Mean daily air temperatures at Fayetteville and Batesville, AR, between the months of July, 2000 and January, 2001.

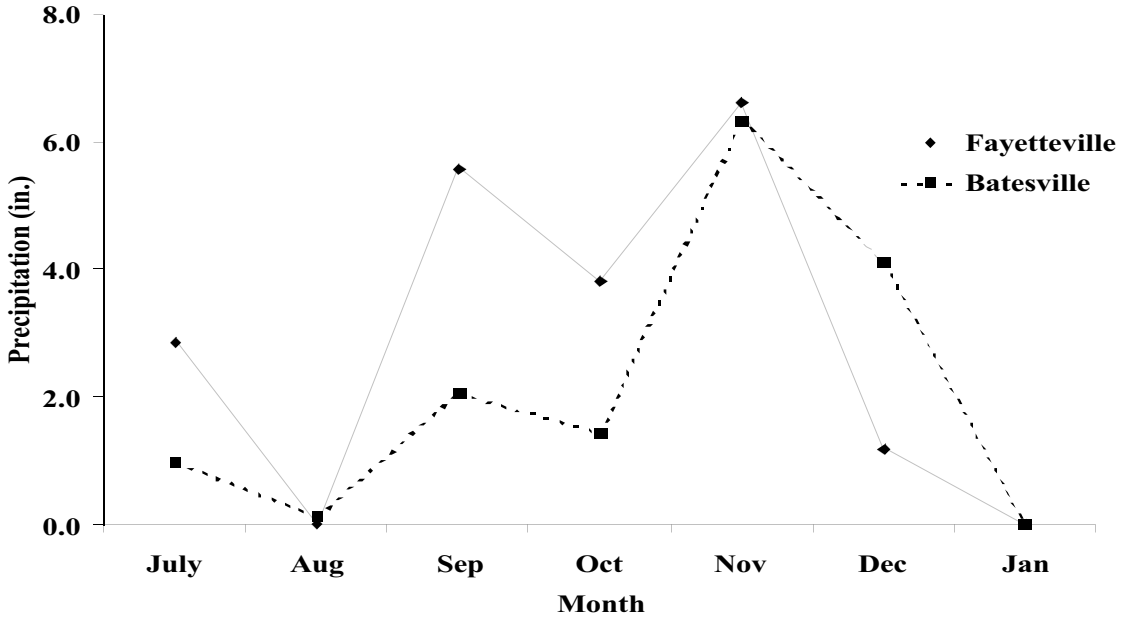

Figure 2. Total monthly precipitation at Fayetteville and Batesville, AR, between the months of July, 2000 and January, 2001.

Effects of Nitrogen Fertilization on Subsequent Partitioning of Nitrogen in Cell Wall and Cell Soluble Fractions in Bermudagrass Forages

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Story in Brief

Estimates of rumen degradable or escape N are an important component of current nutritional models for feeding livestock. One factor that can affect the proportion of forage nitrogen (N) that bypasses the rumen intact is the relative proportion of total plant N that is associated with the cell wall. Relatively little is known about this characteristic of N within bermudagrass [*Cynodon dactylon* (L.) Pers.] forages, and the effects of fertilization with N have not been evaluated in depth. The objective of this study was to assess the relationship between N fertilization rate and the relative proportions of plant N partitioned into the cell solubles and cell wall. Bermudagrass at two sites was fertilized in split applications with 0, 50, 100, or 150 lb N/acre as ammonium nitrate such that the total applications for the year were 0, 50, 100, 150, 200, 250, or 300 lb N/acre. Plots were harvested on three dates (May 30, July 7, and August 18). Based on results for the entire year (three harvests), concentrations of N in the forage increased linearly ($P < 0.0001$) with fertilization rate at both sites. Concentrations of cell-soluble N (NDSN) also increased linearly ($P \leq 0.023$) with fertilization rate; however, the magnitude of change was relatively small (≤ 4.3 percentage units of the total plant N pool). Conversely, the percentage of total plant N associated with the cell wall (NDIN) declined in a linear pattern ($P \leq 0.023$) in response to fertilization with N. Concentrations of acid-detergent insoluble N (ADIN) also decreased linearly ($P < 0.001$) with N fertilization rate, thereby suggesting that bioavailability may be slightly improved with fertilization.

Introduction

Bermudagrass has been described for more than a century as one of the most important grasses grown in the southeastern US. This warm-season grass is used widely by beef and dairy producers for both grazing and hay production throughout this region. Many current nutritional models for ruminants require knowledge of the rumen degradable N concentration in forages (NRC, 2000; Sniffen et al., 1992), and diets are currently balanced on this basis. One factor that affects the relative proportion of plant N that escapes ruminal degradation is the proportion of plant N that is associated with the cell wall (NDIN). Fertilization with N is known to increase concentrations of total N in bermudagrass, but it remains unclear how this N is partitioned within the plant. Most cell soluble N (NDSN) should be available to rumen microorganisms; however, NDIN is likely to have reduced availability in the rumen. The N that is insoluble in acid detergent (ADIN) typically has little or no bioavailability. The objective of this study was to assess the relationship between N fertilization rate and the relative proportions of plant N that are partitioned into the NDSN, NDIN, and ADIN fractions.

Materials and Methods

Generation of Sample Sets. Twenty-eight 10-ft x 20-ft plots were established on two producer farms (Latta and Stephens) located near Lincoln, AR in the early spring of 2000. Both sites had histories of poultry waste application. Poultry waste was applied during the previous year (1999) at the Latta site only. Concentrations of soil-test P were 305 and 571 lb/acre at the Stephens and Latta sites, respectively. The associated levels of soil-test K at these sites were 137 and 496 lb/acre. These sites are representative of many in northwestern Arkansas that have histories of intermittent or annual applications of poultry waste. Nitrogen was applied as ammonium nitrate (34-0-0) in split applications of 0, 50, 100, and 150 lb N/acre on April 28 and July 19. For the year, N fertilizer was applied at cumulative rates of 0, 50, 100, 150, 200, 250, and 300 lb N/acre as shown in Table 1. Plots at each site were arranged in a randomized complete block design with four replications. Plots were clipped to a 2-in. stubble height on May 30, July 7, and August 18 with a sickle-bar mower and representative subsamples were retained for laboratory analysis. The extremely droughty conditions in Arkansas during the late summer of 2000 prevented a final (fourth) harvest in early fall.

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Forage Preparation and Analysis. All forage samples were dried to a constant weight under forced air at 122°F. Dry forage samples were ground through a Wiley mill (Arthur H. Thomas, Philadelphia, PA) equipped with a 1-mm screen before analysis. Total plant N was determined by rapid combustion (850°C); conversion of all N-combustion products to N_2; and subsequent measurement by thermoconductivity cell (LECO Model FP-428; LECO Corp., St. Joseph, MI). Neutral (NDF) and acid detergent (ADF) fiber analyses were conducted by the batch procedures outlined by ANKOM Technology Corp. (Fairport, NY). No sulfite was included in the neutral detergent solution. The concentrations of N in NDF and ADF residues (NDIN and ADIN, respectively) were determined as described previously. Cell-soluble N was calculated as 100 - NDIN, where NDIN was expressed as a percentage of total plant N.

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

Results and Discussion

Nitrogen. At both sites, forages from the initial harvest on May 30 and the third harvest on August 18 exhibited a strong positive linear relationship ($P < 0.0001$) between N fertilization rate and the concentration of N in the forage (Table 2). This is a commonly observed response to N fertilization. The increases observed in forages fertilized with 150 lb N/acre compared with those receiving no fertilization ranged from 0.56 to 1.11 percentage units, which corresponds to 3.5 to 6.9 percentage units of CP. The effects of the first application of N fertilizer on forages harvested on the second date (July 7) were not significant ($P > 0.05$) at either site, indicating that the residual effects of the first application were not sufficient to affect concentrations of N in forages harvested on the second date. When all data for the year was combined, strong positive linear effects ($P < 0.0001$) were found at both sites (Table 3). The higher concentrations of N generally observed for forages grown at the Latta site probably reflects the more recent applications of poultry waste during the preceding year that did not occur at the Stephens site.

Cell-soluble N (NDSN). The percentage of total plant N found in the cell-soluble portion of the plant ranged from 55.5 to 75.6% over the study and was affected by N fertilization in a manner similar to that described for total plant N (Table 4). Positive linear effects ($P = 0.001$ and 0.033 for the Stephens and Latta sites, respectively) were observed for the first harvest; however, no effects ($P > 0.05$) were observed for the second harvest date across both sites. On the third harvest date, linear ($P = 0.047$) and quadratic ($P = 0.022$) effects were observed at the Stephens and Latta sites, respectively. The overall analysis for the entire year indicated that the concentration of NDSN was related to N fertilization rate in a positive linear manner at both sites ($P \leq 0.023$; Table 3).

Cell-wall associated N (NDIN). Concentrations of NDIN in these bermudagrass forages ranged from 24.4 to 44.5% of total N on individual harvest dates (Table 5). At both sites, concentrations of NDIN declined ($P \leq 0.047$) with N fertilization on the first and third harvest dates, but not on the second harvest date ($P > 0.05$). Apparently, the residual or carryover effects of the first application of N fertilizer were not sufficient to affect the relative percentages of N partitioned into the cell wall and cell solubles. The overall analysis for the entire year indicated that the concentration of NDIN was inversely related to N fertilization rate in a linear manner at both sites ($P \leq 0.023$; Table 3).

Acid-detergent insoluble N (ADIN). The N fraction that is insoluble in acid detergent (ADIN) is generally assumed to be indigestible; therefore the effects of N fertilization on this fraction are of particular interest to nutritionists. Normally, this fraction is of considerable interest when spontaneous heating has occurred during the storage of dry hay or during the silage fermentation process. Unlike the other N fractions discussed in this study, substantive differences in concentrations of ADIN were observed between sites. On the first harvest date, ADIN decreased linearly ($P < 0.0001$) with N fertilization rate from 11.48 to 8.32% of the total N pool at the Stephens site (Table 6); however, concentrations of ADIN and fertilization rate were not related ($P > 0.05$) at the Latta site (overall mean = 4.69% of N). There was no relationship ($P > 0.05$) between ADIN and N fertilization rate at either site for the second harvest date. Linear declines in concentrations of ADIN were observed with N fertilization rate at both the Stephens ($P = 0.002$) and Latta ($P = 0.011$) sites on the final harvest date. The overall analysis for the entire year indicated that concentrations of ADIN were inversely related to N fertilization rate in a linear manner at both sites ($P \leq 0.001$; Table 3).

Implications

The results of this study suggest that fertilization with N may result in lower percentages of the total plant N pool being associated with the cell wall. Theoretically, this should increase the degradability of N in the rumen; additional studies are being planned to verify this hypothesis.

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

Total N applied[1]	1st application[2]	2nd application[3]
lb N/acre		
0	0	0
50	50	0
100	50	50
150	100	50
200	100	100
250	150	100
300	150	150

[1] Total application for the entire growing season.
[2] April 28, 2000.
[3] July 19, 2000.

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

	Stephens site			Latta site		
Fertilization rate	May 30	July 7	August 18	May 30	July 7	August 18
lb N/acre	% of DM					
0	1.78	1.94	1.81	2.97	2.56	2.11
50	2.26	1.99	2.11	3.19	2.65	2.45
100	2.47	2.08	2.33	3.33	2.65	2.75
150	2.89	2.10	2.63	3.53	2.79	2.68
SEM[1]	0.097	0.056	0.052	0.048	0.089	0.052
Effect[2]	L < 0.0001	NS	L < 0.0001	L < 0.0001	NS	L < 0.0001
						Q = 0.002

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

Table 3. Cumulative effects of N fertilization in split applications on concentrations of N, cell-soluble N (NDSN), cell-wall associated N (NDIN), and acid-detergent insoluble N (ADIN) in bermudagrass harvested at two sites near Lincoln, AR during 2000.

	Stephens site				Latta site			
Fertilization rate	N	NDSN	NDIN	ADIN	N	NDSN	NDIN	ADIN
lb N/acre	% of DM	% of N			% of DM	% of N		
0	1.84	60.3	39.7	8.92	2.52	65.7	34.3	6.48
50	2.05	62.8	37.2	8.07	2.65	64.6	35.4	5.88
100	2.08	63.2	36.8	7.95	2.75	65.7	34.3	6.06
150	2.25	63.9	36.1	7.74	2.91	64.7	35.3	5.63
200	2.30	62.3	37.7	7.41	2.81	68.7	31.3	5.90
250	2.50	64.6	35.4	7.09	3.07	67.5	32.5	5.23
300	2.46	64.0	36.0	6.95	2.98	68.6	31.4	5.40
SEM[1]	0.062	1.06	1.06	0.330	0.046	1.22	1.22	0.211
Effect[2]	L < 0.0001	L = 0.023	L = 0.023	L = 0.0001	L < 0.0001	L = 0.014	L = 0.014	L = 0.001

[1] Standard error of the mean.
[2] NS, not significant (P > 0.05); L, linear effect.

Table 4. Effects of N fertilization on concentrations of cell-soluble N (NDSN) in bermudagrass harvested at two sites near Lincoln, AR.

	Stephens site			Latta site		
Fertilization rate	May 30	July 7	August 18	May 30	July 7	August 18
lb N/acre	% of N					
0	55.5	61.4	63.9	70.2	63.1	63.6
50	60.2	64.8	65.6	71.6	58.6	65.4
100	60.4	62.3	66.3	73.7	60.3	67.3
150	63.4	62.5	67.3	75.6	63.0	64.6
SEM[1]	1.13	1.38	0.98	1.50	1.95	0.83
Effect[2]	L = 0.001	NS	L = 0.047	L = 0.033	NS	Q = 0.022

[1] Standard error of the mean.

[2] NS, not significant (P > 0.05); L, linear effect; Q, quadratic effect.

Table 5. Effects of N fertilization on concentrations of cell-wall associated N (NDIN) in bermudagrass harvested at two sites near Lincoln, AR.

	Stephens site			Latta site		
Fertilization rate	May 30	July 7	August 18	May 30	July 7	August 18
lb N/acre	% of N					
0	44.5	38.6	36.1	29.9	36.9	36.4
50	39.8	35.2	34.4	28.4	41.4	34.6
100	39.6	37.7	33.7	26.3	39.7	32.7
150	36.6	37.5	32.7	24.4	37.0	35.4
SEM[1]	1.13	1.38	0.98	1.50	1.95	0.83
Effect[2]	L = 0.001	NS	L = 0.047	L = 0.033	NS	Q = 0.022

[1] Standard error of the mean.

[2] NS, not significant (P > 0.05); L, linear effect; Q, quadratic effect.

Table 6. Effects of N fertilization on concentrations of acid-detergent insoluble N (ADIN) in bermudagrass harvested at two sites near Lincoln, AR.

	Stephens site			Latta site		
Fertilization rate	May 30	July 7	August 18	May 30	July 7	August 18
lb N/acre	% of N					
0	11.48	7.21	8.58	4.74	6.03	7.92
50	9.56	5.79	8.07	5.02	5.97	6.28
100	9.17	5.89	7.38	4.60	6.45	5.90
150	8.32	5.66	6.81	4.43	5.93	5.91
SEM[1]	0.363	0.474	0.323	0.225	0.326	0.426
Effect[2]	L < 0.0001	NS	L = 0.002	NS	NS	L = 0.011

[1] Standard error of the mean.

[2] NS, not significant (P > 0.05); L, linear effect.

Influence of Moisture Concentration at Baling on Storage Characteristics of Bermudagrass Hay

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Story in Brief

Concentrations of moisture > 20% are known to cause spontaneous heating and associated deleterious effects on forage nutritive value in hay. Alfalfa (*Medicago sativa* L.) has been thoroughly studied in this respect, but relatively little is known about these relationships in warm season grasses. 'Greenfield' bermudagrass [*Cynodon dactylon* (L.) Pers.] was packaged in conventional rectangular bales at 21.9, 26.5, and 30.2% moisture (LM, MM, and HM, respectively). The MM and HM bales accumulated more ($P < 0.05$) heating degree days >95°F and exhibited greater ($P < 0.05$) mold development than the LM bales. Dry matter recovery was greater ($P < 0.05$) for LM and MM bales than for HM bales.

Introduction

In the southern USA the harvest of bermudagrass often coincides with periods of high relative humidity and a relatively high probability of regular rainfall events. High relative humidity can extend the period needed to dry hay in the field (Moser, 1995), thereby increasing the probability of a rainfall event on the hay prior to packaging. These factors often necessitate baling at higher than optimal moistures or delaying harvest until more favorable weather conditions occur.

Concentrations of moisture >20% in alfalfa and bermudagrass hays produce spontaneous heating, mold growth, and deleterious changes in forage nutritive value (Collins et al., 1987; Coblentz et al., 2000). Previous research (Coblentz et al., 2000) has indicated that bermudagrass hay exhibits two distinct temperature maxima; these occur immediately after baling and then between 5 and 20 d of storage. It is especially important to develop a clear understanding of storage characteristics over a 65-d storage period for bermudagrass, which is the most important forage grown throughout the southeastern USA (Burton and Hanna, 1995). The objectives of this research were to characterize the effects of moisture concentration at baling on storage characteristics of bermudagrass hay.

Experimental Procedures

An approximately 15-yr-old stand of "Greenfield" bermudagrass grown at the University of Arkansas Forage Research Area located in Fayetteville was selected for this trial. The experimental forage was the second cutting for 1999. On 13 July 1999, the bermudagrass forage was mowed in three blocks of 12 swaths each. Swaths in each block were randomly assigned to one of the three moisture concentrations (30.2, 26.5, and 21.9%; HM, MM, and LM, respectively), which were chosen to produce intense, moderate, and minimal heating and similar associated changes in forage nutritive value. For each moisture treatment, 12 conventional bales (average size = 1.57 ft by 1.25 ft by 3.14 ft) were made from each block. Six bales from each group of 12 were placed side by side (strings up) on top of the wooden pallets. The remaining six bales from each treatment were positioned in the same orientation on top of the first six bales, thereby creating stacks two bales high and six bales wide for each field replication of each treatment. Individual stacks containing 12 bales were surrounded on the sides and top by dry bales of wheat straw to limit the effects of diurnal variations in ambient temperature.

All bales were weighed and measured for length prior to being placed on the pallets. The length and weight of the bales were used to determine the density of each hay package. Height and width of bales were not measured; prior observations indicated these measurements to be uniform with our baler. Two bales from each block were visually appraised for mold growth on d 65 of storage by the method of Roberts et al. (1987). Prior to being placed in the stack for storage, four bales from each block had single thermocouple wires inserted into the center of each bale. Bale temperatures were recorded twice daily (0630 and 1500 h) during the initial 14 d of storage and once daily (1500 h) during the remainder of the storage period. The observed temperature was considered to be the mean internal bale temperature for a given day, except during the initial 14 d when the mean of the two observations was used. Heating degree-days >95°F (HDD) were calculated by subtracting 95°F from the recorded daily mean internal bale temperature and summing these differences over

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the entire 65-d storage period. All bales were weighed at the end of the 65-d storage period. Dry matter recovery was determined by dividing the post-storage DM weight by the pre-storage DM weight of the bales.

Dry matter recovery, visual mold score, indices of spontaneous heating and initial bale characteristics were analyzed by PROC ANOVA of SAS (SAS Institute, Inc., Cary, NC) as a randomized complete block design with three replications. The mean square for the bale moisture x block interaction was used as the error term. Fisher's protected least significant difference test was used to compare the actual treatment means of bale characteristics.

Results and Discussion

Bale characteristics of hay packaged at three concentrations of moisture are presented in Table 1. Bale densities were generally comparable to those reported for alfalfa and bermudagrass hays made with comparable equipment at similar concentrations of moisture (Buckmaster and Rotz, 1986, Coblentz et al., 2000). Bale weight and bale density (as-is basis) decreased ($P < 0.05$) as the forage became drier at baling. Bale weight (dry matter basis) was greatest ($P < 0.05$) for HM bales prior to storage.

Internal bale temperature vs. time curves for the three moisture treatments (Fig. 1) were similar to those reported previously for both alfalfa and bermudagrass packaged under similar conditions (Coblentz et al., 1996; 2000). The respiratory processes of plant enzymes and microorganisms associated with the plants in the field have been associated with the initial heating phase (Wood and Parker, 1971). For all treatments, a distinctly elevated bale temperature that was observed initially was partially subsided by d 2 of storage. Immediately following this depression, internal bale temperatures increased for all treatments, and remained elevated in all cases for about 21 d. This secondary heating phase has been attributed to the respiratory processes of storage microorganisms. The intensity and duration of this heating phase was consistent with that reported previously for bermudagrass hay packaged under similar conditions (Coblentz et al., 2000). In the present study, changes in internal bale temperatures observed after 18 d in storage were caused primarily by fluctuations in ambient temperature.

The HDD accumulated during the storage period for these treatments decreased ($P < 0.05$) with moisture concentration at baling (Table 2). The maximum internal bale temperature was greater ($P < 0.05$) in HM than in LM bales; the maximum temperature in MM bales was intermediate between HM and LM bales, but did not differ ($P > 0.05$) from either. Temperature maxima for all treatments exceeded 122°F, indicating that measurable heating occurred in all cases. Average temperatures over the initial 30 d of storage and over the entire 65-d storage period decreased ($P < 0.05$) with moisture concentration at baling. During the course of this project, the ambient air temperature exceeded 95°F on 30 d out of the 65-d storage period; this may have positively influenced the total HDD accumulated during storage relative to studies conducted earlier in the summer or later in the fall. Dry matter recovery after the 65-d storage period decreased ($P < 0.05$) from 96.4% in the LM treatment to 90.2% in the HM treatment. This result was expected; moisture content at baling is considered to be the major factor affecting dry matter recovery (Rotz and Muck, 1994; Collins et al., 1995) and the recoveries of dry matter reported here were generally consistent with those reported previously (Coblentz et al., 2000) for bermudagrass hay packaged and stored similarly.

Elevated concentrations of moisture in hay bales provide a favorable environment for microbial growth (Roberts, 1995). Visual appraisals of mold increased ($P < 0.05$) with moisture content at baling. The LM bales exhibited some presence of spores between the flakes, while the HM bales had spores throughout the bale and evidence of a mycelial mat between the flakes.

Implications

Visual mold, temperature observations and bale weights increased with concentration of moisture in these bales while dry matter recovery increased with decreasing concentrations of moisture. These results are similar to those reported previously for alfalfa and bermudagrass hay.

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Table 1. Bale characteristics of bermudagrass hay made at three concentrations of moisture.

Bale moisture	Moisture content	Bale weight (as-is)	Bale density (as-is)	Bale weight (dry matter basis)	Bale density (dry matter basis)
	%	lb	lb/ft^3	lb	lb/ft^3
HM[d]	30.2[a]	82.0[a]	13.2[a]	57.1[a]	9.3
MM	26.5[a]	72.3[b]	11.7[b]	52.9[b]	8.5
LM	21.9[b]	65.3[c]	11.0[b]	50.9[c]	8.5
SEM	1.9	1.34	0.18	0.28	0.22

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

[d] Abbreviations: HM, high moisture (30.2%); MM, medium moisture (26.5%); LM, low moisture (21.9%).

Table 2. Heating and storage characteristics of bermudagrass hay bales made at three concentrations of moisture.

Bale moisture	HDDe	MIN	MAX	30-d AVG	65-d AVG	Visible mold[f]	DM recovery
		°F	°F	°F	°F		%
HMd	552[a]	77.0	145.0[a]	112.6[a]	111.0[a]	3.75[a]	90.2[b]
MM	472[a]	73.6	138.0[ab]	109.9[a]	108.5[ab]	2.67[b]	94.1[ab]
LM	279b	74.8	126.5[b]	104.9[b]	104.5[b]	1.67c	96.4[a]
SEM	36	1.1	3.0	1.2	1.2	0.24	1.4

[a,b,c]Means within a column with different superscripts differ (P < 0.05).

[d] Abbreviations: HM, high moisture (30.2%); MM, medium moisture (26.5%); LM, low moisture (21.9%).

[e] Abbreviations: HDD, heating degree days > 95°F; MIN, minimum internal bale temperature; MAX, maximum internal bale temperature; 30-d AVG, average internal bale temperature over the initial 30 d of storage; and 65-d AVG, average internal bale temperature over the entire 65-d storage period.

[f] Visible mold assessment score (Roberts et al., 1987).

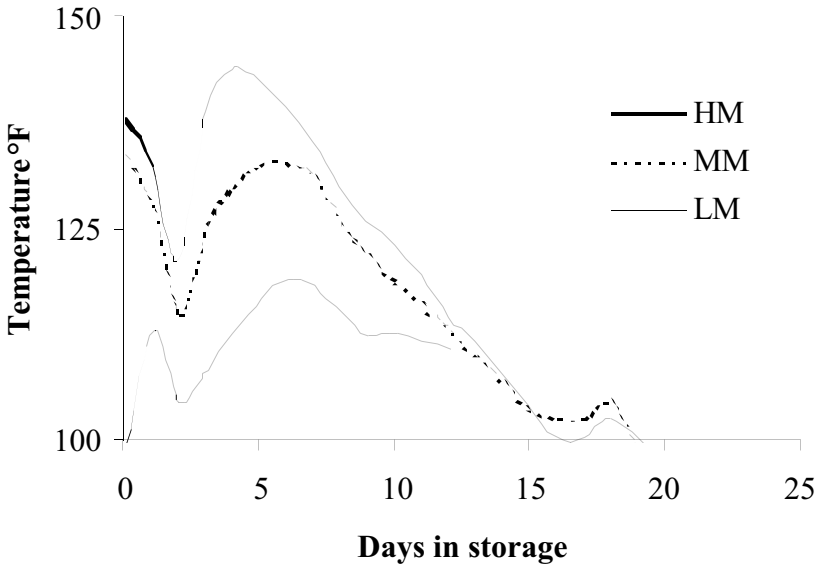

Figure 1. Internal bale temperature versus time curves over the initial 25 d of bale storage for bermudagrass hay baled at moisture concentrations of 30.2% (HM), 26.5% (MM), and 21.9% (LM).

Influence of Moisture Concentration at Baling on the Nutritive Value of Bermudagrass Hay as Affected by Time in Storage

J. E. Turner, W .K. Coblentz, D. A. Scarbrough, D. W. Kellogg, K. P. Coffey, L. J. McBeth, and R. T. Rhein[1]

Story in Brief

Concentrations of moisture > 20% are known to cause spontaneous heating and associated deleterious effects on forage nutritive value in hay. 'Greenfield' bermudagrass [*Cynodon dactylon* (L.) Pers.] was packaged in conventional rectangular bales at 21.9, 26.5, and 30.2 % moisture (LM, MM, and HM, respectively). Bales made at each concentration of moisture were core sampled before storage (d 0) and after 4, 8, 12, 24 and 65 d of storage. Concentrations of most fibrous and fiber-associated N components increased ($P < 0.05$) with time in storage. Concentrations of N increased ($P < 0.05$) with time in storage for HM and MM bales, but the concentration of N in the driest bales did not change ($P > 0.05$) with time in storage. The results of this study demonstrate that negative changes occur in bermudagrass hay packaged at concentrations of moisture > 20.0%. Nitrogen in these bales was clearly susceptible to the effects of heating; N became more associated with fiber constituents as a result of nonenzymatic browning, suggesting a concurrent reduction in bioavailability.

Introduction

Concentrations of moisture >20% in alfalfa (*Medicago sativa* L.) and bermudagrass hays produce spontaneous heating, mold growth, and deleterious changes in forage nutritive value (Collins et al., 1987; Coblentz et al., 1996; 2000). Negative changes in nutritive value are a result of microbial activity and the subsequent production of heat. Rotz and Muck (1994) have indicated that increased microbial activity and the associated heating can result in greater concentrations of fiber components and heat damaged N. The nutritional value of the hay and the subsequent productivity of livestock consuming these forages can be reduced as a result of these factors.

It is especially important to develop a clear understanding of these relationships for bermudagrass, which is the most important forage grown throughout the southeastern U.S. (Burton and Hanna, 1995). The objectives of this study were to describe the relationship between changes in nutritive value and time in storage for bermudagrass hay made at three concentrations of moisture.

Experimental Procedures

A second cutting of a well-established stand of "Greenfield" bermudagrass was selected for this trial. On July 13, 1999, the bermudagrass forage was mowed in three blocks of 12 swaths each. Swaths in each block were randomly assigned to one of three moisture concentrations 30.2% (high moisture, HM) 26.5% (medium moisture, MM), and 21.9% (low moisture, LM), which were chosen to produce intense, moderate and minimal spontaneous heating and similar associated changes in forage nutritive value. Twelve conventional rectangular bales were made from each block for each concentration of moisture.

Bales were stacked on wooden pallets placed on the concrete floor of an open-air pole barn. Six bales from each group of 12 were placed side by side (strings up) on top of the wooden pallets. The remaining six bales from each treatment were positioned in the same orientation on top of the first six bales, thereby creating stacks two bales high and six bales wide for each field replication of each treatment. Individual stacks containing 12 bales were surrounded on the sides and top by dry bales of wheat straw to limit the effects of diurnal variations in ambient temperature.

Core samples were taken from two bales selected at random from each stack prior to stacking and at 4, 8, 12, 24, and 65 d postbaling using a Multi-Forage Sampler (Star Quality Samplers, Edmonton, AB, Canada). Based on previous temperature versus time in storage curves for bermudagrass hay (Coblentz et al., 2000), these sampling dates were selected to approximately coincide with the end of the initial heating period (d 4); the onset, peak, and end of the secondary heating phase (d 8, 12, and 24, respectively); and the end of the study (d 65). The d 0 sampling date served as a prestorage estimate of forage nutritive value. Bales were removed from each stack for coring and then returned to their previous location in the stack for the remainder of the trial to maintain the integrity of the stack. All forage samples were dried under forced air at 131°F for 72 h; for bales sampled on d 0, this technique was used to estimate the initial concentration of moisture for each baling treatment.

Dry forage samples were ground through a Wiley mill

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fitted with a 1-mm screen (Arthur H. Thomas, Philadelphia, PA) and subsequently analyzed for N, neutral-detergent fiber (NDF), acid-detergent fiber (ADF), lignin, neutral-detergent insoluble N (NDIN), and acid-detergent insoluble N (ADIN). The NDF, ADF, and lignin analyses were conducted using batch procedures outlined by ANKOM Technology Corp. (Fairport, NY). Nitrogen was quantified by a modified Kjeldahl procedure (Kjeltech Auto 1030 Analyzer, Tecator, Inc. Herndon, VA); the N concentration in NDF (NDIN) and ADF (ADIN) residues was determined by identical procedures as total N. All N components were reported on the basis of dry matter and total N.

Changes in forage nutritive value over the six sampling dates were tested for treatment effects using a split-plot model using PROC GLM of SAS (SAS Inst., Inc., Cary, NC). Concentrations of initial bale moisture served as the whole-plot term and sampling dates were evaluated as the sub-plot term. Whole-plot treatment effects were tested for significance with the initial bale moisture x block interaction mean square as the error term. The effects of sampling date and the bale moisture x sampling date interactions were tested for significance with the residual error mean square. Fisher's protected least significant difference test was used to separate treatment means.

Results and Discussion

Measurable changes in concentrations of fibrous components were expected in hays baled at all three concentrations of moisture because the driest hay in this study exceeded the 20% threshold for acceptable storage suggested by Collins et al. (1987). Typically, fibrous components are not lost during hay storage; concentrations are thought to increase via indirect mechanisms due to preferential oxidation of non-fiber components, particularly nonstructural carbohydrates (Rotz and Muck, 1994). Sampling date x bale moisture interactions were found ($P < 0.05$) for concentrations of most fibrous components; therefore, only interaction means are presented and discussed (Table 1). Generally, concentrations of all fibrous components (NDF, ADF, and lignin) increased over time in storage for hays baled at all concentrations of moisture. Overall, the total change in NDF for HM bales across the 65-d storage period was 10.5 percentage units. Increases in concentrations of NDF over the 65-d storage period for MM and LM bales were 8.2 and 8.0 percentage units, respectively. Lignin exhibited the largest increases in concentration of all fibrous components on a percentage basis. Relative to d 0, concentrations of lignin increased ($P < 0.05$) by 30.7, 30.7, and 25.5% by d 65 for HM, MM, and LM bales, respectively.

In most cases, large increases ($P < 0.05$) in the concentrations of fibrous components were observed during the first 12 d of storage, but these fractions typically stabilized thereafter. This pattern was observed consistently for all fibrous components across all concentrations of moisture at baling. Increases in concentrations of NDF (8.8 percentage units) and ADF (6.5 percentage units) for HM bermudagrass hays were observed by d 12 of storage. Further increases ($P < 0.05$) in the concentrations of fibrous components were sometimes observed; however, changes in concentration observed after the initial 12 d of storage tended to be relatively small compared to the rapid changes that occurred initially.

Concentrations of total N increased slightly ($P < 0.05$) in MM and HM bales. In the short term (<60 d), concentrations of N are known to increase in heated hays because nonstructural carbohydrates are preferentially oxidized by plant enzymatic processes and microorganisms associated with storage (Rotz and Muck, 1994). Concentrations of N in LM bales exhibited only numerical increases (0.05 percentage units; $P > 0.05$) between d 0 and 65; this result was not unexpected based on the limited heating that occurred in these bales.

Concentrations of ADIN increased ($P < 0.05$) over time in storage for MM and HM bales, but did not ($P > 0.05$) in LM bales. The maximum proportion of N bound in the ADF matrix in HM bales accounted for nearly 18% of the total plant N (at d 24), and more than 10% (at d 65) of total N in MM bales. These findings are consistent with previous work (Coblentz et al., 2000) for bales packaged at comparable concentrations of moisture that accumulated similar increments of heat. Previously, Van Soest (1982) has suggested that feedstuffs can exhibit variable sensitivities to nonenzymatic browning. Sensitivity to nonenzymatic browning is an important consideration in the nutrition of ruminants; ADIN in forages is generally considered to be ruminally undegradable (Sniffen et al., 1993) and to have very low bioavailability (Licitra et al., 1996). Concentrations of NDIN increased ($P < 0.05$) over the 65-d storage period for all hays, while concentrations of cell-soluble N (NDSN) decreased ($P < 0.05$) over this period. The total change in concentration of NDIN in the HM bales was 0.57 percentage units DM, which was greater than that observed previously in bermudagrass hay packaged at 32.5% of moisture (Coblentz et al., 2000). Overall, the proportion of N associated with the residual NDF matrix accounted for approximately half the total plant N on d 0 (mean = 50.7% of N), but this proportion increased ($P < 0.05$) to 59.8, 65.4, and 69.0% of N in LM, MM, and HM bales, respectively, after 65 d in storage. The magnitude of these increases clearly reflects the differences in the heat increments accumulated by each treatment.

Implications

Spontaneous heating resulted in elevated concentrations of fibrous and fiber-bound N components. Changes in the nutritive value of the hays were greatest during the first 12 d of storage; this period corresponded with the most active period of spontaneous heating in our experimental hay bales. A reduction in the bioavailability of N is likely to occur due to the increase in fiber-associated N observed in these bales.

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Table 1. Nutritive characteristics of bermudagrass hay baled at three concentrations of moisture and sampled on six dates during storage in small stacks.

Bale moisture	Day	NDF[d]	ADF	Lignin	N	NDIN	ADIN	NDSN
		% DM						
HM[e]	0	67.8^{d}	32.7^{e}	4.82^{c}	1.93^{c}	0.99^{d}	0.123^{c}	0.94^{a}
	4	72.1^{c}	35.2^{d}	5.73^{b}	2.06^{b}	1.15^{c}	0.169^{c}	0.91^{a}
	8	74.8^{b}	37.1^{c}	6.25^{ab}	2.00^{bc}	1.22^{bc}	0.258^{b}	0.78^{b}
	12	76.6^{ab}	39.2^{ab}	6.45^{ab}	2.04^{bc}	1.31^{b}	0.321^{ab}	0.73^{b}
	24	77.7^{a}	40.1^{a}	6.96^{a}	1.98^{bc}	1.31^{b}	0.352^{a}	0.68^{b}
	65	78.3^{a}	38.0^{bc}	6.30^{ab}	2.25^{a}	1.56^{a}	0.271^{ab}	0.70^{b}
MM	0	68.9^{c}	32.9^{d}	4.63^{c}	1.88^{b}	0.97^{d}	0.104^{c}	0.91^{a}
	4	70.7^{c}	34.0^{d}	4.85^{bc}	1.97^{ab}	1.09^{cd}	0.116^{bc}	0.89^{a}
	8	75.0^{b}	36.7^{bc}	5.92^{a}	1.99^{ab}	1.27^{ab}	0.192^{ab}	0.72^{b}
	12	74.7^{b}	36.0^{c}	5.49^{ab}	1.91^{b}	1.18^{bc}	0.152^{abc}	0.73^{b}
	24	74.6^{b}	39.2^{a}	5.70^{a}	2.04^{a}	1.31^{a}	0.170^{abc}	0.73^{b}
	65	77.1^{a}	37.9^{ab}	6.05^{a}	2.06^{a}	1.35^{a}	0.211^{a}	0.71^{b}
LM	0	66.7^{e}	32.9^{c}	4.67^{c}	1.95	0.96^{d}	0.117	0.99^{a}
	4	69.3^{d}	34.0^{bc}	5.15^{bc}	1.95	1.02^{cd}	0.133	0.94^{ab}
	8	71.5^{c}	35.2^{ab}	5.29^{bc}	1.95	1.08^{bc}	0.156	0.87^{bc}
	12	72.8^{bc}	36.0^{a}	5.94^{ab}	1.97	1.18^{ab}	0.169	0.79^{cd}
	24	73.4^{ab}	36.3^{a}	6.55^{a}	1.94	1.19^{a}	0.186	0.75^{d}
	65	74.7^{a}	36.4^{a}	5.86^{a}	2.00	1.19^{a}	0.156	0.80^{cd}
SEM		0.6	0.6	0.28	0.04	0.04	0.029	0.04

[a,b,c] Means within a column within the same moisture level without a common superscript differ ($P < 0.05$).

[d] Abbreviations: NDF, neutral detergent fiber; ADF, acid detergent fiber; ADIN, acid detergent insoluble nitrogen; NDIN, neutral detergent insoluble nitrogen; NDSN neutral detergent soluble nitrogen.

[e] Abbreviations: HM, high moisture (30.2%); MM, medium moisture (26.5%); LM, low moisture (21.9%).

Effects of Spontaneous Heating on Estimates of Ruminal Nitrogen Degradation in Bermudagrass Hays from Two Harvests

W. K. Coblentz, J. E. Turner, D. A. Scarbrough, K. P. Coffey, D. W. Kellogg, and L. J. McBeth[1]

Story in Brief

Estimates of rumen degradable or escape N are an important component of current nutritional models for feeding livestock, but attempts to estimate these fractions for bermudagrass [*Cynodon dactylon* (L.) Pers.] have been limited, and the relationship between concentrations of these fractions and spontaneous heating during bale storage has not been evaluated. The objective of this study was to assess the relationship between rumen escape N and spontaneous heating in bermudagrass hays harvested from the same site during 1998 and 1999. A preparation of Streptomyces griseus protease was utilized in an in vitro laboratory procedure to quantify rumen degradable N in hays that heated spontaneously during storage in small haystacks. Maximum temperatures in these bales ranged from 98.8 to 157.6°F over 2 years. Rumen escape N for 40 hays ranged from 40.7 to 61.3% of N and increased linearly ($P < 0.05$) with spontaneous heating in both 1998 and 1999; however, r^2 statistics were highest for bales made in 1998 ($r^2 \geq 0.597$). Similar results were observed when ruminal escape N was expressed as a proportion of plant DM. Based on this research, spontaneous heating in bermudagrass hay appears to increase linearly the estimated proportion of plant N escaping the rumen intact.

Introduction

Many current nutritional models for ruminants require knowledge of the rumen degradable or escape N content in forages (NRC, 2000; Sniffen et al., 1992). This approach is utilized to separate N requirements into the needs of the microorganisms within the rumen and the needs of the animal, and is based on the premise than the protein requirements of ruminants are met by both undegraded intake protein and microbial protein (NRC, 2000). Bermudagrass has been described for more than a century as one of the most important grasses grown in the southeastern U.S. This warm-season grass is used widely by beef and dairy producers for both grazing and hay production throughout this region. However, efforts to assess rumen degradability of N in perennial warm-season forages grown in the southeastern U.S. have been very limited, and responses to spontaneous heating during hay storage have not been evaluated. This creates a clear void of needed information for nutritionists serving clients in southern states and clearly complicates the development of supplementation strategies for all livestock classes consuming these forages. Our objective was to utilize a preparation of Streptomyces griseus protease to assess the relationship between rumen escape N and spontaneous heating in bermudagrass hays harvested from the same site during 1998 and 1999.

Materials and Methods

Generation of Sample Sets. An approximately 15-yr-old stand of 'Greenfield' bermudagrass was harvested for hay on June 15, 1998 and July 12, 1999 at the University of Arkansas Forage Research Area in Fayetteville, AR. The hay baled in 1998 was the initial harvest of the season, while the hay harvested in 1999 was regrowth following an initial harvest on June 6, 1999. The bermudagrass was mowed with a John Deere Model 1219 (John Deere Corp., Moline, IL) mower-conditioner equipped with metal conditioning rollers in 1998 and a New Holland Model 465 disc mower without conditioning rollers (Ford New Holland, Inc., New Holland, PA) in 1999. The forage was not tedded either year. Prior to baling, two swaths were raked together with a New Holland Model 258 side-delivery rake. A New Holland Model 320 baler with hydraulic density control was used to produce the conventional rectangular bales (average size = 19-in. x 15-in. x 39-in.) both years. A description of the characteristics and variability of bales produced by this baler has been reported previously (Coblentz et al., 2000). Bales were stacked flat (strings up) and stored on wooden pallets in small stacks that were two layers high; treatment bales were insulated with nonheating bales of either cured hay or straw in both years to limit the effects of fluctuating ambient air temperature on characteristics of spontaneous heating. For this study, bales were made over a wide range of moisture concentrations,

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which created differences in the spontaneous heating characteristics of these bales. A total of 20 bales from each harvest year were selected for evaluation of rumen escape N. Initial moisture concentrations of the treatment bales ranged from 17.8 to 32.5% in 1998 (Coblentz et al., 2000) and 21.9 to 30.2% in 1999.

Temperature data. Internal bale temperatures were monitored by inserting single thermocouple wires into the center of the bales. Bale temperatures were recorded at 0700 and 1600 h for the first 10 d after baling and once daily (at 1600 h) thereafter, until the end of the 60-d storage period. All temperature data were obtained with an Omega 450 AKT Type K thermocouple thermometer (Omega Engineering, Stamford, CT). For purposes of analysis, the mean internal bale temperature for a given day was considered the same as the observed temperature, except during the first 10 d, when the mean of the two observations was used.

Forage Preparation and Analysis. After the storage period, at least two cores (Star Quality Samplers, Edmonton, AB, Canada) were taken from the ends of each bale (35-cm depth). Core samples were dried to constant weight under forced air at 122°F. Dry forage samples were ground through a Wiley mill (Arthur H. Thomas, Philadelphia, PA) equipped with a 1-mm screen prior to analysis. Total plant N was determined using a macro-Kjeldahl procedure (Kjeltec Auto 1030 Analyzer, Tecator, Inc., Herndon, VA). The procedures used to determine estimates of rumen escape N utilized a preparation of Streptomyces griseus protease (P-5147; Sigma Chemical Co., St. Louis, MO) and were similar to those described by Coblentz et al. (1999). Estimates of rumen escape N were expressed on the basis of total plant N and DM. All forty samples of bermudagrass hay were evaluated in each of three separate runs; therefore, estimates of rumen escape N are the means of three individual evaluations.

Statistical Analysis. Estimates of rumen escape N were regressed linearly (PROC REG; SAS Inst., Inc., Cary, NC) on two indices of spontaneous heating; these included maximum internal bale temperature, and the average internal bale temperature over the first 30 d of storage. For purposes of analysis, bale temperatures were averaged over the initial 30 d of storage because little evidence of heating occurred beyond this time interval in previous studies. An independent test of homogeneity (PROC GLM) was included to determine if a common line could be used to describe the data from both years.

Results and Discussion

For our test forages, the mean concentration of N was 2.24 ± 1.3% in 1998 and 2.06 ± 1.2% in 1999 (14.0 and 12.9% CP, respectively). Concentrations of rumen escape N for bermudagrass hays harvested in 1998 exhibited a range of 11.3 percentage units when expressed on a total N basis and 0.41 percentage units when expressed on a DM basis (Fig. 1 and 2, respectively). Slightly smaller ranges were observed for bales harvested in 1999 (9.0 and 0.37 percentage units, respectively), which can probably be explained on the basis of the narrower range of heating characteristics in these bales. Mean concentrations of rumen escape N were numerically greater for hay harvested in 1999 than in 1998 (57.1 vs. 44.6 % of total N or 1.18 vs. 0.99% of DM). Estimates of rumen escape N for warm-season grasses can exceed 50% of the total N pool, and concentrations of rumen escape N for both harvest years were consistent with those determined for other warm-season grasses by various enzymatic and *in situ* methodologies (Coblentz et al., 1999).

Both indices of spontaneous heating (maximum and 30-d average temperature) positively affected ($P < 0.0001$) concentrations of rumen escape N; this was true when rumen escape N was expressed as a percentage of total N (Fig. 1) or DM (Fig. 2). In each of these cases, there was no difference ($P \geq 0.416$) between slopes for hays made in 1998 and 1999, thereby suggesting that heat affected concentrations of rumen escape N consistently across years. Across the entire range of spontaneous heating, estimates of rumen escape N were generally greater in 1999 than in 1998, and intercepts were dissimilar ($P < 0.0001$) for these regression lines; therefore, no single line could be used to describe the relationship between rumen escape N and indices of spontaneous heating in any case. The r^2 statistics for these relationships were substantially greater for hays harvested in 1998 (range = 0.597 to 0.706) than in 1999 (range = 0.294 to 0.439); it remains unclear why these relationships were weaker for hay harvested in 1999.

These data clearly suggest that rumen escape N is increased in bermudagrass hay in response to spontaneous heating during bale storage. The rate of increase in this fraction was similar ($P > 0.05$) across years, implying that this response may be consistent across some storage environments. Other work has shown similar rates of increase with heat for alfalfa hay (Coblentz et al., 1997). These increases in rumen escape N are likely to occur as a greater proportion of the total N pool is associated with the cell wall; these relationships with spontaneous heating have been observed commonly in bermudagrass and other forages. Although our data is based on only two harvests, is also clear that estimates of rumen escape N for bermudagrass can be affected by other factors; an incomplete list could potentially include forage variety, climate, fertilization, frequency of contaminant species, and maturity at harvest. One or more of these factors may explain the numerically higher estimates of rumen escape N observed across all increments of spontaneous heating during the 1999 harvest year. In this study, the proportions of N from bermudagrass that would likely escape the rumen intact are considerably higher than those often reported for cool-season grasses and legumes; however, our estimates of rumen escape N for these bermudagrass hays are consistent with similar estimates for numerous other warm-season grasses.

Implications

Rumen escape N for the 40 hays ranged from 40.7 to 61.3% of total N and increased linearly with all indices of spontaneous heating in both 1998 and 1999. These data sug-

gest clearly that ruminal escape N is increased when spontaneous heating occurs in bermudagrass hay.

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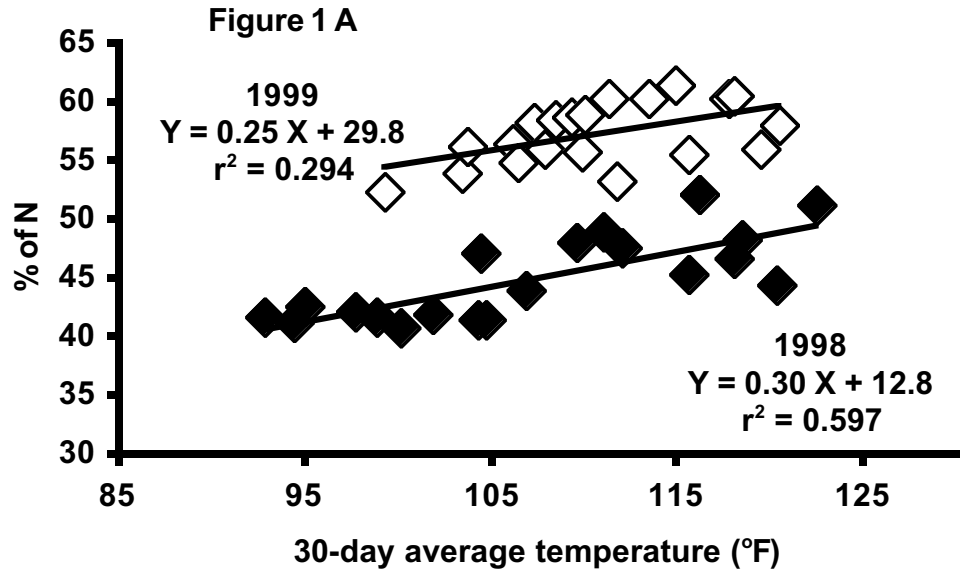


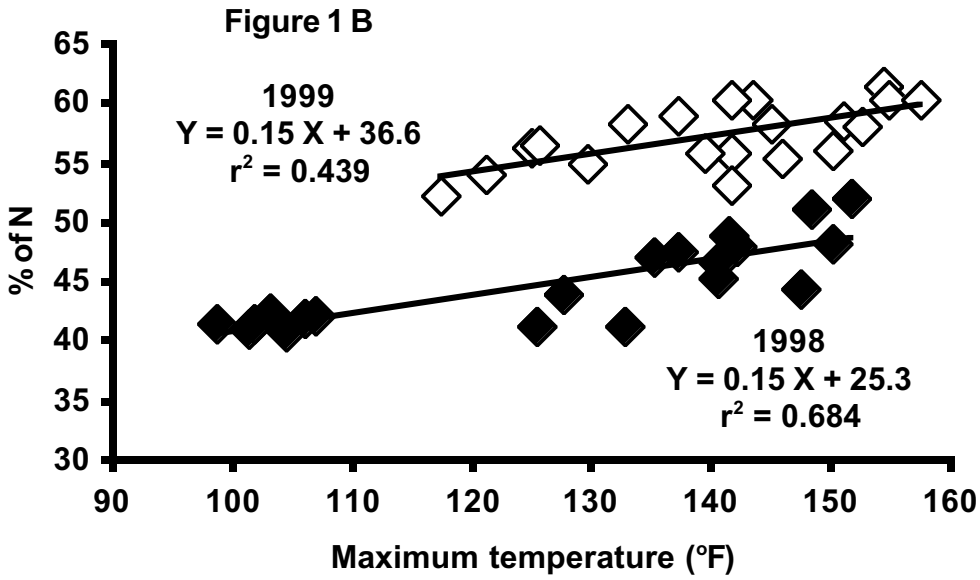
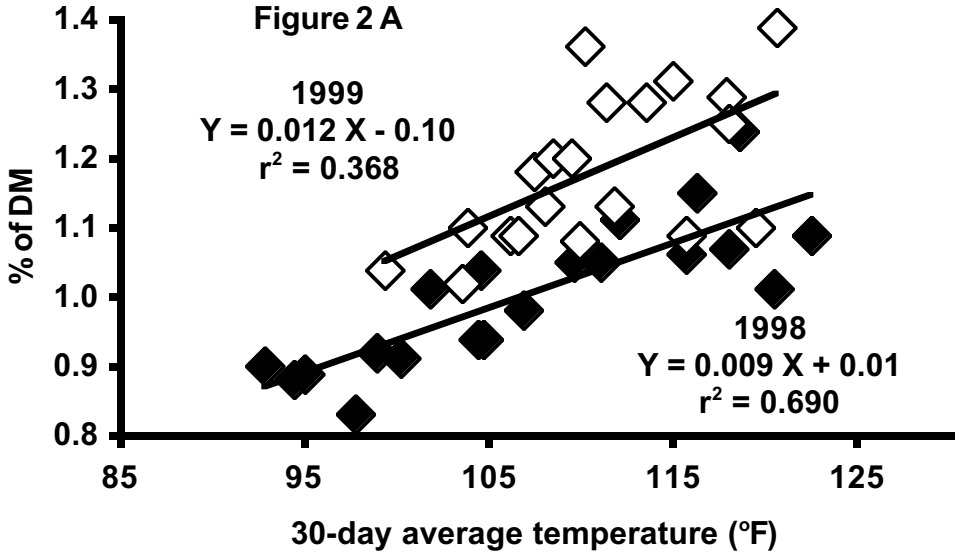


Figure 1. Linear regressions ($P \leq 0.01$) of rumen escape N (% of total N) on (A) 30-d average temperature, and (B) maximum internal bale temperature. Data from 1998 are represented by ◆ ; data from 1999 are represented by ◇. In each case, intercepts associated with regression lines for 1998 and 1999 differed ($P < 0.0001$), but slopes did not differ ($P \geq 0.643$).



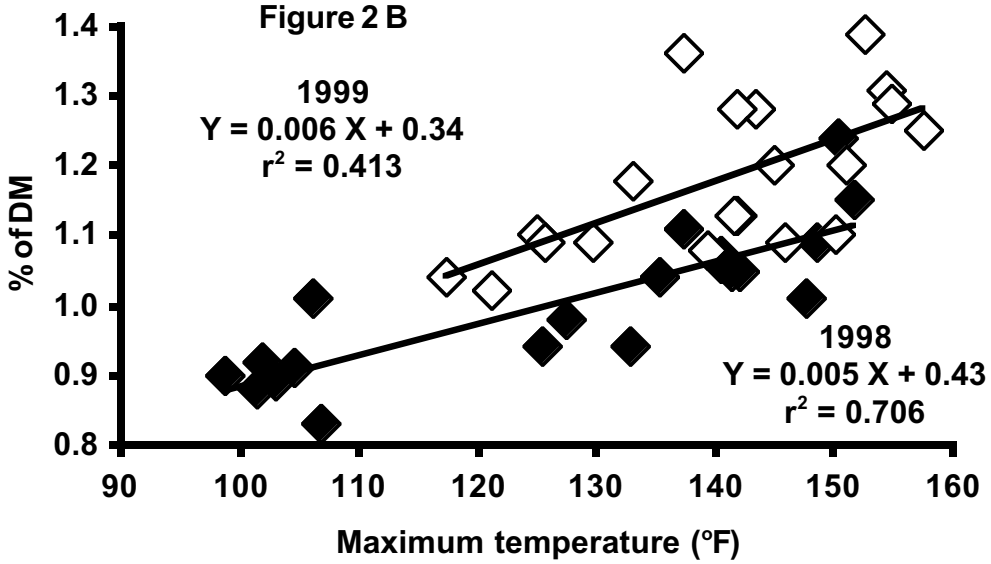


Figure 2. Linear regressions ($P \leq 0.01$) of rumen escape N (% of DM) on (A) 30-d average temperature, and (B) maximum internal bale temperature. Data from 1998 are represented by ◆ ; data from 1999 are represented by ◇. In each case, intercepts associated with regression lines for 1998 and 1999 differed ($P < 0.0001$), but slopes did not differ ($P \geq 0.416$).

Impact of Spontaneous Heating During Storage of Bermudagrass Hay on *In situ* Degradation Kinetics from Steers

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Story in Brief

Spontaneous heating in stored forage has been shown to reduce forage quality and subsequent digestibility of nutrients in alfalfa (*Medicago sativa*) and cool season grasses, but limited information is available for bermudagrass. The impact of spontaneous heating on forage quality was measured by evaluation of degradation of bermudagrass hay from nylon bags suspended in the rumen of five crossbred ruminally cannulated steers (1,023 ± 58.2 lb). Bermudagrass hays that had undergone spontaneous heating, producing either 5, 119, 201, 273, or 401 heating-degree days (HDD; > 95°F) during a 60-d storage period were evaluated for rate and extent of dry matter, fiber, and nitrogen (crude protein) degradation. Effective degradability of dry matter, fiber, and N decreased in a linear manner by 1.6, 1.2, and 2.5 percentage units for each increase of 100 HDD. Therefore spontaneous heating has negative effects on ruminal degradation of bermudagrass hay.

Introduction

Bermudagrass [*Cynondon dactylon* (L.) Pers.] is a major constituent of forage systems in Arkansas and throughout the South. It is commonly stored as a hay crop because of its high level of production in the summer months. Spontaneous heating in stored forages has been commonly reported to occur in hay stored at > 20% moisture (Coblentz et al., 1996). Generally contents of fiber, fiber-bound nitrogen, and lignin increase as levels of accumulated heat increase (Cherney et al., 1987; Coblentz et al., 2000), thereby potentially reducing the availability of forage nutrients (Broderick et al., 1993; Weiss et al., 1986). However, much of the current information pertaining to heat-damaged forages has been conducted in cool-season forages. The objective of this experiment was to evaluate the effect of spontaneous heating during storage of bermudagrass hay on forage degradation in the rumen.

Experimental Procedures

Treatment Hays. Hay was harvested and packaged from a well-established stand of 'Greenfield' bermudagrass at various moisture levels to generate a range of heat accumulation. The bermudagrass was mowed on June 15, 1998 and baled on June 16 at pre-storage moisture levels between 16.9 and 33.6%. Bales were stored on wooden pallets in an open-air pole shed and surrounded with non-heating bales and Styrofoam® to minimize the impact of ambient temperature on internal bale temperature within the stack. Internal bale temperature for each bale was measured with a thermocouple thermometer. Thirty-five was subtracted from the temperature recorded from the thermocouple thermometer on a daily basis. These numbers were added over the 60-d storage period to determine total heating-degree day (HDD) accumulation. Bales were grouped into five groups of five or six bales to achieve a narrow range in heat accumulation within each group, but a wide range of heat accumulation across groups. Bales that had white mold laced throughout were excluded. Average HDD accumulations for each group of bales (treatment) were 5, 119, 201, 273, and 401 HDD. All bales were then composited within treatment and sub-samples were ground in a Wiley mill.

Laboratory Analysis. Forage samples composited across bales within HDD treatment were analyzed for dry matter (DM), ash, neutral-detergent fiber (NDF), acid-detergent fiber (ADF), nitrogen (N), neutral-detergent insoluble N (NDIN), and acid-detergent insoluble N (ADIN).

In Situ Procedure. Five ruminally cannulated crossbred steers (mean BW = 1,023 ± 58.2 lb) were used to determine ruminal degradation characteristics. Steers were housed in individual 11 by 16-ft pens in an open-air pole barn and pens were cleaned regularly. Steers were offered a total-mixed ration twice daily (0700 h and 1700 h) for a total of 2.15% of BW with *ad libitum* access to water. Steers were allowed a 10 d adaptation period to diet and environment prior to initiation of the trial.

Forage samples used for ruminal degradation evaluation were ground and placed into dacron bags. Bags were then placed in the rumen of the five steers simultaneously and incubated for 3, 6, 9, 12, 18, 24, 36, 48, 72, and 96 h.
After removing the bags from the rumen, they were rinsed, and then dried. Residual DM from each bag was sub-sampled and analyzed for NDF, and N.

Statistical Analysis. The amount of DM, NDF, and N

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remaining in the bags was analyzed using SAS NLIN procedures (SAS Inst. Inc., Cary, NC) to determine degradation rate using the nonlinear model of Mertens and Loften (1980). Effective degradability was calculated for DM, NDF, and N and those measurements and degradation rate constants for those parameters were analyzed using SAS regression procedures.

Results and Discussion

Concentrations of organic matter (OM) and hemicellulose declined linearly ($P < .01$) and concentrations of ADF and fiber-bound nitrogen (ADIN) increased ($P < .05$) with increasing HDD. These changes reflect oxidation of more readily digestible carbohydrates from the forage as heating increased. Acid detergent insoluble N concentrations at 401 HDD were 17.62% of total N concentration indicating a high level of heat damage. The 5-HDD treatment fell within the range of normal forages and the 201- and 273-HDD treatments approach levels of ADIN necessary to be considered heat damaged.

Rate of DM degradation (Fig. 1) and effective DM degradability (Fig. 2) decreased linearly ($P < .01$) with increasing HDD. Effective DM degradability decreased by 1.6 percentage units for each increase of 100 HDD. These reductions in degradation rate and effective degradability should result in reduced intake and utilization of the hay by ruminant animals as the level of spontaneous heating increases. The reduction of DM degradation in the rumen should reduce the amount of energy the ruminant animal will be able to derive from the heat-damaged forage.

The NDF degradation rate (Fig. 3) decreased quadratically ($P < .15$) reaching a minimum degradation rate between 200 and 300 HDD. Effective degradability of NDF (Fig. 4) decreased linearly ($P = 0.01$) as HDD increased. Fiber degradation limits forage intake on higher fiber forages such as bermudagrass. Therefore, decreasing the rate of fiber degradation would result in lower forage intake. Since ruminants fed bermudagrass hay derive a considerable amount of their dietary energy from the digestion of forage fiber, the reduction of effective NDF degradation should reduce the amount of energy ruminants can derive from this heat-damaged hay.

Nitrogen degradation rate declined linearly ($P < .01$) as HDD increased (Figure 5). Effective N degradability (Fig. 6) also declined linearly by 2.5 percentage units for each increase of 100 HDD. Therefore, more nitrogen will escape from the rumen as spontaneous heating increases. This would lead to lower total nitrogen utilization since enzymes in the intestine can not degrade much of the heat-damaged forage nitrogen.

Implications

Spontaneous heating decreases the availability of fiber and nitrogen for ruminal degradation. Reductions in digestion rate could limit forage intake and thereby limit total energy intake by the animal. Reductions in ruminal degradability of the fiber and nitrogen from the heat-damaged forage would reduce the availability of both energy and crude protein for the animal. These impacts would not be detected with standard forage analyses. When spontaneous heating has occurred, estimates of intake, energy, and crude protein should be reduced prior to formulating diets for ruminants. Otherwise, reductions in animal performance will occur.

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Table 1. Composition of bermudagrass hays undergoing varying levels of heating degree-day accumulation.

	HDD[a]					Regression components			
Item	5	119	201	273	401	slope	intercept	R^2	P-value
	%								
OM, % of DM	93.5	93.1	93.1	92.8	92.5	-0.0024	93.5	0.96	<0.01
NDF, % of DM	76.8	77.0	77.7	77.0	76.2	-0.0012	77.2	0.14	0.53
Hemicellulose, % of DM	43.0	42.0	40.8	40.3	39.1	-0.010	43.0	0.99	<0.01
ADF, % of DM	33.8	35.0	36.9	36.7	37.1	0.009	34.2	0.82	0.03
N, % of DM	1.87	1.94	1.94	1.83	1.92	0.000017	1.90	0.0029	0.93
NDIN[b], % of DM	1.19	1.26	1.22	1.13	1.18	-0.00013	1.22	0.17	0.49
NDIN[b], % of N	64.0	64.4	63.2	61.2	61.8	-0.0075	64.4	0.67	0.09
ADIN, % of DM	0.12	0.16	0.24	0.25	0.34	0.0006	0.11	0.97	<0.01
ADIN, % of N	6.45	8.25	12.44	13.66	17.80	0.030	5.80	0.98	<0.01

[a]HDD = Heating degree-days, calculated as the summations of the daily increment by which mean internal bale temperature was > 95°F.

[b]NDIN = Neutral detergent insoluble N.

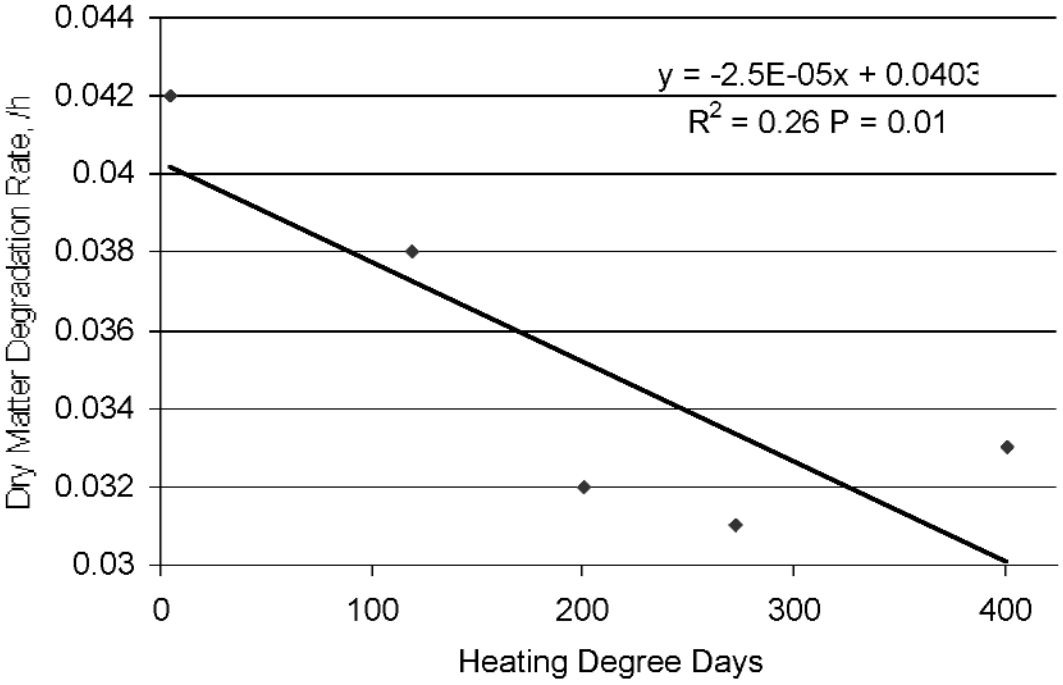

Figure 1. *In situ* dry matter degradation rate of bermudagrass hay undergoing different levels of spontaneous heating. Data points represent the mean of five observations.

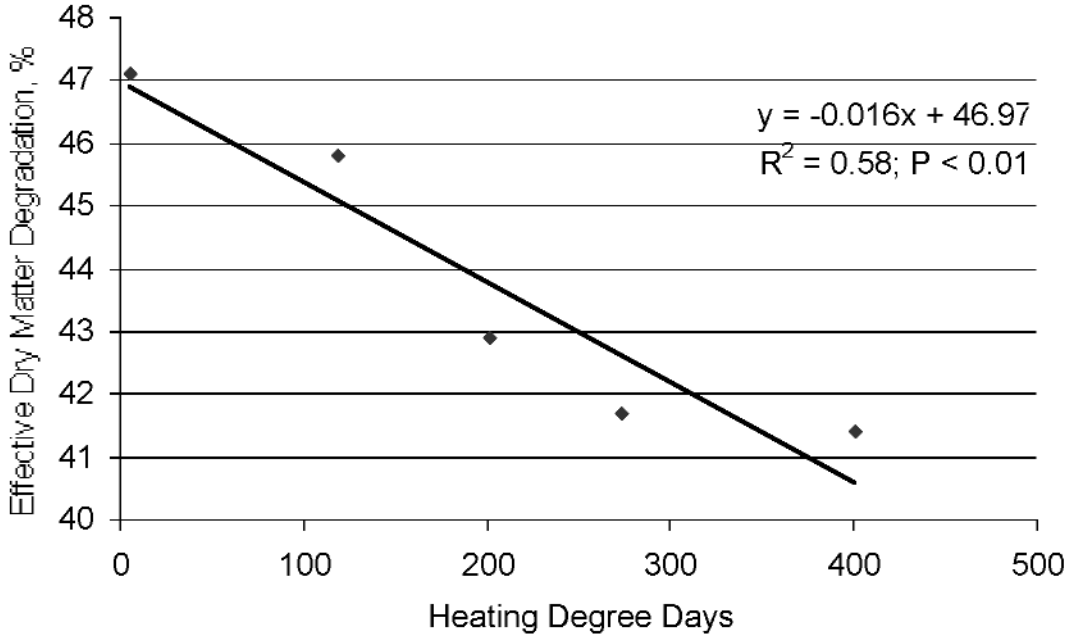

Figure 2. *In situ* effective dry matter degradability of bermudagrass hay undergoing different levels of spontaneous heating. Data points represent the mean of five observations.

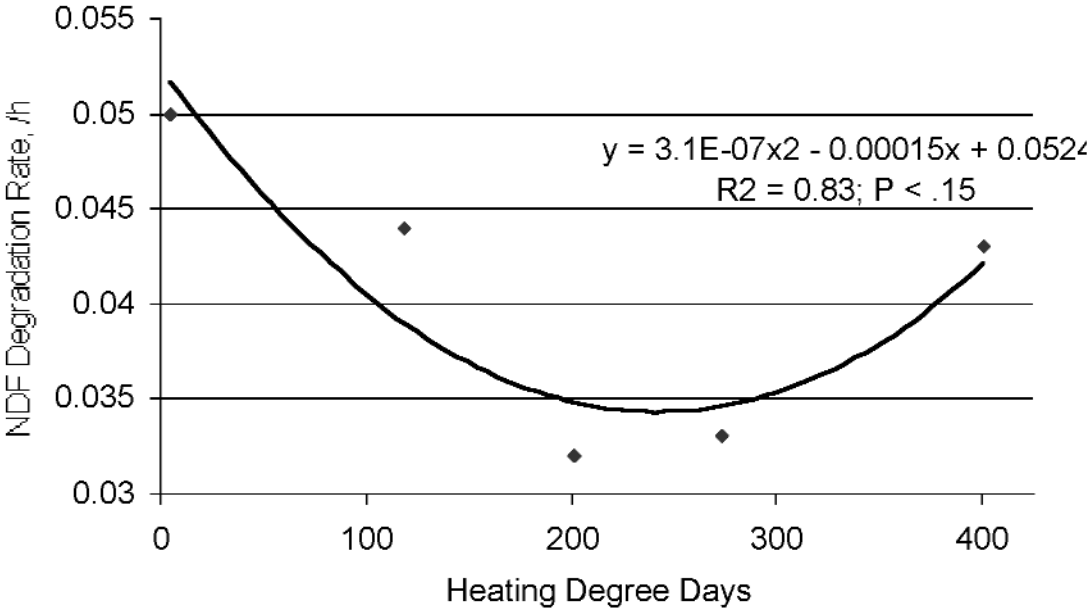

Figure 3. *In situ* neutral-detergent fiber degradation rate of bermudagrass hay undergoing different levels of spontaneous heating. Data points represent the mean of five observations.

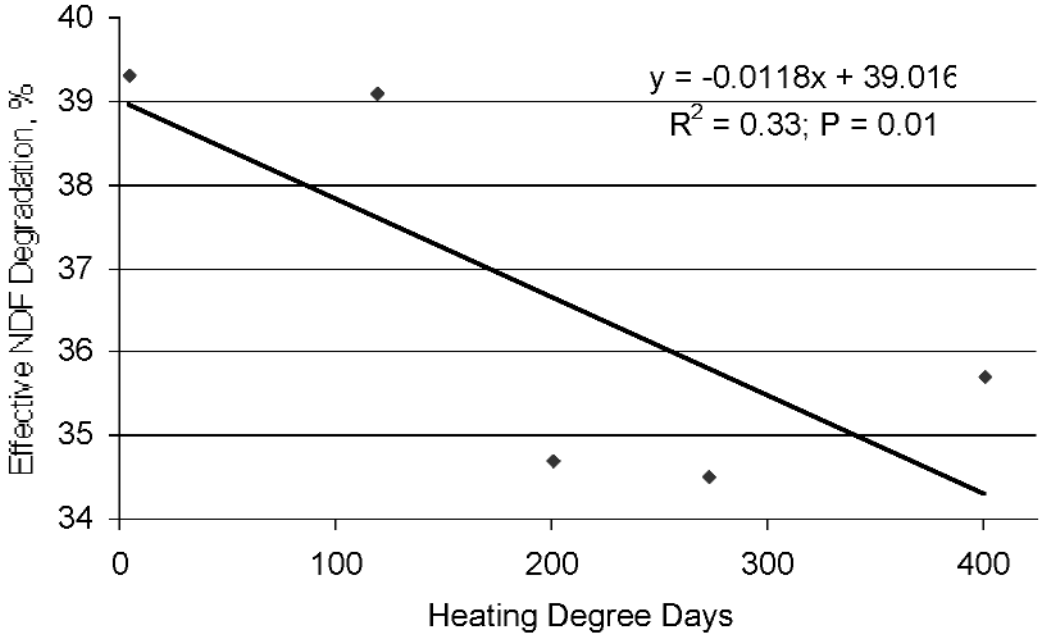

Figure 4. *In situ* effective neutral-detergent fiber degradability of bermudagrass hay undergoing different levels of spontaneous heating. Data points represent the mean of five observations.

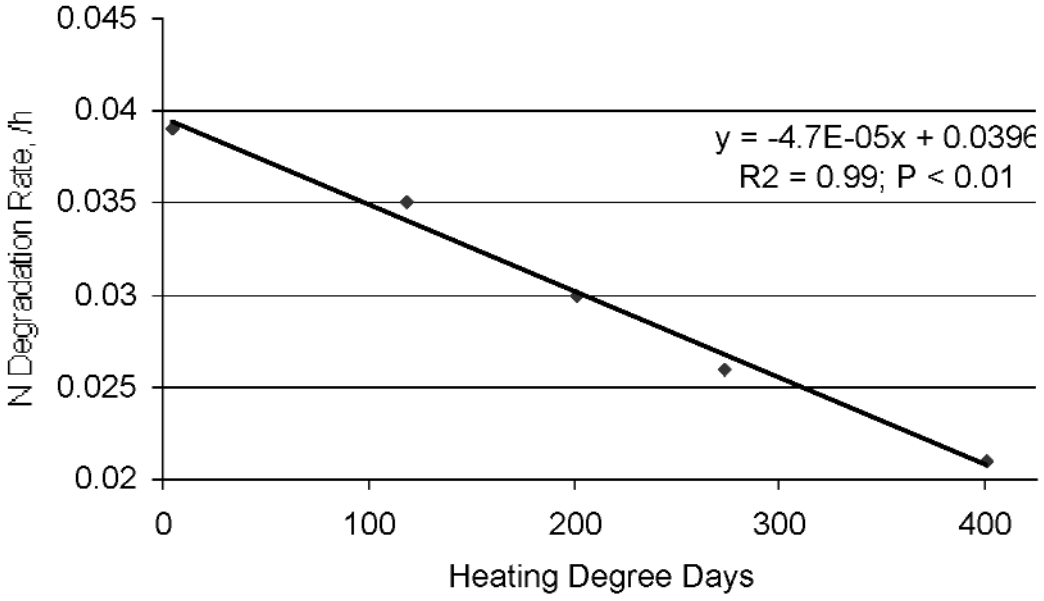

Figure 5. *In situ* nitrogen degradation rate of bermudagrass hay undergoing different levels of spontaneous heating. Data points represent the mean of five observations.

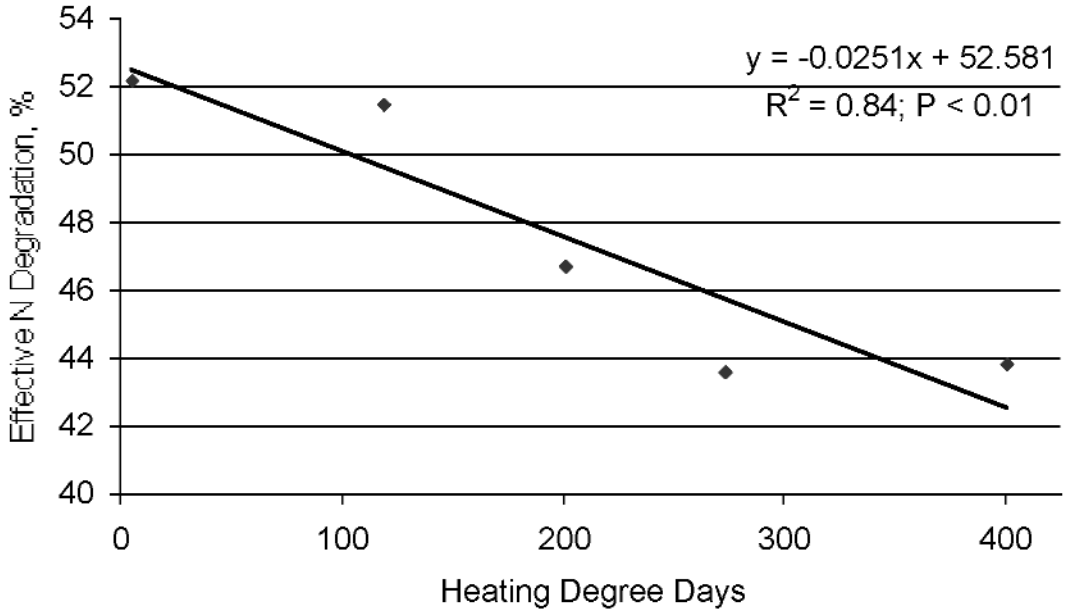

Figure 6. *In situ* effective nitrogen degradability of bermudagrass hay undergoing different levels of spontaneous heating. Data points represent the mean of five observations.

Update: Influence of Grazing System and Stocking Rate on Performance of Stocker Calves

K. A. Cassida, C. B. Stewart, S. A. Gunter, and P. A. Beck[1]

Story in Brief

Interest in rotational grazing is increasing because of perceived benefits in animal performance, forage yield, and forage utilization compared to continuous grazing. We compared stocker calf performance on rotationally- and continuously-stocked winter annual/bermudagrass pastures at three stocking rates in southwestern Arkansas for a second year. In 2000, calves began grazing three weeks later than in 1999, resulting in a shorter winter annual grazing period. There were no differences between grazing systems when calves were grazing pure winter annuals (March-April). During the transition period (May-June) between winter annuals and warm-season grass, rotationally-stocked calves at medium and high stocking rates had better ADG and gain per acre than continuously-stocked calves. Calf performance did not differ between grazing systems when calves were grazing warm-season grass (July-August). For the entire year, stocking rate was negatively related to hay yield and positively related to gain per acre and hay fed. More hay was harvested and less was fed on rotational versus continuously-stocked systems. This update supports data from 1999 that rotational stocking at higher stocking rates on pastures that contain primarily winter annuals (during winter annual or transition forage periods) may increase calf ADG, gain per acre, and hay yield over continuous stocking. However, there was no advantage to either grazing system at low stocking rates on winter annuals or any stocking rate on warm-season grass.

Introduction

Interest in rotational grazing methods is increasing because of perceived benefits to cattle ADG, stocking rates, gain per acre, forage production, and control of forage utilization. However, it has proved difficult to demonstrate these effects in controlled research trials. We are conducting a long-term trial to compare continuously- and rotationally-managed pastures at fixed stocking rates used to create conditions of understocking, ideal stocking, and overstocking. Each pasture is managed for maximum productivity within the stocking rate restriction. Excess forage is harvested as hay. Overall objectives of the experiment are to evaluate calf performance; forage production, quality, and botanical composition; soil fertility changes; net returns; and stability of production and net returns over the entire 5-yr period. In this paper, animal performance results from the second year are presented and compared with results from the first year.

Experimental Procedures

Details of experimental design and procedures can be found in Cassida et al. (2000). To summarize: a 5-year trial is being conducted at the Southwest Research and Extension Center (SWREC) in Hope, AR using twelve 2-acre pastures in a completely randomized design with two replications and a 2 x 3 factorial treatment arrangement. There are two grazing systems: continuous stocking (C) and a six-paddock rotational system (R); and three fixed stocking rates designed to produce understocked (LOW), ideal (MED), and overstocked (HIGH) pasture conditions.

Most procedures followed in 2000 (year 2) were the same as in 1999 (Cassida et al., 2000). Stocking rates remained at two, three, and four calves/acre for LOW, MED, and HIGH. Two changes were made in overseeded winter annual species for 2000. Ladino clover was replaced with 'Bigbee' berseem clover (12 lb PLS/acre) because the ladino stand failed in 1999 and Bigbee has performed well in plot trials at SWREC. 'Variety not stated' wheat was replaced with the improved wheat cultivar 'Coker 9542'. Winter annuals (wheat, annual ryegrass, crimson clover, berseem clover) were drilled October 27 through November 2, 1999. Calves were turned out on March 8, 2000 and grazed until September 5. Calves were supplied on a grazing contract and consisted of preconditioned (weaned, vaccinated, dehorned) mixed breed heifers (initial weight at turnout, 492 lb) that had been assembled from local sales. Heifers were dewormed with ivermectin and implanted with component E-H prior to turnout. Hay was harvested in April, May, and June from pastures with excess forage. Pastures that were not grazed close were mowed prior to planting annuals in fall 1999 because there was not enough residual forage to bale hay. Ammonium nitrate (30 lb N/acre) was applied to pastures in November, February, and May.

Data were analyzed using PROC GLM with initial animal weight and animal gender as covariates (SAS Inst. Inc, Cary, NC). Pasture was the experimental unit. The grazing

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season was divided into three periods by forage types: February through April (winter annual period), May through June (transition period), and July through September (warm-season-grass period). Stocking rate effects were analyzed as linear and quadratic polynomial contrasts. Time effects (periods and year) were analyzed as split plots over time with period as the subplot and year as the sub-subplot. Period differences were analyzed as orthogonal contrasts.

Results and Discussion

For the year 2000 overall, there were no differences in animal performance between the C and R systems (Table 1). Stocking rate was linearly related to final body weight, ADG, gain per calf, and gain per acre. During the winter annual period, ADG and gain per acre were linearly related to stocking rate, and there was no difference between grazing systems. During the warm-season grass period, ADG did not differ with stocking rate or system, but gain per acre increased linearly with stocking rate.

There was a system x stocking rate interaction for ADG during the transition forage period when pasture composition was changing from cool to warm-season grasses in 2000. As was observed in 1999, transition pastures contained primarily winter annual for R and contained a higher proportion of warm-season grass for C (data not shown). At the MED and HIGH stocking rates, ADG and gain per acre were higher on R pastures than on C pastures in 2000. In contrast, cattle performed better on C than R pastures during the transition period in 1999 (Cassida et al., 2000), an effect attributed to poor forage quality of over-mature winter annual pasture on R treatments. In 2000, excess forage was cut as hay about 6 weeks earlier (mid-April versus late May) than in 1999. This prevented R pastures from becoming as mature as they had in 1999 and probably kept higher quality winter annual forage in front of the R cattle in 2000. Forage quality samples are being analyzed to investigate this.

Pooled year data were analyzed in all possible subsets to investigate the source of interactions. All animal performance variables showed significant four-way interactions (system x stocking rate x period x year, $P < 0.05$). The most consistent finding was a positive linear relationship between stocking rate and gain per acre in transition and warm-season grass periods, and for the grazing season as a whole. Among periods, benefits for R versus C grazing systems were only found at MED or HIGH stocking rates in the winter annual (1999) or transition (2000) periods. Since winter annuals were the major component of R pastures in both of these periods, it is possible that the same factors accounted for results in both years. In 2000, spring grazing began about three weeks later than in 1999, which shortened the duration of the winter annual period. If the better pasture management described above for 2000 also improved forage quality during transition period, the combined effect may have been to push the benefit of the R treatment forward into the transition period in 2000.

In 2000, hay feeding was required on C-MED, C-HIGH, and R-HIGH pastures to cover forage shortages. In 2000, more hay was baled on R than on C pastures ($P < 0.05$), with some hay harvested from all R stocking rates (Table 1). More hay was fed than was baled on C-MED and C-HIGH pastures. There were no interactions with year in the pooled year hay analysis. Averaged across years, more hay was fed on C than R pastures (0, 875, 2106, and 0, 0, 471 lb hay DM/acre, $P < 0.05$, for LOW, MED, and HIGH on C and R pastures, respectively). Less hay was baled on C than R pastures (3761, 270, 0, and 4512, 2507, 1622 lb hay DM/acre). Across years, amount of hay fed and harvested was linearly related ($P < 0.01$) to stocking rate for both systems. Less ($P < 0.05$) hay was harvested in 2000 than in 1999 (Cassida et al., 2000) as a result of cutting hay at earlier maturity (hence lower yields) and drought. Less ($P < 0.05$) hay was fed on C pastures in 2000 than in 1999.

Implications

Rotational stocking at medium to high stocking rates may produce better ADG, gain per acre, and hay yield than continuous stocking when calves graze pastures that contain primarily winter annuals. On warm-season-grass pastures, grazing system does not affect calf performance. Stocking rate has a greater effect on calf performance than grazing system.

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Table 1. Calf performance and hay baled and fed under rotational or continuous stocking at 2, 3, or 4 calves/acre (LOW, MED, HIGH) from March 8 to September 5, 2000[a]

	Continuous System			Rotational System			Statistical significance
	LOW	MED	HIGH	LOW	MED	HIGH	
Winter annual period (Mar 8 - Apr 30, 54 days)							
Body weight, lb	664	675	661	681	648	644	system x SR †
ADGb, lb/day	2.31	2.34	2.26	2.51	2.09	1.94	SR linear*
Gain, lb/calf	125	126	122	135	113	105	SR linear*
Gain, lb/acre	280	390	552	308	382	474	SR linear**
Forage transition period (May 1 - Jun 30, 61 days)							
Body weight, lb	739	732	703	739	725	723	SR linear†
ADG, lb/day	1.44	1.07	0.80	1.09	1.43	1.49	system x SR*
Gain, lb/calf	88	65	49	66	87	91	system x SR*
Gain, lb/acre	154	158	168	114	228	316	SR linear†
Warm-season grass period (Jul 1 - Sep 5, 67 days)							
Body weight, lb	816	808	775	790	810	789	NS
ADG, lb/day	1.09	1.08	1.03	0.74	1.22	0.93	NS
Gain, lb/calf	73	72	69	49	82	63	NS
Gain, lb/acre	154	210	286	101	256	262	SR linear**
Year 2000 (Mar 6 - Sep 5, 182 days)[c]							
Body weight, lb shrunk	780	758	726	758	758	740	SR linear**
ADG, lb/day	1.76	1.72	1.54	1.62	1.73	1.61	SR linear**
Gain, lb/calf	287	266	234	265	265	248	SR linear**
Gain, lb/acre	650	870	1131	594	954	1186	SR linear***
Hay fed, lb DM/acre	0	324	1708	0	0	410	SR linear*
Hay baled, lb DM/acre	1752	0	0	3475	1622	477	SR linear**, system*

†,*, **, *** Effects were significant at the 0.10, 0.05, 0.01, and 0.001 levels of probability, respectively.
[a]Animal data is presented as least-squares means.
[b]NS=not significantly different, SR=stocking rate, ADG=average daily gain, DM=dry matter.
[c]Weights for full year data are based on shrunk weights, interim period weights are not shrunk.

Effects of Tall Fescue Inoculated with Novel Endophytes on Steer Growth and Development

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Story in Brief

Fescue toxicosis is thought to be caused by ergot alkaloids produced by the endophyte *Neotyphodium coenophialum*. A study was designed to determine if cattle grazing tall fescue infected with novel endophytes show signs of fescue toxicosis. Steers were allotted to paddock treatments of novel endophyte (HiMag 4 and HiMag 9), endophyte-infected (E+), and endophyte-free (E-) tall fescue. Average daily gain (ADG), respiration rate, rectal temperature, and hair scores were determined during the grazing period. Blood was collected via jugular veni-puncture and used for prolactin analysis. Steers grazing novel endophyte varieties had similar weight gains as steers grazing the E- variety, and greater gains ($P < 0.05$) than steers on E+ paddocks. Steers grazing E+ paddocks had higher ($P < 0.05$) respiration rates, rectal temperatures, and hair scores, compared with steers grazing novel endophyte and E- paddocks. Prolactin concentrations were suppressed ($P < 0.05$) in steers grazing E+ paddocks compared to steers grazing novel endophyte and E- paddocks.

These results indicate that tall fescue varieties infected with novel-endophytes, which are void of the ergot alkaloids, may alleviate the fescue toxicosis problem by enhancing animal production, while protecting the plant from environmental stressors.

Introduction

Tall fescue (*Festuca arundinaca schreb*) is a very popular forage for beef producers throughout portions of the United States because of its persistence and quality. However, a large portion of the fescue plants are infected with an endophytic fungus (*Neotyphodium coenophialum*) that results in stress tolerance for the plant, but toxic effects on cattle. In fact, losses in cattle production due to fescue toxicosis have been estimated at $600 million annually (Hoveland 1993).

The grazing trial presented in this report is part of a long-term research project aimed at developing tall fescue varieties that have stress tolerance and are not toxic to animals. Our objective was to determine if cattle grazing tall fescue varieties containing an endophyte that does not produce ergot alkaloids show signs of fescue toxicosis.

Experimental Procedures

A two-year grazing study was conducted at the Arkansas Agricultural Experiment Station, Fayetteville and the Southwest Missouri Research Center, Mount Vernon. Procedures and results are presented by location due to differences in management and design.

Development of varieties: The experimental grasses ('HiMag 4' and 'HiMag 9') were developed by collecting fescue plants from around the world. Those plants and their associated endophytes were screened based on their production of ergot alkaloids. The endophytes which did not produce ergot alkaloids were considered novel endophytes, and were transferred into the endophyte-free tall fescue variety 'HiMag', which was developed at the University of Missouri.

Fayetteville paddocks: Initially, eight 4-acre paddocks were randomly selected for seeding to one of four tall fescue varieties. The four varieties were endophyte-infected Kentucky-31 (K-31; E+), endophyte-free HiMag (E-), HiMag 4, and HiMag 9. Therefore, each variety had two replicate paddocks except one of the E+ paddocks was overtaken by annual ryegrass and was removed from the study. For the second year, another replicate paddock (4 acres each) of each variety was added. Again, the same E+ paddock was overtaken by annual ryegrass and was removed from the study. Each paddock had a mesh covered shade and was randomly assigned four crossbred steers. Forage was maintained in a vegetative state by mowing and(or) grazing by additional animals.

Mount Vernon paddocks: Nine 2-acre paddocks were randomly assigned to seeding with one of three tall fescue varieties. The varieties used were E+, E-, and HiMag 4. Each

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of the nine paddocks (no shade) had three crossbred steers randomly assigned. Forage availability was maintained in the vegetative state by grazing additional animals.

At both locations, steers had *ad libitum* access to mineral supplement and water during the grazing season which was approximately 150 days, initiated in June and concluded in October. Steers were weighed and blood collected at 28 day intervals throughout the grazing season. Blood was used to prepare serum which was analyzed for prolactin concentrations. In addition, steer body temperature and respiration rates were determined on days when daytime temperatures exceeded 90°F. At Mount Vernon, steer hair coat was scored based on the following system: 1 = slick, short-haired animal (less than 1/2" in length); 2 = has some medium length hair (1/2" to 1"); 3 = medium length hair coat covers most of the body; 4 = medium hair plus some rough, long, dead hair; 5 = hair coat consists primarily of rough, long, and dead hair.

Within each location data from both years were combined and least squares means ± standard error are presented. Analysis was conducted using a general linear model (SAS Institute, Inc. Cary, NC). In the model, forage variety and year were treated as class variables.

Results and Discussion

Fayetteville results: Values shown in Table 1 represent the mean for the combined year effect for each item. Steers grazing E+ had a lower ($P < 0.05$) ADG (0.93 lb/d) than steers grazing HiMag 4, HiMag 9, and E- (1.43, 1.36, and 1.61 lb/d, respectively). Mean respiration rates were higher ($P < 0.05$) in cattle grazing E+ (91.3 breaths/min) compared to those steers grazing HiMag 4, HiMag 9, and E- (59.8, 62.3, and 63.3, respectively). Mean rectal temperatures for steers grazing E+ pastures (105.3°F) were higher ($P < 0.05$) than in cattle grazing HiMag 4, HiMag 9, and E- pastures (103.6, 103.8, and 103.5°F, respectively). Mean prolactin concentrations were higher ($P < 0.05$) in cattle grazing E+ pastures (42.48 ng/ml), compared to the cattle grazing E-, HiMag 4, and HiMag 9 (152.46, 146.82, and 165.32 ng/ml, respectively).

Mount Vernon results: Table 2 presents the combined year means for each item. Average daily gain (ADG) was decreased ($P < 0.05$) in steers grazing E+ (0.55 lb/d), compared to that of steers grazing E- (1.21 lb/d) and HiMag 4 (1.21 lb/d). Mean hair score for cattle grazing E+ (3.96) was higher ($P < 0.05$) than those grazing HiMag 4 (2.46) and E- (2.13) pastures. Cattle grazing E+ pastures had higher ($P < 0.05$) respiration rates (122.8 breaths/minute), compared to those grazing E- and HiMag 4, which were 93.2 and 103.6, respectively. Mean rectal temperature for steers grazing E+ was 106.3°F. This was higher ($P < 0.05$) than for steers grazing E- (104.3°F) and HiMag 4 (104.9°F), which were different from each other ($P < 0.05$). Mean prolactin concentrations were lower ($P < 0.05$) in cattle grazing E+ pastures (16.46 ng/ml), compared to cattle grazing E- and HiMag 4 (108.27 and 154.63 ng/ml, respectively). The results of this study confirm other studies (Bouton et al., 2000) that indicate that tall fescue can be inoculated with non-toxic endophytic fungus.

Implications

Both novel endophtye varieties (HiMag 4 and HiMag 9) of tall fescue survived the hot and dry summers during this grazing trial. In addition, those varieties produced animal gains and physiological responses similar to the endophyte-free control steers. These forages could be very useful for profitable production of livestock.

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Table 1. Growth and physiological variables for steers grazing endophyte-infected (E+), novel-endophyte (HiMag 4, HiMag 9), or endophyte-free (E-) tall fescue for the Fayetteville, AR location.

	Variety of tall fescue				
Item	E+	HiMag 4	HiMag 9	E-	SE
ADG, lb	.93[a]	1.43[b]	1.36[b]	1.61[b]	0.05
Respiration rate, breaths/min	91.3[a]	59.8[b]	62.3[b]	63.3[b]	3.84
Rectal temperature, °F	105.3[a]	103.6[b]	103.8[b]	103.5[b]	0.2
Serum prolactin, ng/ml	42.48[a]	146.82[b]	165.32[b]	152.46[b]	31.21

[a,b]Within a row, means without a common superscript letter differ (P < 0.05). Data are presented as least-squares means ± standard error. These figures represent the overall means of each variable for both years of the combined study.

Table 2. Growth and physiological variables for steers grazing endophyte-infected (E+), novel-endophyte (HiMag 4), or endophyte-free (E-) tall fescue for the Mount Vernon, MO location.

	Variety of tall fescue			
Item	E+	HiMag 4	E-	SE
ADG, lb	0.55[a]	1.21[b]	1.21[b]	0.07
Mean hair score, 1-5d	3.96[a]	2.46[b]	2.13[b]	0.15
Respiration rate, breaths/min	122.8[a]	103.6[b]	93.2[b]	3.76
Rectal temperature, °F	106.3[a]	104.9[b]	104.3[c]	0.24
Serum prolactin, ng/ml	16.46[a]	154.63[b]	108.27[b]	21.82

[a,b,c]Within a row, means without a common superscript letter differ (P < 0.05). Data are presented as least-squares means ± standard error. These figures represent the overall means of each variable for both years of the combined study.

[d]Hair scores based on the following system: 1 = slick, short-hair; 2 = some medium length hair; 3 = medium length hair over most of the body; 4 = medium hair plus some rough, long, dead hair; 5 = primarily rough, long and dead hair.

Macromineral Concentrations of Grazed Forage Fertilized with Broiler Litter

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

Story in Brief

Three farms in Northwest Arkansas and Northeast Oklahoma that utilized broiler litter for fertilizer were monitored for nutrient cycling from April 2000 to February 2001. Forage samples were taken monthly and analyzed for K, Ca, P, and Mg. Concentrations of these minerals in the forages were compared to the requirements of gestating and early lactating beef cattle. The grass tetany ratio (K/[Ca + Mg]) was calculated for each farm at each sampling date to determine the likelihood of grass tetany problems. Calcium and P concentrations for all farms met or exceeded requirements for gestating cows on all dates during the grazing season, and exceeded requirements for lactating cows from April through December. Potassium concentrations from all three farms exceeded the requirements for lactating beef cows from March through early January. Magnesium concentrations on Farm 1 were deficient for cattle in early lactation throughout much of the year except for April and May and were deficient for Farm 3 from early November through February. Forages from Farms 2 and 3 had sufficient quantities of Mg throughout most of the grazing season to meet the requirements of lactating beef cows. However, the grass tetany ratio was above the desirable threshold for all farms throughout the typical spring grass tetany season (February to April) indicating a strong potential for grass tetany on these pastures. Therefore, pastures fertilized with broiler litter may meet the macro-mineral requirements of lactating beef cows, but the grass tetany ratio may be sufficiently high to warrant supplementation of cattle diets with Mg to prevent tetany problems.

Introduction

Broiler litter is commonly applied by many Arkansas cattle producers as fertilizer for pastures and hay meadows. Since litter is usually applied to meet the nitrogen needs of the crop there is often a surplus of nutrients beyond those required for forage growth. Concerns over these nutrients contaminating surface waters has prompted regulations and guidelines that could severely limit the amount of litter that may be spread in some areas. Limiting the use of broiler litter as a fertilizer could significantly increase the cost associated with using commercial fertilizers to produce quality forage. However, since many nutrients are applied in excess of crop needs when applying litter, producers can lower fertilizer cost by having their soil and forage analyzed to determine which specific nutrients need to be added in commercial fertilizers. Nutrient concentrations can vary in forages depending on forage species, maturity of forage, soil fertility, season, and type and amount of fertilizer added. The purpose of this study was to evaluate the concentration of nutrients and the seasonal changes that occur in forages that are fertilized with broiler litter and contrast those concentrations to the nutrient requirements of beef cattle.

Experimental Procedures

Three farms were chosen from a nutrient sensitive watershed in Northwest Arkansas (Farms 1,2) and Northeast Oklahoma (Farm 3). A single pasture was selected from each farm and monitored for additions and removal of nutrients from April 2000 to February 2001. Soil samples were taken from each farm in February, 2000 and analyzed for total phosphorus. Farm 1 was located on Nixa silt loam soil having an average soil phosphorus level of 470 lb/acre. The 16-acre pasture consisted of a mixture of bermudagrass and ryegrass forage. It was continuously grazed except for a period of about 2.5 mo. (early June to mid August) when it was harvested for hay. Broiler litter was applied in April 2000 at 2 tons/acre. Farm 2 was also located on a Nixa silt loam soil having an average soil phosphorus level of 567 lb/acre. Forages were predominantly fescue and bermudagrass on 6 acres that were continuously grazed. Broiler litter was not applied in 2000 but had been applied in previous years. Commercial fertilizer was applied as nitrogen (NH4NO3) at 200 lb/acre and potash (K2O) at 100 lb/acre.

Farm 3 was located on a Newtonia silt loam soil with an average soil phosphorus value of 252 lb/acre. Ten acres of bermuda and white clover were grazed on a rotation with other nearby fields of similar size. Broiler litter was applied at 2 tons/acre in the early spring.

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Four cages were placed in each field to prevent grazing and to allow forage growth to be evaluated. Available forage was measured inside and outside the cages to estimate forage removal by cattle. Cages were moved monthly and forage samples were clipped from the pastures and analyzed for nutrient content. Macromineral concentrations of the forage were compared to the nutrient requirements of beef cattle (Davis, 1996). Requirements for cattle that were gestating and in early lactation were used.

Results and Discussion

In general, forage concentrations of K, Ca, and P were in excess of the recommended nutrient requirements for beef cattle throughout most of the grazing season from all three farms. Potassium concentrations were extremely high for all farms in early spring (at least five times the required amount) and continued to stay above the requirement for beef cattle until January (Fig. 1). The lowest concentration of K during the grazing season occurred in June at Farm 1. This concentration was still nearly twice the amount required by early lactating cows. Forage K concentrations fell below animal requirements during February on Farm 3 and during January and February on Farm 1. Calcium concentrations were considerably lower than K concentrations, but most Ca concentrations exceeded requirements for gestating and lactating beef cattle (Fig. 2). Calcium concentrations started high in the spring and slowly decreased to the required amount by winter. The exception to this was forage gathered from Farm 2 in early May that met the Ca requirement for gestating cows but was insufficient for lactating cows. Forage magnesium (Mg) concentrations remained fairly constant throughout much of the grazing season with the exception of Mg concentrations from Farm 1, that decreased and became deficient from late May throughout the remainder of the year (Fig. 3). Forage Mg concentrations remained below the requirements for lactating beef cows during the winter months. Phosphorus levels exceeded cattle requirements at all three farms throughout the grazing season and declined to levels approximating cattle requirements during the winter months (Fig. 4).

High K values coupled with low Ca and Mg values could lead to grass tetany problems. Kemp et al. (1956) found that when the K/(Ca + Mg) ratio was above 2.2 the occurrence of tetany cases increased substantially. This ratio was plotted for each farm based on the concentrations of K, Ca, and Mg in the forage sampled each month (Fig. 5). For all farms, the ratio exceeded the threshold value of 2.2 throughout most of the grazing season and particularly during the spring grass tetany season. The grass tetany ratio fell below this threshold during the winter months when hay would typically be fed. Although the forages contained 0.2 percent Mg or more, caution should be exercised and supplemental magnesium should be fed when the K/(Ca + Mg) ratio exceeds the 2.2 threshold value.

Implications

Forages fertilized with broiler litter may contain macromineral concentrations in excess of the requirements of beef cattle. These concentrations could reduce the need for supplemental minerals, particularly Ca and P. However, excessive concentrations of K in the forage could lead to problems such as grass tetany. When high levels of K are present and Mg and Ca levels are relatively low, supplements of Mg may need to be given to prevent tetany problems, especially in the spring. Prior to using a commercial fertilizer, a soil analysis should be obtained so that only the nutrients deficient in the soil are added. This should lead to more efficient use of fertilizers and help limit problems associated with cattle performance and environmental issues.

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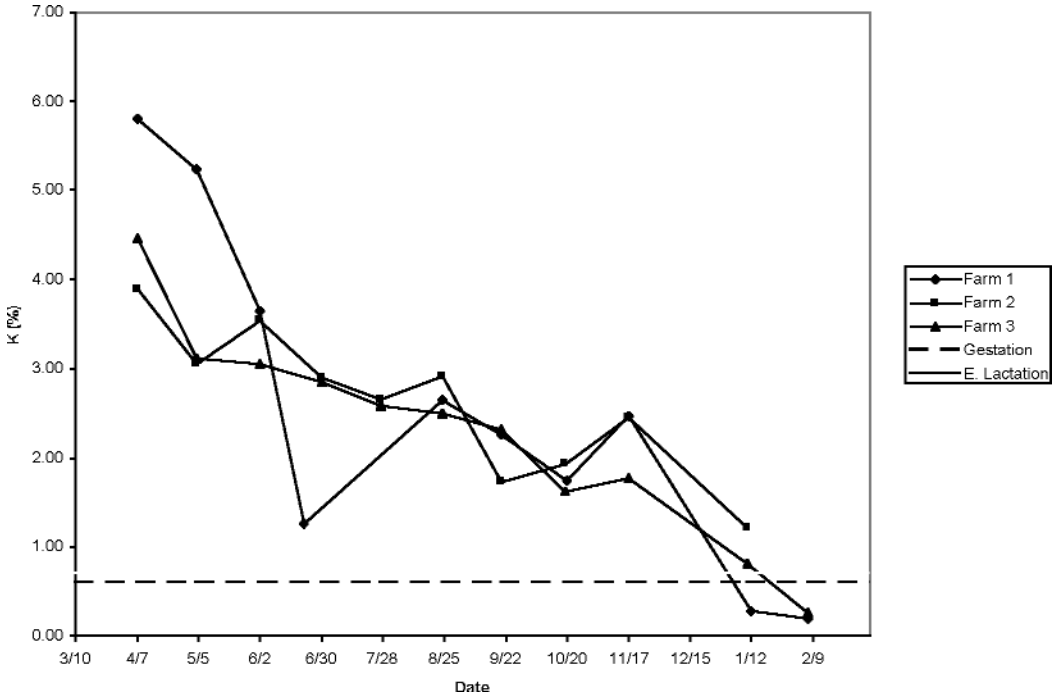

Fig. 1. Potassium concentrations of forage from three farms. Requirements for gestating and early lactating cattle shown.

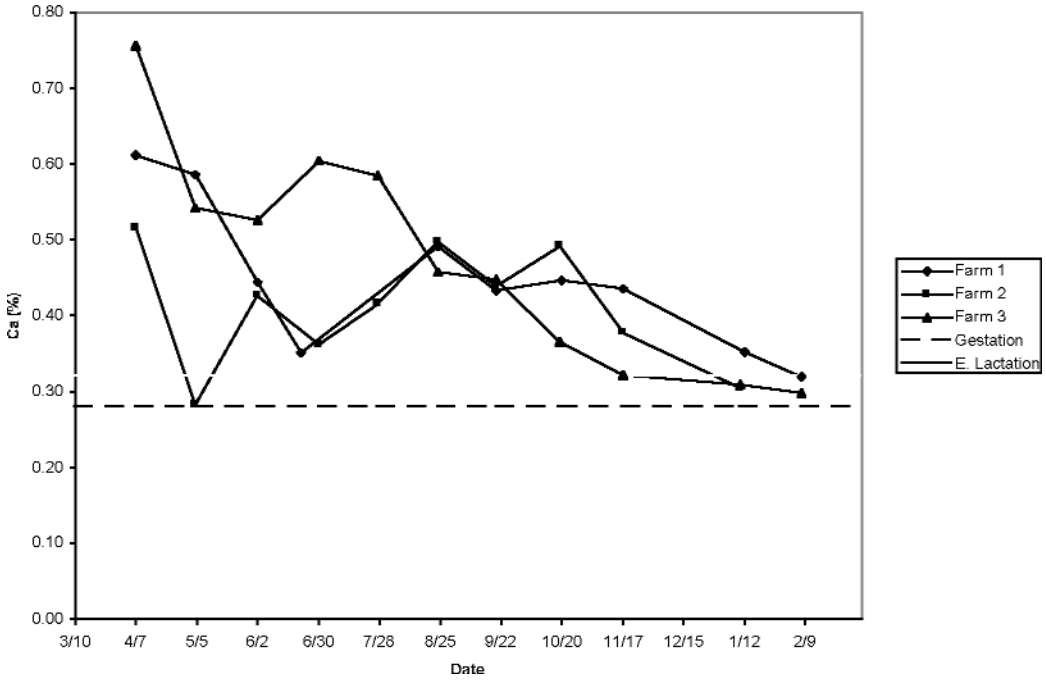

Fig. 2. Calcium concentrations of forage from three farms. Requirements for gestating and early lactating cattle shown.

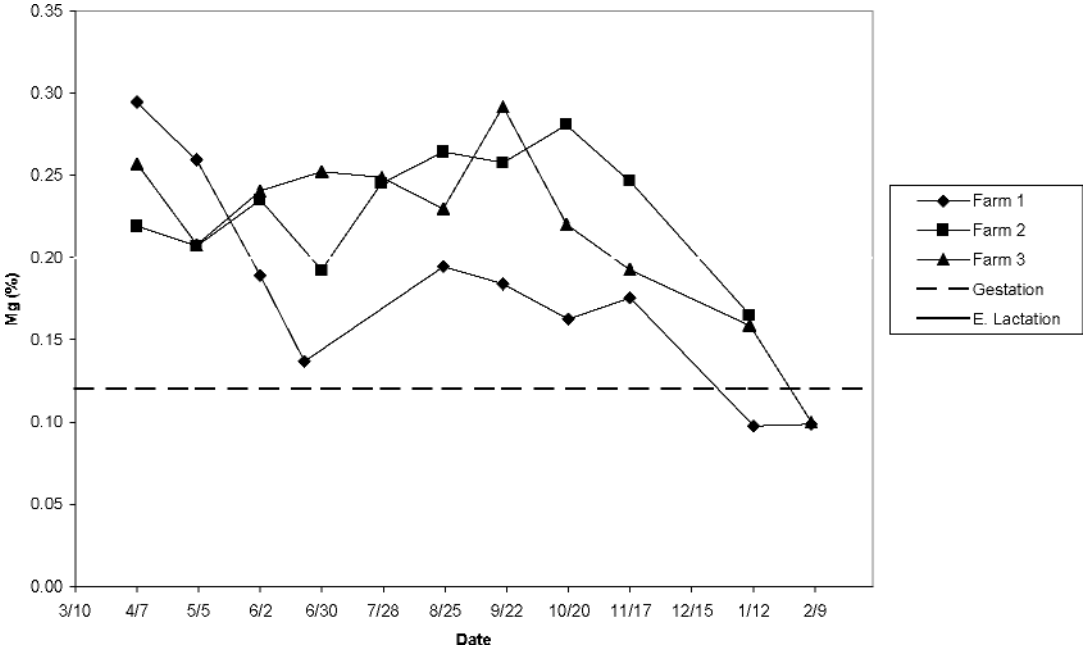

Fig. 3. Magnesium concentrations of forages from three farms. Requirements for gestating and early lactating cattle shown.

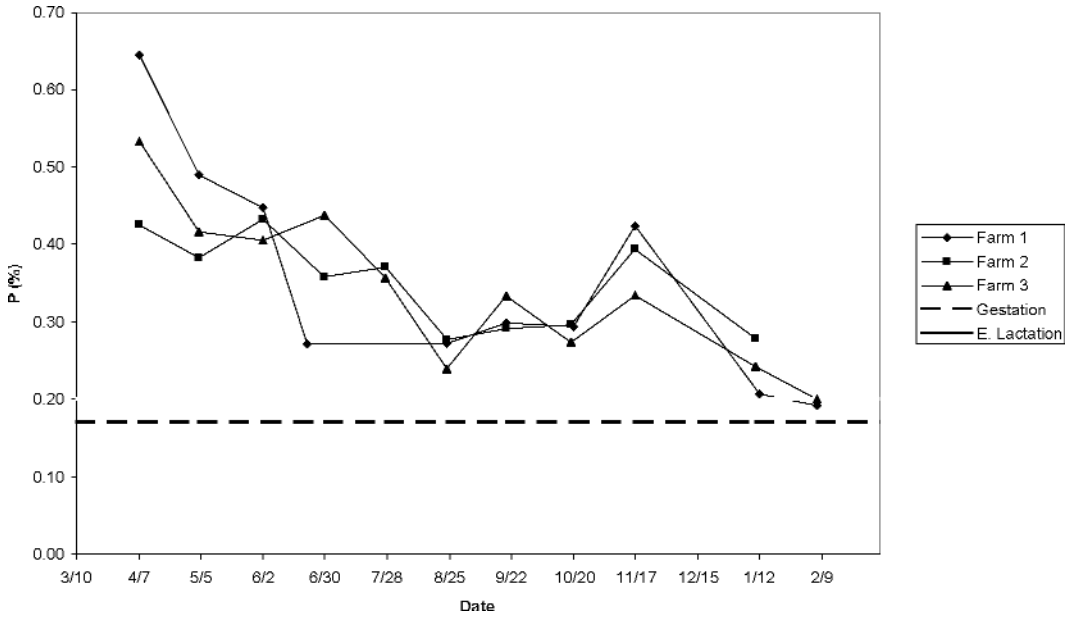

Fig. 4. Phosphorus concentrations of forages from three farms. Requirements for gestating and early lactating cattle shown.

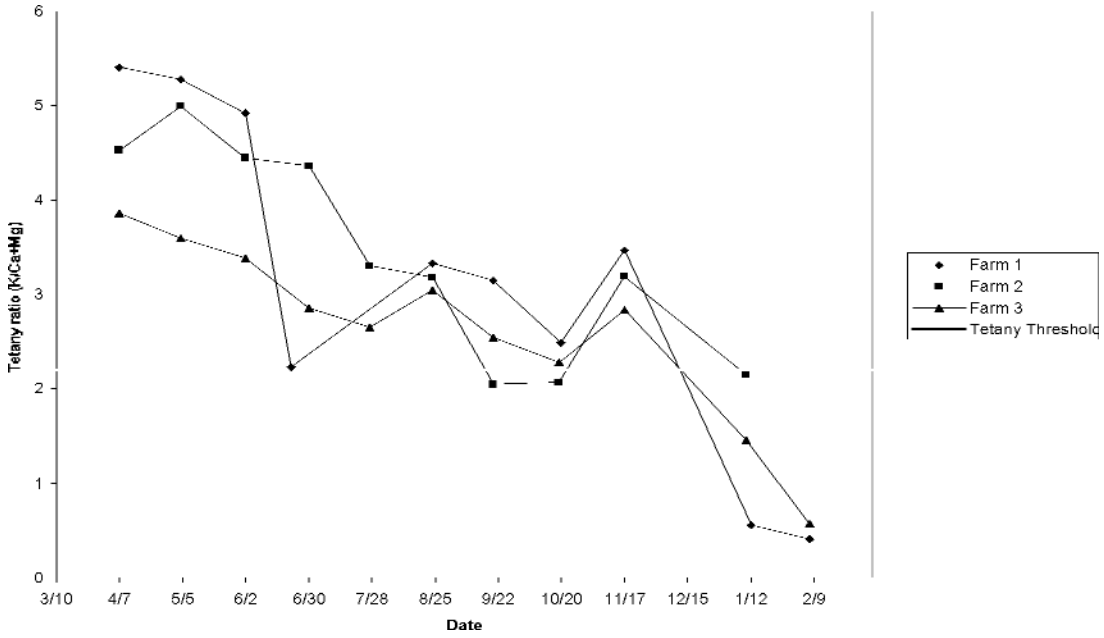

Fig. 5. Grass tetany ratio for three farms fertilized with broiler litter. Threshold value is 2.2.

Yield and Nutritive Value of Eastern Gamagrass at Ten Harvest Dates

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Story in Brief

Yield of 'Pete' eastern gamagrass (EGG; *Tripsacum dactyloides* L.) was evaluated at University of Arkansas Forage Research Farm in Fayetteville, AR. Forage samples were harvested at 7-day intervals beginning on May 15 and ending on July 17, 2000. As EGG matured, plants grew ($P < 0.05$) from 36.7 to 88.6 inches in height, tiller density increased from 7.4 to 43.9/ft^2, and DM yield improved from 1,111 to 8,944 lb/acre. Leaf tissue comprised between 59.9 and 83.2% of the forage DM over the sampling period with the remainder being stems and heads. Neutral detergent fiber (NDF) increased with plant maturity and ranged from 66.2 to 79.0% in whole-plant samples and from 67.1 to 78.5% in leaf samples. Acid detergent fiber (ADF) ranged from 32.3 to 44.5% in the whole plant and from 32.0 to 43.7% in leaves during the experiment. Concentrations of CP declined from 14.4 to 6.3% in the whole plant and from 16.9 to 7.9% in leaves as plants matured. With limited fertilization (50 lb N/acre), EGG demonstrated a tall growth habit, excellent DM yields, and a high proportion of leaf within the canopy.

Introduction

Gamagrass is a perennial, warm season bunchgrass that is native to the eastern half of the United States. It is adapted to moist areas, and grows in clumps that may be more than 3 ft in diameter; plants may also attain heights of 5 to 10 ft. Compared to other tall-growing, perennial warm-season grasses that are native to the Midwest, growth and quality characteristics of 'Pete' eastern gamagrass (EGG) have been incompletely evaluated.

Interest in EGG gained momentum during the late 1980's and 1990's when the cultivar 'Pete' was developed from native EGG populations in Kansas and Oklahoma (Fine et al., 1990). Popularity of EGG has increased because of its ability to produce large quantities of quality forage during the summer months. Studies of the chemical composition of EGG have indicated that concentrations of NDF are generally high (> 60.0%), even at immature stages of growth (Coblentz et al., 1999). The N content may exceed 2.0% at the boot and anthesis stages of growth. Concentrations of fibrous components in EGG resemble those reported commonly for other warm-season grass species; therefore, the proportion of cell wall in whole-plant tissue is high. Concentrations of acid detergent fiber (ADF) have ranged between 29.2 to 44.8% over several studies. The concentration of ADF increases in leaf, stem, and whole-plant tissues and has a positive relationship with plant maturity. EGG produces good regrowth following defoliation, and this allows multiple harvests during the growing season so the grass can be grazed or conserved as hay or silage (Coblentz et al., 1999).

Experimental Procedures

A pasture plot of EGG was established in rows spaced 40-in apart during Spring, 1999. The experimental site was fertilized on May 1, 2000 with ammonium nitrate at a rate of 50 lb N/acre. The plot was divided into four blocks (162.5 x 162.5 ft); forage sampling was initiated on May 15, 2000. Forages were harvested by hand-clipping 39 in of row at an 8-in stubble height with hand shears. On each harvest date, the height of EGG was established by measuring the tallest plants within each 39-in section of row that was sampled on that date. Harvest dates were May 15, May 22, May 29, June 5, June 12, June 19, June 26, July 3, July 10, and July 17 (harvest dates 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10, respectively). Harvested samples were dried to a constant dry weight under forced air at 122°F. Percentages of leaf and stem were determined by separating individual leaves from stems at the leaf collar. Reproductive heads were separated from the stem and not included as stem tissue. Tiller counts were expressed as the number of tillers/ft^2.

Dried whole-plant and leaf samples were ground through a 1-mm screen in a Wiley mill (Arthur H. Thomas, Philadelphia). Both neutral detergent fiber (NDF) and ADF were determined using batch procedures outlined by ANKOM Technology Corp. (Fairport, NY). Concentration of CP was calculated from the % N in each sample, as determined by a modified Kjeldahl procedure (Kjeltech Auto 1030 Analyzer, Tecator, Inc., Herndon, VA).

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Results and Discussion

Plant height and tiller density increased with plant maturity ($P < 0.05$). Plant height at harvest increased from 36.7 to 88.6 in between harvest dates 1 and 10, respectively. Tiller counts for harvests 1 and 10 were 7.5 and 43.9 tillers/ft^2, respectively (Table 1). The number of tillers and the overall trend toward greatly increased tiller density that was observed in this study was comparable with a report by Coblentz et al. (1998), in which EGG was harvested at several stages of growth over a calendar interval that was comparable.

The percentage of leaf tissue varied over harvest dates; the highest percentage was observed on the first harvest date (83.2%) and the lowest on harvest date 8 (59.9%). Tiller counts appeared to affect the percentage of stem tissue in EGG. Tiller counts increased ($P < 0.05$) from 17.0 to 43.9 tillers/ft^2 between June 5 and July 17; concurrently, the percentage of stem tissue declined ($P < 0.05$) from 23.8 to 15.9% over this time period. Percentages of leaf observed in this study were generally higher than those reported in other warm season perennial grasses. Yields of DM increased ($P < 0.05$) with plant maturity from 1,111 lb/acre on harvest date 1 to 8,944 lb/acre on harvest date 10. Our yields of EGG are within the ranges commonly reported in other studies.

The chemical composition of whole-plant EGG is shown in Table 2. In this study, the concentration of NDF in the whole plant was 66.2% on the first harvest date (May 15) and increased ($P < 0.01$) to 79.4% by the eighth harvest date (July 3). Evidently, the heads in the whole plant sample contributed to lower fiber composition. The fiber composition of leaf and whole plant is described by the following equations:

Whole plant NDF % = 66.0 + 0.4258 (days) – 0.0038 (days)^2

Leaf NDF % = 66.7 + 0.3685 (days) – 0.0030 (days)^2

Whole plant ADF % = 33.2 + 0.2859 (days) – 0.0020 (days)^2

Leaf plant ADF % = 31.8 + 0.3918 (days) – 0.0078 (days)^2 + 0.0001 (days)^3. The concentration of NDF and ADF were consistent with findings reported by Coblentz et al. (1998); in that study, EGG harvested at boot stage, anthesis, and full maturity had NDF concentrations of 69.4, 73.1, 78.0%, respectively. Respective concentrations of ADF were 35.3, 39.6, and 44.8% on these same harvest dates (Coblentz et al., 1998).

The CP content of the whole-plant EGG decreased linearly ($P < 0.01$) with maturity: whole plant CP % = 14.2 - 0.1290 (days). The CP concentration in the leaves was best described ($P < 0.01$) by a quadratic equation: Leaf CP % = 16.3 - 0.2393 (days) + 0.0017 (days)^2. Concentrations of CP declined from 14.4 to 6.3% in the whole plant and from 16.9 to 7.9 % in leaf samples over the course of the study. The declining concentrations of CP observed over time are consistent with trends observed in numerous other reports involving EGG and other perennial warm-season grasses.

Implications

Eastern gamagrass produces high yields of DM that increases with plant maturity. However, nutritive quality declined because the concentration of CP was higher at early harvesting dates and declined with maturity and NDF and ADF concentrations increased with maturity. The concentrations of CP and fiber were not dramatically different in leaves compared to whole-plant samples of EGG. Based on DM yield and nutritional characteristics, the first harvest of EGG should occur in late May or early June.

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Table 1. Growth characteristics and DM yield of eastern gamagrass harvested weekly between May 15 and July 17, 2000.

Date	Height	Tillers	Stem	Leaf	Yield
	in	no/ft^2	%	%	lb DM/acre
1	36.7^{f}	7.5^{e}	23.7^{a}	83.2^{a}	1111^{f}
2	46.3^{e}	8.2^{e}	22.4^{d}	75.5^{ab}	1560^{ef}
3	55.7^{e}	10.2^{e}	15.0^{c}	74.7^{abc}	1977^{e}
4	68.2^{c}	17.0^{d}	23.8^{a}	71.0^{bc}	3412^{d}
5	71.5^{c}	25.1^{c}	23.4^{a}	69.4^{bc}	4312^{c}
6	75.9^{b}	30.2^{c}	20.4^{ab}	65.2^{cd}	4572^{c}
7	77.0^{b}	32.5^{b}	16.4^{c}	71.8^{bc}	5055^{c}
8	79.7^{b}	35.0^{b}	16.8^{bc}	59.9^{d}	7233^{b}
9	86.1^{a}	42.4^{c}	16.8^{bc}	69.4^{bc}	8580^{a}
10	88.6^{a}	43.9^{c}	15.9^{c}	82.2^{a}	8944^{a}
SEM	1.4	1.9	2.0	3.5	277

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

Table 2. Chemical composition (DM basis) of whole plant forages harvested at ten dates.

	NDF[1]		ADF[2]		CP	
Harvest	Whole plant	Leaves	Whole plant	Leaves	Whole plant	Leaves
	% of DM					
1	66.2^{b}	67.1^{b}	32.3^{b}	32.0^{c}	14.4^{a}	16.9^{b}
2	67.8	66.9	35.1	33.8	13.1	15.2
3	70.2	69.9	36.7	35.0	12.6	14.0
4	74.4	74.5	38.9	37.6	9.8	11.6
5	73.9	76.3	38.6	38.3	11.1	11.1
6	76.6	75.9	40.3	39.9	10.1	10.0
7	74.2	74.1	39.4	38.9	9.4	9.9
8	79.4	75.9	44.5	40.4	7.1	10.7
9	79.0	78.5	42.2	41.6	6.5	7.9
10	76.2	78.1	43.0	43.7	6.3	7.9
SEM	0.6	0.8	0.9	0.6	0.4	0.5

[1]NDF = neutral detergent fiber
[2]ADF = acid detergent fiber
[a]Linear effect (P < 0.01) with maturity.
[b]Quadratic effect (P < 0.01) with maturity.
[c]Cubic effect (P < 0.01) with maturity.

Climatic Adaptation and Reseeding Potential of Alternative Annual Legumes in Southwest Arkansas

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Story in Brief

Climatic adaptation and reseeding ability of subterranean, persian, rose and balansa clovers, and burr, button, and black medics were evaluated at the Southwestern Research and Extension Center in Hope, Arkansas. Legumes were drilled into clean seedbeds on a Sacul fine sandy loam soil during October 1999, harvested once in spring 2000 when they reached full bloom, and then allowed to regrow and reseed themselves. Reseeded stands were harvested in April 2001. Subterranean clovers were low-yielding but the best reseeders. Rose clover, balansa clover, and button medic had the highest yields in the planted year. Subclovers, balansa clover, persian clover, burr medics and button medics produced good seedling stands in the reseeding year. Persian clover suffered some winter kill in the reseeding year, and yields of medics were reduced by weevil infestation. Balansa, persian, rose, and subterranean clovers and burr and button medics have sufficient climatic adaptation and reseeding ability to warrant further testing for pasture or hay production in southern Arkansas.

Introduction

Legumes are nearly universally desired in mixed species forage stands, where a primary benefit is nitrogen fixation. However, they are difficult to maintain in pastures and hayfields in southern Arkansas. Humidity, high night temperatures during summer, and disease and insect pressures combine to cause very poor persistence of perennial legume species such as alfalfa, white clover, and red clover that are the mainstays in more temperate parts of the US. Producers who use legumes in southern Arkansas rely heavily on annual legumes such as crimson and arrowleaf clovers. However, planting these legumes every year represents an additional cost of production that might be avoided if a legume that will reliably reseed itself could be identified.

The key factors for assessing suitability of annual legumes in a complete forage system are: 1) enough cold tolerance to survive southern Arkansas winters, 2) tolerance of waterlogged soil conditions in winter, and 3) ability to regrow and set seed after moderate defoliation such as might occur with managed grazing or a spring hay cutting. Therefore, a screening trial was conducted to evaluate local climate adaptation and reseeding potential of clovers and medics that have not been widely used in Arkansas.

Experimental Procedures

Plots were established on a clean-tilled Sacul fine sandy loam soil at the Southwestern Research and Extension Center in Hope, Arkansas. Soil pH was 6.7, and the site was fertilized with 30 lb/acre of N, P, and K prior to planting in 1999 and again in October 2000. Legumes were inoculated with the appropriate rhizobia and drilled on October 27, 1999. Legumes were selected for the trial based upon success in environments similar to southwestern Arkansas. Legume species, cultivars, and planting rates used were: subterranean clover (*Trifolium subterraneum* L., >Denmark=, >Goulburn=, 20 lb PLS/acre), balansa clover (*T. balansae* Boiss., >Paradana=, 10 lb/acre), persian clover (*T. resupinatum* L., >Nitro=, 5 lb/acre), rose clover (*T. hirtum* All., >Overton R18', 20 lb/acre), burr medic (*Medicago polymorpha* L., >Armadillo=, >BECOM=, 15 lb/acre), button medic (*M. orbicularis* All., wild collection,15 lb/acre), and black medic (*M. lupulina* L., >George=, >BEBLK=, 15 lb/acre). Button medic was scarified prior to planting. Plots were sprayed with Poast Plus™ (sethoxydim, 1.5 pint/acre) in February 2000 and 2001 to control annual ryegrass.

Plots were visually scored for percent ground cover at intervals after planting, after harvest, and after emergence of seedlings in the reseeding year. Weed presence, winter kill, diseases, and insect damage were monitored. Plots were harvested using a sickle bar harvester at a stubble height of 3 inches. Plots were harvested as close as possible to full bloom stage. In 2000, balansa clover, persian clover, both burr medics, and BEBLK black medic were clipped on March 20 and the remaining legumes were clipped on May 25. Subsamples were hand-sorted into legume and broadleaf weeds, and legume yield determined. Plots were then allowed to regrow and set seed. Seedling emergence date was noted and development was monitored as visual estimates of percent ground cover of live clover plants through the following growing season. In 2001 all reseeded legume plots except rose clover were harvested on April 18; rose clover was har-

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vested May 18. Weather data was collected from a weather station several hundred yards from the plots.

Experimental design was a randomized complete block with four replications and a split plot over time treatment arrangement. Legume cultivar was the main plot and was tested for significance using block x cultivar as the error term. Harvest year was the subplot. Cultivar by harvest year interactions were highly significant ($P < 0.001$) for all variables. Therefore, varieties were compared separately for each harvest year. Fisher's protected LSD ($P<0.05$) was used to compare cultivar means when the main cultivar effect was significant ($P < 0.05$). In order to determine whether cultivar yields differed between harvest years, years were compared separately for each cultivar. Ground cover data was also analyzed as a split plot over time with cultivar as the main plot and scoring date as the subplot. Cultivar x date interactions were highly significant ($P < 0.001$), so cultivars were compared separately for each date. Analysis of variance was conducted using GLM in SAS (SAS Institute, Inc., Cary, NC).

Results and Discussion

In the planting year, rose clover outyielded ($P < 0.05$) all other legumes by approximately 1 ton/acre and yielded approximately twice as much as the next best legume in the reseeding year (Table 1). This was despite a relatively thin reseeded stand as determined by ground cover scores (Table 2). Because rose clover progressed through maturity stages very quickly, it was harvested at late flower/early seed instead of full bloom, which likely enhanced yields somewhat compared to the other legumes.

In the planting year, balansa clover yielded more ($P < 0.05$) than Armadillo burr medic, black medics, persian clover and subclovers (Table 1). Balansa clover stands produced more ($P < 0.05$) ground cover (76.2%) than other legumes by January 25 (Table 2). In the reseeding year balansa produced more ($P < 0.05$) forage than all other legumes except subclovers and rose clover. Balansa clover was developed as a forage in Australia and is new to the U.S. This arrowleaf-like species is advertised as extremely tolerant of wet soils, an excellent reseeder, and non-bloating. Cold tolerance is a question mark, but damage was minor on reseeded stands during the cold winter of 2000/2001 (December 2000 and January 2001 air temperatures averaged 8.5 and 2.8°F below normal, respectively).

Button medic yielded more ($P < 0.05$) than Armadillo burr medic, black medics, persian clover and subclovers in the planting year. Button medic has a history of forage use in the south (Ball et al., 1996), but is rarely used today. Seed availability is a problem, but this species appears to have excellent potential.

The two burr medics differed ($P < 0.05$) in yield in the planting year. The natural collection of burr medic (BECOM) was among the top entries, but Armadillo burr medic had the lowest ($P < 0.05$) harvested yield of any legume in 2000 after suffering from an outbreak of sclerotinia root rot. Sclerotinia did not recur in the reseeded stand despite wetter soil conditions. Early spring reseeded stands of button medic and burr medics looked promising as indicated by ground cover scores (Table 2). Both button medic and Armadillo had 65% ground cover on April 12, higher ($P < 0.05$) any other legume except subclover. However, stands were heavily damaged in the days before harvest by clover and alfalfa weevils, resulting in low harvested yields. Plots were not sprayed with insecticide because tolerance/resistance to local pests is a factor in local adaptability. Visible weevil damage appeared minor to medic stands in the planting year and to subclover, balansa clover, and rose clover stands in both years.

Black medic is a perennial species that behaves as an annual in regions with hot summers. In this trial, yields were intermediate in the planting year, and reseeding was extremely poor. Poor reseeding of black medic was unexpected and the reasons for it are unclear. Possibly weevil damage to developing seeds was responsible, since black medic seeds are not protected by pods as are burr and button medic seeds. Subterranean clovers produced low yields ($P < 0.05$) compared to the best treatments (Table 1), largely because most leaf production was below the harvest height. However, they reseeded very well, and both cultivars were the only treatments where legume yields did not decrease in the reseeding year compared to the first year. The ability of subclover to survive and reseed when maintained at a very short height is one of the traits that makes it valuable as a pasture legume. A perceived disadvantage of subclover in the southern U.S. is that seed often germinates after light summer rains that are inadequate to allow seedling survival until fall. In this trial, drought conditions in July and August prevented evaluation of this problem, since seedlings did not emerge until late September when rainfall is normally adequate for survival.
Persian clover had intermediate yields in both years (Table 1). It was among the most aggressive of the legumes at regrowth after clipping (Table 2). Reseeded stands looked promising in fall 2000, but many seedlings died during the exceptionally cold weather in December and January.

In the reseeding year, all legumes except the two subclovers yielded less than when planted (Table 1). Rose clover, subclovers, and balansa clover yielded more ($P < 0.05$) than other legumes. Yields of other legumes ranged from 28 to 347 lb DM/acre. It is not known whether such small amounts of legume would be sufficient to contribute positive benefits of nitrogen fixation to a mixed species forage system. With the exception of subclovers, all the species evaluated are noted for a high degree of seed dormancy. As a result, reseeding in the first year after planting may not be a dependable test of reseeding ability. Failure of rose clover to regenerate stands in the first year after planting has been observed (Smith, G.R., personal communication) with adequate stands produced in subsequent years. The ultimate test of reseeding dependability will be whether legumes regenerate a stand in more years than not. Collection of data is planned for one more year from these plots in order to evaluate whether regeneration was delayed by seed dormancy.

In the planting year, legume cultivars differed ($P < 0.05$) in broadleaf weed yield. Primary weeds present were curly dock (*Rumex crispus* L.), cutleaf evening primrose

(*Oenothera laciniata* Hill), and Virginia pepperweed (*Lepidum virginicum* L.). In the reseeding year, weed yield did not differ across cultivars (P = 0.11). Across both years, legume yield was negatively correlated with weed yield r = -0.46; P < 0.001). Weed yield on balansa clover plots was higher (P < 0.05) and on rose clover plots tended (P < 0.08) to be higher in the reseeding year than in the planting year, probably because stands were thinner during the reseeding year. Denmark subclover was the only legume that suppressed (P < 0.05) weed yield in the reseeding year compared to the planted year. Ability of legumes to compete with broadleaf weeds will be a factor in local adaptability because there are no currently labeled herbicides that will kill the weeds. Competitiveness with weeds may also reflect ability of legumes to coexist with desirable grasses in mixed swards.

Implications

Balansa, rose, and subterranean clovers, and burr and button medics have met minimum criteria of winter survival and reseeding ability under southwest Arkansas conditions. Cold tolerance of persian clover may be questionable in a very cold winter, but reseeding is excellent. Black medic failed to reseed in this trial.

Acknowledgments

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Table 1. Dry matter yield of annual legumes and weeds after planting of legumes (year 1) and natural reseeding (year 2) in Hope, Arkansas.

	Legume yield (lb DM[a]/acre)				Weed yield (lb DM/acre)			
			year[b]	year			year[b]	year
Species/cultivar	Year 1	Year 2	P <	CV[a]	Year 1	Year 2	P <	CV[a]
Subterranean Clover								
Denmark	1273	1227	NS[a]	23.1	1568	514	0.05	40.9
Goulburn	1352	1101	NS	28.2	1204	894	NS	80.0
Burr Medic								
Armadillo	612	43	0.05	64.0	885	1150	NS	32.1
BECOM	2852	57	0.05	55.4	1036	1234	NS	61.5
Button Medic	3300	265	0.01	34.1	820	1358	NS	25.4
Black Medic								
George	2080	78	0.05	63.7	1720	1604	NS	29.2
BEBLK	1253	28	0.01	33.7	904	730	NS	30.5
Balansa Clover								
Paradana	3657	839	0.01	29.4	267	780	0.01	22.9
Rose Clover								
Overton R18	5610	2450	0.01	5.9	108	1056	0.08	83.4
Persian Clover								
Nitro	1836	347	0.05	37.9	500	947	NS	71.0
LSD[a] (0.05)[c]	953	443			857	NS		
Cultivar CV[a]	27.6	47.4			65.4	46.2		

[a]DM=dry matter, CV=coefficient of variation, NS=not significant, LSD=least significant difference.

[b]Probability of a significant difference between year 1 and year 2.

[c]Cultivar means within columns are different (P < 0.05) when the difference between cultivars is greater than or equal to the LSD value (Fisher's protected LSD, P < 0.05).

Table 2. Live legume ground cover scores of primary growth and regrowth of annual legumes established by planting or natural reseeding in Hope, Arkansas.

	Legume ground cover (% of plot area)					
	2000 (planting year)			2001 (reseeding year)		
Species/cultivar	Jan 2 primary	Mar 2 primary	May 25 regrowth[a]	Jan 3 primary	Apr 12 primary	May 18 regrowth[a]
Subterranean Clover						
Denmark	20.0	47.5	0	85.0	100.0	100.0
Goulburn	15.0	50.0	0	65.0	97.0	93.8
Burr Medic						
Armadillo	38.2	53.8	2.5	3.0	65.0	0.5
BECOM	55.0	77.5	16.2	20.0	37.5	0.5
Button Medic	4.5	16.2	0	16.2	65.0	29.0
Black Medic						
George	16.2	23.8	92.5	0.2	22.5	0.5
BEBLK	26.2	57.5	0	12.8	14.2	12.5
Balansa Clover						
Paradana	76.2	94.8	35.0	2.5	42.5	10.2
Rose Clover						
Overton R18	23.8	57.5	0	2.8	22.5	0
Persian Clover						
Nitro	38.7	68.8	95.0	6.2	21.2	47.5
LSD[b] (0.05)[c]	13.5	16.9	22.0	23.0	20.1	22.2
Cultivar CV[b]	28.9	21.3	29.6	74.2	28.7	39.9

[a]Regrowth cover scores are for early-maturing legumes and represent 66 d of regrowth in 2000 and 29 days in 2001. All cultivars represented by values of 0 were later maturing cultivars cut at the second date, and they did not produce any regrowth.

[b]LSD=least significant difference, CV=coefficient of variation.

[c]Cultivar means within columns are different ($P < 0.05$) when the difference between cultivars is greater than or equal to the LSD value (Fisher's protected LSD, $P < 0.05$).

Effects Of Monensin and Lasalocid on Mineral Metabolism of Wethers Fed Bermudagrass Hay

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Story in Brief

Twenty-four crossbred wethers (initial BW 85 ± 5.7 lb) were used to evaluate the effects of monensin or lasalocid on mineral metabolism in growing lambs. Wethers were randomly assigned to one of four treatments: 1) control, 2) 33 mg/d monensin, 3) 33 mg/d lasalocid or 4) immediately harvested. A corn-based supplement (0.2 lb DM) was individually fed once daily throughout the experiment to administer monensin or lasalocid. Lambs were allowed *ad libitum* access to bermudagrass hay and water while housed in individual pens. The average P concentration of the bermudagrass hay was 0.39%. After 35 d, lambs were moved to metabolism crates for total feed, feces, and urine collection. A 7-d collection period followed a 7-d crate adaptation period. After the collection period, lambs were returned to individual pens and continued on dietary treatments until d 77 or 78, when lambs were harvested. Fecal Mg excretion was lower ($P < 0.10$) and urinary Mg excretion was greater ($P < 0.01$) for monensin-supplemented lambs when compared to controls. Magnesium absorption, expressed as g/d ($P < 0.10$) and as a percentage of intake ($P < 0.05$), was greater for the monensin-fed lambs compared to the controls. Although there were no effects of ionophore supplementation on the retention of P (0.90 g/d and 26%), Ca, or Mg; monensin increased the apparent absorption of Mg in wether lambs.

Introduction

Previous research has shown that feeding ionophores such as monensin and lasalocid increased the retention of some minerals, including P, by sheep and cattle (Starnes et al., 1984). This effect may prove to be important in the environmentally charged search for ways to increase the retention of certain minerals, such as P, in food animals and especially in ruminants grazing waste-amended pastures. While there has been a great deal of work involving the effect of ionophores on mineral absorption and retention in ruminants fed high-concentrate diets, there has been limited research on the effects of ionophores on mineral absorption and retention in ruminants fed forage-based diets (Spears et al., 1989).

Another area in need of further research is the explanation of this increase in mineral retention and particularly to determine the site of increased mineral deposition. Kirk et al. (1985a) suggested that monensin may be acting directly on the animal's tissues in addition to the digestive system. Therefore, this experiment evaluated the effect of monensin and lasalocid supplementation on mineral metabolism and tissue mineral concentrations of wether lambs fed bermudagrass hay with a high concentration of P.

Materials and Methods

Twenty-four crossbred wethers (initially averaging 85 ± 5.7 lb) were obtained from a single source. Wethers were blocked by weight and fed bermudagrass hay and a corn-based supplement. Wethers were randomly assigned to one of four treatments (six wethers/treatment): 1) control, 2) 33 mg monensin/d (Rumensin, Elanco Products Corp., Indianapolis, IN), 3) 33 mg lasalocid/d (Bovatec, Hoffmann-La Roche Inc., Nutley, NJ), and 4) immediately harvested at d 0. Lambs from all four treatments were humanely harvested at the University of Arkansas Red-Meat Abattoir following industry-accepted procedures.

Wethers assigned to treatments 1, 2, and 3 were allowed to adapt to the diet for 35 d. The adaptation diets included *ad libitum* access to bermudagrass hay and 0.2 lb DM/wether of one of three supplements (Table 1). Chemical composition of the supplements and hay are shown in Table 2. During the adaptation period, wethers were fed in individual, raised metal pens (3.5 ft x 5 ft). Hay was offered to lambs at 110% of the previous day's intake.

Total collection period. On d 35, wethers were placed in metabolism crates, designed for the total collection of feces and urine. Lambs had *ad libitum* access to water and continued to receive their appropriate supplement. Hay was fed during the collection phase at 120% of the previous day's intake. There was a 7-d crate adjustment period followed by a 7-d collection period.

Tissue sampling. Wethers were returned to individual pens after the collection period. Treatments were continued until d 77 or 78, when wethers were harvested to obtain tissue samples. Tissue samples and organ weights were obtained from the heart, longissimus muscle, liver, kidney, rumen-reticulum, and spleen.

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Statistical analysis. Total collection data were analyzed by least squares analysis of variance as a randomized design with three treatments. The effect of ionophore was examined. All data were analyzed using the Fit Least Squares procedures of JMP (SAS Inst. Inc., Cary, NC). Orthogonal contrasts were used to compare control versus monensin and control versus lasalocid. Each lamb represented an experimental unit resulting in six replications per dietary treatment. An additional orthogonal contrast was used to compare changes in tissue mineral concentration between the lambs that were initially harvested versus lambs that continued on the study and were fed the high P hay.

Results and Discussion

Phosphorus. There was no difference ($P > 0.10$) in P metabolism (Table 3) between the monensin-fed lambs and the control lambs. Lasalocid supplementation tended to increase ($P < 0.10$) the fecal excretion of P when compared to control lambs (2.58 vs. 2.34 g/d). Monensin or lasalocid did not alter ($P > 0.10$) the apparent absorption or retention of P in this experiment. Kirk et al. (1994) also found no differences in the apparent absorption and retention of P in wether lambs fed monensin or lasalocid. Starnes et al. (1984) and Kirk et al. (1985b), however, found that monensin and lasalocid did increase the apparent absorption and retention of P. While those studies involved ruminants fed high-concentrate diets, Spears et al. (1989) found that monensin and lysocellin increased the apparent absorption of P in steers fed greenchop fescue diets.

There were no differences ($P > 0.10$) in heart or rumen P concentrations (Table 4). Initially harvested lambs had lower liver ($P < 0.01$), kidney ($P < 0.05$), and muscle ($P < 0.10$) P concentrations than the average of lambs that were fed the three dietary treatments. Monensin supplementation increased ($P < 0.05$) spleen and muscle concentrations of P and decreased ($P < 0.05$) bone concentrations of P when compared to control lambs. Kirk et al. (1985b) examined heart, muscle, duodenum, ileum, liver, kidney, brain, and bone samples and found no differences in tissue P concentrations of lambs supplemented with and without monensin.

Calcium. There were no effects ($P > 0.10$) of ionophore supplementation on the apparent absorption or retention of Ca (Table 3). There was a tendency ($P < 0.10$) for lambs supplemented with lasalocid to have a higher intake of Ca when compared to the control treatment. This was due to an increased intake of hay by the lasalocid-supplemented lambs. There were no differences ($P > 0.10$) in concentrations of Ca in heart, liver, kidney, spleen, and muscle (Table 4). Initially harvested lambs had higher ($P < 0.05$) concentrations of rumen Ca compared to lambs harvested following dietary treatment. Lasalocid-supplemented lambs had a tendency to have lower ($P < 0.10$) rumen concentrations of Ca than the control lambs, but there were no differences ($P > 0.10$) due to monensin. Lambs fed monensin had lower ($P < 0.05$) concentrations of Ca in the bone when compared to control lambs.

Magnesium. Lambs supplemented with monensin tended ($P < 0.10$) to have a lower fecal excretion of Mg when compared to the control animals (Table 3). Yet, monensin-supplemented lambs also had a greater ($P < 0.01$) urinary excretion of Mg than the controls. Lambs fed monensin had greater apparent absorption of Mg when expressed as grams per day ($P < 0.10$) and expressed as a percentage of intake ($P < 0.05$) when compared to lambs fed no ionophore. There were no differences ($P > 0.10$) observed in the retention of Mg expressed as grams per day and as a percentage of intake. Control lambs, however, had a greater ($P < 0.01$) retention of Mg when expressed as a percentage of absorbed Mg compared to monensin-supplemented lambs.

Greene et al. (1986) and Kirk et al. (1994) also observed a decrease in fecal Mg excretion when monensin was fed to sheep. Greene et al. (1986) also reported that monensin supplementation increased both the apparent absorption and retention of Mg in concentrate-fed lambs.

There were no differences ($P > 0.10$) in rumen Mg concentrations due to treatment observed in this study (Table 4). Initially harvested lambs had lower liver ($P < 0.05$) and kidney ($P < 0.10$) concentrations of Mg than the average of lambs fed the three supplements. When compared to control lambs, monensin increased concentrations of Mg in the heart ($P < 0.05$), spleen ($P < 0.05$), and muscle ($P < 0.01$), but tended to lower concentrations of Mg in bone ($P < 0.10$).

Implications

Although there were no effects of ionophore supplementation on the retention of phosphorus, calcium, or magnesium, monensin did increase the apparent absorption of magnesium. There were significant effects of ionophore supplementation on tissue mineral concentrations suggesting that ionophores did have a physiological effect on mineral metabolism. Research should continue to explore the variability of ionophore effects on mineral metabolism.

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Table 1. Ingredient composition of supplements (DM basis).

Ingredient	Dietary treatment		
	Control	Monensin	Lasalocid
	%		
Corn	87.14	86.95	86.92
Molasses	5	5	5
White salt	7	7	7
Trace mineral mix[a]	0.11	0.11	0.11
Vitamin ADE premix[b]	0.21	0.21	0.21
Vitamin E premix[c]	0.54	0.54	0.54
Rumensin premix	–	0.19[d]	–
Bovatec premix	–	–	0.22[e]

[a]Trace mineral mix was formulated to contain 5 mg copper, 10 mg zinc, 10 mg manganese, 0.1 mg selenium, 0.1 mg iodine, and 0.1 mg cobalt/ 2.2 lb of supplement.

[b]Vitamin ADE premix was supplied to provide 826,450 IU vitamin A, 165,290 IU vitamin D, and 103 IU of vitamin E/lb of supplement.

[c]Vitamin E premix was supplied to provide 4,100 IU of vitamin E/lb of supplement.

[d]Rumensin premix was supplied to provide 33 mg of monensin/d.

[e]Bovatec premix was supplied to provide 33 mg of lasalocid/d.

Table 2. Chemical composition of supplements and bermudagrass hay (DM basis).

Item	Dietary treatment[a]			
	Control	Monensin	Lasalocid	Hay[b]
Chemical composition	%			
ADF	–	–	–	34.2
NDF	–	–	–	75.1
Crude protein	5.73	6.78	5.78	7.37
Calcium	0.49	0.56	0.55	0.50
Phosphorus	0.07	0.12	0.07	0.39
Magnesium	0.12	0.13	0.12	0.22
Potassium	0.57	0.62	0.58	1.58
	mg/kg			
Iron	85	67	50	99
Zinc	154	193	142	41

[a]An average of seven daily samples of the supplements taken during the collection phase.

[b]Average of seven daily forage samples taken during the collection phase.

Table 3. Effects of monensin and lasalocid on phosphorus, calcium, and magnesium metabolism of wether lambs.

	Dietary treatment				
Item	Control	Monensin	Lasalocid	SEM	Significance[a]
Phosphorus					
Intake, g/d	3.38	3.43	3.71	0.14	
Fecal excretion, g/d	2.34	2.39	2.58	0.16	L†
Urinary excretion, g/d	0.17	0.10	0.22	0.098	
Apparent absorption					
g/d	1.04	1.05	1.13	0.14	
% of intake	30.7	30.2	30.5	3.93	
Retained					
g/d	0.90	0.87	0.95	0.12	
% of intake	25.4	27.3	24.3	3.02	
% of absorbed	86.2	88.0	83.2	7.09	
Calcium					
Intake, g/d	4.40	4.48	4.91	0.18	L†
Fecal excretion, g/d	2.94	3.18	3.27	0.17	
Urinary excretion, g/d	0.39	0.41	0.48	0.079	
Apparent absorption					
g/d	1.46	1.30	1.64	0.17	
% of intake	33.3	28.6	33.3	3.25	
Retained					
g/d	1.08	0.89	1.17	0.18	
% of intake	24.8	19.3	23.8	3.91	
% of absorbed	73.0	51.9	71.8	12.0	
Magnesium					
Intake, g/d	2.01	2.00	2.19	0.078	
Fecal excretion, g/d	1.05	0.84	1.17	0.071	M†
Urinary excretion, g/d	0.38	0.60	0.43	0.031	M**
Apparent absorption					
g/d	0.96	1.17	1.01	0.070	M†
% of intake	48.1	58.0	46.1	2.75	M*
Retained					
g/d	0.58	0.56	0.59	0.048	
% of intake	29.1	28.0	26.8	2.27	
% of absorbed	60.3	47.4	58.1	2.32	M**

[a]L= lasalocid vs. control, M= monensin vs. control.

$^{**}P < 0.01$

* $P < 0.05$

$^{\dagger}P < 0.10$

Table 4. Effects of monensin and lasalocid on tissue mineral concentrations (µg/g) of wether lambs fed bermudagrass hay (DM basis).

		Treatment				
Item	Initial	Control	Monensin	Lasalocid	SEM	Significance[a]
Phosphorus						
Heart	10,475	10,631	10,544	10,599	133	
Liver	12,393	13,314	12,906	13,403	233	H**
Kidney	12,283	12,743	12,484	12,701	111	H*
Spleen	13,821	12,901	14,120	13,615	341	M*
Muscle	9,290	9,370	9,950	9,420	140	M*, H†
Rumen	6,067	6,515	6,006	6,793	208	
Bone[b]	107,030	111,439	100,970	106,546	3,232	M*
Calcium						
Heart	293	294	327	298	13.4	
Liver	212	241	237	215	12.7	
Kidney	698	939	999	820	183	
Spleen	300	289	258	266	13.4	
Muscle	422	376	489	412	83	
Rumen	696	598	591	485	45	L†, H*
Bone[b]	230,051	242,561	203,878	223,889	12,046	M*
Magnesium						
Heart	1,080	1,097	1,166	1,081	19.2	M*
Liver	729	770	807	771	18.6	H*
Kidney	939	997	996	981	23.4	H†
Spleen	961	921	987	966	18.9	M*
Muscle	1,095	1,054	1,144	1,064	18.8	M**
Rumen	713	640	602	715	51	
Bone[b]	4,497	4,633	3,905	4,308	237	M†

[a]H= initially harvested vs. dietary treatments, M= monensin vs. control, L= lasalocid vs. control.

[b]Fat free basis

** $P < 0.01$

* $P < 0.05$

† $P < 0.10$

2000 Dairy Herd Improvement Herds in Arkansas

J. A. Pennington[1]

Story in Brief

In December, 2000, 82 of the 403 dairy cattle herds in Arkansas were enrolled in the Dairy Herd Improvement (DHI) program. Seventy-two herds completed at least six DHI tests with a rolling herd average of 15,971 lb milk, 3.6% fat, and 3.1% protein; mature equivalent averages were 18,233 lb milk, 3.5% fat, and 3.1 protein. The Arkansas average for milk/cow was 12,476 lb/year on all cows. Herds not on DHI records averaged less than 12,000 lb/year compared to the 15,971 lb for herds on DHI. This difference of over 4,000 lb/cow/year affected income per cow by almost $600/cow or approximately $60,000/herd/year. The quartile data of milk production for the Holsteins with DHI records also reinforced that income over feed costs increased as milk production increased. Other records for health, reproduction, genetics, and inventory as well as production contributed to this difference in income/cow. It was surprising that 34.8% of the Holsteins left the herd, and over half of those cows leaving left because of disease or breeding problems. Since less than 25% of the state's herds are enrolled in the DHI record-keeping program, opportunities exist for raising the level of milk production and profitability in the state by encouraging more producers to use DHI records.

Introduction

Successful dairy producers must have accurate and reliable records to make sound management decisions. The Dairy Herd Improvement (DHI) program provides a comprehensive herd analysis and management report that includes information concerning production, reproduction, genetics, herd health, animal and feed inventory, and finances. The data can be used to improve efficiency of milk production by (1) identifying least profitable cows for culling, (2) feeding for more efficient production, (3) selecting animals with the greatest genetic potential for production as replacements, and (4) utilizing summaries of the data to make precise management decisions that improve net income.

Typically, herds on DHI produce 3,500 to 4,500 lb more milk per year nationally than herds not on DHI. This difference in production has a significant effect on net income for the dairies. Income over feed costs is associated with greater milk production per cow. The dairy herd summaries also allow a dairy producer to compare production, health, reproduction, and financial aspects of his dairy to other dairies, so that areas of management that need improvement can be detected.

Experimental Procedures

Dairy cattle herds on test (n = 82) were used to report production and management data for DHI herds. The test milking (or day) for each cow included weighing milk, taking a sample of milk to be analyzed for percentage of fat, 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, KS. Records were processed at Dairy Records Management Services (DRMS), Raleigh, NC.

Results and Discussion

Rolling herd averages for breeds of DHI herds with the ten tests to be considered official herds are in Table 1. Few non-Holstein herds were on DHI, but those results showed a similar trend in yields for breeds to the 1999 Heart of America DHIA Summary. In the United States, over 95% of the cows on test were Holsteins and almost 4% of cows on test were Jerseys. The average milk/cow for the 72 herds in Arkansas with at least six test periods during the year was 15,971 lb/year with 3.6% fat and 3.1% protein; the mature equivalent averages were 18,233 lb milk, 3.5% fat, and 3.1% protein.

Table 2 shows the Holstein DHI averages for herds with six tests by quartile of milk production. The quartile data for the 39 Holstein herds illustrate the relationship of higher milk production to higher income over feed costs. The high quartile of herds also had lower somatic cell scores than other herds. Table 3 shows that higher producing herds also had superior genetics as indicated by the higher predicted transmitting abilities for dollars (PTA$) of the cows and sires, fewer days dry, less days open, lower calving intervals and reported a greater percentage of heats detected than lower producing herds. However, herds in quartiles 3 and 4 had fewer services per pregnancy than herds in quartiles 1 and 2. In larger data sets, lower producing herds have superior reproduction traits compared to higher producing herds.

[1]Animal Science Section, Cooperative Extension Service, Little Rock.

Table 4 shows that 34.8% of Holstein cows left the herd last year. Only 4.2% of the Holstein cows leaving the herd left because of low production. This compares to 17.2% of the cows leaving because they died and another 19.7% of cows left because of reproduction. This data is similar to results from all states included in the Heart of America DHIA Summary for 1999.

The 72 dairy cattle herds reported here are less than the 82 or more dairy herds that have been reported on DHI through other summaries. The primary reason for the difference in numbers is that herds reported here have at least six test periods. For quartile data, all herds were official herds with 10 tests during the year. There also were four goat herds on DHI, plus the list included any herd on DHI in 2000, including herds no longer on the DHI program. Still, less than 25% of the 403 herds in 2000 were involved in the DHI program. Herds on DHI averaged 15,971 lb milk/cow/year compared to the Arkansas average of 12,476 lb milk/cow/year, according to the Arkansas Agricultural Statistics Service. Omitting DHI herds from the state average indicates that the non-DHI herds averaged less than 12,000 lb milk/year. The difference of over 4,000 lb milk/cow/year affects income by almost $600/cow/year. This difference in milk income is $60,000 per year in a 100-cow herd.

Implications

DHI program participation affords dairy producers an opportunity to maintain milk production records on individual cows for milk production and other management practices. Herds utilizing DHI records averaged 15,971 lb milk/cow/year versus less than 12,000 lb/cow for herds not on DHI test. We should continue to encourage producers to enroll in the DHI Testing program.

Table 1. 2000 Arkansas DHIA breed averages on selected traits.

	Breeds				
Trait	**Ayrshire**	**Brown Swiss**	**Guernsey**	**Holstein**	**Jersey**
Number of herds	1	2	2	39	2
Rolling herd average Milk, lb	16,538	13,836	12,147	15,866	12,178
Peak milk, lbs	71.0	65.5	54.5	70.7	55.0
SCC[1] average (x 1000)	438	247	548	523	196
Days to 1st service, total	97.0	–	104.5	76.6	65.0
Days open	228.0	–	252.0	191.3	104.0
Projected calving interval (mon)	16.7	–	17.4	15.5	12.7
Income minus feed costs ($)	$970	$739	$548	$1,184	$1,083

[1]SCC = somatic cell count.

Table 2. 2000 Arkansas DHIA Averages for Official Holstein Herds.

Production traits	Quartile 1[1]	Quartile 2	Quartile 3	Quartile 4
Number of herds	9	10	10	10
Number of cows/herd	118	142	95	70
Rolling herd average milk, lb	20,858	17,388	14,354	11,364
Rolling herd average fat, lb	715	584	499	412
Rolling herd average protein, lb	647	533	447	347
Average days in milk	182	187	185	186
Average test day milk (milking cows)	66.4	56.2	48.8	40.0
Average percentage of cows in milk	86.6	85.4	81.7	76.6
Average standardized 150 day milk	71.0	61.7	52.5	43.9
1st Lact[2] peak milk 1st, lb	74.4	62.9	53.7	50.4
2nd Lact peak milk 2nd, lb	89.3	76.4	66.4	53.0
3+ Lact peak milk 3rd, lb	93.4	82.0	72.3	63.7
All lact peak milk average, lb	87.0	73.8	66.7	57.0
SCC[3] average (x 1000)	436	551	576	522
1st Lact % cows SCC 0 - 3[4]	79	65	63	63
2nd Lact % cows SCC 0 - 3	70	62	65	64
3+ Lact % cows SCC 0 - 3	59	38	48	42
All lact % cows SCC 0 - 3	68	55	57	54
Income minus feed cost, $	1,739	1,205	1,078	768

[1]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.
[2]Lact = Lactation
[3]SCC = somatic cell counts
[4]SCC 0-3 = somatic cell counts of less than 142,000.

Table 3. 2000 Arkansas DHIA for Official Holstein Herds.

Breeding and reproduction traits	Quartile 1	Quartile 2	Quartile 3	Quartile 4
1st Lact AIPL[1] PTA$[2] - cows	102.3	0.1	-41.2	51.0
2nd Lact AIPL PTA$ - cows	73.2	0.6	-76.7	-40.8
3+ Lact AIPL PTA$ - cows	0.5	-13.1	-100.7	-37.6
All lact AIPL PTA$ - cows	22.3	-8.1	-91.0	-3.2
1st Lact AIPL PTA$ - sires	236.0	173.6	156.8	154.2
2nd Lact AIPL PTA$ - sires	182.3	142.1	121.7	134.0
3+ Lact AIPL PTA$ - sires	100.5	119.0	65.7	67.4
All Lact AIPL PTA$ - sires	177.6	148.5	103.9	131.8
Days to 1st service, current	86.9	79.7	72.0	58.1
Days to 1st service, total	82.8	104.8	69.5	57.5
Services per pregnancy, preg.	1.8	1.8	1.1	1.4
Services per pregnancy, all	2.5	2.4	1.5	1.8
Average days dry	69.6	74.2	77.5	82.7
Days open	160.0	170.6	224.4	207.2
Projected calving interval (mon)	14.5	14.8	16.6	16.0
Successful first breedings, %	41.0	59.0	31.1	26.1
Successful total breedings, %	38.9	56.3	30.5	28.9
Average percentage of heats reported	38.9	26.2	28.2	21.8
% Herd bred to proven sires	75.0	43.6	4.7	17.5
% Herd bred to AI young sires	5.1	3.0	0.8	9.5
% Herd bred to other sires	8.7	53.5	54.6	33.0

[1]AIPL = From USDA's Animal Improvement Programs Laboratory
[2]PTA$ = Predicted Transmitting Ability Dollars

Table 4. 2000 Arkansas DHIA reasons for cows leaving herds from official Holstein herds[1].

Reason for leaving herd	Quartile 1	Quartile 2	Quartile 3	Quartile 4	Avg
All lact number left herd	38.7	51.5	27.0	27.9	35.3
Total % left herd	37.8	38.1	29.1	37.4	34.7
% Left for dairy	10.3	33.2	8.5	3.6	13.6
% Left for low production	7.2	5.8	1.9	2.0	4.2
% Left for reproduction	18.7	13.0	21.5	27.6	19.7
% Left for mastitis	15.8	4.3	5.6	6.1	7.6
% Left for udder	2.3	0.4	0.4	4.7	1.9
% Left for feet & legs	8.3	0.9	1.1	3.9	3.3
% Left for injury or other	15.2	1.9	2.6	3.9	5.6
% Left for disease	2.0	2.1	0.0	1.4	1.3
% died	10.6	15.5	22.2	21.5	17.2
% not reported	9.5	17.3	31.4	20.1	19.3

[1]Some cows may have more than one reason for leaving herd.

Growth, Luteal Activity, and Pregnancy Rates of Three Breed Types of Dairy Heifers in a Forage-Based Development Program[1]

A. H. Brown, Jr., D. W. Kellogg, Z. B. Johnson, R. W. Rorie, W. K. Coblentz, B. A. Sandelin, and K. E. Lesmeister[2]

Story in Brief

Growth, estrous, and pregnancy rates were evaluated in 89 dairy heifers. Breed types were Holstein (H, n = 35), Jersey x H (JH, n = 30) and Brown Swiss x H (BSH, n = 24). Heifers were fed to ensure 2.0 lb of daily BW gain. Hip height, chest depth and BW were obtained monthly; Body condition score was recorded at approximately 14 mo of age. Heifers were considered cycling by 12 mo of age if progesterone concentrations were ≥1 ng/ml in either of two samples taken 10 d apart. Heifers were bred artificially (AI) on a synchronized estrus starting at 14 mo of age and pregnancy was determined ultrasonically 60 d post-breeding. The BSH and H had similar ($P > 0.05$) weights and hip heights; whereas JH were lighter and shorter ($P < 0.05$). No differences ($P > 0.05$) occurred for depth of chest and BCS. Estrus occurrence by 12 mo of age was greater ($P < 0.05$) for JH (90%) than for BSH (75%) and lowest ($P < 0.05$) for H (47%). Pregnancy rates did not differ (BSH = 96%, JH = 87%, H = 77%). These data suggest that genetic effects of crossbreeding influence early growth and cyclicity at 12 mo of age for replacement dairy heifers. Forage based development of dairy heifers may be a suitable option to concentrate feeding for dairy producers in Arkansas and the southern region of the U.S.

Introduction

Successful heifer development reduces replacement costs and increases herd life. The importance of well-developed heifers is reflected in breeding recommendations based on BW as well as age. Because of the importance of early growth, developmental programs have emphasized concentrate feeding and selection based on the additive genetic variance for BW gain. Selection based on the additive genetic variance has been emphasized because of the notable merit of purebred Holstein (H) cows for body size and milk production. Additionally, it has been established that crossbred heifers generally exceed parental averages for BW and body dimensions (Robinson et al., 1980), and crossbreds tend to calve at younger ages than purebreds. In previous studies, losses due to reproductive failure, mastitis, lameness, and other diseases were twice as great among purebreds as among crossbreeds (Dickinson and Touchberry, 1961). The objectives of this study were 1) to compare BW and height of purebred Holstein heifers that were developed on a forage-based development program to recent industry standards for replacement heifers; and 2) to compare growth, estrous and pregnancy rates for purebred Holstein (H), Jersey x Holstein (JH) and Brown Swiss x Holstein (BSH) crossbred replacement dairy heifers.

Experimental Procedures

Eighty-nine dairy heifers were obtained from the Norwood Dairy Farm near Goldthwaite, Texas, and moved to the University of Arkansas research farm in December, 1998. All heifers were born to purebred Holstein cows and were sired by H (n = 35), Jersey (JH, n = 30), or Brown Swiss (BSH, n = 24) bulls. The three breed types of heifers were reared as contemporaries in a forage-based development program. During an initial adjustment period, heifers were maintained on high-quality bermudagrass hay, allowed access to grass in a 7.5-acre mixed pasture, and were fed 3.85 lb of grain supplement once daily.

All heifers were weighed individually and hip height and chest depth were determined at a mean age of 6 mo. Hip height was recorded because it matures earlier in beef cattle, and it is slightly higher in heritability than wither height (Brown et al., 1983). Vaccines were injected and were repeated in January. The BW and body measurements were repeated at approximately 28-d intervals until August.

From December 15 until May 31, heifers were allowed to strip graze 2.3 acre paddocks of wheat pasture for 8 to 12 h daily. A concentrate supplement was offered daily and bermudagrass hay was provided *ad libitum*.

At the end of May the heifers were moved to a bermudagrass-dominant mixed pasture and continued on the same supplement and bermudagrass hay. During the late sum-

[1]Acknowledgment is given to W.R. Jackson and R.T. Rhein for their assistance with cattle management, and to K.S. Anschutz and J.E. Turner for their assistance in collecting data.

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mer of 1999, droughty growing conditions limited the availability of forage; therefore cattle were supplemented for *ad libitum* intake with bermudagrass hay and sudangrass baleage. In mid-June, 1999, when the heifers averaged approximately 12 mo of age, two blood samples were obtained 10 d apart for each heifer for progesterone assay. Heifers were considered cycling at 12 mo of age when concentration of progesterone in one of the two samples was ≥ 1 ng/ml.

In late August, heifers were split into two groups based on chronological age, and heifers in the oldest of the two groups were then synchronized and bred AI on observed standing heat. Estrus detection was accomplished by 24 h monitoring with the Heatwatch System. The second group of younger heifers were synchronized 3 wk later and bred as stated above. Artificial insemination was halted on November 15, 1999. Heifers were checked after 60 d of gestation for pregnancy using ultrasonography.

Data were analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC). Sources of variation in the dependent variables of weight, hip height, chest depth, and body condition score were partitioned using a mathematical model that included terms for an overall mean, breed type, age, breed type x age interaction, and residual error. Least squares means were separated using repeated t-tests in the LSmeans option of PROC GLM of SAS. The distributions of heifers cycling and pregnancy rate were tested using Chi-square statistics.

Results and Discussion

Body Weight. The interaction of breed type x age was not significant for BW at 6 mo, but it was an important source of variation in BW at 14 mo for replacement dairy heifers in this study. This may indicate that compensatory growth occurred from 6 to 14 mo of age. These results are in agreement with those of Ruvuna et al. (1986) who reported that crosses of Holstein, Jersey, and Brown Swiss were superior to purebreds for growth. At 6 mo of age the BSH heifers were heavier ($P < 0.05$) than both H and JH heifers, but by 14 mo of age mean BW for the H and BSH heifers were similar ($P > 0.05$, Figure 1). At 6 mo of age the H heifers in our study had smaller mean BW than the industry standards reported by Henrichs and Losinger (1998). However, by 14 mo of age the H heifers in our study were approaching the industry standard range for mean BW, probably due to compensatory growth from 6 to 14 mo of age. It appears that the forage-based system for heifer development was adequate for growth. Henrichs and Losinger (1998) reported that H heifers developed in the Southeast U.S. had lower BW when compared to H heifers developed in other regions. Differences in photoperiod, feeding strategies, and/or predominant forage types in various regions of the U.S. could explain the differences in growth (body weight:age) between the regions.

Hip Height. Skeletal size or frame development is often emphasized as a key factor in replacement heifer rearing programs. Traits that reflect long-bone growth may reflect true size of replacement heifers better than BW because BW is influenced by pregnancy and body condition. In our study the interaction of breed type x age was significant for hip height at 6 mo of age, but not at 14 mo of age ($P > 0.05$). The BSH heifers were taller ($P < 0.05$) than the two other breed types at 6 mo of age, but by 14 mo of age H and BSH heifers were similar ($P > 0.05$) for mean hip height (Figure 2), and were similar to the industry standards for range in mean wither height (Heinrichs and Losinger, 1998). Because hip height reaches maturity before wither weight in beef cattle (Brown et al., 1983), it is expected that heifers in our study would be taller at the hip than the industry standard for wither height at 6 mo of age. However the heifers in our study were shorter in hip height than the industry standards for wither height (Heinrichs and Losinger, 1998), indicating that our heifers had not achieved sufficient long bone growth to 6 mo of age. Mean hip heights for H, JH, and BSH heifers were 40, 38, and 39 inches, respectively, compared to an industry standard range of 40 to 42 inches for H heifers measured at the withers at 6 mo of age.

Depth of Chest. The interaction of breed type x age and the main effect for breed type were not significant for depth of chest at 6 or 14 mo of age. The three breed types ranked highest to lowest for mean chest depth at 6 mo of age were BSH, JH and H and at 14 mo of age were H, BSH, JH (Figure 3). Age was a significant ($P < 0.05$) source of variation for depth of chest in this study.

Body Condition Score. Body condition scores are important predictors of potential reproductive efficiencies of dairy heifers. Mean body condition scores of the three breed types of heifers were similar ($P > 0.05$, Figure 4). Mean body condition score of heifers in our study exceeded (3.0 to 3.1 vs. 2.2 to 2.8) those of H heifers reported by Hoffman (1997).

Reproductive Performance. Reproductive performance of heifers is important because of the proportion of heifers culled for reproductive failure and because reproductive efficiency determines how soon productive life begins. The reproductive performance of three breed types of replacement dairy heifers is presented in Figure 5. By 12 mo of age, the JH breed group had the highest percentage (90%) of heifers cycling, this was followed by BSH (75%), and then by H (48%, $P < 0.05$). At about 15 mo of age, the percentage of heifers pregnant was similar among the three breed types. The breed types ranked from highest to lowest in percentage pregnant were: BSH (96%), JH (87%) and H (77%). These data are in agreement with results of previous studies indicating that crossbreeding tends to improve reproductive efficiency in dairy heifers. McDowell (1982) summarized dairy cattle crossbreeding of the S-49 Southern Regional Cooperative Research Project and concluded that crossbreeds tended to surpass purebreds in overall breeding efficiency.

Wheat Pasture. Our data shows that wheat pasture may be used for replacement dairy heifer development in Arkansas. However, we acknowledge that these data represent wheat production in one growing season; there are studies with differing opinions about the consistency of production patterns of wheat from season to season.

Implications

These results suggest that farmers could potentially raise heifers on forage plus supplements and achieve rapid, economical growth. General considerations on crossbreeding are a change in size and BW early in life and that crossbreeds tend to cycle earlier, breed earlier, and should calve and enter the milking herd younger. Finally, more research is needed to determine alternative development systems for replacement dairy heifers utilizing forage as the primary energy source.

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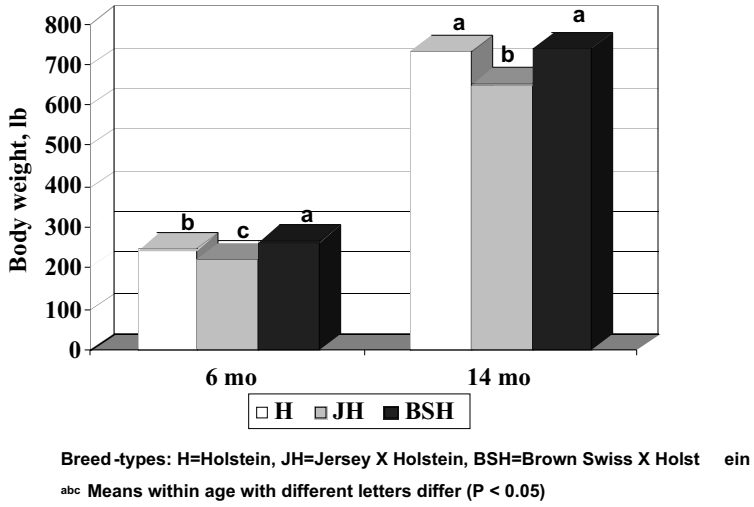
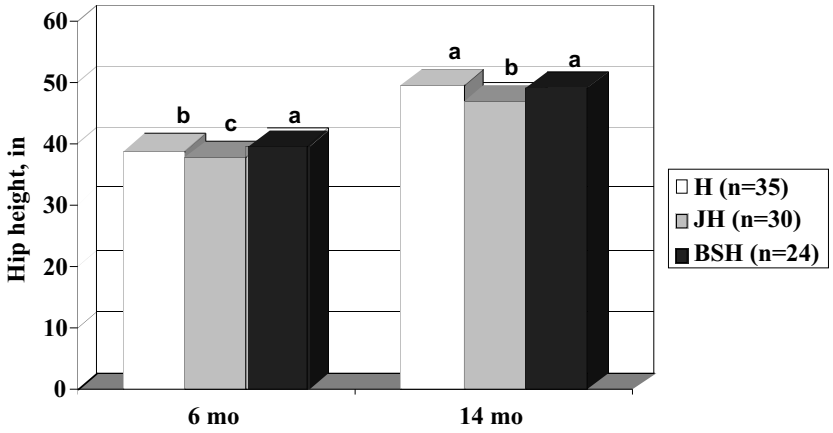


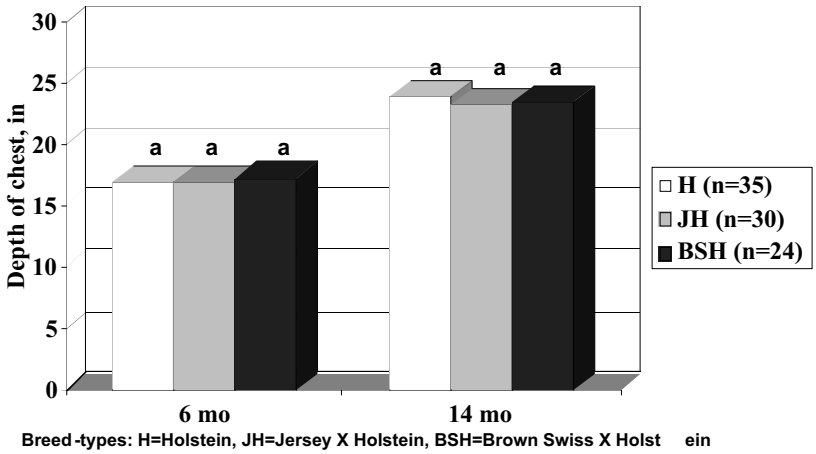
Figure 1. Least-squares means for body weight at 6 and 14 mo of age for three breed types of replacement dairy heifers



Breed-types: H=Holstein, JH=Jersey X Holstein, BSH=Brown Swiss X Holst ein

abc Means within age with different letters differ (P < 0.05)

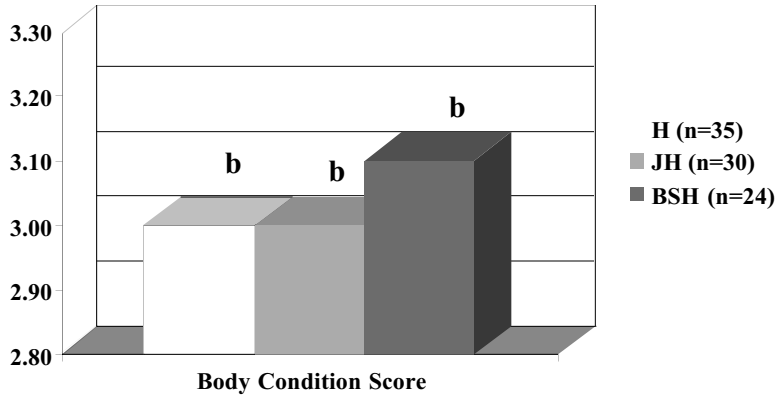
Figure 2. Least-squares means for hip height at 6 and 14 mo of age for three breed types of replacement dairy heifers



Breed-types: H=Holstein, JH=Jersey X Holstein, BSH=Brown Swiss X Holst ein

abc Means within age with different letters differ (P < 0.05)

Figure 3. Least-squares means for depth of chest at 6 and 14 mo of age for three breed types of replacement dairy heifers

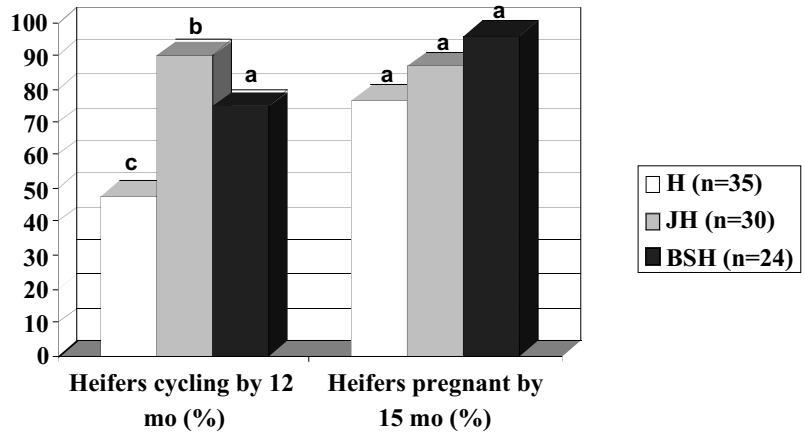


Breed-types: H=Holstein, JH=Jersey X Holstein, BSH=Brown Swiss X Holstein

[a] Scores 1-5 with 1 being thinnest and 5 being fattest (Ferguson et al., 1994)

[b] Means with different letter differ (P < 0.05)

Figure 4. Age adjusted breed type means for body condition score[a] at 14 mo of age for replacement dairy heifers.



Breed-types: H=Holstein, JH=Jersey X Holstein, BSH=Brown Swiss X Holst ein

[abc] Means within age with different letters differ (P < 0.05)

Figure 5. Reproductive performance of three breed types of replacement dairy heifers

The Impact of Multiple Antimicrobial Intervention Agents on Ground Beef Sensory Properties

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Story in Brief

The effectiveness of multiple antimicrobial interventions on ground beef sensory characteristics through display was studied. Beef trimmings were inoculated with *Escherichia coli* (EC) and *Salmonella typhimurium* (ST), then treated with either 1) 5% acetic acid followed by 0.5% cetylpyridinium chloride (AC), 2) 200 ppm chlorine dioxide followed by 0.5% cetylpyridinium chloride (CC), 3) 0.5% cetylpyridinium chloride followed by 10% trisodium phosphate (CT); or 4) control (C). Trimmings were ground, packaged and sampled through display for sensory color and odor characteristics. The CT treatment had less ($P < 0.05$) overall, worst point and percentage discoloration than C by day 7 of display. Ground beef from the CC treated trimmings was similar ($P > 0.05$) in worst point color and percentage discoloration to C through 3 days of display. Although minor differences existed initially, sensory panelists were unable to detect ($P > 0.05$) beef odor or off odor differences between C, CC and CT treatments throughout display. Therefore, treatment of beef trimmings with CC or CT before grinding did not impact sensory evaluated color or aroma of ground beef during simulated retail display.

Introduction

In the wake of ground beef recalls, the safety of this product remains of vital concern; therefore, considerable research continues to be conducted for improving the safety of meat products. It has been reviewed, that the use of single decontamination interventions are effective for reducing pathogens on carcass (Dickson and Anderson 1992; Siragusa, 1995). However, contamination resulting from carcass fabrication can be carried through grinding operations, ultimately contaminating the ground beef product. Therefore, it would be advantageous to develop meat decontamination procedures immediately prior to, or during, ground beef production. The use of single intervention techniques during ground beef manufacture has been relatively effective for reducing microorganisms compared to carcass decontamination (Gill and Bandoni, 1997; Dorsa et al., 1998). However, the use of multiple antimicrobial treatments to decontaminate meat before grinding might provide a greater barrier to microbial survival in ground beef by taking advantage of different weaknesses of differing microbial strains.

In addition to antimicrobial effectiveness another concern is the impact of these treatments on meat color and odor. Therefore, the objective of this research was to determine the effects of an organic acid and other novel decontamination compounds, used in combination, on sensory characteristics of ground beef.

Experimental Procedures

Bacterial preparation and inoculation. Inoculums were prepared from frozen (-80oC) stock cultures of *Escherichia coli* (ATCC #11775; EC) and a nalidixic acid resistant strain of *Salmonella typhimurium* (ATTC 1769NR; ST). *E. coli* was maintained by brain heart infusion (BHI; Difco Laboratories, Detroit, MI) broth with glycerol (20%), and *Salmonella typhimurium* was maintained by BHI broth containing nalidixic acid (Fisher Scientific, Fairlawn, NJ) with glycerol (20%). Frozen cultures of *E. coli* and *Salmonella typhimurium* were thawed, and 0.1 ml of *E. coli* suspension was inoculated into separate 40 ml aliquots of BHI, and 0.1 ml of *Salmonella typhimurium* suspension was inoculated into separate 40 ml aliquots of BHI with nalidixic acid. After 18 hours of incubation at 98.6°F, bacteria were harvested by centrifugation (3649 x g for 20 min @ 98.6°F; Beckman GS-6 series, Fullerton, CA), re-suspended in the same volume of 0.1% buffered peptone water (BPW; Difco Laboratories, Detroit, MI) and then pooled together (1600 ml of *E. coli* and 1600 ml of *Salmonella typhimurium*) to make a bacterial cocktail. The cocktail (3200 ml; log 10^7 colony forming units [CFU]/ml *E. coli* and log 10^7 CFU/ml *Salmonella typhimurium*) was cooled to 39.2°F and combined with boneless beef trimmings (28.2 lb) and allowed to attach for 1 hour. The meat was then drained, separated into 7.8 lb batches, and placed in a 39.2°F cooler for 12 to 14 hours to allow further microbial attachment.

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Antimicrobial treatment application and sample processing. Treatment combinations for this study included: 1) 5% (vol:vol) acetic acid solution (Shurfine Inc., Northlake, IL) followed by 0.5% (wt:vol) cetylpyridinium chloride solution (Zeeland Inc., Zeeland, MI; AC); 2) 200 ppm (vol:vol) chlorine dioxide solution (Midland Chemical Company, Lenexa, KS) followed by 0.5% (wt:vol) cetylpyridinium chloride solution (CC); 3) 0.5% (wt:vol) cetylpyridinium chloride solution followed by 10% (wt:vol) trisodium phosphate solution (Rhone Poulenc, Cranbury, NJ; CT); and 4) an untreated control (C). All antimicrobial treatments were prepared in deionized water with the exception of acetic acid, which was commercially prepared.

For antimicrobial application, inoculated beef trimmings were placed into a Lyco meat tumbler (Model 4Q, Lyco Inc., Janesville, WI) with 400 ml of the first antimicrobial treatment, tumbled for 3 minutes (16 rpm), then removed from the tumbler and placed into a clean tumbler with 400 ml of the second antimicrobial treatment, and tumbled for another 3 minutes (16 rpm).

Upon completion of the antimicrobial application phase, beef trimmings were removed from the tumbler, and ground twice using a Hobart grinder (Model 310, Hobart Inc., Troy, OH) with a 0.13 inch plate. The ground beef was divided into 1 lb samples and packaged on styrofoam trays with absorbent diapers. The trays were overwrapped with polyvinyl chloride film with an oxygen transmission rate of 1400 cc/m^2/24 hr/1 atm (Borden Inc., Dallas, TX) and stored under simulated retail display conditions (39.2°F; deluxe warm white fluorescent lighting, 1630 lx, Phillips Inc., Somerset, NJ). Fat content was standardized to 10% and validated using a Hobart Fat Analyzer (Model F101, Hobart Inc. Troy, OH). Ground beef pH was determined immediately after grinding for each treatment and was 5.72 for C, 4.71 for AC, 5.70 for CC and 6.91 for CT. For this, 0.06 oz of ground beef was homogenized in 18 ml of distilled water and evaluated using an Orion Model 420A pH meter with a ROSS electrode (Model 8165BN, Orion Research, Inc., Beverly, MA).

Sensory color and odor. A six-member trained sensory panel was used to evaluate sensory color and odor characteristics of ground beef samples through display. Panelists were selected and trained by an experienced panel leader according to the American Meat Science Association guidelines (AMSA, 1978; Hunt et al., 1991). On days 0, 1, 2, 3 and 7 of simulated retail display, sensory panelists evaluated overall color and worst point color (5 = bright purplish red, 4 = dull purple red, 3 = slightly brownish red, 2 = moderately brownish red, and 1= brown) and percentage surface discoloration (7 = no discoloration [0%], 6 = slight discoloration [1-20%], 5 = small discoloration [20-39%], 4 = modest discoloration [40-59%], 3 = moderate discoloration [60-79%], 2 = extensive discoloration [80-95%], 1 = total discoloration [96-100%]. In addition panelists evaluated beef odor (8 = extremely beef like, 7 = very beef like, 6 = moderately beef like, 5 = slightly beef like, 4 = slightly non-beef like, 3 = moderately non-beef like, 2 = very non-beef like, and 1= extremely non-beef like) and off odor characteristics (5 = no off odor, 4 = slight off odor, 3 = small off odor, 2 = moderate off odor, and 1= extreme off odor; Hunt et al., 1991). Packages were first viewed under simulated retail lighting conditions for overall color, worst point color, and percentage discoloration. Then, packages were taken to a static pressure room, opened, and evaluated by panelists for beef odor and off odor characteristics.

Statistical analysis. The experiment was replicated three times. The randomized complete block factorial experiment was analyzed using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC). A panelist term was added to the model to account for sensory panelist variation. Treatments were blocked by replicate then analyzed for the main effects of antimicrobial treatment combination, day of display and appropriate interactions. For variables involved in interactions, interaction means were generated, and then separated using the PDIFF option of GLM. Least-squares means for all other variables were generated and separated using the PDIFF option of GLM.

Results and Discussion

The day of display by antimicrobial treatment interaction effects on sensory evaluated overall color, worst point color and percentage discoloration are shown in Figure 1, panels A, B and C, respectively. Sensory panelists found ground beef from the AC treatment to be less ($P < 0.05$) bright purple red in overall color (Fig. 1, panel A) and worst point color (Fig. 1, panel B), and to have a higher ($P < 0.05$) percentage discoloration (Fig. 1, panel C) than C through display. On days 0, 2 and 7 of display, CC ground beef was less ($P < 0.05$) bright purple red in overall color than C ground beef, however, no difference ($P > 0.05$) between C and CC was noted on days 1 and 3 of display (Fig. 1, panel A). Likewise, the CC treatment was similar ($P > 0.05$) in worst point color (Fig. 1, panel B) and percentage discoloration (Fig. 3, panel C) to C until day 7 of display. Similarly, CT ground beef was not different ($P > 0.05$) in overall color (Fig. 1, panel A), worst point color (Fig. 1, panel B), or percentage discoloration (Fig. 1, panel C) from C until day 3 of display, when ground beef from CT treated trimmings was scored as brighter ($P < 0.05$) purple red in overall and worst point color, and lower ($P < 0.05$) in percentage discoloration than any other treatment. These results suggest that the use of cetylpyridium chloride and trisodium phosphates in combination improves ground beef color stability and extends retail shelf life.

The day of display by antimicrobial treatment interaction effects on beef odor and off odor characteristics are shown in Figure 1, panels D and E, respectively. Sensory panelists found the AC treatment to have less ($P < 0.05$) beef odor (Fig. 1, panel D) and more ($P < 0.05$) off odor (Fig. 1, panel E) than any other treatment throughout display. On day 0 of display, ground beef from the CC treatment had less ($P<0.05$) beef odor (Fig. 1, panel D) and more ($P < 0.05$) off odor (Fig. 1, panel E) than C, but was not different ($P > 0.05$) from C for either of these traits through the remainder of display. Sensory panelists found that ground beef from the CT treat-

ment was not different ($P > 0.05$) from C for beef odor through display, and was only different ($P < 0.05$) on day 0 of display for off odor. These results are comparable with those of Garcia-Zepeda et al. (1994), who found that beef subprimals treated with chlorine received higher acceptability scores when compared to water treated subprimals. Therefore, the use of cetylpyridium chloride and trisodium phosphate in combination had little effect on ground beef odor or off odor characteristics.

Implications

Results from this study show that the use of CC on beef trimmings before grinding had little effect on ground beef sensory color and odor characteristics. However, the use of CT multiple interventions enhanced sensory evaluated color stability of ground beef through refrigerated display, without affecting aroma qualities.

Acknowledgments

Appreciation is expressed to the Arkansas Beef Council for funding this research. The authors would like to thank J. Davis, L. Rakes, A. Ivey, L. McBeth, R. Story and E. Kroger for their assistance in conducting these trials.

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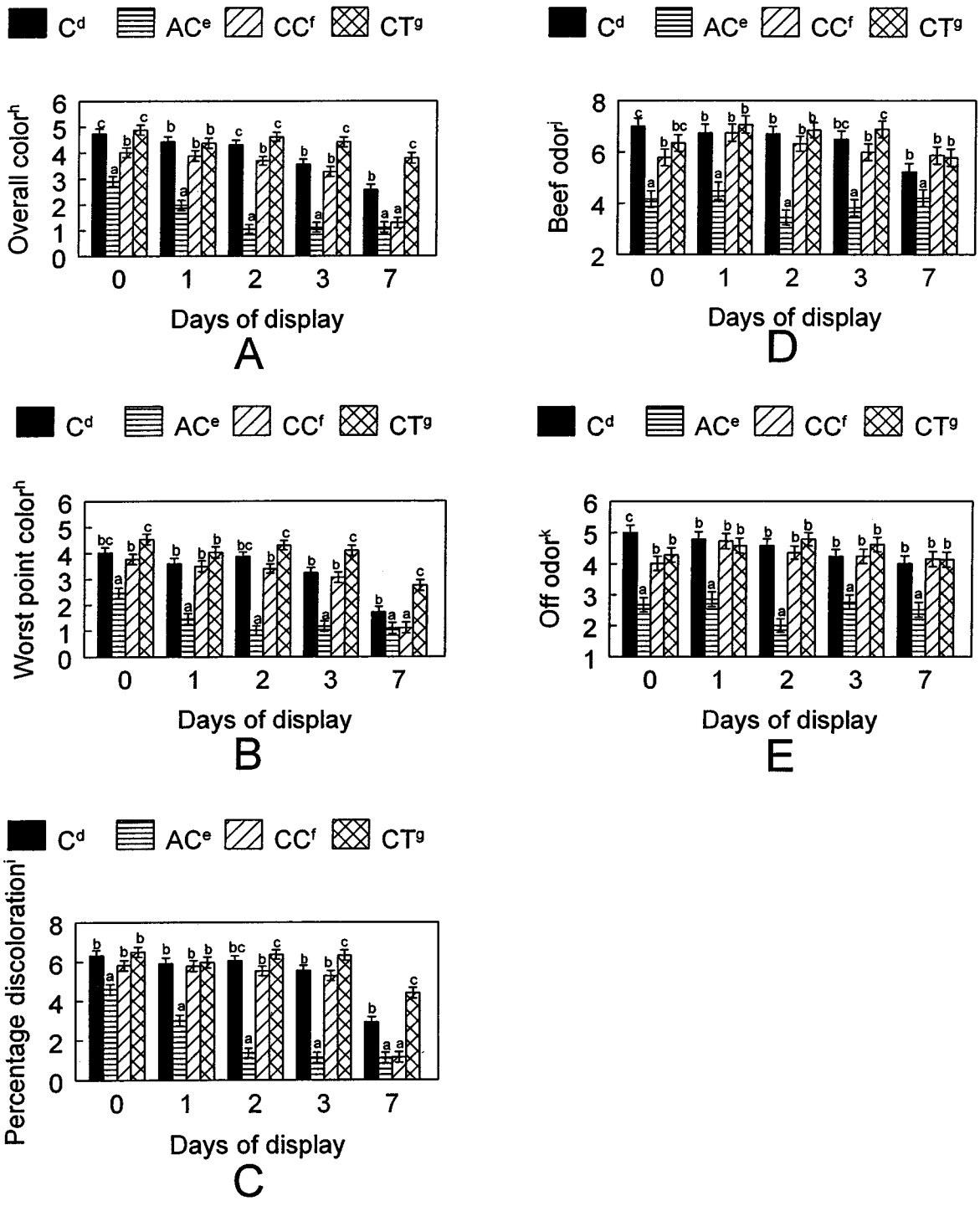

Figure 1. Day of display by antimicrobial treatment interaction effect on the least squares mean (±SE) sensory evaluated (A) overall color, (B) worst point color, (C) percentage discoloration, (D) beef odor, and (E) off odor characteristics of ground beef through simulated display. [abc]Least-squares means within a day bearing different superscripts are different (P<0.05). [d]C = control, [e]AC = 5% acetic acid and 0.5% cetylpyridinium chloride, [f]CC = 200 ppm chlorine dioxide and 0.5% cetylpyridinium chloride, [g]CT = 0.5% cetylpyridinium chloride and 10% trisodium phosphate. [h]Color score: 1 = brown and 5 = bright purple red. [i]Percentage discoloration: 1 = total discoloration and 7 = no discoloration. [j]Beef odor score: 1 = extreme non-beef like and 8 = extreme beef like. [k]Off odor score:1 = extreme off odor and 5 = no off odor.

The Impact of Multiple Antimicrobial Intervention Agents on Ground Beef Color

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Story in Brief

The effectiveness of multiple antimicrobial interventions on ground beef instrumental color through display was studied. Beef trimmings were inoculated with *Escherichia coli* (EC) and *Salmonella typhimurium* (ST) then treated with either 1) 5% acetic acid followed by 0.5% cetylpyridinium chloride (AC), 2) 200 ppm chlorine dioxide followed by 0.5% cetylpyridinium chloride (CC), 3) 0.5% cetylpyridinium chloride followed by 10% trisodium phosphate (CT) or 4) control (C). Trimmings were ground, packaged and sampled through display for instrumental color characteristics. Ground beef from the CC treatment was similar ($P > 0.05$) in redness (a*) to C. The CT treatment remained ($P < 0.05$) redder (a*) in color and contained more ($P < 0.05$) oxymyoglobin than C by day 7 of display. Ground beef from the AC treatment was ($P < 0.05$) lighter (L*), less yellow (b*) and less red (a*) in color than C throughout display. Therefore, the use of CC did not harm ground beef color whereas CT improved ground beef color by extending oxymyoglobin stability and product redness.

Introduction

Multiple intervention technology involves the use of different barriers such as pH changes, oxidizing environments, or other environmental changes to cause disruption of microbial cells or cellular metabolism, to either destroy bacterial cells or retard their growth. Hurdle technology has been more effective than single interventions for beef carcass decontamination (Phebus et al. 1997). In addition, Ellebracht et al. (1999) used 203°F hot water and 2% lactic acid multiple interventions in the production of ground beef to reduce *E. coli*, *Salmonella typhimurium* and aerobic plate counts 1.1, 1.8, and 1.5 log colony forming units (CFU)/g, respectively. Through the development of multiple antimicrobial intervention techniques Pohlman et al. (2001) was able to reduce *E. coli*, *Salmonella typhimirium*, coliform and aerobic bacteria in ground beef.

In addition to the effectiveness of antimicrobial treatments, another concern is the impact of these treatments on meat color. Treatments such as hot water, organic acids, or other decontaminants can have an adverse effect on meat color (Unda et al., 1989; Bell et al., 1986). Therefore, the objective of this research was to determine the effects of multiple antimicrobial interventions on the instrumental color of ground beef.

Experimental Procedures

Bacterial preparation and inoculation. Inoculums were prepared from frozen (-112°F) stock cultures of *Escherichia coli* (ATCC #11775; EC) and a nalidixic acid resistant strain of *Salmonella typhimurium* (ATTC 1769NR; ST). *E. coli* was maintained by brain heart infusion (BHI)(Difco Laboratories, Detroit, MI) broth with glycerol (20%) and *Salmonella typhimurium* was maintained by BHI broth containing nalidixic acid (Fisher Scientific, Fairlawn, NJ) with glycerol (20%). Frozen cultures of *E. coli* and *Salmonella typhimurium* were thawed, and 0.1 ml of *E. coli* suspension was inoculated into separate 40 ml aliquots of BHI, and 0.1 ml of *Salmonella typhimurium* suspension was inoculated into separate 40 ml aliquots of BHI with nalidixic acid. After 18 hours of incubation at 98.6°F, bacteria were harvested by centrifugation (3649 x g for 20 min @ 98.6oF)(Beckman GS-6 series, Fullerton, CA), re-suspended in the same volume of 0.1% buffered peptone water (BPW) (Difco Laboratories, Detroit, MI), and then pooled (1600 ml of *E. coli* and 1600 ml of *Salmonella typhimurium*) to make a bacterial cocktail. The cocktail (3200 ml; log 10^7 CFU/ml *E. coli* and log 10^7 CFU/ml *Salmonella typhimurium*) was cooled to 39.2°F and combined with boneless beef trimmings (28.2 lb) and allowed to attach for 1 hour. The meat was then drained and separated into 7.9 lb batches and placed in a 39.2°F cooler for 12 to 14 hours to allow further microbial attachment.

Antimicrobial treatment application and sample processing. Treatment combinations for this study included: 1) 5% (vol:vol) acetic acid solution (Shurfine Inc., Northlake, IL) followed by 0.5% (wt:vol) cetylpyridinium chloride solution (Zeeland Inc., Zeeland, MI)(AC); 2) 200 ppm (vol:vol) chlorine dioxide solution (Midland Chemical Company, Lenexa, KS) followed by 0.5% (wt:vol) cetylpyridinium chloride solution (CC), 3) 0.5% (wt:vol) cetylpyridinium

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chloride solution followed by 10% (wt:vol) trisodium phosphate solution (Rhone Poulenc, Cranbury, NJ)(CT) and 4) an untreated control (C). All antimicrobial treatments were prepared in deionized water with the exception of acetic acid, which was commercially prepared.

For antimicrobial application, beef trimmings were placed into a Lyco meat tumbler (Model 4Q, Lyco Inc., Janesville, WI) with 400 ml of the first antimicrobial treatment (either 5% acetic acid, 200 ppm chlorine dioxide or 0.5% cetylpyridinium chloride), aerobically tumbled for 3 minutes (16 rpm), then removed from the tumbler and placed into a clean tumbler with 400 ml of the second antimicrobial treatment (either 0.5% cetylpyridinium chloride or 10% trisodium phosphate), and tumbled again for another 3 minutes (16 rpm) aerobically.

Upon completion of the antimicrobial application phase, beef trimmings were removed from the tumbler and ground twice using a Hobart grinder (Model 310, Hobart Inc., Troy, OH) with a 3.2 mm plate. The ground beef was divided into 1 lb samples and packaged on styrofoam trays with absorbent diapers. The trays were overwrapped with polyvinyl chloride film with an oxygen transmission rate of 1400 cc/m^2/24 h/1 atm (Borden Inc., Dallas, TX) and stored under simulated retail display conditions (39.2°F; deluxe warm white fluorescent lighting, 1630 lx, Phillips Inc., Somerset, NJ). Fat content was standardized to 10% and validated using a Hobart Fat Analyzer (Model F101, Hobart Inc. Troy, OH). Ground beef pH was determined immediately after grinding for each treatment and was 5.72 for C, 4.71 for AC, 5.70 for CC and 6.91 for CT. For this, 0.06 oz of ground beef was homogenized in 18 ml of distilled water and evaluated using an Orion Model 420A pH meter with a ROSS electrode (Model 8165BN, Orion Research, Inc., Beverly, MA).

Instrumental color. On days 0, 1, 2, 3 and 7 of simulated retail display, instrumental color was also measured using a HunterLab MiniScan XE Spectrocolorimeter, Model 4500L (Hunter Associates Laboratory Inc., Reston, WV). Samples were read using illuminant A/10° observer and evaluated for CIE (L*, a* and b*) color values. In addition, reflectance measurements were taken in the visible spectrum from 580 nm to 630 nm. The reflectance ratio of 630 nm/580 nm was calculated and used to estimate the oxymyoglobin proportion of the myoglobin pigment (Strange et al., 1974). Prior to use, the Spectrocolorimeter was standardized using white tile, black tile, and working standards. Eight measurements were taken of each sample and averaged for statistical analysis.

Statistical analysis. The experiment was replicated three times. The randomized complete block factorial experiment was analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC). Treatments were blocked by replicate then analyzed for the main effects of antimicrobial treatment combination, day of display and appropriate interactions. For variables involved in interactions, interaction means were generated, separated using the PDIFF option of GLM, and plotted. Least-squares means for all other variables were generated and separated using the PDIFF option of GLM.

Results and Discussion

Effect of antimicrobial treatment combinations on instrumental color. The effect of multiple antimicrobial interventions on the CIE L* and b* values of ground beef are presented in Table 1. Ground beef from the AC and CT treatments were ($P < 0.05$) darker (L*) and less ($P < 0.05$) yellow (b*) in color than ground beef from the C and CC treatments. However, ground beef from the CC treatment was ($P < 0.05$) lighter (L*) in color but similar ($P > 0.05$) in yellowness to C.

Effect of duration of display on instrumental color. As expected, ground beef color changed with increasing duration of display (Table 2). Across 7 days of display, ground beef became ($P < 0.05$) lighter (L*) and less ($P < 0.05$) yellow (b*) in color.

Effects of antimicrobial treatment combinations and duration of display on instrumental color characteristics. Figure 1 illustrates the day of display by antimicrobial treatment interaction effects on instrumental color characteristics. Ground beef from the AC treatment was less ($P < 0.05$) red (a*) in color (Fig. 1, panel A) throughout display and had less ($P < 0.05$) oxymyoglobin (630 nm/580 nm; Fig. 1, panel B) through 3 days of display compared with C. However, ground beef from the CC treatment was less ($P < 0.05$) red (a*) in color initially (day 0), but similar ($P > 0.05$) in redness on days 1 through 3 of display compared to C (Fig. 2, panel A). Likewise, CC ground beef had slightly less ($P < 0.05$) oxymyoglobin (630 nm/580 nm) on days 0, 2 and 7 of display yet was not different ($P > 0.05$) in oxymyoglobin content on days 1 and 3 of display when compared to C (Fig. 2, panel B). Results from this study partially support those of Unda et al. (1989) and Bell et al. (1986) who found that both acetic acid and chlorine dioxide, when used as single antimicrobial interventions, caused negative color effects on beef tissues. However, the impact on ground beef redness (a*) and oxymyoglobin content (630 nm/580 nm) due to chlorine dioxide treatment in this study was minimal.

Ground beef from the CT treatment was less ($P < 0.05$) red (a*) on day 0 of display, but similar ($P > 0.05$) in redness on days 1 through 3 of display compared with C (Fig. 2, panel A). However, by day 7 of display, ground beef from the CT treatment maintained a redder ($P < 0.05$) color (a*) than ground beef from the C treatment. Consequently, ground beef from the CT treatment was not different ($P > 0.05$) in oxymyoglobin content (630 nm/580 nm; Fig. 2, panel B) until day 7 of display, when CT maintained a higher ($P < 0.05$) oxymyoglobin content than C. Therefore, in addition to reducing *E. coli*, *Salmonella typhimurium*, coliforms and aerobic bacteria in ground beef (Pohlman et al., 2001), CT treatment of beef trimmings before grinding also maintained a higher level of the oxymyoglobin pigment, which resulted in prolonged redness of color.

Figure 2, panel C shows the day of display by antimicrobial treatment interaction effect on the hue angle of ground beef. Ground beef from the AC treatment maintained a larger ($P < 0.05$) hue angle than C through display. Since hue angle is a mathematical computation using CIE a* and b* values,

the reduction in redness (a*) values for the AC treatment caused a corresponding shift in the hue angle value. Ground beef from the CC treatment also possessed a larger ($P < 0.05$) hue angle than C with the exception of day 3 of display. However, ground beef color (hue angle) did not differ ($P > 0.05$) between CT and C treatments until day 7 of display, when CT had a smaller ($P < 0.05$) hue angle. The difference in hue angle between CT and C treatments on day 7 of display was due to the superior redness value (a*) for the CT treatment.

Ground beef from the AC treatment was less ($P < 0.05$) vivid in color (saturation index) than all other treatments throughout display (Fig. 2, panel D). However, CC ground beef was not different ($P > 0.05$) in vividness of color (saturation index) when compared to C through display. On day 0 of display, ground beef from the CT treatment was slightly less ($P < 0.05$) vivid in color than C, however, was not different ($P > 0.05$) on days 1 through 3 of display. Conversely, by day 7 of display, ground beef from the CT treatment had a brighter, more vivid color ($P < 0.05$) than C. Therefore, treatment of beef trimmings before grinding with CT caused ground beef to maintain higher levels of oxymyoglobin (630 nm/580 nm) through display, which caused stability enhancement of ground beef color. Advantages in ground beef color for the CT treatment over C were most likely due to the elevated pH of this treatment (6.91) compared with C (5.72), due to the buffering capacity of the trisodium phosphate portion of the CT treatment. The elevated pH for the CT treatment had a stabilizing effect on oxymyoglobin (630 nm/580 nm; Fig. 2, panel B), which in turn extended ground beef vividness (saturation index) and redness (a* and hue angle) of color through display.

Implications

Results from this study show that the use multiple antimicrobial interventions in the production of ground beef has the potential to extend retail shelf life and could increase meat yield and profitability when used as a food safety intervention under the new retained water rule of the USDA.

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Appreciation is expressed to the Arkansas Beef Council for funding this research. The authors would like to thank J. Davis, L. Rakes, A. Ivey, L. McBeth, R. Story and E. Kroger for their assistance in conducting these trials.

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Table 1. Effect of multiple antimicrobial treatments[a] applied to beef trimmings prior to grinding on least-squares means (± SE) CIE L*[b] and b*[b] values of ground beef through simulated retail display.

	Treatment				
	C	AC	CC	CT	SE
CIE L*	48.35yc	47.42x	51.33z	45.73w	.28
CIE b*	19.61z	16.75x	20.11z	18.84y	.23

[a] C = Control; AC = 5% acetic acid and 0.5% cetylpyridinium chloride; CC = 200 ppm chlorine dioxide and 0.5% cetylpyridinium chloride; CT = 0.5% cetylpyridinium chloride and 10% trisodium phosphate.
[b] L*: 0 = black and 100 = white; b*: -60 = blue and +60 = yellow.
[c] Least-squares means within a row without a common letter differ ($P < 0.05$).

Table 2. Effect of duration of display on least-squares means (±SE) CIE L*[a] and b*[a] values of ground beef.

	Day of display				
	0	1	2	3	7
Instrumental color					
CIE L*	47.55 ± .32x[b]	47.85 ± .32xy	48.17 ± .32xyz	48.63 ± .32yz	48.84 ± .32z
CIE b*	19.98 ± .16z	20.25 ± .26z	18.32 ± .26y	18.02 ± .26xy	17.57 ± .26x

[a] L*: 0 = black and 100 = white; b*: -60 = blue and +60 = yellow.

[b] Least-squares means within a row without a common letter differ (P < 0.05).

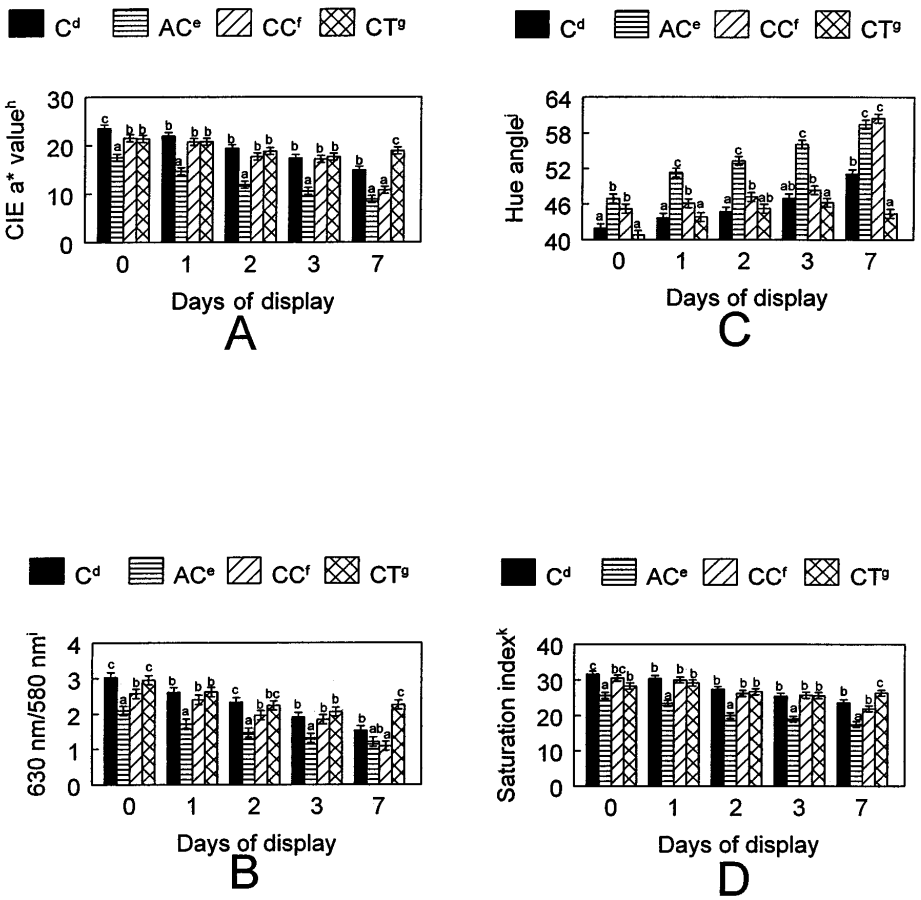

Figure 1. Day of display by antimicrobial treatment interaction effect on the least-squares mean (± SE) (A) CIE a* value, (B) 630 nm reflectance/580 nm reflectance, (C) hue angle and (D) saturation index of ground beef through simulated display. [abc]Least-squares means within a day without a common superscript differ (P < 0.05). [d]C = control, [e]AC = 5% acetic acid and 0.5% cetylpyridinium chloride, [f]CC = 200 ppm chlorine dioxide and 0.5% cetylpyridinium chloride, [g]CT = 0.5% cetylpyridinium chloride and 10% trisodium phosphate. [h]-60 = green and +60 = red. [i]Calculated as 630 nm reflectance/580 nm reflectance. [j]Calculated as tan-1(b*/a*). [k]Calculated as (a*2+b*2)·5.

The Use of Hurdle Technology to Reduce Microorganisms in Ground Beef

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Story in Brief

The effectiveness of multiple antimicrobial interventions (hurdle technology) on ground beef microbial characteristics through simulated retail display was studied. Beef trimmings were inoculated with *Escherichia coli* (EC) and *Salmonella typhimurium* (ST) then treated with either 1) 5% acetic acid followed by 0.5% cetylpyridinium chloride (AC), 2) 200 ppm chlorine dioxide followed by 0.5% cetylpyridinium chloride (CC), 3) 0.5% cetylpyridinium chloride followed by 10% trisodium phosphate (CT) or 4) control (C). Trimmings were ground, packaged and sampled on days 0, 1, 2, 3 and 7 of display for EC, ST, coliforms (CO) and aerobic plate count (APC). All treatments reduced ($P < 0.05$) all bacterial types monitored. In addition, ST was reduced ($P < 0.05$) through 7 days of display and APC was held in check as display progressed. Therefore, the use of hurdle technology was effective for reducing microbial pathogens in ground beef and would subsequently improve the safety of this product.

Introduction

The meat industry continues to face concerns regarding the safety of its products. It has been reviewed that the use of single decontamination interventions are effective for reducing pathogens on carcass surfaces (Dickson and Anderson 1992; Siragusa, 1995). However, since most carcass decontamination treatments do not sterilize the carcass, microorganisms remaining on carcass surfaces can easily become inoculated onto freshly cut surfaces during carcass fabrication, and subsequently carried through grinding operations.

Multiple intervention technology utilizes different barriers or hurdles such as pH changes, oxidizing environments, or other environmental changes to cause disruption of microbial cells or cellular metabolism, to either destroy bacterial cells or retard their growth. Hurdle technology has been more effective than single interventions for beef carcass decontamination (Phebus et al., 1997; Graves-Delmore et al., 1998). In addition, Ellebracht et al. (1999) used 203°F hot water and 2% lactic acid multiple interventions in the production of ground beef to reduce *E. coli*, *Salmonella typhimurium*, and aerobic plate counts 1.1, 1.8, and 1.5 log colony forming units (CFU)/g, respectively. Therefore, the objective of this research was to determine the effects of an organic acid and other novel decontamination compounds, used in combination, on the microbial stability of ground beef.

Experimental Procedures

Bacterial preparation and inoculation. Inoculums were prepared from frozen (-112°F) stock cultures of *Escherichia coli* (ATCC #11775; EC) and a nalidixic acid resistant strain of *Salmonella typhimurium* (ATTC 1769NR; ST). *E. coli* was maintained by brain heart infusion (BHI)(Difco Laboratories, Detroit, MI) broth with glycerol (20%) and *Salmonella typhimurium* was maintained by BHI broth containing nalidixic acid (Fisher Scientific, Fairlawn, NJ) with glycerol (20%). Frozen cultures of *E. coli* and *Salmonella typhimurium* were thawed, and 0.1 ml of *E. coli* suspension was inoculated into separate 40 ml aliquots of BHI, and 0.1 ml of *Salmonella typhimurium* suspension was inoculated into separate 40 ml aliquots of BHI with nalidixic acid. After 18 hours of incubation at 98.6°F, bacteria were harvested by centrifugation (3649 x g for 20 min @ 98.6°F)(Beckman GS-6 series, Fullerton, CA), re-suspended in the same volume of 0.1% buffered peptone water (BPW) (Difco Laboratories, Detroit, MI and then pooled together (1600 ml of *E. coli* and 1600 ml of *Salmonella typhimurium*) to make a bacterial cocktail. The cocktail (3200 ml; log 10^7 colony forming units (CFU)/ml *E. coli* and log 107 CFU/ml *Salmonella typhimurium*) was cooled to 39.2°F and combined with boneless beef trimmings (28.2 lb) and allowed to attach for 1 hour. The meat was then drained and separated into 7.9 lb batches and placed in a 39.2°F cooler for 12 to14 hours to allow further microbial attachment.

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Antimicrobial treatment application and sample processing. Treatment combinations for this study included: 1) 5% (vol:vol) acetic acid solution (Shurfine Inc., Northlake, IL) followed by 0.5% (wt:vol) cetylpyridinium chloride solution (Zeeland Inc., Zeeland, MI)(AC); 2) 200 ppm (vol:vol) chlorine dioxide solution (Midland Chemical Company, Lenexa, KS) followed by 0.5% (wt:vol) cetylpyridinium chloride solution (CC), 3) 0.5% (wt:vol) cetylpyridinium chloride solution followed by 10% (wt:vol) trisodium phosphate solution (Rhone Poulenc, Cranbury, NJ)(CT) and 4) an untreated control (C). All antimicrobial treatments were prepared in deionized water with the exception of acetic acid, which was commercially prepared.

For antimicrobial application, beef trimmings were placed into a Lyco meat tumbler (Model 4Q, Lyco Inc., Janesville, WI) with 400 ml of the first antimicrobial treatment (either 5% acetic acid, 200 ppm chlorine dioxide or 0.5% cetylpyridinium chloride), aerobically tumbled for 3 minutes (16 rpm), then removed from the tumbler and placed into a clean tumbler with 400 ml of the second antimicrobial treatment (either 0.5% cetylpyridinium chloride or 10% trisodium phosphate), and tumbled again for another 3 minutes (16 rpm) aerobically.

Upon completion of the antimicrobial application phase, beef trimmings were removed from the tumbler and ground twice using a Hobart grinder (Model 310, Hobart Inc., Troy, OH) with a 3.2 mm plate. The ground beef was divided into 1 lb samples and packaged on styrofoam trays with absorbent diapers. The trays were overwrapped with polyvinyl chloride film with an oxygen transmission rate of 1400 cc/m^2/24 hr/1 atm (Borden Inc., Dallas, TX) and stored under simulated retail display conditions (39.2°F; deluxe warm white fluorescent lighting, 1630 lx, Phillips Inc., Somerset, NJ). Fat content was standardized to 10% and validated using a Hobart Fat Analyzer (Model F101, Hobart Inc. Troy, OH). Ground beef pH was determined immediately after grinding for each treatment and was 5.72 for C, 4.71 for AC, 5.70 for CC and 6.91 for CT. For this, 1.8 g of ground beef was homogenized in 18 ml of distilled water and evaluated using an Orion Model 420A pH meter with a ROSS electrode (Model 8165BN, Orion Research, Inc., Beverly, MA).

Microbial sampling. On days 0, 1, 2, 3, and 7 of simulated retail display, 25 g of ground beef was aseptically removed from the packages and placed into whirlpack bags (Nasco, Ft. Atkinson, WI) with 225 ml of 0.1% buffered peptone water and buffered to a pH of 7 with either sodium hydroxide or hydrochloric acid. Samples were then stomached in a Model 400 Lab Stomacher (Seward, London, United Kingdom) for 2 minutes and serial dilutions were made. Subsequent duplicate platings were made on *Salmonella shigella* agar (Difco Laboratories, Detroit, MI) containing nalidixic acid, Petrifilm® (3M Corp., St. Paul, MN) aerobic plate count (APC) plates and Petrifilm® *E. coli*/coliform plate count plates. Plates were then incubated at 98.6°F in an aerobic incubation chamber (either VWR Model 5015 or Model 3015 incubators, VWR Scientific, West Chester, PA) and APC along with *Salmonella shigella* agar plates were read at 48 hours, while *E. coli*/coliform plates were read at 24 hours. Counts were recorded as colony forming units per gram (CFU/g).

Statistical analysis. The experiment was replicated three times. The randomized complete block factorial experiment was analyzed using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC). Treatments were blocked by replicate then analyzed for the main effects of antimicrobial treatment combination, day of display and appropriate interactions. For variables involved in interactions, interaction means were generated, separated using the PDIFF option of GLM, and plotted. Least-squares means for all other variables were generated and separated using the PDIFF option of GLM.

Results and Discussion

Effect of antimicrobial treatment combinations on microbial populations. The effect of multiple antimicrobial intervention treatments on the reduction of *Salmonella typhimurium* and aerobic plate count are shown in Table 1. *Salmonella typhimurium* in ground beef was reduced ($P < 0.05$) 1.98, 1.38 and 1.17 log colony forming units (CFU)/g by the acetic acid followed by cetylpyridinium chloride treatment (AC), the chlorine dioxide followed by cetylpyridinium chloride treatment (CC), and the cetylpyridinium chloride followed by trisodium phosphate treatment (CT), respectively. Aerobic plate counts (APC) of ground beef were reduced ($P < 0.05$) by 1.76, 1.17 and 0.88 log CFU/g by AC, CC and CT treatments, respectively. Various researchers have reported that multiple antimicrobial interventions are more effective than single interventions for reducing microorganisms on carcasses or intact tissue (Gorman et al., 1995; Phebus et al. 1997). Graves-Delmore et al. (1998) concluded that the use of sequential antimicrobial applications was more effective for reducing microbial contamination on beef adipose tissue than were individual decontamination treatments. They also reported decontamination treatments were more effective in reducing bacterial numbers when the initial contamination level was high. Therefore, results from this study are in agreement with Graves-Delmore et al. (1998) as well as Fratamico et al. (1996), both of which used similar compounds to obtain comparable microbial reductions on beef carcasses and tissues. Likewise, reductions in microorganisms in this study were also consistent with those of Gorman et al. (1995) and Kochevar et al. (1997) on beef and lamb adipose tissue and with those of Hardin et al. (1995) on beef carcass surfaces.

Effect of duration of display on microbial populations. *Salmonella typhimurium* populations declined ($P < 0.05$) 1.21 log CFU/g through 7 days of display (Table 2). In addition, APC was held in check ($P > 0.05$) through the duration of display. Therefore, multiple antimicrobial intervention treatments had a long-term lethal effect on ST while retarding aerobic bacterial growth through refrigerated display.

Effects of antimicrobial treatment combinations and duration of display on microbial populations. The day of display by antimicrobial treatment interaction effect on *E. coli* and coliform counts are shown in Figure 1 (panels A and B). *E. coli* was reduced ($P < 0.05$) by all antimicrobial treatment

combinations throughout display and were 2.00, 2.61 and 1.13 log CFU/g less ($P < 0.05$) than C for AC, CC and CT treatments, respectively by day 7 of display (Fig. 1, panel A). Likewise, total coliforms were also reduced ($P < 0.05$) by all antimicrobial treatment combinations throughout display, and were 2.65, 2.55 and 0.93 log CFU/g less ($P < 0.05$) for AC, CC and CT treatments, respectively by day 7 of display compared with C (Fig. 1, panel B).

Implications

Results from this study show that the use of multiple antimicrobial interventions during ground beef production can reduce microorganisms and extend shelf life. Additionally, this technology could increase meat yields and profit as an intervention to improve meat safety under the new retained water rule of the USDA.

Acknowledgments

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Table 1. Least-squares means (±SE) for the effect of multiple antimicrobial treatments[a] applied to beef trimmings before grinding on log CFU/g *Salmonella typhimurium* and aerobic plate count (APC) of ground beef through simulated retail display.

	Treatment				
	C	AC	CC	CT	SE
Microorganism					
Salmonella typhimurium	5.81z[b]	3.83x	4.43y	4.64y	.12
APC	7.06z	5.30x	5.89y	6.18y	.11

[a] C = Control; AC = 5% acetic acid and 0.5% cetylpyridinium chloride; CC = 200 ppm chlorine dioxide and 0.5% cetylpyridinium chloride; CT = 0.5% cetylpyridinium chloride and 10% trisodium phosphate.
[b] Least-squares means within a row without a common letter differ ($P < 0.05$).

Table 2. Least-squares means (±SE) for the effect of duration of display on log CFU/g *Salmonella typhimurium* and aerobic plate count (APC) of ground beef.

	Day of display				
	0	1	2	3	7
Microorganism					
Salmonella typhimurium	5.18 ± .13y[a]	5.24 ± .13z	4.53 ± .13y	4.45 ± .13y	3.97 ± .13x
APC	5.96 ± .13	6.25 ± .13	6.11 ± .12	6.05 ± .12	6.14 ± .12

[a]Least-squares means within a row without a common letter differ ($P < 0.05$).

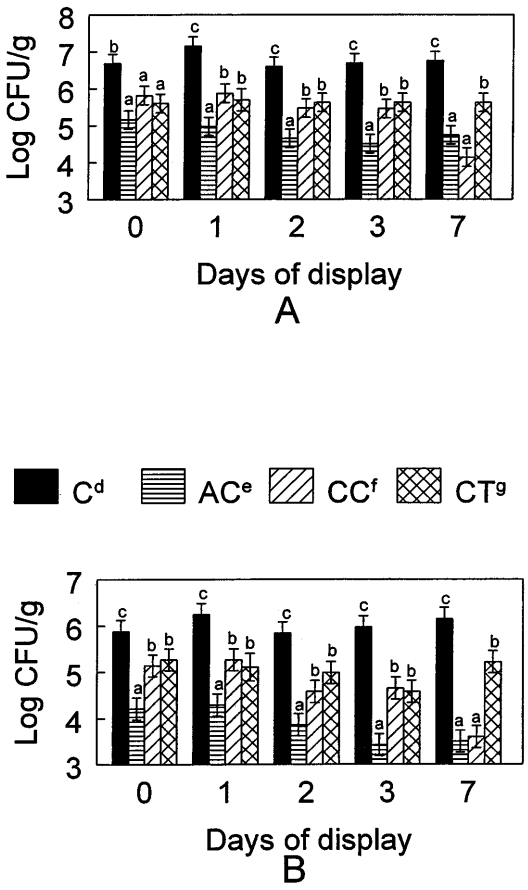

Figure 1. Least-squares means (±SE) for the day of display by antimicrobial treatment interaction effect on log CFU/g (A) *E. coli* and (B) coliform counts in ground beef through simulated display.
[abc]Least-squares means within a day having no common superscripts differ (P < 0.05). [d]C = control, [e]AC = 5% acetic acid and 0.5% cetylpyridinium chloride, [f]CC = 200 ppm chlorine dioxide and 0.5% cetylpyridinium chloride, [g]CT = 0.5% cetylpyridinium chloride and 10% trisodium phosphate.

Consumer Acceptability of Forage Fed Beef

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Story in Brief

Boneless strip loins from Angus steers (n = 32) which grazed soft red winter wheat forage and supplemented with 2 lb of corn per head per day were compared against typical grain-finished beef to ascertain consumer preferences. Steers were harvested after grazing wheat forage for 161 d, and beef quality data was collected by trained, experienced University personnel. Two forage-finished carcasses had small degrees of marbling and the remainder of the carcasses had slight degree of marbling. Strip loins were removed from the right side of each carcass, vacuum packaged and allowed to age at 34°F for 7 d, then frozen until consumer evaluation. Before consumer testing, 1 inch steaks of strip loins with small and slight degrees of marbling from conventional grain finished cattle were purchased. Steaks were cooked to an internal temperature of 160°F. Samples were served warm to 62 consumers, who evaluated samples for flavor, juiciness, tenderness and overall acceptability. No differences ($P < 0.10$) were observed for flavor due to consumer gender when the consumer was over 30 years of age, but a gender by treatment interaction occurred ($P < 0.01$) when consumers were under 30 years of age. Females under 30 accepted the flavor of forage fed beef with a small amount of marbling more than males under the age of 30. Males rated the forage fed beef juicier and more tender than females. Males preferred grain fed beef with slight marbling when compared to females. However, no differences were observed between males and females on the acceptability of grain fed with small marbling or forage fed beef with slight marbling. Preliminary results suggest that consumers under 30 years of age, especially female consumers, find beef from forage-finished cattle to be acceptable.

Introduction

Beef finished on forages have been considered to have carcass characteristics and palatability attributes that are not preferred by consumers. Smith (1990) reported a deleterious effect on carcass and beef quality when cattle were finished on forage. However, others (Crouse et al., 1984; Fortin et al., 1985) found no differences in palatability attributes between forage and grain finished beef.

When compared to grain-finished beef, forage-finished beef has been reported to have intensity of a "milky-oily" flavor (Melton, 1983) or "grassy" flavor (Larick et al., 1987). This flavor decreases in intensity with time as steers are fed grain for an increased number of days after being removed from grass pasture.

Melton (1983) reported flavor difference may not be the reason forage-finished beef is unsuccessful in the marketplace. In a test market for forage-produced beef, she found 52% of a group of 87 consumers, after the first use of range-grazed beef, would definitely buy it again. Therefore, the objective of this study was to evaluate consumer acceptability of forage finished beef compared to grain finished beef.

Experimental Procedures

Strip loins were removed from steers used in a study conducted by Daniels et al. (2000) including 32 Angus steers which grazed soft red winter wheat and were fed 2 lb of corn per day per head from November 17, 1999, until April 26, 2000. Eight randomly selected steers having an average body weight of 1,081 lb were slaughtered and graded at the University of Arkansas Meat Science Abattoir. Two of the strip loins from forage finished beef had small degrees of marbling (Choice) while the six remaining samples had a slight degree of marbling (Select). The day before consumer testing, 1 inch steak from strip loins with small and slight degrees of marbling from conventional grain finished beef were purchased.

Strip loin steaks were cooked in a Blodgett conventional oven for approximately 25 min, until they reached an internal temperature of 160°F. Samples were served warm to 62 consumers, who evaluated samples for flavor, juiciness, tenderness and overall acceptability. All characteristics were scored on a scale from 1 to 8, with 1 = extreme milky oily and 8 = extreme beef fat for flavor; 1 = extremely dry and 8 = extremely juicy for juiciness; 1 = extremely tough and 8 = extremely tender for tenderness; and 1 = extremely undesirable and 8 = extremely desirable for overall acceptability. The consumers were comprised of 25 males under the age of 30, 12 males over the age of 30, 13 females under the age of 30, and 12 females over the age of 30.

Data were analyzed as a split plot using PROC MIXED of SAS (SAS Inst. Inc., Cary, NC) looking at effects of treatment, gender, age category and all interactions. When the three-way interaction of treatment by gender by age category was significant, data were analyzed separately by age category.

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Results and Discussion

There was no difference (P > 0.10) for flavor of steaks due to treatment, age category, or gender (Table 1). However, there was an age category by gender by age category interaction (P < 0.01). Consumers under 30 exhibited a gender by treatment interaction (P < 0.05; Table 2) for flavor. Females under 30 had higher flavor scores for (P < 0.05) for forage-finished beef that was slightly marbled than did males under 30 (5.62 vs 4.83). There were no differences in flavor scores for the over 30 age category.

Gender by treatment and age category by treatment interactions (P < 0.05) were observed for juiciness (Tables 3 and 4). Consumers under the age of 30 rated forage-finished beef that had a small amount of marbling juicier than consumers over 30 (4.34 vs 3.12) while consumers over 30 rated forage-finished beef that had a slight amount of marbling juicier than persons under 30 (4.46 vs 4.18). Females rated beef that had a small amount of marbling less juicy than males (3.17 vs 4.22).

Degree of tenderness differed by gender and age of the consumer (Treatment by age interaction, P < 0.05, Table 3; and treatment by gender interaction, P < 0.01, Table 4). Consumers under 30 found that forage-finished beef having a small amount of marbling more tender than the over 30 age group. Males and females differed in their ratings of degree of tenderness of forage-finished beef, with females preferring beef with a slight amount of marbling (5.65 vs 5.10) and males preferring a small amount of marbling (4.85 vs 3.76). Males found the grain-finished beef with a small degree of marbling more tender than their female counterparts (5.85 vs 4.97).

The overall acceptability of beef also differed among the different gender and age groups (Tables 3, 4, and 5). Males had a higher (P < 0.01) acceptability for grain-finished beef having a slight degree of marbling than females. Forage-finished beef having a small degree of marbling was more acceptable (P < 0.01) to males than females (Table 3). Consumers under 30 found grain-finished beef having a slight degree of marbling more acceptable than consumers over 30 (4.58 vs 3.69; Table 3). Males found grain-fed and forage-fed Choice beef more acceptable than females (5.95 vs 5.19 and 4.89 vs. 3.39; Table 4). There was also an age category by gender interaction (P < 0.01) for overall acceptability (Table 5). Female consumers over age 30 rated all beef samples less acceptable than female consumers under age 30 and all male consumers.

Implications

These data show that there was no consistent pattern or opinion concerning the flavor, juiciness, tenderness, or overall acceptability of forage finished versus grain finished beef. However, it does show that consumers under 30 years of age accepted beef that was forage finished. These data suggest that alternative methods of finishing cattle may be viable for the beef industry for niche market.

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Table 1. Significance levels for sources of variation from overall analysis of variance.

		Significance levels			
Source of variation	DF	Flavor	Juiciness	Tenderness	Acceptability
Treatment	3	NS	*	*	**
Age category	1	NS	NS	NS	NS
Gender	1	NS	+	NS	**
Age category * gender	1	NS	NS	NS	**
Age category * treatment	3	NS	*	*	*
Gender * treatment	3	NS	*	**	**
Age category * gender * treatment	3	**	NS	NS	NS
Residual	299				

+P < 0.10; * P < 0.05; ** P < 0.01.

Table 2. Mean flavor scores[1] for treatment by gender by age category.

		Age category	
Gender	Treatment[2]	Under 30[3]	Over 30[4]
Female	GC	5.62 + .44 [ab]	5.38 + .45
	GS	5.90 + .44 [a]	4.38 + .45
	FC	4.60 + .44 [b]	5.83 + .52
	FS	5.62 + .26 [a]	4.78 + .26
Male	GC	5.32 + .36 [ab]	5.27 + .38
	GS	5.28 + .36 [ab]	5.73 + .38
	FC	5.46 + .37 [ab]	5.10 + .40
	FS	4.83 + .21 [b]	5.16 + .23

1 Flavor scores range from 1 to 8 with 1 = extreme milky oily and 8 = extreme beef fat.

2 Treatment codes: GC = corn fed beef that graded Choice; GS = corn fed beef that graded Select; FC = wheat fed beef that graded Choice; FS = wheat fed beef that graded Select.

3 Treatment x gender interaction (P < 0.05).

4 No difference due to treatment or gender in the over 30 category.

[a,b] Means in a column with no common letters differ (P < 0.05).

Table 3. Treatment by age category means for juiciness, tenderness and acceptability scores of beef steaks.

		Characteristic of steak[1]		
Age category	Treatment[2]	Juiciness[3]	Tenderness[3]	Acceptability[3]
Under 30	GC	5.23 + .36 [a]	5.92 + .35 [a]	6.12 + .23 [ab]
	GS	5.19 + .36 [a]	5.52 + .35 [abc]	5.74 + .23 [abc]
	FC	4.34 + .37 [bc]	4.83 + .36 [c]	4.58 + .24 [e]
	FS	4.18 + .24 [c]	5.16 + .21 [bc]	4.93 + .14 [de]
Over 30	GC	5.22 + .44 [ab]	6.30 + .43 [a]	6.29 + .31 [a]
	GS	5.14 + .44 [a]	5.30 + .43 [abc]	5.40 + .31 [bc]
	FC	3.12 + .47 [d]	3.78 + .46 [d]	3.69 + .34 [f]
	FS	4.64 + .26 [ab]	5.60 + .26 [ab]	5.20 + .19 [cd]

1 Scores range from 1 to 8 with 1 = extremely dry to 8 = extremely juicy for juiciness; 1 = extremely tough to 8 = extremely tender for tenderness; and 1 = extremely undesirable to 8 = extremely desirable for overall acceptability.

2 Treatment codes: GC = corn fed beef that graded Choice; GS = corn fed beef that graded Select; FC = wheat fed beef that graded Choice; FS = wheat fed beef that graded Select.

3 Treatment by age category interaction (P < 0.05).

[a,b,c,d,e,f] Means in a column with no letters in common differ (P < 0.05).

Table 4. Treatment by gender means for juiciness, tenderness and acceptability scores of beef steaks.

		Characteristic of steak[1]		
Gender	Treatment[2]	Juiciness[3]	Tenderness[4]	Acceptability[4]
Female	GC	5.10 + .42 ab	6.32 + .42 a	5.92 + .30 ab
	GS	4.92 + .42 ab	4.97 + .42 b	5.19 + .30 bc
	FC	3.17 + .44 d	3.76 + .44 c	3.39 + .32 d
	FS	4.60 + .25 bc	5.65 + .25 a	5.14 + .18 bc
Male	GC	5.36 + .37 a	5.89 + .36 a	6.49 + .24 a
	GS	5.41 + .37 a	5.85 + .36 a	5.95 + .24 a
	FC	4.30 + .38 bc	4.85 + .37 b	4.89 + .25 c
	FS	4.22 + .22 c	5.10 + .21 b	4.99 + .14 c

1 Scores range from 1 to 8 with 1 = extremely dry to 8 = extremely juicy for juiciness; 1 = extremely tough to 8 = extremely tender for tenderness; and 1 = extremely undesirable to 8 = extremely desirable for overall acceptability.

2 Treatment codes: GC = corn fed beef that graded choice; GS = corn fed beef that graded select; FC = wheat fed beef that graded choice; FS = wheat fed beef that graded select.

3 Treatment by gender interaction (P < 0.05).

4 Treatment by gender interaction (P < 0.01).

[a,b,c,d] Means in a column with no letters in common differ (P < 0.05).

Table 5. Sex by age category means for juiciness, tenderness, and acceptability scores of beef steaks.

		Characteristic of steak[1]		
Age category	Sex	Juiciness[2]	Tenderness[2]	Acceptability[3]
Under 30	Female	4.29 + .25	5.03 + .25	5.23 + .17 b
	Male	4.84 + .21	5.42 + .21	5.45 + .13 b
Over 30	Female	4.64 + .19	5.30 + .19	4.58 + .22 a
	Male	4.82 + .14	5.42 + .14	5.71 + .18 b

1 Scores range from 1 to 8 with 1 = extremely dry to 8 = extremely juicy for juiciness; 1 = extremely tough to 8 = extremely tender for tenderness; and 1 = extremely undesirable to 8 = extremely desirable for overall acceptability.

2 No differences ($P > 0.05$) due to age category or gender.

3 Age category by gender interaction ($P < 0.01$).

a,b Means in a column with no letters in common differ ($P < 0.05$).

Conversion Table

U.S. to Metric			Metric to U.S.		
to convert from	to	multiply U.S. unit by	to convert from	to	multiply metric unit by
length			**length**		
miles	kilometers	1.61	kilometers	miles	.62
yards	meters	.91	meters	yards	1.09
feet	meters	.31	meters	feet	3.28
inches	centimeters	2.54	centimeters	inches	.39
area and volume			**area and volume**		
sq yards	sq meters	.84	sq meters	sq yards	1.20
sq feet	sq meters	.09	sq meters	sq feet	10.76
sq inches	sq centimeters	6.45	sq centimeters	sq inches	.16
cu inches	cu centimeters	16.39	cu centimeters	cu inches	.06
acres	hectares	.41	hectares	acres	2.47
liquid measure			**liquid measure**		
cu inches	liters	.02	liters	cu inches	61.02
cu feet	liters	28.34	liters	cu feet	.04
gallons	liters	3.79	liters	gallons	.26
quarts	liters	.95	liters	quarts	1.06
fluid ounces	milliliters	29.57	milliliters	fluid ounces	.03
weight and mass			**weight and mass**		
pounds	kilograms	.45	kilograms	pounds	2.21
ounces	grams	28.35	grams	ounces	.04
temperature			**temperature**		
F	C	5/9(F–32)	C	F	9/5(C+32)